High School Lesson Plans

Skill Set 1: Science and Engineering

Lesson Activity

Title	**Bottle Rockets (3 sessions, 60-80 minutes)**
ID Number	HS-S-C1
Sequence and Duration	Session 1: Background and Exploration • Lead In: 10-15 minutes • Teacher Demo: 20-30 minutes • Investigation: 30-40 minutes Session 2: Testing • Testing: 60-80 minutes Session 3: Designing the Ideal Rocket • Results Review: 5-10 minutes • Design Challenge: 40-50 minutes • Closure: 10-15 minutes
Age Level	High School
Essential Question	**What variables affect the maximum length of time a bottle rocket stays aloft?**
Learning Objectives	• TSW design investigations to test a variable related to the rocket's length of time in the air. • TSW collect and analyze data from their investigation. • TSW communicate the results of their investigation to their classmates. • TSW build a bottle rocket addressing the specifications and incorporating the results of their investigations.
Other Objectives	• TSW develop a working plan with their group to develop a cooperative environment. • TSW communicate with their group by contributing their vocal input. • TSW write down the procedure they used to investigate the effect of their chosen variable. • TSW listen to their peers discuss the results of their investigation. • TSW contribute to a group discussion about the optimum characteristics of a bottle rocket.
Key Terms	• Newton's 3rd Law: for every force, there is an equal force in the opposite direction. • Pressure: force per unit area. • Force: a push or a pull. • Optimize: to make as effective or useful as possible.
Materials Needed	Per Class: • Duct tape • Scissors • String • Hole punch • Rocket launcher • Safety goggles (optional but a good idea) • Bottle rocket launcher with bike pump • Stopwatches Per Student: • Handout: MESA Day Cargo Bottle Rocket specifications • Handout: MESA Notebook • Handout: Bottle Rocket Data Collection Sheet Teacher Demo:

	- Two 2-liter bottles 3 manila folders - Large plastic trash bag 1 roll masking tape - Golf ball-sized ball of clay Per Team: - Handout: Bottle Rocket Challenge - Two 2-liter bottles 3 manila folders - Large plastic trash bag 1 roll masking tape - Golf ball-sized ball of clay
Session 1	**Background and Exploration**
Lead In	1. Remind students of their previous learning about Newton's 3rd Law. What does this law say about forces? [Every action has an equal and opposite reaction, or every force is paired with an equal force in the opposite direction.] What does this have to do with the motion of an object? [If an object pushes in one direction, whatever it is pushing on pushes *back* in the opposite direction. Forces cause acceleration, so the object will accelerate in the direction of the force.] Have students explain Newton's 3rd Law in their own words and write this in their MESA Notebooks. 2. Ask students what Newton's 3rd Law has to do with rockets. What makes rockets move through space? [The rocket's fuel exhaust is pushed out of the rocket by the pressure inside the rocket; the rocket pushes the fuel gases out and in turn, the gases push back on the rocket, causing it to accelerate.] Note: It is a common misconception that rockets push against the *ground* when they take off, but if this were the case, rockets would not be able to accelerate in space because there would be no ground to push off from.] 3. Hand out the MESA Day Cargo Bottle Rocket specifications and go through them with the students. Explain that there are a number of different ways to go about building a bottle rocket, and a variety of variables that can affect the rocket's performance. Their task as a class will be to investigate ways to *optimize* these variables – that is, to make them as beneficial as possible. Engineers conduct experiments to determine the optimal characteristics for the products they design. 4. Point out that the challenge for MESA Day is to keep the rocket in the air for a maximum amount of time. Ask students what would be the best angle to launch the rockets to maximize how long they stay in the air [straight up and down; the higher they go, the longer it will take them to fall].
Teacher Demo	1. State that in order to look at the variables that affect the bottle rocket's path, you need to have a bottle rocket to examine. You will build a bottle rocket together as a class to look at the components of its design, and launch it to observe its performance. 2. Directions for building a rocket, taken from http://www.lnhs.org/hayhurst/rockets/, are attached below. Enlisting the help of students wherever possible, construct a classroom rocket (including the parachute and detachable nose cone are not essential at this point but you can include them if you wish; otherwise, attach the nose cone to the rocket with tape. The parachute element may be useful for decreasing the amount of damage to the rocket after multiple launches). Note: The instructions call for a plastic cone to be used as the nose cone, but this can be just as easily constructed from a manila folder. 3. As you build the rocket, draw students' attention to the different components and ask them to consider their purpose. Why is the nose cone necessary? [It

	makes the rocket aerodynamic so it will fly straight.] What do the fins do? [Stabilize the rocket as it flies, again, to make it fly straight.] What is the purpose of the ball of clay? [Weights the nose cone, shifting the center of gravity away from the bottom of the rocket to stabilize its flight.] Getting the right answer is not necessary, so long as students are beginning to brainstorm ideas. 4. Prepare the rocket for launch, filling it approximately halfway with water. Bring the students outdoors to an open space far from trees, telephone poles, etc., and make sure the area is clear of passers-by. Stress to students the importance of being a safe distance away from the rocket when it launches and making sure all body parts are clear of the rocket's path, but for the meantime gather students close to the launcher so they can observe what is going on when the rocket launches. Ask students what the bike pump is for [it pressurizes the air in the rocket]. Why is this necessary? [The high pressure pushes the water out, and the water pushes on the rocket, making the rocket accelerate]. Encourage students to ask other questions, such as, what if there were no water in the rocket? What if the bottle were completely filled with water? How much pressure is necessary? Tell students to keep these questions in mind for later. 5. Tell students to observe what happens as the rocket takes off. Clear students back to a safe distance and launch the rocket. Time the length of the journey with a stopwatch. This will be the time for students to beat when they launch their "ideal" rockets later!
Investigation	1. Gather students back in the classroom. Allow time for a brief discussion of what students observed when the rocket launched. 2. Solicit questions that the students came up with about the rocket. Remind them that there are numerous variables affecting the rocket's journey, and that their mission as a class is to optimize those variables. What are some of the variables? In what ways can they be varied? How can the class test for the optimal value of those variables? [examples: volume of water, air pressure, number and length of fins, amount of clay, length of rocket, etc.] If necessary, remind students that some variables are constrained by the event specifications, such as the type of liquid (must be water). 3. Tell the students that as a class, they must decide which variables they feel are the most important ones to investigate, and determine how to divide the work among the class to work most efficiently given that only one rocket can be launched at a time (assuming there is only one rocket launcher). If they want to build the best bottle rocket they can, they need to know as much as possible about the optimal characteristics, but they will have only one class period to test variables before building their own "ideal" rockets. Should they decide to break into groups to investigate different variables, any results the groups find will be communicated to the whole class. 4. Tell students to estimate a reasonable number of launches they might expect to be able to make in one class period. Consider the length of time of the class, the length of time it takes to pressurize the rocket, the length of time the rocket is in the air before it comes down and is ready to be launched again, whether a second or third rocket might be built that could be launched right after the first, and allow time for tweaking the launcher and other unexpected uses of time. Whatever number the students come up with is the total number of tests they can run. 5. Guide a discussion in which students come to an agreement about the best way to make use of this number of launches. How many variables will they test? How many launches will they be able to do for each variable? Do some variables need more launches than others? If necessary, lead students to an understanding that only one variable can be tested at a time or it won't be

	possible to know which variable is having the greatest effect on the dependent variable [the maximum time the rocket is in the air]. 6. With the remaining class time, students should prepare their investigations. They must be completely prepared to begin testing in the next session, so they must come up with hypotheses, procedures, data sheets, and a plan for communicating the results of their investigation to the class (e.g. with graphs, charts or drawings). If they will be altering a variable that is an amount (such as amount of water), they will need to determine what values they will be testing. Students can use their MESA Notebooks to organize their investigations. 7. In the last five to ten minutes of class, have students share their procedures with the whole class to ensure that the class is satisfied with the way the independent variable is being tested and all other variables controlled.
Session 2	**Testing**
	1. Allow students to make use of the whole class period to conduct their investigations. Ensure that proper safety precautions are taken each and every time a rocket is launched. 2. Make sure students are faithfully collecting data. Remind them to record their units. 3. If there are groups who need multiple rockets to test their variables, they can build while other groups launch. If there are students who do not seem to have anything to do, they can help with the building as well. 4. When rocket construction is complete and some groups are finished testing, they can begin organizing and analyzing their data and/or assisting other groups with their launches. No group should be without something to do. 5. If there is still time remaining when all testing is complete, offer the class the option of adding another test to an existing investigation if necessary. If this is not needed, groups can use the remaining time to prepare their data to communicate to the whole class.
Session 3	**Designing the Ideal Rocket**
Results Review	1. At the start of the session, have students pull together their materials and present the results of their investigation with the whole class. Allow the class to ask questions of the group. 2. After each group's presentation, write a conclusion statement on the board that reflects the group's results (provided by the group with the assistance of the rest of the class), for instance "Results indicate that the ideal pressure for a 2-liter bottle rocket is ______ psi." 3. Make it clear that these conclusions can be considered tentative; further testing may yield even more precise values, but the class' results are a good start.
Design Challenge	1. Now that students know more about the ideal characteristics for their rockets, they can build their own "ideal" rockets that fit the MESA Day specs (minus the egg capsule for the time being). Tell students that groups of 4 will have 30 minutes to design and construct their rockets, using the given materials. [Have materials available at a "materials station" rather than passing out materials to each team, so teams only use what they need. You may also decide to have additional materials available, such as Styrofoam plates.] 2. Give students 30 minutes to work on their designs, circulating among the groups to assist where needed. During this time, write the time aloft for the demo rocket from the first day on the board. 3. When time is up, have students clean up their areas. 4. Hand out Data Collection Sheets. Point out the time on the board and remind students that this is the time to beat. Will their ideal rockets be able to stay aloft longer than the demo rocket? 5. Test groups' rockets, making sure students collect data carefully.

	6. Collect rockets and return to the classroom.
Closure	1. Discuss the results of testing. Which rocket stayed aloft the longest? What were the features of this rocket that made it so successful? What did other groups try? What features made these rockets successful or not so successful? 2. Ask groups to consider other variables that might be affecting the rocket's success that the class did not test. What kind of impact might these variables be having on the groups' rockets? 3. What did students learn from this lesson that will help their team be successful on MESA Day? For the competition, rockets will be expected to deploy a capsule containing an egg. How will what students learned from this activity and what they learned in the Clay Drop activity be useful for preparing for the competition? 4. In their MESA Notebooks, have students respond to this conclusion question: *What variables affect the maximum length of time a bottle rocket stays aloft?* 5. Students can use the remaining time to finish their Notebooks with their groups, or they can finish them as homework.
Informal Assessment	• Monitor students' understanding of Newton's 3rd Law through discussion and questioning. • Monitor students' understanding of experimentation and control of variables during the Investigation phase. • Monitor students' participation in discussions and group work. • Informal presentations of groups' rocket designs.
Formal Assessment	• Completed investigation materials: hypothesis, procedures, data collection instruments, data charts, etc. • Presentations of groups' investigation results. • Completed bottle rockets. • Completed MESA Notebooks.
Trouble Shooting	• Start collecting and encouraging students to collect 2-liter bottles for this lesson well ahead of time. You will need two for the teacher demo and two for each group, as well as several extras in the case that the class decides to build additional rockets for testing. • Prior to class, pre-prepare the demo bottle rocket pieces so that assembling the rocket will be quick but also informative, allowing students to see how the components go together. • Don't worry if a rocket doesn't work the first time! Allow students to troubleshoot with you. Is the seal with the launcher tight enough? Are there any holes in the bottle that are letting air or water escape? Is the rocket's weight unbalanced for any reason? Mistakes are opportunities for learning. • Students may be at a loss to draw conclusions from their data. Encourage them to draw scatter plots and do best-fit lines to examine the relationship between variables. Some students may find that their results do not follow a linear pattern; encourage them to consider other possible relationships – the data may more closely fit a parabola.
Extensions	• Directions for constructing simple altimeters to measure the height rockets reach can be found at http://www.arborsci.com/Data_Sheets/P4-2000_DS.pdf (page 4). • If students get excited about conducting more investigations about their rockets, consider adding an additional class period(s) for testing their ideas. Assess students' interest to decide if this lesson should be extended; there are a great number of investigations that students can conduct if they wish.

SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☐ Adaptation of Content	☒ Modeling	☒ Whole class
☐ Links to Background	☒ Guided practice	☒ Small groups
☒ Links to Past Learning	☒ Independent practice	☐ Partners
☒ Strategies incorporated	☐ Comprehensible input	☐ Independent

Integration of Processes	Application	Assessment
☒ Reading	☒ Hands-on	☐ Individual
☒ Writing	☒ Meaningful	☒ Group
☒ Speaking	☒ Linked to objectives	☒ Written
☒ Listening	☒ Promotes engagement	☒ Oral

Arizona Math Standards Addressed	• S1C3: TSW use estimation strategies reasonably and fluently. • S2C1: TSW understand and apply data collection, organization and representation to analyze and sort data. • S3C2: TSW describe and model functions and their relationships.
Arizona Science Standards Addressed	• S1C1: TSW formulate predictions, questions, or hypotheses based on observations and evaluate appropriate resources. • S1C2: TSW design and conduct controlled investigations. • S1C3: TSW evaluate experimental design, analyze data to explain results and propose further investigations. • S1C4: TSW communicate results of investigations. • S5C2: TSW analyze relationships between forces and motion, using Newton's 3rd Law to explain forces as interactions between bodies.

Mr. Hayhurst's Quick and Easy Bottle Rocket

Much of this information was "borrowed" from Jake Winemiller of N.E.R.D.S. Inc. and observations of many rockets launched in competitions in which I have participated. Please treat it with respect. Also remember that this is only a start. You have to do the testing and the minor adjustments.

Problem

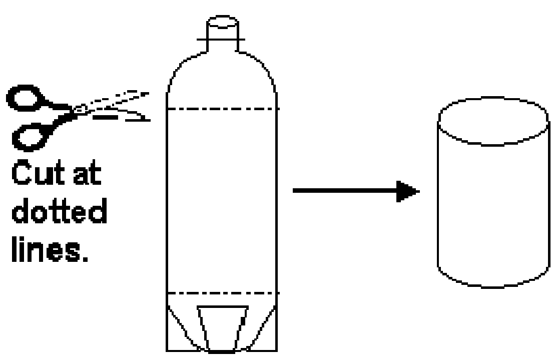
Create one bottle rocket that will fly straight and remain aloft for a maximum amount of time.

Materials

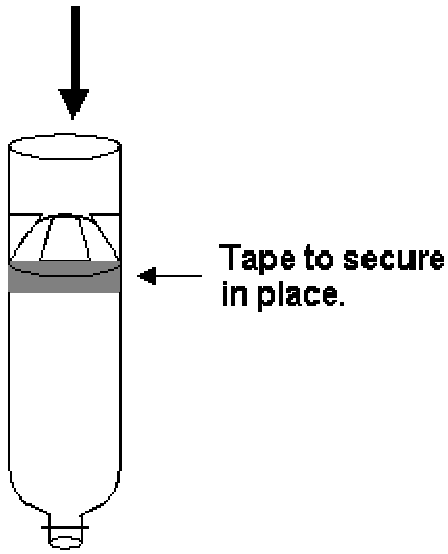
Two 2-liter bottles
One small plastic cone (athletic)
Duct Tape
Scissors
String
Manila Folder
Large Plastic Trash Bag
Masking Tape or Avery Paper reinforcement labels (you'll need 32/chute.)
Hole punch

Procedure

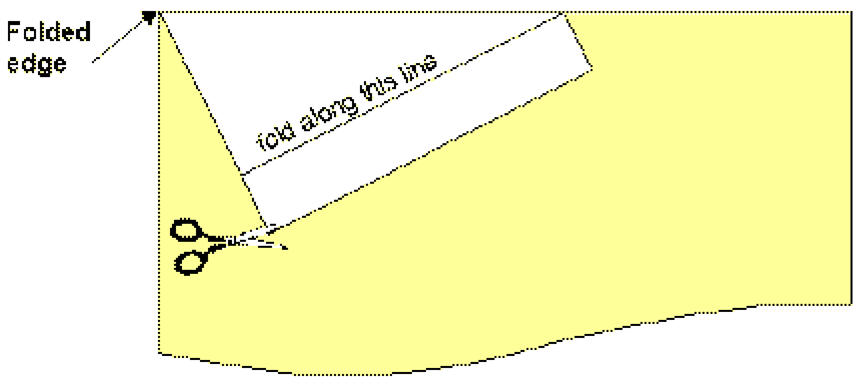
Cut the top and the bottom off of one bottle, so that the center portion or a cylinder remains.

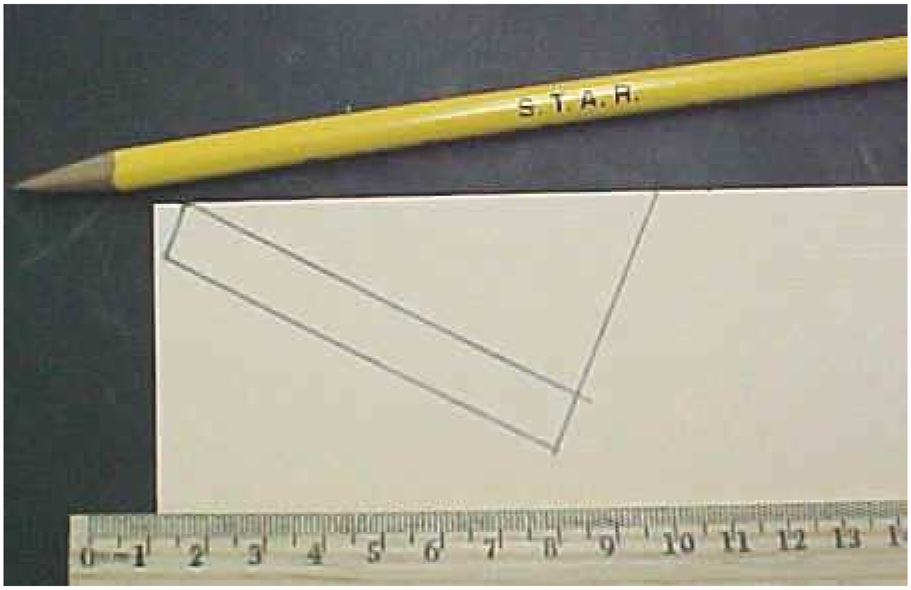


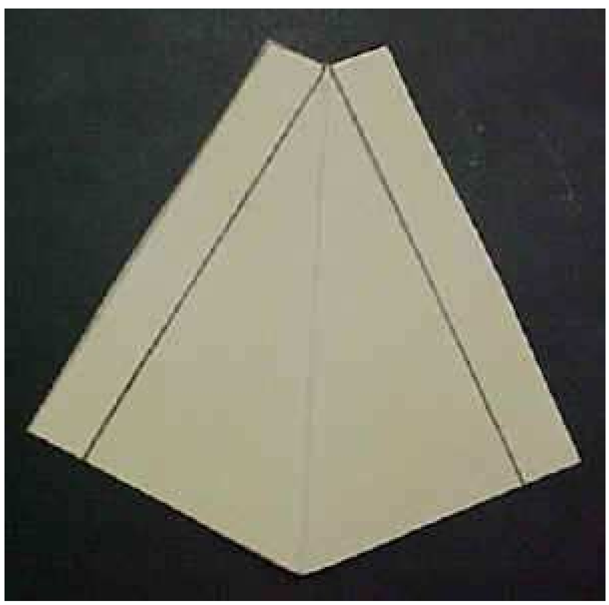
Tape the cylinder to another bottle to create a fuselage (a place to store the parachute).



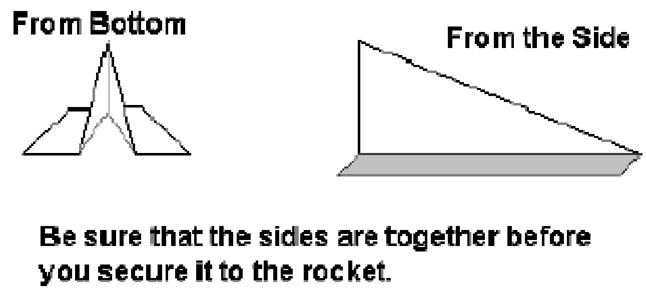
Get the manila folder; fins will be made from it. Cut three shapes out of the folded bottom in the shape that the diagram shows. Your fins will be triangular.

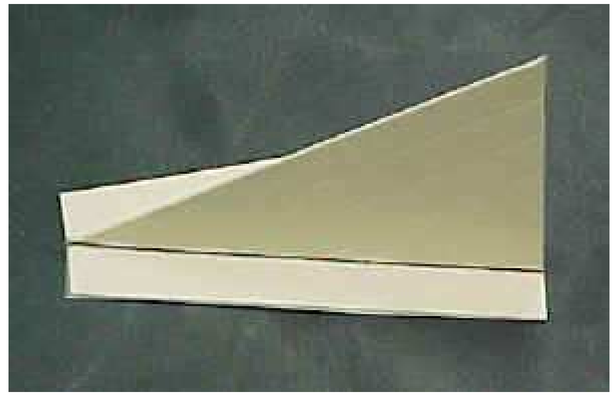






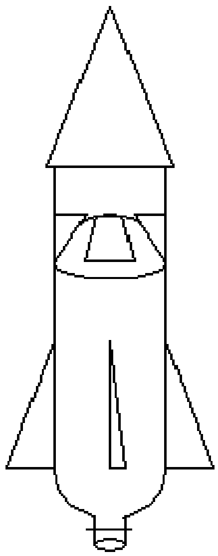
The next drawing indicates how the fin should look once folded.





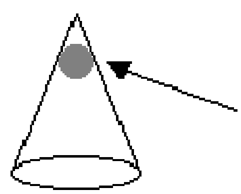
Mark straight lines on the bottle by putting the bottle in the door frame or a right angle and trace a line on the bottle with a marker. Use these lines as guides to place the fins on the bottles.

Make three fins and tape them on the rocket. Be sure that the fins are spaced equally around the rocket body. This can be achieved by using a piece of string and wrapping it around the bottle and marking the string where it meets the end. Mark the string and lay it flat on a meter-stick or ruler. Find the circumference of the bottle by measuring the length of the string to the mark. Once you know the circumference, then you can divide it by three to find the distances the fins should be separated.



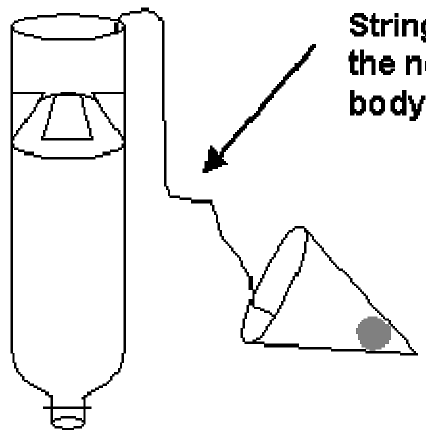
Secure fins with duct tape.

Use the athletic cone to make your nose cone. Use fairly rigid scissors and cut the bottom square off of the cone. Depending upon your project's mass limitations, place a golf ball sized piece of clay in the tip of the cone. This will add mass to the cone and give the rocket/cone more inertia. Then, using scissors, trim the cone to make it symmetrical. (Hint: the diameter of the bottom of the cone should be a little wider than the diameter of a 2-liter bottle.

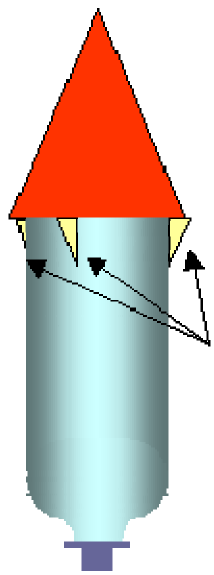


Clay stuffed inside.

Attach the cone with string to the top of the other two-liter bottles so that it looks like the diagram. Tie a knot in the end of each piece of string to give it more friction and tape it using a piece of duct tape to the inside of the cone and to the inside of the rocket body.



Many students have trouble with their nosecone getting stuck on the top of the rocket and not coming off. This can be prevented by making a pedestal for the cone to sit on. It should be high enough up so that there is space between the cone and the top of the parachute compartment. You can make a pedestal out of the same material you will make the fins, the manila folder. Make three mini-fins, invert them and tape them on the rocket where the cone should sit.



Making the Parachute

Don't forget a good parachute has shroud lines that are at least as long as the diameter of the canopy.

Lay your garbage bag out flat. Cut off the closed end. It should look like a large rectangle and be open at both ends. Lay down the bag on a flat surface and smooth it out.

The bag has a long side and a short side and is open at both ends. Fold it in two so that the short side is half as long as it was originally.

Make sure the edges are perfectly lined up during each fold. Now fold it in half along the long axis.

Make a triangle with the base of the triangle being the closed end of the previous fold.


Now fold it again. Fold the hypotenuse so that it lines up with the right side of the triangle in the above drawing.

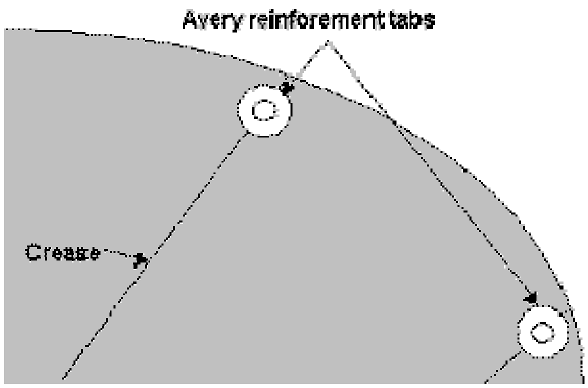
Examine the base of the triangle and find the shortest length from the tip to the base. This is the limiting factor for chute size. The most pointed end will end up being the middle of the canopy.

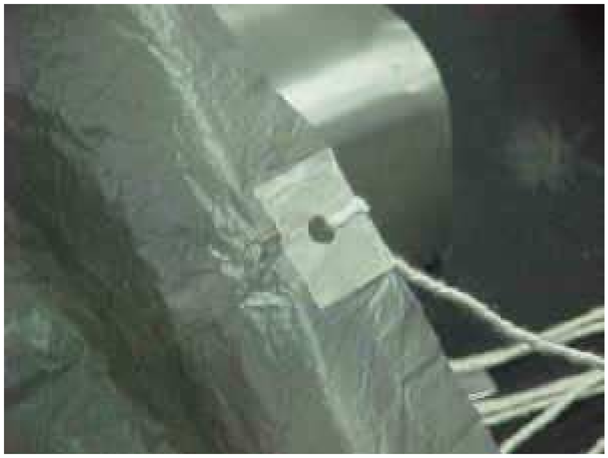
For an example; if you want the diameter of the chute to be 34 inches then measure 17 inches from the center of the canopy (the most pointed side of the parachute) along each side, mark it and then cut it.


After cutting it, unfold it. If you have been successful there should be two canopies.

Fold the canopy in half, then into quarters, then into eighths. Carefully crease the folds each time. Crease it well and fold it again. Now the canopy is divided into 16ths. Unfold the parachute. Notice the crease marks. Get masking tape and put a piece around the edge at each fold mark. You may also use Avery reinforcement tabs. Place one on both the inside and outside of every crease, making sure that they are overlaid on top of each other.

Punch holes through every piece of masking tape or Avery tab pairs and use these to attach the kite-string shroud lines.





As mentioned earlier the minimum length of the shroud line should be the same length as the diameter of the canopy.

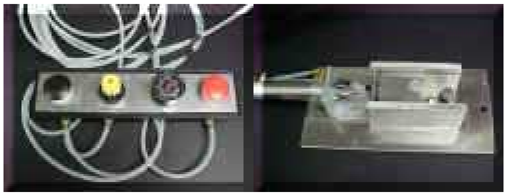
After punching the holes fold the canopy in half. Pick four holes and tie the shroud lines to the holes. After doing this tie the four lines together at the end most distant from the canopy.

Repeat this four times until the chute is completed.

Once you have it complete attach it inside the fuselage. Generally a couple of pieces of duct tape will hold the parachute to the rocket. Pack the parachute loosely and put the nosecone on the rocket.

You are now ready to launch your rocket.

Carefully read the safety instructions. Fill the rocket half full of water, place on the launch pad, pressurize, and launch.



Be safe, and have fun!

Bottle Rocket Data Collection Sheet

Demo Rocket Time Aloft: ______________________________

Group	Volume of Water	Air Pressure	Time Aloft	Notes

Lesson Activity

<table>
<tr><td>Title</td><td>Cantilever (40-55 minutes)</td></tr>
<tr><td>ID Number</td><td>HS-E-C1</td></tr>
<tr><td>Sequence and Duration</td><td>• Lead In: 15-20 minutes
• Activity: 15-35 minutes
• Closure: 5-10 minutes</td></tr>
<tr><td>Age Level</td><td>High School</td></tr>
<tr><td>Essential Question</td><td>How does a cantilever's design allow it to project over something without crashing?</td></tr>
<tr><td>Learning Objectives</td><td>• TSW identify, define, and apply the term 'cantilever'.
• TSW illustrate and explain the basic cantilever concept.
• TSW recognize various cantilever structures.
• TSW design and construct a cantilever using given materials.
• TSW modify their construction to improve the overall structure.
• TSW evaluate the strengths and weaknesses of their cantilever.
• TSW compare their cantilever to their peers'.
• TSW describe the process they took to complete the cantilever.
• TSW identify some of the uses for cantilevers in today's society.</td></tr>
<tr><td>Other Objectives</td><td>• TSW communicate with their group by contributing their vocal input.
• TSW listen as their peers discuss the construction of their cantilever.
• TSW write down the procedure they used to design their project.</td></tr>
<tr><td>Key Terms</td><td>• Cantilever
• Projecting</td></tr>
<tr><td>Materials Needed</td><td>Per Student
• Handout: Cantilevers
• Handout: MESA Notebook
Per Team (2 students)
• Cantilever Competition
• 10 popsicle sticks
• 15 paperclips
• 5 straws
• 2 meters of masking tape
• 10 pipe cleaners
• 2 sheets of newspaper</td></tr>
<tr><td>Lead In</td><td>1. Pass out 'Cantilevers' handout.
2. Give students time to look at the images to speculate what a cantilever is.
3. After 5 minutes, write the term 'cantilever' on the board. Pass out MESA Notebook while they are looking at the images.
4. Ask students to come up with characteristics that cantilevers have in common. Guide them to a common idea.
5. When the class agrees, ask them to come up with a definition of a cantilever. Guide their discussion and write common definition on the board. Some student definitions may include:
• a part of an object that sticks out
• a part of a structure that hangs over the edge
6. Tell them to write this definition in the 'key terms' section of their Notebook.
7. Write the following actual definition on the board:
• A projecting beam or member supported at only one end.
8. Compare the students' definition with the dictionary definition. Discuss to give students a complete understanding of a cantilever.
9. Write the term 'projecting' on the board and have them come up with a common definition. Write this on the board and have them copy it in the 'key terms' section of their MESA Notebook.
10. Ask, "How do you think a cantilever can project over something like a building or water without crashing into it?" Discuss possibilities and guide students to a</td></tr>
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	common understanding. *A cantilever is supported because one end has more weight on it. The most stable cantilevers are short. Brackets can be used to support cantilevers. Sometimes, as the cantilever arm extends out, it gets narrower so that a bulk of the weight and support is near the base.* 11. Ask students to think of other objects they have seen that they can now identify as cantilevers (examples: balcony, some patio umbrellas, certain chair designs; search the web for other examples). Solicit answers and discuss. 12. Ask, "Looking at the pictures and what you know about cantilevers, why are they important to us? How are they useful?"
Activity	1. Pass out the handout 'Cantilever Competition'. 2. Read handout and check for understanding by having students retell directions in their own words. 3. Tell students they have 15-35 minutes to build a cantilever with the given materials. 4. Have students get into teams and pass out the materials. 5. Monitor students while they build their cantilevers. Check to make sure they are following the rules and guidelines of the competition. 6. When time is up, have students quickly clean up. 7. Have students look at all the teams' cantilevers and compare to their own. 8. Get a measuring tape and measure how far out the cantilever extends from the table. 9. When a team winner has been announced, discuss that team's design.
Closure	1. Ask each team, "What would you do differently if you could do this activity again?" Let each team reflect on their design and their successes. 2. Have students take out their MESA Notebooks. 3. Tell them to complete the 'materials used' section, the 'procedure' section, and the 'conclusion' section at home. 4. Write the following conclusion question on the board: How does a cantilever's design allow it to project over something without crashing?
Informal Assessment	• Monitor students for understanding. • Monitor students to check for participation. • Oral evaluation of their project and what they would do differently.
Formal Assessment	• Completed cantilever. • Completed MESA Notebook.
Trouble Shooting	• Make sure all materials are ready before activity begins. • Make sure all students get the same amount/size of newspaper. • Make sure students do not share their materials.

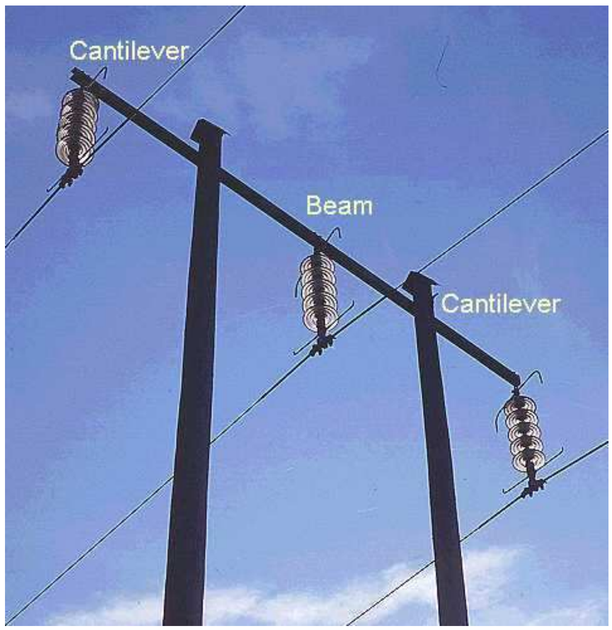
SEI Strategies Used

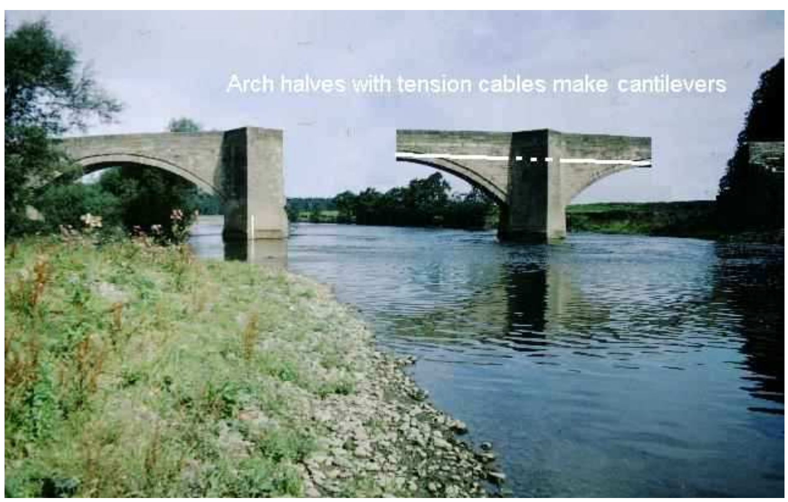
Preparation	Scaffolding	Grouping Options
☐ Adaptation of Content	☒ Modeling	☐ Whole class
☒ Links to Background	☐ Guided practice	☒ Small groups
☐ Links to Past Learning	☒ Independent practice	☐ Partners
☒ Strategies incorporated	☒ Comprehensible input	☐ Independent
Integration of Processes	**Application**	**Assessment**
☒ Reading	☒ Hands-on	☐ Individual
☒ Writing	☒ Meaningful	☒ Group
☒ Speaking	☒ Linked to objectives	☒ Written
☒ Listening	☒ Promotes engagement	☒ Oral

Arizona Math Standards	• (none)

Addressed	
Arizona Science Standards Addressed	• S1C4: TSW communicate the results of their investigation.

Cantilevers





This tree is a natural cantilever. But it is being supported by the 2 braces.

Cantilever Competition

Goal:

- Each team will build one cantilever using the given materials that extends as far as possible off the table.
- The cantilever will stay on the table with its own weight and will not be fastened to the table with clay, glue, or tape.

Materials:

- 10 popsicle sticks
- 15 paperclips
- 5 straws
- 2 meters of masking tape
- 10 pipe cleaners
- 2 sheets of newspaper

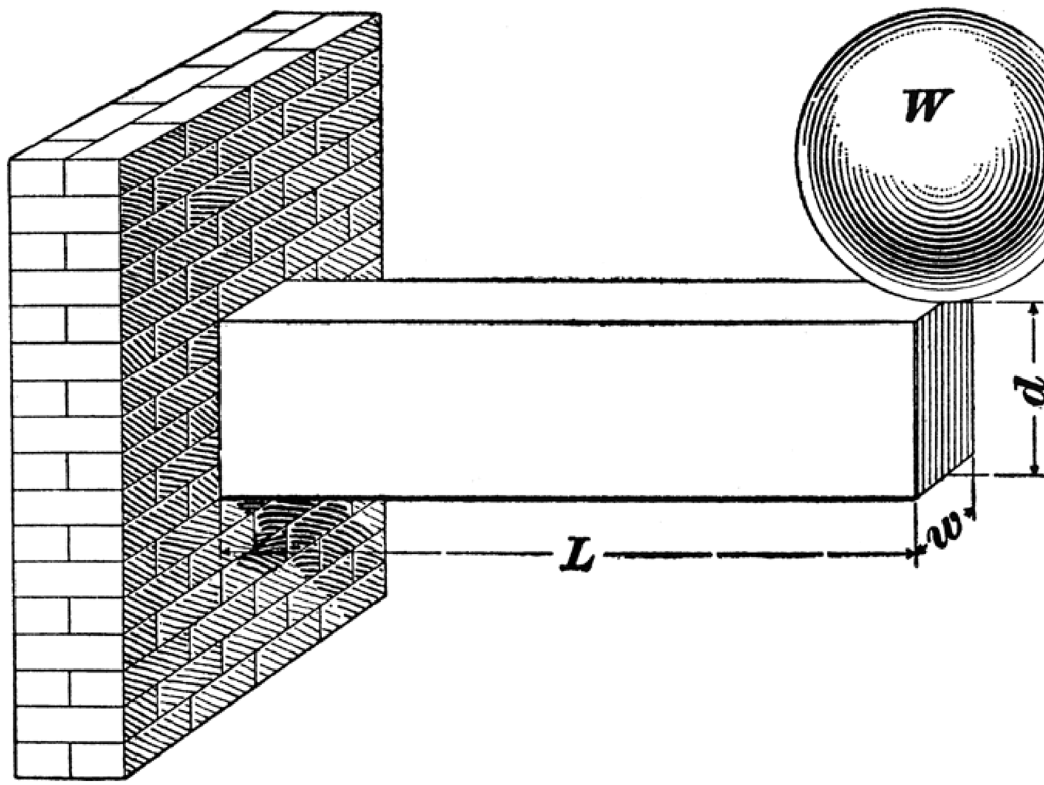
Instructions:

1. Discuss cantilevers and cantilever designs with the group.
2. Read the 'Cantilever Competition' handout. Ask questions to make sure you understand the rules.
3. Get into teams of 2-3 students.
4. Get your supplies from the advisor.
5. Brainstorm with your team to quickly come up with a design that incorporates the given materials. Use what you have learned in the cantilever discussion.
6. Begin constructing your cantilever. Your advisor will tell you how much time you have.
7. When time is up, watch as the advisor measures how far out your cantilever projects off the table.

Rules:

1. You may not use clay or tape to keep your cantilever on the table. It must be supported by its own weight.
2. You may not share your materials with the other teams. You do not have to use all your materials, but you cannot give away materials you are not using.

<u>Good Luck and Have Fun!</u>



Lesson Activity

Title	**Clay Drop – Momentum & Impulse (2 sessions, 60-80 minutes)**
Id Number	HS-S-C2
Sequence and Duration	Session 1: Background and Exploration • Lead In: 20-30 minutes • Activity: 30-40 minutes Session 2: Design Challenge • Activity: 40-45 minutes • Closure: 20-30 minutes
Age Level	High School
Essential Question	**What do momentum and impulse have to do with the design of a bike helmet?**
Learning Objectives	• TSW relate impulse and momentum to Newton's 2nd Law. • TSW describe scenarios involving objects with greater or lesser momentum. • TSW explain the variables that affect the impulse and force of an impact. • TSW complete math problems relating the force of impact to velocity and the duration of the impact. • TSW investigate the design of a helmet engineered to minimize the force of impact. • TSW engineer a product designed to protect a ball of clay from the force of impact from being dropped.
Other Objectives	• TSW develop a working plan with their group to develop a cooperative environment. • TSW communicate with their group by contributing their vocal input. • TSW listen to their peers discuss their approaches to the problem. • TSW contribute to group discussions about momentum, impulse, and products engineered to decrease the force of impact.
Key Terms	• Newton's 2nd Law: Force = mass x acceleration. • Force: a push or a pull. • Velocity: speed in a particular direction; distance / time. • Acceleration: change in velocity over time. • Momentum: the quantity of motion of an object; mass x velocity. • Impulse: a force over time that changes the momentum of an object.
Materials Needed	For Group: • One or several bicycle helmets • Scale Per Student: • Handout: MESA Notebook • Handout: Impulse and Momentum worksheet • Handout: Impulse and Momentum Math worksheet • Handout: Clay Drop data sheet Per Team: • Handout: Clay Protection Product mission • Ball of soft clay, at least as large as a golf ball • Scissors • Roll of masking tape • 4 Styrofoam plates • 15 cotton balls • 2 pieces of oaktag/1 manila folder

	• Trash bag/piece of plastic wrap • Pint-sized milk carton, empty and washed • Meter stick
Session 1	**Background and Exploration**
Lead In	1. Ask students to tell you Newton's 2nd Law, writing the equation relating force, mass and acceleration on the board. Ask students to consider when they have used or discussed this equation in the past. [previous MESA lessons, other classes, etc.] After some discussion of their previous learning, solicit explanations of Newton's 2nd Law in students' own words, and have them write these in their MESA Notebooks. [example: The heavier something is, the more force it takes to move it; *or* The more force you apply to an object, the faster it moves.] 2. Write the term *momentum* on the board; how have students heard this term used before? What do people mean by momentum? For instance, it is used to refer to something that can't be stopped (or would be hard to stop), like saying someone "has the momentum of a train". "Picking up momentum" is another common usage; what does it mean? 3. Solicit students' ideas about the term *momentum*; provide the following definition if students do not provide it themselves: momentum is the product of an object's mass and its velocity (momentum = mv). Encourage students to discuss similarities and differences between momentum and other concepts; for instance, how does momentum compare to kinetic energy (1/2 mv^2)? [Momentum, mv, is a large component of an object's kinetic energy; kinetic energy = 1/2 velocity * momentum.] 4. Discuss with students the meaning of momentum. Momentum is a combination of an object's mass and velocity; you can increase momentum by increasing either mass or velocity. Have students give examples of objects with a large momentum (e.g. moving cars, airplanes, planets, etc.). How does the momentum of a car on the freeway compare to the momentum of the same car on a small dirt road? [mass stays constant, but velocity is higher on the freeway so momentum is greater] How does the momentum of a bicycle compare to the momentum of a Hummer going the same speed? [velocities are the same, but the mass of the Hummer is greater so it has a greater momentum] Have students define momentum in their own words in their MESA Notebooks. 5. Ask students if they've ever heard the term *impulse*; what does it mean in everyday language? [example: a sudden urge or wish.] Allow students to offer examples of impulses, such as an impulse to buy a pack of gum in the check-out line, or an impulse to kiss an attractive person! 6. Tell students that you can think about impulse as a sudden *change* in the way you were feeling, or a change in the way things are going. If you describe momentum as "the way things are going", impulse can be defined as a change in momentum. This is what the term impulse means in physics: a change in momentum. [Note: Impulse is also the force over a period of time that *causes* the change in momentum. Students may be confused by this when they learn more about impulse below, but remind them that the two things (force*time and the change in momentum) are equivalent, so impulse can be described either way.] 7. For students who are unfamiliar with the "Δ" symbol, tell them it is the Greek letter *delta* and is used in math and science to refer to a change in a quantity. For instance, you would read the term "Δ velocity" as "the change in velocity". 8. Ask students, "What's another word for change in velocity?" [acceleration] "What does it take to accelerate an object?" [a force] Explain to students that in order to change an object's momentum, a force must be exerted on that object over a period of time. This force exerted for a period of time is the impulse. The impulse causes a change in momentum. Have students define

	this term in their Notebooks. 9. Hand out the Impulse and Momentum worksheet, which derives Newton's 2nd Law in terms of impulse and momentum. Go through the handout with the students and make sure everyone follows the transformation of the equation. It's simple algebra, but for students who are less familiar with the math, it may be useful to walk through the worksheet together using the board to show the steps. 10. With a discussion, encourage students to think about what this means, e.g. if you fall off your skateboard, crash your car into a pole, jump from a swing, etc. [When your velocity suddenly goes to zero, causing a large change in momentum and therefore a large impulse]. How will the collision impact you? What factors will affect the *force* of that impact? [The factors impacting the force are the magnitude of the change in momentum as well as the length of time the force must be exerted. If you are moving more slowly, you have less momentum, so the impulse and thus the force on you will be less. If the impact takes place over a greater time, the force will also be less.]
Activity	1. Hand out the Impulse and Momentum Math worksheet and allow students time to work through it in pairs or small groups. Allow sufficient time for students to work quietly together while you circulate amongst the groups. If questions arise, discuss them with the whole class. 2. After ten to twenty minutes, discuss the worksheet with the whole class. The overarching idea is that the greater the length of time of impact, the lesser the force need be to cause the change in momentum, so ensure that students are catching on to this idea. 3. Ask students to consider products that have been engineered to minimize the force of impact. (examples: helmets, knee pads, airbags, bumpers, car crumple zones, knees, sneakers, trampolines, parachutes, etc.) What are the conditions for which these products are designed [large changes in momentum] and how do they affect the force of impact? [attempt to lengthen the time of impact] 4. Pass around a helmet(s) and have students examine its design, making observations about how it has been engineered to increase the length of time of impact. 5. Collect the helmet(s) and tell students that next week they will be given a design challenge involving momentum and impulse.
Session 2	**Design Challenge**
Lead In	1. Remind students of their discussion the previous week. Remind them of their earlier learning by asking them to explain the meaning of momentum and impulse. 2. Ask students to discuss the relationship between momentum and impulse, and the relationship between the force of impact and the time of impact.
Activity	1. Tell students that for the first activity, they will drop lumps of clay from different heights and look at the deformation that results. Ask students to identify what variable they are manipulating by varying the height from which the clay is dropped. [Because the clay picks up speed as it falls, the higher the height from which it is dropped, the faster it will be going when it hits the ground, thus students are manipulating the *velocity*. If they have prior learning, such as from the roller coaster activity, students should be able to identify the relationships between height and potential energy, potential energy and kinetic energy, and kinetic energy and velocity.] 2. Tell students that they will work in small groups to choose five heights to drop the ball from, measure out those heights, drop the ball (making sure to reroll the clay after each drop), and draw a picture of the ball after it hits the ground. 3. Hand out the Clay Drop data sheets and balls of clay to each group. Give

	students 15-20 minutes to complete the activity. Circulate among the groups to make sure all students are on task. 4. When time is up, collect the clay and gather students back together for a brief whole-group discussion. How deformed were the balls when dropped from the lowest height the class tried? What was the highest height the class tried? What did the clay look like when dropped from that height? 5. Ask students what makes the clay change shapes when it hits the ground [the force of the floor on the clay, from the impulse needed to change the clay's momentum]. What could be done to decrease that force so that the clay stayed as round as possible? 6. Hand out the Clay Protection mission challenge. Tell students that their mission for today is to create a design that will protect the clay and minimize the deformation when it is dropped from a ten-foot height. Each group of three to four students will have the same materials, and they will have twenty minutes to create their design. The product can be on the ground to catch the clay, or it may travel with the clay, but not both. They may not alter the clay; during testing, everyone will receive a ball of equal weight. Remind students to draw on what they know about momentum and impulse when they design their product. 7. Give students twenty minutes to design and build their devices. During this time, weigh the balls of clay to make sure they're still all the same mass, and adjust them as needed. Roll the clay into balls and line them up on a table or other flat surface. In front of each ball, place a masking-tape label with group members' names. When finished, circulate among the groups to make sure all students are on task, and allow them to ask questions if needed. 8. When twenty minutes is up, give each group the ball of clay assigned to it and give students time to assemble their designs. Watch to make sure groups do not alter their clay. One student from each group will drop the clay; the rest of the class will observe, making sure all groups drop from the same height and making initial observations of the deformation of each ball of clay. 9. After the drop, carefully collect the balls of clay and place them by their group's label, making sure to avoid changing the shape of the clay. Allow students to circulate among the different groups' balls of clay and observe the results of the impact. Have students vote on which group won the challenge.
Closure	1. In a whole-group discussion have students describe their strategies for reducing the force of impact. Did they attempt to increase the time of impact? Did they attempt to reduce the velocity of the clay ball? What did they build to help them achieve their goal? How do the engineering strategies of the different groups compare to other products that exist to reduce the force of impact? 2. In their MESA Notebooks, have students respond to the following question, drawing on their experiences from the last two sessions: *What do momentum and impulse have to do with the design of a bike helmet?* Students can use the remaining time to finish their Notebooks with their groups, or they can finish them as homework.
Informal Assessment	• Monitor students' understanding through their responses in group discussion. • Monitor students' participation in discussions and activities. • Informal presentation of each group's design and rationale for the strategy taken.
Formal Assessment	• Completed math worksheet. • Completed data sheet. • Completed clay protection design. • Completed MESA Notebook.
Trouble Shooting	• What materials the groups receive to create their designs is not as important as the fact that all groups have the same materials. Feel free to improvise with

	materials you have on hand. • Test out the clay before class. Some clay-like substances will bounce, which is not the desired outcome for this activity! You want clay that is soft enough that it will deform when dropped, not rebound – that is, you want an inelastic collision, not an elastic collision! Substances that tend to bounce instead of deform are Play Dough and Silly Putty, and even some children's modeling clay. • To ensure that each group has an equal amount of clay, portion out and weigh the clay prior to class, making sure to keep the portions covered so they don't dry out (if necessary). • Sort out each group's materials for the mission prior to class as well; these can be packaged in large Ziploc bags or placed in different corners of the room to minimize the time needed to distribute them. • For testing of the clay protection products, seek out ahead of time an area for the drop (this can be in the classroom if there is a stable surface on which students can stand, or over a stair well, etc.). Measure off and label a ten-foot height.

SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☒ Adaptation of Content	☒ Modeling	☒ Whole class
☒ Links to Background	☐ Guided practice	☒ Small groups
☒ Links to Past Learning	☒ Independent practice	☒ Partners
☒ Strategies incorporated	☐ Comprehensible input	☒ Independent
Integration of Processes	**Application**	**Assessment**
☒ Reading	☒ Hands-on	☒ Individual
☒ Writing	☒ Meaningful	☒ Group
☒ Speaking	☒ Linked to objectives	☒ Written
☒ Listening	☒ Promotes engagement	☒ Oral

Arizona Math Standards Addressed	• S1C2: TSW understand and apply numerical operations and their relationship to one another by solving word problems using grade-level appropriate operations and numbers. • S3C3: TSW represent and analyze mathematical situations and structures using algebraic representations.
Arizona Science Standards Addressed	• S1C2: TSW design and conduct controlled experiments. • S1C4: TSW communicate the results of an investigation. • S3C2: TSW develop viable solutions to a need or problem. • S5C2: TSW analyze relationships between forces and motion, using Newton's 2nd Law of Motion to analyze the relationship between force, mass and acceleration, and analyzing the impulse required to produce a change in momentum.

Impulse and Momentum

Newton's 2nd Law: This law states that the force required to change an object's motion is equal to the mass of the object multiplied by the acceleration of the object.

Force = Mass * Acceleration, or F = ma

Acceleration is any change in an object's motion. It can be an increase in velocity, a decrease in velocity, or a change in the direction of the velocity. Acceleration happens over a certain time period.

Acceleration = change in velocity over time = Δv/t

So Newton's 2nd Law can be written as:

Force = Mass * Change in velocity over time, *or*

F = m * Δv/t

Remember that *momentum* is an object's mass multiplied by its velocity (m * v), and the change in momentum is its mass times the change in its velocity (m * Δv). If we isolate these two terms on the right side of the equation by multiplying both sides by time, we get:

F * t = m * Δv

This new equation is still Newton's 2nd Law, but in a rearranged form. The law is now stated in terms of momentum (the right side of the equation) and impulse (the left side of the equation).

Impulse is defined as the force needed to change an object's momentum, multiplied by the length of time the force is applied.

Impulse and Momentum Math

For a set change in momentum, what will happen to the force if the time is increased? Write your prediction below.

Predict what will happen to the force if the time is decreased.

Problems

1. A 0.15 kg baseball is traveling at 40 meters per second (about 90 miles per hour). What is its momentum?

2. If the ball comes to a complete stop when it hits the catcher's mitt, what is the change in velocity?

3. What must be the impulse imparted by the catcher's mitt?

4. If the catcher needs to exert a force for 0.003 seconds in order to catch the ball, what is the force on the catcher's mitt?

5. The catcher relaxes his arm when he catches the ball, extending the time it takes to slow the ball to a stop. The time he exerts the force is now 0.005 seconds. What is the force now?

6. If the catcher held his arm very stiff and decreased the time to 0.002 seconds, what would the force be?

7. Do your predictions above match what you found by doing the math? Explain.

8. What is another way of reducing the force the catcher must exert on the ball? Create your own problem with a scenario that would reduce the force on the mitt (keeping all other variables constant) and solve for the force.

Impulse and Momentum Math (key)

For a set change in momentum, what will happen to the force if the time is increased? Write your prediction below.

> What students predict at this point does not matter, so long as they make a prediction. However, if the time were increased, the force would decrease, since the total impulse for a given change in momentum must remain constant.

Predict what will happen to the force if the time is decreased.

> If the time were decreased, the force would increase.

Problems

1. A 0.15 kg baseball is traveling at 40 meters per second (about 90 miles per hour). What is its momentum?

   momentum = mass * velocity

   momentum = 0.15 kg * 40 m/s

   momentum = 6 kg*m/s   or   6 Newton*seconds

2. If the ball comes to a complete stop when it hits the catcher's mitt, what is the change in velocity?

   change in velocity = final velocity – initial velocity

   change in velocity = 0 m/s – 40 m/s

   change in velocity = -40 m/s

3. What must be the impulse imparted by the catcher's mitt?

   The impulse must be equal to the change in momentum.

   change in momentum = mass * change in velocity

   change in momentum = 0.15 kg * -40 m/s

   change in momentum = -6 kg*m/s   or   -6 Newton*seconds

4. If the catcher needs to exert a force for 0.003 seconds in order to catch the ball, what is the force on the catcher's mitt?

   The impulse is equal to the change in momentum, which students already found to be -6 kg/s. Since impulse is equal to force over time, the force is equal to impulse divided by time.

force = (-6 kg*m/s) / 0.003 s

force = -2000 kg*m/s^2 or -2000 Newtons

Note: The negative sign on this number simply indicates that the direction of the force is *opposite* the direction that the ball is traveling. If you like, you could talk here about how a force that *increased* the object's velocity (resulting in a positive change in velocity) would have to be in the same direction as the direction in which the object is traveling.

5. The catcher relaxes his arm when he catches the ball, extending the time it takes to slow the ball to a stop. The time he exerts the force is now 0.005 seconds. What is the force now?

force = (-6 kg*m/s) / 0.005 s

force = -1200 kg*m/s^2 or -1200 Newtons [the force has decreased significantly]

6. If the catcher held his arm very stiff and decreased the time to 0.002 seconds, what would the force be?

force = (-6 kg*m/s) / 0.002 s

force = -3000 kg*m/s^2 or -3000 Newtons [the force has increased significantly]

7. Do your predictions above match what you found by doing the math? Explain.

Responses will vary. When discussing this question, ensure that all students understand that increasing the time of impact *decreases* the force required, and decreasing the time of impact *increases* the force required.

8. What is another way of reducing the force the catcher must exert on the ball? Create your own problem with a scenario that would reduce the force on the mitt (keeping all other variables constant) and solve for the force.

The force can be reduced by reducing the total impulse, which can be accomplished by reducing the change in momentum. The change in momentum can be reduced by decreasing the change in velocity. For instance, if a student created a problem in which the ball were traveling at half the speed, 20 m/s, keeping the time of impact constant at 0.003 seconds and the mass constant at 0.15 kg, the resulting force would be:

force = (change in momentum) / time

force = [0.15 kg * (0 m/s – 20 m/s)] / 0.003 s

force = (0.15 kg * -20 m/s) / 0.003 s

force = (-3 kg*m/s) / 0.003 s

force = -1000 kg*m/s^2 or -1000 Newtons

Clay Drop Activity Data Sheet

Height (cm)	Image of Dropped Clay

Mission: Clay Protection Product

Your mission for today is to design protection for a ball of clay to be dropped from a height of ten feet. The goal is to minimize the amount of deformation the ball of clay undergoes when it hits the ground. Your design must meet the following specifications:

- The product you design can travel with the clay or be on the ground to catch it, but you must choose one or the other.
- You may not alter the clay. Each group will have a lump of clay of uniform mass, rolled into a ball.
- You may use only the materials provided to you. You do not need to use all the materials, but you may not give any unused materials to other groups.

You have twenty minutes to create your product. You may use the space below to sketch out your design. Make sure you draw on what you know about momentum and impulse when you design your product!

Lesson Activity

Title	**On-Site Design Challenge: Design a Glider (60-80 Minutes)**
ID Number	HS-E-OS1
Sequence and Duration	• Lead In: 10-15 Minutes • Activity: 40-50 Minutes • Closure: 10-20 Minutes
Age Level	High School
Essential Question	**How should I approach an on-site engineering challenge?**
Learning Objectives	• TSW design and build a glider to specs. • TSW reflect on and evaluate their approach to the problem and the strategies they used to address it. • TSW evaluate their ability to design and construct under pressure. • TSW brainstorm strategies to help them be successful at on-site design challenges in the future.
Other Objectives	• TSW develop a working plan with their group to develop a cooperative environment. • TSW communicate with their group by contributing their vocal input. • TSW develop critical reading skills by finding relevant information in given materials. • TSW listen to their peers discuss their approaches to the problem. • TSW contribute to a group discussion about being successful in on-site design challenges.
Key Terms	• On-site design challenge • Approach • Strategy
Materials Needed	Per Class: • Stopwatch • Scale • On-Site Engineering Design Data Collection Sheet Per Group: • Handout: On-Site Engineering Design specs • 2 pieces printer paper • 2 pieces oak tag/cardstock • Roll of masking tape • Bottle of white glue • 12 popsicle sticks • 6 pipe cleaners • Stapler • 10 paper clips • 2 pairs of scissors • Other materials of your choice, such as cardboard, Styrofoam, balsa wood, etc., ensuring that all teams have identical supplies
Lead In	1. Remind students to sign in as they enter. 2. Tell students you will be talking about preparing for one particular MESA Day competition today: the On-Site Design challenge. If there are students in the class who have participated in previous MESA Day events, allow them to comment on the On-Site challenge. If there are no students with previous experience, solicit students' ideas about what the on-site design challenge will

	be like. 3. If it has not already been discussed, tell students that for the on-site challenge, teams will receive their mission and the specs only when they arrive "on site", and they must design, build and test their structure within the given time period and with the given materials. So they will essentially be "designing under pressure", relying on their ability to address the mission quickly by drawing on their prior knowledge and being strategic about their decisions and process. 4. Ask students what kinds of skills and strategies might be useful for this kind of challenge. Possible skills include: the ability to work under pressure; patience; ability to apply previous learning to the task; having a solid understanding of the mission; ability to work well with your team members. Strategies include: reading the specs carefully; reviewing what you know about the science behind the mission; taking the time to design prior to building; working efficiently so you have time to test and modify prior to competing.
Activity	1. Tell students they will be doing a practice on-site design challenge today. Once they have their materials, they will have exactly 30 minutes to complete the mission. Remind them to consider the skills and strategies they discussed that will help them to be successful. 2. Separate students into groups of three or four and hand out the supplies. When all supplies have been distributed, hand out the specs face down, instructing students not to turn them over until you tell them to. Tell them they may raise their hands if they need clarification about the rules, but to think of you as the judge, not their advisor. 3. Call out "begin!" and start the 30 minute count-down. 4. After 30 minutes are up, call time and have students clean up their areas and bring their gliders to the testing area (be sure to use an area where there is little chance of a passer-by being hit by a glider). 5. Weigh each glider and record the weights on the On-Site Engineering Design Data Collection Sheet. 6. Begin the competition. If there is sufficient time remaining you may want to launch the gliders one by one to observe that each team is launching under the same conditions (e.g. watching for students who might give their gliders a push or start the launch from above or below the starting line). This also allows all groups to receive an individual time rather than having it be a race of sorts. It also avoids inter-glider interference! However, if there is insufficient time, have all gliders launched at once, and the winner is the one that stays in the air the longest. Record times on the Data Collection Sheet. 7. Collect gliders and other materials and return to class.
Closure	1. Initiate a discussion of students' strategies in approaching the challenge, and their experiences as they were engaged in designing and constructing. Were all students able to build successful gliders? Why or why not? 2. For teams that were successful, what helped them figure out how to design their gliders? What else helped them succeed? 3. Ask how many students have an understanding of what helps a glider fly. How did this understanding help them make decisions about their designs? For students who did not have this understanding, what did they need to do as they were designing their gliders? How did they compensate for not having the background knowledge they needed? 4. If students did not know how to proceed without this knowledge, discuss some possibilities. Students could try experimenting with different designs quickly, thinking of examples of things that glide, relating other scientific knowledge they have to gliding, etc. 5. Ask students, for future on-site design challenges, how might you approach the problem? What strategies will you use? How will you make the best use of

	your time? 6. In their MESA Notebooks, have students respond to the following conclusion question: *How should I approach an on-site engineering challenge?* They can use the remaining time to complete their Notebooks or finish them as homework.
Informal Assessment	• Monitor students' participation in the activity. • Monitor students' participation in the discussion.
Formal Assessment	• Completed MESA Notebook. • Completed glider.
Trouble Shooting	• Prior to this lesson, find an area where it will be safe to drop the gliders, and which is high enough that the gliders will have sufficient time to glide. For instance, you might use a stairwell that is open on one side, an auditorium stage, or gymnasium bleachers from which to drop the gliders. Set up a "starting line" from which all gliders will be dropped. • Separate out each team's materials and place them in baggies or boxes prior to students' arrival to class. • What materials the groups receive to create their designs is not as important as the fact that all groups have the same materials. Feel free to improvise with materials you have on hand. • You may have students who freeze under time constraints; urge these students to relax and take one step at a time. Encourage them to just begin talking or designing and do the best they can with the time they have. • Remind students who are testing their gliders prior to competition to be mindful of safety; have them test in an open area or outdoors.

SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☐ Adaptation of Content	☐ Modeling	☒ Whole class
☐ Links to Background	☐ Guided practice	☒ Small groups
☒ Links to Past Learning	☒ Independent practice	☐ Partners
☒ Strategies incorporated	☐ Comprehensible input	☐ Independent
Integration of Processes	**Application**	**Assessment**
☒ Reading	☒ Hands-on	☐ Individual
☐ Writing	☒ Meaningful	☒ Group
☒ Speaking	☒ Linked to objectives	☐ Written
☒ Listening	☒ Promotes engagement	☒ Oral

Arizona Math Standards Addressed	(none)
Arizona Science Standards Addressed	• S3C2: TSW develop viable solutions to a need or problem.

ON-SITE ENGINEERING DESIGN
High School Level
Glider

OBJECTIVE:

Your engineering team has been hired to design and build a glider that will stay aloft for the greatest length of time. The team shall compete with other teams in a head-to-head competition.

MATERIALS:

2 – Pieces printer paper
2 – Pieces oak tag/cardstock
1 – Roll of masking tape
1 – Bottle of white glue
6 – Pipe cleaners
10 – Paper clips
12 – Popsicle sticks

Other materials available for use but not included in the design:

Scissors Stapler Pencil Paper

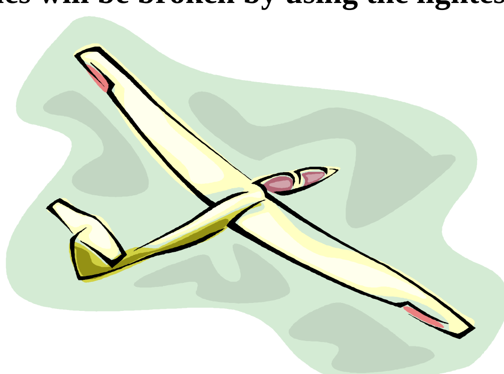
RESTRICTIONS and INSTRUCTIONS:

1. All gliders must be powered by gravity; no other energy source will be allowed.
2. Glider must stay together in flight; gliders that fall apart will be disqualified.
3. No assistance and no physical contact can be made with your glider once launched.
4. A team representative will stand above the starting line. When signaled, the representative will drop the team’s glider. The representative may not release the glider from any point beyond the starting line.
5. Time will begin when the glider is released from the representative’s hand and end when the glider first hits the ground.

SCORING:

- Time will be measured by judge(s) using standard digital stop watches.
- Each glider will be weighed for tie-breaking purposes.

Time ties will be broken by using the lightest glider!



ON-SITE ENGINEERING DESIGN
High School Level
Glider

Data Collection Sheet

Group Members	Weight (g)	Time (s)

MESA Mathematics Engineering Science Achievement

Lesson Activity

Title	**Design a Roller Coaster (2 sessions, 60-80 minutes)**
ID Number	HS-S-C3
Sequence and Duration	Session 1: Background and Planning • Lead In: 30-40 minutes • Activity: 20-30 minutes Session 2: Building and Testing • Activity: 40-45 minutes • Closure: 20-30 minutes
Age Level	High School
Essential Question	**What affect do Newton's Laws and the Law of Conservation of Energy have on the motion of roller coasters?**
Learning Objectives	• TSW use the Law of Conservation of Energy to explain the layout of a roller coaster. • TSW explain how a roller coaster works in terms of physics concepts. • TSW design and build a roller coaster that fits within the given specifications. • TSW identify and explain the features of their roller coaster and describe how it works.
Other Objectives	• TSW develop a working plan with their group to develop a cooperative environment. • TSW communicate with their group by contributing their vocal input. • TSW write down the procedure they used to design their project.
Key Terms	• Gravity • Potential energy • Kinetic energy • Law of Conservation of Energy • Newton's 1^{st} Law • Newton's 2^{nd} Law • Acceleration • Velocity • Inertia • Centripetal force • Thrill elements
Materials Needed	For Group: • Box of assorted materials for building, such as: popsicle sticks, pipe cleaner, oak tag, paper towel rolls, empty 2-liter bottles, plastic tubes, scissors, glue, tape • Roller coaster kit (optional; can check out from EAO) Per Student: • Handout: MESA Notebook Per Team: • Handout: Design a Roller Coaster Competition • Handout: "Roller Coaster Run" MESA Day Event Specifications • Drawing paper • Colored pencils • Meter stick • Stopwatch • Marble

Session 1	Background and Planning
Lead In	1. Ask students about their experiences with roller coasters. How many of them have ever ridden one? Who loves roller coasters; who hates them? Why? What is it about roller coasters that makes them fun/scary? Allow time for students to relate their experiences and discuss roller coaster elements they have seen or heard about that they find especially exciting or frightening. 2. Ask students if they know what makes a roller coaster work. Guide students to an understanding that roller coasters are powered by *gravity*. Make sure students have a solid understanding of gravity: the force of attraction between two masses; on Earth, the force that pulls objects toward the center of the Earth. Write this term on the board and have students write it and define it in their MESA Notebooks. 3. Ask students if they can think about what all roller coasters have in common at the beginning of the ride. [They are pulled up to the top of a big hill to start the ride; this hill is the biggest hill on the track.] Why do all roller coasters start this way? What does this do? [Going to the top of the hill provides the roller coaster with enough *potential energy* to complete the rest of the track.] Remind students of their previous learning about potential energy [impact craters lesson; other relevant lessons] and write and define this term in their MESA Notebooks. Example definition: stored energy. In the case of roller coasters, it is *gravitational potential energy*, energy that an object has by virtue of its position in a gravitational field (i.e. if the object is some height above the ground, it has the potential to fall to the ground because gravity is pulling on it). How much potential energy the roller coaster has depends on how high it is lifted at the beginning of the ride. 4. Ask students what happens once the coaster is let go at the top of the hill [it rolls faster and faster down the hill]. What happens to the potential energy at that time? [It is transformed, or converted, into *kinetic energy*.] Remind students of their previous learning about kinetic energy, the energy associated with motion. Students should write this term in their Notebooks. 5. Ask, “Why do they call them ‘roller coasters’? What does it mean to *coast*?” Guide students to an understanding that all the energy for the ride comes from the potential energy of being at the top of the first hill, and that the coaster uses this energy to coast along the rest of the track. [Note: There are some roller coasters that use other sources of power at certain points of the ride, but true roller coasters simply coast the whole way.] 6. Ask if anyone can explain the Law of Conservation of Energy [energy cannot be created or destroyed; it can only be transformed (changed from one type to another) or transferred (exchanged between objects)]. Have students discuss this concept until they can define it in their own words in their MESA Notebooks. Ask, “How does the Law of Conservation of Energy apply to roller coasters?” [The roller coaster’s potential energy from being at the top of the first hill is transformed into kinetic energy as it falls down the hill; the energy is often transformed multiple times as the roller coaster goes over additional hills and loops.] 7. Ask, “Why does the first hill have to be the tallest? Why can’t there be any taller hills later?” [There isn’t sufficient energy in the system for the coaster to climb a taller hill.] “Why can’t there be any hills just as tall as the first one later in the ride?” [Even though the coaster begins with enough energy to climb a hill equally tall as the first one, the system loses energy to *friction*. Friction of the wheels on the tracks, as well as friction from air resistance, causes some energy to be converted to heat, which then escapes. Make sure students understand that the energy is lost to the *system*, not the Universe! Energy is still being conserved.] Make sure students can define friction, and write this in their Notebooks. Example definition: the force of rubbing between two

	objects that opposes motion. 8. Ask students to think about what they've learned about objects in motion (Newton's Laws from previous lesson on mousetrap cars). Have students discuss Newton's Laws of motion as they relate to roller coasters. Newton's 2nd Law states that force equals mass times acceleration, or acceleration equals force over mass. Make sure that students are able to explain this in their own words: the greater the force on the object, the more it will accelerate; the more massive the object, the smaller the change in acceleration for a given force. Ask, "What does it mean to *accelerate*?" [to experience a change in velocity] "What is *velocity* (or speed)?" [how fast an object is going] "What are some ways that velocity can change?" [it can increase (go faster), decrease (go slower, or *decelerate*), or change direction] Have students write these terms in their Notebooks. 9. Have students talk about what it *feels* like to accelerate. Tell students that they've all experienced the different types of acceleration when they've ridden in (or driven) a car. What happens to your body when the car speeds up? [your body goes backward] When the car slows down? [your body goes forward] When the car changes direction, like going around a turn? [your body moves in the opposite direction] What makes your body do these things when the car accelerates? [your inertia] Make sure students write *inertia* in their Notebooks and can describe it in their own words: a tendency to keep doing what you're doing, or a tendency to continue moving at a constant velocity (even if that velocity is zero). Remind students that this is Newton's 1st Law. 10. Explain that it is inertia that keeps people from falling out of the roller coaster when it goes through a loop. Your body wants to keep moving in a straight line, regardless of what the roller coaster is doing. When you get to the top of the loop, both you and the roller coaster want to keep going in a straight line headed away from the track, but the track pushes against the roller coaster to keep it in the loop, and the roller coaster pushes against you! This push is toward the center of the loop, and is called the *centripetal force*. The centripetal force is what keeps objects moving in a circle instead of continuing off on a straight line. Students can play with centripetal force by swinging objects *carefully* around their heads on a piece of string, or you can demonstrate this motion for the class. What is providing the centripetal force? [the string and your hand] Ask students to predict what will happen if you let go of the string – will the object keep moving in a circle? (It is a common misconception among students that it will.) Demonstrate that the object does indeed continue moving in a straight line when the centripetal force toward the center of the circle is no longer acting on it. Have students write *centripetal force* in their Notebooks and ensure that they understand it by describing it in their own words. 11. Loops and other parts of the roller coaster ride that are especially exciting are called *thrill elements*, and they include hills (where the roller coaster slows down going up and speeds up coming down), turns (where the roller coaster changes direction), and loops (where it changes in speed and direction!). Have students think about thrill elements they've experienced or seen on roller coasters, and what makes them thrilling. They will find that many of these thrill elements are thrilling because they involve acceleration. The feeling of your body's inertia reacting to the acceleration of the roller coaster cart is what makes roller coasters so exciting (and scary!).
Activity	1. Tell students that their mission is to design a roller coaster for a marble "rider" that satisfies the specs on the handout they will receive. Their roller coasters must have at least two thrill elements and must safely deliver the marble to the end of the track after a ride of 10-25 seconds. 2. Hand out the Design a Roller Coaster instructions and the drawing paper and

	colored pencils. Tell them they have the rest of the session to come up with their design and to try out different things using the materials available in class. The marble will be provided and the classroom materials will be available, but they must bring any other objects they might need from home to build their final roller coaster designs. [Note: Strips of oak tag work well as a cheap material for prototyping designs.] 3. Write the following questions on the board: What thrill elements will your coaster have? How will you control the length of the marble's ride? How can you minimize friction so the marble has enough energy to finish the ride? How will you make sure the marble completes the ride safely? How will you get your marble to a complete stop at the end? 4. Monitor and check student progress. Before students begin building, make sure their concept drawing addresses competition rules and specifications. Make sure their materials are reasonable things they can easily get from home or the classroom. 5. Have students identify on their drawings where the roller coaster will experience maximum potential energy (at the top of the first hill) and where it will experience maximum kinetic energy (at the bottom of the first hill). Have them identify where the coaster experiences a centripetal force, and the direction of that force (centripetal force comes into play whenever the roller coaster travels on a curve, and the force points toward what would be the center if the curve were a complete circle). 6. During the last 5 minutes of project time, tell teams to assign materials. Who is going to bring materials for the next meeting? (You may want to follow up this meeting with an email to all MESA students reminding them to bring their materials for the next meeting.)
Session 2	**Building and Testing**
Activity	1. Have students get with their teams and get out their designs and the materials they brought from home. Tell teams that they can use the classroom supplies as well. 2. Give them 5 minutes to gather their supplies and to go through your supplies. 3. After 5 minutes, ask teams if they need to modify their drawings based on their supplies. If they do, they may do so now. Pass out colored pencils to the teams that need to modify their design. 4. Tell teams they have 25-40 minutes to build their roller coasters. Advise them to work together in their teams and to ask for help if they need it or if they have questions. 5. Monitor student progress and check to make sure their construction follows their design concept and the competition specs closely. 6. When teams begin to wrap up their construction, encourage them to test their designs and make modifications as necessary. 7. When time is up, have students clean their areas and bring their roller coasters to a common area.
Closure	1. When all students have had a chance to finish building and testing their designs, allow each team an opportunity to demonstrate their coaster and explain their design for the whole class. Have the rest of the class point out ways each team satisfied the specs and how the team's creativity came through. 2. Review the ways the physics concepts discussed the previous week affected the roller coasters. Revisit the questions on the board from last week and ask the students to talk about how they answered those questions with their designs. 3. Make sure students can apply the concepts they've copied into their MESA Notebooks to their experience with their roller coasters. 4. Tell students they have the remainder of the time to complete the MESA Notebook. They may work with their team. Write the following 'conclusion'

<table>
<tr><td></td><td>questions on the board and tell them to answer them using what they have learned from the activity:
How do Newton's laws of motion affect the motion of roller coasters?
How does the Law of Conservation of Energy apply to roller coaster design?
How does friction affect roller coasters? How can friction be reduced?
If you could do this activity again, what changes would you make to your roller coaster to make it better?
5. Monitor their progress.
6. Students may complete their MESA Notebook at home.
7. Optional extension: Explain that for the MESA Day competition, the roller coaster will need to have a theme. What themes could work for a roller coaster design?</td></tr>
<tr><td>Informal Assessment</td><td>Monitor students as they progress through the project.
Monitor students to check for understanding periodically.
Informal Oral Presentation of team design and roller coaster.</td></tr>
<tr><td>Formal Assessment</td><td>Completed roller coaster design.
Completed roller coaster.
Completed MESA Notebook.</td></tr>
<tr><td>Trouble Shooting</td><td>Use visuals and manipulatives to demonstrate concepts in Session 1 as much as possible. You can use a toy car track or model roller coaster to point out concepts such as potential energy, kinetic energy, acceleration, and friction. You can also fashion your own roller coaster design, but be wary of the possibility that students might mimic your design rather than come up with an original design and construction technique.
Consider having students build roller coaster prototypes with cheaper materials, such as strips of oak tag, to test out their ideas about how the marble will move, prior to building with more expensive or harder to come by materials.
Encourage students to be creative in their design and choice of materials. Each roller coaster should be unique!</td></tr>
<tr><td colspan="2">SEI Strategies Used

Preparation
☐ Adaptation of Content
☒ Links to Background
☒ Links to Past Learning
☒ Strategies incorporated

Scaffolding
☐ Modeling
☐ Guided practice
☒ Independent practice
☒ Comprehensible input

Grouping Options
☒ Whole class
☒ Small groups
☐ Partners
☐ Independent

Integration of Processes
☐ Reading
☒ Writing
☒ Speaking
☒ Listening

Application
☒ Hands-on
☒ Meaningful
☒ Linked to objectives
☒ Promotes engagement

Assessment
☐ Individual
☒ Group
☒ Written
☒ Oral</td></tr>
<tr><td>Arizona Math Standards Addressed</td><td>(none)</td></tr>
<tr><td>Arizona Science Standards Addressed</td><td>S5C2: TSW analyze the relationships between forces and motion by explaining how Newton's 1^{st} law applies to objects at rest or moving and use Newton's 2^{nd} law of motion to analyze the relationships among the force acting on a body and the resulting acceleration.
S5C3: TSW understand ways that energy is conserved, stored and transferred.</td></tr>
</table>

Team Members:____

Design a Roller Coaster Competition

Goal:

Your mission is to design a roller coaster that satisfies the specifications below. In teams of three or four, you will first draw your design on paper. If you are not sure if something will work, try it out with materials like paper, cardstock and masking tape. Once you have a final design, have your advisor approve it and you can start building with materials of your choosing. Choose your materials wisely, and BE CREATIVE!

Roller Coaster Specifications:

- Fit within a $70x70x70\ cm^3$ space and weigh no more than 10 kg
- Have at least 2 thrill elements
- Keep contact with the marble at all times
- Consist of a ride of 10 – 25 seconds, more points for longer rides without going over
- Get the marble to a complete stop at the end

Treat the marble like a car full of people – make sure it reaches the end of the track safely! Don't allow the marble to do anything that roller coaster designers wouldn't allow with people: no flying through the air, crashing, etc.

Team Materials:

Design Drawing

- Drawing paper
- Colored Pencils

Roller Coaster

- One marble (provided by advisor)
- Meter stick
- Stopwatch
- Any other materials decided upon by each team

Instructions:

Day 1:

1. Design your roller coaster with your team.
2. Draw your design on the drawing paper provided by your advisor. Use colored pencils.
3. Your drawing must show what types of materials are being used in your design.
4. Identify on your drawing the place where the roller coaster will experience the maximum potential energy.
5. Identify on your drawing the place where the roller coaster will experience the maximum kinetic energy.
6. Identify on your drawing any place where the roller coaster experiences a centripetal force, and draw an arrow indicating the direction of that force.
7. If there are any components you want to test out before you prepare your final design, take some time to use the materials set out by your instructor to construct a model to test.
8. Have your advisor approve your design before you build your final design.
9. Be creative!

Day 2:

1. Check to make sure your team has all the materials needed for your roller coaster. If not, you need to modify your drawing.
2. Build your roller coaster with your team.
3. Test your roller coaster with any remaining time.

Lesson Activity

Title	**Disposable Camera Dissection (50-70 minutes)**
ID Number	HS-E-C1
Sequence and Duration	• Lead In: 5-10 minutes • Activity: 40-50 minutes • Closure: 5-10 minutes
Age Level	High School
Essential Question	**What engineering went into designing the disposable camera?**
Learning Objectives	• TSW name products from their everyday lives that have been engineered. • TSW examine and dissect a disposable camera, identifying its parts and their functions. • TSW assemble lenses so to perform different functions (projection, telescope, and magnifier).
Other Objectives	• TSW communicate with their group by contributing their vocal input. • TSW investigate the functions of camera components. • TSW record and sketch their observations.
Key Terms	• Engineering • Capacitor • Discharge • Component • Function • Lens
Materials Needed	Per Class: • Metal tool with an insulator handle, e.g. plastic-handled screwdriver • Disposable camera • Rubber gloves • Goggles Per Group: • Handout: Disposable Camera Dissection & Notes worksheet • Disposable camera • Tool, such as a flathead screwdriver or letter opener (optional) • Fresnel lens magnifying card or other converging lens (optional) Per Student: • Safety goggles
Lead In	1. Encourage the students to think about all the things they come in contact with everyday that have been developed by engineers. Ask them, “What machines have you touched today?” Create a list on the board of all the ideas they come up with. 2. Ask the students if they think people usually think about all the engineering that goes into the products they use every day of their lives, or if they tend to take these things for granted. How do engineers help make people’s lives better? 3. Tell the students that today they will be looking at one example of a device they probably all have used without appreciating the engineering that went into it: a disposable camera.
Activity	1. Separate the students into small groups of two or three and hand out the cameras, goggles and worksheets to each group. 2. Give the students about 5 minutes to explore the camera and play with its functions. Make sure they are making observations on the Notes worksheet, but do NOT allow them to open the cameras’ cases yet. While they make observations, put on your gloves and goggles and prepare the classroom demonstration camera, removing its battery and

	opening up the case to give you access to the circuit board. Be VERY CAREFUL not to touch the leads of the capacitor, attached to the flash. 3. When you are ready with the camera and insulator-handled tool, call the students' attention to you. Tell them you are about to show them why they need to be careful when they open their cameras. If any student has prior learning about electronics, he/she may know what a capacitor is; if so, have that student explain it for the class. If not, tell the students that capacitors store electrical charge so it can be used when needed. What in the camera would require a burst of charge that can be used when needed? [The flash.] 4. Use your insulator-handled tool to touch the leads of the capacitor; this will usually cause a loud pop and spark as the capacitor discharges. Touch the leads again to discharge the capacitor fully, in case any charge remained after the first discharge. Ask the students what would happen if their hands connected the leads like the tool did. [They would get a huge shock!] This is why discharging capacitors is a job for an advisor! 5. Have the students pop open their cameras and remove the batteries (or you may want to do this for them, to be safe). Go to each group and discharge every camera's capacitor. 6. Now that all the capacitors are discharged, give the students 20-25 minutes (and any tools you may have available) to take their cameras apart and examine all the components. Different brands of cameras will look different on the inside, but any brand of camera should be simple to take apart with minimal force. 7. Direct students' attention to the questions on the worksheet to help guide their exploration. Some students will be more attracted to the circuit board, others may be more interested in the lenses, while others are interested in the gears. Let the students follow their interests, but make sure they keep track of their observations and ideas on their Notes sheet. 8. Have the students pop out the main lens in the camera, as well as the viewfinder lenses, and explore their properties. Do the lenses magnify images? How close does the object need to be before it comes into focus for each lens? Have the students try aiming the lens at a window or bright light and trying to project an image onto a piece of paper behind the lens. What do the images look like? What if you look through, or project through, two lenses at once? If you have access to Fresnel lenses, or other longer focal length lenses, you can have the students try constructing telescopes. They can make these telescopes permanent by mounting the lenses in tubes of cardstock and sliding one inside the other until objects come into focus.
Closure	1. Have the students report out on what they found in their cameras and what they were able to discern about how the different components help make the camera work. Who explored the shutter mechanism? Who explored the electronics? Who figured out how the dial advances the film? Did anyone trace the path that light takes through the lenses? 2. Ask the students to think about the engineering that went into designing this product. What considerations do they think the engineers who designed the camera had to make? What kinds of scientific knowledge must they have had? What kinds of engineer do they think were involved in the design of their cameras (e.g. industrial engineer, electrical engineer, mechanical engineer, etc.)?
Extensions	1. For more information about capacitors, have students check out the capacitor page in How Stuff Works at http://www.howstuffworks.com/capacitor.htm. 2. If students are interested in learning more about types of engineers, have them research the possibilities online. For instance, you can have groups choose a field of engineering and report back to the class about what these engineers do, where they work, and the kind of projects they are involved in. A good site for doing this is: http://www.engineeringk12.org/students/What_Is_Engineering/Engineering_alphabet/default.php.
Informal	• Monitor students' participation in discussions.

Assessment	• Monitor students' engagement in the dissection and observation recording.
Formal Assessment	• Dissected camera. • Recorded notes and observations.
Trouble Shooting	• Used disposable cameras can be obtained from any photo lab. It may pay to call around to your local Walgreen's and Wal-Mart before you make the trip, to ensure they have old cameras available. Make sure to mention that you will be using the cameras in the classroom, or they may not give them up to you! Or, you may be asked to pay a nominal fee, such as 25 cents per camera. • Disassemble and explore a camera before this activity on your own so you'll be able to point students to areas of interest, as well as anticipate any problems. You'll definitely want to try out discharging the capacitor on your own before you do it for students. • If you are worried about the danger of giving the students charged capacitors, and rightly so, it is fairly simple to pop the cameras open, discharge the capacitors, and reassemble the casing before you give them to students. Discharging the capacitor for the class makes a good demonstration of electrical energy, and students do not need to deal with discharging the capacitors themselves – even if they want to! • Because the lenses are so tiny, it is easier to work with them if they are mounted on cardboard. If you have the time and resources, provide the students with cardboard and glue or tape so they can more easily manipulate the lenses. • If you are willing to sacrifice it, students can learn more about how the camera works (such as how the film advances and how the flash is triggered) if they are able to explore a new camera. This could also be an opportunity to take pictures of students and their projects, for the sake of posterity!
Citations	• Raytheon Company. (2006). Product dissection: An engineer's-eye view of your toaster. Raytheon Classroom Projects – High School [CD]. • NASA Explores. Disposable camera dissection. http://media.nasaexplores.com/lessons/02-029/9-12_1.pdf • Byrd, G. & Graham, M. (1999). Camera and telescope free-for-all! *The Physics Teacher*, *37*, p. 547-550.

SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☐ Adaptation of Content	☒ Modeling	☐ Whole class
☐ Links to Background	☒ Guided practice	☒ Small groups
☒ Links to Past Learning	☒ Independent practice	☒ Partners
☒ Strategies incorporated	☐ Comprehensible input	☐ Independent

Integration of Processes	Application	Assessment
☐ Reading	☒ Hands-on	☐ Individual
☒ Writing	☒ Meaningful	☒ Group
☒ Speaking	☒ Linked to objectives	☒ Written
☐ Listening	☒ Promotes engagement	☒ Oral

Arizona Math Standards Addressed	(none)
Arizona Science Standards Addressed	• S1C1: TSW formulate predictions, questions, or hypotheses based on observations.

Disposable Camera Dissection Notes

Drawings & Observations – Unopened Camera

Thoroughly examine your camera. Look at it, look through it, push the buttons, play with the features, etc. Sketch drawings of what you see.

- How do you think the camera works?
- What kinds of parts do you think it has inside?

Disposable Camera Dissection Notes

Drawings & Observations – Dissected Camera

When your advisor gives the go-ahead, open up your camera. Take the camera apart and examine the pieces, sketching the camera and its components as you discover new things.

- What kinds of parts does the camera have?
- What do they allow the camera to do?

Lesson Activity

Title	**Electricity Flow (40-55 minutes)**
ID Number	HS-S-A1
Sequence and Duration	• Lead In: 5-10 minutes • Activity: 30-35 minutes • Closure: 5-10 minutes
Age Level	High School
Essential Question	**How does electricity get from one place to another?**
Learning Objectives	• TSW use trial and error to light a bulb and use this experience to infer how electricity flows. • TSW successfully construct open and closed circuits. • TSW insert a working switch into their circuits. • TSW extend their understanding of the way that current flows by lighting a bulb with a battery and only one wire.
Other Objectives	• TSW communicate their initial ideas about electricity verbally and in drawing. • TSW listen to a description of the way that electricity flows in a wire. • TSW collaborate with their group mates and other classmates to develop their understanding. • TSW reflect on their experience to understand how their initial ideas compare to their new ideas. • TSW contribute to a discussion about their initial and resulting ideas.
Key Terms	• Electron • Current • Open Circuit • Closed Circuit
Materials Needed	Per Class: • Scissors • Brads or aluminum foil • Insulated wire, can be precut into ~6 inch pieces (available at hardware store) • Masking or electrical tape, can be precut into ~6 inch pieces • Broken bulb (light bulb with the glass carefully broken and removed, filament intact) Per Team: • Piece of blank white paper • Battery (AA or C) • Small bulb, e.g. flashlight bulb (available at hardware store)
Lead In	1. Ask the students to try counting the number of times they made use of electricity during their day today. Did they turn on the lights when they got up this morning? Did they curl their hair? Sharpen their pencils? Drink a cold beverage? Eat something baked in an oven? In this modern world, electricity is everywhere and we use it all the time, sometimes without even noticing it. Do the students think about electricity when they make food, listen to music, or go to the movies? How about when they use the windshield wipers or radio when they drive (or when someone else does)? Do they think they could go a whole day without using ANY electricity? 2. Ask the students to talk about how electricity works. How does it get from one place to another? (Try to get a feel for how familiar students are with the concept of electricity.) 3. Tell the students that today they will find out what they really know about electricity.

Activity	1. Ask the students to raise their hands if they think they would know how to light a light bulb with just wire and a double-A (or C) battery. What would they try? 2. Form groups of 2-3 students and hand out blank pieces of paper. Tell the students to sketch their arrangement of the bulb, battery and wire. Give them 3-4 minutes to discuss their ideas with their groups and draw their arrangements. Walk around to view groups' drawings, making comments and asking questions to clarify students' thinking. 3. When the groups have committed to an idea, they can collect their materials: one bulb, one battery, and as many pieces of wire as they think they'll need (within reason, of course). They will need to strip a little bit of the insulation off both ends of the strips of wire; this can be done with scissors but it may be possible to just pull off a little bit of insulation with the help of their fingernails. Then they can use tape to secure the wire when they have it where they want it. Warn them that the wire and the bulb can get hot so they will need to handle them carefully. 4. Give the groups 10-15 minutes to try to light their bulbs. 5. When a group successfully lights their bulb, challenge them to light it using only ONE piece of wire while they wait for the other groups to finish. Or, they can assist other groups in lighting their bulbs. 6. When all the groups have been successful in lighting their bulbs, engage the students in a debrief. What did they think was going to light the bulbs, and how do their initial ideas compare to what actually DID light the bulb? Have the students as a group offer several setups that did not light the bulb and at least one setup that did. What do the unsuccessful setups have in common? What is the difference between them and the successful setup(s)? 7. Tell the students that electricity flow, called *current*, is the motion of *electrons*, the negatively charged particles in atoms. Current moves in a *circuit*, or loop. (Point out that the word *circuit* is similar to *circle*, which is also a loop.) In order for the current to flow, the circuit must be closed: it must be a complete loop with no breaks. If the circuit has a break in it, it is called an *open circuit*, and the current can't flow. Have the students apply these concepts to describe the different setups they discussed above. (The setups that didn't work were open circuits, and the setups that did were closed circuits.) 8. Instruct students to form an example of a closed circuit. Check their work. (This can be any circuit that forms a loop – even with no bulb, or no battery! If students construct a circuit with a battery but no bulb, they can verify that the current is indeed flowing by feeling the uninsulated wire heat up.) 9. Instruct students to form an example of an open circuit. Check their work. (This can be any circuit that does NOT form a complete loop. This includes circuits in which wires are connected to only one terminal of a battery. Ask the students why current will not flow in this way.) 10. Pass around the broken light bulb and direct students' attention to the way the wires are connected to the base. Show how the electrons flow from the bottom of the base up through the filament and out through the side of the base (or vice versa; the direction of the flow is not important). 11. Ask the students, for what purpose would you ever want to break a circuit? (To stop the flow of electricity, e.g. to turn off an electrical device.) What device is built into many circuits to open them when needed? (A switch.) Students can play with adding switches to their circuits using brads or aluminum foil. 12. To assess how well students understand the concept of electricity flow and closed circuits, challenge them to light the bulb using just the battery and ONE piece of wire. It is possible! (There are actually multiple arrangements of the materials that will light the bulb.) 13. Walk around and observe the students' work. Ask questions to prompt students' thinking. (Such as, how does the electricity flow through the battery? How does it flow through the bulb?)

	14. Draw students' attention to strategies other groups are trying. Encourage groups who figure out how to light the bulb to help other groups, without giving it away! 15. When all groups have lit their bulbs with just one wire, have them put away their materials.
Closure	1. Ask the students to reflect on this activity. Were they surprised that they knew/didn't know how to light the bulb? What were their previous mental models about how electricity works? How did they change their mental models? 2. Ask the students if what they have learned today could be helpful to them in the future. How? 3. What new questions do they have about electricity that could be explored next? If time permits, allow the students to explore these questions and ask them to reflect on what they've learned at the end of the session. 4. Ask the students to reflect on the summary question: *How does electricity get from one place to another?*
Informal Assessment	• Monitor students' participation in discussion. • Check that each group completes a sketch of their ideas. • Monitor students' participation in the activity.
Formal Assessment	• Lit bulbs. • Formation of both an open and a closed circuit. • Working switch in a closed circuit.
Trouble Shooting	• Check all the bulbs and batteries before the activity to make sure they work; this will keep students from accidentally ruling out setups that should light the bulb due to faulty equipment. As well, if you can vouch for all the equipment, students won't be able to use faulty equipment as an excuse for why they can't light their bulbs! • Assess students' prior knowledge during the lead in to the activity. You can skip having students sketch and try out the first challenge if you can tell that setting up the bulb with two wires won't be challenging to them. However, it is often surprising (to both the students and the teacher) that students don't immediately know how to light the bulb even if they think they do. Try it and see!

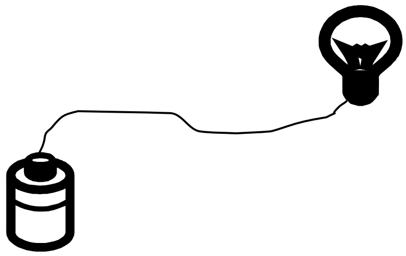
SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☒ Adaptation of Content	☐ Modeling	☐ Whole class
☒ Links to Background	☐ Guided practice	☒ Small groups
☐ Links to Past Learning	☒ Independent practice	☒ Partners
☒ Strategies incorporated	☒ Comprehensible input	☐ Independent

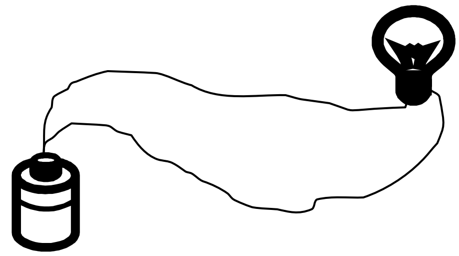
Integration of Processes	Application	Assessment
☐ Reading	☒ Hands-on	☐ Individual
☐ Writing	☒ Meaningful	☒ Group
☒ Speaking	☒ Linked to objectives	☐ Written
☒ Listening	☒ Promotes engagement	☒ Oral

Arizona Math Standards Addressed	(none)
Arizona Science Standards Addressed	• S1C1: TSW formulate predictions, questions, or hypotheses based on observations.

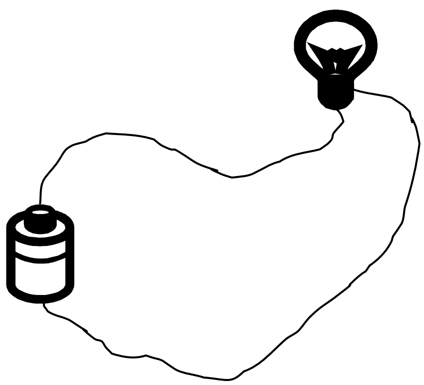
Circuit Diagrams



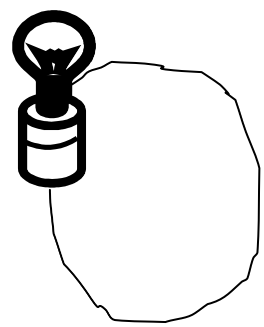
Open Circuit
Bulb won't light



Closed circuit, no current through battery
Bulb won't light



Closed circuit
Bulb will light



One-wire circuit
Bulb will light

Lesson Activity

Title	**Electricity Flow II (45-60 minutes)**
ID Number	HS-S-A2
Sequence and Duration	• Lead In: 15-20 minutes • Activity: 15-20 minutes • Closure: 15-20 minutes
Age Level	High School
Essential Question	**Which properties of a circuit affect the intensity of a light bulb?**
Learning Objectives	• TSW apply the concepts of voltage, current and resistance to real-life experiences with light bulbs. • TSW use Ohm's Law and the Power formula to defend their predictions about whether bulbs connected in series or in parallel result in brighter bulbs. • TSW use Ohm's Law and the Power formula to defend their predictions about whether batteries connected in series or in parallel result in a brighter bulb. • TSW apply what they determined from free exploration of batteries and bulbs to what they know about Ohm's Law and the Power formula.
Other Objectives	• TSW listen in order to gather information needed to engage in the activity. • TSW interpret diagrams and use them to manipulate materials accordingly. • TSW communicate with their groups to enact their ideas. • TSW write and diagram what they learn from free exploration of the materials. • TSW present what they learned from free exploration of the materials.
Key Terms	• Ohm's Law • Current • Voltage • Ohm • Resistance • Power • Light Intensity • Series • Parallel
Materials Needed	Per Class: • Scissors • Ammeter/voltmeter (optional) • Extra batteries • Extra wire • Extra light bulbs Per Team: • 2 AA or C batteries • Four pieces insulated wire, about 6 inches each (available at hardware store) • 2 small bulbs, e.g. flashlight bulbs (available at hardware store) • Bulb holders (optional; available at hardware store) • Strip of masking or electrical tape, about 6 inches Per Student: • Handout: Types of Connection
Lead In	1. Ask the students what they have learned thus far about how electricity works. If they have already done the "Electricity Flow I" activity, have them restate what they learned about open and closed circuits. Hand out lengths of wire and tape, a bulb, and a battery to each group of two or three students and

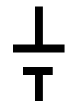
	have them create open and closed circuits. Remind the students that they will need to strip some insulation from the ends of the wire, and that they need to handle all the materials carefully. 2. Ask the students, is a closed circuit the only thing you need to get electricity to flow? Is there a current in just a closed loop of wire? Why or why not? [There is no current because there is no reason for the electrons to flow; they are in equilibrium.] Have the students relate this idea to the same concept with objects such as balls or carts. When the ball or cart is at the lowest point on the ground, it is in equilibrium and has no reason to fall. But when there is a potential difference between where the cart is and the lowest point, the cart will fall to the lowest point. 3. Tell the students that the potential difference in electrical circuits is called *voltage*. Ask if the students are familiar with this word and have them talk about where they've seen it used. (E.g. on batteries, on plug adaptors, on electric fences, etc.) Tell them that the greater the voltage, the greater the *potential energy* in the circuit, and the stronger the force that is acting on the electrons. 4. Tell the students that today they will become amateur electricians by exploring *Ohm's Law*. Write Ohm's Law on the board: Voltage = Current x Resistance. <u>Note</u>: The symbols used in Ohm's Law are I (capital i) for current, V for voltage, and R for resistance. 5. Ask them if they have ever heard of an *ohm* or seen the word used anywhere. (The symbol for ohms is the Greek letter omega, Ω, which students may have observed on some light bulbs.) Ohms are the unit of *electrical resistance*, which, like friction, is a force that opposes motion, in this case the motion of electrons. Resistance is like the friction in a circuit, and like friction it causes heat (usually), by converting some of the energy of motion. Ask if the students have ever felt a plug adaptor, such as for a laptop, that's been plugged in for a while. What happens to it? [It gets very warm.] 6. Tell the students that the resistance in circuits can be used to do useful things. Ask them what happens to an object when it gets very hot. (It begins to glow; if they have trouble thinking of this, ask them what happens when burners on an electrical stove get very hot – they glow red.) Ask them what they think is happening in a light bulb that causes it to give off light. (The resistance in the filament of the light bulb causes it to get very hot, which causes it to glow.) 7. [Optional: Ask the students if the format of Ohm's Law looks familiar. (If students have done the activities such as the Mousetrap Car, they may notice that this looks like Newton's 2nd Law, F=ma.) Write "F = ma" on the board. Relate the components of this formula to Newton's 2nd Law: the voltage is similar to the *force* because it causes the motion of electrons; the resistance is similar to the *mass* because it is resistant to motion (as mass is due to its inertia, by Newton's 1st Law), and the current is similar to the *acceleration* because it is the motion of the electrons.] 9. Tell the students that there is another formula which applies to circuits, and it pertains to the amount of *power* in a circuit. Power is a rate (like velocity) that describes how much energy is delivered in a certain amount of time. When have students heard the word "power" applied to electricity? (E.g. power plants, "powering down" a computer, "power" button on a TV.) 10. Write "Power = Current x Voltage" on the board. Tell the students that the amount of power delivered to a device (like a light bulb) depends on the amount of current and the magnitude of the voltage, or force. (If students are familiar with substitution in algebra, they can easily derive that power is also equal to voltage times the square of the current.) 11. Tell the students that they will be experimenting with different kinds of

	circuits to see which increase the light intensity of the bulbs. Ask the students what evidence they will use to determine that the light bulb is receiving more power. (It will be brighter, more *intense*.)
Activity	1. Hand out an additional bulb to each group. Ask if anyone knows what it means to connect components of a circuit *in series* or *in parallel*. If there is someone who knows, have them demonstrate this to the class using their materials or a diagram, and assist by guiding their thoughts and handing out the Connection Types handout. Otherwise, show the students yourself. 2. Have the students predict whether bulbs connected in series or bulbs connected in parallel will be brighter. Ask them to discuss and defend their predictions using Ohm's Law and the Power formula. 3. Have the students build their circuits but not connect the batteries (only have them connect the batteries and allow the current to flow when you tell them to, so the bulbs and batteries don't wear out). When all the groups' circuits are ready, have them connect the batteries and compare the brightness of the bulbs in series and the brightness of the bulbs in parallel. Can they explain the result based on Ohm's Law and the Power formula? [Of the bulbs connected in series, one will be brighter than the other because one of the bulbs is "using up" some current before it gets to the other bulb. The bulbs connected in parallel both get the same amount of current so they are both equally bright.] 4. Ask the students, when there is more than one bulb in the circuit, what is adding up? [Resistors. Note: Resistors add linearly when connected in series but as 1/R when connected in parallel. There is no need to emphasize this fact unless you are comfortable with it; the fact that the resistors are adding is sufficient.] 5. Have one of the groups whose bulbs are connected in parallel break the circuit to one of the bulbs. What happens and why? [The other bulb stays lit because it is still connected in a closed circuit where current can flow.] What if a group with bulbs in series tried the same thing? What would happen and why? [Students will no doubt quickly notice that breaking the current to one bulb breaks the whole circuit, so removing one bulb from the circuit will extinguish both bulbs.] 6. Ask the student what would happen if they connected multiple *voltages* in the circuit instead of multiple *resistors*. That is, what if they had more than one battery? Have the students predict whether the bulb will be brighter if the batteries are connected in series or in parallel, and have them discuss and defend their predictions. 7. Collect one bulb from and hand out one battery to each group (so now each has one bulb and two batteries, as well as wire and tape). Have them conduct their experiments. 8. Have the students informally present the results of their investigation. Which arrangement resulted in a brighter bulb? [Both result in making the bulb brighter than it was with a single battery, but the batteries connected in series make the bulb the brightest.] 9. Ask the students to try to explain this result using Ohm's Law and the Power formula. [Because the bulb is brighter, it must be receiving more power, so the product of the current and the voltage must be increasing in both cases, but in the case of the batteries in series it is increasing more. The batteries connected in parallel increase the current to the bulb; it is as if there are two separate circuits both flowing through the bulb. The batteries connected in series increase the current as well, but they also increase the voltage, making the bulb even brighter. It is more important that students brainstorm explanations that make sense, given their observations and the formulas, than that they get the "correct answer."]
Closure	1. Ask the students what other arrangements of batteries and bulbs they might

	like to explore. Create a list of their questions and ideas on the board. 2. Allow them time for free exploration of electricity, but ensure that they are making note of their results and drawing diagrams of their arrangements in order to present to the class later. 3. In the last ten minutes of class, regroup the students to talk about what they were able to discern about electricity from their free exploration. Were they able to answer any of the questions on the board? Can they apply what they learned to Ohm's Law and the Power formula? 4. Ask the students to reflect on and discuss the summary question: *Which properties of a circuit affect the intensity of a light bulb?*
Informal Assessment	• Monitor students' understanding of previous learning. • Monitor students' participation in discussions. • Monitor students' participation in activities.
Formal Assessment	• Formation of circuits with components connected in series and components connected in parallel. • Ability to relate experiential learning to the new concepts and formulas. • Development of new lines of inquiry based on class experiment.
Trouble Shooting	• Check all the bulbs and batteries before the activity to make sure they work. • Remind students to break their circuits whenever they can to save their batteries and bulbs.
Extensions	• If you have access to ammeters or voltmeters, you can have students quantify the components of Ohm's Law by taking readings of the voltage and current in various locations of the current. • To include more math in this activity, have the students practice using the two equations by giving them example problems to work out.
SEI Strategies Used Preparation ☐ Adaptation of Content ☒ Links to Background ☒ Links to Past Learning ☐ Strategies incorporated Integration of Processes ☐ Reading ☐ Writing ☒ Speaking ☒ Listening	Scaffolding ☐ Modeling ☒ Guided practice ☒ Independent practice ☒ Comprehensible input Grouping Options ☒ Whole class ☒ Small groups ☒ Partners ☐ Independent Application ☒ Hands-on ☒ Meaningful ☒ Linked to objectives ☒ Promotes engagement Assessment ☐ Individual ☒ Group ☐ Written ☒ Oral
Arizona Math Standards Addressed	Extensions: • S1C2: TSW understand and apply numerical operations and their relationship to one another. • S2C1: TSW understand and apply data collection, organization and representation to analyze and sort data.
Arizona Science Standards Addressed	• S1C1: TSW formulate predictions, questions, or hypotheses based on observations. • S5C5: TSW understand the interactions of energy and matter.

Connection Types*

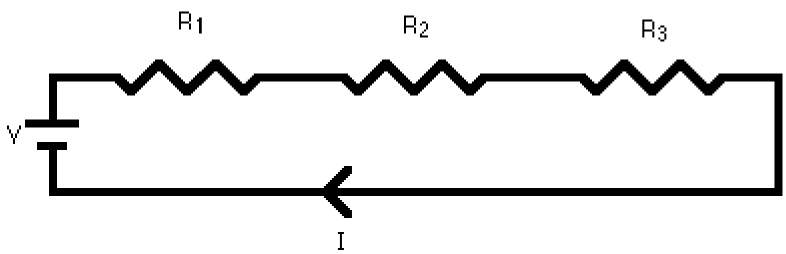
Symbols:

Voltage source (e.g. battery) 

Resistor (any device that is *using* electricity) 

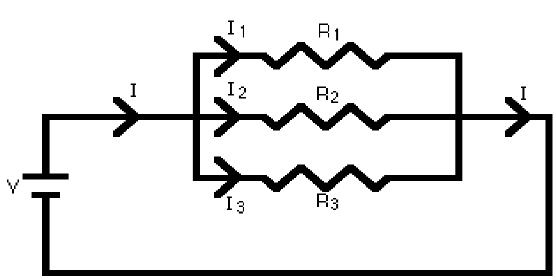
Types of Connection:

When components are connected **IN SERIES**, the same current is flowing through each of them.



Resistors in series

When components are connected **IN PARALLEL**, different currents, flowing from different branches of a circuit, are flowing through each of the different components.



Resistors in parallel

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* Images obtained from http://physics.bu.edu/py106/notes/Circuits.html.

Lesson Activity

Title	**On-Site Design Challenge: Exercise in Space (55-65 minutes)**
ID Number	HS-E-OS4
Sequence and Duration	• Lead In: 5 minutes • Activity: 35-40 minutes • Closure: 15-20 minutes
Age Level	High School
Essential Question	**What are some creative ways for travelers to exercise in space?**
Learning Objectives	• TSW design a product to address the need for space travelers to exercise in low-gravity environments. • TSW identify similarities and differences between this challenge and other on-site design challenges.
Other Objectives	• TSW develop a working plan with their group to develop a cooperative environment. • TSW communicate with their group by contributing their vocal input. • TSW develop critical reading skills by finding relevant information in given materials. • TSW listen to their peers present their designs. • TSW contribute to a group discussion about their approaches to the challenge.
Key Terms	• On-site design challenge • Atrophy • Microgravity
Materials Needed	Per Group: 1. Handout: Living in Space – the Challenge 2. 10 rubber bands 3. 4 paper cups 4. 10 popsicle sticks 5. 1 yard of twine or string 6. 2 spools of thread or other small objects that can be used to construct pulleys 7. 2 small washers 8. 10 paper clips 9. 24" clear tape 10. 4 pins or tacks 11. 2 pairs of scissors 12. 1 ruler 13. Other materials of your choice, such as cardboard, small springs, elastic cording, wood dowels, etc., ensuring that all teams have identical supplies
Lead In	1. Ask the students to discuss whether they believe space travel increase in the future. What kinds of issues will travelers face? How does space travel affect people's health? If students have done the Vertebral Variation! activity, remind them to consider what they've already learned about the effect of low-gravity environments on our bodies. 2. Tell the students that today they will be doing an on-site design challenge that has to do with improving life for space travelers. They will receive some background information to read, and from that they will learn what their challenge is. They will have 35 minutes to complete the challenge. Remind them to consider the skills and strategies for on-site design challenges they learned about already that will help them to be successful.
Activity	1. Separate students into groups of three or four and hand out the supplies.

	When all supplies have been distributed, hand out the background information and specs face down, instructing students not to turn them over until you tell them to. Tell them they may raise their hands if they need clarification about the rules, but to think of you as the judge, not their advisor. 2. Call out “begin!” and start the 35 minute count-down. 3. After 35 minutes are up, call time and have students clean up their areas.
Closure	1. Call up each group one by one and have them demonstrate their design. Play the role of a NASA specialist who is charged with choosing the exercise equipment for all the space crafts. Ask each group to discuss how they balanced the need to create a compact design with the need for efficiency in providing a workout. Have them point out ways that the design would be effective for certain needs or for different types of person. 2. If you wish, you can have students vote on the best design after all groups have presented, or relate the designs you have chosen for the fleet based on their size and usefulness. 3. Give students time to reflect on their approaches and strategies with this challenge, first with their groups and then reporting out to the whole class. How was their approach different with this activity than with other on-site design challenges they’ve tried? How was it similar? 4. In their MESA Notebooks, have students respond to the following conclusion question: *What are some creative ways for travelers to exercise in space?*
Informal Assessment	• Monitor students’ participation in the activity. • Monitor students’ participation in the discussions.
Formal Assessment	• Completed MESA Notebook. • Completed exercise machine.
Trouble Shooting	• Separate out each team’s materials and place them in baggies or boxes prior to students’ arrival to class. • What materials the groups receive to create their designs is not as important as the fact that all groups have the same materials. Feel free to improvise with materials you have on hand.
Extension	• Have the students research how many calories are burned in different activities (running, walking, weight training, cycling, etc.), and have them estimate the calories that would be burned by using their devices.
Citation	• Adapted from: Raytheon Company. (2006). Human energy and space fitness. Raytheon Classroom Projects – High School [CD].

SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☐ Adaptation of Content	☐ Modeling	☒ Whole class
☐ Links to Background	☐ Guided practice	☒ Small groups
☒ Links to Past Learning	☒ Independent practice	☐ Partners
☒ Strategies incorporated	☐ Comprehensible input	☐ Independent
Integration of Processes	**Application**	**Assessment**
☒ Reading	☒ Hands-on	☒ Individual
☐ Writing	☒ Meaningful	☒ Group
☒ Speaking	☒ Linked to objectives	☒ Written
☒ Listening	☒ Promotes engagement	☒ Oral

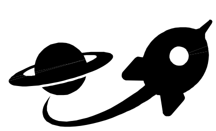
Arizona Science Standards Addressed	• S3C2: TSW develop viable solutions to a need or problem.

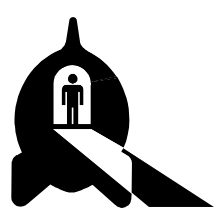
Living in Space – the Challenge

Background Information

One of the most exciting challenges humans will likely face in the future is to learn to live and work in space. Life aboard space stations and spacecraft traveling between Earth and the moon and Mars may become routine for literally hundreds of people. One of the great debates among spacecraft designers is whether these spacecraft should simulate some or all of the Earth's gravitational environment, or should let the inhabitants remain in a weightless environment. All spacecraft flown so far have required the astronauts or cosmonauts to adapt to the absence of gravity. Unfortunately, when the human body does not have to use the energy necessary to fight gravity – such as for pumping blood from the feet back to the heart, standing up, walking, running, or lifting objects – the muscles in the body *atrophy* (become much weaker), and bones lose some of their calcium. There are other changes in body chemistry as well.

The early Mercury, Gemini, and Apollo spacecraft were so small that exercise to combat the effects of what is called the "microgravity" environment was almost impossible. On the larger Skylab space station, an area as big as a three-bedroom house, there was plenty of room for exercise. The astronauts had a bicycle *ergometer* (exercycle), which measured how much energy they used during exercises, and could do gymnastics and other exercises in the large forward compartment. Cosmonauts from the former Soviet Union aboard the Mir space station wore garments that forced muscle activity to try to maintain conditioning. Space Shuttle astronauts can tie themselves with bungee cords to a treadmill and walk for fitness. The expending of energy in exercise will not halt all of the effects of microgravity, but research so far has shown that it helps, and that without it, returning astronauts could have serious problems readjusting to gravity here on Earth.





Objective:

You will design a working model of an exercise machine that can be used in space. Your design should be a model that demonstrates the basic working principles of a full-sized machine. Your model should:

a) Be original to the group.
b) Demonstrate the types of exercise the astronauts would do
c) Provide similar exercise(s) to exercises that can be done on Earth.
d) Include a mechanism for anchoring either the machine or the exercising astronaut.

You will also prepare a brief two-minute presentation. During your presentation, you will demonstrate your machine to a NASA specialist in charge of ordering the entire space fleet's provision of exercise equipment. The NASA specialist will be interested in:

a) the compactness of the design (to take up as little of the precious space in the craft as possible),
b) how many muscle groups the machine can exercise,
c) the machine's ability to produce the best workout in the shortest time, and
d) how well the machine meets the needs of different kinds of people.

Materials:

10 – rubber bands
4 – paper cups
10 – popsicle sticks
1 – yard of twine or string
2 – spools of thread or other small objects that can be used to construct pulleys
2 – small washers
10 – paper clips
24 – inches clear tape
4 – pins or tacks

Other materials available for use but not included in the design:

Scissors Ruler Pencil Paper

You may use your desks, the backs of chairs, doorknobs, wall hooks, or other fasteners to anchor your model or yourselves when you demonstrate your machine.

Mathematics Engineering Science Achievement

Lesson Activity

Title	**Impact Craters (2 sessions, 60-80 minutes)**
ID Number	HS-S-A3
Sequence and Duration	• Session 1: Background (50-65 minutes) • Session 2: Activity (60-80 minutes)
Age Level	High School
Essential Question	**What factors affect the size of an impact crater?**
Learning Objectives	• TSW identify the properties of craters. • TSW explore how the characteristics of the impact that affect those properties. • TSW investigate what craters can tell us about the surfaces of other planets. • TSW form impact craters and investigate their properties. • TSW examine the relationship between the projectile energy and the size of the crater.
Other Objectives	• TSW develop a working plan with their group to develop a cooperative environment. • TSW communicate with their group by contributing their vocal input. • TSW listen as their peers discuss the design of their investigation. • TSW write down the procedure they used to design their project.
Key Terms	• Raised rim: the protruding edge of a crater. • Central peak: raised feature in the center of some craters. • Diameter: distance from one side of the crater to the other on a line through the center. • Ejecta: material thrown out from the crater often found lying around it. • Impact crater: feature caused by an object hitting a solid surface. • Projectile: an object propelled through space by a force. • Potential energy: stored energy. • Kinetic energy: energy of motion. • Velocity: speed in a particular direction; distance over time.
Materials Needed	Session 1 Per Group • Images of craters (handouts, projected images, http://www.lpi.usra.edu/publications/slidesets/craters/ has a slide show of impact craters) Per Student • Handout: MESA Notebook Per Team (2-3 students) • Handout: Moon Images • Handout: Mercury Image • Handout: Mars Images (Images from *Mars in the Classroom*, 2000. • Cups or small basins of water • Eyedropper (optional) Session 2 Per Student • Handout: MESA Notebook • Handout: Impact Craters Activity Per Team • Shallow Aluminum Pan

	• Flour • Cocoa • 1 marble • 1 golf ball • 1 ping pong ball • Scale • Meter stick or tape measure (metric) • Ruler • Graph paper

Session 1	**Background**
	1. Ask, “How many of you know what a crater looks like? Have you ever seen a crater?” Pause and see how many students raise their hands.
	2. Ask, “Who could describe what a crater looks like?” Solicit answers from students and guide oral description to illustration on the board.
	3. Ask, “What are craters caused by?” Solicit answers and write responses on the board. Common answers are asteroids, meteors, and comets.
	4. Ask, “Where are craters found?” This is a general question, but they can respond with all over the Earth, on the Moon, and on other planets.
	5. Ask, “Why are craters on Earth different sizes?” Solicit answers and write their responses on the board.
	6. Show students images of various craters on Earth, the Moon, and Mars. You may choose to set up a projector connected to a computer and use the website http://www.lpi.usra.edu/publications/slidesets/craters/ to show the crater slideshow. Point out various features of a crater:
	    • raised rim
	    • central peak (if applicable)
	    • diameter
	    • depth
	    • ejecta
	7. Hand out cups or basins of water to small groups of students. Have students take turns dropping water into the basins while their group members look closely at the “craters” that are formed by the drops. Tell students to look especially for the central peak caused when the water springs back, as this can be hard for students to visualize with a rocky surface. Allow students time to experiment with making different sizes of craters if time permits (free exploration). Students can draw and label diagrams in their MESA Notebooks.
	8. Ask students to clean up their areas.
	9. Discuss the variables that could affect the sizes and shapes of craters on the surfaces of planets. Write these down to reference at the end of the image presentation/slide show with group. Examples include:
	    • Size of the projectile
	    • Mass of the projectile
	    • Composition of the projectile
	    • The angle of the projectile
	    • Velocity of the projectile: how fast it hits the surface
	    • The properties of the surface
	10. Hand out pictures of cratered surfaces on the Moon and Mercury.
	11. Ask, “Why do we see so many impact craters on bodies like Mercury and the Moon? Why don’t we see very many on the Earth?” Allow students to brainstorm ideas in pairs or small groups, writing their ideas in their Notebooks. Then have them share their ideas as a class. Write down students’ ideas on the board. If they are struggling, encourage them to think about the differences between the Earth and Moon (e.g. presence of an atmosphere, plate tectonics, volcanism, and weathering on Earth but not on the Moon).

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12. Ask, "What can impact craters tell us about the age of a surface? What can you say about a heavily-cratered planet compared to a planet with fewer craters?" (A heavily-cratered surface is probably much older than a lightly-cratered surface. You can also infer that a heavily-cratered surface must belong to a planet with minimal or no weathering processes, such a wind and water erosion, or plate tectonics or volcanism. You will also see more small craters on planets with little or no atmosphere, because small projectiles tend to burn up when they enter thick atmospheres.)
13. Hand out the two images from Mars (but don't let them know what they are!) and give them time to look at them in pairs or small groups. Ask students to come up with an explanation for why the two surfaces have such different numbers of craters. Give students time to share their ideas.
14. Tell students that both images are of the surface of Mars. Ask students to explain why different surfaces of the same planet might have different numbers of craters. Ask, "Which of these two surfaces do you think is older? How do you know?" (The surface with fewer craters has experienced less bombardment, so it is likely younger. It may have been covered with water in the past, or it may have been created by a lava flow when Mars' volcanoes were active.)
15. Ask students to take a closer look at the first image. Can they identify any craters that must be younger or older than another crater? How can they tell? (There are several examples of craters within craters, or craters overlapping other craters. The crater "on top" must be younger than the crater underneath.) Tell students that using visual clues such as these, scientists are able to tell a great deal about other planets, such as Mars.
Closure:
1. Collect MESA Notebook from students. They will be using it for Session 2's activity.
2. Review the key terms from today and ask students to point them out on an image of a crater.
</td></tr>
<tr><td>Session 2</td><td>
Activity:
Teacher Prep:
For each aluminum pan, pour in flour to approximately one-inch deep. The flour can be sifted in, or "fluffed" with your fingers once it's poured. Sprinkle a thin layer of cocoa over the flour. This contrast will make the features of the craters more visible to the students.

1. Hand out the Impact Crater Activity and MESA Notebooks.
2. Show the students the materials they will be using: a pan of flour, three projectiles (marble, golf ball and ping pong ball), a meter stick or tape measure, and a ruler. Scales will be available for students to determine the mass of each projectile.
3. Show students how they will be dropping projectiles into their pans, and how to resurface the flour if needed before making the next drop. Point out that the conditions for each set of drops should be as similar as possible (for instance, the flour should not be fluffy for one drop and compact for the next if the properties of the surface are not the variable of interest).
4. Remind students that they have already spent time exploring craters in water. What kinds of things did they discover?
5. Ask, "What did you need to do to make bigger craters?"
6. Ask, "What might you be able to do with the materials you have now to affect
</td></tr>
</table>

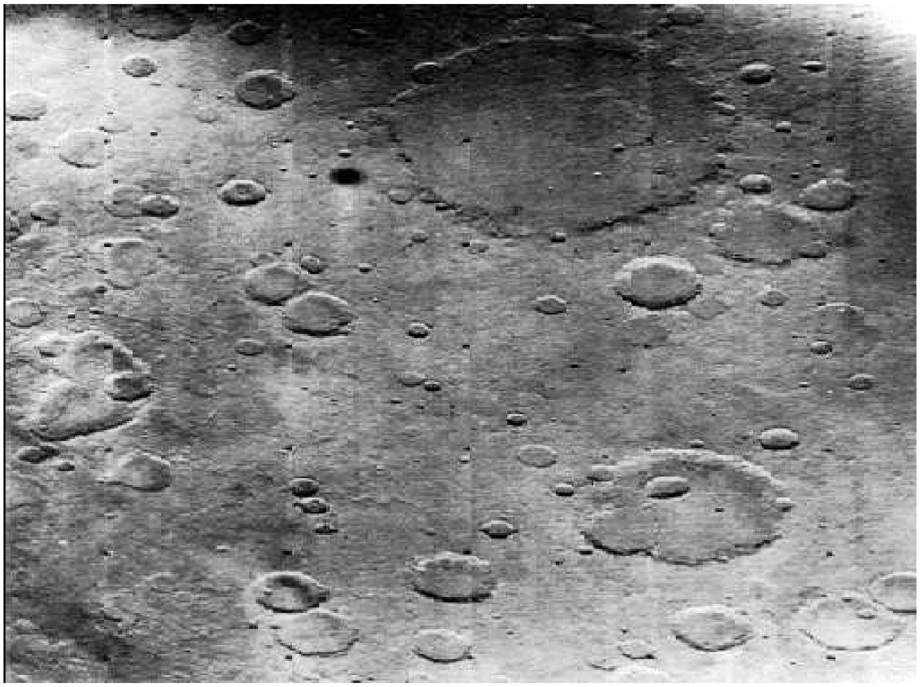
	the size of the craters you make? What variables can you change?" (mass and size of the projectile, height dropped; students may come up with others) 7. Ask students to predict what the relationship between the variables mentioned and the size of the crater will be. They can write their predictions in their MESA Notebooks. 8. Give students time to go through the activity. Rotate through student groups as they collect their data. If time permits, allow students to conduct their own experiments, working with another variable of their choosing (e.g. angle of trajectory, characteristics of the surface, density of the projectile).
Closure	1. Discuss the different results that each team got and make a correlation between height dropped, mass, size, and angle if applicable. 2. Have students complete their MESA Notebook. 3. Conclusion Question: What factors affect the size of impact craters? 4. If students have had time to conduct their own experiments, allow time for them to present their results to the class.
Informal Assessment	• Monitor students for understanding of the activity. • Monitor students for participation.
Formal Assessment	• Completed Data Charts. • MESA Notebooks.
Trouble Shooting	• Prepare the aluminum pans filled with flour and cocoa before the meeting begins on day 2. • Flour and cocoa can be messy; if dropping projectiles indoors, you may want to have newspaper laid out on the ground around student areas. • You may want to allow students to bring in additional projectiles from home or to try other things in the classroom – make sure they know to ask for your approval first! • Consider other areas where students might drop projectiles; for instance, in a sandbox. • Be sure to discuss safety considerations with the students before they begin their tests. You may or may not want to limit the height from which they drop their projectiles. If handled appropriately, students can have success making craters with projectiles dropped from second-story windows.

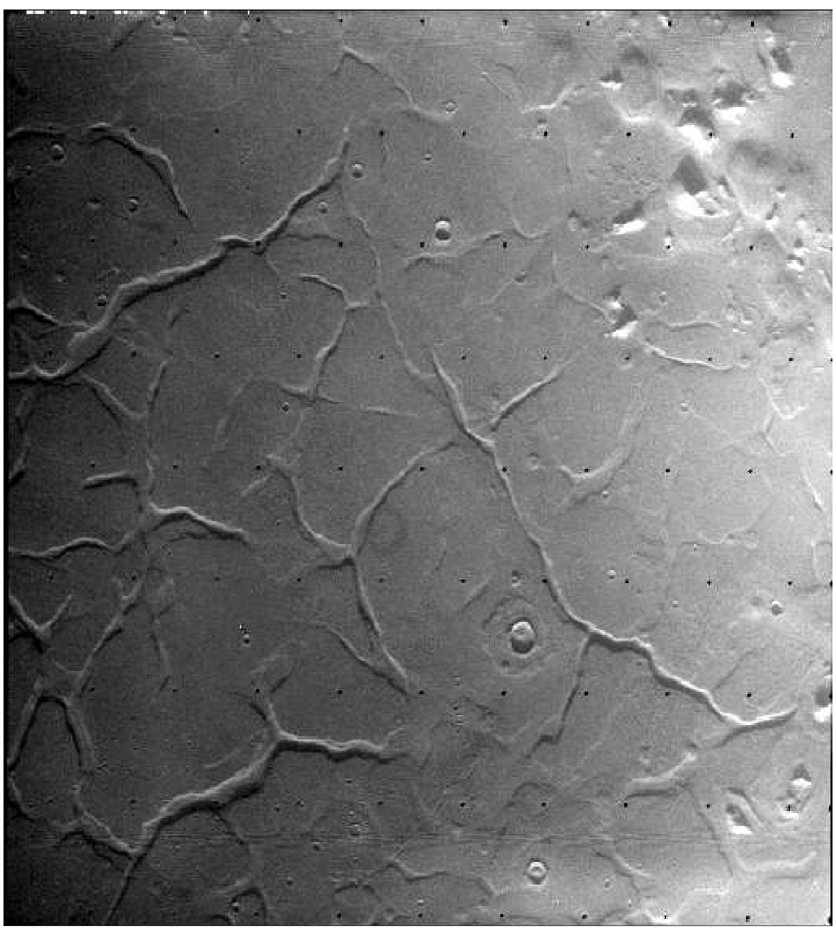
SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☒ Adaptation of Content	☐ Modeling	☐ Whole class
☒ Links to Background	☐ Guided practice	☒ Small groups
☒ Links to Past Learning	☒ Independent practice	☐ Partners
☒ Strategies incorporated	☒ Comprehensible input	☐ Independent

Integration of Processes	Application	Assessment
☒ Reading	☒ Hands-on	☒ Individual
☒ Writing	☒ Meaningful	☒ Group
☒ Speaking	☒ Linked to objectives	☒ Written
☒ Listening	☒ Promotes engagement	☒ Oral

Arizona Math Standards Addressed	• S5C2: TSW evaluate situations, select problem-solving strategies, draw logical conclusions, develop and describe solutions and recognize their applications.
Arizona Science Standards Addressed	• S5C2: TSW analyze relationships between forces and motion. • S6C3: TSW analyze the factors used to explain the history and evolution of the earth by addressing the characteristics, location, and motions of the various kinds of objects in our solar system including comets, meteors, and asteroids.





Images from **zebu.uoregon.edu/~soper/Moon/surface.html**.

Images from **zebu.uoregon.edu/~soper/Moon/surface.html**.

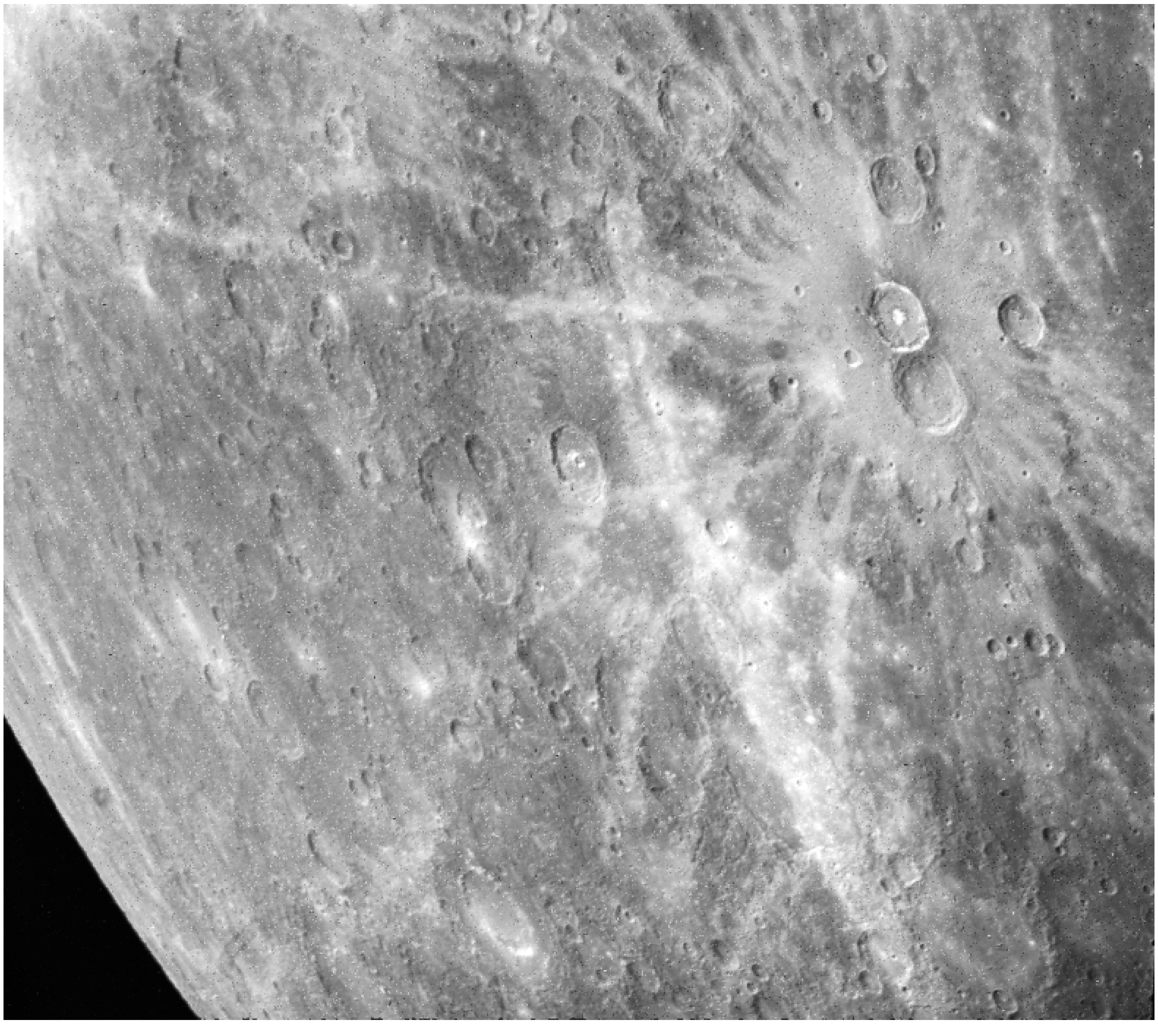


Image from **www.windows.ucar.edu/.../mercury5_Image.html**.

Impact Crater Activity

What factors affect the appearance of impact craters? You've talked about different factors, and you probably have a good sense of what makes a big crater compared to a small crater. With this activity, you will explore the characteristics of different craters that you make by trying different things.

What you need:

- A pan of flour and cocoa
- A golf ball
- A marble
- A ping pong ball
- A meter stick or tape measure
- A ruler
- A scale
- Graph paper
- Other objects – optional

Pre Activity Questions:

1. Record your predictions about what factors affect the size of a crater.

2. What do you predict is the relationship between the crater size and the height from which you drop a projectile?

3. If you want to explore that relationship, what variable(s) should be held constant?

4. What do you predict is the relationship between the crater size and the mass of a projectile?

5. If you want to explore that relationship, what variable(s) should be held constant?

Activity:

6. Use the scale to measure the mass of each projectile. Record this information in your Data Table.
7. Choose one projectile to start with, and drop the projectile into the pan from a low height (for instance, 30 cm).
8. Measure and record the diameter of the resulting crater. Record any other observations you make in your Data Chart as well.
9. Drop the same projectile from other heights, spaced at regular intervals (e.g. 25 cm, 50 cm, 75 cm, etc.).
10. Drop the other projectiles from the same series of heights.
11. What do you notice about the results? Create two graphs of your data:
    - Graph 1: Crater diameter vs. Projectile height
    - Graph 2: Crater diameter vs. Projectile mass
12. Do your results support your hypotheses?
13. As mass increases, crater diameter ___________________. When the object's mass increases, so does its **kinetic energy**. Kinetic energy is the energy associated with motion. When the projectile impacts the surface, nearly all that energy goes into making the crater.
14. As height increases, crater diameter ___________________. The greater the height at which you drop the projectile, the greater its **potential energy**. Potential energy is stored energy; in this case, energy from the force of gravity that the object can use to fall when you release it. This energy is then converted into kinetic energy.
15. The other part of kinetic energy is an object's **velocity**. The faster the projectile is traveling, the more kinetic energy it has. When you give the projectile different potential energies, you change its resulting kinetic energy, which changes how fast it is going when it hits the surface. You are simulating projectiles that enter the atmosphere with different **velocities**.
16. What do you think is the relationship between velocity and crater diameter? As velocity increases, crater diameter __________________.
17. What other variables affect the appearance of impact craters? Can you test any of those variables? With your group, choose a variable you would like to test, create a data chart for your results, and conduct your experiments.

Impact Crater Data Chart

	Mass (g)	Height #1: (cm)	Height #2: (cm)	Height #3: (cm)	Height #4: (cm)	Height #5: (cm)	Observations
Projectile #1							
Projectile #2							
Projectile #3							
Projectile #4							
Projectile #5							
Projectile #6							

Impact Crater Math

Using the formulas for potential and kinetic energy, it's possible to determine how fast your projectile was going when it hit the surface if you know how far from the surface it was when you dropped it. Make sure your units are metric, and that you measured your heights from the pan!

Potential energy, in this case potential *gravitational* energy, depends on the mass of the object, how high it is from the ground (or the pan of flour), and the force of gravity. On Earth, we can assume the force of gravity is constant at 9.8 m/s^2 (notice that this is an acceleration!). The formula for potential energy is:

$$PE = mgh$$

…where **m** is the mass in kg, **g** is the acceleration due to gravity in m/s^2, and **h** is the height in meters.

When the object is dropped from that height, its potential energy is gradually converted into kinetic energy, which depends on the object's mass and its velocity. The formula for potential energy is:

$$KE = 1/2\ mv^2$$

Because energy is conserved (cannot be lost or gained), all the object's potential energy must be converted to kinetic energy. So, you can set the two equations equal to each other.

$$PE = KE$$

$$mgh = 1/2\ mv^2$$

$$(9.8\ m/s^2)mh = 1/2\ mv^2$$

Because mass is on both sides, you can cancel it out. Solve this equation for v.

Now, using your different heights, you can figure out your projectiles' velocities when they hit the surface. (Make sure your heights are in meters!) Notice that the velocity does not depend on mass.

Graph your results.

What is the relationship between velocity and crater diameter?

MESA® Mathematics Engineering Science Achievement

Lesson Activity

Title	**Index Card Tower (35-40 minutes)**
ID Number	HS-E-C2
Sequence and Duration	• Lead In: 5 minutes • Activity: 20 minutes • Closure: 10-15 minutes
Age Level	High School
Essential Question	**How does the manipulation of index card shape and size engineer a stronger tower?**
Learning Objectives	• TSW design and construct a tower made of index cards. • TSW manipulate individual index cards to various shapes and sizes with folds and cuts to maximize the strength and efficiency of their tower. • TSW compare their index card tower to those of their peers and analyze the strengths and weaknesses of each.
Other Objectives	• TSW develop a working plan with their group to develop a cooperative environment. • TSW communicate with their group by contributing their vocal input.
Key Terms	• None
Materials Needed	Per Group • Stopwatch • Measuring Tape • Sturdy wooden or plastic clipboard • Textbooks • Scale Per Student • Handout: MESA Notebook Per Team of 2-3 Students • Handout: Index Card Tower Design Competition • 100 Index Cards
Lead In	1. Pass out the MESA Notebook handout. (If necessary, tell students that they will be completing this handout for each MESA activity. Tell them you will guide them through the handout today.) 2. Pass out Handout: Index Card Tower Design. 3. Read handout with students and have them re-tell you the activity in their own words. Check for understanding and ask if they have any questions. 4. Show the students the clipboard that will be used to test their towers so they have a general understanding of how it will be tested. Tell them that textbooks will be placed on top of the clipboard. 5. Tell students they have 20 minutes to construct their tower using only the index cards.
Activity	1. Begin time using stopwatch and monitor student progress. Check to make sure they are only using the index cards. Ask

	questions to guide them toward manipulation of cards using tears and folds. 2. After 20 minutes, call time. 3. Have each team look at the towers of other teams. As a group, hypothesize about which tower they think will be the strongest. Discuss predictions and make references to structural design and engineering. 4. Put the clipboard on top of each tower. Begin stacking books until the tower collapses. 5. Find the weight of the clipboard and the textbooks. Use the simple scoring formula at the bottom of the handout to find out which team has the best design. *6.* Clean up.
Closure	1. Tell students to take out their MESA Notebook handout. 2. Review the basic sections of the handout to familiarize students with layout. 3. Ask students, "What was the purpose of the activity today? What were we trying to accomplish?" Solicit answers. Tell them that each activity should have a purpose. Generate a general purpose on the board that the students agree on. *Ex: The purpose of this activity is to construct a tower out of index cards.* Tell students to write this in the 'purpose' section of their notebook. 4. Now, tell students to fill in the materials used section. "What materials did you use to complete this activity?" Have students complete 'materials used' section. 5. Point to the 'procedure' section and explain that this is where a chunk of their Notebook is. The procedure section is a step by step reflection of what the student did to accomplish the activity. It should be in sequential order and written toward a general audience. Tell students to be as thorough as possible. *For example, "My team got the index cards. We discussed how we were going to make the base of the tower. We began the base using 10 index cards. We added a second layer using 8 cards. Etc.* 6. The last section is the 'conclusion' section. Tell students that the advisor will be writing a conclusion question for each activity. They will answer this question in the 'conclusion' section. Write the following question on the board, "How does the manipulation of index card shape and size engineer a stronger tower?" Tell them to use what they learned from the activity to answer this question. **Note: Students may complete the 'Procedure' and 'Conclusion' section of the MESA Notebook at home before the next MESA meeting if time is an issue.*
Informal Assessment	• Monitor students to check for understanding. • Monitor students to check for participation.
Formal Assessment	• Completed Index Card Tower. • Completed MESA Notebook (They may complete this before the next MESA meeting).
Extensions	• Use activity to demonstrate Newton's 3rd law to explain the interactions of forces between bodies. [If the force exerted by the books *down* on the tower is greater than the force exerted by the tower *up* on the books, the tower will

<table>
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<tr><td>Trouble Shooting</td><td>Make sure students understand the rules for this activity.
Reset scale after each weighing of clipboard and textbooks.
Make sure all students participate in clean up.</td></tr>
<tr><td colspan="2">SEI Strategies Used

Preparation
☐ Adaptation of Content
☐ Links to Background
☐ Links to Past Learning
☒ Strategies incorporated

Scaffolding
☐ Modeling
☐ Guided practice
☐ Independent practice
☐ Comprehensible input

Grouping Options
☐ Whole class
☒ Small groups
☐ Partners
☐ Independent

Integration of Processes
☒ Reading
☒ Writing
☒ Speaking
☒ Listening

Application
☒ Hands-on
☒ Meaningful
☒ Linked to objectives
☒ Promotes engagement

Assessment
☒ Individual
☒ Group
☒ Written
☐ Oral</td></tr>
<tr><td>Arizona Math Standards Addressed</td><td>(none)</td></tr>
<tr><td>Arizona Science Standards Addressed</td><td>S2C2: TSW design and conduct a controlled investigation and record observations, notes, sketches, and ideas using tools such as a journal.
S1C4: TSW communicate the results of an investigation.</td></tr>
</table>

Team Members:___________________________________

Index Card Tower Design Competition

Goal:

Your team will build a tower that carries the greatest amount of weight using the least amount of index cards.

You will work in teams of 2-3 students and must build a tower that is at least 11 inches tall. Your team will get 100 index cards. You do not have to use all the cards; in fact, you want to construct a strong tower using the *least* amount of cards.

The cards can be cut, folded, and twisted to achieve your tower goals. You may not use glue, staples, fasteners, tape, or other binding materials in your tower.

Team Materials:

100 3” x 5” Index Cards

Instructions:

1. Read Index Card Tower Design Competition Handout.
2. Ask questions to make sure you understand the rules.
3. Get supplies.
4. Your team has 20 minutes to construct the tower.
5. When time is up, clean up your area and wait for your tower to be tested.

Competition:

A piece of ¼” plywood will be put on top of your tower. Books will be stacked on the plywood until the tower collapses. When the tower collapses, your team and advisor will find the total weight of the plywood, books, and index cards. Using the simple formula below, your team will find the weight carried per card. The team with the most weight per card calculation has built the strongest tower.

$$\frac{\text{Total weight of clipboard, textbooks, and index cards}}{\text{Total number of index cards}} = \text{weight / card}$$

$$\frac{\rule{4cm}{0.4pt}}{} = \qquad \text{gram/card}$$

Lesson Activity

Title	**Make a Magnet (2 sessions, 40-50 minutes)**
ID Number	HS-S-C4
Sequence and Duration	**Session 1: Introduction to Magnets** • Magnet Exploration (20-25 minutes) • Magnetic Field Demonstration (10 minutes) • Making Magnets (10-15 minutes) **Session 2: Electromagnets** • Electromagnet Challenge (30-35 minutes) • Closure (10-15 minutes)
Age Level	High School
Essential Question	**How can a normal nail become a magnet?**
Learning Objectives	• TSW discover properties of magnets. • TSW explain how domains affect a material's magnetic properties. • TSW describe the shape of an object's magnetic field. • TSW relate the strength of an electromagnet to manipulated properties.
Other Objectives	• TSW communicate with their group by contributing their vocal input. • TSW draw their ideas about and observations of magnetic field lines. • TSW record their observations of the properties of magnets and electromagnets. • TSW contribute to a group discussion about the properties of magnets and electromagnets.
Key Terms	• Magnet: An object that exerts a magnetic force and creates a magnetic field. • Magnetic field: Area in space where a magnet's force can be felt. • Magnetic force: Force resulting from charges (charged particles) in motion. • Attraction: Pulling force, which *attracts*. • Repulsion: Pushing force, which *repels*. • Pole: One of the two ends of a magnet, north or south. • Domain: A small region in a metal in which all atoms are magnetized in the same direction. • Electromagnet: A magnet created with electricity, whose magnetism can be turned on (when electric current is flowing) and off (when electric current is not flowing)
Materials Needed	**Magnet Exploration (per student pair)** • At least 2 magnets, any kind • Assorted materials (paper clips, pennies, push pins, dimes, buttons, etc.) **Magnetic Field Demonstration** • Clean glass jar with tight lid • 1 strong bar magnet • Iron filings • Clear glycerin or baby oil • Clear plastic wrap **Making Magnets Activity (per student pair)** • 1 long nail (at least 2 ½") • 1 strong bar magnet • several metal paper clips, uncoated **Electromagnet Challenge (per team)** • Handout: MESA Notebook

	• 1 bar magnet • 1 long nail • 12" of coated wire • 20 metal paper clips, uncoated • 1 C battery • 3" electrical tape • Scissors **Electromagnet Challenge (extra materials for class use)** • Roll of electrical tape • Variety of batteries • Variety of magnets (optional) • Spool of wire
Session 1	**Introduction to Magnets**
Magnet Exploration	1. Ask students about their experiences with magnets. Where do students see magnets in their everyday lives? (e.g. in classrooms, on their refrigerators, in jewelry, in toys) What do they use magnets to do? Do they know of products that have magnets inside them to make them work? (E.g. stereos, telephones, MRI machines, motors, etc.) 2. Ask the students, what is it about magnets that makes them useful? What do magnets do? Have students explain magnets' behavior in their own words. 3. Hand out magnets and other materials to pairs of students. Tell them they have ten minutes to make as many discoveries about magnets as they can. [You can adjust this time limit if students need more or less time. If they are still engaged with the magnets after ten minutes, you might want to let them keep exploring!] 4. Give the students time to report out on what they found. Create a list of magnets' properties on the board. You will have observations such as: a. Magnets have two sides that are stronger than the rest (poles) b. Magnets only stick to metal things c. Magnets stick to some metals and not others d. Magnets can both push and pull on each other e. The magnet's force can go through air, paper, etc. f. The magnet's force is weaker the further it is from the object it's attracting g. Attaching something small to the magnet, such as a paper clip, will make the small object slightly magnetic too h. Like poles repel each other i. Opposite poles attract each other
Magnetic Field Demonstration	1. What *is* a magnet? Explain that a magnet is simply any object that produces a magnetic field. The magnetic field is basically the area in space where the magnetic force can be felt. Students will already have experienced that the magnetic field is stronger at the poles and weaker everywhere else on the magnet. Ask students to visualize what they think the magnetic field might look like. You can have them sketch their idea in their MESA Notebooks, or have a few students describe their ideas to the class. Allow time for discussion if there is any debate. 2. Place the plastic-wrapped bar magnet in the jar of baby oil (see Troubleshooting #1). Turn the jar upside down to shake up the iron filings. 3. Gather the students around to watch the filings settle around the magnet. What shape do the filings make? Tell the students that the shape the filings make is a close approximation for what the magnetic field around the magnet looks like. [You should see higher concentrations of filings around the poles, radiating out from the poles in lines that are roughly where the magnetic field lines are (the filings themselves become magnetized with their own fields,

	altering the bar magnet's field slightly).] If the magnet is strong enough, those lines will go all the way from one pole to the next. 4. Draw students' attention to the fact that the field is three dimensional. 5. If you have extra filings, pour about a tablespoon onto a blank piece of paper. Have the students move around a magnet under the paper to see the filings make a two-dimensional picture of the field. They can try different shapes of magnets to see how a magnet's shape affects the shape of its field. 6. How close did students' visions of the field come to what these demonstrations are showing? 7. Have students draw representations of magnetic fields.
Making Magnets	1. Get students to think about how magnets come about. Are they found naturally in the world? [Yes.] What makes something magnetic? Why are some things magnetic and others not? 2. Allow students time to brainstorm about these questions. If you have the time and resources, allow the students to research these questions online or in the library. 3. Explain to the students that magnetic fields are caused by moving charges. Charged particles that are free to move around, such as the electrons in a metal, create their own tiny magnetic fields. If a large number of these particles all move the same way, their fields add up to create a larger field. 4. Explain that an unmagnetized material can be made magnetic in the presence of a magnetic field, as the students may have seen in their exploration when a paper clip became slightly magnetic when attached to a magnet. In an unmagnetized metal, there are small areas of magnetization called domains. The particles in a domain have fields that all point in the same direction, but under normal circumstances the domains are not aligned with each other so their fields cancel each other out. When a strong magnet is brought near, the magnetic force causes the domains to line up antiparallel with the field of the stronger magnet, so the unmagnetized material becomes magnetized as well. Note: For a visualization of this phenomenon, have the students visit http://ww2.slcc.edu/schools/hum_sci/physics/tutor/2220/magnetism_in_matter/. 5. Hand out one long nail, a strong magnet, and a pile of paper clips to pairs of students. Have them confirm that the nail is not magnetized by holding it close to the paper clips – the paper clips should not be attracted to the nail. But show the students how the nail can become magnetized by having its domains aligned – rub the magnet down the length of the nail repeatedly and hold the nail close to a paper clip (hold the magnet away so its field does not affect the paper clip too). Can students get the nail to attract the paper clip, even slightly? Give them a few minutes to try this out. 6. Tell the students that in the next challenge they will use what they've learned to create a magnet with special properties.
Session 2	**Electromagnets**
Electromagnet Challenge	1. Remind students about what they were doing in the last session. What did they find out about how magnets work? What did they learn about what makes a magnet? [Moving charges; the more charges aligned the same way, the stronger the overall magnetic field.] 2. Ask the students if they can think of another way to make a large number of electrons all do the same thing. If they have a hard time figuring it out, give them hints, such as, where else would you see electrons all moving together? How do we use moving electrons? Where in the room are a large number of electrons moving in unison? [Electricity, or electrical current] 3. (If applicable, remind students of what they learned in Electricity Flow I and II.) Explain that currents create their own magnetic field, and this field can be very strong. It can be strong enough to influence other electrons to align themselves and make the material they're in become magnetic.

	4. Cut a length of wire and demonstrate how to strip the coating from the both ends with scissors (remove about 2 inches of coating from each end). Wrap the wire a few times around a long nail and tape the ends of the wire to opposite ends of a battery. Try to pick up paper clips with the nail. Tell the students that you have created an electromagnet – a magnet created (or made stronger) by electricity. 5. Tell the students their challenge is to try to make a stronger electromagnet. The strength will be measured by the number of paper clips the electromagnet will pick up. Tell them to be sure to keep good records of what they try and what results they get in their MESA Notebooks. 6. Hand out the materials and handouts. Give the students 15-20 minutes to complete the challenge. 7. When time is up, have the students clean up their materials.
Closure	1. Ask the students what they tried. What worked? What didn't work? [Electromagnets can be made stronger by increasing the voltage of the battery and/or the number of coils of wire around the nail. Students may have also tried wrapping the coils around a natural magnet instead of the nail.] 2. What was the greatest number of paper clips that any electromagnet was able to pick up? What made that electromagnet so strong? 3. What did they find out about electromagnets by trying this challenge? [For example, that increasing the amount of electricity around the metal, either by increasing the voltage of the battery or increasing the number of coils, increases the strength of the magnet; that electromagnets can be turned on and off; that the electric circuit must be complete for the electromagnet to work; that the poles of the electromagnet (i.e. which one is north and which one south) depend on the direction in which the current flows.] 4. What might electromagnets be useful for? [Electromagnets are useful for any purpose that requires a strong magnet, a magnet whose strength can be changed, magnets whose poles can switch, and/or a magnet that can be turned on and off. For instance, magnets that are used to lift cars in junkyards, to levitate train on magnetic rails, to power motors, etc. 5. In their MESA Notebooks, have students respond to the reflection question: *How can a normal nail become a magnet?*
Informal Assessment	• Monitor students' participation in discussion. • Monitor students' participation in group work.
Formal Assessment	• Completed sketches and notes. • Functional electromagnet. • Completed MESA Notebook.
Trouble Shooting	1. Prepare the materials for the electromagnet challenge prior to the lesson. 2. Prepare the magnetic field demonstration prior to class by removing any labels from the glass jar and filling it not quite to the top with clear baby oil. Place a generous amount of iron filings in the jar – at least a good heaping tablespoon (amount needed will depend on the size of the magnet). Wrap a bar magnet in a layer of clear plastic wrap – this will make it easy to remove the iron filings after the demonstration is over; otherwise they are very difficult to get off! When you're ready to do the demonstration, place the magnet in the jar and screw the lid on tightly. 3. You can also do the demonstration by taping a bar magnet to the outside of the jar, although the field will be weaker inside the jar. 4. If you do not have a jar and baby oil, you can skip to the demonstration with iron filings on a piece of paper. However, this will not illustrate the three-dimensional nature of the field.
Extensions	• If you or the students have an old stereo speaker you don't mind having destroyed, you can take it apart and find the magnet inside. If you pull the

	magnetic mechanism apart and manually hook it up to a battery, you can see what happens when the battery is oriented one way (magnet pulls the speaker in) and when it is oriented the other way (magnet pushes the speaker out). You can use this demonstration to talk about alternating current and how it will switch the poles of the magnet, or you could use it to talk about how vibrations create sound waves – or you could talk about both! • You can have the students collect and graph data on the strength of the electromagnets based on how many paper clips it attracts relative to how many coils it has and how much current is flowing through it. Have the students determine if the relationship is linear or nonlinear.

SEI Strategies Used

Preparation
- ☒ Adaptation of Content
- ☒ Links to Background
- ☒ Links to Past Learning
- ☐ Strategies incorporated

Scaffolding
- ☒ Modeling
- ☐ Guided practice
- ☒ Independent practice
- ☒ Comprehensible input

Grouping Options
- ☒ Whole class
- ☒ Small groups
- ☒ Partners
- ☐ Independent

Integration of Processes
- ☐ Reading
- ☐ Writing
- ☒ Speaking
- ☒ Listening

Application
- ☒ Hands-on
- ☒ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☒ Individual
- ☒ Group
- ☒ Written
- ☒ Oral

Arizona Math Standards Addressed	Extension: • S2C1: TSW understand and apply data collection, organization and representation to analyze and sort data.
Arizona Science Standards Addressed	• S1C1: TSW formulate predictions, questions, or hypotheses based on observations. • S1C2: TSW design and conduct controlled investigations. • S1C4: TSW communicate results of investigations. • S5C1: TSW understand physical, chemical, and atomic properties of matter.

Lesson Activity

Title	**Mousetrap Car (3 sessions, 45-70 minutes)**
ID Number	HS-S-C5
Sequence and Duration	• Session 1: Background and Design (30-45 minutes) • Session 2: Construction (40-55 minutes) • Session 3: Competition (50-70 minutes)
Age Level	High School
Essential Question	**How do Newton's 3 Laws of motion affect the motion of my mousetrap car?** **What kind of modifications can I make to a car that will address the forces of friction and gravity?**
Learning Objectives	• TSW identify and recognize Newton's 3 Laws of Motion. • TSW describe how Newton's 1st Law affects the motion of an object. • TSW describe how we can calculate the force of an object by using the formula F=ma (Newton's 2nd Law). • TSW describe how Newton's 3rd Law affects the motion of an object. • TSW design and construct a mousetrap vehicle using given materials. • TSW devise with their partner a mousetrap car design concept that is powered by the mousetrap and activated by tripping the original mousetrap trip mechanism. • TSW modify their design to improve the overall structure. • TSW submit a final mousetrap car that addresses the following challenges: travels the furthest distance up a 30 degree incline and travels 10 meters in the shortest time. • TSW evaluate the strengths and weaknesses of their design and their mousetrap car. • TSW compare their design concept and their mousetrap car design to those of their peers. • TSW describe the process they took to complete the mousetrap car project. • TSW explain how Newton's Laws are affecting the motion of their car.
Other Objectives	• TSW develop a working plan with their group to develop a cooperative environment. • TSW communicate with their group by contributing their vocal input. • TSW listen as their peers discuss the design of their investigation. • TSW write down the procedure they used to design their project.
Key Terms	• Speed – distance over time (how fast an object is going). • Velocity – speed in a certain direction (e.g. 50 mph west). • Acceleration – rate of change of velocity (change in velocity over time). • Force – a push or pull. • Friction – "rubbing" force that acts in the opposite direction of

	the motion. • Gravity – force between masses; generally, the pull toward the center of the Earth.
Materials Needed	<u>Session 1</u> For Group • Toy cars (2) • Balloon Per Student • Handout: Newton's 3 Laws of Motion • Handout: Types of Forces Per Team (2-3 students) • Handout: Mousetrap Car Competition • Drawing Paper • Colored Pencils <u>Session 2</u> For Group • Box of assorted materials for teams to use as additional resources Per Student • Handout: Mousetrap Car Competition Per team (2-3 students) • Team Mousetrap Car Design from Week 3 • 1 Mousetrap • Materials brought from home that fulfill the team's design <u>Session 3</u> • Handout: MESA Notebook For Group • Ramp at 30 degree angle to test for power • Track measured out to specification to test for speed • Stopwatch Per Student • Handout: MESA Notebook • Handout: Mousetrap Car Competition • Handout: Newton's 3 Laws of Motion • Handout: MESA Mousetrap Car Speed Competition • Handout: MESA Mousetrap Car Power Competition Per Team (2-3 students) • Mousetrap Car • Team Mousetrap Car Design from Week 3
Session 1	**Background and Design** 1. Pass out Handout: Newton's 3 Laws of Motion 2. Read handout and discuss each law. Use examples to demonstrate how the laws apply to motion.

Examples:
<u>Newton's 1st Law</u>: Push a toy car across a table. Ask them why it stops. It stops because of friction and gravity, 2 forces acting on the car. If there were no forces acting on the car, it would remain in motion because of its inertia.
<u>Newton's 2nd Law</u>: f=ma You can do a basic comparison. The force needed to accelerate an object will increase if either the mass or the acceleration increases. You can use 2 toy cars to demonstrate this. If you have identical cars with identical masses, both at rest, you have to push one car harder than the other (give it more force), if you want it to go faster. You may want to tell students that force is measured in a unit called a Newton.
<u>Newton's 3rd Law</u>: Crawl up on a table. Ask students, "Why am I not falling through the table?" The answer is that the table is pushing up on you with the same force that your weight is pushing down on the table. Newton's 3rd law states that bodies in equilibrium (i.e. neither accelerating) exert equal forces on each other. Blow up a balloon. Let it go and watch it fly through the air. Ask students, why does the balloon fly? Where is the force being applied? The air being released from the balloon is pushing against the balloon, just as the balloon is pushing out the air.

3. Ask students to think about other examples of Newton's 3 Laws of Motion. Discuss.
4. Pass out the handout: Types of Forces.
5. Discuss handout and ask students to come up with more examples of forces. Add these to the handout.
6. Tell students that they will be building a mousetrap car that will demonstrate Newton's 3 laws of motion. Their car will be acted on by outside forces such as friction and gravity.
7. Pass out handout: Mousetrap Car Competition.
8. Read handout completely as it addresses the rules and specifications for building and competing the cars. Have students retell you in their own words after each section. When discussing the competition aspect of the project, students may ask how far 10 meters is for the speed race. Show them by pointing out a 10 meter distance in the room. If students ask how much a 30 degree angle is, model it for them using objects in the room or the ramp.
9. Tell students that the project will take 3 MESA meetings. You may want to write this on the board. This first meeting will cover the rules and specifications. They will also be designing their vehicle and drawing it on drawing paper. The second meeting will be set aside for building the vehicle. The third meeting will be set aside for testing the vehicle and the actual competition.
10. Have students break up into teams of 2 or 3.
11. Show students a mousetrap and ask them to retell you what they can do with the mousetrap and what they cannot do. Demonstrate how a mousetrap works. Some students already know, but some will not. Discuss the mechanism and ask how the mechanism demonstrates Newton's Laws of Motion. [Newton's 3rd Law – The clamp, when released by the spring, pushes down on the ground, and the ground pushes back on the clamp, making the whole trap spring up.]
12. Pass out drawing paper to the teams. Pass out colored

	pencils. Tell them they have 20-35 minutes to come up with a design. The mousetrap is going to be provided to them. They must bring other objects from home to add to the mousetrap. 13. Write the following questions on the board: What will the wheels be? What can I add to make it go faster? What can I add to make it go up the ramp better? Discuss modifications and how modifications improve a vehicle's performance. 14. Monitor and check student progress. Make sure their concept drawing is addressing competition rules and specifications. Make sure their materials are reasonable things they can easily get from home. 15. Have students add arrows to their drawing that label where friction and gravity will be acting on their vehicle. (Friction will be acting on their wheels and gravity will be pulling down on the vehicle.) 16. During the last 5 minutes of project time, tell teams to assign materials. Who is going to bring materials for the next meeting? (You may want to follow up this meeting with an email to all MESA students reminding them to bring their materials for the next meeting.) 17. Collect drawings from each team. Collect handouts from each student. 18. Clean up.
Session 2	**Construction** 1. Have students get with their teams. 2. Pass out Handouts to students: Newton's 3 Laws of Motion, Types of Forces and Mousetrap Car Competition. Review with students and have them give you other examples of Newton's 3 Laws and types of forces. Discuss rules for competition. 3. Pass out team drawings. 4. Have teams get out their supplies that they brought from home. 5. Tell teams that you also have a box of assorted supplies they may use, too. 6. Give them 5 minutes to gather their supplies and to go through your supplies. 7. After 5 minutes, ask teams if they need to modify their drawings based on their supplies. If they do, they may do so now. Pass out colored pencils to the teams that need to modify their design. 8. Tell teams they have 25-40 minutes to build their car. Advise them to work together in their teams and to ask for help from the advisor when they need it. 9. Monitor student progress and check to make sure their car construction follows their design concept closely. 10. If a team gets done constructing their car, they may test it to see if it works. 11. Allow the last 5 minutes for clean up. 12. Have students put their cars in a safe, designated area in your room.
Session 3	**Competition** 1. Pass out Handout: Mousetrap Car Competition. 2. Discuss competition rules again to clarify. 3. Show them area for Speed competition. Point out dimensions and clarify questions. Pass out handout: MESA Mousetrap Car

	Speed Competition to each student and explain how it needs to be filled out. See sample sheet. 4. Show them 30 degree ramp incline for Power Competition. Clarify any questions. Pass out Handout: MESA Mousetrap Car Incline Competition to each student and explain how it needs to be filled out. See sample sheet. 5. Have teams get their cars from the designated area. 6. Tell them they have 10-15 minutes to get their cars ready and to test them. 7. When time is up, have each team present their car to the group and point out features they added to make it go faster or be stronger. Have groups show their original design drawings and point out what modifications they had to make as they began to construct their cars. Groups may ask questions of each team as they present. 8. Have students bring their cars to the speed ramp. 9. Allow students one practice run before getting their actual time. 10. Tell students to record each team's time on their MESA Mousetrap Car Speed Competition handout. 11. Discuss winning car's design. What features made it go the fastest? Discuss with group. 12. Move onto the Incline competition. 13. Allow students one practice run. 14. As each team gets their run, have teams record distance onto their MESA Mousetrap Car Power Competition handout. Measure in cm and convert to m. 15. Discuss winning car's design. What made it go the furthest up an incline? What could they have done to their car to make it better? 16. Review types of forces that acted on their cars. Ask each team, what did you do to your car to try to overcome the force of friction? What did you do to your car to help it work against gravity? 17. Clean up.
Closure	1. Pass out MESA Notebook to each student and have them copy the following terms into the 'key terms' section: Speed, Velocity, Acceleration, Force, Friction, and Gravity. 2. Discuss each term as it applies to the activity and come up with a group definition for each. Make sure students can apply the definition to their experience with their mousetrap cars. 3. Tell students they have the remainder of the time to complete the MESA Notebook. They may work with their team. Write the following 'conclusion' questions on the board and tell them to answer it using what they have learned from the activity: • *How do Newton's 3 Laws of motion affect the motion of my mousetrap car?* • *What kind of modifications can I make to a car that will address the forces of friction and gravity?* • *If I could do this activity again, what changes would I make to my car to make it more competitive?* 4. Monitor their progress. 5. Students may complete their MESA Notebook at home.
Informal	• Monitor students as they progress through the project.

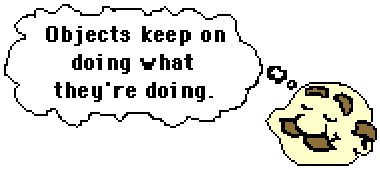
Assessment	• Monitor students to check for understanding periodically. • Informal Oral Presentation of team design and car.
Formal Assessment	• Completed Mousetrap Car Design. • Completed Mousetrap Car. • Completed MESA Notebook.
Extensions	• Math: Use graph paper to graph each team's speed (distance over time).
Trouble Shooting	• Have materials ready before students come to the meeting. • Email students after meeting 1 and before they come to meeting 2 to remind them to bring their materials. • Have additional mousetraps in case of breakage. • Make sure all students participate in clean up.

SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☒ Adaptation of Content	☐ Modeling	☐ Whole class
☐ Links to Background	☐ Guided practice	☒ Small groups
☒ Links to Past Learning	☒ Independent practice	☐ Partners
☒ Strategies incorporated	☒ Comprehensible input	☐ Independent

Integration of Processes	Application	Assessment
☒ Reading	☒ Hands-on	☐ Individual
☒ Writing	☒ Meaningful	☒ Group
☒ Speaking	☒ Linked to objectives	☒ Written
☒ Listening	☒ Promotes engagement	☒ Oral

Arizona Math Standards Addressed	• (none)
Arizona Science Standards Addressed	• S5C2: TSW analyze relationships between forces and motion by explaining how Newton's 1st law applies to objects at rest or in motion; using Newton's 2nd law of motion to analyze the relationships between the force acting on a body and the resulting acceleration; and using Newton's 3rd law to explain the forces as interactions between bodies.



First Law of Motion

According to Newton's first law...

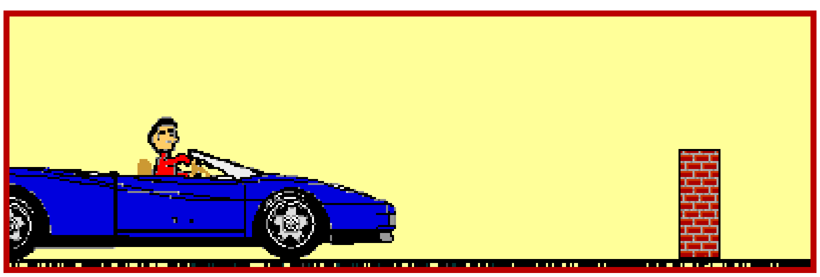
An object at rest will remain at rest unless acted on by an unbalanced force. An object in motion continues in motion with the same speed and in the same direction unless acted upon by an unbalanced force.

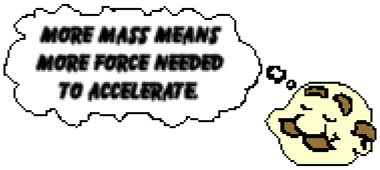
This law is often called "the Law of Inertia".

What does this mean?

This means that there is a natural tendency of objects to keep on doing what they're doing. This tendency is called *inertia.* All objects resist changes to their state of motion. In the absence of an unbalanced force, an object in motion will maintain this state of motion.

This law is the reason why you should always wear your seatbelt.





Second Law of Motion

According to Newton's second law...

Acceleration is produced when a force acts on a mass. The greater the mass (of the object being accelerated) the greater the amount of force needed (to accelerate the object).

What does this mean?

Everyone unconsciously knows the Second Law. Everyone knows that heavier objects require more force to move as fast as lighter objects.

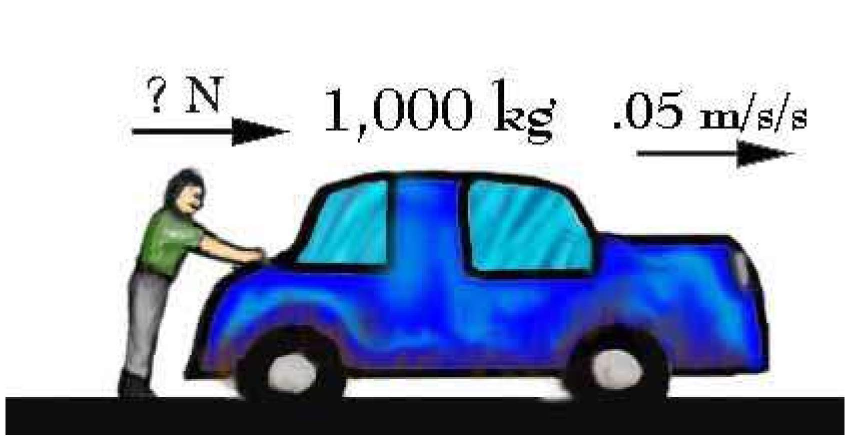
However, the Second Law gives us an exact relationship between force, mass, and acceleration. It can be expressed as a mathematical equation:

$$F = MA$$

or

FORCE = MASS times ACCELERATION

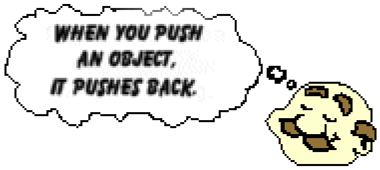
This is an example of how Newton's Second Law works:



Mike's car, which weighs 1,000 kg, is out of gas. Mike is trying to push the car to a gas station, and he makes the car go 0.05 m/s/s. Using Newton's Second Law, you can compute how much force Mike is applying to the car.

F=1,000 X 0.05

Answer = 50 Newtons



Third Law of Motion

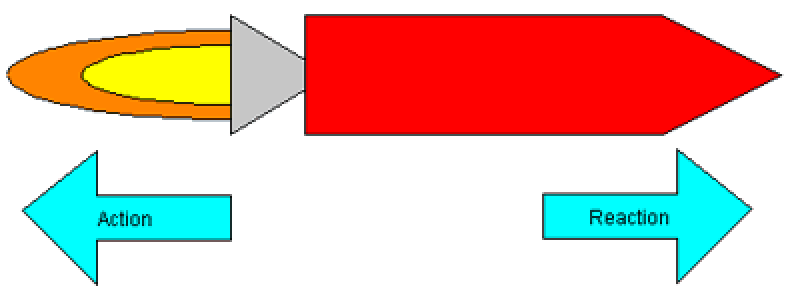
According to Newton's third law...

For every action there is an equal and opposite reaction.

What does this mean?

This means that for every force there is a reaction force that is equal in size, but opposite in direction. That is to say that whenever an object pushes another object it gets pushed back in the opposite direction equally hard.

Let's study how a rocket works to understand Newton's Third Law.



The rocket's action is to push against its fuel exhaust with the force of its powerful engines, and the reaction is that the fuel pushes back on the rocket with an equal force.

images from http://teachertech.rice.edu/Participants/louviere/Newton/

Types of Forces

Define the following terms in your own words and try to give examples.

- Gravity:

- Friction:

- Air Resistance:

Can you come up with other examples?

Mousetrap Car Competition

Goal:

Each team will build one mousetrap car. It must be powered by the mousetrap mechanism and be built to perform the following tasks:

- Speed: Travel 10 meters in the shortest time
- Power: Travel the furthest distance up a 30 degree-incline ramp

Materials:

Design Drawing

- Drawing paper
- Colored pencils

Mousetrap Car

- One standard mousetrap (provided by advisor)
- Any materials decided upon by each team

Instructions:

Day 1:

1. Design your mousetrap car with your team.
2. Draw your design on the drawing paper provided by your advisor. Use colored pencils.
3. Your drawing must show what types of materials are being used in your car.
4. Your drawing must show how friction is acting on your car.
5. Your drawing must show how gravity is acting on your car.
6. Get final approval from your advisor.

Day 2:
1. Check to make sure your team has all the materials needed for your car. If not, you need to modify your drawing.
2. Build your car with your team.
3. Test your vehicle if time permits.

Day 3:
1. Competition day! Follow your teacher's instructions for competition participation.

Rules:

1. The mousetrap car must be solely powered by the mousetrap and activated by tripping the original mousetrap trip mechanism.
2. No other energy source may be added to make the car move. (CO2, batteries, elastic strings, rubber bands, etc.)
3. The mousetrap must be mounted to the chassis (frame of the vehicle).
4. Hardware and other materials may be added to the mousetrap, but the original hardware and mounting block may only be altered to attach it to the vehicle.
5. The mousetrap may not be disassembled and then reassembled.
6. The springs on the mousetrap may not be cut, bent, over-wound, heat treated, or altered in any other manner.
7. No part of the vehicle may be attached to any part of the track or ramp.
8. Vehicle must roll or coast along track or ramp.
9. All wheels must stay in contact with the surface of the track and ramp.

Good Luck and Have Fun!

Mousetrap Car
Speed Competition

Directions: Under 'Team', write down the team members' names. Under 'Time', write down the recorded time by your advisor. Under 'Speed', use the formula
speed = distance/time to find the speed in m/s.

Team	Time in s	Speed in m/s

Math Extension: Use graph paper and graph the speed of each team.

Mousetrap Car
Power Competition

<u>Directions:</u> Under 'Team', write down the team members' names. Under 'Distance in cm', write down the distance recorded by your advisor in cm. Under 'Distance in m', use the following conversion to find distance in m: 1 meter = 100 centimeters.

Team	Distance in cm	Distance in m

Lesson Activity

Title	Pendulum Clock (50-65 minutes)
ID Number	HS-S-C6
Sequence and Duration	• Lead In: 5 minutes • Activity: 35-45 minutes • Closure: 10-15 minutes
Age Level	High School
Essential Question	**How can you design a pendulum to have a specific period?**
Learning Objectives	• TSW design and conduct experiments to investigate potential relationships between pendulums' properties and their performance. • TSW determine that there is a relationship between the length of the pendulum's string and its period. • TSW describe the relationship between the length of the pendulum's string and its period. • TSW predict the length needed to create a pendulum with a specific period and vice versa using a graph of the class' collective data. • TSW build a pendulum with a specified period.
Other Objectives	• TSW collaborate with their group members to devise a plan for answering a question. • TSW prepare a written proposal describing their plan. • TSW engage in group discussions to determine ways to solve a problem and collect accurate data.
Key Terms	• Pendulum • Period • Dependent variable • Independent variable • Line of best fit
Materials Needed	Per Class: • Scale(s) • Scissors • Items of different masses to be used as pendulum bobs – e.g. fishing weights, scale masses, washers, etc., at least two per group • String (enough that each group can cut multiple lengths as needed) • Stopwatches • Meter sticks • Rulers • Graph paper (optional) Per Team: • Handout: Pendulum Clock Investigation Proposal
Lead In	1. Ask the students to describe what a pendulum is in their own words. (Example definition: A mass suspended from a fixed point that is able to swing freely back and forth. Accept other descriptions such as something that swings back and forth; an object suspended by a string from a fixed point and set in motion; an oscillating mass attached to a pivot.) 2. What are some examples of pendulums (or pendula) that students know of? (E.g. grandfather clocks, swing sets) 3. If the students are familiar with the use of pendulums in grandfather clocks, then they already know that pendulums are useful for keeping time fairly

	accurately. What property or properties of pendulums make them good timekeepers? Tell the students that their mission for today will be to learn about pendulums and figure out how to design a “clock” from a pendulum.
Activity	1. Lay a pencil on the edge of a table where all students can see it, and tape it to the table so that a few inches of it are off the edge. As you tie a bob and string to the end of the pencil, ask the students, what makes a pendulum move the way it does? What forces and other influences act on the bob? Let the students observe how the demo pendulum moves and play with it. Encourage discussion amongst the students about what is making the pendulum move, and allow students to draw diagrams on the board to illustrate their ideas if they like. [The pendulum is powered by gravity, which makes the bob continuously fall. The string keeps the bob from falling completely, and the bob’s inertia makes it want to keep moving in a straight line, so these combined influences cause the bob to move in a back-and-forth arc.] 2. Now ask the students to think about ways the pendulum’s motion can be varied. What characteristics of the pendulum can be changed? [E.g. its velocity, the mass of the bob, the height of the pivot off the ground, the height from which the bob is dropped, the time it takes the pendulum to swing from one side to the other, the length of the string, etc.] Write students’ suggestions on the board. 3. Which of these variables identified by the students might be connected? That is, could one or several of these variables be *independent variables* (factors that cause a change in the pendulum’s motion) while others are *dependent variables* (factors that change as a result of changes in the dependent variable)? Encourage discussion. How can the students determine if there are relationships between different variables, and whether any of these relationships could have an effect on how well the pendulum keeps time? [They will need to design investigations to explore the effects of changing different variables.] 4. Help the students divide themselves into groups based on the class’ interest in pursuing different questions. For instance, allow one group to look at the relationship between mass of the bob and velocity of the bob; one to look at height from which the bob is dropped and velocity of the bob; and another to look at the length of the string and the period of the bob. Try to make sure that each of the variables is being investigated by at least two students; if not, assign groups to another investigation after they’ve completed their first. 5. Before the groups begin gathering their investigations, have them prepare a brief proposal of what they intend to do using the Pendulum Clock Investigation Proposal worksheets. Before you allow students to collect the materials they need for their investigations, review their proposals and ask follow-up questions to make sure the students have a clear procedure that will work, and that they have considered how to get the most accurate data (e.g. by running multiple trials, having multiple students make measurements and take an average; being precise in defining what and when they will measure, preparing to take sufficient data to determine if a relationship exists, etc.). 6. Give students 10-15 minutes to collect their data and analyze their results. 7. When the groups are ready, have them report out on their results. Be sure they include what their question was, what they did to collect their data, what data they collected, and what their results indicate. 8. As a class, decide which, if any, of the variables had any impact on the pendulum’s usefulness for timekeeping. [Only the length of the string has any influence on how quickly the pendulum swings from one side to the next.] [Note: If the class cannot come to this conclusion, have them revisit their experiments and collect more data. Have groups switch and use other groups’ proposals.]

	9. Have the group that worked on length and the pendulum's *period* (the time it takes the bob to complete a full swing from one side to the next) put their data table up on the board so the whole class can look at it. What kind of relationship exists between the variables? If one doubles, does the other double? Is it easy to tell how long you would need the string to be to give the pendulum an exact period? [The relationship is non-linear, meaning that the students will need to collect a fairly large amount of data before it is clear how the two variables are related.] As a class, discuss the best way to collect enough data to be able to accurately predict what length you would need to time out a certain period. (E.g. one group could collect data on lengths under 10 cm, another could do 10-20 cm, another 20-30, etc.) 10. Before students begin collecting data, initiate a discussion on how you can be sure that every group is collecting data in the same way as every other group. What procedures need to be established to make sure the data collection is consistent across groups? (E.g. establish the points that mark off the length of the string, how students will time the period, the number of swings they should time to determine the time of just one period, controlling any other variables that might impact the data.) 11. While the groups collect the second round of data, create a large graph on the board or overhead. As groups finish collecting data, have them plot their data on the graph. As other groups finish, have them begin predicting where the next data point will fall. 12. When all the data is up, discuss the class' results. If the students are familiar with the term *line of best fit* (see the Barbie Bungee activity), have them relate this term to their results. Would a straight line accurately represent the relationship? [No!] What kind of line would best represent the relationship between the variables? [A parabola.] Have one student sketch in a parabolic line that comes as close as possible to as many data points as possible. From this the class will be able to predict the length the string will need to be to create a pendulum with a specific period.
Closure	1. Randomly choose times or lengths and have the students read the graph to identify the lengths or times, respectively, that the pendulum would need to have. 2. Choose a time that is not represented by students' data (e.g. 5 seconds) and have students construct pendulums that can tick off the appropriate intervals. 3. Choose a time/length that is NOT on the graph and have students predict the length/time that would be associated with it, according to their results. 4. In their MESA Notebooks, have students respond to the following summary question: *How can you design a pendulum to have a specific period?*
Informal Assessment	• Monitor students' participation in the activity. • Monitor students' participation in discussions. • Assess students' understanding of how to read and interpret the graph.
Formal Assessment	• Completed data sheets. • Completed assessment pendulum. • Completed MESA Notebooks.
Trouble Shooting	• Be sure students are careful with their bobs and tie them tightly with their strings. Flying bobs can be dangerous!
Extensions	• If you have access to the internet in class, have the students review this kid-friendly website from the California Academy of Sciences to learn how a pendulum can be used to show the Earth's rotation: http://www.calacademy.org/products/pendulum/index.htm. • There is a great deal of interesting science that can be taught via pendulums. If students have prior understanding of energy and energy transformations, you can use the pendulums to demonstrate transformations of potential to kinetic

	energy and vice versa, highlighting the conservation of energy. Students can measure the velocity of the bob experimentally and compare it to the velocity they would expect given the relationship between the potential energy (PE=mgh) and the kinetic energy (½mv^2).

SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☐ Adaptation of Content	☒ Modeling	☒ Whole class
☒ Links to Background	☒ Guided practice	☒ Small groups
☒ Links to Past Learning	☒ Independent practice	☒ Partners
☐ Strategies incorporated	☒ Comprehensible input	☐ Independent

Integration of Processes	Application	Assessment
☐ Reading	☒ Hands-on	☒ Individual
☒ Writing	☒ Meaningful	☒ Group
☒ Speaking	☒ Linked to objectives	☒ Written
☐ Listening	☒ Promotes engagement	☒ Oral

Arizona Math Standards Addressed	• S2C1: TSW understand and apply data collection, organization and representation to analyze and sort data. • S3C2: TSW describe and model function and their relationships.
Arizona Science Standards Addressed	• S1C1: TSW formulate predictions, questions, or hypotheses based on observations. • S1C2: TSW design and conduct controlled investigations. • S1C3: TSW evaluate experimental design, analyze data to explain results and propose further investigations. • S1C4: TSW communicate results of investigations. • S5C2: TSW analyze relationships between forces and motion.

Pendulum Clock Investigation Proposal

Research Question – What does your group plan to investigate? What variables will you be working with?

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Procedure – What will you do to investigate changes in your variable(s)?

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Materials Setup – Draw a picture of the set up you will use to collect your data in the space below.

Date Table – Create a data table to record your data on the back of this sheet. Allow space for multiple trials.

Lesson Activity

Title	**On-Site Design Challenge: Ping Pong Launcher (60-80 Minutes)**
ID Number	HS-E-OS3
Sequence and Duration	• Lead In: 10-15 Minutes • Activity: 40-50 Minutes • Closure: 10-15 Minutes
Age Level	High School
Essential Question	**What have I learned about on-site engineering challenges?**
Learning Objectives	• TSW design and build a ping pong launcher to specs. • TSW reflect on and evaluate their approach to the problem and the strategies they used to address it. • TSW evaluate their comfort level with on-site design challenges. • TSW continue brainstorming strategies to help them be successful at on-site design challenges in the future.
Other Objectives	• TSW develop a working plan with their group to develop a cooperative environment. • TSW communicate with their group by contributing their vocal input. • TSW develop critical reading skills by finding relevant information in given materials. • TSW listen to their peers discuss their approaches to the problem. • TSW contribute to a group discussion about being successful in on-site design challenges.
Key Terms	• On-site design challenge • Approach • Strategy
Materials Needed	Per Class: • Large receptacle target (e.g. empty waste basket, basin, coffee can, etc.) • On-Site Engineering Design Data Collection Sheet Per Group: • Handout: On-Site Engineering Design specs • 2 paper towel or toilet paper rolls (or a piece of paper) • 5 rubber bands • 8 paper clips • 6 popsicle sticks • 12 inches of masking tape • 1 pair of scissors • 1 ruler • 1 stapler
Lead In	1. This lesson plan is another option for practicing with on-site design challenges. You can use this activity in place of one of the previous activities (Design a Glider: intro to on-site design; Watercraft: review of on-site design) with more elaborate lesson plans. Or you can use this activity to continue practice with on-site design challenges. 2. Feel free to incorporate pre and post-activity discussions that meet your goals, such as having students reflect on their strategies for approaching on-site design challenges, their prior knowledge about the challenge, strategies for working together as a team, or their comfort level with designing under pressure.

Activity	1. Separate students into groups of two or three and hand out the supplies to each pair. When all supplies have been distributed, hand out the specs face down, instructing students not to turn them over until you tell them to. Tell them they have thirty minutes to complete the challenge. They may raise their hands if they need clarification about the rules, but they should think of you as the judge, not their advisor. 2. Call out “begin!” and start the 30 minute count-down. 3. After 30 minutes are up, call time and have students clean up their areas and bring their launchers to the area designated for testing (an auditorium, empty hallway, soccer field, etc.). 4. Give each group one ping pong ball which they are NOT to shoot until you call time. Then have them spread out in the space somewhat so they’re not interfering with each other. They don’t need to go far; you might have them just line up all facing the same direction so ping pong balls aren’t being hit at other people. 5. Give the whole group two minutes to practice launching, then call time. Collect all the ping pong balls. 6. Call each group up one at a time to test their launchers. Have them place their launchers on the starting point and give them the supply of ping pong balls. Give each group exactly two minutes to launch as many ping pong balls as possible at the targets. Collect that data on the Data Collection Sheet. 7. Tally up the group’s results while they collect all the ping pong balls and reset the testing space. 8. When all the groups’ launchers have been tested, declare the winner as the group with the most ping pong balls in the target or the most overall points. In the case of a tie, have the launchers shoot one final ping pong ball and determine the winner to be the one that launched the ball the greatest straight distance. 9. Have the students help clean up the testing area, then return to the classroom.
Closure	1. Give students time to reflect on their approaches and strategies with this challenge, first with their groups and then reporting out to the whole class. 2. Guide the discussion to meet your objectives, having the students reflect on, for instance, how previous challenges prepared them for this one, what they did differently or similarly, what scientific knowledge they used in their design, etc.
Informal Assessment	• Monitor students’ participation in the activity. • Monitor students’ participation in the discussion.
Formal Assessment	• Completed MESA Notebook (optional). • Completed launcher.
Trouble Shooting	• Separate out each team’s materials and place them in baggies or boxes prior to students’ arrival to class. • You can have students build their launchers with whatever materials you happen to have on hand. Feel free to improvise to create your own challenge. • Mark the spot where all launchers must be placed during testing. • For the target, set up a receptacle with a large opening that can also catch the ping pong balls when they fall inside. • You can set up more than one target and assign different point values to each target. You could also assign different point values for balls that bounce back out of the target, balls that hit the target but don’t go in, balls that bounce in after hitting another surface, etc. Adjust the Data Collection Sheet as necessary. • Make sure you also mark the spots where your target(s) should be placed, in case they get bumped out of position between different groups’ testing times. Give students the distance from the launchers to the target(s) in their specs.

	• Collect paper towel/toilet paper rolls well in advance of doing this activity, and have students bring them in from home as well. If paper rolls are not available, have students construct a roll from regular paper before the activity. Or have them improvise without them!

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☐ Links to Background
- ☒ Links to Past Learning
- ☒ Strategies incorporated

Scaffolding
- ☐ Modeling
- ☐ Guided practice
- ☒ Independent practice
- ☐ Comprehensible input

Grouping Options
- ☒ Whole class
- ☐ Small groups
- ☒ Partners
- ☐ Independent

Integration of Processes
- ☒ Reading
- ☐ Writing
- ☒ Speaking
- ☒ Listening

Application
- ☒ Hands-on
- ☒ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☐ Individual
- ☒ Group
- ☐ Written
- ☒ Oral

Arizona Math Standards Addressed	(none)
Arizona Science Standards Addressed	• S3C2: TSW develop viable solutions to a need or problem.

ON-SITE ENGINEERING DESIGN
High School Level
Ping Pong Launcher

OBJECTIVE:

Your challenge is to design and build a ping pong launcher from the given materials. Your team shall compete with other teams in a head-to-head competition.

MATERIALS:

2 – Paper towel/toilet paper rolls
5 – Rubber bands
8 – Paper clips
6 – Popsicle sticks
12 – inches masking tape

Other materials available for use but not included in the design:

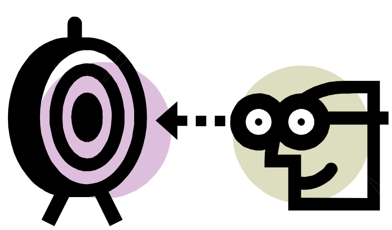
Scissors Stapler Ruler Pencil Paper

RESTRICTIONS and INSTRUCTIONS:

- Each launcher must be built from only the supplied materials. No other materials can be used.
- The distance between the launcher and target during testing is fixed. Launchers cannot be moved closer to or further from the targets.
- Ping pong balls cannot be launched *solely* by the force of the team members (i.e. balls cannot be thrown or batted). However, team members can operate the launcher.

SCORING:

- Teams will have thirty minutes to design their launchers. They will then have exactly two minutes to practice launching, and exactly two minutes to test their launchers.
- During the two minutes of testing time, teams will attempt to hit as many ping pong balls into the target as possible.
- Adjustments to the launcher may be made during the two-minute testing period, but the clock will not be stopped.
- The team that launches as many ping pong balls into the target is the winner.
- In the event of a tie, the tying launchers will each launch one ping pong ball. The launcher whose ball flies the longest straight distance will be declared the winner.



ON-SITE ENGINEERING DESIGN
High School Level
Ping Pong Launcher

Data Collection Sheet

Group Members	Number of ping pong balls in the target	Tie Breaker: Distance of final ping pong ball

Lesson Activity

Title	**Pizza Box Solar Oven (30-40 minutes)**
ID Number	HS-S-A4
Sequence and Duration	• Lead In (5 minutes) • Solar Oven Construction (25-35 minutes)
Age Level	High School
Essential Question	**How does the solar oven convert light to heat?**
Learning Objectives	Pizza Box Solar Oven • TSW will learn how sunlight is converted to heat. • TSW will recognize that energy is conserved in a closed system. • TSW will recognize that black objects absorb sunlight. • TSW will use reflection to capture sunlight.
Other Objectives	• TSW participate in a discussion about solar heating. • TSW will work with their teammates to construct their ovens.
Key Terms	• Energy Transfer: energy moving from one place/object to another. • Energy Conservation: minimizing the amount of energy used or lost. • Conduction: energy transferred when one molecule bumps into another. • Insulation: material that inhibits the transfer of energy; used to conserve energy in a system. • Insolation: solar energy received by a surface.
Materials Needed	Per Group • Oven Thermometer (optional) Per Student • MESA Notebook Handout • Pizza Box Solar Oven instructions handout Per Team (2-3 students) • Pizza Box (either recycled or acquired from a pizza store) • Newspaper (have students collect or bring from home) • 5 sheets black construction paper • 6 feet of Aluminum Foil • 2 Transparency sheets • Scotch Tape • Non-toxic glue • 2 straws • Graham Crackers – 2 per student • Milk Chocolate Bar – 1 per team • Large Marshmallows – 1 per student Equipment Needed: • Scissors or Box cutters • Ruler • Markers
Lead In	1. Ask students “It is hot enough to fry an egg outside?” 2. Wait for their response and then ask “Do you want to prove it?” 3. Explain that although they won’t be actually frying eggs, then will

	be cooking using only the Sun today. 4. Ask student to divide themselves into groups of 2-3 or place them in groups if necessary. 5. Explain that each group will be building a Solar Oven and that if all goes well they will leave with a little treat.
Activity	1. Handout the Pizza Box Solar Oven directions to each student. 2. Handout the materials to each group. 3. Ask the students to follow the directions to create their ovens. 4. After students have completed their ovens, have the groups go outside and position their ovens to starting baking their s'mores. Once the ovens are positioned, return to the classroom. 5. Handout MESA Notebook. 6. Ask students to draw a diagram of their oven on their Notebook. Then ask them to label the different parts of the oven (i.e. reflective flap, window, insulation, interior). 7. Ask students what they think is happening in their solar ovens. Make sure they discuss the role of each part. Lead the discussion so that students understand and can define that their oven is a closed system that transfers energy through conduction and conserves it through insulation. 8. Have the students draw or describe the process under Procedure. 9. Have students define energy transfer, conduction, and energy conservation in their MESA Notebook.
Closure	1. Ask the students to retrieve their ovens and return to the classroom. 2. Have them examine each others' results, then sit and enjoy. 3. Ask the students to answer the following question in the conclusion portion of their Notebook: "What factors played a key role in the success/failure of your pizza box oven?"
Informal Assessment	• Monitor students to check for understanding of directions. • Monitor the students to check for participation.
Formal Assessment	• Students should create an oven that melts the chocolate and marshmallows.
Trouble Shooting	• Have materials pre-packaged inside a pizza box to hand them out faster. • Have a demo oven that you created to help students. • Keep an eye on time. • If short on time, ask students to research conduction for the following meeting to ensure you have time to do the Introduction to MESA.

Extension	• Have students use an oven thermometer to track the temperature of their ovens at different times of the day, different intervals of time, and different times of the year, then analyze their observations.
	• You can use the following websites to delve deeper into solar cooking:
	    ◦ http://www1.eere.energy.gov/education/learning.html
	    ◦ http://www.solarcooking.org/default.htm
	• Discussion about best use of solar cooking. (i.e. reduce energy consumption, third world applications).
	• Discussion about ways to improve their ovens.
	• Discussion about other application of solar energy.

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☒ Links to Background
- ☐ Links to Past Learning
- ☐ Strategies incorporated

Scaffolding
- ☐ Modeling
- ☒ Guided practice
- ☐ Independent practice
- ☐ Comprehensible input

Grouping Options
- ☒ Whole class
- ☒ Small groups
- ☐ Partners
- ☐ Independent

Integration of Processes
- ☒ Reading
- ☒ Writing
- ☒ Speaking
- ☒ Listening

Application
- ☒ Hands-on
- ☒ Meaningful
- ☐ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☒ Individual
- ☒ Group
- ☒ Written
- ☒ Oral

Arizona Math Standards Addressed	• None
Arizona Science Standards Addressed	• S5C3: TSW understand ways that energy is conserved, stored, or transferred by describing various ways energy is transferred from one system to another.

Mathematics Engineering Science Achievement

Pizza Box Solar Oven

This solar oven has been adapted from many designs. If you make one on your own please feel free to improvise! For today please follow the directions below.

The pizza box solar oven can reach temperatures of 275 degrees, hot enough to cook food and to kill germs in water. A general rule for cooking in a solar oven is to get the food in early and don't worry about overcooking. Solar cookers can be used for six months of the year in northern climates and year-round in tropical locations. Expect the cooking time to take about twice as long as conventional methods, and allow about one half hour to preheat. At home you can try cooking hot dogs or English muffin pizzas; you can even try to bake cookies or biscuits.

What You'll Need

- Recycled pizza box
- Black construction paper
- Aluminum foil
- Transparency Sheets (Another clear plastic will also work) or Saran-Wrap
- Non-toxic glue, tape, scissors, ruler, magic marker
- Wooden dowel or straw

How to Make Your Pizza Box Oven

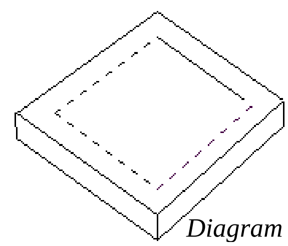


Diagram #1

1. Make sure the cardboard is folded into its box shape.

2. Draw a 7.5" by 10" rectangle on the top of the box. Cut along three sides leaving the line along the back of the box uncut. (Diagram #1)

3. Form a flap by gently folding back along the uncut line to form a crease. (Diagram #2)

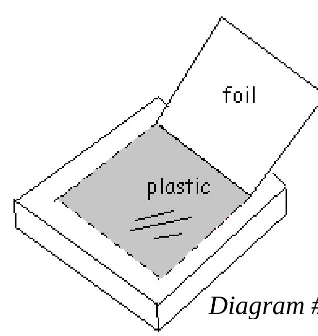


Diagram #2

4. Cut a piece of aluminum foil slightly larger than the flap. Wrap the underside (inside) face of this flap with the aluminum foil. Tape it so that the foil is held firmly but so that there's not too much tape showing on the foil side of the flap. (Diagram #2)

5. Tape the transparency sheet to the underside of the lid opening to cover the hole. If possible add another transparency to the top of the lid opening. Be sure the plastic creates a tightly sealed window so that the air cannot escape from the oven interior. (Diagram #2)

6. Cut another piece of foil to line the bottom of the pizza box and carefully glue into place. Cover the foil with a piece of black construction paper and tape into place. (Diagram #3)

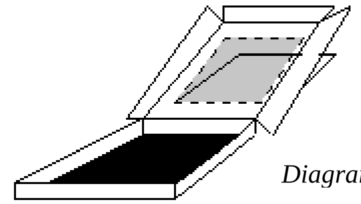


Diagram #3

7. Roll up some newspaper and fit it around the inside edges of the box to act as insulation. It should be about 1-1.5" thick. Use tape or other materials you can think of to hold the newspaper in place.

8. Close the pizza box top (window), and prop open the flap of the box with a straw and face towards the sun. (Diagram #4) Adjust until the aluminum reflects the maximum sunlight through the window into the oven interior.

9. Your oven is ready! Take your graham crackers, chocolate and marshmallow and make a s’more.

10. If available, test how hot your oven can get using a simple oven thermometer!

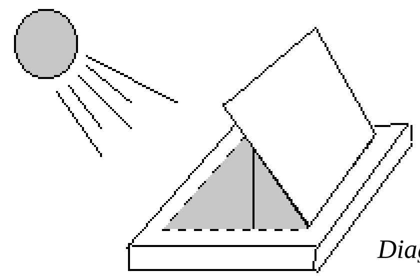


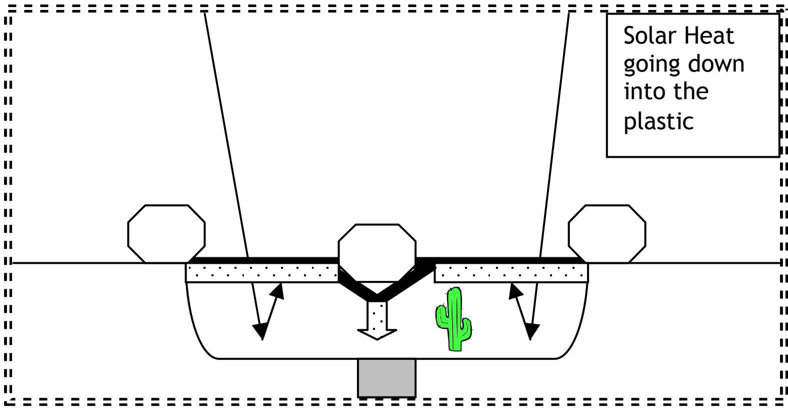
Diagram #4

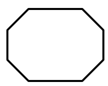
Lesson Activity

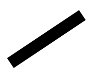
Title	**Solar Water Stills (65-70 minutes)**
ID Number	HS-S-A5
Sequence and Duration	• Lead In (15-20 minutes) • Activity (45-50 minutes) • Closure (5-10 minutes)
Age Level	High School
Essential Question	**How does the greenhouse effect contribute to the success of a solar water still?**
Learning Objectives	• TSW identify and describe the following terms: o Solar energy o Greenhouse effect o Evaporation o Condensation o Precipitation o Distillation • TSW explain how the greenhouse effect allows a solar water still to collect fresh drinking water. • TSW compare the water cycle process to the solar water still and distinguish the similarities and differences. • TSW construct a simple water still using given materials. • TSW identify and explain the features of their water still and describe how it works. • TSW evaluate the strengths and weaknesses of their solar water still.
Other Objectives	• TSW read the directions for constructing the solar water still and discuss their clarification with their group and/or their MESA Advisor. • TSW communicate with their group by contributing their vocal input. • TSW listen as their peers discuss the construction of their solar water still. • TSW write down the procedure in their MESA Notebook.
Key Terms	• Solar energy: energy from the Sun. • Greenhouse effect: process by which a surface is warmed by energy re-emitted by gases in the atmosphere. • Evaporation: phase shift of a liquid to a gas. • Condensation: phase shift of a gas to a liquid. • Precipitation: moisture falling from the air to the ground. • Distillation: purification by evaporating, condensing and re-collecting a substance.
Materials Needed	Per Group • Images of Solar Water Stills (Optional) Per Student • Handout: Solar Water Stills • Handout: MESA Notebook Per Team (3-4 students) • Handout: Soil Still Preparation Activity • 4.75" 2 x 4 wood block • Heavy Foil 9"x11" • Plastic Transparency Sheet 4.25"x5/5" (Cut a 8.5"x11" sheet into ¼)
Lead In	1. Ask, "How many of you take advantage of the hiking around Tucson?" Discuss with students their experiences. 2. Ask, "Why is it important to always have water with you when you go out hiking, or biking, or even walking?" Discuss. 3. Ask, "Let's pretend. You are lost in the Sonoran Desert without any water. What would your biggest concern be?" Discuss dehydration and its symptoms. 4. Ask, "How long can your body survive in a desert without water?" Discuss and guide students to a maximum of 3 days.

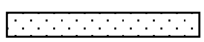
	5. Ask, “What could you do to get water in the desert?” Discuss and write possibilities on the board. 6. Ask, “How does the desert get the water it needs?” Guide students to RAIN. 7. Ask, “Why does it rain? What is the process for rain? Remember, rain is a form of precipitation.” Discuss and guide students to draw the water cycle model on the board. 8. Discuss the water cycle in depth with students. They should already have the background for this, but may need a refresher. 9. Ask, “What causes evaporation?” Discuss and guide students to heat from the Sun. 10. Ask, “If you were stranded in the Sonoran Desert without any water, could you make your own rain?” Discuss with students.
Activity	1. Pass out Handout: Solar Water Stills to each student. 2. Ask, “How many of you have heard of a solar water still or have seen one?” Discuss and have students volunteer their input. 3. Review Solar Water Still page 1 with students. Read aloud or have students read in pairs or individually. Have students underline/highlight the following words: greenhouse effect, solar energy, evaporation, condensation. 4. Have students write the terms into their ‘key terms’ section of their MESA Notebook. Define terms as a class. 5. Turn handout over to page 2. Look at the ‘Greenhouse Effect’ model illustration. Read, examine, and discuss model. Ask, “If we are trying to make rain in the desert, why is it important for infrared heat to be trapped. What does the heat do to a source of water, for example, a cup of dirty water?” Guide students to understand that if dirty water were heated by solar energy, it would eventually evaporate. The evaporated water would rise and leave behind the “dirty” part. When it then cools and condenses, the water is safe to drink. 6. This process of purification is called ‘distillation’. Add this term to the ‘key terms’ section and define as a group. Have students read the text in the middle of the page. Discuss and relate it to earlier discussions about evaporation and condensation. 7. Review the ‘Water Cycle’ model at the bottom of page 2. 8. Ask again, “If you were stranded in the Sonoran Desert without any water, could you make your own rain?” Discuss any new suggestions with students. 9. Say, “Let’s look at the Greenhouse Effect model again. What is keeping the heat from going back up into the air?” Guide students to say, the glass. 10. Ask, “If you were stranded in the desert, you could build a solar still with some glass. But, who’s gonna carry a glass window around with them. What could you be carrying that is similar to glass but portable?” Discuss and guide students to clear plastic. Point out that many hikers always carry plastic with them in case they do get lost so they can make their own water stills. 11. Say, “Now, if I am lost in the Sonoran Desert without water, but I do have some plastic in my backpack, I can try to build a solar water still. What could I use as a source of water?” Solicit answers and discuss possibilities. Possible sources of water are: soil, plant life, and urine. 12. Say, “You tell me. I have my plastic, I have my source of water. Now, how am I going to collect the water? I need some kind of container.” Guide students to pretend you have a cup in your backpack. 13. Say, “Now, I have my plastic, I have my container to collect the water, and I have my source of water. I have a plant in the ground. How could I build a simple solar water still? What would I do first? Walk me through this. Remember, use what you know about the Greenhouse Effect and the Water Cycle.” Discuss and write down their suggested steps on the board. Guide them to understanding. <u>One example can be:</u> Dig a big, wide hole in the ground. If there is a plant in the hole, even better. Dig a small hole in the big hole to put the cup into. This is where the water will collect. Put the plastic over the big hole. The plastic should lay over the hole

without touching the ground where you dug it out. Put rocks, dirt, anything around the edge of the plastic so the heat is trapped under it. Now, put a rock on top of the plastic right over the cup under the plastic. The rock is going to act as a spout. The water that condenses under the plastic will drip into the cup because the rock is making the plastic over the cup the lowest point. See diagram below.

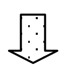


 Rock to hold down plastic

 Plastic

 Water is evaporating and collecting as condensation on plastic

 Container in small hole to collect the drips of clean water

 Angle of plastic is dripping water into the container

14. Review class solar still. Draw their model concept on the board.
    - Label where evaporation occurs, where condensation occurs, where distillation occurs, and where precipitation occurs.
    - Label how solar heat enters the plastic from the top and gets trapped under the plastic.
15. Check for understanding and review key concepts of the solar water still.
16. Ask, "Is this the only way to build a solar water still?" Discuss and have students come up with alternatives.
17. Say, "Today, we are going to make a mini-solar water still. It uses the same concepts, but the design is much different. What does every solar water still need?" Guide students to say: plastic, a container to catch water, a source of water.
18. Pass out the Handout: Soil Still Preparation Activity.
19. Read handout and clarify how it is to be built.
20. Have students break up into teams of 3-4 students. Pass out team materials.
21. Tell students they have 10-15 minutes to construct project.
22. Monitor students as they construct their solar water stills.

Closure

1. Have students describe the components of their water still. Where is the water evaporating, condensing, and precipitating? Where is the solar heat being trapped? How is the greenhouse effect trapping the heat?
2. Have students analyze the strengths and weaknesses of the design. Does it work? What would they do to improve it?

	3. Have students complete their MESA Notebook reflecting on this activity. The closure question is, “How does the greenhouse effect contribute to the success of a solar water still?” Discuss the question orally to get them thinking and have them write down their answers in their own words. 4. Make sure they draw the design on the back of their MESA Notebook and have them label evaporation, condensation, precipitation, and how/where the solar heat is trapped.
Informal Assessment	• Monitor students and check for understanding often.
Formal Assessment	• Completed MESA Notebook. • Completed solar still.
Trouble Shooting	• Make sure you have enough supplies. • 3-4 students per group is effective, any more than that and some students will get bored. • Make sure tape is secured onto the wood so that no air is released.

SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☒ Adaptation of Content	☒ Modeling	☐ Whole class
☒ Links to Background	☒ Guided practice	☒ Small groups
☒ Links to Past Learning	☐ Independent practice	☐ Partners
☒ Strategies incorporated	☒ Comprehensible input	☒ Independent

Integration of Processes	Application	Assessment
☒ Reading	☒ Hands-on	☒ Individual
☒ Writing	☒ Meaningful	☒ Group
☒ Speaking	☒ Linked to objectives	☒ Written
☒ Listening	☒ Promotes engagement	☒ Oral

Arizona Math Standards Addressed	• (none)
Arizona Science Standards Addressed	• S1C1: TSW formulate predictions, questions, and hypotheses based on observations. • SCC2: TSW develop viable solutions to a need or problem, specifically, analyzing the renewable resource water in Arizona.

Solar Water Stills

What is it?

A solar water still is a tool that condenses water from a source such as soil or plants to provide fresh, purified drinking water.

How does it work?

The solar water still functions under the general principle of the "greenhouse effect". Solar energy heats the ground by passing through a clear plastic barrier. Moisture from the soil then evaporates, rises and condenses on the underside of a clear barrier above.

Why is a solar water still important?

Solar distillation is a proven technology for water disinfection. The still has the ability to purify tainted water. In fact, it condenses pure water from just about anything. Even urine will produce clean, drinkable water.

Solar Water Stills and Survival in the Sonoran Desert:

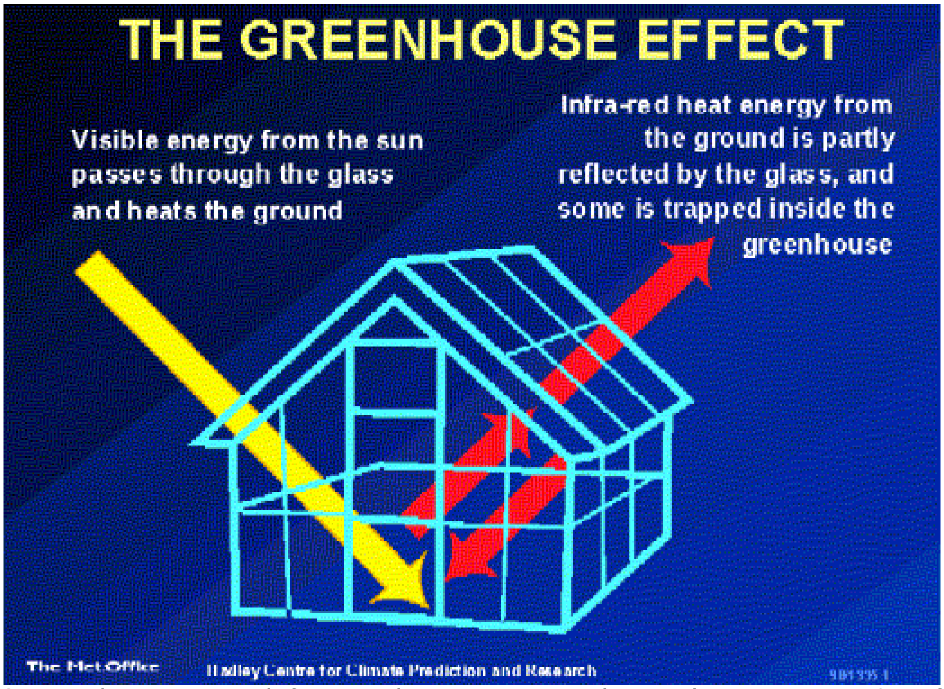
Living in Southern Arizona, many of us take advantage of the outdoor opportunities provided by the desert landscape. This includes hiking, biking, and camping. We should always take precautions to have plenty of drinking water available to prevent dehydration.

In 100 degree temperatures, the human body can survive a maximum of 3 days without water. However, the decline in physical and mental health begins long before that if our bodies are not properly hydrated.

Symptoms of dehydration include mental irrationality. Physically, depletion of the body's fluids causes the volume of blood to decrease. Blood vessels then constrict because there is not enough blood to keep them expanded. Nausea, headaches, muscle cramps and dizziness quickly follow.

The basic knowledge of how to construct a solar water still can provide a person with a small, but life saving supply of fresh drinking water.

Sources:
Jones, Gregory T. http://www.desertusa.com/mag98/dec/stories/water.html
El Paso Solar Energy Association. http://www.epsea.org/stills.htm

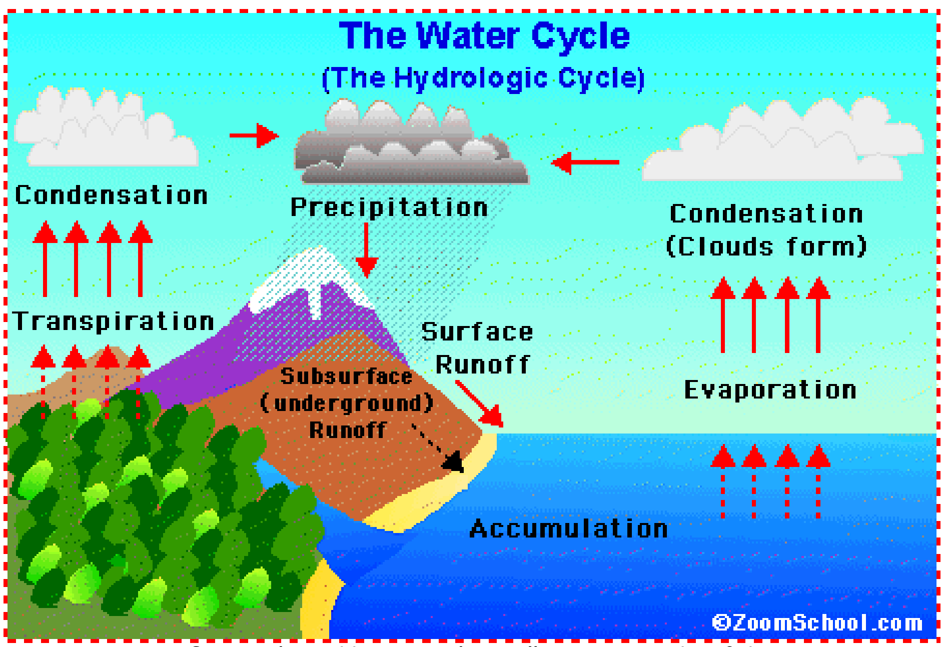


Source: http://www.defra.gov.uk/environment/climatechange/images/01.gif

The Solar Water Still uses the concept of the greenhouse effect:

1. The solar water still collects solar energy from the sun.
2. The solar energy heats up the source of water inside the still. This could be the soil or a plant.
3. The water from the soil or the plant evaporates from the heat.
4. The evaporated moisture begins to rise. As it rises, the pure water vapor leaves behind any kind of impurities and chemicals.
5. The vapor collects on the greenhouse surface. As it cools, it condenses.
6. The condensed water can be collected and is ready to drink.

What does this process sound like?



Source: http://www.enchantedlearning.com/wgifs/

Lesson Activity

Title	**Swamp Cooler (45-55 minutes)**
ID Number	HS-S-A6
Sequence and Duration	• Lead In: 15 minutes • Activity: 25-30 minutes • Closure: 5-10 minutes
Age Level	High School
Essential Question	**How does a swamp cooler work to cool air?**
Learning Objectives	• TSW relate the concept of evaporative cooling to the function of a swamp cooler. • TSW use the concept of evaporative cooling to explain why we feel hotter in higher humidity. • TSW construct and test swamp coolers using household materials.
Other Objectives	• TSW follow written instructions to construct a swamp cooler. • TSW engage in a discussion about the energy efficiency and environmental effects of swamp coolers versus air conditioners.
Key Terms	• Evaporative cooling • Endothermic process
Materials Needed	Per Class: • Scissors • Stapler • Compass (for drawing curved lines) • Spray bottles with water • Thermometer Per Team: • Small fan • Cardboard box that the fan can fit completely inside • Three strong paper towels (or enough to completely cover the back side of the box with a layer three towels thick) • Packing tape or waterproof glue (hot glue, epoxy, or gorilla glue) • Access to an electrical outlet • Handout: Swamp Cooler Instructions
Lead In	1. Ask the students what kinds of things they do to keep cool in the desert in the summer. How do they keep their bodies cool? 2. Ask the students how they keep their homes cool. How many students have central air conditioning where they live? How many students have air conditioner units? How many students use swamp coolers? 3. Ask the students to brainstorm ways these different cooling techniques are different and similar. Which do they think is the most energy efficient? Which do they think does the least damage to the environment? 4. Tell the students that air conditioners use a lot of energy to cool air by transferring heat from a cooler area to a warmer area, which is the opposite direction that heat normally flows in (heat naturally flows from warmer areas to cooler areas). Swamp coolers are more energy efficient because they cool with a natural process. Ask if any of the students know the name of this process. If not, ask them if they've heard of "*evaporative cooling*" and what they think it means. 5. Ask them if they've ever noticed how a fan keeps them cool without actually lowering the temperature of the room, or if they've noticed how it feels hotter

	during monsoon season when it's actually not. Both of these effects have to do with evaporative cooling. 6. Evaporation is an *endothermic process*, meaning that in order for a substance to evaporate, it must absorb some heat energy from its surroundings. That is, it removes some heat from the environment in order to change phase, thus evaporation results in a cooling of the substance's surroundings. This is why sweating cools us down – when our sweat evaporates, it cools our skin. A fan helps sweat evaporate more quickly, making us feel cooler. 7. Ask the students to continue this line of reasoning and see if they can deduce why we feel hotter during monsoon season. (When the air is humid, it is hard for it to absorb any more evaporated moisture. Thus evaporation slows down and it is much harder for our bodies to cool.) 8. Swamp coolers use the process of evaporative cooling to cool homes by circulating hot air through wet pads and into the home. Have the students explain how this would cool the air entering the home, using diagrams when needed. (The warm air pulled into the swamp cooler evaporates some of the water on the pad, and this endothermic evaporation removes some heat from the air, which is then blown into the home.) 9. Ask the students to describe what they know about what it's like to use a swamp cooler during monsoon season. (They don't work well at all!) Why is this? (During monsoon season the air is humid, so evaporation and thus cooling slows. Also, swamp coolers add humidity to the air when they cause water to evaporate, making it more uncomfortable for people and even harder to cool.) 10. If you have access to the internet, show students the swamp cooler animation at http://www.consumerenergycenter.org/home/heating_cooling/evaporative.html. (There is additional interesting information here as well.) 11. Tell the students that today they will be building their own mini evaporative coolers and testing them to see how well they work.
Activity	1. Break students into groups of three to four and hand out the supplies and instructions. 2. Give the students 20-25 minutes to construct their swamp coolers. 3. When students are ready, pass out water spray bottles for groups to start soaking their paper towels. Warn them not to saturate the towels to the point of falling apart! 4. Take a reading of the room's temperature with the thermometer while students are working. Record this temperature on the board. 5. When all the swamp coolers are ready, turn them all on and leave them on until the end of class. Have students record this start time. 6. Engage in another activity until the end of class (e.g. a math puzzle, review of MESA calendar or MESA Day book, preview of upcoming activities, etc.).
Closure	1. Have the students discuss ways they might improve their swamp coolers. 2. Have students discuss the pros and cons of installing a swamp cooler in one's home (be sure to mention swamp coolers' consumption of valuable water in the desert environment, if it does not come up). 3. Review the summary question with the students: *How does a swamp cooler work to cool air?* 4. When there are only 5 minutes of class remaining, take a final reading of the room's temperature and record this on the board. Have the students figure out how much the temperature changed in how much time. 5. Are the students surprised by their swamp coolers' efficiency? Did they expect them to cool the room more or less?
Informal Assessment	• Monitor students' participation in discussions. • Monitor students' participation in the activity. • Monitor students' understanding of evaporative cooling.

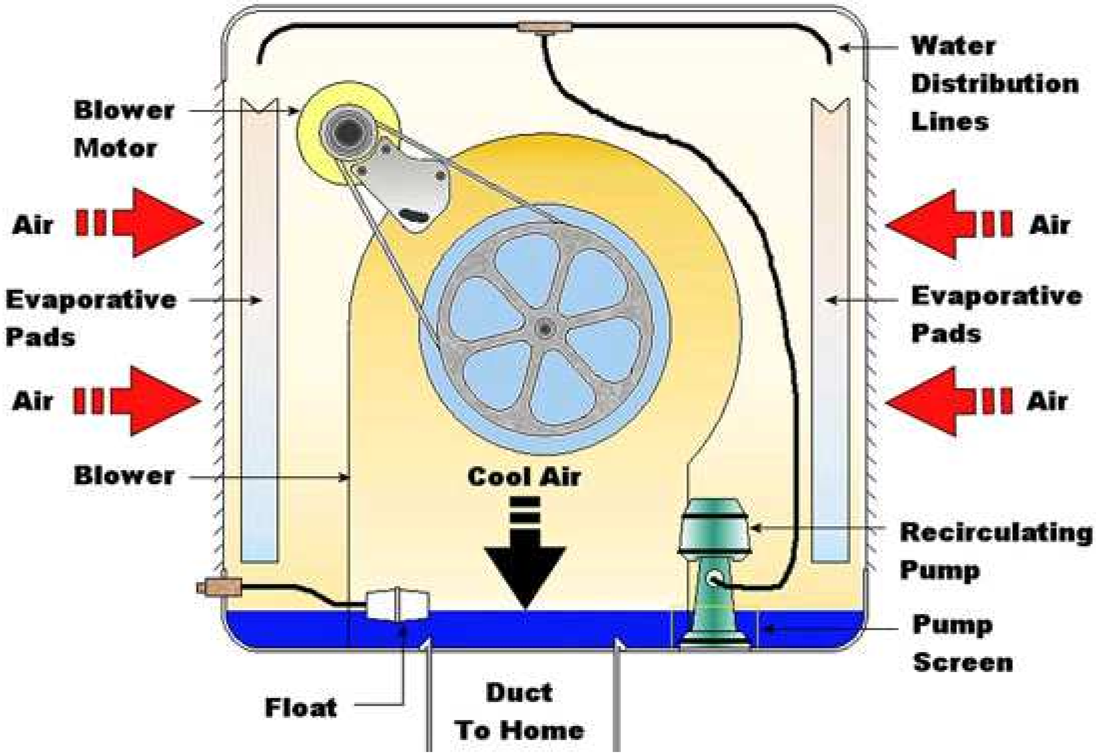
Formal Assessment	• Completed swamp coolers.
Trouble Shooting	• Have students bring in small fans from home and solicit boxes from grocery stores and the cafeteria in order to keep costs low. • A surge protector or two would be useful for allowing all the students to plug their fan cords into just one or two outlets.
Extension	• See the TeachEngineering lesson plan (citation below) for math extensions involving temperature and relative humidity as well as a formula for rating the "strength" of a swamp cooler based on the size of the space it needs to cool.
Citation	• Microsoft Corporation. (2004). "Swamp Cooler." From TeachEngineering - Resources for K-12. http://teachengineering.org

SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☐ Adaptation of Content	☐ Modeling	☐ Whole class
☒ Links to Background	☒ Guided practice	☒ Small groups
☒ Links to Past Learning	☐ Independent practice	☐ Partners
☐ Strategies incorporated	☒ Comprehensible input	☐ Independent
Integration of Processes	**Application**	**Assessment**
☒ Reading	☒ Hands-on	☐ Individual
☐ Writing	☒ Meaningful	☒ Group
☒ Speaking	☒ Linked to objectives	☐ Written
☒ Listening	☒ Promotes engagement	☒ Oral

Arizona Math Standards Addressed	(none)
Arizona Science Standards Addressed	• S1C2: TSW design and conduct controlled investigations. • S5C3: TSW understand ways that energy is conserved, stored, and transferred.

Swamp Cooler Instructions



1. Cut out the bottom of your cardboard box, leaving a rim (about 1-inch [2.5 cm] thick) around the edge. This becomes the back of the cooler. See Figure 2.

Figure 2. Back of the cooler.
Copyright © 2007 Landon B. Gennetten, ITL Program, College of Engineering, University of Colorado at Boulder.

2. Tear off three sheets of paper towels large enough to span the box floor. Staple them together to create one thick paper towel sheet.

3. Glue or staple the paper towel sheet to the inside rim of the box floor (see Figure 3).

Figure 3. (left) Lay the paper towel sheet in the bottom of the cooler box, attaching it to the box bottom rims on four sides (right).
Copyright © 2007 Landon B. Gennetten, ITL Program, College of Engineering, University of Colorado at Boulder.

4. Insert a small electric fan into the box with the front of the fan facing the top of the box. Then stand the box on its side. See Figure 4.

5. Use a pencil to mark cut lines on the box flaps to make it clear what cardboard to remove from the front of the box so as to not block air flow to/from the fan. For round fans, use a compass to draw cut lines that result in a neat circle shape (see Figure 4).

Figure 4. (left) Place the fan inside the cooler casing, facing away from the paper towel side. (right) Use a compass with the point placed on the center of the fan to draw box flap cut lines at the outer fan edge.
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6. Cut out the marked areas on the box flaps (see Figure 5).

7. Tape or glue the flaps down so that they form a seal around the fan. Use packing tape to seal up any other gaps in the cardboard casing so that air may only enter from the back (see Figure 5).

Figure 5. (left) Cardboard cut along marked lines. (right) Flaps attached to one another and sealed, closing off the front of the cooler.

8. Cut a flap on the top or the side of the box to permit access to the fan control (see Figure 6). Make sure you are able to close the flap again.

Figure 6. Make a closeable flap on the box casing to provide access to fan controls.

MESA Mathematics Engineering Science Achievement

Lesson Activity

Title	**Toxicology (55-75 minutes)**
ID Number	HS-S-A7
Sequence and Duration	• Lead In: 20-25 minutes • Activity: 30-40 minutes • Closure: 5-10 minutes
Age Level	High School
Essential Question	**How do chemicals affect us?**
Learning Objectives	• TSW be able state that all matter is a chemical or combination of chemicals. • TSW acknowledge that chemicals can be manmade or natural, and that either can be toxic at a large enough dose. • TSW describe the dose-response relationship. • TSW explain how individual susceptibility affects one's response to a dose. • TSW analyze variability in threshold limit across the class. • TSW apply the concept of threshold limit to a discussion of water quality.
Other Objectives	• TSW follow written instructions to conduct three experiments. • TSW communicate with their group by contributing their vocal input. • TSW collect written data to create a visual picture of their experimental results. • TSW write their responses to reflection questions for each activity. • TSW contribute to a group discussion about chemicals, toxins, and variability in individual response to toxins.
Key Terms	• Chemical • Toxicity • Dose • Response • Toxicology • Threshold limit • Individual susceptibility
Materials Needed	Preparation (all chemicals necessary for preparing Stations materials): • Scale • Metric measuring cups • Stirring sticks or spoons • Tap water • 7.5 grams salt ($NaCl$) • 2-3 L distilled water • 50-75 mL sodium hydroxide (0.1 N $NaOH$) • 75-100 mg Bromophenol blue (BPB) • 20 mL pH 10 buffer • 20-40 mL Hydrochloric acid (0.1 N HCl) • 5-10 mL Hydrochloric acid (0.3 N HCl) Lead In Demonstrations: • 4 large beakers or other clear containers, all the same size • 4 pieces of blank white paper • 3 stirring sticks or spoons • Water (tap is fine) • Food coloring Station 1 – Threshold Limit:

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- 5 beakers or other containers, to hold salt solutions
- Salt solutions: 1000 ppm, 2000 ppm, 3000 ppm, 4000 ppm, & 5000 ppm (see preparation)
- Eye dropper
- Threshold Limit Instructions
- Threshold Limit Bar Chart

Station 2 – Dose-Response Relationship:

- 3 beakers or other clear containers: 1 large for buffer solution, 1 small for 0.1 N HCl, 1 large for student-prepared solutions
- Eye dropper
- Metric measuring cup
- Stirring stick or spoon
- Buffer solution (see preparation)
- 0.1 N HCl
- Waste container
- Gloves and goggles
- Dose-Response Relationship Instructions
- Handout: Dose-Response Relationship Data Sheet (1 per student)
- Soap and paper towels

Station 3 – Individual Susceptibility:

- Large beakers or other containers filled with solution (see preparation)
- Clear plastic cups (4 per group)
- BPB solution (see preparation)
- Eye dropper
- Stirring sticks or spoons
- Waste container
- Gloves and goggles
- Individual Susceptibility Instructions
- Soap and paper towels

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Preparation

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1. <u>Lead In Demonstrations</u>: Select 4 beakers of all the same size. Place a sheet of blank white paper behind each beaker to use as a backdrop, so that it will be easier for students to distinguish difference in shade when the mixtures are complete (paper can also be taped in place). Fill them with water: three of them 3/4 full, and the last one 1/4 full.
2. <u>Station 1</u>: Threshold Limit
   - Label each beaker ("1000 ppm", "2000 ppm", etc.) ahead of time so you will know how much salt to add to each.
   - **Solutions:** The "ppm" in the solution refers to "parts per million"; for instance, for 1000 ppm salt solution, there are (approximately) 1000 parts of salt for every 1 million parts of water, by weight. To prepare the solutions, fill each beaker with 500 mL of water. Add ½ gram salt to the 1000 ppm solution, 1 gram salt to the 2000 ppm solution, 1.5 grams to the 3000 ppm solution, 2 grams to the 4000 ppm solution, and 2.5 grams to the 5000 ppm solution. Be precise with all measurements. Stir until the salt is completely dissolved. (Smaller quantities of solution can be prepared, so long as the ratios are maintained.)
   - Place the 5 beakers and other Station 1 supplies into the area designated for Station 1.
3. <u>Station 2</u>: Dose-Response Relationship
   - Label the beakers: one large beaker as "Organism" to hold students' solutions (empty until student use), one small beaker as "Toxin" to hold the hydrochloric acid, and one large beaker labeled as "Body Fluid" to hold the buffer solution described below. You will also need an additional small container to hold the BPB solution below.

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	o **Buffer Solution** (amount per group; double and triple as needed)**:** 100 mL distilled water, 15 drops **BPB solution** (see below), 3 drops pH 10 buffer. Combine until completely dissolved. o **BPB Solution** (may need to double; will also need for Station 3): 25 mL 0.1 N NaOH, 50 mg bromophenol blue. o Place the three beakers and other Station 2 supplies into the area designated for Station 2. 4. <u>Station 3</u>: Individual Susceptibility o Label four beakers as "Body Fluid A", "Body Fluid B", etc. o **Solutions:** Fill all four beakers with distilled water. Add several drops of 0.3 HCl into one of them and stir until completely dissolved. Three of the "solutions" will simply be water. o Take the beaker of **BPB solution**, prepared above, and label it "Potential Toxin." o Place all five beakers and the other Station 3 supplies into the area designated for Station 3.
Lead In	1. Ask the students what they think of when they hear the word "chemical." What is a chemical? Solicit students' ideas without judgment. Ask students to suggest things that are chemicals or made of chemicals, and list their ideas on the board. (They will probably suggest synthetic, mostly toxic substances such as pesticides.) 2. When the students have exhausted their ideas, say you'd like to add a few substances to the list. If these have not already been suggested by the students, add substances such as gold, water, salt, air, corn, cotton, steel, etc. 3. Ask the students to comment on this list. Are they surprised that things like water and gold are chemicals, and that things like corn, cotton and steel are made of chemicals? Can they conclude that all chemicals are manmade? Are all chemicals bad/toxic? Are all chemicals liquid/solid/gas? 4. Ask the students to revisit their definitions of "chemical" and come up with a new one that is inclusive of the examples listed on the board. [A chemical is any matter with a defined molecular composition; that is, anything made of the same type of molecule, such as gold, water, salt, hydrochloric acid, methane, sugar, etc.] Things that are not pure substances made of just one kind of molecule, like crackers, circuit boards, cotton/rayon blend cloth, etc., are just combinations of different chemicals. In summary, ask the students what things are chemicals or made of chemicals? [Everything, or more specifically, everything that is made of matter.] 5. Tell the students our bodies rely upon the chemicals in the food we eat, the air we breathe, and the water we drink to fuel the ongoing chemical reactions that keep us alive. These chemicals, in moderation, are beneficial to our health; however, toxic substances may contaminate the beneficial chemicals that we take into our bodies. Ask the students if they are ever concerned about the *toxicity*, or ability to cause damage, of the chemicals they take into their bodies. 6. Tell the students that all chemicals, both manmade and natural, *can* be toxic if they are used carelessly or abused (even food and water!). The *response* to exposure to a chemical varies by species, by the individual, by chemical, and by the type of exposure, but generally speaking the greater the *dose*, or amount of chemical taken into the body, the greater the response. Set up the three three-quarters full beakers in a location where all the students can see them. Tell the students that our bodies are about 70% water, which is about 3/4; each of these beakers represents a human body. Ask for three student volunteers to stir the substances while you put 1 drop of food coloring in one beaker, 3 drops in another, and 5 drops in the last. These represent different doses of the same chemical. At what dosage do the students begin to see a

	change in the individual's "body"? This dosage represents the *threshold limit*, the point at which the body begins to exhibit a *response* to the chemical. 7. Ask the students to brainstorm reasons why one person might be more *susceptible* (sensitive, or less resistant) to a chemical than another person. (Different individuals may be more susceptible due to their specific characteristics, such as their body chemistry, weight and size, or because of medications or medical conditions.) Take out the beaker that is filled 1/4 of the way and tell the students that it represents the body of a small child. Put 5 drops of food coloring into this beaker and stir; place it side by side with the "adult" beaker that had 5 drops and ask the students to comment on which individual would likely have a more adverse response to this dose. 8. Tell the students that t*oxicology* is the study of the effects of toxic substances on living organisms. Toxicologists work to determine how chemicals affect our bodies, and how much of a chemical you can be exposed to before you start to experience harmful effects. In today's activity, they will learn more about the concepts of *threshold limit*, *dose-response relationship*, and *individual susceptibility* to toxic substances.
Activity	1. Draw students' attention to the three stations set up around the room. Tell them they will work in groups to do each of the activities in turn. 2. Briefly summarize the instructions for each station and ensure that students know what they will be doing. Tell them to work efficiently because they will only have 10 minutes at each station. 3. Divide students into 3 groups and set the groups up at the stations. Give the students 10 minutes at each station, then have them rotate. Repeat this process until all groups have completed the activities at every station.
Closure	1. Share the graph of the whole class' data from Station 1 and discuss the distribution of threshold limits. What does this tell the students about the possibility that other chemicals exist in their water supply? Would they know if there were? How could they find out for sure? 2. Ask one student or group to share their results from Station 2. How large did the dose have to be before the organism began to exhibit a response? How does this relate to the concept covered at Station 1? What happened to the organism after this point? 3. Ask one student or group to share their results from Station 3. What happened when this group of individuals was exposed to the toxin? What might be some reasons why one individual reacted differently from the others? 4. Ask the students if they will think the same way when they hear the word "chemical" as they did before today. Will they be more aware of potential dangers in their food, water and air supplies? Will they be more able to critically assess media reports of chemical threats? 5. In their MESA Notebooks, have students respond to the summary question, *How do chemicals affect us?*
Informal Assessment	• Monitor students for participation at stations. • Monitor students for participation in discussions.
Formal Assessment	• Completed data sheets. • Completed reflection questions. • Completed MESA Notebook.
Trouble Shooting	• Obtain chemicals and equipment from your school's chemistry department; all are commonly available. If your school does not possess these materials, they can be ordered from a supplier such as www.sciencestuff.com. • If you are unable to obtain the sodium hydroxide (NaOH) and hydrochloric acid (HCl), you can eliminate Stations 2 and 3 and have the students do the activity from Station 1 in small groups simultaneously. • Bromophenol blue (BPB) makes the procedures for Stations 2 and 3 simpler, but

	other pH indicators can be used instead if you don't have BPB available. • Try out the different activities ahead of time so you will know what the students will experience when they try the procedures themselves. • If you have a large group of students, you may need to have two setups of each station so two groups can be working on the same activity at the same time. Ideally there should be 2-3 students per group, and no more than 4-5. • After class, discard all chemicals safely. Consult your school's chemistry teacher and/or the material safety sheet for each chemical on how to do so.
Extension	• See the "Introduction to Toxicology Lesson Plan" below (downloadable as a PDF online) for an activity in which students monitor the effects of different chemicals on the germination of radish seeds. However, be wary that some students may find it unethical to deliberately plant seeds in compromised conditions. • Have students visit http://www.dhmo.org, particularly this page http://www.dhmo.org/truth/Dihydrogen-Monoxide.html, a satirical site on the dangers of dihydrogen monoxide (water). The page is a convincing portrayal of the way the media can put a slant on facts to make any chemical sound dangerous. Couple this with a discussion about the need to be critical about what one reads or hears about in the news and to not get caught up in scare tactics designed to boost ratings.
Citation	• Hines, Stefani. (2002). "Basic Toxicology Lab Stations." University of Arizona Southwest Environmental Health Science Center. http://coep.pharmacy.arizona.edu/curriculum/basictoxlab • "Introduction to Toxicology Lesson Plan." University of Georgia College of Agricultural and Environmental Sciences. http://apps.caes.uga.edu/sbof/main/lessonPlan/IntroToToxicology.pdf

SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☐ Adaptation of Content	☒ Modeling	☒ Whole class
☒ Links to Background	☒ Guided practice	☒ Small groups
☐ Links to Past Learning	☒ Independent practice	☐ Partners
☒ Strategies incorporated	☐ Comprehensible input	☐ Independent
Integration of Processes	**Application**	**Assessment**
☒ Reading	☒ Hands-on	☒ Individual
☒ Writing	☒ Meaningful	☒ Group
☒ Speaking	☒ Linked to objectives	☒ Written
☒ Listening	☒ Promotes engagement	☒ Oral

Arizona Math Standards Addressed	• S2C1: TSW understand and apply data collection, organization and representation to analyze and sort data.
Arizona Science Standards Addressed	• S1C2: TSW design and conduct controlled investigations. • S1C4: TSW communicate results of investigations. • S3C2: TSW analyze factors that affect human populations. • S5C4: TSW investigate relationships between reactants and products in chemical reactions.

Threshold Limit Instructions

Materials:

- Salt solutions:
  - 1000 ppm
  - 2000 ppm
  - 3000 ppm
  - 4000 ppm
  - 5000 ppm
- Eye droppers
- Threshold Limit bar chart
- Goggles

Overview: The threshold limit is the amount of chemical an organism can be exposed to before it begins to have an effect. In this activity you will determine your own sensitivity to the presence of salt in drinking water to find your personal threshold level to this chemical. Individual sensitivity varies, so the class will create a bar chart of everyone's threshold limits to compare results across the whole group.

Background Information: Each solution's salt concentration is labeled in units of ppm, which stands for "parts per million." For example, in the solution marked 1000 ppm, there are 1000 parts of salt for every 1,000,000 parts of water (by volume).

Instructions:

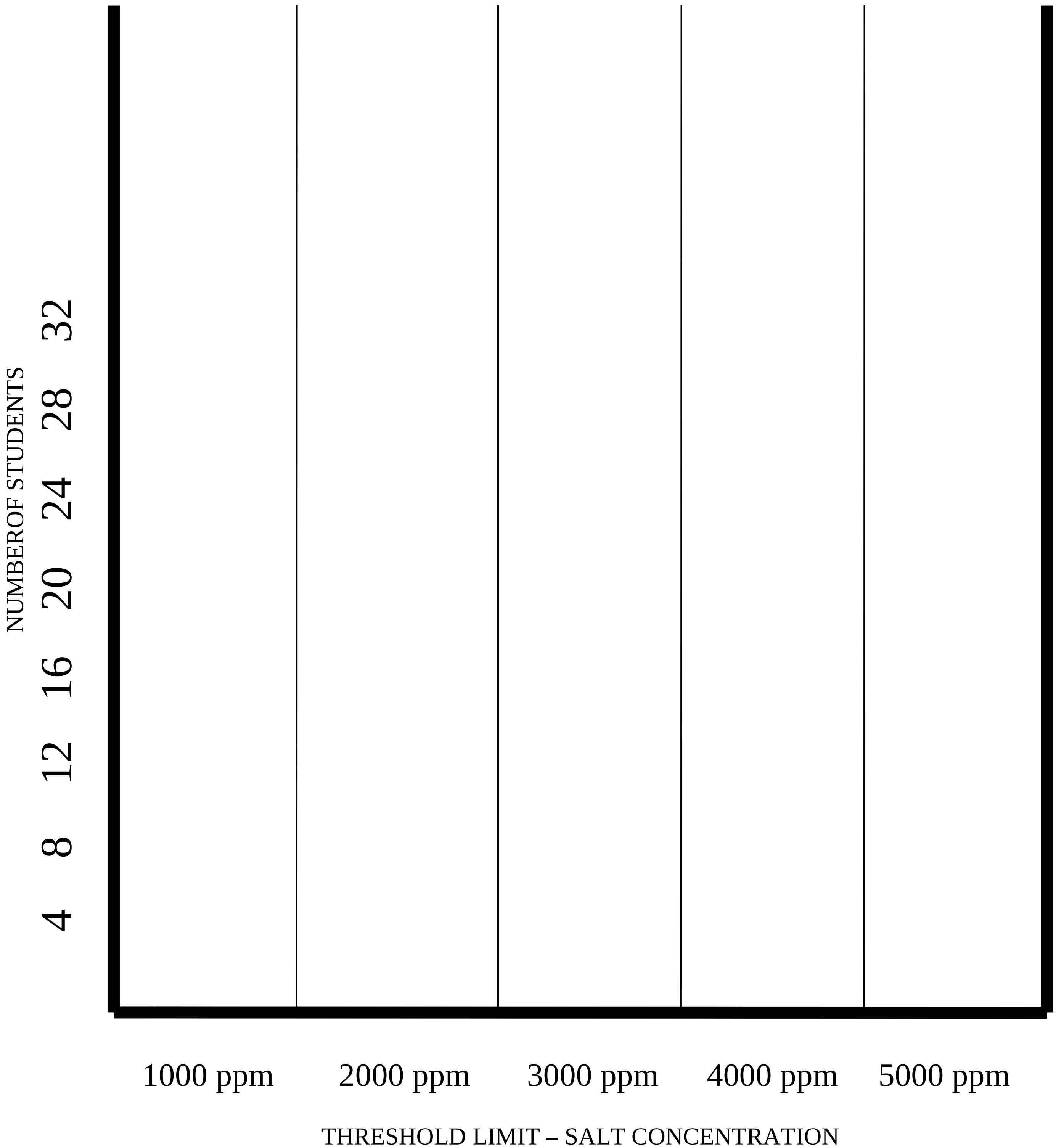
1. Put on the goggles.
2. Using the eyedropper, place 2-3 drops from the 1000 ppm solution on your tongue. Can you taste the salt?
3. Taste 2-3 drops from each solution in order from least to greatest concentration of salt.
4. Make note of the concentration of the solution in which you were first able to taste the salt.
5. Mark on the bar graph the value of the salt concentration where you were first able to taste the salt.
6. Repeat this process for each member of your group.

Reflection Questions:

1. How dependable is our sense of taste in determining whether salt is present in our drinking water?
2. If we can't taste salt, does that mean that none is present?
3. The next time you take a drink, check the label to see if there is sodium in your beverage.

MESA Mathematics Engineering Science Achievement

Threshold Limit Bar Chart



Dose-Response Relationship Instructions

Materials:
- Body Fluid beaker
- Toxin beaker
- Organism beaker
- Eye dropper
- Measuring cup
- Stirring stick
- Waste container
- Goggles and gloves
- Dose-Response Relationship data sheets

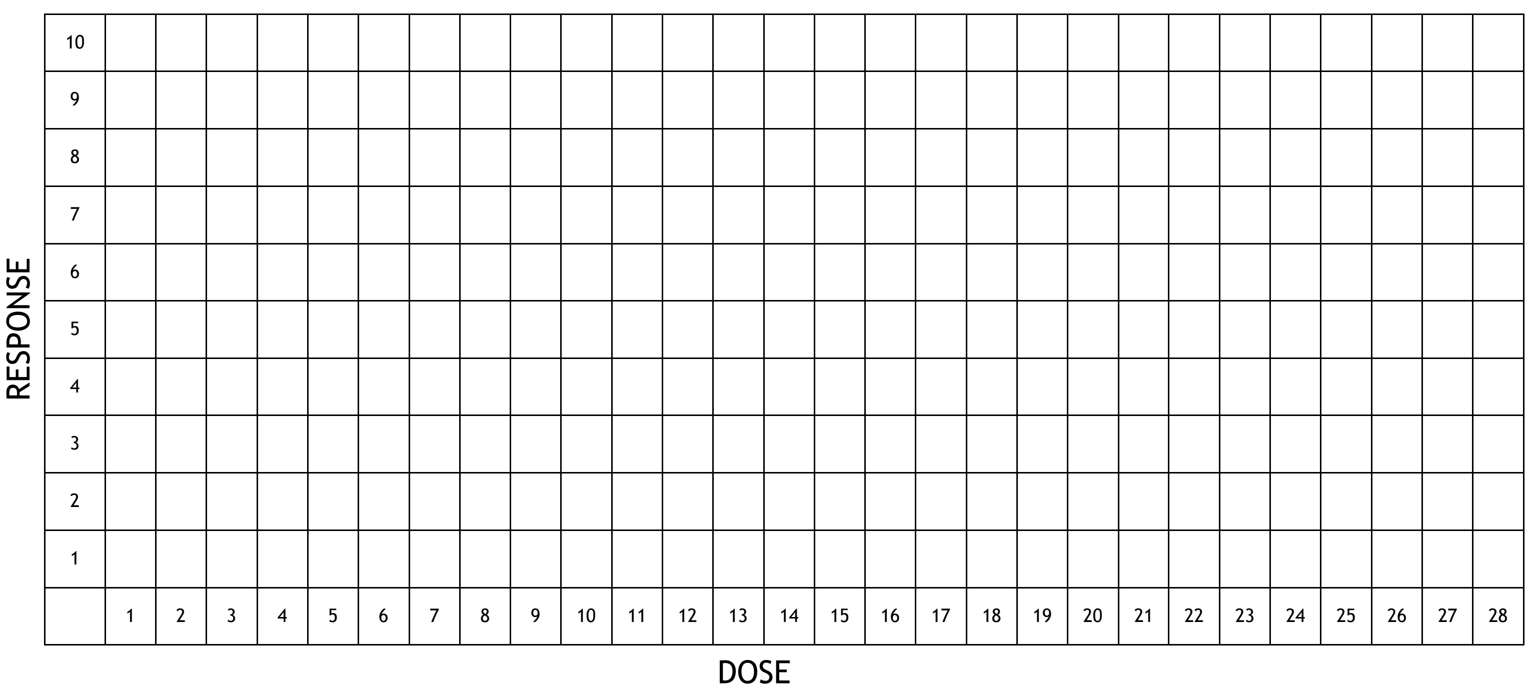
Overview: In this activity you will investigate the relationship between the dose of a toxin an organism receives and the response the organism has to the toxin. As you have learned, generally the greater the dose, the more significant the response. With the materials at this station, you will be able to visualize this relationship.

Instructions:
1. Put on the goggles and gloves.
2. Fill the Organism beaker with approximately 25 mL of the Body Fluids. This will represent the organism being exposed to the toxin. Notice the color of the organism when it has had no exposure to the toxin.
3. Add drops of the toxin one at a time, stirring after the addition of each drop. Each drop represents an additional dose of toxin.
4. After each dose and stir, record the organism's response (its color) on your Dose-Response Relationship data sheet.
5. Continue adding doses and recording responses until the organism dies (turns completely yellow).
6. Pour the dead organism into the Waste container and wash out your Organism beaker.
7. When you are finished collecting data, translate your response data into numbers. (0 = completely blue; 5 = reddish-purple; 10 = completely yellow)
8. Plot dose versus response on your data sheet.
9. Mark the threshold level on the plot: the dose just below the one where you first began to see the response.

Reflection Questions:
1. How was the organism affected by the different dosages?
2. Why was it unaffected by the dose up to the threshold level?

Dose-Response Relationship Data Sheet

DOSE (Drops)	RESPONSE (Color)	RESPONSE (Number)	DOSE (Drops)	RESPONSE (Color)	RESPONSE (Number)
1			15		
2			16		
3			17		
4			18		
5			19		
6			20		
7			21		
8			22		
9			23		
10			24		
11			25		
12			26		
13			27		
14			28		



Individual Susceptibility Instructions

Materials:
- Body Fluids A through D
- Potential Toxin
- Plastic cups
- Eye dropper
- Stirring sticks
- Waste container
- Goggles and gloves

Overview: In this activity, you will simulate the experiences of a group of people who have been exposed to a potential toxin. The body fluids in your materials belong to Individual A, Individual B, Individual C, and Individual D, all of whom were eating at a small café when a potentially dangerous cleaning fluid was spilled in the kitchen area. You will observe the effects on these four individuals in the following procedure.

Instructions:
1. Put on the goggles and gloves.
2. Pour a sample of Body Fluid A into one of the plastic cups; this will represent Individual A. Repeat this process for each of the Individuals.
3. Add three drops of the potential toxin to Individual A and stir. Repeat this process for each Individual, using a clean stirring stick for each person.
4. Observe what happens to each individual.
5. Pour the used fluids into the Waste container and wash the stirring sticks.

Reflection Questions:
1. Did every individual respond the same way to exposure to the toxin?
2. What might be some reasons why different individuals are more or less sensitive to certain chemicals than others?

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Lesson Activity

Title	**Vertebral Variation! (2 sessions, 50 minutes each)**
ID Number	HS-S-A8
Sequence and Duration	Week 1 - Introduction to Data Collection Project (35-50 minutes) • Lead In: 5-10 minutes • Activity: 20-25 minutes • Closure: 10-15 minutes Week 2 - Data Analysis (50-65 minutes) • Lead In: 5-10 minutes • Activity: 35-40 minutes • Closure: 10-15 minutes
Age Level	High School
Essential Question	**What effect does low gravity have on your height?**
Learning Objectives	• TSW reflect on ways their bodies are adapted to environmental conditions. • TSW construct a simple model of a spinal column. • TSW collect data on their heights over the course of a week. • TSW analyze the data to identify variables that correlate with greater height differences.
Other Objectives	• TSW develop a working plan with their group to develop a cooperative environment. • TSW communicate with their group by contributing their vocal input. • TSW listen to their peers discuss their findings. • TSW present their findings to the class in a poster session-style environment. • TSW contribute to group discussions about adaptations, potential research questions, and the results of their investigations.
Key Terms	• Vertebrae • Discs • High-gravity • Low-gravity • Research question
Materials Needed	<u>Week 1</u> Per Class: • Bucket of water • Tarps or tablecloths to spread over student work areas • Towels • Tape measure Per Team: • Three or more bricks or comparably-sized blocks • Two or more square sponges • Pencil and textbook (optional) Per Student: • Handout: Vertebral Variation worksheet • Handout: Vertebral Variation data sheet <u>Week 2</u> Per Class: • Ream of graph paper Per Team:

	• Large Post-It or 3' to 4' sheet of butcher paper • Markers or colored pencils • Handout: Poster Guidelines Per Student: • Vertebral Variation data sheet, filled out by students during the week
Week 1	**Introduction to Data Collection Project**
Lead In	1. Ask the students to think about the ways their bodies have adapted to life in southern Arizona. Have any of them been to a place whose conditions were completely different from what their bodies were used to (e.g. places with extreme heat or cold, high/low altitude, high/low humidity, hard/soft water, high/low sunlight, etc.)? How did their bodies react to the change? Give the students time to discuss their ideas and experiences. 2. Tell the students that just as we adapt to living in different places, we are all adapted to the conditions present here on planet Earth. Give the students a chance to talk about any Earth conditions they can think about, to which we Earthlings (both great and small!) are uniquely adapted. 3. Ask the students, if your bodies react when you just change your location on Earth, how might they react if you left the Earth altogether? Ask the students if they've ever thought about what life as an astronaut would be like. Have them imagine living in outer space in a low-gravity environment. How would the conditions be different? How might their bodies react? What changes might they experience? 4. If it has not yet been addressed, ask the students what effect they think living in space might have on their height. Do they think it would cause their height to increase, decrease, or stay the same? Why? 5. Tell the students that they will engage in a week-long data collection project that will help them answer this question.
Activity	1. Tell students that this experiment will simulate the change from a high-gravity environment to a low-gravity environment, and they will be able to measure the effect of this change on their height. They will be measuring their heights at the very beginning and very end of each day. How do these times of day relate to high-gravity and low-gravity environments? [People experience the high-gravity conditions on Earth throughout their days while they stand/sit upright, so at the end of the day students will be able to measure the cumulative effect of the environment on their heights. At night, we lie horizontally, so gravity has no effect on our heights. In the morning, students will be able to measure the effects of this simulated low-gravity environment on their heights.] 2. When do students predict they will be tallest – at the beginning or end of the day? Why? [Students will probably deduce that the high-gravity conditions on Earth compresses their bodies when they are upright, making them shorter as they go about their day. They may even put two and two together to conclude that as they sleep their bodies become uncompressed again.] Ask the students to think about what is compressing and how big of an effect on their height this might have. 3. Have the students lay out tarps or tablecloths on two or three large tables, and have all the students sit around these tables. 4. Hand out blocks or bricks and sponges to small groups of students. Pass around a bucket of water so students can soak their sponges. Show students how they will lay all the bricks their sides and place wet sponges between them. When their set up is ready, they can carefully set the whole thing on its side, so they have a stack of alternating bricks and wet sponges. What happens to the sponges when they do this? 5. Encourage the students to extend the analogy if they haven't already. Which part of this activity corresponds to a person lying down? [All the bricks and

	sponges in a row.] Which part corresponds to a person standing up? [All the bricks and sponges in a stack.] What part of the person does the setup represent? [The spinal column.] What do the bricks represent? [The vertebrae.] What do the sponges represent? [The intervertebral discs, made of cartilage.] 6. If time permits, combine groups and re-circulate the water bucket so students can build even taller "spinal columns." Have them pay close attention to what happens to the discs when the spines "stand up". [They compress due to the weight of the bricks, and the ones at the bottom compress more than the ones at the top.] How does this affect the height of the spinal column, and thus the height of the person? 7. Have students clean up their work area. 8. Tell the students that we experience this same effect when we stand upright all day; the weight of our bodies compresses our discs, especially those lower in our bodies (which feel a greater force from the weight of the body above them). Fluids squeeze out of the discs during the day, and are reabsorbed when our bodies are at rest in a horizontal position while we sleep. The question (which students will probably already be asking) is how much of an effect does this have on our heights? And how long does it take for these effects to be measurable?
Closure	1. Hand out the Vertebral Variation worksheets and data sheets to each student. Go over the instructions for making measurements and make sure students understand what to do. Have students work in pairs to practice measuring. When they have the hang of it and are getting consistent results, have them take a measurement (or average of several measurements) of their heights to use as their baseline. They should record this number on their data sheets. [Note: For consistency across the whole group, it would be best to have the students record all measurements in the same units. However, if they do not, it will be an opportunity to practice unit conversion.] 2. Go over the data sheets and answer any questions students have about what they will be recording. Make sure to remind them to make measurements first thing when they get up and every evening! They should begin taking their measurements the next morning. 3. Encourage students to think about questions they might be able to answer when they have a whole classful of data. For instance, do they think the amount of sleep a student gets will affect their change in height? Do they think the change in height will depend on students' sex, height, weight, shoe size, diet, physical activity, etc.? Record the questions that students are interested in pursuing, and/or have them write the questions in their notebooks. If there are any variables about which the class agrees would be worthwhile to record data, they can add columns to their data sheets to ensure the whole class records this information.
Week 2	**Data Analysis**
Lead In	1. Ask the students what their experience collecting a week's worth of data was like. What did they find out about their heights? Give the students time to report out on their observations in an informal discussion. 2. Have all the students pull out their data sheets and post them on a single bulletin board or wall. Point out that they now have a large collection of data across a week's time. What kinds of conclusions can they draw by just looking at the data? Does the amount of data seem overwhelming? Does it make sense to look at it this way? If not, what would be a better way of analyzing it? 3. Direct students' attention to the questions they were interested in pursuing before they began collecting data. Tell them that data doesn't make any sense until you have a question (or questions!) that you can answer with it. These questions are called *research questions*, and they are the basis for any

	research that is conducted. They define the kind of data that is collected, how it is analyzed, and the results that are reported. For this experiment, which research question directed the kind of data they collected? [How much of an effect does gravity have on their heights?, or some variant of this.] The students also came up with other potential research questions when they were thinking about this experiment last class. Now they can use these research questions, and any others they come up with, to look for patterns in the data.
Activity	1. Have students begin by analyzing their own data sheets. They will each have individual data across time that they will be to analyze for patterns. For instance, does their height change more on some days and less on others? What might be the reason(s) for this? Have the students discuss possible research questions to explore. They can graph, for instance, their change in height from evening to morning versus the length of time they spent lying down; their change in height from morning to evening versus the length of time they spent doing rigorous physical activities during the day; their change in height from morning to evening versus the length of time they spent in passive activities (like sitting at a desk or playing video games) during the day; the percent change in height (morning to evening or evening to morning) versus the estimated amount of water they drank during the day, etc. Let students explore analyzing the data according to their interests. 2. After ten to fifteen minutes, give the students time to report out their findings to the class in an informal discussion. 3. Students will also be able to compile class data, and analyze it according to their interests as well. Have students work in groups to pursue different inquiries. For instance, which students have the largest or smallest changes in height; can students come up with a hypothesis for why, and defend their hypothesis with data? How do athletic students' height changes compare to non-athletes? How do males and females compare? How do tall students and short students compare? Allow students time to investigate their questions, letting their curiosity drive their inquiries. 4. Have the students prepare their results, to present poster session-style for the whole class. Hand out the poster paper and Poster Guidelines to groups to help them prepare their posters. Give students about 10 minutes to prepare their posters.
Closure	1. When students are finished preparing their posters, give them time to briefly present their posters to the class, answering at minimum the questions posed in the Poster Guidelines. Ask follow-up questions if students' presentations are unclear or if they spark other potential inquiries. 2. Open up discussion for reflection. What did students learn from this experience? Did any groups' findings connect with each other? What did the class as a whole learn as a result of different groups' inquiries? 3. Tell the students that astronauts can "grow" up to two inches in the low-gravity conditions of space! How does this compare with the class' results?
Informal Assessment	• Monitor students for participation in discussions. • Monitor students' contributions to group work.
Formal Assessment	• Completed data sheet. • Graphs or charts of students' selected variables. • Completed poster.
Trouble Shooting	• You may want to set up a system for reminding students to collect their data every night. You could have groups of students call each other in the mornings and evenings, or set up a telephone tree with the whole class. You could even try tying a piece of string to students' fingers for them to wear all week, to remind them to make their measurements! • Students may get so excited about pursuing connections between variables that

	they overemphasize positive results and minimize negative results. If this happens, have students think about what they would expect to see as evidence of a relationship between variables, and how much data is enough to conclude that a relationship exists. You may also want to point out that showing that there is no apparent relationship between variables is just as interesting as finding that there is one.
Extension	• On a weekend day, have students record data at intervals until their morning height reaches their average end-of-day height. How long does it take for their heights to return to "normal"? Have them predict how long this will take and justify their answers. (For instance, does the behavior of the sponges give them a hint? How similar do they expect cartilaginous discs to be to wet sponges?) • For background information about spines and intervertebral discs, see the online resources associated with the Bon-e Voyage lesson at the website below. • For an additional data set, you can collect height data on yourself, and maybe ask other teachers or parents to do the same. Even with just your data, the students will be able to compare the data of a student and an adult. Are there any differences? Are these differences attributable to age, or there are other variables that could have an influence (e.g. weight, lifestyle, diet)? • If you have the background, you may want to expose the students to more sophisticated statistical analyses such as Chi squared, or bring in a math expert to show the students how to conduct these analyses on their data.
Citation	• Activity adapted from: Defying Gravity. (2005). Bon-e Voyage: Laboratory Session. http://www.defyinggravity.net/bone.htm. • Poster Guidelines worksheet adapted from test at http://www.pitt.edu/~etbell/upj-space/PosterGuide.htm.

SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☐ Adaptation of Content	☐ Modeling	☒ Whole class
☒ Links to Background	☒ Guided practice	☒ Small groups
☒ Links to Past Learning	☒ Independent practice	☒ Partners
☐ Strategies incorporated	☒ Comprehensible input	☒ Independent
Integration of Processes	**Application**	**Assessment**
☐ Reading	☒ Hands-on	☒ Individual
☒ Writing	☒ Meaningful	☒ Group
☒ Speaking	☒ Linked to objectives	☒ Written
☒ Listening	☒ Promotes engagement	☒ Oral

Arizona Math Standards Addressed	• S2C1: TSW understand and apply data collection, organization and representation to analyze and sort data.
Arizona Science Standards Addressed	• S1C1: TSW formulate predictions, questions, or hypotheses based on observations. • S1C2: TSW design and conduct controlled investigations. • S1C3: TSW evaluate experimental design, analyze data to explain results and propose further investigations, and design models. • S1C4: TSW communicate results of investigations.

Vertebral Variation!
Instructions

Materials:
A hardcover book
Pencil
Tape measure or ruler

Directions:
1. Choose a wall or doorframe where you can make your measurement, preferably on a floor with no carpet. At home, you should make all measurements in the same location.
2. Take off your shoes and stand with your back and heels straight against the wall or doorframe.
3. Place one edge of the book against the wall over your head. Slide the book down the wall until it rests on top of your head. Adjust your head until it feels like the book is lying flat against the top of your head. You are creating a right angle, which is important for obtaining reliable measurements.
4. Holding the book tightly against the wall, carefully move away and turn around so you can make the position of the bottom of the book lightly with your pencil.
5. Measure the distance from the floor to the mark and record this height on your data sheet. Your first measurement is your **baseline measurement**: the standard measurement to which you'll compare all other measurements.
6. Erase the mark.
7. Repeat this procedure at the end of every day just before going to sleep, and as soon as you wake up every morning. Record all your measurements on your data sheet.
8. At the end of every day, record your estimates for the amount of water you drank and the amount of physical activity you engaged in that day.
9. Every morning, record your calculation of the number of minutes you spent lying down.
10. Record any other important data as agreed upon by your class in the blank columns.

Vertebral Variation!
Data Sheet

Baseline Height: ________________________________

Day	Time	Height	Time spent lying down during the night	How much water did you drink today?	How much physical activity did you do today?		
Day 1	Morning			-----	-----		
	Evening		-----				
Day 2	Morning			-----	-----		
	Evening		-----				
Day 3	Morning			-----	-----		
	Evening		-----				
Day 4	Morning			-----	-----		
	Evening		-----				
Day 5	Morning			-----	-----		
	Evening		-----				
Day 6	Morning			-----	-----		
	Evening		-----				
Day 7	Morning			-----	-----		
	Evening		-----				

Average morning height: ________________________________

Average evening height: ________________________________

MESA Mathematics Engineering Science Achievement

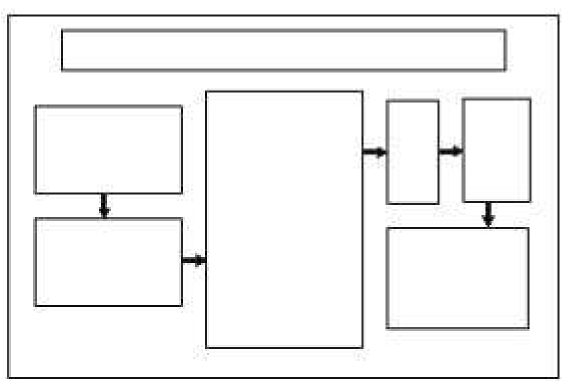
Poster Guidelines

A poster is a graphical approach to presenting research. It allows researchers to show the results of their analyses and present and defend their conclusions in a very visual format. With your group members, design a poster that communicates the results of the analysis (or analyses) you conducted with the class' height data.

General guidelines for designing a poster are provided below.

Guidelines:

- Limit the text to about one-fourth of the poster space, and use visuals (graphs, photographs, drawings, schematics, etc.) to tell your story.
- A banner displaying your poster title and names should be positioned at top-center of the board.
- Make it obvious to the viewer in which order to view the poster. The poster generally should read from left to right, and top to bottom.
- Leave some open space in the design. An open layout is less tiring to the eye and mind.
- Design your poster to creatively answer the following questions:
  - Research question(s): What were you trying to find out?
  - Data: What kind(s) of data did you analyze?
  - Analysis: What did you do with the data?
  - Results: What did your analysis show?
  - Uncertainty: What error might be present in your data or analysis?
  - Next steps: After seeing the results of your investigation, what might you want to investigate next?



Sample poster layout

Lesson Activity

Title	**On-Site Design Challenge: Watercraft (60-80 Minutes)**
ID Number	HS-E-OS2
Sequence and Duration	• Lead In: 10-15 Minutes • Activity: 40-50 Minutes • Closure: 10-15 Minutes
Age Level	High School
Essential Question	**What have I learned about on-site engineering challenges?**
Learning Objectives	• TSW design and build a watercraft to specs. • TSW reflect on and evaluate their approach to the problem and the strategies they used to address it. • TSW evaluate their comfort level with on-site design challenges. • TSW continue brainstorming strategies to help them be successful at on-site design challenges in the future.
Other Objectives	• TSW develop a working plan with their group to develop a cooperative environment. • TSW communicate with their group by contributing their vocal input. • TSW develop critical reading skills by finding relevant information in given materials. • TSW listen to their peers discuss their approaches to the problem. • TSW contribute to a group discussion about being successful in on-site design challenges.
Key Terms	• On-site design challenge • Approach • Strategy
Materials Needed	Per Class: • Body of water (e.g. large sink, kiddy pool, large basin) • Weights (e.g. sinkers, magnets, 1-gram masses) • On-Site Engineering Design Data Collection Sheet Per Group: 1. Handout: On-Site Engineering Design specs 2. 15 straws 3. 2 12″x10 ¾” sheets of aluminum foil 4. 1 Styrofoam plate 5. 24” clear tape 6. 10 pins or tacks 7. 4 paper clips 8. 2 pairs of scissors 9. 1 ruler 10. Other materials of your choice, such as cardboard, balsa wood, duct tape, etc., ensuring that all teams have identical supplies
Lead In	1. Remind the students that for the on-site challenge, teams will receive their mission and the specs only when they arrive “on site”, and they must design, build and test their structure within the given time period and with the given materials. So they will essentially be “designing under pressure”, relying on their ability to address the mission quickly by drawing on their prior knowledge and being strategic about their decisions and process. 2. Ask students to think about when they last practiced with an on-site design challenge. Allow time for discussion, using prompts such as the following:

	What did they learn from the on-site challenge? What kinds of skills and knowledge did they need to use to be successful with it? What did they think they might do differently next time to help them do better? 3. If they are available, have students review what they wrote in their MESA Notebooks for that challenge, in response to the question: "How should I approach an on-site engineering challenge?" 4. Tell students they will be doing a practice on-site design challenge today. Once they have their materials, they will have exactly 30 minutes to complete the mission. Remind them to consider the skills and strategies they discussed that will help them to be successful.
Activity	1. Separate students into groups of two and hand out the supplies. When all supplies have been distributed, hand out the specs face down, instructing students not to turn them over until you tell them to. Tell them they may raise their hands if they need clarification about the rules, but to think of you as the judge, not their advisor. 2. Call out "begin!" and start the 30 minute count-down. 3. After 30 minutes are up, call time and have students clean up their areas and bring their watercrafts and remaining tape to the testing area. Measure the pieces of tape and record this information on the Data Collection Sheet. 4. Begin the competition. For each watercraft, you will add weights slowly until the craft begins to sink. Be sure to define what "sink" means before you begin, e.g. the point at which the craft begins to take on water. Set a standard rate for adding weights as well, such as adding one sinker every three seconds (to allow the crafts to "settle" under the new weight). 5. Record final weights on the Data Collection Sheet. Once all crafts have been tested, declare the team whose craft carried the greatest weight to be the winners. In the case of a tie, the craft that used the *least* amount of tape is the winner. 6. Clean up the materials and testing area and have students return to their seats.
Closure	1. Give students time to reflect on their approaches and strategies with this challenge, first with their groups and then reporting out to the whole class. Were they better prepared to approach this challenge after trying an on-site challenge once before? What did they learn from the first challenge that helped them be successful with this one? What did they do differently? What did they do similarly? 2. Ask students what knowledge they used for this challenge, e.g. knowledge of what makes things float; knowledge of surface area; knowledge of team work strategies; knowledge of the engineering process, etc. 3. Ask students to reflect on their level of anxiety when approaching this challenge. Did trying out two on-site challenges help them feel more comfortable about doing on-site design in the future? 4. In their MESA Notebooks, have students respond to the following conclusion question: *What have I learned about on-site engineering challenges?* They can use the remaining time to complete their Notebooks or finish them as homework.
Informal Assessment	• Monitor students' participation in the activity. • Monitor students' participation in the discussion.
Formal Assessment	• Completed MESA Notebook. • Completed watercraft.
Trouble Shooting	• Prior to this lesson, set up your testing area by filling your pool or sink several inches deep. • If your weights are different from each other, establish the order in which you will be adding them so it is the same for each group of students.

	• Separate out each team's materials and place them in baggies or boxes prior to students' arrival to class. • What materials the groups receive to create their designs is not as important as the fact that all groups have the same materials. Feel free to improvise with materials you have on hand.

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☐ Links to Background
- ☒ Links to Past Learning
- ☒ Strategies incorporated

Scaffolding
- ☐ Modeling
- ☐ Guided practice
- ☒ Independent practice
- ☐ Comprehensible input

Grouping Options
- ☒ Whole class
- ☒ Small groups
- ☐ Partners
- ☐ Independent

Integration of Processes
- ☒ Reading
- ☐ Writing
- ☒ Speaking
- ☒ Listening

Application
- ☒ Hands-on
- ☒ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☐ Individual
- ☒ Group
- ☐ Written
- ☒ Oral

Arizona Math Standards Addressed	(none)
Arizona Science Standards Addressed	• S3C2: TSW develop viable solutions to a need or problem.

ON-SITE ENGINEERING DESIGN
High School Level
Watercraft

OBJECTIVE:

Your engineering team has been hired to design and build a watercraft that will carry the greatest weight before sinking. The team shall compete with other teams in a head-to-head competition.

MATERIALS:

15 – Straws
2 – 12″ x 10 ¾″ sheets of aluminum foil
1 – Styrofoam plate
24 – inches clear tape
10 – pins or tacks
4 – paper clips

Other materials available for use but not included in the design:

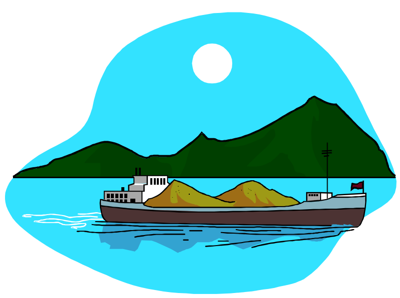
Scissors Ruler Pencil Paper

RESTRICTIONS and INSTRUCTIONS:

1. Design and build a watercraft that can hold the maximum amount of weight before sinking.
2. A judge will add weight to the watercraft until it begins to sink.
3. No assistance and no physical contact can be made with your craft once launched.

SCORING:

- When the watercraft begins to take on water or fall apart, the total weight the craft carried to that point will be recorded.
- In the event of a tie, the team that used the least amount of tape will be declared the winner.



ON-SITE ENGINEERING DESIGN
High School Level
Watercraft

Data Collection Sheet

Group Members	Remaining Tape (in)	Total Weight Carried (g)

Skill Set 2:
Math and Math Puzzles

MESA Mathematics Engineering Science Achievement

Lesson Activity

Title	**Math Puzzle: A Quiz**
ID Number	HS-M-P1
Duration	10 minutes
Age Level	High School
Learning Objectives	• TSW solve a logical mathematical word problem using grade appropriate problem-solving strategies. • TSW solve a multi-step word problem by applying various numerical operations.
Other Objectives	• TSW participate in a group discussion about problem solving.
Materials Needed	• Handout: A Quiz
Activity	1. Pass out puzzle. 2. Tell students they have 5 minutes to try to solve the puzzle and remind them to sign in for attendance. 3. After 5 minutes, discuss math puzzle solutions with class.
Informal Assessment	• Monitor students to check for engagement. • Monitor students to check for participation.
Formal Assessment	• Solution to problem.

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☐ Links to Background
- ☐ Links to Past Learning
- ☒ Strategies incorporated

Scaffolding
- ☐ Modeling
- ☐ Guided practice
- ☒ Independent practice
- ☐ Comprehensible input

Grouping Options
- ☐ Whole class
- ☐ Small groups
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Integration of Processes
- ☒ Reading
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Application
- ☐ Hands-on
- ☐ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☒ Individual
- ☐ Group
- ☒ Written
- ☒ Oral

Arizona Math Standards Addressed	• S5C1: TSW use reasoning to solve mathematical problems in contextual situations.

A Quiz...

You are a participant in a quiz. The quizmaster shows you three closed doors. He tells you that behind one of these doors there is a prize, and behind the other two doors there's nothing. You select one of the doors, but before you open it the quizmaster deliberately picks out a remaining empty door and shows that there is nothing behind it. The quizmaster offers you a chance to switch doors with the remaining closed door.

The Question: Should you stick to your choice?

A Quiz...

You are a participant in a quiz. The quizmaster shows you three closed doors. He tells you that behind one of these doors there is a prize, and behind the other two doors there's nothing. You select one of the doors, but before you open it the quizmaster deliberately picks out a remaining empty door and shows that there is nothing behind it. The quizmaster offers you a chance to switch doors with the remaining closed door.

The Question: Should you stick to your choice?

In this puzzle, you should *not* use your intuition, but let your common sense do the job: the chance that your first choice for a door was correct is 1/3; therefore, the chance that your first choice was wrong is 2/3.

So the chance that one of the remaining doors is correct is also 2/3. With the help of the quizmaster (who knows which door hides the price, and thus is able to open one of the remaining doors which does not contain the price), you get to know which one of the remaining doors is incorrect. Now you also know which one of the remaining doors could be correct with a chance of 2/3!

Conclusion: You should switch doors, which doubles your chances!...

For the disbelieving few: consider the situation where there are 1000 doors instead of 3. After you have chosen one door, the quizmaster points out 998 of the 999 doors that are left, that do not contain the prize. Should you switch to the other remaining door? Of course! If, out of 999 doors, the quizmaster (deliberately) leaves that door, chances are very large (999/1000) that it is the right one!

For the still disbelieving few: write a computer program which simulates this quiz thousands of times, and you will see that the chances are double if you switch doors!...

MESA Mathematics Engineering Science Achievement

Lesson Activity

Title	**Barbie Bungee (75-80 minutes)**
ID Number	HS-M-A1
Sequence and Duration	• Lead In (15-20 minutes) • Activity (45-50 minutes) • Closure (10 minutes)
Age Level	High School
Essential Question	**What is the maximum number of rubber bands that will allow Barbie to safely jump from a height of 400 cm?**
Learning Objectives	• TSW collect data on the distance Barbie falls. • TSW graph the distance versus the number of rubber bands used to make the bungee cord. • TSW generate a line of best fit to determine the relationship between the distance and the number of rubber bands. • TSW calculate the slope and find the equation for their lines of best fit. • TSW extrapolate from their lines of best fit the number of rubber bands needed to drop Barbie safely from 400 cm.
Other Objectives	• TSW communicate with their group by contributing their vocal input. • TSW write down and graph data. • TSW contribute to a group discussion about extrapolating from a small set of data.
Key Terms	• Scatter plot • Linear relationship • Line of best fit • Extrapolate
Materials Needed	Per Class: • Extra bags of identical rubber bands in case of breakage, loss, etc., and for building the final bungee cords Per Team: • 15-20 rubber bands, all alike, handing out 12 to start • 1 Barbie doll or doll/action figure of a similar size (all teams should have figures of identical or similar masses) • 6-inch piece of masking tape • Meter stick or tape measure • Calculator (preferably graphing) Per Student: • Handout: Barbie Bungee Activity Sheet • One piece of unbroken spaghetti • Handout: Linear Relationships – Line of Best Fit worksheet
Lead In	1. Ask students if they've ever done a bungee jump, or know anyone who has. What do they think it's like to fall like that and be caught by a bungee cord? 2. If you have access to the internet, show students the bungee jump video clip at http://www.extremeworld.com/attractions/bungee_jump/video.aspx. You can also show the video of a group of South Pacific islanders' jumping ritual at http://news.nationalgeographic.com/news/2005/11/1109_051109_video_landdive.html. [Note: Preview videos prior to showing to class.] Have the students compare the two set-ups. How does what the villagers experience differ from what a bungee jumper experiences? 3. Ask, what are the properties of a bungee cord that make it the material of

	choice for this kind of activity? [E.g. its strength, its elasticity, its length] How might these properties affect the jumper's experience? [The stretchiness of the bungee, combined with its length, affect how far the jumper will fall. The stretchier the bungee is, the more it will extend when the jumper falls, and the further the jumper will fall. Likewise, the longer the bungee is, the further the jumper will fall.] 4. Tell students that they will be simulating a bungee jump for a Barbie doll using rubber bands. They will be looking at the relationship between the length of the bungee cord (in number of rubber bands) and the distance Barbie falls. Their ultimate objective will be to determine how many rubber bands should be used to allow Barbie to jump safely from 400 cm, so that she has as long a drop as possible (in order to be the most exciting for Barbie) but stays clear of the floor.
Activity	1. Have students get into groups of 3 or 4. Hand out the Activity Sheets to each student and the materials to each group. Make sure each group has a space from which to drop their Barbie without interfering with other groups. 2. Show students how to make a slipknot with the rubber bands (see Activity Sheet) and how to wrap the first rubber band around Barbie's feet. 3. Give students approximately twenty minutes to complete their data collection. Circulate among the groups to ensure that students are measuring distances properly and recording data accurately. 4. When students are done collecting data, they should compute averages from the three trials at each cord length, then plot the points on the graph area provided. If students are not familiar with this vocabulary word, tell them that they are making a *scatter plot*. A scatter plot is a graph in which values for two variables are indicated; it is good for seeing visually if there is a relationship between the two variables. If the points seem to cluster into a pattern, it is apparent that there is a relationship between the variables. If there is no relationship between the two variables (e.g., if they were to plot shoe size against number of siblings) the points would be randomly distributed with no particular pattern among them. 5. When students have their points plotted, ask if they see a relationship between the two variables. What is the relationship? [As one variable increases, the other increases as well.] When the students are all comfortable with seeing the relationship, tell them that there is a *linear relationship* between the two variables. A linear relationship is one in which the two variables are directly proportional to each other; if you double one variable, the other variable also doubles. This kind of relationship can be plotted as a straight line. In contrast, a non-linear relationship would be a curve, such as a parabola. In a non-linear relationship, the two variables are not directly proportional, so a change in one variable would not result in a change of the same size in the other variable. 6. Tell students that when there is a linear relationship between the two variables of a scatter plot, you can draw a *line of best fit* that approximates the relationship. The line of best fit is a straight line that falls as close to possible to all the data points; it may or may not go through any of the points students plotted. It is a best-guess representation of the data, and the equation of the line is a best-guess approximation of the relationship between the two variables. 7. Hand out pieces of spaghetti and the Linear Relationships - Line of Best Fit worksheet to students. Have them place the spaghetti on their graphs so that they find a place where it is as close to as many data points as possible. When they have placed it where they think it should go, have them trace the line it makes on their graphs (making sure their spaghetti strand is actually straight!). 8. Help students work through the rest of the worksheet. They should be able to choose two points that the line goes through and calculate the slope of the line

	using rise over run. Using this information and the y-intercept, students should be able to determine an equation for their lines of best fit. They can then *extrapolate* (infer other values based on information they have) by projecting their line outward to solve for a value of 400 cm. They can do this visually, if they have enough graph paper to extend the line out, but they should also be able to use algebra to solve for x. [Note: Students can work through the worksheets individually and come up with their own predictions, but have each group come up with a single prediction to test, in order to save time.] 9. Once the students have their predictions, have them construct their bungee cords for Barbie. 10. Bring all the Barbies and bungees to the 400 cm drop zone. The advisor or other adult should drop all the Barbies one by one while the students observe the results from below.
Closure	1. Back in the classroom, discuss the results. Which group got Barbie closest to the ground without getting her *too* close? Were there any surprises? 2. Did any groups vastly under or over-estimate the number of rubber bands that would be needed? What might account for sources of error in groups' predictions? 3. Ask the students what properties of the jumper his or herself could affect the experience. [E.g. his or her height and mass/weight] What might happen if the jumper lied about his/her weight or height? How would giving the wrong information affect a bungee jumper? How would it affect a jumper from the South Pacific islands?
Informal Assessment	• Monitor students for participation in activity and discussions. • Monitor students' understanding through one-on-one questioning and discussions.
Formal Assessment	• Completed Barbie Bungee data table and graph. • Completed Line of Best Fit worksheet with prediction. • Constructed bungee cord for 400 cm drop.
Trouble Shooting	• Set up an area for the 400 cm drop ahead of time. 400 cm is 4 meters, which is approximately thirteen feet. Other heights can be used; choose your drop zone and set the height accordingly. • Try out the experiment yourself and try to determine how many rubber bands are needed for your height, so you will have a gauge for determining approximately how many rubber bands each group will need, and for informally assessing students' predictions.
Extension	• If students have graphing calculators, they can input the data points and have the calculators come up with the *best* line of best fit. They should do this after they come up with their own determinations of the equation for the line of best fit, and compare their results to the calculators'. How close did they get? What would you predict for the number of rubber bands for 400 cm based on the calculators' calculations? How different are students' predictions and the "correct" number? What are the sources of error in students' predictions?
Citation	National Council of Teachers of Mathematics, http://illuminations.nctm.org/LessonDetail.aspx?ID=L646

SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☐ Adaptation of Content	☐ Modeling	☐ Whole class
☐ Links to Background	☒ Guided practice	☒ Small groups
☐ Links to Past Learning	☒ Independent practice	☐ Partners
☒ Strategies incorporated	☐ Comprehensible input	☒ Independent

<table>
<tr><td colspan="2">Integration of Processes
☒ Reading
☒ Writing
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☒ Listening</td><td>Application
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☒ Individual
☒ Group
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☒ Oral</td></tr>
<tr><td>Arizona Math Standards Addressed</td><td colspan="3">S2C1: Understand and apply data collection, organization and representation to analyze and sort data, including making reasonable predictions based upon linear patterns in data sets or scatter plots (PO 7), evaluating the reasonableness of conclusions drawn from data analysis (PO 11), and drawing a line of best fit for a scatter plot (PO 13).
S3C2: Describe and model functions and their relationships, including interpreting the relationship between data suggested by a graph (PO 8).
S3C3: Represent and analyze mathematical situations and structures using algebraic representations, including writing a linear algebraic sentence that represents a data set that models a contextual situation (PO 7) and writing an equation of a line given (PO 10).
S3C4: Analyze change in a variable over time and in various contexts by determining the slope and y-intercept of a linear equation (PO1).</td></tr>
<tr><td>Arizona Science Standards Addressed</td><td colspan="3">S1C2: Design and conduct controlled investigations.
S1C3: Evaluate experimental design, analyze data to explain results and propose further investigations, including evaluating the design of an investigation to identify possible sources of procedural error (PO 4).</td></tr>
</table>

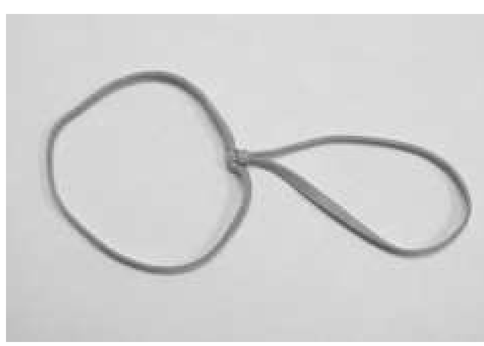
Barbie Bungee

Your mission today is to add some excitement to Barbie's life by preparing her for the bungee jump of a lifetime! Barbie will be jumping from a height of 400 cm at the end of the class, and you need to determine how many rubber bands will be needed for her to jump safely from this height. Experiment with the materials you have to determine the relationship between the number of rubber bands and the distance Barbie falls.

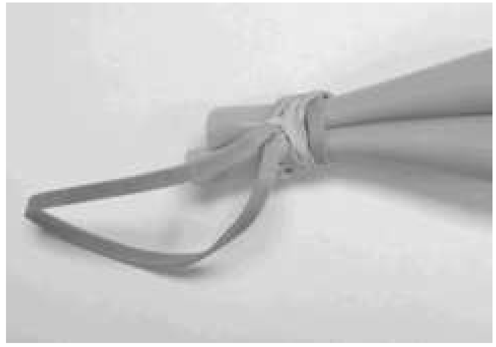
Read through all instructions before beginning your experiment!

Instructions:

1. What is the maximum number of rubber bands that will allow Barbie to safely jump from a height of 400 cm? Write your prediction for the number of rubber bands that will be needed: ___________________________
2. Tape a piece of masking tape to the wall at a height of about 6 feet. This is the line from which Barbie will "jump". Try to make sure the line is as level as possible.
3. Connect two rubber bands together with a slip knot.



4. Wrap the open rubber band tightly around Barbie's feet.



5. Attach another rubber band to the first with a slipknot – this now makes two rubber bands for Barbie's bungee cord.

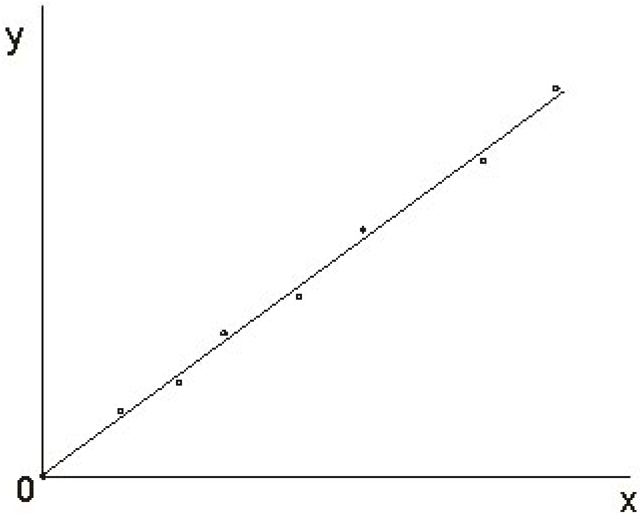
6. Hold the end of the cord to the line with one hand and "stand" Barbie on the line with the other. Let Barbie fall (head first) from the line while you hold onto the cord.
7. One team member should keep track of the lowest point Barbie reaches when she drops. Another team member should measure the distance from this point to the line for each drop. One team member should be in charge of recording this data for the team.
8. Repeat the drop for three trials at each bungee cord length.
9. Add two rubber bands for each new cord length.
10. Fill in the data sheet with the data recorded by your team recorder.
11. Make sure you record your data in centimeters!
12. Find the average jump distance for each bungee cord length.

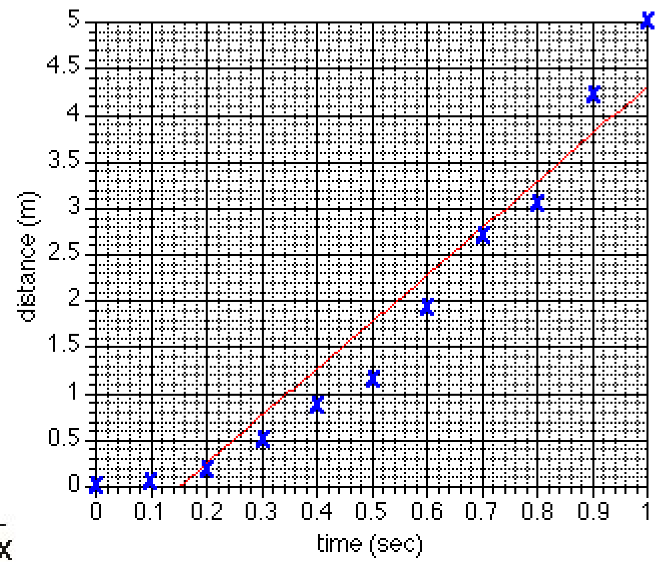
Barbie Bungee Data Sheet

Number of Rubber Bands	Jump Distance – Trial 1 (cm)	Jump Distance – Trial 2 (cm)	Jump Distance – Trial 3 (cm)	Jump Distance - Average (cm)
2				
4				
6				
8				
10				
12				

13. Now create a scatter plot of your data. Make sure to indicate the scale of each axis, and to label your axes.

Linear Relationships – Line of Best Fit





A line of best fit comes as *close* as possible to *as many* points as possible on a scatter plot. The line of best fit is an *approximation*, or best estimate, of the relationship between the two variables represented by the scatter plot. The line may or may not actually go through any of your plotted points, and it may or may not go through zero.

You can determine the equation for your line of best fit by finding the slope and the y-intercept, and plugging them into the equation y = mx + b.

To find the slope of your line, find any two points the line goes through (the further apart, the better), and find the coordinates of those two points. For instance, the line in the graph on the right goes through (0.15, 0) and (0.84, 3.5). When you have two coordinates, you can use the following formula to find the slope of the line:

$$\text{slope} = \frac{\text{rise}}{\text{run}} = \frac{(y_2 - y_1)}{(x_2 - x_1)}$$

Using the example above:

 Last updated 8/5/2008

$$\text{slope} = \frac{(y_2 - y_1)}{(x_2 - x_1)} = \frac{(3.50 - 0.00)}{(0.84 - 0.15)} = \frac{(3.50)}{(0.69)} = 5.07$$

Once you find the slope of your line of best fit, all you need is the y-intercept (location where the line crosses the y-axis) to complete the equation for a line, y = mx + b, where *m* is the slope and *b* is the y-intercept.

You can also solve for b, using the slope for *m* and plugging in the coordinates of one of the points you chose above for *y* and *x*.

Using the example above:

y = mx + b
3.5 = (5.07)(0.84) + b
3.5 = 4.26 + b
b = -0.76

Check to see if this answer makes sense. This value for the y-intercept means that the line crosses the y-axis *below* the x-axis (at a negative value for y). If you extended the line in the top right graph above, is this what you would expect for the y-intercept?

If you are satisfied with your values for *m* and *b*, you have the complete equation for your line of best fit. For our example:

y = mx + b
y = 5.07x – 0.76

You can now plug in any value for x to solve for y, and vice versa.

Find the equation for your line of best fit!

Step 1: Find two points

Identify two points that your line goes through. For increased accuracy, set them as far apart as you can.

What are the coordinates for your two points?

Point 1: ________________ Point 2: ________________

Step 2: Find the slope

Using your two points, calculate the rise (change in y) and run (change in x) for the two coordinates, and divide to find the slope.

slope = $\frac{(y_2 - y_1)}{(x_2 - x_1)}$ =

slope =

Step 3: Find the y-intercept

There are two ways to find the y-intercept. The simplest way is to examine your graph and identify the y-coordinate for the point where the line crosses the y-axis. For instance, if your line crosses the y-axis at (0,4) your y-intercept is 4.

If you want to check your accuracy, you can calculate the value of the y-intercept using the equation for a line and one of the two points you identified above. Solve the equation for b; b is your y-intercept.

y = mx + b

_________ = (_________)(_________) + b

What does this value for the y-intercept represent?

____

<u>Step 4</u>: Complete the equation for your line

Once you've solved for m and b, you have all the information you need to complete the equation.

Slope = m = _________________

Y-intercept = b = _________________

Plug in your values for m and b into the equation for a line.

y = mx + b

y = _________x + _________

Use your equation to find what number of rubber bands (y) you will need to drop Barbie from a height (x) of 400 cm. Remember that she needs to clear the floor! Should you use a value of exactly 400 cm? Slightly less? Slightly more?

Use the space below to solve for the number of rubber bands you think you'll need. You'll be able to test your prediction with the class!

Lesson Activity

Title	**Graphing Motion (50-70 minutes)**
ID Number	HS-M-A3
Sequence and Duration	• Lead In: 10 minutes • Activity: 30-40 minutes • Closure: 10-20 minutes
Age Level	High School
Essential Question	**How does a graph represent motion?**
Learning Objectives	• TSW draw on their understanding of distance, time, velocity and graphing to determine how to collect information on the motion of a rolling ball. • TSW collect data on the motion of a rolling ball. • TSW graph the velocity of a rolling ball. • TSW predict the appearance of graphs of other kinds of motion. • TSW apply their understanding of velocity graphs to draw graphs of other kinds of motion.
Other Objectives	• TSW communicate with their group members to establish a collaborative environment. • TSW design a procedure with their classmates that involves every student. • TSW reflect on their initial and final understandings.
Key Terms	• Distance • Time • Constant velocity • Acceleration • Graph
Materials Needed	Per Class: • Ball • Meter sticks • 5-10 Stopwatches • Graph paper Per Team: • 2-3 pieces of graph paper Per Student: • Tracking an Alien Ship calculations (optional) • 3 pieces of graph paper
Lead In	1. Ask the students what they were trying to do when they did the “Tracking an Alien Ship” activity. (They were trying to figure out where the ship would be and when.) What did they need to know in order to figure out this information? (They needed to know where the ship started and at what time, and how fast it was going in what direction.) 2. What is the word for “how fast and in what direction”? (Velocity.) How did they figure out the ship’s velocity? (They calculated the distance it traveled over how long it took to travel it.) 3. What did they have to assume about ship’s velocity in order to figure out what it was, and where the ship would be at what time? (They had to assume that the ship’s velocity was constant.) 4. What could you do to describe the motion of an object whose velocity is changing (i.e. an object that is *accelerating*)? This is the students’ challenge for today.

Activity	
	5. Hand out graph paper to the students in pairs or small groups. Have the students get out their "Tracking an Alien Ship" calculations (if available; otherwise provide the students with the information they will need.) Tell the students that they will be translating their calculations into a graph that represents the ship's motion. On the y-axis they will chart the distance the ship traveled, and on the x-axis the time it took to travel this total distance. 6. Help the students to graph the motion of the ship relative to the known times and distances that the ship traveled (At 8 o'clock it was in Augusta, then at 9:30 it was over Milwaukee, so it traveled 1083 miles in 1.5 hours. It then traveled an additional 1080 miles to Monticello in the next 1.6 hours, approximately.) Have them sketch in the line. 7. Ask the students to identify the y-intercept of the line. (It goes through (0,0).) Does this make sense? (Yes; we arbitrarily set Augusta, Maine to be the "zero point" of the distance, and the ship traveled zero miles in zero hours.) 8. Using the formula y=mx + b, have the students identify the slope of the line. They can use the coordinates of any point on the line for x and y. What do they find for m? (Students may or may not be surprised to find that the slope of the line, m, is equal to the velocity of the ship. That is, the velocity of an object and the slope of a line graphing its displacement over time are equivalent concepts.) 9. Ask the students what the slope of the line would look like if the ship had been traveling more slowly. (It would be flatter.) What if it had been going faster? (It would be steeper.) If the students have trouble visualizing this, have them try graphing a new line with different values. E.g. what if the ship was traveling so fast, it went 2200 miles in 1.5 hours? Or what if it was going so slowly it didn't get to Milwaukee until 2 hours later? 10. Ask the students, what would the graph look like if the ship wasn't moving? (A straight line at y=the ship's location.) 11. Ask the students, what would the graph look like if the velocity of the ship were changing? Allow students to discuss but do not judge their responses. 12. Take out the ball you will be using as your moving object. Tell the students that you plan to roll this ball and have the students collect data to determine its velocity/velocities. Tell the students where you will be rolling the ball (e.g. in the cafeteria, down a carpeted hallway, outside in the grass or on the pavement) and have them discuss what will happen to the ball once you roll it. (If there is enough space, it will keep going until friction slows it to a stop. If there is not enough space, it will hit an obstacle and change course.) 13. Hand the students another piece of graph paper and have them draw their predictions of the shape of the graph of the ball's motion. 14. Bring out the materials you are providing: stopwatches and meter sticks. Have the students design a procedure for making measurements of the ball's motion and run it by you. You may need to ask guiding questions to help the discussion along. For instance: a. What information do you need to know to chart the ship's motion? [Its position and the time it's at each position.] b. How can you collect this information? [Choose some positions and record the time when the ship arrives at those positions.] c. How many positions should you pick to get a good idea of how the ship is moving? [Two is enough to find an average velocity, but what if the velocity is changing? The more positions they have, the better idea they'll have of the ship's motion.] d. How should those positions be spaced? [The positions can be spaced however the students choose, but if they are all spaced evenly it will be more apparent if the velocity is constant or changing.] 15. Have the students delegate tasks so that everyone knows what they are doing,

	and make sure that someone will be recording the data. 16. Go to the location where you'll be rolling the ball and implement the students' procedure. 17. Back in the classroom, give the students time to analyze their data. What can they tell about the ship's motion from working with their data? 18. Hand out a fresh sheet of graph paper to each student and have them graph their results. 19. Ask the students to discuss how their predicted graphs compare to their final graphs. Were there things they failed to consider when they made their predictions? Were there things they thought would happen that didn't? Did anything surprise them?
Closure	1. Have students get into pairs or small groups and hand out fresh graph paper. 2. Tell the students you will be playing the role of "Moving Object." You will move in a certain way and they will need to discuss as a group how to represent that motion with a graph. 3. Walk across the classroom where all students can see you, demonstrating different kinds of motion. Begin simply, i.e. with a constant velocity, then a faster or slower velocity. Move up to more complex motion, e.g. constant acceleration, acceleration to a constant velocity, acceleration then deceleration, etc. Allow students time to discuss and draw between demonstrations. 4. After a handful of examples, begin a group discussion, having groups share their drawings and discuss the reasoning they used to come up with them.
Informal Assessment	• Monitor students' participation in the activities. • Monitor students' participation in discussions. • Monitor students' understanding of verbal directions.
Formal Assessment	• Graph of the ship's motion. • Procedure for collecting data on the ball's motion. • Graph of the prediction of the ball's motion. • Graph of the ball's motion. • Graphs to represent advisor motion.
Trouble Shooting	• A sample data collection sheet is attached, but students may design their own.
Citation	• Adapted from Miller, John J. *Motion of a Bowling Ball*. Retrieved December 5th, 2007 from http://www.iit.edu/~smile.

SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☐ Adaptation of Content	☐ Modeling	☒ Whole class
☐ Links to Background	☐ Guided practice	☒ Small groups
☒ Links to Past Learning	☒ Independent practice	☐ Partners
☐ Strategies incorporated	☐ Comprehensible input	☐ Independent
Integration of Processes	**Application**	**Assessment**
☐ Reading	☒ Hands-on	☒ Individual
☐ Writing	☒ Meaningful	☒ Group
☒ Speaking	☒ Linked to objectives	☒ Written
☐ Listening	☒ Promotes engagement	☐ Oral

Arizona Math Standards Addressed	• S2C1: TSW understand and apply data collection, organization and representation to analyze and sort data. • S3C2: TSW describe and model functions and their relationships. • S3C3: TSW represent and analyze mathematical situations and structures using algebraic representations. • S3C4: TSW analyze change in a variable over time and in various contexts.

Arizona Science Standards Addressed	• S1C2: TSW design and conduct controlled investigations. • S5C2: TSW analyze relationships between forces and motion.

Motion of an Alien Ship — Data Collection Sheet

Position Number	Total Distance Traveled (km)	Distance Between Points (km)	Time Recorded at Position (s)	Time Between Points (s)
1	0	0	0	0
2				
3				
4				
5				
6				
7				
8				
9				

Mathematics Engineering Science Achievement

Lesson Activity

Title	**Math Puzzle: John and Julia**
ID Number	HS-M-P3
Duration	10 minutes
Age Level	High School
Learning Objectives	• TSW solve a logical mathematical word problem using grade appropriate problem-solving strategies. • TSW solve a multi-step word problem by applying various numerical operations.
Other Objectives	• TSW participate in a group discussion about problem solving.
Materials Needed	• Handout: John and Julia
Activity	1. Pass out puzzle. 2. Tell students they have 5 minutes to try to solve the puzzle and remind them to sign in for attendance. 3. After 5 minutes, discuss math puzzle solutions with class.
Informal Assessment	• Monitor students to check for engagement. • Monitor students to check for participation.
Formal Assessment	• Solution to problem.

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☐ Links to Background
- ☐ Links to Past Learning
- ☒ Strategies incorporated

Scaffolding
- ☐ Modeling
- ☐ Guided practice
- ☒ Independent practice
- ☐ Comprehensible input

Grouping Options
- ☐ Whole class
- ☐ Small groups
- ☒ Partners
- ☒ Independent

Integration of Processes
- ☒ Reading
- ☒ Writing
- ☒ Speaking
- ☒ Listening

Application
- ☐ Hands-on
- ☐ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☒ Individual
- ☐ Group
- ☒ Written
- ☒ Oral

Arizona Math Standards Addressed	• S5C1: TSW use reasoning to solve mathematical problems in contextual situations.

John & Julia

Julia is as old as John will be when Julia is twice as old as John was when Julia's age was half the sum of their present ages.

John is as old as Julia was when John was half the age he will be 10 years from now.

The Question: **How old are John and Julia**?

John & Julia

Julia is as old as John will be when Julia is twice as old as John was when Julia's age was half the sum of their present ages.

John is as old as Julia was when John was half the age he will be 10 years from now.

The Question: How old are John and Julia?

The Solution: **John** is **30** years old and **Julia** is **40** years old.

An explanation:
Let Julia's age be a and let John's age be b.
The first sentence tells us that "Julia is as old as John will be when Julia is twice as old as John was when Julia's age was half the sum of their present ages".
"Half the sum of their present ages" is:
$0.5*(a+b)$
So "Julia's age was half the sum of their present ages", the following number of years ago:
$a - (0.5*(a+b)) = 0.5*a-0.5*b$
At that moment, "John's age" was:
$b - (0.5*a-0.5*b) = 1.5*b-0.5*a$.
So "twice that age" is:
$3*b-a$
"Julia's age will be twice that age", in the following number of years:
$(3*b-a) - a = 3*b-2*a$
At that moment, John will be:
$b + (3*b-2*a) = 4*b-2*a$
And we are told that "that's Julia's age", so:
$a = 4*b-2*a$
or
$3*a = 4*b$.

The second sentence tells us that "John is as old as Julia was when John was half the age he will be 10 years from now".
"10 years from now", John will be:
$b+10$
"Half that age" is:
$0.5*b+5$
"John was that age", the following number of years ago:
$b - (0.5*b+5) = 0.5*b-5$
At that time, "Julia was", the following number of years old:
$a - (0.5*b-5) = a-0.5*b+5$
And that "is John's current age", so:
$b = a-0.5*b+5$
or
$a = 1.5*b-5$.

Now we have two equations:

$3*a = 4*b$ and $a = 1.5*b-5$.

Substitute *a* in the first equation for the value of *a* from the second equation and we get:

$3*(1.5*b-5) = 4*b$

Solving this equation, we get:

$b=30$

Since $a = 1.5*b-5$:

$a=40$

So Julia's age is 40, and John's age is 30.

Lesson Activity

Title	**Math Puzzle: Little Lies**
ID Number	HS-M-P4
Duration	10-15 minutes
Age Level	High School
Learning Objectives	• TSW solve a logical mathematical word problem using grade appropriate problem-solving strategies. • TSW solve a multi-step word problem by applying various numerical operations.
Other Objectives	• TSW participate in a group discussion about problem solving.
Materials Needed	• Handout: Little Lies Math Puzzle
Activity	1. Pass out puzzle. 2. Tell students they have 10 minutes to try to solve the puzzle. 3. After 10 minutes, discuss math puzzle solutions with class.
Informal Assessment	• Monitor students for engagement. • Monitor students for participation.
Formal Assessment	• Completed solution to problem.

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☐ Links to Background
- ☐ Links to Past Learning
- ☒ Strategies incorporated

Scaffolding
- ☐ Modeling
- ☐ Guided practice
- ☒ Independent practice
- ☐ Comprehensible input

Grouping Options
- ☐ Whole class
- ☐ Small groups
- ☐ Partners
- ☒ Independent

Integration of Processes
- ☒ Reading
- ☐ Writing
- ☒ Speaking
- ☒ Listening

Application
- ☐ Hands-on
- ☐ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☒ Individual
- ☒ Group
- ☐ Written
- ☒ Oral

Arizona Math Standards Addressed	• S1C2: TSW understand and apply numerical operations and their relationship to one another such as solving word problems using grade level appropriate operations and numbers.

Little Lies

Richard is a strange liar. He lies on six days of the week, but on the seventh day he always tells the truth. He made the following statements on three successive days:

Day 1: "I lie on Monday and Tuesday."

Day 2: "Today, it's Thursday, Saturday, or Sunday."

Day 3: "I lie on Wednesday and Friday."

The Question: On which day does Richard tell the truth?

Little Lies

The Solution:

We know that Richard tells the truth on only a single day of the week. If the statement on day 1 is untrue, this means that he tells the truth on Monday or Tuesday. If the statement on day 3 is untrue, this means that he tells the truth on Wednesday or Friday. Since Richard tells the truth on only one day, these statements cannot both be untrue. So, exactly one of these statements must be true, and the statement on day 2 must be untrue.

Assume that the statement on day 1 is true. Then the statement on day 3 must be untrue, from which follows that Richard tells the truth on Wednesday or Friday. So, day 1 is a Wednesday or a Friday. Therefore, day 2 is a Thursday or a Saturday. However, this would imply that the statement on day 2 is true, which is impossible. From this we can conclude that the statement on day 1 must be untrue.

This means that Richard told the truth on day 3 and that this day is a Monday or a Tuesday. So day 2 is a Sunday or a Monday. Because the statement on day 2 must be untrue, we can conclude that day 2 is a Monday.

So day 3 is a Tuesday. Therefore, the day on which Richard tells the truth is Tuesday.

Source: http://www.puzzle.dse.nl/teasers/index_us.html

MESA Mathematics Engineering Science Achievement

Lesson Activity

Title	**Math Puzzle: The Masters Plaza (20-25 minutes)**
ID Number	HS-M-P5
Duration	20-25 minutes
Age Level	High School
Learning Objectives	• TSW solve a logical mathematical word problem using grade-appropriate problem-solving strategies. • TSW solve a multi-step word problem by applying various numerical operations.
Materials Needed	• Handout: The Masters Plaza
Activity	1. Pass out puzzle. 2. Tell students they have 20 minutes to try to solve the puzzle. 3. After 20 minutes, discuss math puzzle solutions with class.
Informal Assessment	• Monitor students for participation in activity.
Formal Assessment	• Completed solution to problem.

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☐ Links to Background
- ☐ Links to Past Learning
- ☒ Strategies incorporated

Scaffolding
- ☐ Modeling
- ☐ Guided practice
- ☒ Independent practice
- ☐ Comprehensible input

Grouping Options
- ☐ Whole class
- ☐ Small groups
- ☐ Partners
- ☒ Independent

Integration of Processes
- ☒ Reading
- ☐ Writing
- ☒ Speaking
- ☒ Listening

Application
- ☐ Hands-on
- ☐ Meaningful
- ☒ Linked to objectives
- ☐ Promotes engagement

Assessment
- ☒ Individual
- ☐ Group
- ☐ Written
- ☐ Oral

Arizona Math Standards Addressed	• S5C1: TSW use reasoning to solve mathematical problems in contextual situations.

The Masters Plaza

You have the chance to take your room in the "Masters Plaza", a hotel in which 5 masters (5 of the most intelligent people who ever lived) are present. The hotel consists of 5 rooms and a small restaurant that contains 5 tables. Each master has a rank which shows his level of thinking with respect to the whole group. The master with the first rank is said to be the head master, and he is not you. Rooms, as well as tables, are successively numbered from 1 to 5 in a way that each master lives in a room and eats on a table different in number from his rank. To avoid confrontation, masters with successive ranks are neither allowed to live in rooms next to each other nor to eat on tables next to each other. The four present masters are: Albert Einstein, Galileo Galilei, Hassan Issa and Archimedes. To have your room in the Plaza, you just have to know your rank, table number and room number knowing that:

Archimedes doesn't eat on the fifth table.
Einstein is not the head master.
Archimedes has exactly the middle rank between Hassan and You.
Einstein is more intelligent than Archimedes.
Galileo eats on a table next to that of Einstein.
Hassan does not eat on a table with the same number as his room number.

The Question: What are the ranks, room numbers, and table numbers of the five masters?

The Masters Plaza

Solution:

The first step is to know the ranks of the 5 masters.

Archimedes has a middle rank between *Hassan* and *You*. Then *Archimedes* has the 2nd, 3rd or 4th rank.

If *Archimedes* is in the 2nd rank then *Hassan* has the first and *You* have the 3rd rank. So *Einstein* can't have a higher rank than *Archimedes*, so this possibility is false.

If *Archimedes* has the 4th rank then *Hassan* and *You* are in the 3rd and 5th rank, so *Galileo* and *Einstein* have the 1st and the 2nd rank which is impossible because they eat on tables next to each other.

If *Archimedes* has the 3rd rank and *Hassan* and *You* have the 2nd and the 4th rank then *Einstein* has the 1st rank and *Galileo* has the 5th, because *Einstein* is more intelligent than *Archimedes*, and that is impossible because *Einstein* is not the head master.

The only true possibility is that *Archimedes* has the 3rd rank, *Hassan* has the 1st and *You* the 5th, because *You* are not the headmaster. Then *Einstein* has the 2nd rank and *Galileo* the 4th, because *Einstein* is more intelligent than *Archimedes*.

The second step is to list all the possibilities for successive ranks so that they are not next to each other.

Table/room number	1	2	3	4	5	Result
Ranks	1	3	5	2	4	Rejected
	1	4	2	5	3	Rejected
	2	4	1	3	5	Rejected
	2	**4**	**1**	**5**	**3**	**Accepted**
	2	5	3	1	4	Rejected
	3	1	4	2	5	Rejected
	3	**1**	**5**	**2**	**4**	**Accepted**
	3	5	1	4	2	Rejected
	3	5	2	4	1	Rejected
	4	1	3	5	2	Rejected
	4	2	5	1	3	Rejected
	4	2	1	3	5	Rejected
	5	2	4	1	3	Rejected
	5	3	1	4	2	Rejected

Here two possibilities are true as shown in the table but *Archimedes* (rank 3) doesn't eat on the 5th table, so the 1st possibility is not the table number. The 2nd possibility is true in table and room numbers case, but since *Hassan* does not eat on a table with the same number as his room number, then the 2nd possibility is for the table number and the 1st for the room number. The results are shown in this table:

	Hassan	Einstein	Archimedes	Galileo	**You**
Rank	1	2	3	4	**5**
Table number	2	4	1	5	**3**
Room number	3	1	5	2	**4**

Lesson Activity

Title	**Math Puzzle: Mystery Math Ball! A Logic-based Mystery**
ID Number	HS-M-P6
Duration	25-30 minutes
Age Level	High School
Learning Objectives	• TSW solve higher order math logic puzzles using grade level problem solving strategies. • TSW use reasoning to solve mathematical logic puzzles using given information.
Other Objectives	•
Materials Needed	• Handout: The Mystery Math Ball! A Logic-based Mystery
Activity	1. Pass puzzles out to students as they arrive for MESA meeting. Inform students that they may work in groups of two. Instruct them not to give the answer if they solve it before time is up. 2. Monitor and guide students to the solution. 1. After 20-25 minutes, discuss each puzzle, its solution, and the logical reasoning students used to solve it. Call on students at random or have them volunteer to explain their problem-solving strategies.
Informal Assessment	• Monitor students for participation.
Formal Assessment	• Completed solution to problem.

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☒ Links to Background
- ☐ Links to Past Learning
- ☒ Strategies incorporated

Scaffolding
- ☐ Modeling
- ☐ Guided practice
- ☒ Independent practice
- ☐ Comprehensible input

Grouping Options
- ☐ Whole class
- ☐ Small groups
- ☒ Partners
- ☒ Independent

Integration of Processes
- ☒ Reading
- ☐ Writing
- ☒ Speaking
- ☒ Listening

Application
- ☐ Hands-on
- ☐ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☒ Individual
- ☒ Group
- ☒ Written
- ☒ Oral

Arizona Math Standards Addressed	• S5C1: TSW use reasoning to solve mathematical problems in contextual situations.

Name ____ Date ___________

The Mystery Math Ball! A Logic-based Mystery

Jennifer received the following invitation in the mail.

You're Invited

to a

"Mystery Math Ball!"

date: to be figured out by you

place: to be figured out by you

hosted by: to be figured out by you

Jennifer really wants to go to this party. Can you help her figure out the missing information? Use your deductive reasoning skills and the clues provided to solve the mystery about when and where this party will be held, and who is hosting the party. Good luck!!

Name ____ Date ___________

The Mystery Math Ball! A Logic-based Mystery

Mystery Date

Use the clues and the calendar to help Jennifer figure out the date of the "Mystery Math Ball."

	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

Clues:

1. The date is not a prime number.
2. The date is not a multiple of 4 or 5.
3. The date is a multiple of 2.
4. The date is divisible by 6.
5. If you have eliminated dates correctly, you should have two possible dates left. The date of the "Mystery Math Ball" is the greater number of those two dates.

When is the "Mystery Math Ball?" __________

Name ____ Date ___________

The Mystery Math Ball! A Logic-based Mystery

Mystery Place

Next, Jennifer must figure out where the "Mystery Math Ball" will be held. Can you help her? Use the clues provided to figure out the 5-digit house number.

Clues:

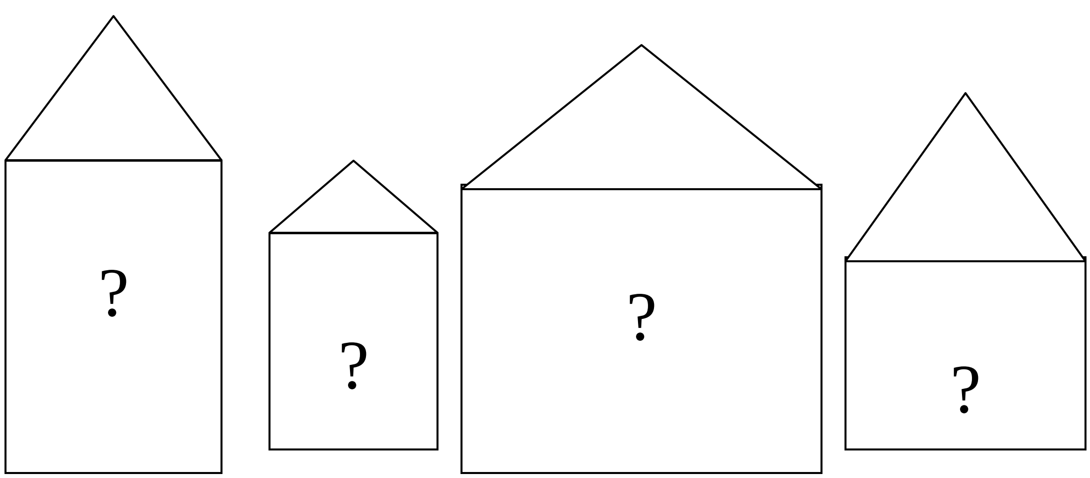
1. The house number is an even number.

2. The product of the digits in the one's place and the hundred's place is 6. The sum of these two digits is 5.

3. The digit in the ten thousand's place is the difference between the hundred's digit and the one's digit.

4. The ten's digit is the greatest even digit.

5. The sum of the digits in the ten thousand's place and the thousand's place is equal to the digit in the ten's place.



Where is the "Mystery Math Ball?"____ ____ _____ _____ _____

Name ____ Date ___________

The Mystery Math Ball! A Logic-based Mystery

Mystery Host

Jennifer's last task is to figure out who is hosting the "Mystery Math Ball" so that she can contact the host for final details about the party. She knows the host is 16 years old and is one of the following people - John, Joe, Jill, Janet, or Jim. She knows that the these five people's ages range from 14- to 18-years old. Use the deductive reasoning chart and the clues provided to help Jennifer figure out who is hosting the "Mystery Math Ball."

	18	17	16	15	14
John					
Joe					
Jill					
Janet					
Jim					

Clues:

1. Jill is 3 years younger than John.
2. Jim is younger than Joe.
3. Janet is older than Jill.
4. Jill is not 15 years old.
5. Jim is not the youngest person.
6. John is the second-oldest person.
7. Joe is 2 years younger than Janet.

Who is the host of the "Mystery Math Ball?" _______________

Name ____ Date ___________

The Mystery Math Ball! A Logic-based Mystery

Answer Key

Mystery Date (the 18th)

Clue 1 eliminates the prime numbers: 2, 3, 5, 7, 11, 13, 17, 19, 23, 29, and 31
Clue 2 eliminates multiples of 4 and 5: 4, 8, 10, 12, 15, 16, 20, 24, 25, 28, and 30
Clue 3 eliminates odd numbers: 1, 9, 21, and 27
Clue 4 eliminates remaining numbers that are not divisible by 6: 14, 18, 22, and 26
Clue 5 eliminates the number 6, which means the Mystery Date is the 18th.

Mystery Place (House number is 17382)

Clue 1: One's digit must be 0, 2, 4, 6, or 8.
Clue 2: One's digit must be 2 and hundred's digit must be 3. The other possible combination, 1 and 6, does not have a sum of 5.
Clue 3: Digit in the ten thousand's place is 1. (3 – 2 = 1)
Clue 4: Ten's digit is 8.
Clue 5: Digit in the thousand's place is 7. (1 + 7 = 8)

Mystery Host (Joe)

Clue 1: Jill is not 18, 17, or 16, since she is 3 years younger than John. John, likewise, is not 14, 15, or 16, since he is 3 years older than Jill.
Clue 2: Jim is not 18. Joe is not 14.
Clue 3: Janet is not 14.
Clue 4: Jill is not 15. We now know that Jill is 14-years old, which means all the others can be eliminated as 14-years old.
Clue 5: This clue is redundant, but Jim is not 14-years old.
Clue 6: John is 17 years old.
Clue 7: Janet is 18 and Joe is 16. If Janet is 16, then Joe is 14, but we have already concluded that Jill is the 14-year old.

Lesson Activity

Title	**Math Puzzle: Plus and Minus**
ID Number	HS-M-P7
Duration	10-15 minutes
Age Level	High School
Learning Objectives	• TSW solve a logical mathematical word problem using grade appropriate problem-solving strategies. • TSW solve a multi-step word problem by applying various numerical operations.
Other Objectives	• TSW participate in a group discussion about problem solving.
Materials Needed	• Handout: Plus and Minus
Activity	1. Pass out Math Puzzle Handout. 2. Tell students they have 10 minutes to solve the puzzle. 3. After 10 minutes, discuss puzzle and have students volunteer to share their strategies/answer.
Informal Assessment	• Monitor students for engagement. • Monitor students for participation.
Formal Assessment	• Completed solution to problem.

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☐ Links to Background
- ☒ Links to Past Learning
- ☒ Strategies incorporated

Scaffolding
- ☐ Modeling
- ☐ Guided practice
- ☒ Independent practice
- ☐ Comprehensible input

Grouping Options
- ☐ Whole class
- ☐ Small groups
- ☐ Partners
- ☒ Independent

Integration of Processes
- ☒ Reading
- ☐ Writing
- ☒ Speaking
- ☒ Listening

Application
- ☐ Hands-on
- ☐ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☒ Individual
- ☒ Group
- ☐ Written
- ☒ Oral

Arizona Math Standards Addressed	• S1C2: TSW understand and apply numerical operations and their relationship to one another such as solving word problems using grade level appropriate operations and numbers.

Plus & Minus

Below is an equation that isn't correct yet. By adding a number of plus signs and minus signs between the ciphers on the left side (without changing the order of the ciphers), the equation can be made correct.

123456789 = 100

The Question: How many different ways are there to make the equation correct?

Plus & Minus

The Solution:

There are 11 different ways:

123+45-67+8-9=100
123+4-5+67-89=100
123-45-67+89=100
123-4-5-6-7+8-9=100
12+3+4+5-6-7+89=100
12+3-4+5+67+8+9=100
12-3-4+5-6+7+89=100
1+23-4+56+7+8+9=100
1+23-4+5+6+78-9=100
1+2+34-5+67-8+9=100
1+2+3-4+5+6+78+9=100

Remark: if it is not only allowed to put plus signs and minus signs *between* the ciphers, but also *in front of* the first 1, then there is a twelfth possibility: -1+2-3+4+5+6+78+9=100.

Source: http://www.puzzle.dse.nl/math/index_us.html#plus_and_minus

MESA Mathematics Engineering Science Achievement

Lesson Activity

Title	**Math Puzzle: Square Puzzle**
ID Number	HS-M-P8
Duration	10-15 minutes
Age Level	High School
Learning Objectives	• TSW solve a logical mathematical word problem using grade appropriate problem-solving strategies. • TSW solve a multi-step word problem by applying various numerical operations.
Other Objectives	• TSW participate in a group discussion about problem solving.
Materials Needed	• Handout: Square Puzzle
Activity	**Math Puzzle:** 1. Pass out puzzle. 2. Tell students they have 10 minutes to try to solve a puzzle and remind them to sign in for attendance. 3. After 10 minutes, discuss math puzzle solutions with class.
Informal Assessment	• Monitor students for engagement. • Monitor students for participation.
Formal Assessment	• Completed solution to problem.

SEI Strategies Used

Preparation
- [ ] Adaptation of Content
- [ ] Links to Background
- [ ] Links to Past Learning
- [x] Strategies incorporated

Scaffolding
- [ ] Modeling
- [ ] Guided practice
- [x] Independent practice
- [ ] Comprehensible input

Grouping Options
- [ ] Whole class
- [ ] Small groups
- [ ] Partners
- [x] Independent

Integration of Processes
- [x] Reading
- [ ] Writing
- [x] Speaking
- [x] Listening

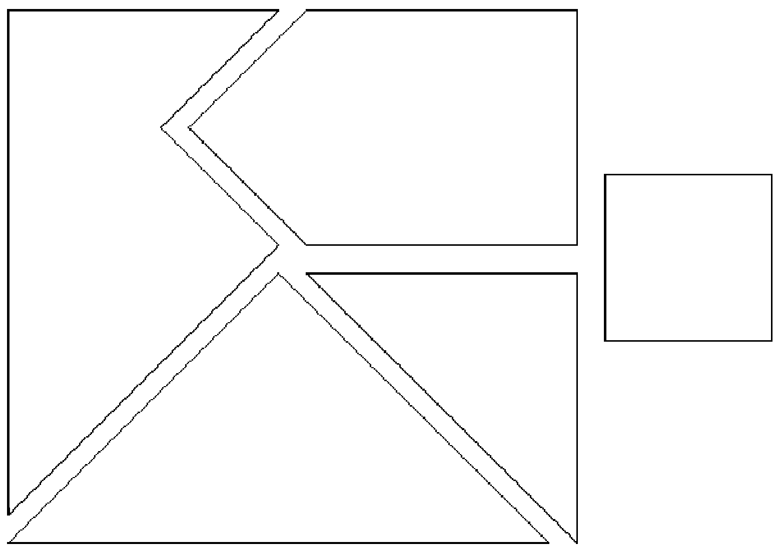
Application
- [ ] Hands-on
- [ ] Meaningful
- [x] Linked to objectives
- [x] Promotes engagement

Assessment
- [x] Individual
- [x] Group
- [ ] Written
- [x] Oral

Arizona Math Standards Addressed	• S1C2: TSW understand and apply numerical operations and their relationship to one another such as solving word problems using grade level appropriate operations and numbers.

Square Puzzle

The five pieces shown below must be put together to a square.

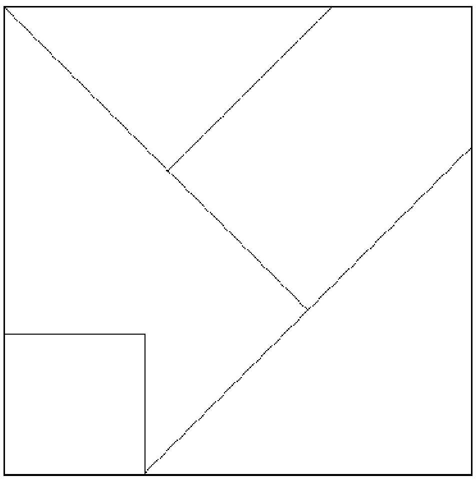


The Question: How should this be done?

A Hint : Print the picture with the pieces, and cut the pieces out. It's more difficult than it looks!

Square Puzzle

The Solution:



Source: http://www.puzzle.dse.nl/teasers/index_us.html

MESA Mathematics Engineering Science Achievement

Lesson Activity

Title	**Math Puzzle: The Bridge**
ID Number	HS-M-P2
Duration	10 minutes
Age Level	High School
Learning Objectives	• TSW solve a logical mathematical word problem using grade appropriate problem-solving strategies. • TSW solve a multi-step word problem by applying various numerical operations.
Other Objectives	• TSW participate in a group discussion about problem solving.
Materials Needed	• Handout: The Bridge
Activity	1. Pass out puzzle. 2. Tell students they have 5 minutes to try to solve the puzzle. 3. After 5 minutes, discuss math puzzle solutions with class.
Informal Assessment	• Monitor students to check for engagement. • Monitor students to check for participation.
Formal Assessment	• Solution to problem.

SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☐ Adaptation of Content	☐ Modeling	☐ Whole class
☐ Links to Background	☐ Guided practice	☐ Small groups
☐ Links to Past Learning	☒ Independent practice	☒ Partners
☒ Strategies incorporated	☐ Comprehensible input	☒ Independent
Integration of Processes	**Application**	**Assessment**
☒ Reading	☐ Hands-on	☒ Individual
☒ Writing	☐ Meaningful	☐ Group
☒ Speaking	☒ Linked to objectives	☒ Written
☒ Listening	☒ Promotes engagement	☒ Oral

Arizona Math Standards Addressed	• S5C1: TSW use reasoning to solve mathematical problems in contextual situations.

The Bridge

Four men want to cross a bridge. They all begin on the same side. It is night, and they have only one flashlight with them. At most two men can cross the bridge at a time, and any party who crosses, either one or two people, must have the flashlight with them.

The flashlight must be walked back and forth: it cannot be thrown, etc. Each man walks at a different speed. A pair must walk together at the speed of the slower man. Man 1 needs 1 minute to cross the bridge, man 2 needs 2 minutes, man 3 needs 5 minutes, and man 4 needs 10 minutes. For example, if man 1 and man 3 walk across together, they need 5 minutes.

The Question: How can all four men cross the bridge in 17 minutes?

The Bridge

Four men want to cross a bridge. They all begin on the same side. It is night, and they have only one flashlight with them. At most two men can cross the bridge at a time, and any party who crosses, either one or two people, must have the flashlight with them.

The flashlight must be walked back and forth: it cannot be thrown, etc. Each man walks at a different speed. A pair must walk together at the speed of the slower man. Man 1 needs 1 minute to cross the bridge, man 2 needs 2 minutes, man 3 needs 5 minutes, and man 4 needs 10 minutes. For example, if man 1 and man 3 walk across together, they need 5 minutes.

The Question: How can all four men cross the bridge in 17 minutes?

First man 1 and man 2 walk across the bridge. This takes 2 minutes.
After this, man 1 walks back with the flashlight. This takes 1 minute.
Then man 3 and man 4 walk across the bridge. This takes 10 minutes.
After this, man 2 walks back with the flashlight. This takes 2 minutes.
Then man 1 and man 2 walk across the bridge. This takes 2 minutes as before.
In total: 2+1+10+2+2=17 minutes.

Lesson Activity

Title	**Tracking an Alien Ship (50-60 minutes)**
ID Number	HS-M-A2
Sequence and Duration	• Lead In: 10 minutes • Activity: 30-40 minutes • Closure: 10 minutes
Age Level	High School
Essential Question	**How can math help you track down a moving object?**
Learning Objectives	• TSW velocity, scale, and unit conversion to solve a problem given a limited amount of information. • TSW establish and implement a process for solving the problem. • TSW reflect on the efficiency of a collaborative/competitive problem-solving strategy.
Other Objectives	• TSW listen to and record information provided by the instructor. • TSW communicate with their peers to create a problem-solving strategy. • TSW collaborate with their peers and instructor to solve the problem efficiently.
Key Terms	• Velocity • Scale distance • Conversion
Materials Needed	Per Class: • Projector • Image of alien ship • Image of the message • Image of the message, decoded • Image of Lockheed SR-71 Blackbird • Problem solutions Per Student or Pair: • Handout: Map of the U.S. • Handout: Packet of the images (optional) • Protractor • Ruler • Calculator
Lead In	1. Tell the students, "Today you are all members of a think tank of scientists at the Pentagon, and you have an incredible mission. This morning, an alien ship was seen flying over American soil. The whole country is on edge, and the President is desperate to meet the aliens wherever they plan to land. The trouble is, no one knows for sure where they're going. The President has called on you to use your collective genius to examine the intel and deduce their path from the clues." 2. Hand out the maps of the United States. Project the "intel" so all the students can see it. Tell them to take notes, as you will

	only be able to divulge the following information once. Project the image of the alien ship and say, "This ship was seen flying over Augusta, Maine at 0800 this morning. It was traveling 105 degrees west of north. It passed over two major cities, then was seen passing over a third at 0930. The residents of the city were too terrified to identify themselves so they called in the sighting anonymously." 3. Project the image of the message. Tell the students, "We received this message from the aliens at 0945. We handed it to our most talented translators, and they were able to decode all but a word of it. We believe this word to be the alien name for one of our cities." 4. Project the decoded message. Say, "The decoded message indicates that the aliens are on their way to a particular place. The last word of the message is pronounced 'gleep' and is a unit of time. It is equivalent to 0.5536 hours." 5. Project the image of the Blackbird. Say, "The President has commissioned the use of our fastest passenger jet, the Lockheed SR-71 Blackbird, to make the journey from D.C. to the landing site. This jet is able to travel at Mach 3.3. What we need from you is a destination, and your assurance that the President will make it there before the aliens." 6. Say, "Here are your supplies." Hand out the protractors, rulers, and calculators. "The time is currently 1015. We're counting on you." Set a timer or record the start time when you are finished speaking; this start time will be your local "1015."
Activity	1. Let the students figure out what they need to do to solve this problem. Encourage them to act as a think tank and collaborate to brainstorm and delegate to complete tasks. 2. Encourage the students to write their intel in a space where they can all see it and discuss what they know and what they need to know. 3. Allow them to struggle, but if they are getting too frustrated ask them questions to get them started, such as: a. What information do you need to figure out where an object is going? (Its direction and its speed.) b. How can you figure out the alien ship's speed? (By dividing the distance it travels by the time it takes to travel it.) c. Where was the ship at 0800? In what direction was it traveling? (It started at Augusta, Maine and was heading 105 degrees west of north. Encourage the students to use their protractors and rulers to sketch out a line representing the ship's path, and mark the major cities that the line passes through or near. See the problem solution for a list of the cities.) d. Where was it at 0930? (It had passed two major cities, Montpelier and Toronto, and was seen flying over the third, which would be Milwaukee.) e. What is the distance between Augusta and Milwaukee? How could you find out? (The students will need to measure the scaled distance with their rulers, measure the scale as indicated by the map, and convert the scaled distance to the true distance. Precision is essential!)

	f. If you have the distance and the time, what is the velocity of the ship? (Divide the distance by the time, which is 1.5 hours, to find the ship's velocity.) g. When will the ship land? (Convert gleeps to hours, add this to 0945 to find the landing time.) h. How far will it have gone in that time? (Use the difference between the sighting in Milwaukee and the landing time to find the time the ship will travel after leaving Milwaukee, and multiply this by the velocity to find the distance from Milwaukee.) i. What city will the ship be in when it lands? (Use the scale of the map to convert the distance to inches and measure this distance from Milwaukee along the line to find the destination city.) j. Can the President get there in time? (The students will need to measure the distance between Washington D.C. and the landing site, and divide this by the amount of time left between the ship's landing time and the "local time" to find the velocity the President would need to make it in time. They will then need to compare this to the Blackbird's actual velocity of 3.3 times the speed of sound (770 mph) and see if the President will make it.) k. What time will the President arrive? Will there be time to spare? If the President will be late, how late? (Use "local time" as the departure time, the distance between D.C. and the landing site, and the Blackbird's velocity to determine when the President will land, and find the difference between this and the alien's landing time.)
Closure	1. Compare students' solution to the problem solution provided. 2. Ask the students to reflect on their problem-solving process. Were they able to see a clear path to the answer right away, or did they struggle to figure out what to do? Did working together help? 3. Did they work collaboratively? Did they work competitively? How did their problem-solving style affect their ability to work efficiently? 4. Were the students surprised by what they were able to deduce from what little intel was available to them? 5. What science knowledge did they use to solve the problem? 6. Have the students reflect on the summary question: *How can math help you track down a moving object?*
Informal Assessment	• Monitor students' participation in the activity. • Monitor students' understanding of the problem-solving process.
Formal Assessment	• Check the accuracy of each student's contribution to the solution of the problem.
Trouble Shooting	• You can use real times rather than establishing a "local" time, but you will need to be careful to set the sighting times properly if you wish to use the same solution, or adjust the solutions based on the times you use. • You can include the decoding of the alien message as an activity for the students, for example by translating the decoded message into ASCII beforehand. • The map scale in the problem solutions was based on the map

	found at the site listed in the materials list and attached here. If you use a different map, be sure to update the scale conversion factor in the solutions.
Citation	• Alien ship: Thanks to Eric Gooch at Cybergooch.com for permission to use this image.

SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☐ Adaptation of Content	☐ Modeling	☒ Whole class
☐ Links to Background	☐ Guided practice	☐ Small groups
☒ Links to Past Learning	☒ Independent practice	☒ Partners
☐ Strategies incorporated	☒ Comprehensible input	☒ Independent

Integration of Processes	Application	Assessment
☒ Reading	☐ Hands-on	☐ Individual
☒ Writing	☒ Meaningful	☒ Group
☐ Speaking	☒ Linked to objectives	☒ Written
☒ Listening	☒ Promotes engagement	☐ Oral

Arizona Math Standards Addressed	• S1C2: TSW understand and apply numerical operations and their relationship to one another. • S3C3: TSW represent and analyze mathematical situations and structures using algebraic representations.
Arizona Science Standards Addressed	• S5C2: TSW analyze the relationships between forces and motion.

Alien Ship

http://www.cybergooch.com/pages/tibsunarchive/alienship.htm

Alien Message:

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◊⁂✷☙✗☛.

©жж ¤ҹي

ỗΔж؛ж ₪ð̌

ﷲ♫▓L ╙⌂◙!

Alien Message Decoded:

On our way to ◊⁂✷☙✗☛.

See you there in 2.5 ╙⌂◘!

Last updated 8/5/2008

Lockheed SR-71 Blackbird

NASA Dryden Flight Research Center Photo Collection
http://www.dfrc.nasa.gov/gallery/photo/index.html
NASA Photo: EC94-42883-4 Date: December 1994 **USAF photo / Judson Brohmer**

SR-71 - In-flight from Tanker

Last updated 8/5/2008

Problem Solutions

c. The ship was spotted flying over Augusta, Maine at 0800 and was traveling 105 degrees west of north. A line extending from Augusta, Maine at 105 degrees west of north goes through, or comes close to, the following cities:

Montpelier, Vermont;
Toronto, Canada;
Milwaukee, Wisconsin;
Des Moines/Ames, Iowa;
Omaha, Nebraska;
Colorado Springs, Colorado;
Monticello, Utah;
Marble Canyon, Arizona;
San Bernardino, California; and
Los Angeles, California.

The ship could be heading to any of these cities.

e. The measured distance between August and Milwaukee is 3.16 inches. As indicated by the map's scale, 7/8 of an inch equals 300 miles. So the scaled distance between Augusta and Milwaukee is:

3.16 inches * (300 miles / 0.875 inches) = 1083 miles

f. The ship traveled this distance in 1.5 hours, so its velocity is:

1083 miles / 1.5 hours = 722 miles/hour

g. One gleep is 0.5536 hours, so 2.5 gleeps is (2.5)(0.5536) = 1.384 hours.
1.384 hours * 60 minutes/hour = 83.04 minutes
83.04 minutes after 0945 is 1108.

h. You already know the time between the receipt of the message and the landing time is 1.384 hours. Add the time between the Milwaukee sighting message receipt time (0945-0930 is 15 minutes, or 0.25 hours) to get 1.384 + 0.25 = 1.634 hours between the ship's departure from Milwaukee and its arrival at the landing site.

With a velocity of 722 miles per hour, the ship will have traveled
722 mph * 1.634 hours = 1179.748 miles.

i. Multiply the distance the ship traveled by the conversion factor of the map's scale to convert it to inches.

1179.748 miles * (0.875 inches/300 miles) = 3.44 inches, about 3 and 7/16 inches

Which city is 3 and 7/16 inches from Milwaukee? Monticello, Utah.

j. The measured distance between D.C. and Monticello is 5 1/6 inches, so 5.16 inches * (300 miles / 0.875 inches) = 1736 miles.

The Blackbird's actual average velocity is Mach 3.3, which is 3.3 times the speed of sound. If you use 770 miles per hour as the speed of sound, the Blackbird's velocity is:

3.3 * 770 miles per hour = 2541 miles per hour.

If, for instance, the students discovered the ship's destination by local time 1045, there would be 23 minutes before the ship arrived in Monticello. Multiply this by the conversion factor of 1 hour/60 minutes to find this time in hours:

23 minutes * 1 hour/60 minutes = 0.383 hours

The Blackbird would need to travel 1736 miles in 0.383 hours, which is a velocity of:

1736 miles / 0.383 miles = 4532 miles per hour.

Thus, because the Blackbird's actual velocity is less than the needed velocity, the President would not be able to arrive in time to meet the aliens before they land.

How quickly would the students need to finish in order to get the President there in time? The Blackbird can cover the 1736 miles in (1736 miles / 2541 miles per hour) = 0.683 hours. If the President will need 0.683 hours to arrive in Monticello, and must arrive before 1108, the Blackbird would have to leave on or before:

1108 – (0.683 hours * 60 minutes/hour) = 1108 – 41 minutes = 1027.

You can also have the students figure out how late/early the President will be, given the time they determined the alien ship's destination and using a similar problem-solving technique.

http://geology.com/world/the-united-states-of-america-map.gif

Skill Set 3:
College Prep Activities

MESA Mathematics Engineering Science Achievement

Lesson Activity

Title	**MESA CPW: College Essay Writing** (55-65 minutes)
ID Number	HS-CPW-1
Sequence and Duration	• Lead In (15 minutes) • Activity (30-40 minutes) • Closure (10 minutes)
Age Level	High School
Essential Question	**How can I write a college or scholarship essay that will strengthen my application?**
Learning Objectives	• TSW understand that context, purpose and audience for an essay shape its content. • TSW develop ideas and a rough draft for their own college application or scholarship essays.
Other Objectives	• TSW gain an awareness of college and scholarship application requirements. • TSW gain increased comfort and familiarity with the college essay and college going process.
Key Terms	• Context • Purpose • Audience • Topic
Materials Needed	Per Group: • Copies of college and scholarship applications that require essays – MESA scholarship, Gates Millennium scholarship, UA application, others of your choosing Per Student: • Handout: Dollars for Scholars • Handout: Tips from the Pros • Handout: Three Column Brainstorming • Handout: Seven Things to Remember When Writing Your Essay
Lead In	1. Circulate examples of MESA scholarship, Gates Millenium Scholarship and UA admissions applications for students to look at. Walk students through the application so that they become familiar with the types of information they will need to provide in the application form, including essays. Have students read aloud the essay topics and instructions to the class. Tell them that today you will be discussing how to use the essay section as a tool to strengthen their applications and help them stand out from the crowd. 2. Discuss the following with the students: • The **context** of the essay is an application form listing your name and identifying information, your grades and courses, your extracurriculars and awards, etc. Why do you think essays are requested in addition to all this other information? (Facilitator should try to draw out the point that many students who apply have taken the same courses and participated in activities; the essay makes the application more personal and gives a better sense of how applicants distinguish themselves in terms of character, values, goals, etc). • What do we know about the **audience** for the essay application? Try to help students imagine the person on the other end not as a gatekeeper but as someone who wants to help them by giving them money or admission to college: these are people who care about education and students and want a good reason to admit/give money to students who will be successful.

	They are also people who read A LOT of essays and will only remember an essay that is unique and personal. • What is the **purpose** for writing an essay for an application? Try to get students to come up with a statements in their own words that include not only the desired end result ("get a scholarship", "get admitted to the UA") but also includes statements about how the essay will help them do that ("by showing some of my best personal qualities" or "by talking about my unique goals" or "by distinguishing myself from other applicants with my essay").
Activity	1. Pass out the Dollars for Scholars handout and have a student read the instructions out loud. 2. Give students about 15-20 minutes to read the essays and decide together who they want to give scholarships to. 3. Have each group report which students they chose and why. 4. Hand out the Tips from Professionals handout and discuss how the groups' choices and reasons match or differ from the reasons given by the UA professionals. 5. If you have more time, have students choose a question from one of the applications to practice with. 6. Hand out the Three Column Brainstorming sheet and give students time to free-write a rough draft of their essay.
Closure	1. Hand out "Seven Things to Remember When Writing Your Essay". 2. Review the handout with the students and discuss any areas that students find interesting or confusing.
Informal Assessment	• Monitor students' participation in activity. • Monitor students for participation in discussion.
Formal Assessment	• Completed Decision Sheet. • Completed Brainstorming Sheet. • Free Writing.

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☒ Links to Background
- ☐ Links to Past Learning
- ☒ Strategies incorporated

Scaffolding
- ☐ Modeling
- ☐ Guided practice
- ☒ Independent practice
- ☒ Comprehensible input

Grouping Options
- ☒ Whole class
- ☒ Small groups
- ☒ Partners
- ☐ Independent

Integration of Processes
- ☒ Reading
- ☒ Writing
- ☒ Speaking
- ☒ Listening

Application
- ☒ Hands-on
- ☒ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☐ Individual
- ☒ Group
- ☒ Written
- ☒ Oral

Dollars for Scholars: You Decide!

Your group has three $1,000 college scholarships to award. All applicants have a 3.4 grade point average and have participated in three activities (sports, jobs, clubs, or volunteering). All of them have financial need. The only additional information you have about the students is a paragraph responding to the question "Tell us about how your experiences in high school have prepared you to pursue your goals." **You can only give money to three out of six applicants**. Your group must come to a consensus about which students to award money to and give your reasons for selecting or not selecting each student.

Student 1

Visiting my cousins in Chihuahua, Mexico each summer taught me to appreciate my U.S. high school in a new way. No longer could I take for granted all the opportunities offered at my school. While I was leading my team to a district basketball victory, my cousins were playing soccer in the street. Most of them drop out of school to work before they're 16. I have to work also, but my teachers help me before school so that I can keep my grades up. The differences between my life and my cousins' lives taught me to make the most of every opportunity I'm given, even when I'm not sure where it might lead me.

Student 2

I was voted MVP of my basketball team, served on the student council, maintained a 3.4 average, traveled to Honduras, and worked at a greenhouse after school. I'm really looking forward to being involved in these same activities on a university campus. I'm not sure what I want to be when I grow up, but I'm sure I'll do something interesting and I need college to do it. I took all the classes required for college to prepare. Thank you for considering me for this scholarship.

Student 3

As a student council representative, I like to be surrounded by people with a variety of backgrounds and interests. I would like to go to college because I think I'll meet people who are different from me. It's best to have a lot of variety in life and that includes among your friends and teachers. Meeting different people is something I'm really good at, so I think that my future classmates and instructors at college will be glad to meet me, too.

Student 4

After school I work a community senior center. In this job, I discussed baseball with a former coach who thinks he's Mickey Mantle, discussed the war in Iraq with a lady whose son is a soldier, and learned more than I ever wanted to know about another woman's cactus garden. I like to think my perspective as a young person trying to make her way in the world added something to there lives as well. My goal is to learn as much for the people I meet in college. They will open my eyes to even more interests and help me discover the best way to use my talents, and my interests will broaden their perspectives as well.

Student 5

I'd like to tell you about an experience that shaped my goals. My parents divorced and it was one of the hardest times of my life because I thought our family was very close. But I learned from this experience that it's important for everyone in a family to be happy and healthy, even if that family has to find new ways to interact with each other. We were able to overcome this difficult time by attending counseling together, and that's how I discovered my interest in psychology. I've always tried to help my friends and family to understand each other and communicate, and now I know the profession that's right for me.

(over)

Student 6
As my MESA team accepted an award, I glanced at my family in the audience. My father's slumped shoulders showed his fatigue after a hard day sanding and painting, yet I knew that, he'd never miss a chance to wrap his arm around my own shoulders to praise me after an event. My mother still wore her nursing uniform, and I knew that she would go home and wash my school uniforms for the next day. My parents may be tired, but I know they will never tire of supporting me. That kind of commitment motivates me to achieve my career as an engineer.

Record your decision about each student here:

Student Number	Decision	Reason

Tips from College Professionals

Here are the notes from a committee made up of actual University of Arizona employees who reviewed these fictional examples for Students 1-6:

Student Number	Decision	Reason
1	Awarded $1000	Essay conveys commitment to education and gives very specific examples of experiences that prepared and motivated the student.
2	No Award	The essay mainly repeats information listed in the application form without going into depth to answer the question. All applicants are prepared and want to go to college. We can't tell why this person is special or what other goals she has.
3	No Award	The student makes a statement about himself and has a good reason for wanting to go to college. Essay would have been strengthened by details that would show <u>how</u> the person interacts with others or how this quality is related to a specific goal.
4	No Award	This was a very tough call. This student's essay stood out because of the detailed descriptions and personal passion that came through. Some of us wanted to give this person an award. However, it also stood out for typos and spelling errors that others felt showed a lack of seriousness about this application. In the end, this applicant was not chosen.
5	Awarded $1000	It's difficult to write about such a personal topic as divorce and some of the committee thought this topic was not as appropriate as some others. However, the student does a good job of connecting this experience to a specific goal, so he was chosen for the scholarship.
6	Awarded $1000	Wow! This student's details were powerful and personal and nicely tied to the point about the hard work that will be required to achieve her goal.

Seven Things to Remember When Writing Your Essay

Making decisions about scholarships is subjective; there are no clear cut answers when many students are deserving of awards and resources are limited. That's why it's important for students to:

1. Make sure to answer the question that is asked.
2. Provide some information that expands on one particular aspect of your application you would like to emphasize.
3. Write about an experience or a topic that is truly meaningful to <u>you</u> and try to help your reader understand why it matters.
4. Give details and unique examples to support your main point. If the question is about you, make sure that your essay is one that only you could have written.
5. Pay attention to grammar and spelling—don't let that be the factor that distinguishes your otherwise great essay from another applicant's!
6. Even if an essay is optional, make sure to do it. This might be the only thing that sets you apart from another applicant.
7. Apply for a lot of scholarships. Essays seem like work, but they can really pay off. After all, how long would it take you to earn $1,000 or more in an after-school or summer job? Spend even one-fifth of that time on your applications and essays and you have a good chance of getting some awards.

Three Column Brainstorming

Instructions: Use this sheet to begin to think of ideas for your essay. After writing your essay question in the first row, use the first column to list one or two specific experiences, events or examples that come to mind. You're just warming up here, so just write the first things that come to mind and include all the details you can think of. Spend about 5-10 minutes.

In the second column, move from specific to general. What do these details mean? This might take 5-10 minutes also.

In the third column, try to write a sentence that sums up the ideas you've gotten from your brainstorming. Check to make sure this sentence answers the essay question. If so, you're ready to write a rough draft of your essay. If not, put this aside for a while and try again later.

Essay Question:		
Specific Experience, Event or Example (include details)	Qualities, Values, Goals represented by this event	Main idea of your essay:

MESA Mathematics Engineering Science Achievement

Lesson Activity

Title	**MESA CPW: College Track (60 minutes)**
ID Number	HS-CPW-2
Sequence and Duration	• Comfort Zone: 10-15 minutes • College Track: 35-40 minutes • Closure: 5-10 minutes
Age Level	High School
Essential Question	**What do I need to know to be on track for College Admissions?**
Learning Objectives	Comfort Zone • TSW will evaluate their knowledge of college admissions. College Track • TSW will become familiar with the ABOR Course Work Competency Requirements. • TWS will become familiar with their district's High School Graduation requirements. • TSW will become familiar with the Admissions Review Process. • TSW will learn common College Admissions terminology.
Other Objectives	• TSW will identify with other college-going students. • TSW will create a College Track 4-year plan. • TSW will establish goals for the next 1-4 years of high school.
Key Terms	• ABOR – Arizona Board of Regents • ABOR Course Work Competency requirements • AP – Advanced Placement • CLEP – College Level Examination Program • Assured Admission • Comprehensive Review
Materials Needed	• College Track Handout • UA Admissions Application • College Track Checklist • Rope, tape, or other materials to create large circles • Rolling Admissions Game board – 1 per student • Six-sided die – 1 per student
Lead In	Comfort Zone 1. Create two concentric circles on the floor, big enough for the students to step in and out of. 2. Explain that the inner circle represents "the comfort zone." This is a place where you know everything there is to know. Between the outer circle and the inner circle is "the challenge zone." This is the place where you know a little but need to learn more. Outside of the outer circle is "the starter zone." This is a place where you know nothing or almost nothing and need to learn the most. 3. Tell the students that you will announce a topic/category and they must pick which zone they belong to in that topic/category. 4. To make sure everyone understands, start off with some simple examples: tomorrow's lunch, addition of whole numbers, quantum physics, etc. 5. End the examples with College Admissions. After the students have selected their zone, let the students know that this is today's topic. Have them look around to see where everybody is, identify if everyone is in the same boat, if there are students who could be resources for other students, and which students may need the most guidance from their peers. 6. Continue activity with the following:

	• High School Graduation Requirements • ABOR Course Competency Requirements • Assured Admissions Requirements • PSAT and/or SAT • ACT 7. Inform everyone that after today everyone should be on the edge of the comfort zone if not in it with regard to College Admissions.
Activity	College Track 1. Hand out MESA Notebook. 2. Ask students to assemble into groups of 3 to 4 students. 3. Tell students to create two lists in the Procedure portion of their MESA Notebook. The first list will be their high school graduation requirements. The second list will be the courses required for admission to UA. 4. Give the students 5 minutes to discuss and create these lists. 5. After 5 minutes, ask the students to share their lists and write down their responses on the board. 6. Hand out College Track handout and compare them to what the students listed. Discuss with the group why there may be differences and where misinformation can come from. Remind them that part of reaching your goals is having complete and accurate information. 7. Ask the students to share their responses for UA admission and write their responses on the board. 8. Hand out UA Admissions Application for 2007-2008. Ask students to find the page that lists the ABOR Course Competency requirements. Explain what ABOR is and how these requirements apply to all in-state public universities. Ask the students to write down ABOR and the ABOR Course Competency Requirements in their MESA Notebooks as terms. 9. Compare student responses to actual requirements. Make sure the students understand that these requirements ensure that the students will be admissible to any in-state university but that they are not excluded from admission if they do not meet the requirements. 10. Review and discuss the assured admissions and comprehensive review sections of the application. 11. Handout "Rolling" Admissions game and dice to students. 12. Play game until everyone completes a game card. 13. Ask students if anyone ended in comprehensive review. 14. Discuss what they would need to improve their chances of admission. Ensure that students cover extra-curricular activities, honors/AP courses, leadership experience, work experience, college entrance exam scores and the personal statement. 15. Hand out College Track Checklist and inform the students that they will be creating a 4-year plan to ensure that they are on the College Track (on track to meet high school and ABOR course competency requirements).
Closure	1. Hand out College Track checklist to students. 2. Ask the students to take this home and complete it with their parents and create a 4-year plan to stay on the College Track. 3. Ask the students to answer the following questions in the 'conclusion' section of their MESA Notebook: What will my biggest challenge be in completing the college track? What can I do to meet that challenge?
Informal Assessment	• Monitor students to check for engagement. • Monitor students to check for understanding.
Formal Assessment	• Completed MESA Notebook • Completed "Rolling" Admissions Game • Completed College Track Check list
Trouble Shooting	• Make sure students are participating in the game, if not with the group then on paper. • Keep an eye on the time. Shorten discussions if necessary to stay on task. • Have seniors and/or juniors present workshops to engage them in the activity.
Extension	• Take a more in-depth look at Admissions application

	• Have students complete mock UA admissions applications and bring in an admissions representative to review them for "admission". • Have a discussion about taking more than the minimum requirements for major-specific content areas (i.e. 4th year of science for science majors, additional year of fine arts for fine arts majors). • Discussion of alternate way to meet requirements per Admission Applications.

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☐ Links to Background
- ☐ Links to Past Learning
- ☐ Strategies incorporated

Scaffolding
- ☐ Modeling
- ☐ Guided practice
- ☒ Independent practice
- ☐ Comprehensible input

Grouping Options
- ☒ Whole class
- ☒ Small groups
- ☐ Partners
- ☒ Independent

Integration of Processes
- ☒ Reading
- ☒ Writing
- ☒ Speaking
- ☒ Listening

Application
- ☒ Hands-on
- ☒ Meaningful
- ☐ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☐ Individual
- ☒ Group
- ☒ Written
- ☐ Oral

"Rolling" Admissions

ABOR Course Competency		2.0	Extra
English (4)	☐ ☐ ☐ ☐	☐	
Math (4)	☐ ☐ ☐ ☐	☐	
Science (3)	☐ ☐ ☐ ☐	☐	
Soc Studies (2 + 1_{HS})	☐ ☐ ☐ ☐	☐	
Foreign Language (2)	☐ ☐ ☐ ☐	☐	
Fine Arts (1)	☐ ☐ ☐ ☐	☐	
	Top 25%	☐	

☐ **HS Grad –** Did you meet your graduation requirements? Assume you have all of your electives.

☐ **ABOR Course Competency –** Have you taken all 16 course competency requirements?
Engl – 4, Math – 4, Science – 3, Social Studies – 2, Foreign Language – 2, Fine Arts – 1

☐ **Assured Admission –** Did you meet course competency requirements, a minimum 2.0 GPA in each subject area, and are you in the Top 25% of your class? If so, congratulations, you are assured admission to the UA!

☐ **Comprehensive Review –** If you did not get assured admission, don't worry, you can still be admitted to the University. In fact, most of this year's freshman class was admitted through comprehensive review. Let your admissions application prove you are college-ready.

Rules:

Units

1. Roll a six-sided die
2. Result = # of units available
3. Choose a course competency category and use as many of the available units you would like. Place any left over units into the extra box.
   (example - If you roll a 5, you could put 4 units into Math and the remaining unit would go into extra.)
4. Repeat steps 1-5 until you have rolled for each course competency category.
5. Use the Extra to complete your course competency for university admissions and high school graduation
   (example – Your extra Math unit could be used to complete your Science units if you rolled a 2 for Science.)

Grades

6. Roll the die once for each course competency category.
7. If you roll at 2, 3, 4 or 5 put a check in the 2.0 box for that category.
8. If you roll a 6, check the 2.0 box for all categories and check the TOP 25% box. Congrats Brainiac! Skip to step 10.
9. Repeat steps 6 and 7 until you have rolled for each competency category or have rolled a six.

Graduation & Admissions

10. Complete the checklist.

College Track Checklist

College Track Courses

*Required for College Track (High School Graduation & University Course Competency)

English	Class	Grade	Honors/AP
*1.			
*2.			
*3.			
*4.			
	GPA		

Math	Class	Grade	Honors/AP
*1.	Algebra 1		
*2.	Geometry		
*3.	Algebra II		
*4.			
	GPA		

Science	Class	Grade	Honors/AP
*1.			
*2.			
*3.			
4.			
	GPA		

Social Studies	Class	Grade	Honors/AP
*1.	American History		
*2.			
*3.			
4.			
	GPA		

Foreign Language	Class	Grade	Honors/AP
*1.			
*2.			
3.			
4.			
	GPA		

Fine Arts	Class	Grade	Honors/AP
*1.			
2.			
3.			
4.			
	GPA		

Electives

1.		7.
2.		8.
3.		9.
4.		10.
5.		11.
6.		12.

Last updated 8/5/2008

The University of Arizona
Office of Early Academic Outreach
District Graduation & University Admission Requirements

Amphitheater

Required Classes	Middle School Units/Years	High School Graduation Requirements Units/Years	University Admission Requirements Credits/Years	College Track High School Graduation & University Admission Requirements
English	3.0	4.0	4.0	4.0
Math	3.0	2.0/3.0*	4.0	4.0
Science	3.0	2.0/3.0*	3.0	3.0
Social Studies American Economic Systems U.S. / Arizona Government U.S. / Arizona History World History/ Geography	3.0	0.5 0.5 1.0 1.0 3.0	2.0 American History Required	3.0
Foreign Language	Determined by School	N/A	2.0 Same Language	2.0 Same Language
Fine Arts or Vocational Ed	Determined by School	1.0	1.0 Fine Arts Only	1.0 Fine Arts Only
Physical Education	Determined by School	1.5	N/A	1.5
Electives	Determined by School	6.5	N/A	6.5
Total Units/Credits/Years	**Total Determined by School**	**20.0**	**16.0**	**25.0**

* 3.0 units will be required for the Class of 2010 and all subsequent classes.

NOTE: The requirements stated above are the minimum district requirements. Each middle and high school has the flexibility to add other classes to their curriculum. Honors and AP classes are highly recommended for college preparation.

Last updated 8/5/2008

The University of Arizona
Office of Early Academic Outreach
District Graduation & University Admission Requirements

Flowing Wells

Required Classes	Middle School Units/Years (7th & 8th Grade Only)	High School Graduation Requirements Units/Years "Blue Diploma"	University Admission Requirements Credits/Years	College Track High School Graduation & University Admission Requirements "Gold Diploma"
English	2.0	4.0	4.0	4.0
Math	2.0	3.0	4.0	4.0
Science	2.0	2.0	3.0	3.0
Social Studies Global Studies, Economics, U.S. History and U.S. Government	2.0	3.5	2.0 American History Required	3.5
Health / Driver's Ed / Life Rec	N/A	1.0	N/A	1.0
Foreign Language	Determined by School	1.0	2.0 Same Language	2.0 Same Language
Fine Arts or Vocational Ed	Determined by School	1.0	1.0 Fine Arts Only	1.0 Fine Arts Only
Physical Education	2.0	N/A	N/A	N/A
Learn to Learn	2.0	N/A	N/A	N/A
Electives	Determined by School	6.5	N/A	6.5
Total Units/Credits/Years	**Total Determined by School**	**22.0**	**16.0**	**25.0**

NOTE: The requirements stated above are the minimum district requirements. Each middle and high school has the flexibility to add other classes to their curriculum. Honors and AP classes are highly recommended for college preparation.

The University of Arizona
Office of Early Academic Outreach
District Graduation & University Admission Requirements

Indian Oasis

Required Classes	Middle School Units/Years	High School Graduation Requirements Units/Years	University Admission Requirements Credits/Years	College Track High School Graduation & University Admission Requirements
English	3.0	4.0	4.0	4.0
Math	3.0	3.0	4.0	4.0
Science	3.0	2.0	3.0	3.0
Social Studies U.S. History, AZ Govt, Free Enterprise, World History, Tohono O'odham History (1/2)	3.0	4.0	2.0 American/U.S. History Required	4.0
Foreign Language Tohono O'odham	Determined by School	N/A	2.0 Same Language	2.0 Same Language
Health	Determined by School	.05	N/A	.05
Driver's Education	N/A	.05	N/A	.05
Fine Arts or School To Work	Determined by School	1.0	1.0 Fine Arts Only	1.0 Fine Arts Only
Physical Education	Determined by School	1.0	N/A	1.0
Electives	Determined by School	6.0	N/A	6.0
Total Units/Credits/Years	**Total Determined by School**	**22.0**	**16.0**	**26.0**

NOTE: The requirements stated above are the minimum district requirements. Each middle and high school has the flexibility to add other classes to their curriculum. Honors and AP classes are highly recommended for college preparation.

The University of Arizona
Office of Early Academic Outreach
District Graduation & University Admission Requirements

Nogales

Required Classes	Middle School Units/Years	High School Graduation Requirements Units/Years	University Admission Requirements Credits/Years	College Track High School Graduation & University Admission Requirements
English	3.0	4.0	4.0	4.0
Math	3.0	2.0	4.0	4.0
Reading	3.0	Built into English classes	N/A	N/A
Science	3.0	2.0	3.0	3.0
Social Studies U.S. /Arizona History World History / Geography U.S./Arizona Government & Free Enterprise	Determined by School	1.0 1.0 <u>1.0</u> 3.0	2.0 American History Required	3.0
Foreign Language (Spanish)	Determined by School	1.0	2.0 Same Language	2.0 Same Language
Fine Arts or Vocational Ed	Determined by School	1.0	1.0 Fine Arts Only	1.0 Fine Arts Only
Physical Education	Determined by School	1.0	N/A	1.0
Computer Class	Determined by school	1.0	N/A	1.0
Electives	Determined by School	7.0	N/A	6.0
Total Units/Credits/Years	**Total Determined by School**	**22.0**	**16.0**	**25.0**

NOTE: The requirements stated above are the minimum district requirements. Each middle and high school has the flexibility to add other classes to their curriculum. Honors and AP classes are highly recommended for college preparation.

Last updated 8/5/2008

The University of Arizona
Office of Early Academic Outreach
District Graduation & University Admission Requirements

Sunnyside

Required Classes	Middle School Units/Years	High School Graduation Requirements Units/Years	University Admission Requirements Credits/Years	College Track High School Graduation & University Admission Requirements
English	3.0	4.0	4.0	4.0
Math	3.0	2.0	4.0	4.0
Science	3.0	2.0	3.0	3.0
Social Studies U.S. and Arizona History World History / Geography American Government American Economic Institutions	3.0	1.0 1.0 0.5 0.5 3.0	2.0 American History Required	3.0
Foreign Language	Determined by School	N/A	2.0 Same Language	2.0 Same Language
Fine Arts or Vocational Ed	Determined by School	1.0	1.0 Fine Arts Only	1.0 Fine Arts Only
Health	Determined by School	0.5	N/A	0.5
Physical Education	Determined by School	1.0	N/A	1.0
Electives	Determined by School	6.5	N/A	6.5
Total Units/Credits/Years	**Total Determined by School**	**20.0**	**16.0**	**25.0**

NOTE: The requirements stated above are the minimum district requirements. Each middle and high school has the flexibility to add other classes to their curriculum. Honors and AP classes are highly recommended for college preparation.

Last updated 8/5/2008

The University of Arizona
Office of Early Academic Outreach
District Graduation & University Admission Requirements

TUSD

Required Classes	Middle School Units/Years	High School Graduation Requirements Units/Years	University Admission Requirements Credits/Years	College Track High School Graduation & University Admission Requirements
English	3.0*	4.0	4.0	4.0
Math	3.0*	3.0	4.0	4.0
Science	3.0*	2.0	3.0	3.0
Social Studies American & Arizona History American & Arizona Constitutions Government World History / Geography	3.0*	3.0	2.0 American History Required	3.0
Foreign Language	Determined by School	N/A	2.0 Same Language	2.0 Same Language
Fine Arts or Vocational Ed	Determined by School	1.0	1.0 Fine Arts Only	1.0 Fine Arts Only
Physical Education	Determined by School	1.0	N/A	1.0
Health	Determined by School	0.5	N/A	0.5
Electives	Determined by School	6.5	N/A	6.5
Total Units/Credits/Years	**Total Determined by School**	**21.0**	**16.0**	**25.0**

*3 years recommended

NOTE: The requirements stated above are the minimum district requirements. Each middle and high school has the flexibility to add other classes to their curriculum. Honors and AP classes are highly recommended for college preparation.

MESA Mathematics Engineering Science Achievement ®

Lesson Activity

Title	**MESA CPW: Test Taking Skills (2 sessions, 60-80 minutes)**
ID Number	HS-CPW-3
Sequence and Duration	Session 1 • Lead In: Test of Knowledge (10-20 minutes) • Activity: Test-Taking Strategies Review (30 minutes) • Closure (5 minutes) Session 2 • Who Wants to Be a Millionaire Game (60-80 minutes)
Age Level	High School
Essential Question	**What test-taking strategies can I incorporate to help me do well?**
Learning Objectives	• TSW learn test-taking strategies to use on tests, • TSW increase their familiarity with College Admissions Tests.
Other Objectives	• Recognize test anxiety and how to overcome it.
Key Terms	• Standardized Tests: tests administered and scored in a consistent manner. • AIMS – Arizona Instrument to Measure Standards • PSAT – Preliminary SAT • SAT – standardized test for college admissions in the U.S. • ACT – standardized test for college admissions in the U.S.
Materials Needed	Per group • Easel Paper – 2 sheets • Markers • 1 portion of "Before, During and After; Test Taking Strategies" handout Per student • Copy of "Test of Knowledge" handout • Copy of "Before, During and After; Test Taking Strategies" handout • Copy of MESA Notebook handout • Copy of "Overview of Standardized Tests" handout • Copy of "SAT or ACT" handout
Lead In	**Test of Knowledge** 1. Ask the students to take out a pen or pencil and clear their desks. 2. Tell them that they are being given a surprise quiz. 3. Hand out the "Test of Knowledge." As you are passing it out, make sure you stress to them that they must clearly read the instructions. They can't talk to anyone in the room and they have only 10 minutes to finish the test. 4. Observe the students….move on when all of the students have read the last question and caught on that this was a fake test. 5. Ask the student what the purpose of the exercise was. Write down responses. 6. Explain to the students the importance of reading through all of the instructions and understanding a test before taking it!! 7. Handout the MESA Notebook and have students fill in their

	name, date, and put Test-Taking Strategies in the title box. 8. Ask the students how they felt when you announced the surprise quiz and why. Remind them that MESA is extra-curricular and no grade is given, but point out that they still had some test anxiety. 9. Have a brief discussion about the purpose of tests and how students feel about them. Have the students write down their answer in the procedure portion of their MESA Notebook. This will help you gauge where your students are in terms of test-taking skills and anxiety. 10. Have them write Improving Test-Taking Strategies in the purpose portion of their MESA Notebook. [Note: It might be an interesting bonus to actually research the answers to the Knowledge Test questions ahead of time, in case some students are truly curious about some of the answers. (Amaze them with your impressive collegiate smarts!)]
Activity	**Test-taking Strategies Review** 1. Ask the students what kinds of tests they are or will be taking while in high school and list them on the board. Make sure that they include standardized tests such as AIMS, PSAT, SAT, ACT and AP. Have them also list other tests that they may face (i.e. driver's test, fine arts/sports tryout). Have the students write these in the key terms of their MESA Notebook. Make sure they include the term "Standardized Test" – Def: A test that is administered to a broad group of people to measure their knowledge in the test subject and make comparisons to the rest of the group. 2. Tell the students that although there are a number of different tests they will be taking, they all have one thing in common. "In order to do well on them, you will need to use good test-taking strategies." 3. Have the students break up into four groups. 4. Give each group one portion of the "Before, During and After" Handout. The four portions are: before, test day, during, and after. 5. Tell them that they are going to play four truths and a lie. 6. They will need to pick four of the strategies on the list and make up one to try and fool the rest of the group. Note: If interested you can keep score to see which group identifies the most lies or which had the best lie and give those students a small prize. 7. Give the students 10 minutes to prepare their lists 8. When time is up, give each group 3-5 minutes to present their tips and then allow the other groups to guess the lie. 9. After every group has gone, hand out the "Before, During, and After: Test Taking Strategies" handout to the students. Highlight any strategies you feel need to be mentioned that were not covered during the exercise. 10. Remind the students that these strategies can be used on any test. 11. Also, remind the students that sometimes what they learn from the mistakes they made on the test is more important then the test itself.
Closure	1. Hand out the "Overview of Standardized Tests" and "SAT or ACT" handouts

<table>
<tr><td></td><td>
2. Remind the students that these tests are important for college admissions and that they will need to prepare for them by learning more information about the tests.
3. Tell them that free practice tests are available for each test and they should at minimum take one of these to familiarize themselves with the test and figure out which one is best for them.
4. Also, remind them that they can take the office’s PSAT/SAT Preparation Workshop for free.
5. Tell the students that in order to help them practice their test prep strategies they will be tested at the next meeting on all of the handouts from today. The test will be in the format of the “Who Wants to be a Millionaire” game show.
</td></tr>
<tr><td>Informal Assessment</td><td>
• Monitor students to check for engagement.
• Monitor students to check for understanding.
</td></tr>
<tr><td>Formal Assessment</td><td>
• Completed MESA Notebook.
</td></tr>
<tr><td>Trouble Shooting</td><td>
• The “Test of Knowledge” can be removed to save time or allow more time for review of the Standardized Tests handouts.
• If there are too many students for four groups, assign the larger portions of the test taking-strategies to more than one group.
• This workshop can be done over two days to provide a more in-depth review of standardized tests.
• Use your juniors and or seniors to lead the activity or have small group discussions with your underclassmen.
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<tr><td colspan="2">
SEI Strategies Used

Preparation
☐ Adaptation of Content
☒ Links to Background
☒ Links to Past Learning
☒ Strategies incorporated

Scaffolding
☐ Modeling
☒ Guided practice
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☐ Comprehensible input

Grouping Options
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☐ Independent

Integration of Processes
☒ Reading
☒ Writing
☒ Speaking
☒ Listening

Application
☐ Hands-on
☐ Meaningful
☐ Linked to objectives
☐ Promotes engagement

Assessment
☐ Individual
☐ Group
☐ Written
☐ Oral
</td></tr>
</table>

Test of Knowledge

Directions: This test is a measure of your intelligence. This test does not reflect in any way your ability to succeed at the college level. However, it may show a need for improvement. Read through all questions before answering. This test will be timed. Work efficiently and you will have no problem answering the questions. Pace yourself. Good Luck!

1. What is the chemical formula for sugar?

2. How many bases are on a football field?

3. 3+5=

4. Write a paragraph on the telephone.

5. Who invented oranges?

<u>Test of Knowledge – page 2</u>

6. How many presidents has the United States had?

7. How much memory does a computer have?

8. How much wood could a woodchuck chuck if a woodchuck could chuck wood?

9. What is the square root of 52,498,754,223,687,000,215?

10. Do not complete this test. Simply put your name on your paper and begin tapping your pen/pencil on your desk.

MESA Mathematics Engineering Science Achievement

Before, During, and After the Test

Test Taking Strategies

Before the test

- Write the test date in your planner.
- Begin review at least two weeks before the test.
- What type of test will it be? (Multiple choice, essay, etc.) Each test requires a different skill.
- What will the test cover? Does it only cover material from the last exam? Ask your teacher what concepts are most important, which chapters to focus on, and if possible, request sample test questions.
- Pay special attention in class because your teacher will often mention specific items that will or will not appear on the test.
- Make a study checklist of the areas that you need to cover. Make a list of readings that you have yet to do (especially if you are short on time). Based on your assessment of what the test will cover, decide what to study and what to skip.
- Review your notes to see if there are any areas discussed in class with which you are unfamiliar. See your teacher individually or ask questions in your next class.
- Highlight or indicate possible test questions that you find while reviewing class notes and textbook readings.
- Assign time to study the information for the test each day, increasing the time as the test approaches. Setting aside a part of each day for study (called "chunking") helps you to avoid last minute cram sessions.
- Prevent fatigue by studying in small blocks of time from 50 minutes up to 90 minutes. Make sure to take a 10 minute break after the block is up.
- Organize each study session. Categorize and prioritize material that you need to review.
- Separate your homework from what you need to study.
- Review chapters in your textbook and your notes from class, and create self-test questions. Study the most difficult information first.
- If you notice that you are procrastinating, get started. Reward yourself for starting.

- Work with study partners and study groups only AFTER you have reviewed and prepared for the test on your own.
- Think positively.
- Briefly review the material the night before the test and get a good night's sleep.

<u>On Test Day</u>

- Try to eat a light nutritious snack or meal before the exam. This may help calm your stomach and give you energy. Avoid greasy or acidic foods, caffeine pills, and overeating.
- Exercise an hour or two before a test. This will most definitely reduce your stress level.
- Be well rested.
- Take a shower (warm water can relax you and cold water will stimulate).
- Give yourself enough time to get to the test without hurrying. Arrive on time.
- Wear comfortable clothing. Layers will help you be prepared for both hot and cold rooms.
- Be prepared with all necessary supplies (pencils, scratch paper, watch). Consider taking a brief outline that you know well with you to class on the day of the test and leave your textbooks at home. Reviewing last minute can be upsetting.
- Clear your mind of all other thoughts and worries. Develop a positive attitude—you can only do your best.

<u>During the Test</u>

- Anxiety is contagious so avoid anxious students before the test.
- Sit in your regular seat, if possible. Sit close to the front and away from distractions such as windows, doors, and other students.
- Tell yourself that you will do your best on this test and try to relax.
- Listen carefully to all verbal instructions and read all directions.
- If you are allowed to write on the test and you are afraid you will forget something, list this information on the back of your test.
- Skim through the entire test, then budget your time according to the number of questions and time allotted.
- Read each question carefully. Circle or underline key words. Ask your teacher to explain unclear questions.
- Answer the <u>easiest</u> questions first and save the most difficult for last. Acknowledge that you may not know all of the answers. Focus on what you do know rather than on what you don't.

- Think before you write. Do not be concerned if other students are writing and you aren't.
- Do not panic! If you cannot remember an answer, skip it, return to it later, and if you must, just guess (if possible, eliminate the answers you know are wrong and guess from those that are left).
- If you find that you are nervous or anxious during the test, close your eyes and take a deep breath.
- Make sure you mark your answer sheet correctly and never leave a blank on the exam.
- Do not worry if other students complete their tests before you do. Use as much time as you are allowed.
- Look over your exam before you turn it in. DO NOT change answers unless you are **very** sure that your first answer is incorrect.

<u>After the Test</u>

- Reward yourself for taking and surviving the test.
- Analyze your performance in terms of the test-taking strategies you used.
- Give yourself credit for what you did right.
- Identify the reason you made any mistakes on the test.
  - Mastery of Information: You didn't study properly and don't know the material.
    Correcting "mastery of information" mistakes:
    - Go back and look at how you studied. What do you need to change? Did you give yourself enough time? Are there other study strategies that would work better?
  - Thinking Gap: You misunderstood what you were being asked.
    Correcting "thinking gap" mistakes:
    - Next time, raise your hand and ask your teacher to rephrase the question.
    - Keep asking until you feel that you fully understand the question.
  - Method of Test Taking: You made some bad mistakes like reading too quickly and missing key words.
    Correcting "method of test taking" mistakes:
    - Read/listen to the directions carefully
    - Force yourself to slow down and read the questions carefully
    - Identify the key words in the questions
    - Read all answers before you select one
  - Reaction to Situation: Test anxiety got the better of you.
    Stress reduction and management:
    - Have a study plan
    - Get some exercise

    - Proper nutrition
    - Keep a positive attitude
    - Get enough rest
- Apply what you’ve learned:
    - Get a copy of a test that you’ve already taken
    - Code your mistakes using the categories we’ve discussed
    - Describe how you plan to address these mistakes in the future
    - Determine the source of the question you missed (class notes, textbooks).

SAT or ACT – Which Test Should I Take?

What are the SAT and ACT?

The SAT and ACT are both college admissions tests. Most four-year universities require one of these tests as a part of the admissions process. These tests are used to gauge a student's academic preparation in comparison with other incoming freshmen. They may also be used for merit-based scholarship decisions. Community colleges do not normally require the SAT or ACT for admission. In Arizona, community colleges do not require these tests. The three Arizona universities, ASU, NAU and UA, will accept either the SAT or ACT.

How many times can I take the SAT or ACT?

Students may take either or both tests as often as they wish. However, scores do change, and while scores of nearly two-thirds of test takers rise, some decline. We recommend that students take the SAT or ACT at least two times: first, in the spring of the junior year and second, in the fall of the senior year. These tests are administered in Tucson from September through June. Testing dates and locations will vary. Students should contact their school counseling office or go online to ***actstudent.org*** or ***collegeboard.com*** for more details on dates, registration, and test locations.

Which test should I take?

Determine if the college in which you are interested requires a specific test for admission. Since most colleges will accept either test, look at both tests to see which one would be best for you.

The SAT measures readiness to learn and is less school-related. It tests for critical thinking skills and logical reasoning. It is divided into three sections – critical reading, math and writing. The types of critical reading questions are sentence completion and passage-based reading. The math portion has four categories of questions: number and operations; algebra & functions; geometry & measurement; and data analysis, statistics & probability. There are some grid-in math questions (where you work out the answer). A calculator can be used during the math section. The writing section has questions on improving sentence errors, improving sentences, and improving paragraphs, as well as an essay. The SAT has a penalty for wrong answers (except the grid-in math answers), while the ACT does not.

The ACT is a curriculum based test. Most students find the ACT more closely related to the work done in high school classes. The ACT consists of 215 multiple choice questions divided into four parts: English, Math, Reading and Science Reasoning. The ACT tests English grammar, while the SAT does not. The math portion includes trigonometry. The science portion presents seven sets of scientific information, each followed by a number of multiple choice questions. The writing portion of the ACT is optional.

How can I prepare for the tests?

The best preparation for the SAT and ACT is a solid college prep curriculum in high schools. Test booklets with sample questions and tests are provided by SAT and ACT with the registration materials and on ***actstudent.org*** and ***collegeboard.com***. Use this information to determine the best test for you. When in doubt, take both tests and compare scores. Remember, each test has a deadline for registration. Please go to your high school counseling office for questions regarding these tests and the registration process.

There are a number of other organizations who also provide SAT or ACT preparation programs. Most students find these programs help improve scores. The Office of Early Academic Outreach at The University of Arizona offers PSAT and SAT preparation workshops. These workshops are free for MESA students. Please call (520) 626-2300 for more information.

MESA Mathematics Engineering Science Achievement

	SAT I	ACT
Test Fee		
	$43.00 Includes Score Reports Sent to 4 Colleges or Universities	**$30.00** (plus $14.50 for optional writing section) Includes Score Reports sent to 4 Colleges or Universities
Test Content		
	Critical Reading – 33% Sentence Completions Reading Comprehension Paragraph-length Critical Reading **Math – 33%** Number and Operations Algebra and Functions Geometry and Measurement Data Analysis, Statistics, and Probability **Writing – 33%** Improving Sentence Error Improving Sentences Improving Paragraphs Essay	**English – 25%** Measures standard written English and rhetorical skills. **Math – 25%** Measuring mathematical skills students have typically acquired in courses taken up to the beginning of grade 12. **Science– 25%** Measures the interpretation, analysis, evaluation, reasoning, and problem-solving skills required in the natural sciences. **Reading – 25%** Measures reading comprehension. **Writing (optional)** Measures writing skills emphasized in high school English classes and in entry-level college composition courses.
Test Purpose		
	Measures developed verbal and mathematical reasoning abilities related to successful performance in college.	Measures academic achievement in English mathematics, science, and reading; contains analytical and problem solving exercises.
Scoring Method		
	Scores based on the number of questions answered correctly, minus a fraction for wrong answers. No reward for haphazard guessing. No penalty for wrong answers on grid in mathematics questions.	Scores based on number of right answers. No penalty for guessing. Multiple choice only (except optional writing test)
Test Score Scales		
	Critical Reading: 200 – 800 Mathematics: 200 – 800 Writing Skills: 200 – 600 (essay sub score: 0, 2 – 12)	English: 1 – 36 Reading: 1 – 36 Mathematics: 1 – 36 Science Reasoning: 1 – 36

SAT I Total: 600 – 2400
(Sum of scores on each section)

ACT Composite: 1 – 36
(Average of 4 Test Scores)

Overview of Standardized Tests

Test Name	Purpose	Grade Levels	Subjects Covered	Test Format	Scoring	Date Administered	Test Fee
Stanford 9 (Spanish version: Aprenda)	Arizona students are compared to a national group of students in the same grade level.	2 - 11	Reading Language Math	Multiple choice	50% rank = average performance per subject & composite score	April 1 - May 1 Dates determined by school district Application Deadline: None	None
***AIMS** (Arizona's Instrument to Measure Standards)	Measures a student's progress in comparison to Arizona's Academic Standards set by the AZ Dept. of Education.	3, 5, 8,10, 11,12	Reading Writing Math	Multiple choice and short-answer plus an essay question or extended writing piece in the Writing portion of the test	500 points per subject area	Late March – April Dates determined by school district Application Deadline: None	None
***PSAT**	Practice for SAT and qualifying test for National Merit Corporation Scholarships.	10, 11	Critical Reading Math Writing	Multiple choice and math problem solving responses	Verbal 20-80 Math 20-80 Writing 20-80	Fall Only Application Deadline: See school counselor	$13.00
***SAT** SAT I: Reasoning SAT II: Subject	College Entrance Exam for University Admission and Merit Scholarships	11, 12	Critical Reading Math Writing	Multiple choice and math problem solving responses Written essay	Critical Reading 200-800 Math 200-800 Writing 200-800 Total: 600-2400 Penalty for wrong answers.	Fall & Spring Seniors must take test before October 1 for early college admission and scholarship consideration Application Deadline: See school counselor	$43.00
***ACT**	College Entrance Exam for University Admission and Merit Scholarships	11, 12	English Math Reading Science	Multiple choice plus analytical and problem solving exercises Optional essay	Scores based on correct answers. NO penalty for guessing.	Fall & Spring Seniors must take test before October 1 for early college admission and scholarship consideration Application Deadline: See school counselor	$30.00 (plus $14.50 for optional writing)

*See notes on the reverse side of this page.

Overview of Standardized Tests – page 2

***NOTES:**

AIMS:

- AIMS test administered on an annual basis over a 3-day period. No make up tests available after scheduled test dates. If a student is absent during an AIMS test date, the student must wait until the following year to take the test.

- Spanish version of AIMS test available for grades 3, 5, & 8 only. Spanish version can be taken only once during these grades. All other subsequent tests, after the first Spanish version, are administered in English. The Spanish version is not a direct translation. No Spanish version is available at the high school level.

- No calculators allowed for the math section.

- Not a timed test. Students complete each subject area in an average of 2.5 - 3.0 hours.

a) Elementary/Middle School:

- AIMS test administered only in the spring.

b) High School:

- All high school students, effective beginning with the class of 2006, must demonstrate proficiency in each subject area of the AIMS test in order to receive a high school diploma.

- Entire AIMS test administered during the spring semester to all 10th graders. 11th and 12th graders are permitted to retake sections of the test in which they received low scores.

PSAT/SAT:

- The UA Office of Early Academic Outreach provides PSAT/SAT Workshops throughout the fall and spring semesters each year. Contact their office for more information on workshop dates at (520) 626-2300.

- For more information about the PSAT/SAT refer to *www.collegeboard.org*.

ACT:

- For more information about the ACT refer to *www.actstudent.org*

ADDITIONAL NOTES:

- It is highly recommended that sophomores take the PSAT
- It is highly recommended that all juniors and seniors take the SAT and/or ACT before October 1 of their senior year.
  Early test scores are required for early college admission and merit scholarship decisions.

Who Wants to be a Millionaire?

Test Preparation: Standardized Tests & General Strategies version

Game Rules

Setup:

- Chalk or White board with columns for Dollar amount and four teams; U, A, Blue, Red
- Rows for dollar amounts of; $1,000; $8,000; $16,000; $32,000; $64,000; $125,000; $250,000; $500,000; $1,000,000**.** The $16k, $64K, and $250K rows should be starred (*) as safe spots.
- Lifeline cards: see Excel spreadsheet for template.
- Game cards or print-out for questions.

Play:

- Divide the students into a maximum of 4 groups. There are four teams possible: the "U" team, the "A" team, the "Blue" team and the "Red" team. There is a game piece for each of these teams.
- Each team receives 2 lifeline cards: an "Ask the Team" and a "Hint". Each team gets a $1,000 question; if they are correct, place a checkmark on the $1,000 column.
- When all teams have had one turn, the next round will begin. If a team should miss a question, they are not out of the game...they go back to the beginning and start again, or to the last "safe" space they passed.
- The gold sticker pockets are the "safe" places. Once that level of "money" has been won, it cannot be lost even if a question is answered incorrectly at a higher level.
- Whichever team reaches $1,000,000 first or has the highest number of points at the end of the allotted time wins.

Lifelines: Each team gets one of each lifeline card per game.

(Advisors need to be creative and come up with the hints; they are NOT provided for you.)

Ask the Team: The advisor will restate the question and the team will be allowed to confer and decide on an answer. The team will have one minute to decide.

Hint: The player would be given a hint by the advisor.

	1,000 What is the SAT? *Answer:* College entrance exam for university admission and merit scholarships.
	8,000 What high school grade levels should take the PSAT? *Answer:* Grades 10 and 11.
	16,000 What is one way to avoid anxiety before the test? *Answer:* Be prepared, know what to expect
	32,000 Name three college entrance tests that have a fee. *Answer:* PSAT, SAT, and ACT
	64,000 What does the SAT measure? *Answer:* *A student's reasoning and problem solving skills*

	125,000 What is the purpose of the AIMS test? *Answer:* Measures a students progress in comparison to AZ Academic Standards set by the AZ Dept ofEducation
	250,000 What subjects does the AIMS test cover? *Answer:* Reading, Writing and Math.
	500,000 Name two things you should do during a test? *Answer:* Listen carefully, read all instructions, be aware of your time and think before you write.
	1,000,000 What is the score range for the SAT essay? *Answer:* 1-6 or 2-12

Mathematics Engineering Science Achievement	1,000 What is the ACT? *Answer:* College entrance exam for university admission and merit scholarships.
Mathematics Engineering Science Achievement	8,000 List three things you should do on test day to help you *physically* prepare for the test. *Answer:* Eat a nutritious meal, be well rested, exercise, wear comfortable clothing.
Mathematics Engineering Science Achievement	16,000 What does AIMS stand for? *Answer:* Arizona's Instrument to Measure Standards
Mathematics Engineering Science Achievement	32,000 In what order should you answer questions on a test? *Answer:* Easiest to hardest
Mathematics Engineering Science Achievement	64,000 Where should you sit during a test? *Answer:* In your regular seat and near the front of the room away from distractions

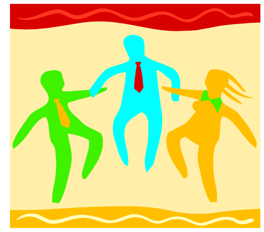
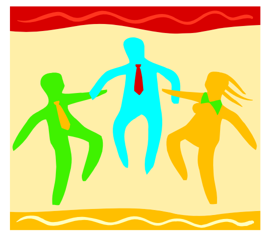
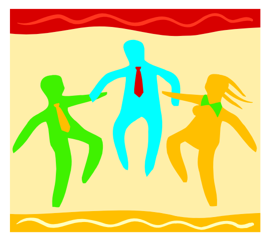
	125,000 What does the ACT measure? *Answer:* *Assesses general educational development and ability to complete college level work*
	250,000 What are the SAT II tests? *Answer:* *Subject-specific tests*
	500,000 What is the test format of the ACT? *Answer:* Multiple choice plus analytical and problem solving exercises
	1,000,000 What is the most important thing you should take away from each test? *Answer:* How to better approach the next test

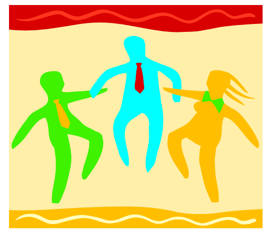
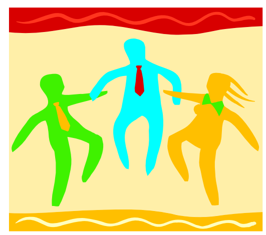
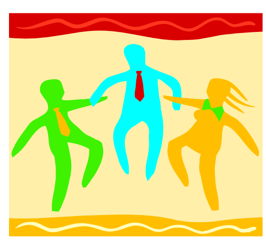
Mathematics Engineering Science Achievement	1,000 What high school grade levels should take the SAT? *Answer:* Grades 11 and 12.
Mathematics Engineering Science Achievement	8,000 When is the SAT administered? *Answer:* Fall and Spring. Priority date for seniors is October 1.
Mathematics Engineering Science Achievement	16,000 What does SAT stand for? *Answer:* Nothing
Mathematics Engineering Science Achievement	32,000 Fill in the blanks: When arriving for a test you should be (blank) and (blank)? *Answer:* A few minutes early and prepared
Mathematics Engineering Science Achievement	64,000 What is the best way to break up your studying time? *Answer:* In small blocks of 50 to 90 minutes with 10 minute breaks

Mathematics Engineering Science Achievement	125,000 How is the SAT scored? *Answer:* *Critical Reading* 200-800, Math 200-800, Writing 200-800
Mathematics Engineering Science Achievement	250,000 What subjects does the ACT cover? *Answer:* English, Math, Reading and Science
Mathematics Engineering Science Achievement	500,000 Should you change your answers on a test? *Answer:* Do not change answers unless you are VERY sure the first answer is wrong.
Mathematics Engineering Science Achievement	1,000,000 How is the AIMS test scored? *Answer:* You receive 500 points per subject area.

MESA® Mathematics Engineering Science Achievement	1,000 What is the PSAT/NMSQT? Answer: A practice for the SAT and the National Merit Scholarship Qualifying Test
MESA® Mathematics Engineering Science Achievement	8,000 When is the ACT administered? *Answer:* Fall and Spring. Priority date for seniors is October 1.
MESA® Mathematics Engineering Science Achievement	16,000 What does ACT stand for? *Answer:* Nothing
MESA® Mathematics Engineering Science Achievement	32,000 On what standardized tests can you use a calculator? *Answer:* PSAT, SAT, and ACT
MESA® Mathematics Engineering Science Achievement	64,000 What sections are on the SAT? Answer: Critical Reading, Writing, Math

Mathematics Engineering Science Achievement	125,000 What is the first thing you should do after finishing a test? *Answer:* Reward yourself for taking the test.
Mathematics Engineering Science Achievement	250,000 What is the first thing you should do when you get a test back? *Answer:* Identify the reasons for missed questions.
Mathematics Engineering Science Achievement	500,000 What is the test format of the SAT? *Answer:* Multiple choice, student-produced response math, and an essay
Mathematics Engineering Science Achievement	1,000,000 What is the test format of the AIMS test? *Answer:* Multiple choice and short-answer in addition to a writing piece

Hint 	Ask the Team 
Hint 	Ask the Team 
Hint 	Ask the Team 
Hint 	Ask the Team 

Hint 	Ask the Team 
Hint 	Ask the Team 
Hint 	Ask the Team 
Hint 	Ask the Team 

Skill Set 4:
MESA

MESA Lesson Activity

Title	**Careful Reading: Know the MESA Day Specs! (70-80 minutes)**
ID Number	HS-MESA-3
Sequence and Duration	• Lead In (10-15 minutes) • Activity (50-60) • Closure (10 minutes)
Age Level	High School
Essential Question	**What does careful reading have to do with being an engineer?**
Learning Objectives	• TSW discuss the importance of careful reading in the career of an engineer. • TSW review the MESA Day Competition Specifications. • TSW review critical reading strategies and apply them to understanding competition specifications. • TSW communicate information about an event to their classmates.
Other Objectives	• TSW communicate with their group by contributing their vocal input. • TSW utilize critical reading strategies. • TSW summarize and communicate information to their peers. • TSW engage in a group discussion about the importance of careful reading.
Key Terms	• Critical reading strategies
Materials Needed	For Teacher: • MESA Day Competition Specifications Per Team: • MESA Day Competition Specifications • Large paper or a section of the board Per Student: • Handout: Critical Reading Strategies
Lead In	1. Ask students, what does being a careful reader have to do with being a good engineer? Solicit student responses. Possible answers include reading the warnings associated with dangerous materials they may be using, reading engineering plans and blueprints, and reading briefs and memos from the company the engineer is working for. 2. Ask students to think of examples, real or fictional, where NOT reading carefully could result in poor designing or even disaster. 3. Ask students what they think careful reading has to do with being successful on MESA Day [teams need to really know the specs for their competitions to ensure that their designs will pass inspection; all designs must conform to the same specs so the competitions are fair]. Ask students to think about what could happen if they do NOT read and follow the specs carefully [if their designs don't meet the specs they'll be disqualified, and the team won't be allowed to compete]. 4. Ask the students what strategies they can use to ensure that all team members for a competition are aware of the specs and follow them, so that the team's design will pass inspection. Suggestions may include rewriting the specs in a more concise form, making a checklist of the specs and checking the design against it periodically, or rewording the specs into non-technical language.
Activity	1. Hand out copies of the MESA Day specs to students in pairs or groups (depending on how many copies you were able to make). Have students flip through the pages, and look at and talk amongst themselves about whatever

	interests them. Give them five or ten minutes to do this. 2. After five or ten minutes, ask them, "Do you think you're ready to compete now? Do you think you have all the information you need to start designing and building? Why or why not?" Give them time to talk about how prepared they feel and why. Some students may be comfortable, but there will likely be some who are overwhelmed by the amount of information presented in the MESA Day book. 3. Ask students how the class might proceed to help everyone become comfortable with what they're supposed to do. 4. Ask students what kinds of things they do when they're reading to make sure they've understood the material. Allow students to discuss their strategies and/or advice and tips from other sources that they've heard about. 5. Hand out the Critical Reading Strategies handout. Review the strategies with the students. 6. Ask all students to flip to the On-Site Engineering Design specs. Go through the reading strategies with this document, focusing first on the title (top right corner), then the headings, then the objective. There is not much information available for this event (since the specs are not handed out until students are on-site), but go through the document briefly, making notes about the information that will be most important to students. 7. When finished reading through the material together, create an outline on the board, letting the students assist in putting it together. Be sure to include the event title, and bullets for the number of teams per school, number of members per team, level of the competition, process of the event, and scoring procedures. Model for the students how to capture the most important information, paraphrase it by putting into one's own words, and boiling it down to the most essential elements. Tell students that creating an outline is one way of summarizing information to make it easier to understand. 8. Randomly assign each group to a competition, excluding the national competition (which is probably much longer than the others). There may be more than one group for each competition. 9. Tell the students their mission will be to become the experts on a certain event, and be able to communicate the rules of that event to the rest of the group. They can use the strategies from the hand out and their own strategies to carefully read through their specs, then come up with a presentation on it for the group. They can write a summary paragraph, create a bulleted list, draw a diagram, or whatever they like, to communicate the most essential information to their peers. They should also make note of any questions they come up with about the event, because their classmates will likely have similar questions. They will be able to discuss these questions following their presentation. 10. Hand out large pieces of paper to each group, or assign them an area of the board for writing out their summaries. 11. Give students approximately fifteen minutes to work together to read and summarize their event specs. Circulate among the groups to assist and answer questions. 12. When all groups are prepared, have them present one by one to the class. For events to which multiple groups were assigned, let the groups work together to present. 13. If time permits, consider giving the class time to peruse the national competition specs, using critical reading strategies. You can do this as a whole group or individually, depending on the level of interest.
Closure	1. Ask the students if they now feel more comfortable understanding the information in the MESA Day book. Do they feel more ready to begin designing for one of the events now? Do they have a good idea about how to approach

	other reading materials they'll need to understand in the future? 2. Ask, how does reading and following the MESA Day specs relate to what real engineers do? [engineers have to know and be mindful of the parameters and constraints placed on their work ahead of time, so the design they create serves the intended purpose]
Informal Assessment	• Monitor students for participation in group work and discussions. • Monitor students' understanding through questioning by both you and their peers.
Formal Assessment	• Completed event specification summary. • Presentation on summary.
Troubleshooting	• If students are not reading at grade level, this activity may be difficult for them. Encourage students to go at their own pace and not to give up. This activity can be extended over multiple class periods in conjunction with other activities, provided time permits prior to competition. The most important thing is that students know how to understand and follow the specs, not that they complete this activity in one session. • If there is sufficient space, consider leaving up students' summaries for the rest of the semester, or having the groups type them up and make them available to the rest of the class.

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☐ Links to Background
- ☒ Links to Past Learning
- ☒ Strategies incorporated

Scaffolding
- ☒ Modeling
- ☒ Guided practice
- ☒ Independent practice
- ☒ Comprehensible input

Grouping Options
- ☐ Whole class
- ☒ Small groups
- ☒ Partners
- ☐ Independent

Integration of Processes
- ☒ Reading
- ☒ Writing
- ☒ Speaking
- ☒ Listening

Application
- ☐ Hands-on
- ☒ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☐ Individual
- ☒ Group
- ☒ Written
- ☒ Oral

Arizona Math Standards Addressed	(none)
Arizona Science Standards Addressed	(none)

Critical Reading Strategies

Using critical reading strategies will allow you to be a more careful reader, helping you to get the most of your reading so you can understand and remember the material for later.

You can apply these strategies to reading the MESA Day event specifications, and to any other kind of reading material.

Step 1: Before you read

- Read the title, the introduction or overview, and the headings.
- Scan the material and try to get a feel for its structure and overall message.
- Look at the illustrations, if any.

Step 2: While you read

- Underline, circle, or highlight important ideas in the text.
- Jot down notes in the margins – your ideas, questions, and comments.

Step 3: After you read

- Review your notes and highlights.
- Rephrase the author's words in an outline or summary paragraph.

Lesson Activity

<table>
<tr><td>Title</td><td>Introduction to Technical Papers (70-80 minutes)</td></tr>
<tr><td>ID Number</td><td>HS-MESA-4</td></tr>
<tr><td>Sequence and Duration</td><td>Lead In: 10 minutes
Activity: 50-60 minutes
Closure: 10-15 minutes</td></tr>
<tr><td>Age Level</td><td>High School</td></tr>
<tr><td>Essential Question</td><td>What goes into a technical paper?</td></tr>
<tr><td>Learning Objectives</td><td>TSW brainstorm about the kinds of information that go into each section of a technical paper.
TSW apply their understanding of technical papers to reflect on previous activities they've done and how they would write about them.</td></tr>
<tr><td>Other Objectives</td><td>TSW engage their critical reading skills in reviewing the technical paper specs.
TSW present their ideas to the class.
TSW communicate with their group by contributing their vocal input.
TSW listen as their peers discuss their posters.</td></tr>
<tr><td>Key Terms</td><td>Technical paper: paper describing one's own research.</td></tr>
<tr><td>Materials Needed</td><td>Per Class:
Students' MESA Notebooks from previous projects
Copies of instructions for different projects
Per Team:
Handout: Parts of a Technical Paper
Handout: Technical Paper Brainstorming
Handout: Technical Paper Organizing
Handout: Guide to Technical Papers
Poster paper
Per Student/Pair of Students:
Handout: MESA Day Book or national competition technical paper specs</td></tr>
<tr><td>Lead In</td><td>Ask students if they can think of any examples of writing an engineer would do. What are the reasons an engineer would write something? What would be the purposes for that writing? [In the course of their careers, engineers often have to prepare proposals for work they would like to do; manuals for products they design; letters to companies and state/city officials; reports on their work for funders and/or supervisors, etc. The purposes for the writing vary, but are often related to communicating to others the details of their work.]
Remind or inform students that the MESA national competition requires groups to submit a technical paper. The technical paper is worth more than 20% of the points for the competition, so it is a very important part of being successful with the national event. What is the purpose of requiring a technical paper for this event? [To help them practice the skills that a professional engineer needs.]
Ask students if they know what a technical paper is. Have they ever written one before? What goes into a technical paper?
Tell students that the purpose of a technical paper is to clearly document the engineering process and communicate to the reader everything they learn when they design, build and test their devices.
Writing the technical paper might seem like something they need to do AFTER they finish their engineering process, but if they keep careful notes and work on the paper as they do their designing and testing, writing it will be a lot easier. It can even help them as they do their projects, by helping them organize their thinking.</td></tr>
<tr><td>Activity</td><td>Have students get into pairs and hand out the "Parts of a Technical Paper"</td></tr>
</table>

	worksheet. Give students five to ten minutes to brainstorm what kind of information they think should go into each section of the paper. 2. Hand out the MESA Day Book (or simply the specs for the technical paper for the national competition). Have students look at the requirements for the different sections of the paper. Advise them to use their critical reading skills. (Refer to Careful Reading lesson if you have done the lesson previously). Advise them to highlight and underline important information, and to ask questions and discuss any areas that jump out at them. 3. In a whole-group discussion, have the students think back over projects they've done throughout the year (e.g. Mousetrap Cars, Solar Ovens, Clay Drop). Create a list of these activities on the board. What kind of writing did students do when they were doing these activities? [MESA Notebooks] How can their MESA Notebooks help them write a technical paper? [They took notes on their procedures, key terms, set-up and conclusions – information that can help them put together their report.] 4. Tell the students that they will be doing a brainstorming activity to help them think about writing a technical paper. In groups, they will choose one of the projects and find their MESA Notebooks for those projects. Allow a few minutes for students to decide on their projects, helping them to avoid overlapping when possible. 5. Hand out the "Technical Paper Brainstorming" worksheet. Tell students to write the name of the activity they chose at the top. The rest of the sheet is blank; tell students that in the blank area they can write anything about that activity that comes to mind, even if it's not on topic: words, phrases, pictures, sentences, etc. You will give them ten minutes and they should just keep going until they run out of time, or out of ideas! 6. Give students ten minutes to brainstorm anything they can think of relative to their project. After ten minutes, have the students get together with their groupmates and circle anything they've written down that they think they can use for the paper. 7. Hand out the "Guide to Technical Papers" and "Technical Paper Organizing" handouts, and have the students work in their groups to sort their thoughts into the appropriate sections of the paper. Tell them they will be creating a poster for their activity to present to the rest of the class. The poster should have the same headings as the "Technical Paper Organizing" worksheet, and can have other headings if students have ideas they want to place in them. 8. When groups are ready, hand them a piece of poster paper so they can prepare their presentations. 9. Have groups present their posters to the class. Allow the rest of the students to add their comments about the project, and other information they would include on the poster. Have the presenting group add other students' thoughts to their posters in the appropriate sections.
Closure	1. Tell students that these posters can now serve as an outline for technical papers about these activities. Ask, how might students proceed to write their papers from here? 2. What kinds of information should students be mindful of as they conduct investigations, in order to be prepared to write technical papers about those investigations? Have students discuss what kinds of information they need and how best to record it as they engage in the engineering process. 3. Tell students that when they begin preparing for the competition on MESA Day, they can go through this process as a class to help the competing team outline their paper. 4. Point out that this is only the first step; writing the paper and getting it to its final draft will take a lot of time! Ask students what they might do to help them prepare a well-written technical paper in time for MESA Day. [They should start early!]
Informal Assessment	• Monitor students for participation in group work and discussions. • Monitor students' brainstorming for parts of a technical paper and for ideas

	about a project.
Formal Assessment	• Completed worksheets. • Completed poster.
Trouble Shooting	• If you aren't saving students' MESA Notebooks, or aren't using them, this activity will be more difficult but not impossible. Consider having the whole class brainstorm on just one project, and have the creation of the poster be a more collaborative process among all the students. • If students have difficulty with reading the specs, read through them together as a class, taking plenty of time to discuss the different components and ensure that all students have a good understanding of what is expected.

SEI Strategies Used

Preparation
- ☒ Adaptation of Content
- ☐ Links to Background
- ☒ Links to Past Learning
- ☒ Strategies incorporated

Scaffolding
- ☐ Modeling
- ☒ Guided practice
- ☒ Independent practice
- ☒ Comprehensible input

Grouping Options
- ☒ Whole class
- ☒ Small groups
- ☒ Partners
- ☐ Independent

Integration of Processes
- ☒ Reading
- ☒ Writing
- ☒ Speaking
- ☒ Listening

Application
- ☐ Hands-on
- ☒ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☐ Individual
- ☒ Group
- ☒ Written
- ☒ Oral

Arizona Math Standards Addressed	• (none)
Arizona Science Standards Addressed	• S1C4: Communicate results of investigations.

Parts of a Technical Paper

Instructions:

Read each of the headings for a technical paper, listed below. With a partner, brainstorm about what kinds of information you think should be included under each of these headings.

Title Page:

Abstract:

Table of Contents:

Introduction:

Discussion:

Conclusions:

Recommendations:

References:

Acknowledgments:

Appendix:

Technical Paper Brainstorming

Title of Project: ____

Technical Paper Organizing

Introduction:

Discussion:

Conclusion:

Recommendation:

Guide to Technical Papers

Title Page:
The title page includes the title of the project, information about the authors (their names, state and school), and the date.

Abstract:
The abstract is a paragraph-long synopsis of your *whole* paper (including the conclusions and recommendations!). A reader should be able to read the abstract and understand what your whole paper is about, including its purpose, an overview of the discussion, its main conclusions and recommendations. The abstract should be written *last*. It is worth **20 points**.

Table of Contents:
The table of contents should list the required sections and the page number for each.

Introduction:
The introduction is the first section of the paper, covering the purpose of the project and paper, the scope of the project, and any background on the project the reader should know. It is worth **15 points**.

Discussion:
The discussion is the longest section of the paper, detailing everything you did and everything that happened as you went through your project. It should include scientific concepts that relate to your project, the procedures of your project (include pictures where needed), your data and the ways you analyzed it, including data charts, graphs, pictures and diagrams, and the results from the data. It is worth **40 points**.

Conclusion:
In this section, draw a conclusion from the results reported in the previous section. Based on what you learned from doing your project, what can you say about the concept or device you studied?

Recommendations:
Your recommendations should be a discussion of further work to be done or a strong suggestion about what to do next. The conclusion and recommendations together are worth **15 points**.

References:
List and properly cite all sources you used in doing your project and writing your paper.

Acknowledgments:
The acknowledgment section recognizes and thanks people who helped you along the way.

Appendix:
The appendix or appendices contain all the information that doesn’t belong in the rest of the paper but is needed to support it. It can be additional evidence that supports your conclusions, such as data charts, photos, results, etc.

Lesson Activity

Title	**Writing a Technical Paper (80 minutes)**
ID Number	HS-MESA-5
Sequence and Duration	• Lead In: 20 minutes • Activity: 55 minutes • Closure: 5 minutes
Age Level	High School
Essential Question	**How do I write a good technical paper on my project?**
Learning Objectives	• TSW identify the characteristics of well-done and poorly-done technical papers. • TSW conduct an investigation in groups, fulfilling the responsibilities of their chosen role. • TSW prepare an outline of a technical paper that approaches competition standards.
Other Objectives	• TSW practice their reading and writing skills. • TSW present their ideas to the class. • TSW communicate with their group by contributing their vocal input. • TSW listen as their peers discuss their posters.
Key Terms	• Technical paper • Roles
Materials Needed	Per Class: • High school-level technical papers and score sheets from previous years • Bucket of water for testing Per Team: • Bucket of water • Roughly 3 feet of aluminum foil • 6 marbles • 1 sheet of cardstock, cut into 6” by 12” square • Scissors • Roll of Scotch tape • Handout: Float Your Boat instructions • Poster paper Per Student: • Handout: Guide to Technical Papers (if students do not already have them) • Handout: The Technical Paper Process • Handout: Tasks for Different Roles
Lead In	1. Tell students that in this session, they will practice writing a technical paper with their teammates. Before they do this, they will have a chance to look at examples of real technical papers and how judges scored them. 2. Hand out examples of technical papers and score sheets to pairs of students. If they do not already have them, hand out the “Guide to Technical Papers” handouts as well. 3. As students read the papers, focus their attention on the papers’ sections and the kinds of information the authors put in each section. Encourage them to look at how the papers were scored for each criterion, and think about how the papers could have scored higher. 4. Allow time for students to share out to the whole group about the papers they read and what they were able to learn about technical papers by reading them. Were there any that were especially good? Especially bad? Why?

Activity	1. Have students get into groups of four. Tell them they will be conducting an investigation and preparing to write a technical paper on it. They will each have a role to play in preparing the paper as they conduct the investigation. 2. Hand out "The Technical Paper Process" and the "Tasks for Different Roles" table. Make sure all students have their roles and understand what they're expected to do. 3. Hand out the "Float Your Boat" investigation instructions. Hand out the supplies for the investigation, or send students to stations where the materials are set up. 4. Give students ten to fifteen minutes to complete their devices. Circulate among the groups and make sure that they are being careful to document their process as well as work on their designs. 5. Test the final designs as a group. Remind the groups that their Notetakers and Illustrators should be recording the results, and the Researchers and Spec Checkers should be assisting with this. 6. After testing, give the students roughly twenty minutes to work on outlining their papers – more if time is available. During this time, hand out the poster paper. Circulate among the groups to answer questions and provide guidance. 7. With fifteen minutes remaining in the session, have students present their posters.
Closure	1. Ask students what it was like to think about writing and doing an investigation at the same time. Was it harder? Was it helpful? Did doing it help them write their technical paper? 2. Ask students to look again at the question at the bottom of the worksheet. How *would* they proceed to write real sentences and paragraphs from the outlines they created? What else would they need to do? [E.g. revise, edit, send to peers and teachers for critiques.]
Trouble Shooting	• Monitor students for participation. • Monitor students' understanding through observation and direct questioning.
Informal Assessment	• Completed paper outline. • Completed poster. • Presentation on poster.
Formal Assessment	• Although there is a lot to pack into this session, if you have different students coming each week, try to keep the investigation and paper outlining to one session. If necessary, separate the lesson between the "Lead In" and "Activity" sections.

SEI Strategies Used

Preparation	Scaffolding	Grouping Options
☐ Adaptation of Content	☐ Modeling	☐ Whole class
☐ Links to Background	☐ Guided practice	☒ Small groups
☒ Links to Past Learning	☒ Independent practice	☐ Partners
☒ Strategies incorporated	☐ Comprehensible input	☐ Independent
Integration of Processes	**Application**	**Assessment**
☒ Reading	☒ Hands-on	☐ Individual
☒ Writing	☒ Meaningful	☒ Group
☒ Speaking	☒ Linked to objectives	☒ Written
☒ Listening	☒ Promotes engagement	☒ Oral

Arizona Math Standards Addressed	• (none)

Arizona Science Standards Addressed	• S1C1: Formulate predictions, questions or hypotheses based on observations and locate appropriate resources. • S1C2: Participate in planning and conducting investigations and recording data; design and conduct controlled investigations. • S1C3: Organize and analyze data; evaluate experimental design and analyze data to explain results and propose further investigations. • S1C4: Communicate results of investigations.

Guide to Technical Papers

Title Page:
The title page includes the title of the project, information about the authors (their names, state and school), and the date.

Abstract:
The abstract is a paragraph-long synopsis of your *whole* paper (including the conclusions and recommendations!). A reader should be able to read the abstract and understand what your whole paper is about, including its purpose, an overview of the discussion, its main conclusions and recommendations. The abstract should be written *last*. It is worth **20 points**.

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Conclusion:
In this section, draw a conclusion from the results reported in the previous section. Based on what you learned from doing your project, what can you say about the concept or device you studied?

Recommendations:
Your recommendations should be a discussion of further work to be done or a strong suggestion about what to do next. The conclusion and recommendations together are worth **15 points.**

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Getting Started: The Technical Paper Process

1) Assigning roles to group members helps you organize your thoughts and keep your paper in mind while you design. Assign one role from the list below to each group member:
    a. Researcher: Finds needed information and keeps track of sources; leads the investigation.
    b. Spec Checker: Is the expert on the specs and ensures that the group follows them.
    c. Notetaker: Records any ideas discussed by the group.
    d. Illustrator: Creates any tables, charts, graphs, and sketches needed.

2) Review the table showing tasks for each role. This table shows *possible* responsibilities for each team member, but every member of the group should be helping every other member with each part of the investigation. Each team member is equally responsible for the investigation and paper!

3) Get your supplies and begin the investigation. As you get started, think about the questions below:
    a. How will you tell your reader what you were investigating?
    b. What background information will your reader need in order to understand the investigation?
    c. How will you document the steps you took in your investigation?
    d. What diagrams, pictures, data tables, charts, etc. can you create to help the reader visualize your investigation and results?
    e. How can you provide enough information for your reader to believe in your conclusion(s) and recommendation(s)?
    f. What can each group member do along the way that will help the group write their technical paper?

4) When you are finished with the investigation, you can focus on organizing your paper. Work together to put your ideas into the outline of a technical paper.

5) When you have your paper outlined, prepare to present it by creating a poster.

6) For this activity, you are only creating an outline of your paper. How would you go from an outline to a final written paper?

Phase of the Project:	**Tasks for Different Roles:**			
Each member of the group choose a role:	**Researcher** Finds resources and keeps track of citations; tests the properties of materials, etc.	**Notetaker** Records ideas discussed by the group; records data from tests.	**Illustrator** Creates all tables, charts, graphs, and sketches needed.	**Spec Checker** Becomes the expert on the investigation and paper specs and makes sure that the group follows them.
Identify the technical question	Find additional information and record the sources.	Record the results of the group's discussion.	Create any diagrams or models needed.	Review the specs and identify the purpose of the investigation.
Brainstorm possibilities	Brainstorm with the group.	Brainstorm with the group; write down the group's ideas.	Brainstorm with the group.	Brainstorm with the group.
Come up a hypothesis	Work with the group to come up with a hypothesis.	Record the hypothesis.	Sketch a diagram representing the hypothesis.	Make sure the hypothesized solution fits with the investigation specs.
Test your ideas	Perform any tests that need to be done. Work with the group to come up with new ideas.	Record data from testing. Keep track of group's ideas.	Create diagrams of testing set-ups and representations of data (e.g. charts, tables).	Ensure design is staying within the specs. Make sure information for the paper is recorded.
Build and test your final design	Work with the group to decide on the final design. Build the final design. Perform testing.	Work with the group to decide on the final design. Record the group's ideas and data.	Work with the group to decide on the final design. Finalize representations of data.	Work with the group to decide on the final design. Make sure the design fits within the investigation specs.
Refine your design	Work with the group to make final adjustments.	Work with the group to make final adjustments.	Work with the group to make final adjustments.	Work with the group to make final adjustments.
Outline the *Discussion* section	Work with the group to organize ideas.	Work with the group to organize ideas. Make sure all important data and notes are included.	Work with the group to organize ideas. Insert important illustrations into the outline.	Work with the group to organize ideas. Make sure group follows the paper specs.
Write the *Conclusion* and *Recommendation*	Draw conclusions and recommendations with the group.	Draw conclusions and recommendations with the group.	Draw conclusions and recommendations with the group.	Draw conclusions and recommendations with the group. Make sure group follows the paper specs.
Outline the *Introduction*	Work with the group to organize ideas. Insert any resources and citations recorded earlier.	Work with the group to organize ideas. Make sure all important notes are included.	Work with the group to organize ideas. Insert pictures, etc. from resources.	Work with the group to organize ideas. Make sure group follows the paper specs.
Outline the *Abstract*	Summarize the paper with the group.	Summarize the paper with the group.	Summarize the paper with the group.	Summarize the paper with the group. Make sure group follows the paper specs.

Investigation: Float Your Boat

Your mission for this activity is to create a “boat” out of cardstock that will carry as many marbles as possible before sinking.

You will only get one piece of cardstock! In order to determine what shape your boat should take, you can experiment by testing aluminum foil “boats”.

Rules:

1. You can reuse the aluminum foil to make new boats if needed.
2. Your final design must be cardstock and tape only (no aluminum, etc.).
3. The tape can only be used to attach cardstock to cardstock. It cannot be used to extend the width of the cardstock piece or to laminate the cardstock.
4. Marbles will be added one by one by the judge, until the judge determines that the boat has been sunk.
5. The boat that holds the most marbles wins.
6. In the event of a tie, the most creative design, as determined by the judge, will be declared the winner.

MESA Mathematics Engineering Science Achievement

Lesson Activity

Title	**Welcome to MESA (20-30 minutes)**
ID Number	HS-MESA-1
Sequence and Duration	• Name Game (10-15 minutes) • Introduction to MESA (10-15 minutes)
Age Level	High School
Essential Question	**What is MESA all about?**
Learning Objectives	• TSW will learn about the purpose and objectives of MESA. • TSW will meet and learn the names of the other MESA students.
Other Objectives	• TSW will practice teamwork. • TSW will practice non-verbal communication.
Name Game	1. Ask the students to introduce themselves loud and clear, giving their names and why they are here. Also, tell everyone that it is important that they listen to everyone. 2. Make sure everyone's introduction is loud and clear. 3. After everyone has introduced themselves tell everyone to stand. Let them know that they will have 3 minutes to put themselves into alphabetical order, but there are rules: 1) can only use helpful pointing, 2) no talking, no signing, no gesturing. 4. After three minutes, have everyone repeat their name to see how close they were.
Introduction to MESA	1. Ask students why they are interested in MESA. 2. Ask students what they think MESA is about and what they think they will be doing at MESA meetings. 3. Introduce and discuss what MESA is about and how it will make them more successful in various aspects of their life. 4. Have a former member of MESA describe their experiences with MESA and allow students the opportunity to ask questions. 5. Inform students of the next MESA meeting and give them a heads up about what the next activity will be.
Informal Assessment	• Monitor students for participation in group activity.

SEI Strategies Used

Preparation
- ☐ Adaptation of Content
- ☒ Links to Background
- ☐ Links to Past Learning
- ☐ Strategies incorporated

Scaffolding
- ☐ Modeling
- ☐ Guided practice
- ☒ Independent practice
- ☒ Comprehensible input

Grouping Options
- ☒ Whole class
- ☐ Small groups
- ☐ Partners
- ☐ Independent

Integration of Processes
- ☐ Reading
- ☐ Writing
- ☒ Speaking
- ☒ Listening

Application
- ☐ Hands-on
- ☒ Meaningful
- ☒ Linked to objectives
- ☒ Promotes engagement

Assessment
- ☐ Individual
- ☒ Group
- ☐ Written
- ☒ Oral

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[redacted], Tucson

8/1/2005

Arizona

TECHNICAL PAPER SCORING CRITERIA

[redacted] MESA USA National Engineering Design Competition

TEAM: **SCHOOL:** **LEVEL: MS or HS**

Discussion (Physical Phenomena, Experiment Procedures, Data & Analysis, Tables & Charts, Results)	**Abstract** (Length, Purpose & Key Features, Conclusions & Recommendations, Non-technical, Informative & Interesting)	**Introduction** (Purpose, Scope, Background Information)	**Conclusion & Recommendations** (Inferences & Evidence – Further Work & Reasoning)	**Written Presentation** (Length, Font, Key Sections, Supporting Sections)
8 points each a. Very thorough discussion of Physics, Math and/or Engineering concepts b. Very complete description of experimental/testing procedures including diagrams or pictures c. Thorough description of analysis tools used d. Highly relevant tables, graphs, charts, etc. e. Very clear explanation of results w/graphics	4 points each a. Length: <250 words b. Very clearly restates Purpose & Key Features of report c. Very clearly restates Conclusions and Recommendations of report d. Written very clearly in non-technical terms e. Engages and informs the reader	5 points each a. Purpose: Very clearly states why project undertaken AND why report developed b. Scope: A very thorough description of parameters, methods, limiting factors & technical terms c. Background: Share key facts, conditions, events prior to project AND previous work on this topic	5 points each a. Conclusion: Inferences follow very logically from discussion evidence No new material included b. Recommendations: Further work/best solution well identified Written in first person w/ active verbs	2 points each a. Length: 5-15 pages (cover & title page) b. Font: 12, Times New Roman c. Spacing: double spaced d. All Key Sections included: Title page, Abstract, Contents, Introduction, Discussion, Conclusion, Recommendations e. All Supporting Sections included: References, Acknowledgments, Appendix
6 points each a. Effective discussion of key concepts b. Effective description of procedures including diagrams or pictures c. Good description of analysis tools d. Tables, graphs, charts, etc. useful to report e. Good explanation of results w/graphics	3 points each a. Length: Slightly over length b. Good restatement of Purpose/Key Features c. Good restatement of Conclusions & Recommendations d. Well written, but includes some technical terms e. Modestly engages and informs reader	4 points each a. Effective/complete statement of purpose b. Effective statement of scope, 1 or 2 items appear missing or overlooked c. Effective and complete background details, 1 or 2 items appear missing or overlooked	4 points each a. Conclusion: Inferences follow loosely from discussion evidence No new material included b. Recommendations: Further work/best solution not well identified	1½ points each a. Length: Slightly over or under length b. Font: Some inconsistency throughout c. Spacing: Some inconsistency throughout d. 1 Key Section not identified or missing e. 1 Supporting Section not identified or missing
4 points each a. Limited discussion of key concepts b. Limited description of procedures, with few diagrams or pictures c. Analysis tools poorly described or not used d. Graphics not well used to support report e. Very little discussion of results, no graphics	2 points each a. Length: too short b. Poor restatement of Purpose or Key Features c. Poor restatement of Conclusion or Recommendations d. Many technical terms e. Uninteresting to reader	3 points each a. Incomplete statement of purpose for project and report b. Incomplete statement of scope, multiple items missing or overlooked c. Limited background information included	3 points each a. Conclusion: Inferences follow poorly from discussion, evidence not clear Some new material included b. Recommendations: Further work/best solution not well identified	1 point each a. Length: too short/long (cover & title page) b. Font: very inconsistent throughout c. Spacing: very inconsistent throughout d. 2-3 Key Sections not identified or missing e. 2 Supporting Sections not identified or missing
2 points each a. Little or no discussion of key concepts b. Little or no description procedures c. Data analysis not included d. Graphics do not support report e. No discussion of finding/results	1 point each a. Length: >250 words b. Purpose or Key Features not included c. Conclusion or Recommendations not included d. Does not engage reader	2 points each a. Very poor statement of purpose for project b. Very poor statement of scope, very little information included c. Very poor background provided, very little information provided	1 point each a. Conclusion: Inferences do not follow from discussion or evidence present new material included b. Recommendations: Further work/best solution not identified	½ point each a. Length: <5 pages or >15 page b. Font: incorrect throughout or not typed c. Spacing: incorrect throughout d. Most Key and Supporting Sections not identified or missing
Score 40 /40	Score 19 /20	Score 13 /15	Score 5+9 /15 = 14	Score 10 /10
Judge	[redacted]		Total	91+5 = 96

Judge Feedback (optional):

EXCELLENT GRAPHICS

288

HS-A

AZ

MESA

TECHNICAL PAPER SCORING CRITERIA

[redacted] MESA USA National Engineering Design Competition

TEAM: [redacted] SCHOOL: [redacted] LEVEL: MS or HS

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Score 36 /40	Score 16 /20	Score 15 /15	Score 13.5 /15	Score 10 /10
Judge	[redacted]		Total	90.5

Judge Feedback (optional):

Friction
Traction
3rd class Lever
PE
KE
Torque
Newton's 3 Laws

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HS-A

TECHNICAL PAPER SCORING CRITERIA

2005-2006 MESA USA National Engineering Design Competition

TEAM: Gasper, Mankel, Davis-Rosas, Blue SCHOOL: Pueblo Magnet LEVEL: MS or HS

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Score 34 /40	Score 18 /20	Score 13 /15	Score 15 /15	Score ~~10~~ /10
Judge	Kelly		Total	90

Judge Feedback (optional): See Paper.

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HS-A

THE MIGHTY MOUSETRAP CAR

MESA USA [redacted]

Tucson, Arizona

Thursday, [redacted]

Multipurpose Vehicle

Technical

Paper

By:

[redacted]

THE FINAL FRONTIER

Where no car has gone before…

HS-A

B. Abstract:

Building and competing with spring-powered cars for the third and final year has continued to be an exciting and educational experience for the team. This project utilized the physical forces of friction, acceleration, gravity, potential and kinetic energy, and Newton's Three Laws of Motion in combination with the principles of simple machines. Understanding these concepts were important for the purpose of designing a mousetrap car capable of (1) traveling to and stopping accurately at a target five meters away, (2) traveling the length of a 10-meter track as quickly as possible, and (3) climbing a 30° inclined plane as high as possible. Modifying models from previous competitions, the current model incorporates features such as small diameter wheels and a much lighter body frame with a chassis length ranging between 30 cm and 45 cm. To better take advantage of the car's capabilities, it is highly recommended to continue experimenting with and refining the design parameters, such as figuring gear sizes. It is also important to practice the precise methods of the setup and release process of the mousetrap car.

C. Table of Contents:

D. Introduction:

Purpose:

This project was undertaken to design a spring-powered car that could successfully complete three tasks. These tasks included: (1) traveling to and stopping accurately at a target five meters away, (2) traveling the length of a 10-meter track as quickly as possible, and (3) climbing a 30° incline plane as far as possible. Additionally, the purpose of this technical paper was to report findings and recommendations of the kind of car that can best accomplish these three tasks.

Scope:

Constructing a spring-powered vehicle for three years has continued to be an amazing learning experience. Repeated testing of trials and analytical processes gave a better understanding of how to apply Newton's Three Law's of Motion, kinetic and potential energy, friction, acceleration, and the design principles incorporated in simple machines. These concepts were used to explore and perfect different design parameters for the car. This was challenging, however, because the design was limited to the use of the spring on a mousetrap as the sole energy source. Furthermore, this spring could not be modified by any means, such as cutting or restructuring its existing form. This technical report will aid in the understanding of physical principles involved in the performance of the mousetrap car, the manner in which these principles were applied towards designing and testing the mousetrap car, and conclusions about which prototype can best perform and accomplish the three required tasks.

Background:

The conversion of a mousetrap spring into a car's energy source is one example of a mechanized vehicle. Figure 1 (page 10) shows a diagram of the basic components of a mousetrap car. A mousetrap car's operation is based on Newton's Laws of Motion, friction, and kinetic and potential energy. A car is a "complex" machine because its function is dependent upon the interaction of many smaller component "simple" machines – design units such as levers, screws, and pulleys. Physical concepts were applied in making sure that the simple machine components of the car worked together efficiently with the remaining non-mechanistic parts (such as the chassis and string) towards the car's overall performance. With the right prescription of design parameters, the mousetrap car would have a high mechanical advantage, or high "comparison between the force put into a machine and the force out of a machine" (Balmer 2002).

The developments of the mousetrap cars were based on designs tested in previous multipurpose-vehicle competitions at the regional, state and national levels. In 2004 and 2005, the [redacted] team competed successfully at each of these levels, providing a substantial foundation of data to serve as a starting ground for new models designed in the current national competition. Over the last three years the hypothesis has developed from originally believing that a chassis length of greater than 45 cm was the best design, to realizing that a shorter chassis length ranging from 30 cm to 45 cm was a lighter model, and therefore performed more efficiently.

E. Discussion:

<u>Physical Phenomena:</u>

Physical forces were involved in every component of the mousetrap car. One force was friction, which is common in everyday life. It is the resistance encountered by any moving object upon another object or surface (MSN Encarta Premium), such as walking on the ground. Friction affects the tires of the car as they spin on the floor; it is what holds the car back in opposition to the accelerating force that moves the car forward. The more moving components a mousetrap car has, the greater the force of friction encountered and energy consumed (Balmer 2002). Figure 2 (p.10) shows how friction counteracts the accelerating force.

Another force is traction, which enables the mousetrap car to move. Without traction the tires would have no grip with which to move forward, and they would just spin in place. To help the car's wheels counter the forces of friction and traction, a simple machine was created. This simple machine was a third class lever, characterized by having the applied force placed between the fulcrum and the bail of the trap (see Figure 3, p.10), (Balmer 2002 for different kinds of levers as based on the location of the applied force with respect to the fulcrum).

Two other simple machines utilized were the wheel and axle. The central axle locks the wheels together, so that when one turns the other must spin as well. So, when the wheels turn, the "motion at the edge of the wheel is converted to a shorter more powerful motion at the axle" (Balmer 2002). In other words, if the energy created from the release of the mousetrap lever can be localized towards rotating the axle a short distance very quickly, this will translate into a greater rotation, and therefore a farther distance covered by the wheels. Duct tape was wrapped around the axle to serve as a gear. This was convenient because layers of duct tape can be easily added or removed to change its size. Without the duct tape the gear would simply remain the size of the axle, and there would be no room for modifications. Overall, these simple machines were part of what helped the mousetrap car's performance and its mechanical advantage.

What else powered the mousetrap car? All power came from two types of energy: potential and kinetic. Potential energy is the energy that a body or system holds because of its at rest position, while kinetic energy is the energy that a body or system has because of its motion (MSN Encarta Premium). The potential energy is located in the spring of the mousetrap when it is cocked and ready to be released. As the spring releases, its potential energy converts into kinetic energy, which propels the mousetrap car forward. Appendix (p.15) shows the conversion of potential to kinetic energy, and Figure 4 (p.10) shows the initial and final positions of potential and kinetic energy. It is better to conserve kinetic energy and use it at the lowest possible rate, so that it is not expended too quickly. This allows the lever to translate more slowly, which turns the wheels longer letting the car travel farther. Another force involved is torque, which is the rotating force capable of overcoming resistance during turning (MSN Encarta Premium). Torque is applied perpendicularly to the axle and causes it to spin faster, providing a greater forward acceleration to the mousetrap car and increasing its distance in the time that the lever has to change position.

The motion of the mousetrap car can fundamentally be explained using Newton's Three Laws of Motion. Newton's First Law of Motion states that an object at rest (or in motion) will stay at rest (or in motion in a straight line) until an outside force acts upon it. This is the Law of Inertia. Before the spring is released the mousetrap car is at rest, and afterwards an accelerating force is created. The forward motion of the car continues until it is acted upon by the forces of gravity and friction. Gravity slows the car by pulling it towards the floor, and friction slows the car by pulling it backwards.

Newton's Second Law of Motion states that, "the net force on an object is proportional to its acceleration and its mass, represented in the equation.

$$F = ma$$

Where F is the force, m is the mass, and a is the acceleration. It will accelerate in the same direction as the force applied" (MSN Encarta Premium). In other words, the greater an object weighs, the larger the force necessary to accelerate it; hence the decision was made to minimize the cars weight. The mass of each mousetrap car model is relatively the same, so a larger applied force (stronger lever arm) will create more acceleration than a smaller applied force.

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. When the spring is released and the arm swings forward (the action), the car accelerates in the opposite direction with the same force that was created from the spring (the reaction).

All of these principles are readily demonstrated in the mousetrap car. Based on the understanding of these physical forces and previous data collected this last year, many ideas were developed for improving the mousetrap car. The car's wheels were covered with rubber bands to create more traction and allow them to better grip the surface of the incline plane in the power trial. When traction is maximized, it is possible to achieve more power output by modifying the length of the lever arm. Shorter lever arms produce more force than longer lever arms. With this in mind, a small but strong lever arm was made from a carbon fiber rod and was connected to the sides of the bail. This last modification was expected to increase the force from the spring's release. To a similar effect, all three cars' chassis lengths were maintained between 30 cm to 45 cm. This modification kept the cars light in order to improve each car's overall performance. In addition, car Model #3 (Figure 1,p.10) had holes drilled into the wheels and chassis making it even lighter.

Hypothesis:

A lightweight mousetrap car with a chassis length between 30 cm and 45 cm will perform and accomplish the three tasks better than a heavier and longer chassis.

Materials:

*Ball Bearings	Compact Discs	Pins	Straws
*Balsa Wood	*Duct Tape	Popsicle Sticks	*Strings
*Basswood	*Foam	PVC pipes	Super Glue
Cable Ties	Hot Glue	*Rubber Bands	Thread Bobbins
Carbon Fiber Rod	Masking Tape	Scissors	*Wheels
CD Wheel adaptors	Metal Wire	Standard Mousetrap	X-Acto Knife

*Different sizes were used.

Experimental Procedure:

The procedures for building each of the three mousetrap cars are explained in five steps. For all three models, the first part of the construction was the design of the lever arm that was attached to the bail. This component was critical in regard to power consumption, or power conservation. Extending the lever arm past the length of the bail is what controls the force released from the trap in a manner that makes the car more powerful. The bail also has a string attached to it, and it was found that the more string used, the farther the mousetrap would travel.

The second part was the construction of the chassis, which involved the car's overall length and the distance separating the front and rear wheels. This design feature affected both the speed and power of the mousetrap car: The speed is the distance traveled over time, while the power is the distance traveled up a 30° incline plane. Ideally, a mousetrap car has to be both fast and powerful. Chassis length is also relevant to the overall mass of the mousetrap car: A shorter chassis will not weigh the car down as much as a longer chassis, while still providing a strong body frame.

The third part of the construction was the design of the axle. This is where different sized gears, made of duct tape, were wrapped around the axle to suit the different tasks. The larger the gear's diameter, the higher the gear, therefore achieving the effect of a transmission system. In addition, these gears make the working length more or less tailored to the individual tasks. These gears also held the lever arm back when cocked; a pin was inserted into one of the axle gear's, which protruded out slightly in order to hook a string loop that is tied to the lever arm. Gear size is determined through a mechanical advantage formula (Zitzewitz, 1992):

$$F = W \bullet \sin(30) \bullet D/G$$

where F is the force, W is the weight of the mousetrap car, D is the diameter of the rear wheel, and G is the gear size. The weight and diameter are known, and the force is figured out by holding the level and bail perpendicular on a scale and from these values, solve G to obtain the optimal gear size. The gear size for each model was set differently. It ranged between 3 mm to 6 mm in diameter.

The fourth part of construction was the assembly of the wheels. In model #3, CDs were used as the rear wheels with holes drilled in them to make them lighter. The CDs were super-glued to CD adaptors, which in turn were glued to the rear axle. This part of construction required a lot of precision, or else the car would travel off course in the speed and accuracy trials. Whereas, in model #1, six-centimeter diameter lightweight wheels, taken from a modeling kit, were used.

The final part of construction was the assembly of the front wheels. Model #1 had 6 cm diameter wheels, Model #2 had 1.5 cm diameter wheels, and Model #3 had 2.5 cm diameter front wheels. Again, it is important that wheel construction was done with precision so that the car would not travel off the course. Figure 5 (p.11) displays the mousetrap car designs.

<u>Test Setup</u>:

The mousetrap car was designed to perform three tasks: it had to travel accurately to a target five meters away and stop, it had to travel across a ten meter runway as quickly as possible, and lastly, it had to travel up a 30° incline. The setup for each of the three tasks is shown in Figure 6 (p.11).

Data Reduction, Analysis Tools, Models and Data:

Figure 1 – Basic Components of a Mousetrap Car

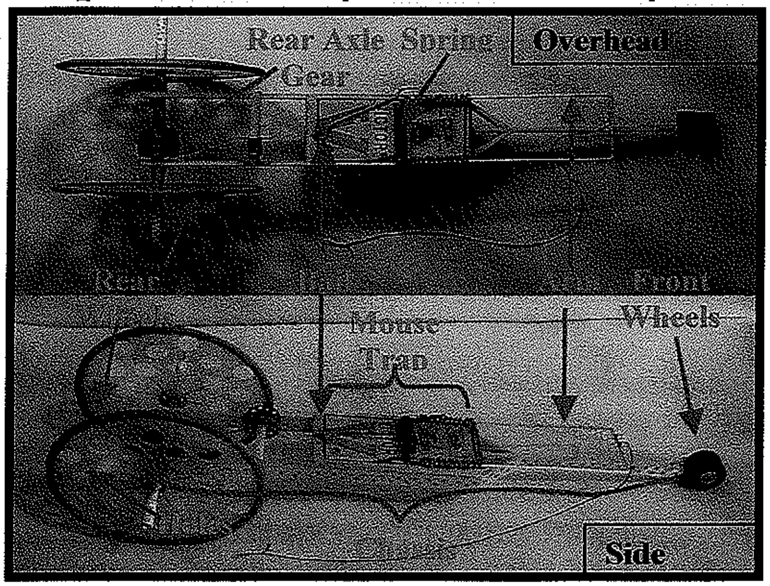

Figure 2 – Counteraction between Friction and Acceleration

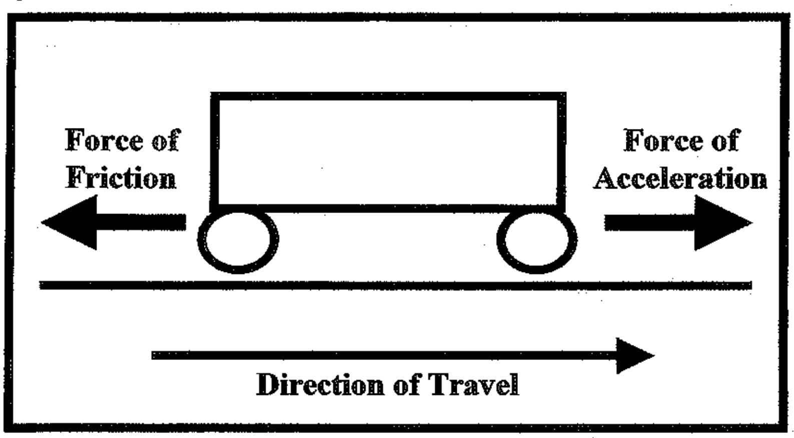

Figure 3 – Three Classes of Simple Machine Levers

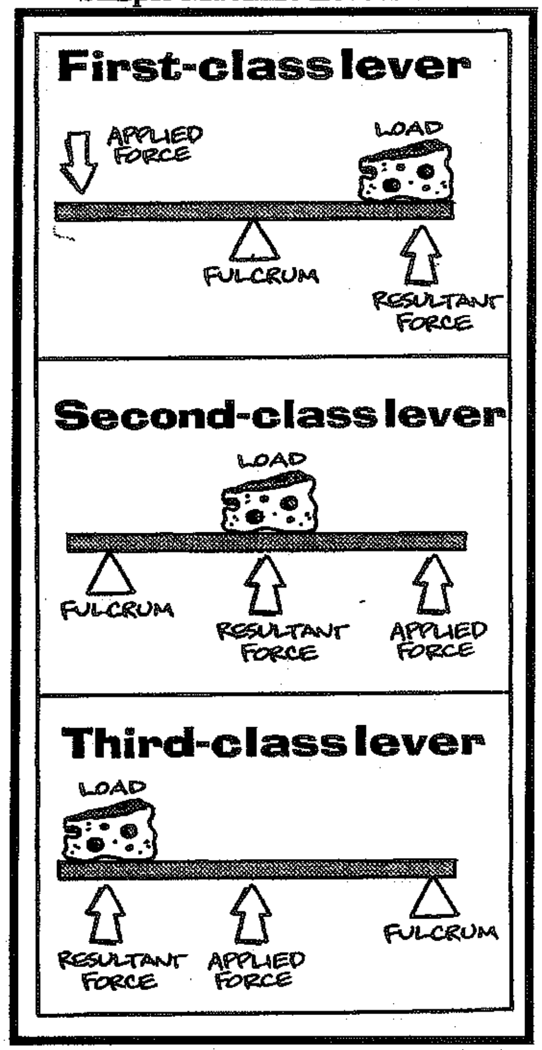

Figure 4 – Initial and Final States of Potential and Kinetic Energy

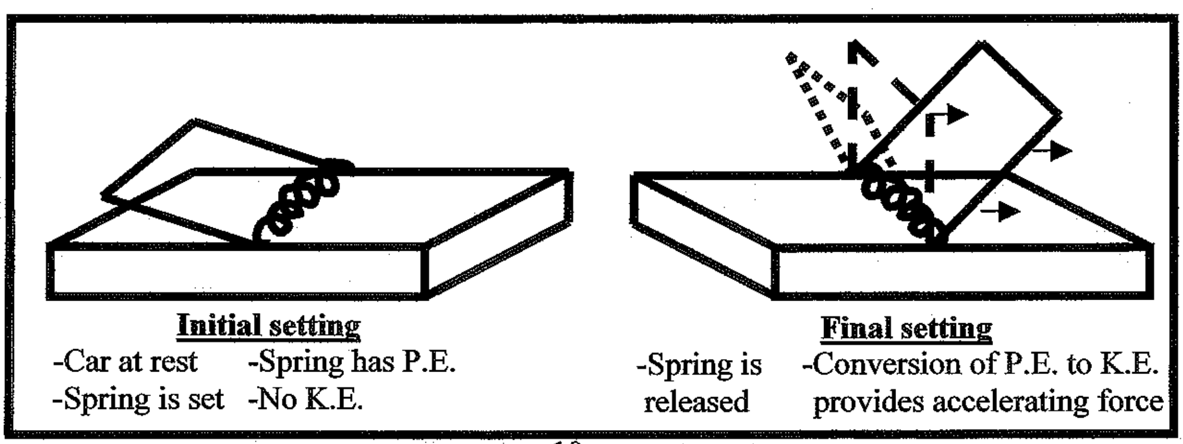

Figure 5 – Overhead View of Mousetrap Cars and Their Gears

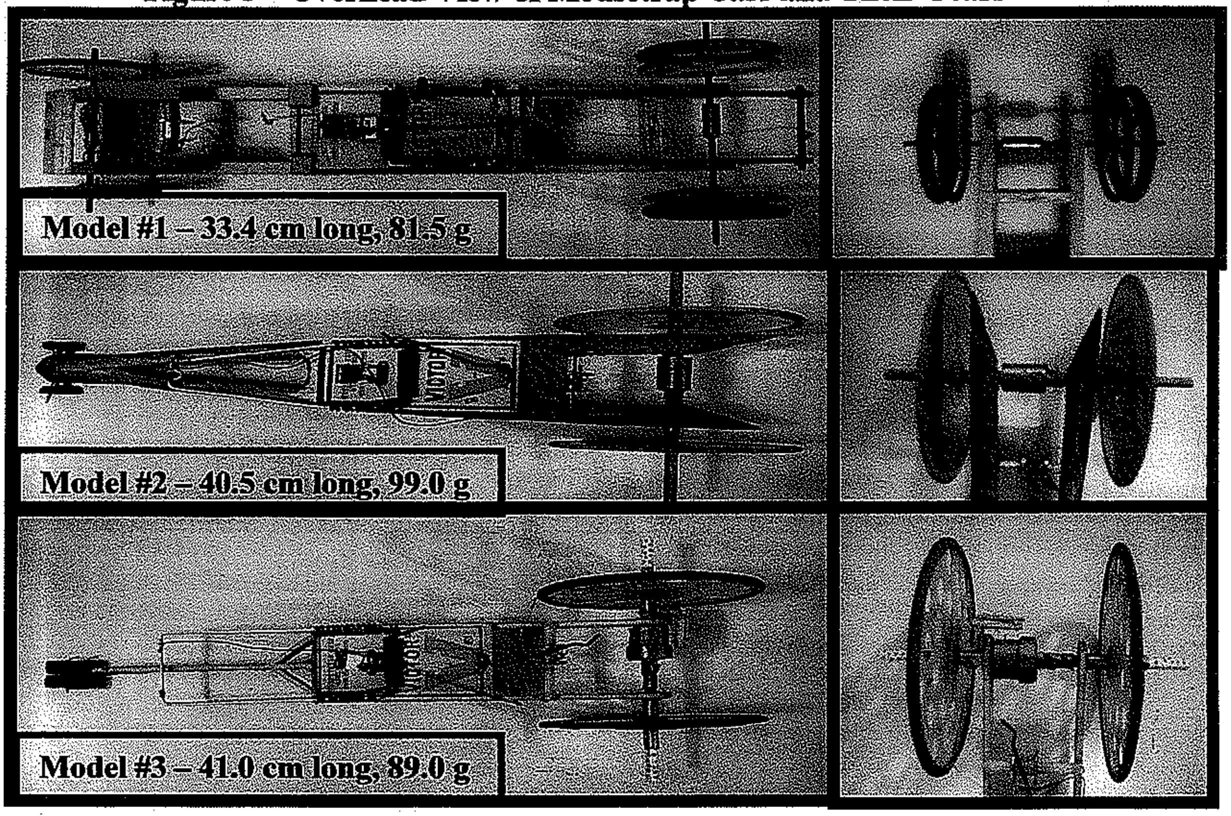

Figure 6 – Mousetrap Car Testing Setup

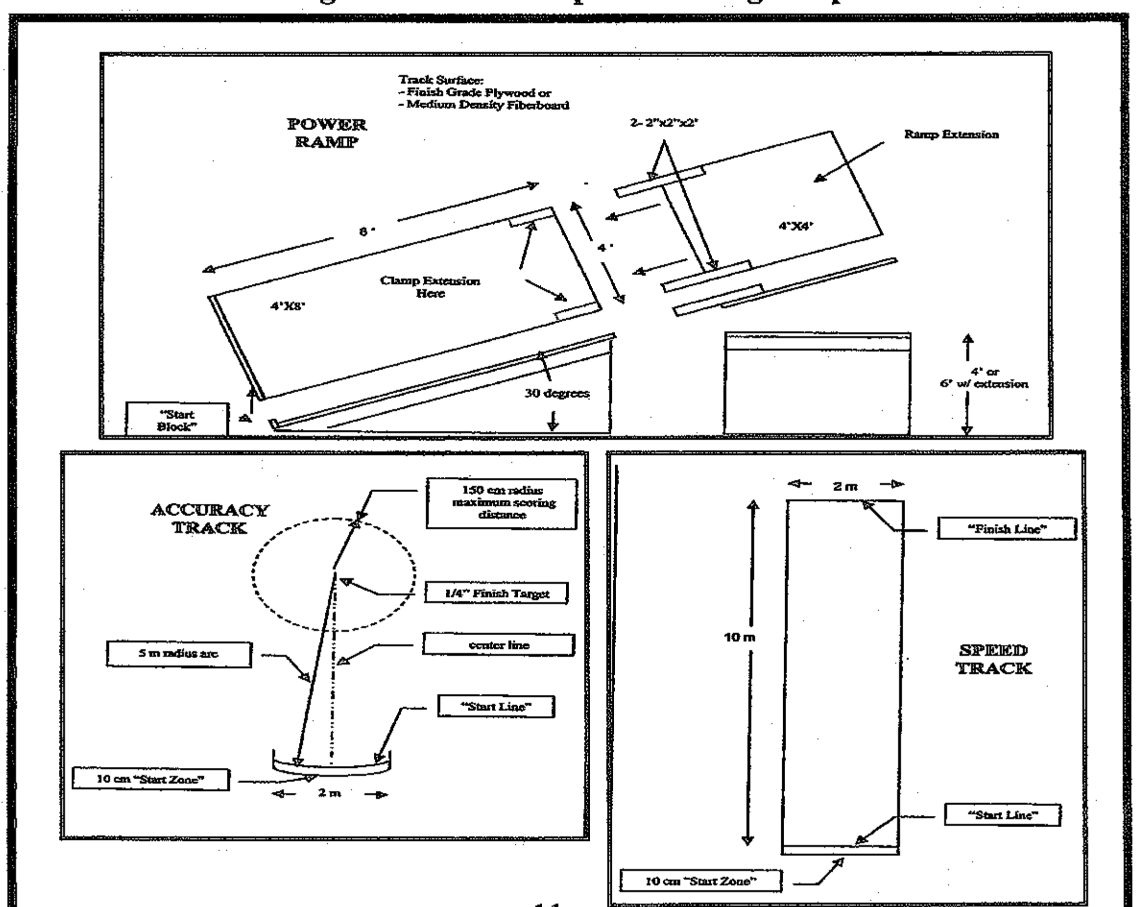

Figure 7 – Average Accuracy Performance of Mousetrap Car

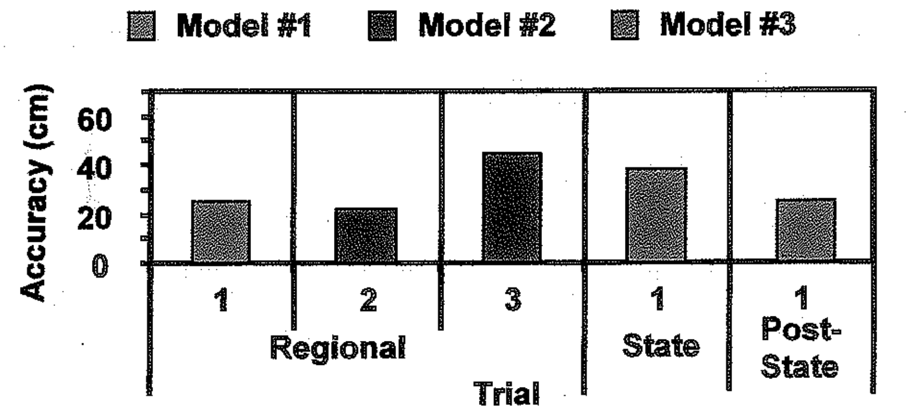

Figure 8 – Average Power Performance of Mousetrap Car

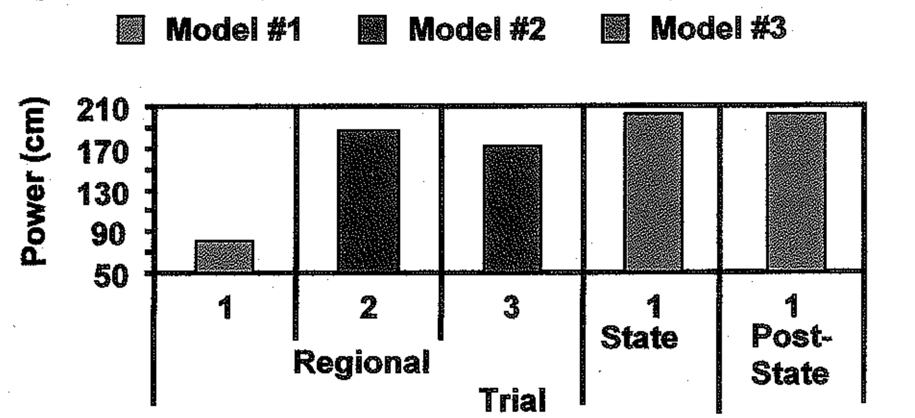

Figure 9 – Average Speed Performance of Mousetrap Car

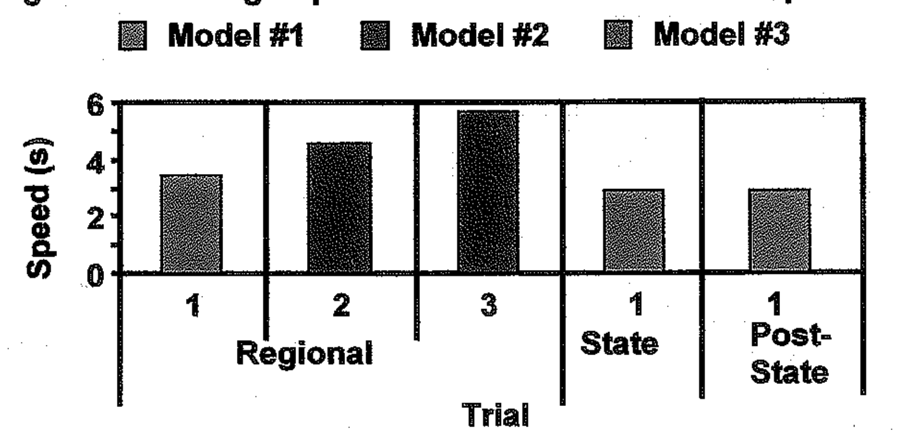

Table 1: Mousetrap Car Model Performance

		Speed (s)			Power (cm)			Accuracy (cm)		
Trials	Model #	1	2	Avg	1	2	Avg	1	2	Avg
Regional	1	3.4	3.9	3.65	65	79	72	29	25	27
	2	4.3	DQ	4.13	175	180	177.5	DQ	25	25
	3	5.5	6.3	5.89	165	170	167.5	32	57	44.5
State	1	3.3	DQ	3.3	213	198	205.5	39.5	39.5	39.5
Post-State	1	3.4	3.2	3.3	209	203	206	30	28.3	29.15

Results:

Our cumulative data (Table 1 and Figures 7-9, p.12 and 13) for mousetrap car Model #1, between the Regional, State, and Post-State trials showed that there was much improvement.

In speed, the mousetrap car improved from an average of 3.65 seconds at the Regional competition, to an average of 3.3 seconds in the State and Post-State trials. In power, it improved from an average of 72 cm. at Regional, to and average of 205.5 cm. at State, and then remained in that range during the Post-State trial. In accuracy, the mousetrap car performed worse from Regional to State, but did improve slightly in the Post-State trial, with and accuracy of 28.76 cm.

F. Conclusions:

The three mousetrap car models demonstrated varying levels of performance ability. As shown in the Regional data, Model #1 performed the best in speed and accuracy, but failed to perform well in power. This was due to the fact that the gear was slightly too small. In the State competition, this gearing error was corrected, and the performance of power improved. The car with the shorter chassis length was lighter, therefore, there was less of a force of gravity and friction acting upon it. These findings from the results proved that the mousetrap car Model #1, with a short chassis length and a lighter weight performed best overall, which was predicted in the hypothesis.

In addition, these cumulative findings have helped to open research for further improvement. For example, Model #1 has the different rear wheel design, being small, narrow, aerodynamic, and with added rubber bands for traction. This feature was an important modification from the previous year's models. The larger wheel diameter allowed the car to cover greater distances with less rotation; however, the friction created by the doubled smaller wheels helped it to climb the incline farther. Also, the smaller wheeled car had more power for the ten meter straight. The body shapes of these models were also improved. They were more streamlined which improves speed. Model #1 will be used in the National Competition, because it is the lightest and has the shortest chassis length. The design of the mousetrap car will be refined and modified until the National Competition, to achieve and create the simplest machine that will give us the best results. Overall, this has been an exciting and challenging journey to see how well the mousetrap car has performed and improved over the past two years, and in this years State Competition. The upcoming National Competition will certainly create anticipation to see how well the car will perform, for the last time, against the competing states.

G. Recommendations:

Based on the performance of the mousetrap car models thus far, it is highly recommended to continue fine-tuning the existing design parameters, in preparation for the National Competition. This does not include testing new variables, but rather honing the adjustments already made in combination with applying physical forces and the properties of simple machines. Furthermore, it is recommended to continue practicing each of the three required tasks, because it is just as important as knowing what design parameters to use. A well-designed mousetrap car can still perform to varying abilities depending on adjustments made during the winding-up process and position alignment to the starting line. Lastly, always remember to have some fun too!

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I. Acknowledgments:

We would like to acknowledge our MESA advisor, [redacted] who inspired us to reach our goal; [redacted] for helping develop our recent models; Principal [redacted] and Vice-principal [redacted] for their support; and most of all, our beloved parents for all their support and encouragement. Lastly, we would also like to thank the University of Arizona MESA Early Outreach Program for giving us this wonderful opportunity again to participate in this project for the final frontier.

J. Appendix (Optional)

Conversion of Potential Energy (PE) to Kinetic Energy (KE)		m = mass g = gravity
1) $PE = mgh$ $KE = \frac{1}{2} mv^2$	3) $PE_f = 0$ and $KE_i = 0$	h = height v = velocity i = initial
2) $PE_i + PE_f = KE_i + KE_f$	4) Therefore: $PE_i = KE_f$ $mgh = \frac{1}{2} mv^2$	f = final

MESA

TECHNICAL PAPER SCORING CRITERIA

[redacted] MESA USA National Engineering Design Competition

TEAM: **SCHOOL:** [redacted] **LEVEL: MS or HS**

Discussion (Physical Phenomena, Experiment Procedures, Data & Analysis, Tables & Charts, Results)	**Abstract** (Length, Purpose & Key Features, Conclusions & Recommendations, Non-technical, Informative & Interesting)	**Introduction** (Purpose, Scope, Background Information)	**Conclusion & Recommendations** (Inferences & Evidence – Further Work & Reasoning)	**Written Presentation** (Length, Font, Key Sections, Supporting Sections)
31-40 • Very thorough discussion of Physics, Math and/or Engineering concepts • Very complete description of experimental/testing procedures including diagrams or pictures • Thorough description of analysis tools used • Highly relevant tables, graphs, charts, etc. • Very clear explanation of results w/graphics	16-20 • Length: <250 words • Very clearly restates Purpose & Key Features of report • Very clearly restates Conclusions and Recommendations of report • Written very clearly in non-technical terms • Engages and informs the reader	13-15 • Purpose: Very clearly states why project undertaken AND why report developed • Scope: A very thorough description of parameters, methods, limiting factors & technical terms • Background: Share key facts, conditions, events prior to project AND previous work on this topic	13-15 • Conclusion: • Inferences follow very logically from discussion evidence • No new material included • Recommendations: • Further work/best solution well identified • Written in first person w/ active verbs	9-10 • Length: 5-15 pages (-cover & title page) • Font: 12, Times New Roman • Spacing: double spaced • All Key Sections included: Title page, Abstract, Contents, Introduction, Discussion, Conclusion, Recommendations • All Supporting Sections included: References, Acknowledgments, Appendix
21-30 • Effective discussion of key concepts • Effective description of procedures including diagrams or pictures • Good description of analysis tools • Tables, graphs, charts, etc. useful to report • Good explanation of results w/graphics	11-15 • Length: Slightly over length • Good restatement of Purpose/Key Features • Good restatement of Conclusions & Recommendations • Well written, but includes some technical terms • Modestly engages and informs reader	9-12 • Effective/complete statement of purpose • Effective statement of scope, 1 or 2 items appear missing or overlooked • Effective and complete background details, 1 or 2 items appear missing or overlooked	9-12 • Conclusion: • Inferences follow loosely from discussion evidence • No new material included • Recommendations: • Further work/best solution not well identified	5-8 • Length: Slightly over or under length • Font: Some inconsistency throughout • Spacing: Some inconsistency throughout • 1 Key Section not identified or missing • 1 Supporting Section not identified or missing
11-20 • Limited discussion of key concepts • Limited description of procedures, with few diagrams or pictures • Analysis tools poorly described or not used • Graphics not well used to support report • Very little discussion of results, no graphics	6-10 • Length: too short • Poor restatement of Purpose or Key Features • Poor restatement of Conclusion or Recommendations • Many technical terms • Uninteresting to reader	5-8 • Incomplete statement of purpose for project and report • Incomplete statement of scope, multiple items missing or overlooked • Limited background information included	5-8 • Conclusion: • Inferences follow poorly from discussion, evidence not clear • Some new material included • Recommendations: • Further work/best solution not well identified	3-4 • Length: too short/long (-cover & title page) • Font: very inconsistent throughout • Spacing: very inconsistent throughout • 2-3 Key Sections not identified or missing • 2 Supporting Sections not identified or missing
0-10 • Little or no discussion of key concepts • Little or no description procedures • Data analysis not included • Graphics do not support report • No discussion of finding/results	0-5 • Length: >250 words • Purpose or Key Features not included • Conclusion or Recommendations not included • Does not engage reader	0-4 • Very poor statement of purpose for project • Very poor statement of scope, very little information included • Very poor background provided, very little information provided	0-4 • Conclusion: • Inferences do not follow from discussion or evidence present • new material included • Recommendations: • Further work/best solution not identified	0-2 • Length: <5 pages or >15 page • Font: incorrect throughout • Spacing: incorrect throughout • Most Key and Supporting Sections not identified or missing
Score 30 /40	Score 16 /20	Score 12 /15	Score 13 /15	Score 10 /10
Judge	[redacted]		Total	81

307

HS-B

TECHNICAL PAPER SCORING CRITERIA

[redacted] MESA USA National Engineering Design Competition

TEAM: **SCHOOL:** [redacted] **LEVEL: MS or HS**

Discussion (Physical Phenomena, Experiment Procedures, Data & Analysis, Tables & Charts, Results)	**Abstract** (Length, Purpose & Key Features, Conclusions & Recommendations, Non-technical, Informative & Interesting)	**Introduction** (Purpose, Scope, Background Information)	**Conclusion & Recommendations** (Inferences & Evidence – Further Work & Reasoning)	**Written Presentation** (Length, Font, Key Sections, Supporting Sections)
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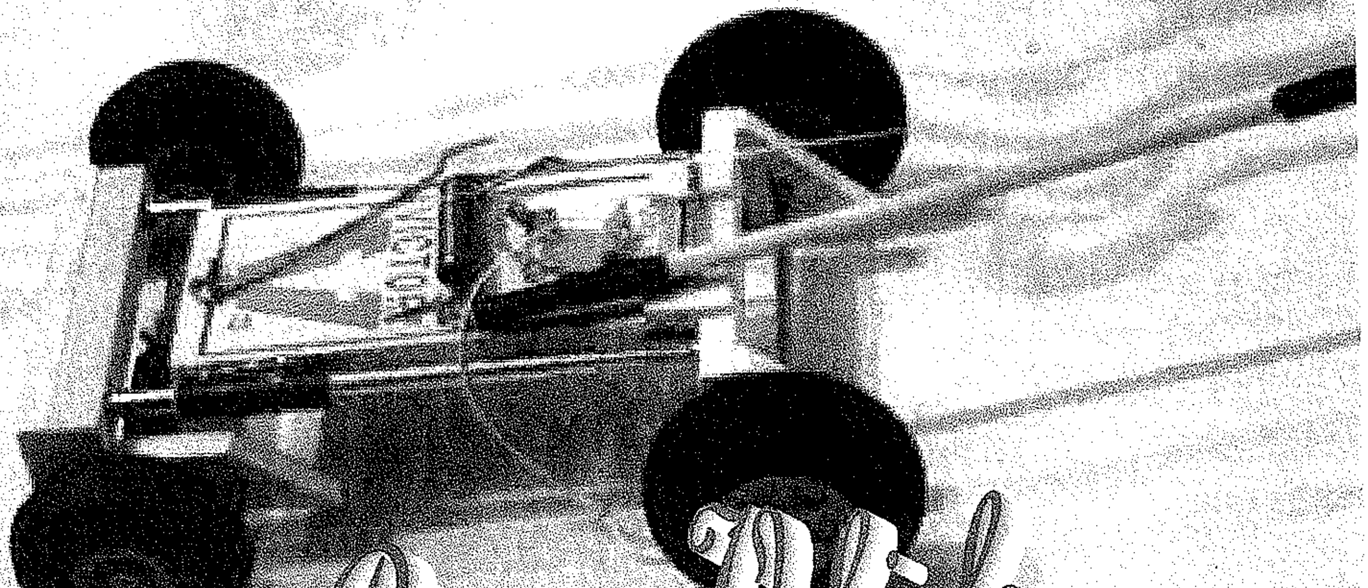
Score 35/40	Score 8 /20	Score 8 /15	Score 8 /15	Score 10 /10
Judge			Total	69

308

HS-B

[redacted] School



Multi-Purpose Vehicle

[redacted]

HS-B

Abstract

A mouse-trap car is a vehicle that is mechanically driven by the energy that can be stored in a wound up spring of a mouse-trap. To make this one single spring supply the energy needed to complete three distinctly different tasks was a challenge. The most basic devise can propel a vehicle several meters for any first-time builder; but in order to create a vehicle that can perform in a speed, accuracy, and power test you must learn of many different variables that affect the performance of a mouse-trap car. For example, this paper will discuss such engineering and physics concepts as friction, energy, Newton's Laws of Motion, and rotational inertia. You will also learn how we solved our problems and created a top performing vehicle. The paper goes on to present experimental procedures, and test results. The end test results after extensive research and experimentation, show a fast, accurate and powerful mouse-trap car that is very consistent.

Table of Contents

Introduction

Purpose

Building a mouse-trap car allows one to experience the means of design and engineering first-hand. When building a vehicle, one must start with an idea and then turn that idea into a real life model that works. This model must fit the specifications provided, and perform the designated tasks. The first task is one of speed; to cross a 10 meter mark in the fastest time. The next task is for power; furthest distance up a 30 degree incline. The final task is for accuracy; the nearest stop to a 5 meter target. A major problem that occurred during the process of construction was designing and building an adequate braking system. The braking system had to be light weight and effective every time.

Scope

One evident consideration in the design of our mouse-trap car was the frame or chassis. The chassis is a mechanical section that must provide support for the mousetrap, wheels, and axels. A chassis that is too light will have less weight pushing down on the wheels, causing less tire traction. A chassis that is too heavy will require more energy at the start than a lighter frame. With this in mind we constructed our chassis out of balsa wood that proves to be strong, stiff and a perfect balance of weight.

The next consideration was the wheel set. After numerous tests and many different types of wheels we concluded that our rear wheels be constructed out of compact mini-disks, and our front wheels are made of lightweight aluminum. We placed a rubber band around our rear wheel set for traction. Our front wheels are made of lightweight aluminum, designed for speed. We chose these wheels because they have almost no rotational resistance to the ground compared to many of our previous tires which created a lot of friction.

Next was the design and construction of our braking system. The braking system has to be effective on a consistent basis. This was one of the most challenging portions of the construction. Our first three attempts of constructing a braking system failed. The string we had connect to the front axle kept getting tangled. We finally constructed a model that can stop at the 5 meter mark on our 4th mouse-trap car. It is a fairly simple idea of transferring a fixed amount of string from a spool to an axle. When the spool runs out of string the axle stops rotating causing the wheels to come to a stop.

Background

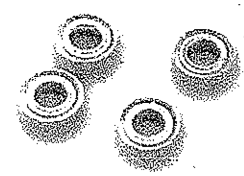
The [redacted] State MESA Day competition, included the state-wide event of the incline mouse-trap car. The incline was set at a 30 degree angle, similar to this years' national competition for power. The vehicle that placed first in that competition was very compact in size, from [redacted] it traveled a distance of 117 cm the first trial and 116 cm the second trial. Beating the competition by 42 cm. Second Place was awarded to [redacted] which traveled a distance of 30 cm on their first trial and 75 cm on their second trial. Third place was awarded to [redacted] traveling 55 cm on their first trial and 60 cm on their second trial.

Discussion

Physical Phenomena

The physical phenomena behind the mouse-trap car are explained through a number of engineering and physics concepts. These included such concepts as: friction, energy, Newton's Laws of Motion, and rotational inertia.

Friction is a force that always opposes motion, it acts in a direction that is opposite to the motion of the object. Our mouse-trap car is affected by friction in the aspect that friction will slow it to a stop. Friction will occur anytime two surfaces slip, slide, or move against one another (Hopewell, L 1998), as in our wheel axles and wheels making contact with the floor. Therefore to reduce friction we placed ball bearings in our axles. A ball bearing is a set of balls in the hole which is arranged so that the axle rolls on the balls instead of sliding in a sleeve. Therefore, our vehicle runs with ball bearings. The most important thing to understand is that the greater the amount of friction between two surfaces, the larger the force that will be required to keep an object moving. In order to overcome friction, a constant force is needed. In order to maintain a constant force, there must be a supply of energy.



Perhaps the concept most central to building a mouse-trap car is energy. Energy is always stored or contained in some physical system. (Swackhamer 2003) Therefore, we will always have to think of energy as a property of some identifiable physical system. So energy will always have a home, there can be no such thing as "pure energy." Energy flows or is transferred from one physical entity to another during interactions. (Swackhamer 2003) Lastly, regardless of where energy is, it remains always and only energy. (Swackhamer 2003) The substance metaphor entails an invariant identity of the substance being transferred and so avoids the transformation trap. Regardless of where a substance is, it remains the same substance. The concepts of mass and momentum benefit from this substance metaphor, because they are always regarded as the same. The objective during construction was to transfer energy into forward motion. The tasks to be accomplished by our vehicle each involve a variety of motions. Our study of Physical Phenomena must include a discussion of Newton's Law's of Motion.

Sir Isaac Newton's First Law of Motion stated, "Every material object continues in its state of rest or in uniform motion in a straight line unless it is compelled to change that state by forces acting on it." (Stern, D. P. 2001) This is also recognized as Galileo's concept of inertia, and this is often termed simply as the "Law of Inertia". Inertia is just a technical term that means resistance to change. Mass is the numerical measurement of inertia. Weight is related to mass and inertia but weight is not the same thing. Weight is a product of the amount of mass an object has and the amount of gravity pulling on the mass. Objects resist change in motion. Simply put, things tend to keep on doing whatever they are already doing.

Newton stated, "The acceleration of an object is directly proportional to the net force acting on the object, and is inversely proportional to the mass of the object." If you want to change the motion of an object, you have to apply a force. Net forces cause objects to accelerate or change their state of motion. (Bastea-Forte, M.1999) Newton recognized that his first law needed some additional explanation because most of the motion we observe around us undergoes changes and is the result of one or more applied forces; therefore, Newton wrote a Second Law of Motion which relates force, mass, and acceleration. The relationship between an object's mass $\boldsymbol{m}$, its acceleration $\boldsymbol{a}$, and the applied force $\boldsymbol{F}$ is $\boldsymbol{F = ma}$. Simply put, mass resists change or acceleration, and force cause acceleration. If you want to double the acceleration of an object, you have to double the pulling or pushing force. If you can't increase the force and you still want to increase the acceleration, then you have to remove mass.

Newton's Third Law of motion states, "Whenever one object exerts a force on a second object, the second objects exerts an equal and opposite force on the first." (Bastea-Forte, M.1999) In its most basic definition the law stated, "For every action there is an equal and opposite reaction." For example, you cannot push or pull any harder than something that pushes or pulls back. Therefore, during construction of our mousetrap we realized that the wheels we use can only push as hard as the floor can push back. As a result, with a speed car that produces a lot of torque, the wheels can only push as hard as the floor can push back. Therefore, if the floor can not push back with the same force as the wheels push, then our wheels would spin in place and our car would not accelerate to its fullest potential.

Another key concept is the idea of rotational inertia. Just as an object at rest tends to stay at rest and an object in motion tends to stay in motion, an object rotating about an axis tends to remain rotating about the same axis unless an external force or torque acts on it. The property of an object to resist changes in its rotational state of motion is called rotational inertia, and is a restatement of Newton's First Law of Motion. (Microsoft

Encarta 1997) Rotational Inertia is the resistance an object has to changes in rotation. During the construction of the wheels on our mouse-trap car we decided to use wheels that have as little rotational inertia as possible. As a result, less rotational inertia in the wheels means less required pulling force and greater travel distance with higher acceleration off the start. To help with this, here are some of the more common rotational inertia equations that were used during the building process of our vehicle's wheels.

Disk	Thin Ring	Thick Ring
$I = mr^2$ 	$I = \frac{1}{2}mr^2$ 	$I = \frac{1}{2}m(r_1^2 + r_2^2)$ 

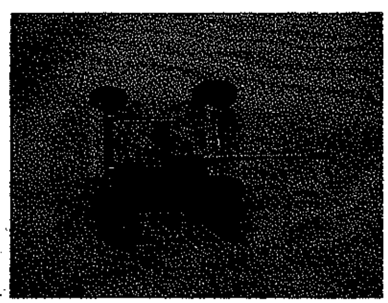
Experimental Procedures

The procedures were vital in designing, constructing and testing a successful multi-purpose vehicle. The first step in building a multi-purpose mouse-trap car was to brainstorm and find research about mouse-trap car designs that can perform all three tasks needed. Next, was to gather materials and create a model from using the designs we researched as a basis. The supplies that were used include: balsa wood, one unaltered Victor mouse-trap, compact mini-disks, two spools of thread, four micro ball bearings, one wood spool, brass tubing, jet super glue, rubber stoppers, and two lightweight aluminum wheels. After 26 grueling days of construction and failure, we finally had a vehicle that worked. An amazing vehicle that we are all proud of.

Data Reduction, Analysis Tools and Models

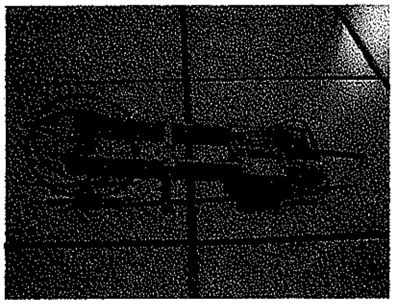
When our first vehicle was constructed it was unsuccessful. The vehicle was horrendous. The vehicle never went straight for more than three meters, it always curved to the left. We believed the problem lied in the front wheels. We replaced the wheels with thin lightweight wheels and straightened out the axle. This eliminated the constant turning problem, but what use was it if the vehicle would only travel one meter more. At that point we had a vehicle that would travel straight , but only for four meters and approximately 3 cm up the incline. We started on a completely new vehicle. This is when we started to use our materials wisely. We added micro ball bearings, and created a rigid lever attached to the mousetrap. We were making progress and, the car was able to travel the ten meter track with ease, slow and steady. Our braking system was still a failure, although we were able to travel 12 cm up the incline. The third car was much of the same with a difference of a movable mouse-trap. By moving the mousetrap closer to the rear wheels we were able gain approximately another 10 cm up the incline and we improved our speed by adding a wooden spool to the rear axle adding a larger wheel to axle ratio. The final vehicle is a replica of the third, although it's mass is reduced and has a better looking shape.

This is a photo of our fourth vehicle in it's compact state.

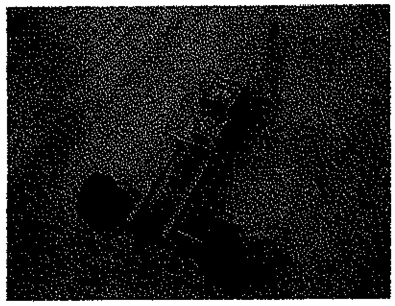


This is a photo of our fourth vehicle in it's extended state.

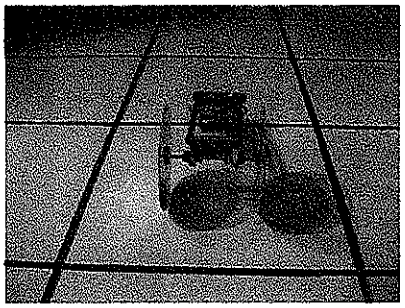
Vehicle 1



Vehicle 2



Vehicle 3



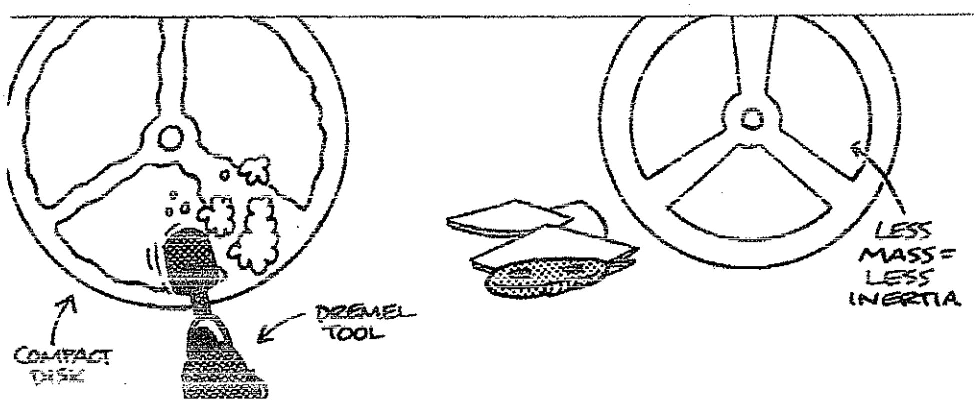
Date	Vehicle	Speed (sec.)	Accuracy (cm.)	Power (cm.)	Adjustments
2/17	1	Did not comp.	164	3	Added rigid lever arm
2/18	1	Did not comp.	182	2	No adjustments
2/24	1	Did not comp.	158	2	New design
2/26	2	Did not comp	109	2	Add spool in rear (torq.)
2/27	2	13.9	107	2	New compact design
3/2	2	14.2	115	4	Rubber band traction
3/3	3	8.8	31	21	Antenna extender
3/4	3	8.1	42	28	No adjustments
3/5	3	7.4	36	35	Lighter mass
3/8	4	5.3	5	72	No tangle thread (brakes)
3/9	4	5.1	2	68	No adjustments
3/10	4	5.7	8	70	Final Vehicle

Conclusion

After conducting this engineering challenge, it was determined how to best design and construct a successful multi-purpose vehicle. Friction, Energy, Newton's Laws of Motion, and Rotational Inertia were all incorporated during the construction of the mouse-trap car. The concept of Friction was used when creating the wheel and axle set to give it maximum acceleration. The concept of energy helped us understand that when constructing our mouse-trap car the objective was to transform the stored energy of the spring into forward motion. Newton's Laws of Motion helped us during the construction of our vehicle by making us realize the key concepts of force, acceleration, inertia, mass, and motion. The concept of Rotational Inertia helped during the construction of our wheels. We used wheels with less rotational inertia which means less required pulling force and greater travel distance with higher acceleration off the start. With all the knowledge we gained from our research on Friction, Energy, Newton's Laws of Motion, and Rotational Inertia we were able to construct what has proven in experimental tests to be a phenomenal multi-purpose vehicle.

Recommendations

During the construction process of our mousetrap car we found that a couple of techniques were easier and supplied the same results. When cutting the balsa wood for the frame using a dremel tool worked best. It made accurate, straight cuts. Then use a little sandpaper to smooth the cut out. As we stated in the Rotational Inertia portion of the Discussion, the [redacted] multi-purpose vehicle team wanted wheels with as little inertia as possible. By cutting out sections of the wheels, our wheels would require less force and energy to turn and accelerate. Less mass = Less inertia (Balmer, A 2002)



We also recommend having a movable mousetrap. We had the mouse-trap running on a track from the front of the car to the back. We placed the mouse-trap close to the rear wheels when performing the Power test up the incline. This position proved to be very effective for this portion of competition. We then placed the mouse-trap in the front of the vehicle for the Speed and Accuracy Tests. This proved to be the best area when going for speed.

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Acknowledgments

The [redacted] multi-purpose vehicle team would like to thank the following people for there help and support.

[redacted] M.E.S.A. Advisor

[redacted] Physics teacher

[redacted] Math teacher

[redacted] Science teacher

[redacted] English teacher

[redacted] Parents

Appendix

Speed (time it completes the 10 meter track in seconds)

Vehicle	Trial 1 (sec.)	Trial 2 (sec.)	Trial 3 (sec.)	Avg. (sec.)
1	Did not comp.	Did not comp.	Did not comp.	Did not comp.
2	Did not comp.	13.9 sec	14.2 sec	9.4
3	8.8	8.1	7.4	8.1
4	5.3	5.1	5.7	5.4

Accuracy (measured in how many centimeters close to the 5 meter target)

Vehicle	Trial 1 (cm.)	Trial 2 (cm.)	Trial 3 (cm.)	Avg. (cm.)
1	164	182	158	168
2	109	107	115	110
3	31	42	36	36
4	5	2	8	5

Power (measured in how many centimeters the vehicle traveled up the incline)

Vehicle	Trial 1 (cm.)	Trial 2 (cm.)	Trial 3 (cm.)	Avg. (cm.)
1	3	2	2	2
2	2	2	4	3
3	21	28	35	28
4	72	68	70	70

MESA

TECHNICAL PAPER SCORING CRITERIA

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TEAM: **SCHOOL:** [redacted] **LEVEL:** MS or HS

Discussion (Physical Phenomena, Experiment Procedures, Data & Analysis, Tables & Charts, Results)	**Abstract** (Length, Purpose & Key Features, Conclusions & Recommendations, Non-technical, Informative & Interesting)	**Introduction** (Purpose, Scope, Background Information)	**Conclusion & Recommendations** (Inferences & Evidence – Further Work & Reasoning)	**Written Presentation** (Length, Font, Key Sections, Supporting Sections)
31-40 • Very thorough discussion of Physics, Math and/or Engineering concepts • Very complete description of experimental/testing procedures including diagrams or pictures • Thorough description of analysis tools used • Highly relevant tables, graphs, charts, etc. • Very clear explanation of results w/graphics	16-20 • Length: <250 words • Very clearly restates Purpose & Key Features of report • Very clearly restates Conclusions and Recommendations of report • Written very clearly in non-technical terms • Engages and informs the reader	13-15 • Purpose: Very clearly states why project undertaken AND why report developed • Scope: A very thorough description of parameters, methods, limiting factors & technical terms • Background: Share key facts, conditions, events prior to project AND previous work on this topic	13-15 • Conclusion: • Inferences follow very logically from discussion evidence • No new material included • Recommendations: • Further work/best solution well identified • Written in first person w/ active verbs	9-10 • Length: 5-15 pages (-cover & title page) • Font: 12, Times New Roman • Spacing: double spaced • All Key Sections included: Title page, Abstract, Contents, Introduction, Discussion, Conclusion, Recommendations • All Supporting Sections included: References, Acknowledgments, Appendix
21-30 • Effective discussion of key concepts • Effective description of procedures including diagrams or pictures • Good description of analysis tools • Tables, graphs, charts, etc. useful to report • Good explanation of results w/graphics	11-15 • Length: Slightly over length • Good restatement of Purpose/Key Features • Good restatement of Conclusions & Recommendations • Well written, but includes some technical terms • Modestly engages and informs reader	9-12 • Effective/complete statement of purpose • Effective statement of scope, 1 or 2 items appear missing or overlooked • Effective and complete background details, 1 or 2 items appear missing or overlooked	9-12 • Conclusion: • Inferences follow loosely from discussion evidence • No new material included • Recommendations: • Further work/best solution not well identified	5-8 • Length: Slightly over or under length • Font: Some inconsistency throughout • Spacing: Some inconsistency throughout • 1 Key Section not identified or missing • 1 Supporting Section not identified or missing
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Score 30 /40	Score 16 /20	Score 10 /15	Score 13 /15	Score 10 /10
Judge	[redacted]		Total	79 /100

325

HS-2

MESA

TECHNICAL PAPER SCORING CRITERIA

[redacted] MESA USA National Engineering Design Competition

TEAM: Buffaloes **SCHOOL:** [redacted] **LEVEL:** MS or HS

Discussion (Physical Phenomena, Experiment Procedures, Data & Analysis, Tables & Charts, Results)	Abstract (Length, Purpose & Key Features, Conclusions & Recommendations, Non-technical, Informative & Interesting)	Introduction (Purpose, Scope, Background Information)	Conclusion & Recommendations (Inferences & Evidence – Further Work & Reasoning)	Written Presentation (Length, Font, Key Sections, Supporting Sections)
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Score 26 /40	Score 5 /20	Score 8 /15	Score 8 /15	Score 10 /10
Judge			Total	57

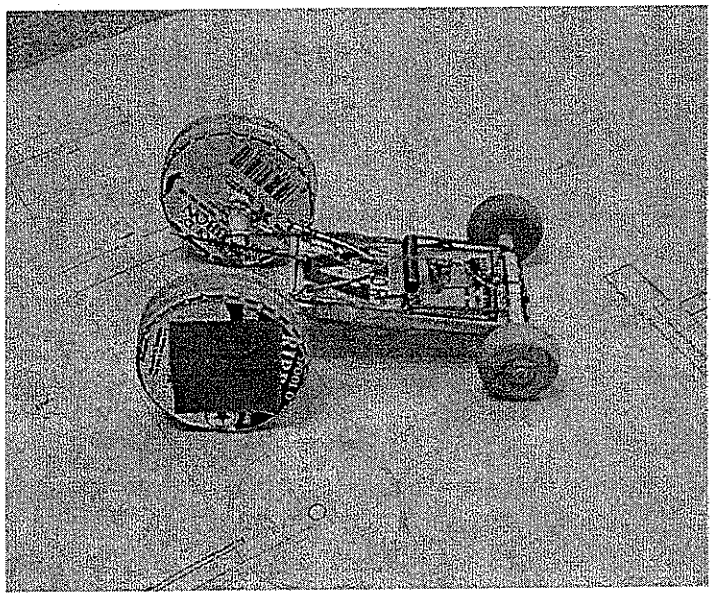
326

HS-C

The True Blue and White Buffaloes

Mousetrap Car [redacted]

[redacted]



By: [redacted]

[redacted]

HS-C

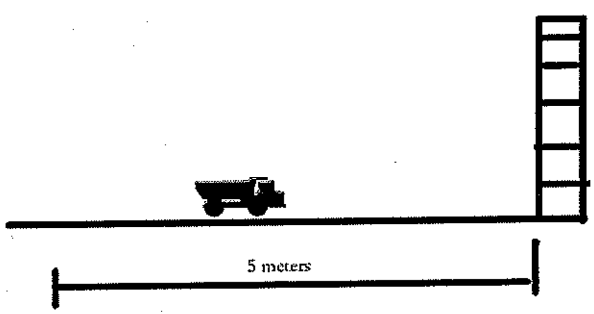
Abstract

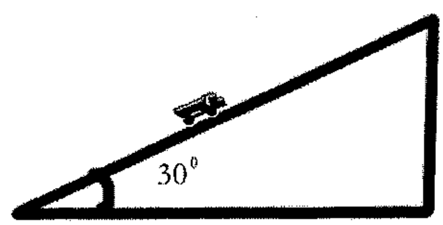
For many years now people have been searching for the perfect car that can handle any terrain, a car that can accelerate with a flip of a switch, scale hills, and is equipped with brakes that will prevent it from hitting any barrier. Usually when you think of a vehicle that could do it all, you think of a big monstrous truck, like a Ram 1500 with a hemi engine. Now were headed in the opposite direction, this car will have the strength of all trucks, speed of a Corvette, and the off-road abilities of a Jeep 4X4 all combined into one small compact car. Just think, a car that only weighs 86 grams, only 18 centimeters long, and is able to get the job done. You wonder how its powered then, all that needs to be done to get from point A to B is attach a small cable to the axle each time, and it will be riding effortlessly in no time. With the body of the car being made of just a regular household mousetrap, people have been very weary about the durability of this vehicle, but several tests were run where the car ran into wall and still was capable of performing to satisfaction. This project will require our mousetrap car to travel 10 meters as quickly as possible, stop closest to a wall set 5 meters away, and must climb a 30 degree ramp as high as feasible.

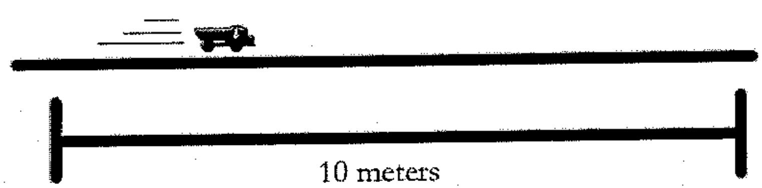
Table of Contents

Introduction:

A mousetrap car was a very interesting project to pursue. It is a project that would allow us, the students, to use our imaginations and test our teamwork skills. We had to take a standard mousetrap and transform it to a car using anything we could possible think of except for a motor. The M.E.S.A specification states that the only source the car could use to move is the pull of the spring on the mousetrap. They also stated that we could not take any thing off the mousetrap. The guidelines that we had to follow was; travel 10 meters as quick as possible, climb up a 30 degree wall as far as it could, and stop the closest to a wall placed five meters away. While preparing this car, we all put our minds together to come up with the best possible design. In building this car there was no individuality, we worked together and got the job done.



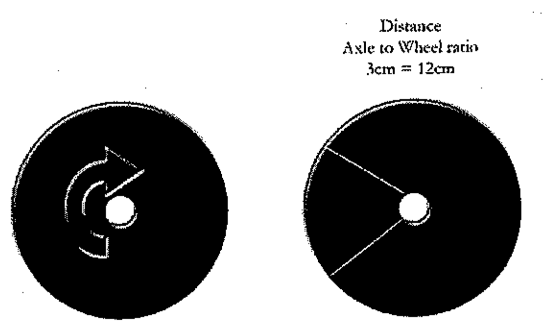




Discussion:

In this project we were faced with many problems which include the tasks of a speed trial in which we have to go as fast as we can over the distance of 10 meters, to go across the same flat smooth surface but this time to stop in 5 meters before hitting an object, and finally to climb up a hill of a 30 degree angle without changing any elements of the design. How we first tackled this project is we created a car with a paper tube chassis but because of the added length and weight comparable to one of the mousetrap cars from th[redacted]State MESA Competition we felt that we needed to conserve our weight and length for better purposes to improve our performance (College Physics p.121). How the mousetrap car works is it takes the stored elastic energy of the spring. This is then transferred to kinetic energy or moving energy when the trap is released. The energy is then channeled through a simple lever displayed by the bar of the trap snapping (College Physics p.119). Then if we attach a chassis to the trap and have a string that when pulled it will turn the axle you have a moving car.

As the multipurpose car many times the car will not have enough strength in general to climb a hill like required in this project for this task the concept of gear ratios or another kind of mechanical advantage will be required to complete the task (College Physics p.119). You see in diagram one by the difference between the circumferences of or the axle and of the wheel can cause us to either too much power and peel out on the hill or go nowhere because the lack of power to drive the car up the hill. Have you ever been in a car and it is stuck in mud or gavel? Well that brings up another point if



So when the axle is spun 3cm the wheel is moved 12cm in the same spin any car has poor traction it will also slip and slide on hills. Then key to the perfect car for this task is one with good traction and the correct gear ratio.

One of the other tasks is the speed test. In this task, we need to get our car up to speed as fast as we can and get it past a point 10 meters or about 33 feet. Once again, if you have bad traction or bumpy traction you might not get the full efficiency from your vehicle. However, with higher gear ratios, you may get up to speed faster but you cannot make the distance because you have used up your stored power.

Finally with the 5 meters and stop trial the only way we've thought to stop that fast we would need a higher gear ratio which makes the car spin out and go just the 5 meters or shorter and stop successfully to complete the task.

Now that we have figured out the aspects of this project, we revamped our car pushing the envelope of time and burning the candle of sleep at both ends. Distinct differences between other cars and our car includes our light rear wheels, our magnificent steering system, and our original chassis design. Our rear wheels are made from ribbon spools, which are hollow in the middle and are large giving us two ¾ in or 7 cm in diameter wheels. Our chassis is built right on to the body of the mousetrap removing any extra weight and having the back axle extended back with butterfly paper clips which eliminates the tendency for the car to pop wheelies. Our new car is a lot lighter than other cars including our first car, which weighed 105 grams. It is 19 grams less than the first and only 18 centimeters long our car is exceeding in all task areas. Since the track that we will be tried on is so slender, we need the ability to change and correct our steering. To tackle this problem we attached a butterfly paper clip to the front axle tubing to allow this adjustment.

In the following paragraphs, we will explain each graph found in the appendix trial by trial:

Flat Trial

In trial one, we were just barely starting and our string was not able to incorporate all of the power from the mousetrap into the axel, giving our distance of 15 feet. On trial two we wrapped the string the hot glue lowering the gear ratio, which resulted in our 25 feet. In trials, three, four, five, and eight we were having difficulties, such as steering problems and the string getting caught on the drive hook. Trials six, seven, and nine all surpassed 30 plus feet. With our car spinning out so frequently and feeling we did not have enough traction to go up a hill, we decided to add toothpicks underneath our rubber band tires for traction.

Hill Trials

This being our first time trying to tackle the hill on trial one the car went only seven inches, which was not very impressive for us. Trial two was even worse with only five inches. Trial three do to the low gear ratio, too much power was added to the axel, causing the car to spin out and climb a short distance of 12 inches up the hill. After trial, four being unsuccessful with only seven inches we removed the added duct tape that was around the axel, which improved quality on trial, six and seven. The distances on trial six and seven were 16 and 20 inches. After completing these trials we tested its performance on the flat land, our car hopped and shuttered making the idea of toothpicks unreasonable.

Hill Trials 2

Testing our car with the toothpicks altered at a 45-degree angle we had to test the car on the hill again. On the first trial we got 1.6 feet, second we got 2.3 feet. On the third trial, it went up the hill 1.3 feet, but slid back down the ramp. On trials 4-11, it consistently reached around 2.6 feet every time, except for in trial six when the string was caught on the hook. Since we had the car going up the ramp with great consistency, all we needed was to test it on the flat land again.

Flat Trials 2

In trials, two and four we had difficulties, one due to steering and the other due to the string being caught on the drive hook. On all of the other runs, we accomplished getting 24 feet on each run. We still need it to go farther, but at least the car was consistent.

Experimentation

In our experimentation, we played with all aspects including the chassis, wheels, axles, and string lengths. Through changing these aspects of the car, we drastically altered its performance. Since we did not have a ramp set up at 30 degrees, already we improvised taking a school table and using books to increase the angle. For the speed and the accuracy trial, we ran down the hallway, which is 152 centimeters away from the two-meter track width giving us an almost perfect track.

Conclusion:

Based on the information we have gathered and through many tests that we have run, we feel comfortable enough to run our car at regionals and state with no worries. This care has already reached and surpassed many of the cars that have been built at [redacted] throughout the years. We believe that with our chassis design we will be able to compete with other schools.

Recommendations

For anyone trying to build a mousetrap car, we have a few recommendations. First of all you must make sure your car is light, because the only way you can get your car to move is to the spring, and if your car is heavy its not going to pull very far. In addition, you have to make sure your axle is smooth, so it will not lose any momentum when trying to spin. The last thing that we strongly recommend is to have some type of steering system. If you mount your axle and it is crooked, you will have to rip it off and remount it. Whereas, if you just put a paper clip attached to your axle you will be able to move it freely whenever it needs adjustments. Something else you must remember when your building this car is to have fun while your doing it.

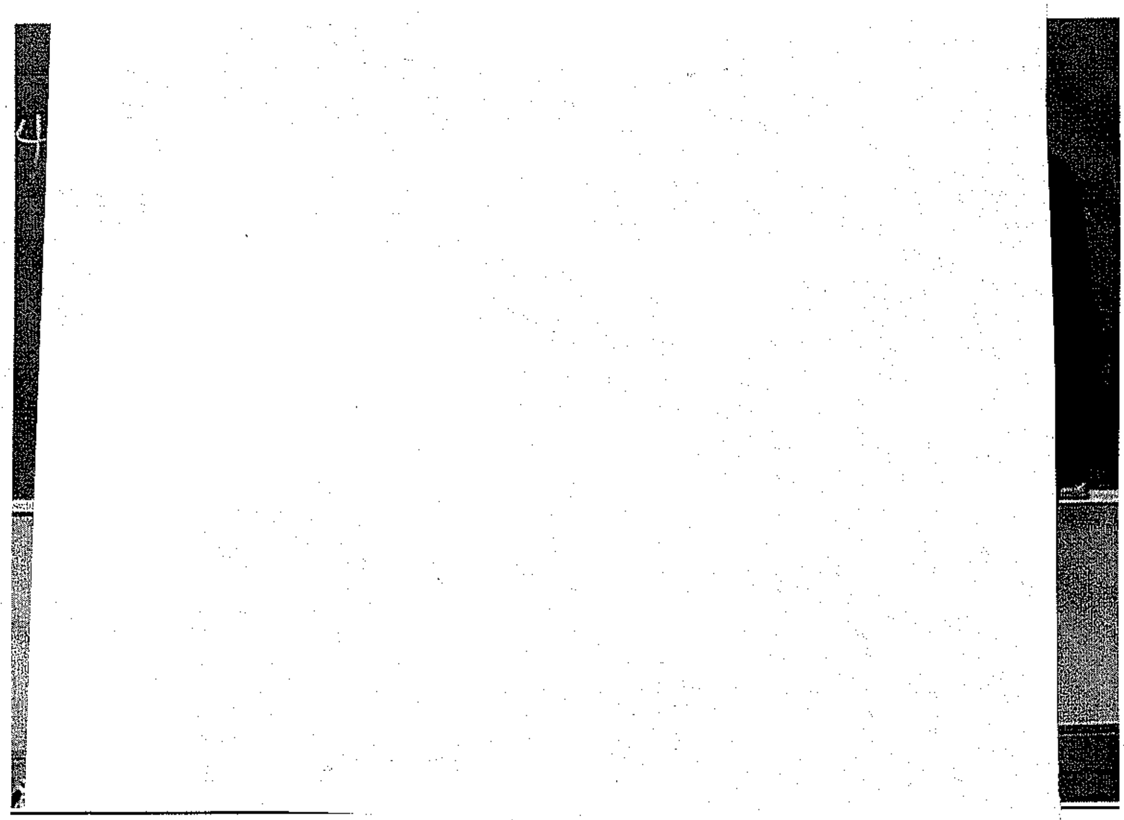
References or Bibliography

Serway, R. and Faughn, J. (1985) *College Physics, Fifth Edition.* Orlando: Emily Barrosse

Balmer, A. (2002) Doc *Fizzix's Mousetrap Powered Cars and Boats.* Round Rock: Doc Fizzix Publishing Company

Acknowledgments:

The member of the Mousetrap Car team would like to express our sincerest gratitude to [redacted]. She is our M.E.S.A teacher and she has put endless hours toward helping us set-up, test, and collect supplies for our project. Also we would like to give a special thanks to [redacted], a Physics teacher at [redacted] that helped us with a lot of the definitions needed for this essay. We would also like to thank [redacted] he helped us by always giving constructive criticism by saying he could beat our car with his year old car. Thank you all.



Appendix

Flat trial * flat level ground tiled floor no tooth picks in the tires*

Trial #	Distance in feet	Notes
1	15	String not long enough
2	25	String wrapped on hot glue
3	5	String got caught on hook
4	Incomplete	Steered off the course
5	Incomplete	Steered off the course
6	30	Looking good (string raped on axle only)
7	31	String on axle only
8	Incomplete	Steering off
9	33	Wrapped on axle then back to hot glue

Hill trials *table set up at 30 degree angle with wood laid on top of table toothpicks Placed in tires perpendicular to the tire edge for traction*

Trial #	Distance in inches	Notes
1	7	Not enough power to climb
2	5	
3	12	Spun out not enough traction
4	7	(Removed duct tape from the axle)
5	Incomplete	String disconnected from trap
6	16	
7	20	

Note *in between trials we did one run on flat land and the car hopped around Jaggedly droving that we need different traction*

Hill trials

Table set up at 30 degree angle with wood laid on top of table toothpicks placed in at 45 degree angle

Trial #	Distance in feet	Notes
1	1.6	
2	2.3	
3	1.3	Slid
4	2.5	
5	2.5	
6	Incomplete	Caught on hook
7	2	
8	2.3	
9	2.2	
10	2.9	
11	2.8	

Note*wrapped all on hot glue*

Flat trial * flat level ground tiled floor tooth picks at 45 degree angle in the tires*

Trial	Distance in feet	Notes
1	24	
2	Incomplete	Due to steering
3	23	
4	15	String caught on hook
5	24	
6	24	
7	24	

Trials ended due to consistency

MESA

TECHNICAL PAPER SCORING CRITERIA

[redacted] MESA USA National Engineering Design Competition

TEAM: [redacted] **SCHOOL:** [redacted] **LEVEL:** MS or HS

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Score 35 /40	Score 8 /20	Score 12 /15	Score 13 /15	Score 9 /10
Judge			Total	77

340

HS-D

MESA

TECHNICAL PAPER SCORING CRITERIA

[redacted] MESA USA National Engineering Design Competition

TEAM: **SCHOOL:** [redacted] **LEVEL: MS or HS**

Discussion (Physical Phenomena, Experiment Procedures, Data & Analysis, Tables & Charts, Results)	Abstract (Length, Purpose & Key Features, Conclusions & Recommendations, Non-technical, Informative & Interesting)	Introduction (Purpose, Scope, Background Information)	Conclusion & Recommendations (Inferences & Evidence – Further Work & Reasoning)	Written Presentation (Length, Font, Key Sections, Supporting Sections)
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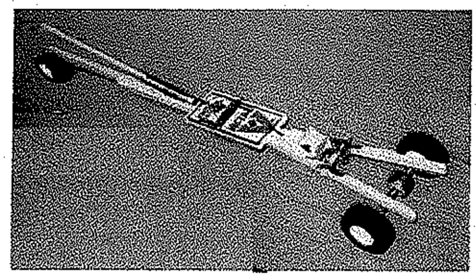
Score 39 /40	Score 19 /20	Score 15 /15	Score 15 /15	Score 10 /10
Judge	[redacted]		Total	98

341

HS-D

The Mighty Mousetrap Car



[redacted]

By

[redacted]

[redacted]

[redacted]

Tucson, Arizona

MESA Day [redacted]

[redacted]

HS-D

A. Abstract:

Building a mousetrap car has been an exciting and educational experience this year. In order to fulfill the requirements of designing a mousetrap car that could successfully perform three challenging tasks, we had to learn about forces such as friction, acceleration, torque, gravity, potential and kinetic energy, and Newton's three laws of motion. Understanding these principles helped us design a mousetrap car that could climb up a 30° incline plane, that could race down a 10-meter path and lastly, travel to a target five meters away as accurately as possible and come to a stop there. After undergoing many trials, we concluded that there were varying levels of performance ability demonstrated by the models built. The main variables distinguishing the two designs were the chassis, or body length, and the front wheel size. The first variable seemed to be more effective in the car's performance in the power trial, while the second variable may have been important in the accuracy trial. Our recommendation is to experiment with more variables, and comparisons of different variables in trying to better understand how each affects the performance of the mousetrap car.

Table of Contents:

B. Introduction:

Purpose:

The purpose of this experiment was to design, build and test a spring-powered vehicle that can perform three specific tasks. The spring for this vehicle is found in the form of a mousetrap, and the tasks it had to perform included climbing an incline, speeding down a 10-meter path and lastly, traveling to a target five meters away as accurately as possible.

Scope:

Constructing a car powered solely by a mousetrap was an amazing and educational experience. Through repeated trial and error, we gradually came to understand principles of motion, kinetic and potential energy, and friction. We tried to use these concepts to our advantage in designing the mousetrap car. There were a lot of limiting factors that we had to consider. The only source of energy allowed was the spring of the mousetrap, and this could not be enhanced by additional elements such as rubber bands or strings. Ultimately, these principles and the trials and errors of building a mousetrap vehicle that utilized them have helped us design the model we are now using.

Background:

For centuries the growth of human civilization has been directly linked to the development of technology, and more than any other technology, locomotion has enabled people to travel, explore new worlds and redefine what it means to be human. Today, we are completely dependent on transportation for our every need; we take it for granted, but it will only persist for as long as we can maintain a fuel source, or develop alternative fuel- or mechanized vehicles.

The conversion of a spring-powered mousetrap into a car is one example of a mechanized vehicle. **Figure 1** shows a diagram of the basic components of a mousetrap car. Although a mousetrap car is nowhere near the scale of modern modes of transportation, it is based on the same laws of motion. The principles we studied that most commonly affected the design and operation of the mousetrap car were that of friction and kinetic and potential energy.

C. Discussion:

What were these principles and what do they mean? One principle is friction, which is common in everyday life. It is there when you slide down a slide, when you glide on the ice, and when you drive a car. Friction is the resistance encountered by any moving object (MSN Encarta Premium). On the mousetrap the tires were affected by friction when they spun on the floor; friction is what opposed the accelerating force trying to move the car forward, and is what held the car back. **Figure 2** shows how friction counteracts the accelerating force. In addition, another form of friction was traction, which enabled the car to move. Without traction there would be no grip for the tires to help the car to move forward, and they would just spin in place.

What powered the mousetrap? All power came from a source of energy. In the case of the mousetrap there were two types of energy, potential and kinetic. Potential energy is the energy that a body or a system has because of its position, and kinetic energy is the energy that a body or system has because of its motion (MSN Encarta Premium). The potential energy was initially located in the spring of the mousetrap when it was set and ready to be released. As the spring was released, its potential energy was converted into kinetic energy, which propelled the mousetrap car forward. **Figure 3** shows the initial and final positions of potential and kinetic energy.

The manner in which the kinetic energy was released is very important. It was better to conserve kinetic energy and use it at the lowest possible rate, so that it was not expended too quickly. To do this, another force was involved: torque, which is a rotating force that provides the ability to overcome resistance in turning (MSN Encarta Premium). Torque provided greater forward acceleration to the mousetrap car, and allowed it to cover a greater total distance.

The motion of the mousetrap car can fundamentally be explained using Newton's three laws of motion. Newton's first law of motion states that an object at rest (or in motion), will stay at rest (or in motion in a straight line) until an outside force acts upon it. This is often called the law of inertia. The mousetrap car was at rest before its spring was released, which created a force that accelerated the car forward. The car remained in motion until two forces that oppose acceleration acted on the car: gravity, which slowed the car down by pulling it towards the floor, and friction, which pulled the car backwards and created drag. Thus, the forces of both gravity and friction resulted in slowing the velocity of the car.

Newton's second law of motion states that, "the net force on an object is proportional to its acceleration and its mass. It will accelerate in the same direction as the force applied" (MSN Encarta Premium). In other words, Newton's second law means that the greater an object weighs, the larger the force necessary to accelerate it. Since the mass of each mousetrap car remained constant, a larger applied force created a greater acceleration than a smaller applied force.

Newton's third, and final law of motion states that every action has an equal and opposite reaction. When the spring of the mousetrap car was released and the arm swung forward (the action), the car accelerated in the opposite direction with the same amount of force that was created from the spring (the reaction).

All of these principles were easily demonstrated when testing our mousetrap car. We attempted to utilize the forces acting on the mousetrap car to our best advantage. One idea we had was to cover the tires with rubber bands, which we thought would create more traction and allow the tires to better grip the surface of the incline plane. Another idea was to extend the length of the arm, which we thought would increase the force created by the release of the spring.

Hypothesis:

We predicted that a mousetrap car with a longer chassis would perform more efficiently and accomplish the three tasks more easily than a car with a shorter chassis. We believed that the longer chassis would help keep the car traveling in a straight line and allow it to better accomplishing the tasks.

Materials:

Balsa Wood	Pliers	Staple Gun
Cardboard	Popsicle Sticks	Stop Watch
Dental Floss (Waxed)	Rubber Bands	Thread Bobbin
Drinking Straws	Rulers	Used Toy Car Tires
Elmer's White Glue	Sand Paper	Wood Dowel
Hand Saw	Scissors	Wooden Spools
Hot Glue Gun	Standard Mousetrap	X-acto Knife
Masking Tape		

Procedure:

The procedure we followed for building our mousetrap car can best be explained in five parts. The first part was the construction of the chassis. For this part, we had to decide how long the car should be, which also entailed deciding how far apart the front and rear wheels should be from each other. This was a critical design feature because it affected both the speed and power of the mousetrap car: speed is different from power in that it is the distance traveled over time, while power is the distance traveled up a 30° incline plane. We wanted to design a mousetrap car that combined the best of both worlds - that would be both fast and powerful.

The second part of construction was the design of the front wheel or wheels. The important factor to keep in mind for this feature is that the function of the front wheel or wheels is just to keep the car straight. The front wheel did not receive the full force of the mousetrap when sprung; it was more like a steering wheel in that it did not use any energy. Therefore, the front wheel or wheels should revolve easily and freely around its axis.

The third part of construction was of the rear wheels. Unlike the front wheels, the rear wheels received the full force of the spring when it was released. The force of the spring was transferred into the rear axle, which made the rear wheels spin. We wanted to design the rear wheels so they would utilize the kinetic energy of the mousetrap as efficiently as possible, but still turn easily.

The fourth part of the mousetrap car construction was the extension of the bail, which is the part of the mousetrap that kills the mouse if it is unlucky enough to not get away with the cheese. This component was critical when it came to power consumption, or power conservation. Extending the bail past the length of the mousetrap is what controlled the force released from the trap, in a manner that made the car more powerful.

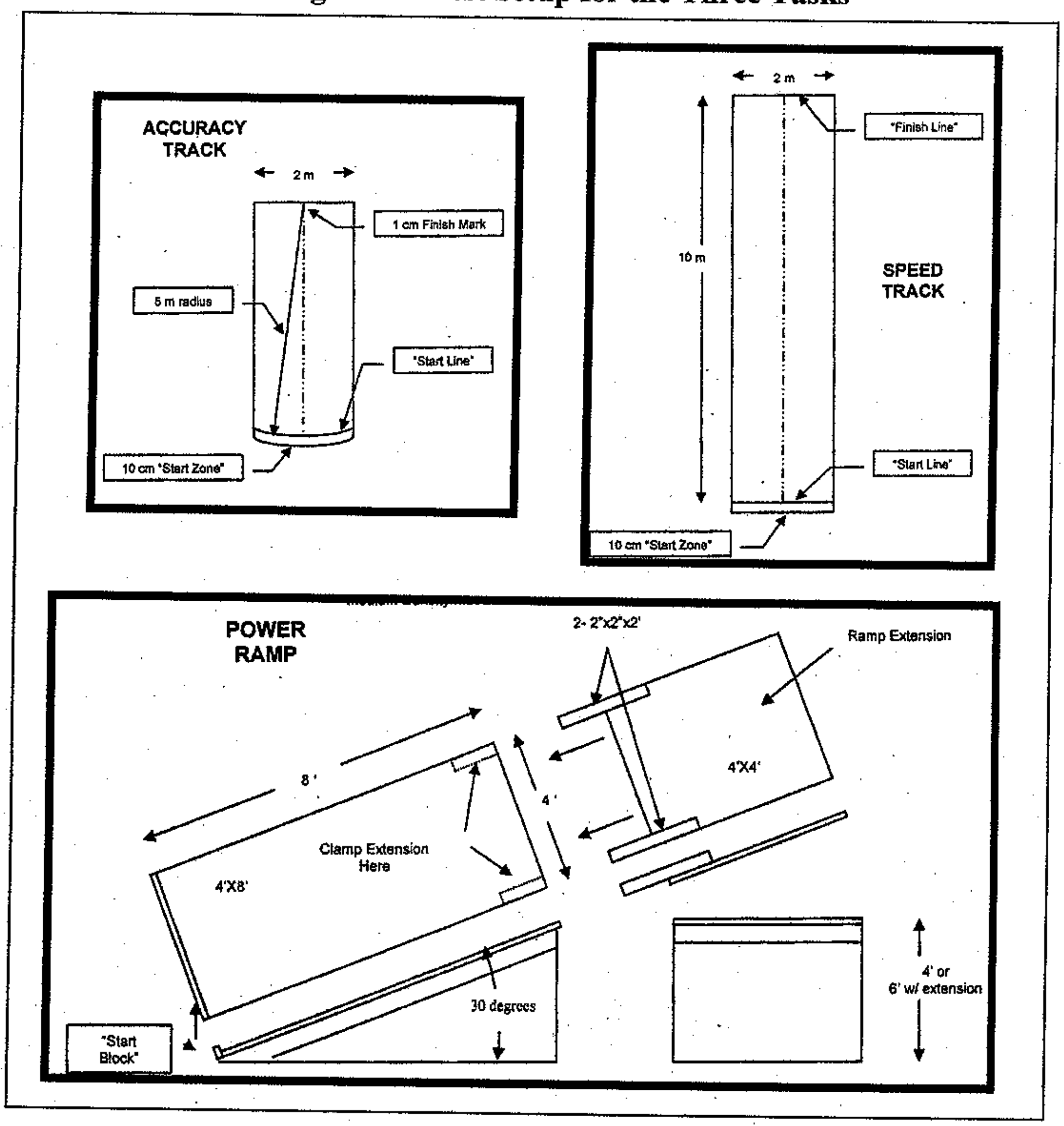
The fifth and final part of the mousetrap car construction was the size of the rear axle. We created a gear by wrapping the rear axle with duct tape, which increased the diameter of the axle and served to transmit more energy from the spring to the rear wheels (Balmer 2002).

Increasing the diameter of the rear axle is what provided more torque to the axle. We determined how much duct tape to add and increase the axle's diameter through trial and error.

Test Setup:

The mousetrap car was designed to perform three tasks: it had to travel up a 30° degree incline, travel accurately to a target five meters away and stop, and it had to travel across a 10 meter runway as quickly as possible. The setup for each task is in **Figure 8**. In each of these tasks the car was powered by the spring of a single mousetrap as an energy source.

Figure 8 – Test Setup for the Three Tasks *



* Figure information came from the National Competition MESA specifications.

Data Reduction, Analysis Tools and Models:

Figure 5 - Accuracy Performance of Mousetrap Car Models

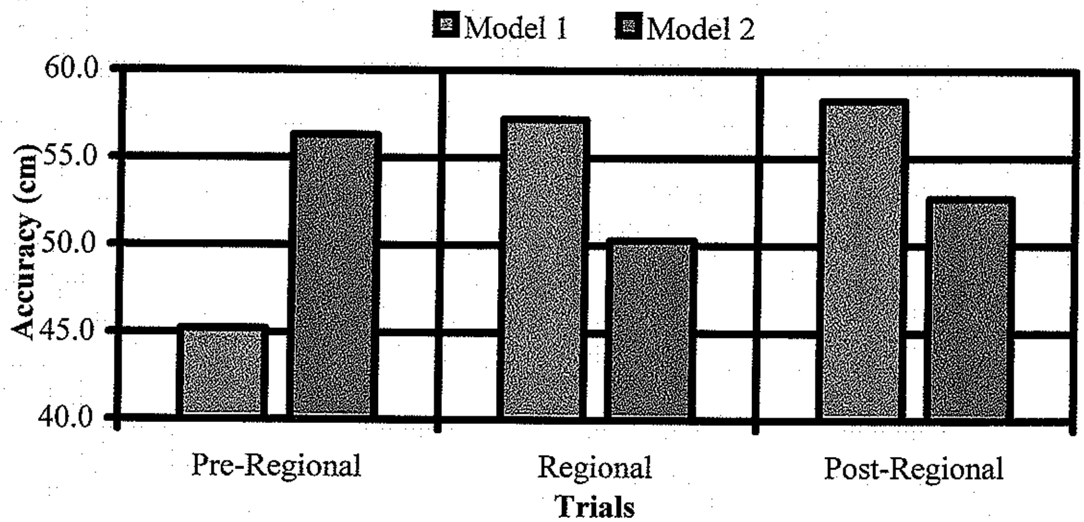


Figure 6 - Power Performance of Mousetrap Car Models

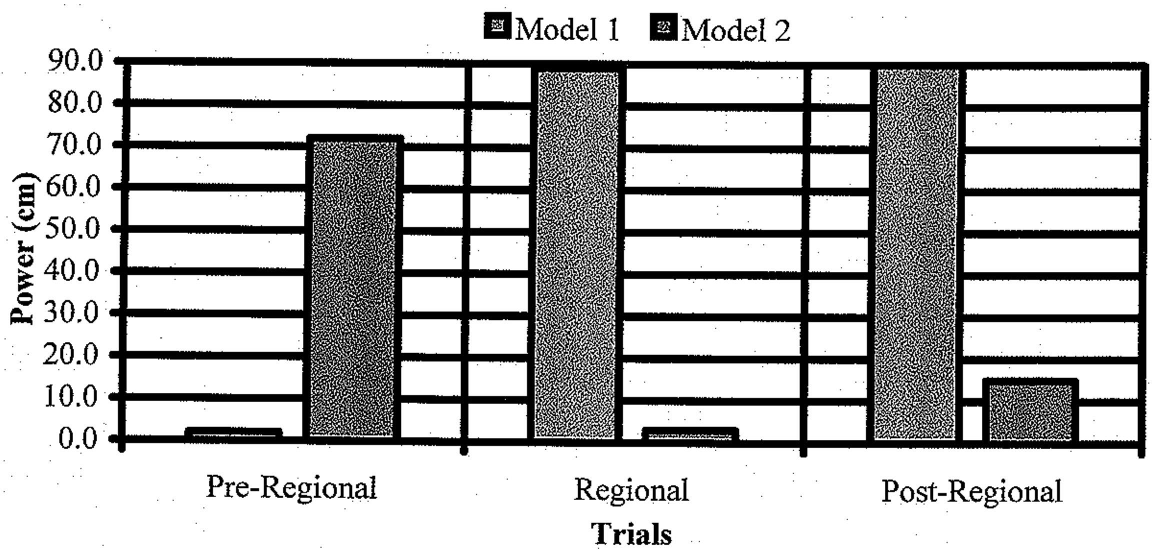
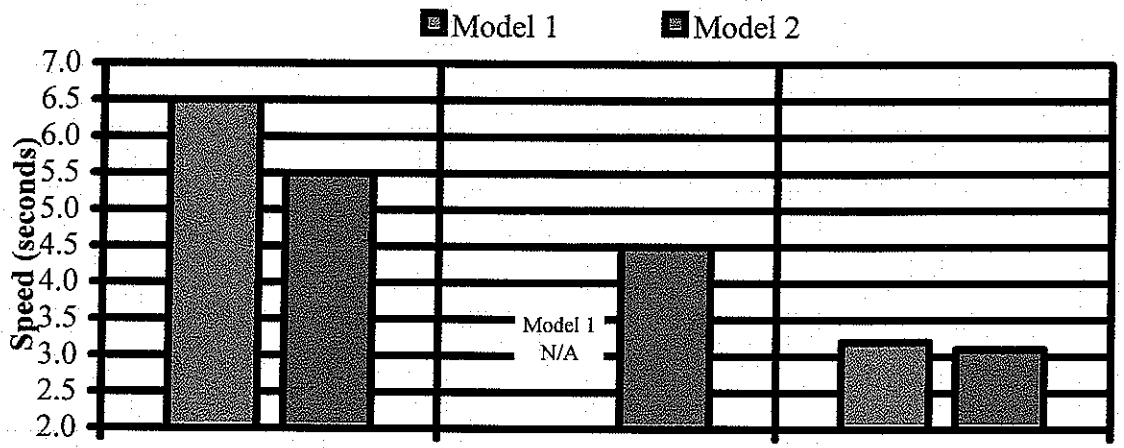


Figure 7 - Speed Performance of Mousetrap Car Models



Data:

Table 1 - Mousetrap Model Performance

Trials	Model #	Accuracy (cm)	Power (cm)	Speed (s)
Pre-Regional	1	45.2	2.0	6.5
	2	56.3	72.0	5.5
Regional	1	57.2	89.0	N/A *
	2	50.3	3.0	4.5
Post-Regional	1	58.3	90.0	3.2
	2	52.7	15.0	3.1

* The rear axel of Model 1 came off at the end of the power trial, and could not be repaired to compete in the speed trial

Table 2 - Summary of Mousetrap Model Performance

Model #	Accuracy (cm)	Power (cm)	Speed (s)
1	increase	increase	decrease
2	decrease	decrease	decrease

(Shaded areas indicate improvements in performance)

Figure 1 – Basic Components of a Mousetrap Car

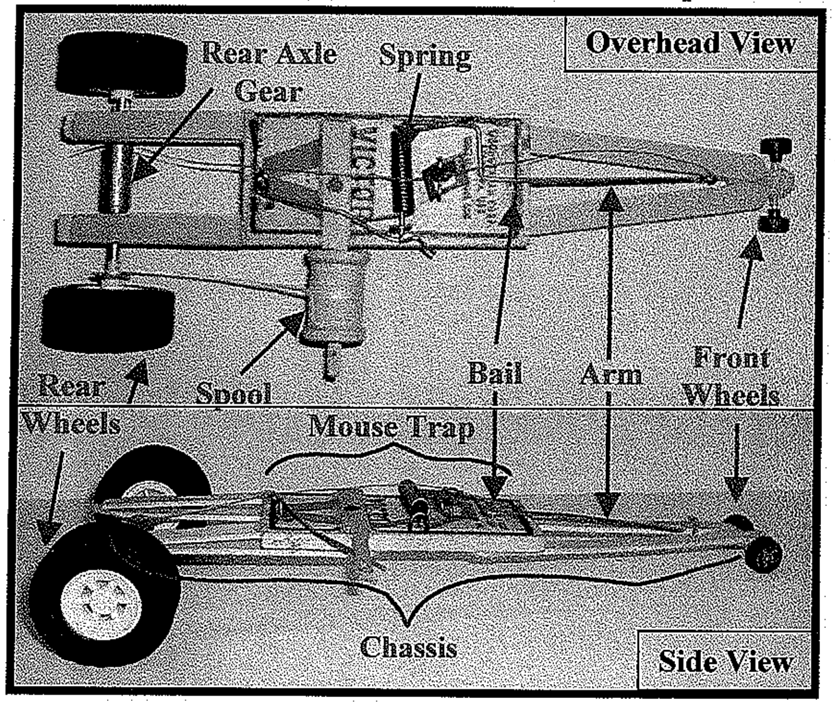


Figure 1a – Mousetrap Car with Rubber Bands on Rear Tires

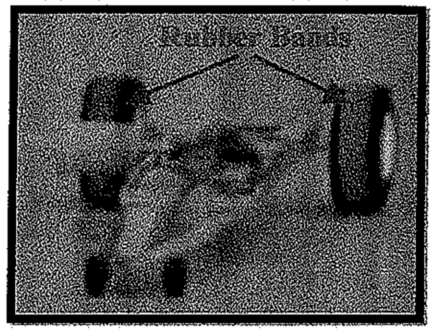


Figure 2 – Counteraction between Friction and Acceleration

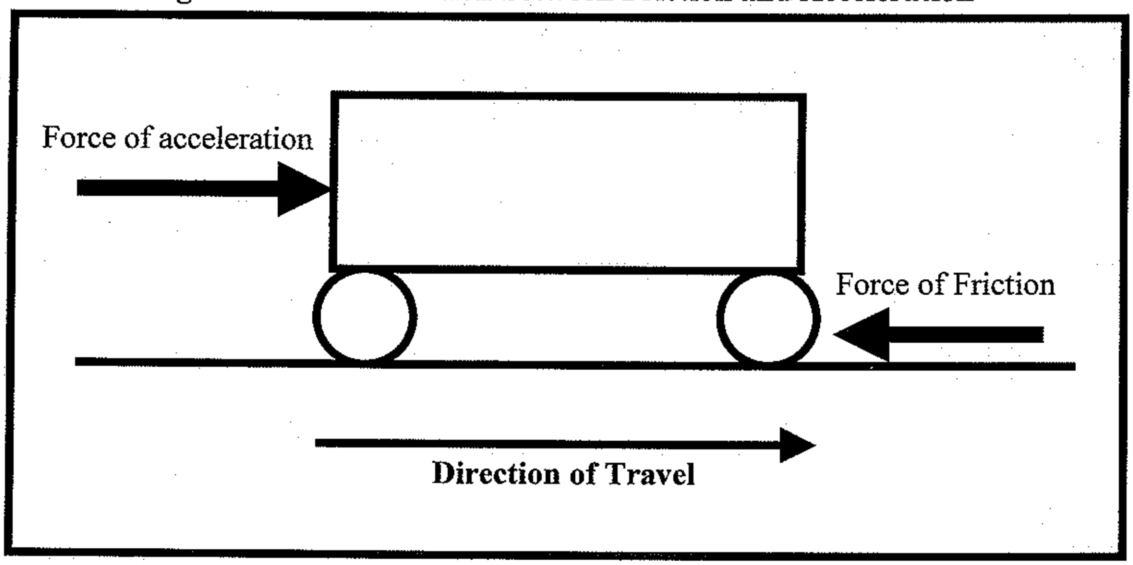


Figure 3 – Initial and Final States of Potential and Kinetic Energy

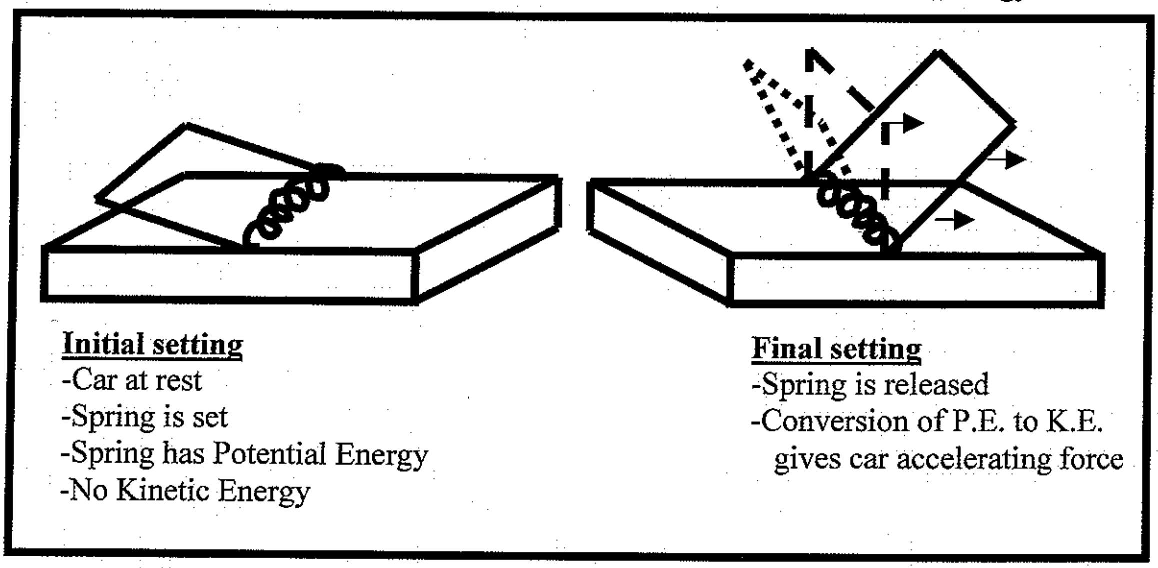
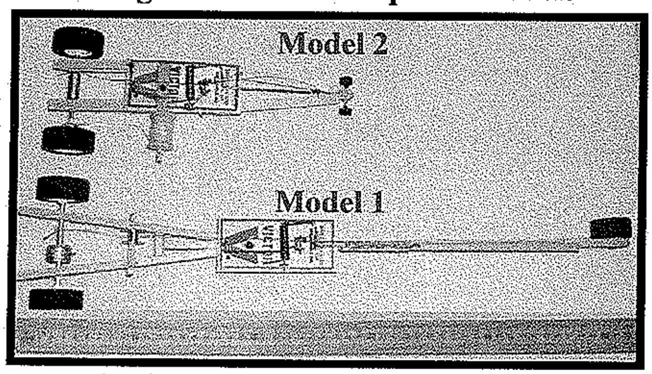


Figure 4 – Mousetrap Car Models



Results:

Our cumulative data (**Table 1**) of the two mousetrap models indicated varied levels of effectiveness in performance. Both model cars improved their effectiveness in two of the three required tasks, and experienced a decrease in performance in one task (**Table 2**). However, the improvements and decreases in performance where not the same for both models: Both models improved in speed (**Figure 7**), Model 1 by 51% and Model 2 by 44%. However, only Model 2 improved in accuracy (by 6%, **Figure 5**) and only Model 1 improved in power (by more than

100%, **Figure 6**). Of the three tasks though, power was the most challenging to succeed in, and in this regard, Model 1 may be considered as the better performing car. **Figure 4** shows Model 1 and Model 2 for comparison.

D. Conclusion:

Varying levels of performance ability were demonstrated by the model mousetrap cars. Contrary to our hypothesis, the longer-chassis model did not compete more effectively in all three tasks in comparison to the shorter-chassis model. However, the longer-chassis model did succeed in the most difficult task of climbing a 30^{0} incline plane, and it is reasonable to conclude that its success was due to its longer chassis. More specifically, the longer-chassis model had a longer arm, which provided greater leverage and torque when the bail was sprung, so that the kinetic energy produced was conserved more effectively than the model with a short arm.

The longer arm of Model 1 also demonstrated Newton's third law of motion: the torque provided by the longer arm generated a greater initial force of acceleration in the opposite direction from the direction in which the bail snapped. Having a longer arm allowed Model 1 to excel in the power trial of the competition, while Model 2 expended its kinetic energy too quickly to be effective.

On the other hand though, having a longer chassis did not notably improve the effectiveness of Model 1 versus Model 2 in the speed and accuracy tasks, so it is reasonable to conclude that other variables in the cars' design could affect their performance differently in these tasks. For example, the force of friction working against the models' acceleration would differ depending on the size of the front wheel or wheels. A car with a smaller front wheel or wheels would not have to compete against as great a force of friction as a car with a larger front

In addition, the size of the model and its individual components is important with regard to gravity. The greater the mass of a model or its component pieces, the greater the force of gravity that pushed down on the car. The rear wheels of both our models were large, and may have impeded their forward acceleration somewhat. However, these large wheels provided greater traction for helping the models accelerate. In designing our mousetrap cars, we had to compromise whether to keep them lighter, or whether to make parts of them (the rear tires) larger and modify them (with rubber bands, **Figure 1a**) to increase the traction.

We will continue to refine and modify our mousetrap car design to achieve and create the simplest machine that will give us the best results. Overall we were exited to see how well our mousetrap cars did in the regional competition, and we are excited to see how our revised design will perform against other schools' models in the state competition.

E. Recommendations:

Based on analyses of the performance of our mousetrap car models thus far, we highly recommend focusing on structural elements such as front wheel size, arm and chassis length, rear wheel size and traction, and total mass of the car. We recommend designing and testing as many models as possible, to better learn how these variables affect the performance of the mousetrap car individually, and in combinations with each other. For example, it would be difficult to examine how chassis length influences the car's performance without also studying the effect of the total mass. How can the forces of motion be applied to the improvement of the mousetrap car without limiting it? In addition to designing different models and performing repeated trials, we recommend researching what other people have found about mousetrap cars. Lastly, always remember to have fun!

F. References:

Arizona State University. MESA DAY 2004 Event Specifications Handbook. p.20. 2004

Balmer, Alden J. Doc Fizzix's Mousetrap Powered Cars and Boats. Doc Fizzix Publishing Company. Round Rock, Texas, 2002.

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G. Acknowledgments:

We would like to acknowledge our MESA advisors, [redacted] and [redacted] Next, we would like to recognize our principal, [redacted], for all the support and encouragement he gave us throughout the year and especially in competition. Lastly, we want to thank our parents for all the support they have given us through thick and thin and all the confidence they have had in us throughout the year.

MESA

TECHNICAL PAPER SCORING CRITERIA

[redacted] MESA USA National Engineering Design Competition

TEAM: **SCHOOL:** [redacted] **LEVEL:** MS or HS

Discussion (Physical Phenomena, Experiment Procedures, Data & Analysis, Tables & Charts, Results)	**Abstract** (Length, Purpose & Key Features, Conclusions & Recommendations, Non-technical, Informative & Interesting)	**Introduction** (Purpose, Scope, Background Information)	**Conclusion & Recommendations** (Inferences & Evidence – Further Work & Reasoning)	**Written Presentation** (Length, Font, Key Sections, Supporting Sections)
31-40 • Very thorough discussion of Physics, Math and/or Engineering concepts • Very complete description of experimental/testing procedures including diagrams or pictures • Thorough description of analysis tools used • Highly relevant tables, graphs, charts, etc. • Very clear explanation of results w/graphics	16-20 • Length: <250 words • Very clearly restates Purpose & Key Features of report • Very clearly restates Conclusions and Recommendations of report • Written very clearly in non-technical terms • Engages and informs the reader	13-15 • Purpose: Very clearly states why project undertaken AND why report developed • Scope: A very thorough description of parameters, methods, limiting factors & technical terms • Background: Share key facts, conditions, events prior to project AND previous work on this topic	13-15 • Conclusion: • Inferences follow very logically from discussion evidence • No new material included • Recommendations: • Further work/best solution well identified • Written in first person w/ active verbs	9-10 • Length: 5-15 pages (-cover & title page) • Font: 12, Times New Roman • Spacing: double spaced • All Key Sections included: Title page, Abstract, Contents, Introduction, Discussion, Conclusion, Recommendations • All Supporting Sections included: References, Acknowledgments, Appendix
21-30 • Effective discussion of key concepts • Effective description of procedures including diagrams or pictures • Good description of analysis tools • Tables, graphs, charts, etc. useful to report • Good explanation of results w/graphics	11-15 • Length: Slightly over length • Good restatement of Purpose/Key Features • Good restatement of Conclusions & Recommendations • Well written, but includes some technical terms • Modestly engages and informs reader	9-12 • Effective/complete statement of purpose • Effective statement of scope, 1 or 2 items appear missing or overlooked • Effective and complete background details, 1 or 2 items appear missing or overlooked	9-12 • Conclusion: • Inferences follow loosely from discussion evidence • No new material included • Recommendations: • Further work/best solution not well identified	5-8 • Length: Slightly over or under length • Font: Some inconsistency throughout • Spacing: Some inconsistency throughout • 1 Key Section not identified or missing • 1 Supporting Section not identified or missing
11-20 • Limited discussion of key concepts • Limited description of procedures, with few diagrams or pictures • Analysis tools poorly described or not used • Graphics not well used to support report • Very little discussion of results, no graphics	6-10 • Length: too short • Poor restatement of Purpose or Key Features • Poor restatement of Conclusion or Recommendations • Many technical terms • Uninteresting to reader	5-8 • Incomplete statement of purpose for project and report • Incomplete statement of scope, multiple items missing or overlooked • Limited background information included	5-8 • Conclusion: • Inferences follow poorly from discussion, evidence not clear • Some new material included • Recommendations: • Further work/best solution not well identified	3-4 • Length: too short/long (-cover & title page) • Font: very inconsistent throughout • Spacing: very inconsistent throughout • 2-3 Key Sections not identified or missing • 2 Supporting Sections not identified or missing
0-10 • Little or no discussion of key concepts • Little or no description procedures • Data analysis not included • Graphics do not support report • No discussion of finding/results +	0-5 • Length: >250 words • Purpose or Key Features not included • Conclusion or Recommendations not included • Does not engage reader	0-4 • Very poor statement of purpose for project • Very poor statement of scope, very little information included • Very poor background provided, very little information provided	0-4 • Conclusion: • Inferences do not follow from discussion or evidence present • new material included • Recommendations: • Further work/best solution not identified	0-2 • Length: <5 pages or >15 page • Font: incorrect throughout • Spacing: incorrect throughout • Most Key and Supporting Sections not identified or missing
Score 3 /40	Score 5 /20	Score 2 /15	Score 1 /15	Score 8 /10
Judge			Total	19

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HS-E

MESA

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TEAM: **SCHOOL:** [redacted] **LEVEL: MS or HS**

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Score 15 /40	Score 10 /20	Score 8 /15	Score 8 /15	Score 4 /10
Judge [redacted]			Total	45

359

HS-E

Mousetrap Car

[redacted]

HS-E

Abstract

The purpose of our project was to build a mousetrap car that performs well in three areas: Power, Speed, and Accuracy. Power is demonstrated by the distance a car can go up a 30 degree incline, Speed is demonstrated by the amount of time the car takes to go 10 meters, and Accuracy is demonstrated by the ability of a car to stop close to a 5 meter point. A mousetrap car is simply a small car that is powered by the release of a mousetrap. The problem myself and my teammates face was to build the best mousetrap car that would perform the best in the three areas mentioned above. The following report details the information that we collected from out testing, building, and final performance of the vehicle. Our conclusion was that our car was adequate, not necessarily the best, but good enough to work.

Table of Contents

Introduction

The purpose of building a mousetrap car was to compete against other teams from around the state in three categories: Power, Speed, and Accuracy. For the Power category, the car that is able to travel the farthest up a 30 degree incline wins the category. In the Speed category, the car that is able to cross 10 meters the fastest is the winner for that category. The winner of the Accuracy category is the car that comes that closest to a 5 meter mark.

Using a mathematical formula, each team is given points based on their performance in each category. The winner of each category is given 33 points, and each other team gets the aforementioned points. For the Power category, the distance traveled by a team is divided by the winning distance and multiplied by 33 to get a team's score. For the Speed category, the time taken by a team is divided by the winning time and multiplied by 33 to get a team's score for that category. For the Accuracy category, 500 cm minus the teams distance is divided by 500 cm minus the winning teams distance and multiplied by 33 to get the score for the Accuracy category. The team with the most points wins the Mousetrap Car Competition.

The purpose of this report is to detail the design, construction, testing, and further design of the University/ Rincon High School Mousetrap Car.

Discussion

The first step in creating the mousetrap car was design. We decided on using a wood base to attach the wheels and mousetrap to. We decided to mount the wheels by drilling a hole through the back of the base and cutting a square block out of the middle of the base. The open space allows a string to be attached to the rear axle. The string is in turn attached to the mousetrap. When the mousetrap is fired, it pulls the string, pulling the axle, which powers the car. The wheels were to be tested using three different wheels: pre-built ones such as K-Nex wheels, CD-ROM wheels, or wood wheels.

The next step was to design a simple car to test out the effectiveness of different types of material for the string. We built a simple K-Nex car for this purpose. From the testing, we determined string worked well, yarn and twine were inadequate, and fishing wire worked well but was hard to work with.

The final step was to build the car. We started with a plank of wood and cut out a square in the rear. In between the confines of the square, we drilled holes through the plank big enough for a dowel to pass through. The dowel held our wheels. In the front we cut another square block and drilled another two holes allowing a dowel to hold one wheel, inside of the cut square. We then attached the mousetrap as far in front of the plank as possible. We then took string, wrapped in around the rear dowel, and attached it to the mousetrap's arm.

Conclusion

In conclusion, our car works adequately. While it does not work incredibly well, our car runs well enough to compete. Time limitations did not allow for very much experimentation on the car, but enough to get it to run.

Recommendations

Due to time constraints, not very many alterations were made to the vehicle. However, we do have some thoughts on how to make our car better. First, getting rid of the excess wood that isn't an essential part of the car would reduce the weight of the car and allow it to move at a faster rate. Second, while fishing wire was too hard to work with, the use of it would probably reduce the amount of friction that comes with the use of string.

References

http://www.docfizzix.com/

http://www.mousetrap-vehicles.com /article.cfm?article_id=12

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21-30 • Effective discussion of key concepts • Effective description of procedures including diagrams or pictures • Good description of analysis tools • Tables, graphs, charts, etc. useful to report • Good explanation of results w/graphics	11-15 • Length: Slightly over length • Good restatement of Purpose/Key Features • Good restatement of Conclusions & Recommendations • Well written, but includes some technical terms • Modestly engages and informs reader	9-12 • Effective/complete statement of purpose • Effective statement of scope, 1 or 2 items appear missing or overlooked • Effective and complete background details, 1 or 2 items appear missing or overlooked	9-12 • Conclusion: • Inferences follow loosely from discussion evidence • No new material included • Recommendations: • Further work/best solution not well identified	5-8 • Length: Slightly over or under length • Font: Some inconsistency throughout • Spacing: Some inconsistency throughout • 1 Key Section not identified or missing • 1 Supporting Section not identified or missing
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Score 3 /40	Score 0 /20	Score 1 /15	Score 1 /15	Score 1 /10
Judge			Total	6

366

HS-F

MESA

TECHNICAL PAPER SCORING CRITERIA

[redacted] MESA USA National Engineering Design Competition

TEAM: **SCHOOL:** [redacted] **LEVEL: MS or HS**

Discussion (Physical Phenomena, Experiment Procedures, Data & Analysis, Tables & Charts, Results)	**Abstract** (Length, Purpose & Key Features, Conclusions & Recommendations, Non-technical, Informative & Interesting)	**Introduction** (Purpose, Scope, Background Information)	**Conclusion & Recommendations** (Inferences & Evidence – Further Work & Reasoning)	**Written Presentation** (Length, Font, Key Sections, Supporting Sections)
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Score 5 /40	Score 0 /20	Score 0 /15	Score 2/15	Score 6 /10
Judge	[redacted]		Total	13

367

HS-F

MOUSETRAP:

A SOURCE OF ENERGY

BY: [redacted]

From the team of: [redacted] and [redacted]

[redacted] MESA

HS-F

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Mousetraps; A source of Energy

A mouse trap is a really powerful force of energy, it is not only able to "trap" a mouse but to move a brick meters away and also to power a car over a short or long distance. The spring of a mouse trap car is where all the energy is stored, it drives a wheel by some arrangement such as a string connected from the trap's jaws. But the spring is not the only source of energy that the car has; kinetic energy and potential energy are all important to the movement of a mousetrap car. It is because of kinetic and potential energy that the car has the capability of moving.

The definition of kinetic energy is the energy of motion. An object which has motion whether vertical or horizontal motion has kinetic energy. Vibrational energy is one form of kinetic energy, as well as rotational and translational which is when energy transfers from one object to another. The amount of translational kinetic energy that a object can have all depends upon the mass it has and also the speed. The formula used for kinetic energy of an object is KE=½ x m x v2. The meaning of m is the mass of the object and the meaning of v is the velocity of speed of the object. This equation demonstrates that the kinetic energy of an object is directly proportional to the square of its speed , which means that for a twofold to increase in the kinetic energy will increase by a factor of four, for a threefold increase the factor would increase in speed by a factor of nine. The kinetic energy is dependent upon the square of the speed. Kinetic energy does not have a direction, it is a scalar quantity. Kinetic energy of an object is completely described by magnitude alone. The standard metric unit for kinetic energy as well as potential is the joule. One joule is equivalent to 1 kg x (m/s)^2. Potential energy exists whenever an object which has mass has a position within a force field.

An object can store energy as the result of its position. This stored energy of position is referred to as potential energy. Potential energy is the stored energy of position possessed by an object. Gravitational potential energy is the energy stored in an object as the result of its vertical position. The energy is stored as the result of the gravitational attraction of the Earth for the object. There is a direct relation between gravitational potential energy and the mass of an object; more massive objects have greater gravitational potential energy. There is also a direct relation between gravitational potential energy and the height of an object; the higher that an object is elevated, the greater the gravitational potential energy. These relationships are expressed by the following equation:

$$PE_{grav} = mass * g * height$$

$$PE_{grav} = m * g * h$$

Both Potential and kinetic affect the performance of the mousetrap car. But another important factor to the performance of a mousetrap car is the shape to the car itself. A great design of a car can make or break it. In order for a car to work successfully it most be well designed for all it should be capable of doing. There have been various designs to the mousetrap car. Some of the designs have failed and some have worked. Also those designs that have succeed in moving have not been able to move a sufficient distance. We have been experimenting with various designs of mousetrap cars. Our basic one has been able to move the car about 5 meters in distance, this of course has not been acceptable. Other cars have been able to move a longer distance yet a slower pace. What we need is for the car to be able to move at the highest speed possible and also to reach the longest distance a mousetrap car can possibly reach. In order to find a perfect car we have researched various methods of constructing a car. Some individuals have come up with different versions of a mousetrap car, though some cars are capable of moving items ten times its weight, it is not exactly what we are looking for. Also we have designed cars that are capable to go up a ramp. Yet some have driven of course or are not capable to move on such an incline. But the fundamental design of a mousetrap car has been the same for most of the cars we have put to the distance and speed test.

As stated before, the energy for a mousetrap car is located or stored in the spring, it drives a wheel by some arrangement such as a string which is connected from the trap's "jaws". A string is attached to the mouse trap's lever arm and then it is attached to the drive axel. Then wind the wheels in the direction opposite to the motion you wish the mouse trap car to travel, by doing so the string will wind around the axle. Once the car is released the string is then pulled off the axle, which will cause the wheels to rotate propelling the vehicle. The mousetrap cars are a source of energy when set to spring. The mouse trap powered car uses the spring energy of the mousetrap as a motor. Mousetrap cars demonstrate principles of engineering such as energy storage, energy conversion, friction, inertia, resistance, materials science, levers and gearing, and problem solving.

Newton's first law of motion states that An object at rest tends to stay at rest and an object in motion tends to stay in motion with the same speed and in the same direction unless acted upon by an unbalanced force. In fact, it is the natural tendency of objects to resist changes in their state of motion. This tendency to resist changes in their state of motion is described as inertia. Another great scientist, Galileo, who discovered the telescope, developed the concept of inertia. Galileo reasoned that moving objects eventually stop because of a force called friction. In experiments using a pair of inclined planes facing each other, Galileo observed that a ball will roll down one plane and up the opposite plane to approximately the same height. If smoother planes were used, the ball would roll up the opposite plane even closer to the original height. Galileo reasoned that any difference between initial and final heights was due to the presence of friction. Galileo postulated that if friction could be entirely eliminated, then the ball would reach exactly the same height.

Isaac Newton built on Galileo's thoughts about motion. Newton's first law of motion declares that a force is not needed to keep an object in motion. Slide a book across a table and watch it slide to a rest position. The book in motion on the table top does not come to a rest position because of the absence of a force; rather it is the presence of a force - that force being the force of friction - which brings the book to a rest position. In the absence of a force of friction, the book would continue in motion with the same speed and direction - forever! (Or at least to the end of the table top.) A force is not required to keep a moving book in motion; in actuality, it is a force which brings the book to rest. All objects resist changes in their state of motion, they have the tendency to do this - they have inertia. The tendency of an object to resist changes in its state of motion is dependent upon mass. Inertia is that quantity which is solely dependent upon mass. The more mass which an object has, the more inertia it has - the more tendency it has to resist changes in its state of motion. the more massive the object, the more that object tends to resist changes in its state of motion.

The friction force is the force exerted by a surface as an object moves across it or makes an effort to move across it. The friction force opposes the motion of the object. For example, if a book moves across the surface of a desk, then the desk exerts a friction force in the opposite direction of its motion. Friction results from the two surfaces being pressed together closely, causing intermolecular attractive forces between molecules of different surfaces. As such, friction depends upon the nature of the two surfaces and upon the degree to which they are pressed together. The friction force can be calculated using the equation:

$$F_{frict} = \mu \times F_{norm}$$

where μ = coefficient of friction

There are many forces that move a car, such as kinetic, energy and potential energy. Also there are many forces that affect the cars movement such as friction, mass, and ofcourse gravity, none the less we must discover the perfect mousetrap, one which can move a far distance and can accelerate the most fastest speed that a mousetrap can reach. In order to reach a successful point, we are still experimenting with various mouse trap cars in order to calculate which one is better.

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2. <u>Glencoe Physics: Principles and Problems</u>. By Paul W. Zitzewitz, Ph. D. Published by Glencoe-McGraw-Hill.

3. <u>Physics: Principles and Problems</u>. By James T. Murphy. Published by Charles E. Merrill Publishing Co.

MESA

TECHNICAL PAPER SCORING CRITERIA

[redacted] MESA USA National Engineering Design Competition

TEAM: **SCHOOL:** [redacted] **LEVEL:** MS or HS

Discussion (Physical Phenomena, Experiment Procedures, Data & Analysis, Tables & Charts, Results)	**Abstract** (Length, Purpose & Key Features, Conclusions & Recommendations, Non-technical, Informative & Interesting)	**Introduction** (Purpose, Scope, Background Information)	**Conclusion & Recommendations** (Inferences & Evidence – Further Work & Reasoning)	**Written Presentation** (Length, Font, Key Sections, Supporting Sections)
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Score 26 /40	Score 0 /20	Score 13 /15	Score 6 /15	Score 4 /10
Judge	[redacted]		Total	49

376

HS-6

TECHNICAL PAPER SCORING CRITERIA

[redacted] MESA USA National Engineering Design Competition

TEAM: **SCHOOL:** [redacted] **LEVEL:** MS or HS

Discussion (Physical Phenomena, Experiment Procedures, Data & Analysis, Tables & Charts, Results)	**Abstract** (Length, Purpose & Key Features, Conclusions & Recommendations, Non-technical, Informative & Interesting)	**Introduction** (Purpose, Scope, Background Information)	**Conclusion & Recommendations** (Inferences & Evidence – Further Work & Reasoning)	**Written Presentation** (Length, Font, Key Sections, Supporting Sections)
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Score 21 /40	Score 0 /20	Score 8 /15	Score 5 /15	Score 5 /10
Judge			Total	39

HS-6

The MPV 3000

[redacted]

MESA Day [redacted] Multi Purpose Vehicle Paper

H5-6

Table of Contents

Purpose: to design and build a mousetrap-powered vehicle that can accomplish three tasks. The tasks deal with power, speed, and accuracy. This report was compiled in order to explain the engineering behind our particular vehicle.

Background: the parameters of the task are as follows:

- **Power task** – The vehicle will travel up a plywood ramp at an angle of thirty-degrees from the floor. The goal of this task is to achieve the maximum distance.
- **Speed task** – The vehicle will travel ten meters in the shortest time possible. The goal of this task is to acquire the maximum velocity of the vehicle.
- **Accuracy task** – The vehicle will travel five meters and engage a braking system to stop near or at the five-meter mark for accuracy. The goal for this task is to design the car so that it can properly brake while being nearest to the mark.

Discussion:

Section I: Physical Phenomena

A. Energy: There are many physical properties which the vehicle will have listed as follows: mass, inertia, potential energy, kinetic energy, and others, which are less significant. When a vehicle is at rest the only properties that apply to the vehicle are inertia, mass, and potential energy. While the vehicle is in motion, kinetic energy and momentum apply to it.

B. Newton's Laws of Motion:

a. An object in motion tends to stay in motion unless an external force is applied.

b. The relationship between an objects mass *m*, its acceleration *a*, and the applied force F is $F = ma$.

c. For every action there is an equal and opposite reaction.

C. <u>Gear Ratios</u>: The vehicle has been equipped with variable gear ratios, which determine the three tasks in which it will compete. When set at a lower gear ratio, the vehicle will be executing the power task. Conversely, when the gear ratio is set towards a higher setting, the vehicle will be executing the speed test. Accuracy is somewhat dependent on a moderate gear ratio; however, additional minor adjustments must be applied due to its necessity to become precise.

D. <u>Weight Factor/Mass</u>: With more weight, the vehicle would require more energy to move it. The weight factor has a major influence towards the gear ratios the vehicle is powered by. If it requires less energy to move the vehicle, the gear ratios can be reduced or increased in size to provide more power, energy, or distance.

Section II: Experimental Procedures

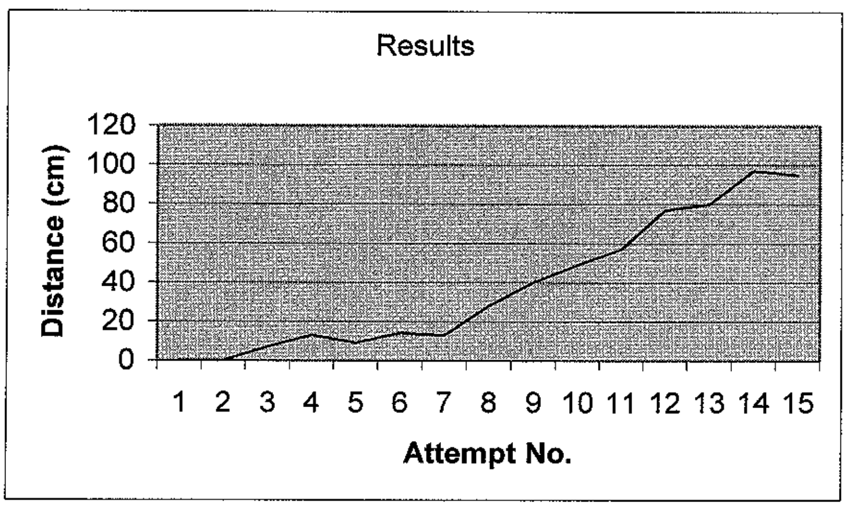
A. **Power Task**: The main idea for this task is that of power. The testing conditions revolved around the central idea of obtaining the maximum/optimum amount of power from the mousetrap. Changes in gear ratios and mousetrap-arm-lengths were tested for optimal performance. Through many tests, it was found that the mousetrap provided the greatest amount of power on the arm's intervals from 0 to 30 degrees and 150 to 180. Therefore it is weakest, between 60 and 120 degrees. To overcome this period of weakness, momentum must be gained in the initial 30 degrees of the mousetrap-arm's arc.

B. **Speed Task**: For this task, a larger gear ratio is needed. This allows more string to be pulled from the axle, providing further distance for the vehicle. An initial short burst of speed provides momentum for the car to be propelled quickly.

C. **Accuracy Task**: To achieve accuracy, only a portion of the string was wound around the axel. That portion of string is wound in such a way that the string rolls back upon itself as the vehicle is propelled forward, effectively stopping it at 5 meters. Tests were done to determine how much string was required for obtaining the 5-meter target.

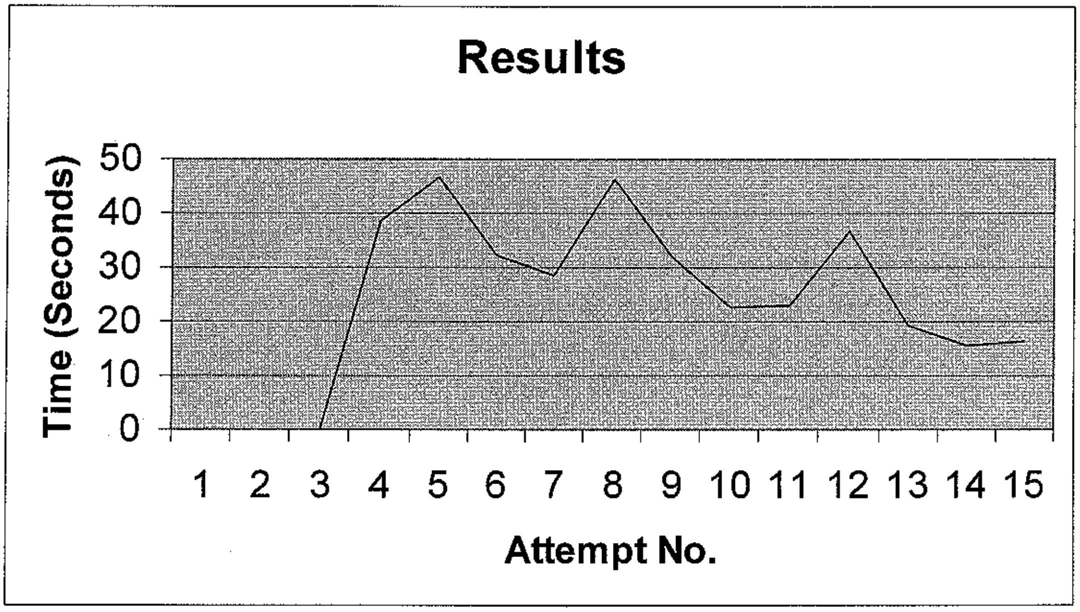
Section III. Data

A. <u>Power Task</u>



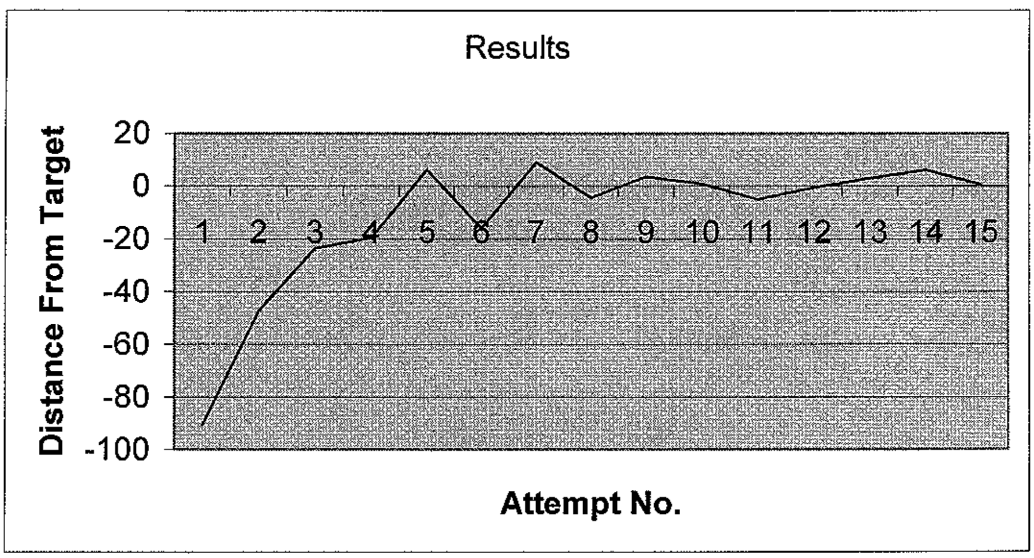
Attempt No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Distance (cm)	0	0	7	13	9	14	13	28	40	49	57	77	80	97	95

B. Speed Task



Attempt No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Distance (cm)	0	0	0	38	46.84	32.16	28.64	46.35	32.01	22.64	22.79	36.77	19.35	16.46	16.24

B. Accuracy Task



Attempt No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Distance (cm)	-90.6	-47.4	-23.6	-19.5	6.3	-16	9	-4.3	3.6	1	-4.9	-0.6	3	6.1	0.5

D. Data Analysis: Concerning the data of the power task, additional attempts to test the vehicle resulted in an overall improvement in distance. Minor negative fluctuations occur when the modifications to the vehicle affect its performance poorly. It is shown that more testing and researching caused more modifications, which in turn enhanced the vehicles performance up to 97 centimeters.

With respect to the speed task, the first attempts failed due to its difficulty in reaching the 10-meter marker. It is apparent that the vehicle is highly sensitive to minor modifications, affect the time. After accomplishing many different tests and applying several modifications, the time for the vehicle to travel the distance of 10 meters, was reduced to approximately 16.24 seconds.

With the accuracy task, the initial attempts were very poor as well. During the first testing of the vehicle for the accuracy task, it obtained a location just within one meter of the target. Further testing lead to better accuracy. In our results, we modified the car to acquire a distance within approximately .5 cm; however the results are still unstable. Although the modifications for accuracy were also sensitive to the vehicle's performance, it became increasingly easier to understand the outcome of the modifications compared to the dynamic behaviors for the speed task. To conclude, it has been proven, through these results, that an increased amount of time spent in testing and modifying the vehicle will greatly improve its performance in all three of the tasks.

Conclusion: The testing conditions proved to be extremely helpful towards the efficiency and development of the vehicle. Through a multitude of tests and intensive labor, the multipurpose vehicle has proven to be a helpful learning experience. The extensive testing built vital problem solving and engineering principles. These skills provided an educational experience that was not only satisfying, but also fueled our desire to become future engineers.

Acknowledgements

[redacted]

3/17/2004

TECHNICAL PAPER SCORING CRITERIA

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TEAM: **SCHOOL:** [redacted] **LEVEL: MS or HS**

Discussion (Physical Phenomena, Experiment Procedures, Data & Analysis, Tables & Charts, Results)	Abstract (Length, Purpose & Key Features, Conclusions & Recommendations, Non-technical, Informative & Interesting)	Introduction (Purpose, Scope, Background Information)	Conclusion & Recommendations (Inferences & Evidence – Further Work & Reasoning)	Written Presentation (Length, Font, Key Sections, Supporting Sections)
31-40 • Very thorough discussion of Physics, Math and/or Engineering concepts • Very complete description of experimental/testing procedures including diagrams or pictures • Thorough description of analysis tools used • Highly relevant tables, graphs, charts, etc. • Very clear explanation of results w/graphics	16-20 • Length: <250 words • Very clearly restates Purpose & Key Features of report • Very clearly restates Conclusions and Recommendations of report • Written very clearly in non-technical terms • Engages and informs the reader	13-15 • Purpose: Very clearly states why project undertaken AND why report developed • Scope: A very thorough description of parameters, methods, limiting factors & technical terms • Background: Share key facts, conditions, events prior to project AND previous work on this topic	13-15 • Conclusion: • Inferences follow very logically from discussion evidence • No new material included • Recommendations: • Further work/best solution well identified • Written in first person w/ active verbs	9-10 • Length: 5-15 pages (-cover & title page) • Font: 12, Times New Roman • Spacing: double spaced • All Key Sections included: Title page, Abstract, Contents, Introduction, Discussion, Conclusion, Recommendations • All Supporting Sections included: References, Acknowledgments, Appendix
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Score 23 /40	Score 16 /20	Score 13 /15	Score 11 /15	Score 10 /10
Judge [redacted]			Total	73

387

HS-H

12/18

MESA

TECHNICAL PAPER SCORING CRITERIA

[redacted] MESA USA National Engineering Design Competition

TEAM: **SCHOOL:** [redacted] **LEVEL:** MS or HS

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Score 18 /40	Score 12 /20	Score 8 /15	Score 9 /15	Score 9 /10
Judge			Total	56

388

HS-H

Multi-Purpose Vehicle

[redacted]

Arizona

[redacted]

HS-H

Abstract

The multi-purpose vehicles are commonly known as mousetrap cars that are vehicles powered by the power of the spring on the mousetrap. The purpose of our group was to design the mousetrap car to accelerate up a 30-degree incline and complete a ten-meter length with in the fastest time and stop on a five-meter mark. The most important features were the length of the arm, the size of the rear wheels and the thickness of the rear axle. Due to the fact that we used super glue on metal joints the car was not as stable as it should have been and was unable to complete the judging. For the next trial we will solder all metal joints utilize large rear wheels and a thicker rear axel.

Table of Contents

Introduction

The purpose of our experiment was to design a mousetrap car able to accelerate up a 30-degree incline and complete a ten-meter length with in the fastest time and stop on a five-meter mark. The design was to include a mouse trap with simple additions to convert it into a functional vehicle. This report was written after a trial test at the Southern Arizona State Regional competition. The car design was not the best possible. It had flaws in its construction but great aesthetics.

The purpose of this report is to define problems and offer solutions in the design of the mousetrap vehicle. We tested several trial designs and concluded that an aluminum frame offered minimal weight with affective strength. In our test we measured speed, torque, and stopping ability. All the designs were increasingly better but the only limiting factor that we weren't able to overcome was power of the spring built in to the mousetrap.

Discussion

The multi-purpose vehicle had many challenges to over come like decreasing the weight of the car and the finding the perfect length of the lever. The team had to discover which size rear wheels should be used and the size of the rear axle. Having brass as the axels caused the car to be to heavy decreasing the power output because it was compensating for the extra weight. The team decided to use aluminum axels to decrease the weight but keeping the strength of metal allowing it to spin better than wood. Aluminum seemed like the best choice for everything so the frame of the car was constructed of aluminum. The flaw of the aluminum is the joining of two aluminum tubing with super glue. The group now knows to solder them together. The group's multi-purpose vehicle had a smaller lever arm but was increased to add speed and distance to the results of the test runs. In the first trial run of the car it went about the distance of six meters. Knowing that six meters couldn't even finish the speed trial at the competition. The group decided to decrease the weight and it made the car travel an extra two and a half meters. Finally the team increased the length of the arm adding more distance to the trial runs. The team accomplished the goal of finding the correct length that gave the car the distance to finish the speed trial without losing the speed from the extra weight. Too long of an arm would decrease the power coming from the spring of the mousetrap. The team discovered that with a extra long arm it took forever for the arm to completely unwind the string from the axle. With the extra long arm the power wasn't there to carry the car up the 30-degree incline. The arm had to be decreased to add power to the vehicle.

The size of the axle was a large debate to go with a small one to lessen friction or a larger one needed for adding torque. The team used a ¼ inch aluminum axle and it worked very well because it gave the car power. During the regional trials our group had to use a 1/16-inch tubing to replace the other axle after it broke the night before the competition. The team wasn't able to replace the missing part but didn't think it was necessary because with smaller axle it didn't have to rub against the inside of the outside tubing as much, reducing the friction. The string wrapped around the axle more causing the wheel to have more complete turns meaning longer distance traveled. The other disadvantage with a smaller axle was stability. The small axle was fragile and if jerked hard enough by the force of the mousetrap spring it would bend.

The frame itself was made of the sixteenth inch aluminum tubing to save on weight. During the regional the team realized that this was a mistake because it was not strong enough to withstand the power of mousetrap spring. During the power test the team captain let a little bit of slack on the string so the mousetrap car could over come the inertia. When setting the car off it jumped in place and after looking at the car the frame had bent. The frame was meant to decrease the weight of the car but the team didn't think of the consequences that it would decrease the stability of the vehicle.

The team didn't make any exact graphs or kept perfect records but the group notice the flaws in the current mousetrap car and can improve on it. The frame of the vehicle needs to be more stable and instead of circular tubing the frame will be made of square aluminum tubing. The rear wheels will be increased to allow distance. The rear axle will be increase to allow power and the arm on the mousetrap will be increase or decrease with the new the car. The length of the vehicle might be shorten as well. The main flaw that will be fix is stability and this can accomplished by the soldering the joints. The ne[redacted] mousetrap car will be better, faster, stronger, we will rebuild.

Conclusion

In conclusion there are many modifications that can be made to the design in order to maximize the abilities of the vehicle. As per the specifications of this project not much can be done to the mouse trap itself but the additions can be modified. Although the car did fail structurally during the competition, I believe that there was nothing wrong with the design. If the construction of the vehicle itself was done with more appropriate supplies the design would have been better utilized. As for the aerodynamics of a mousetrap vehicle there is a reasonable amount of drag but not much can be done to reduce or prevent it, with out becoming disqualified form competing. Another physical property of the mousetrap vehicle is its acceleration. If the rear axle was to be made thicker the same force from the spring would provide more torque.

Recommendations

In order to make a more productive mousetrap vehicle the use of super glue are not recommended. The joints needed to be stronger, the car needs thicker wheel axles, and bigger rear wheels. These improvements to the vehicle would help a lot.

The use of super glue on metal to metal contact didn't work because it didn't adhere well. Our design team should have soldered it together instead, making the vehicle stronger and less likely to break as during the trial. The car needed stronger joints because the frame of the car as to be durable for best results. We could fix that by using rectangular aluminum tubing instead of a circular tubing making it easier to adhere to the sides of the mousetrap. A thicker rear axle would increase the amount of torque making the car go faster. Larger rear wheels would also aid in the making of the car because it would increase in the distance traveled and compensate for the larger rear axle.

Acknowledgements

Special Thanks To:

[redacted] our MESA club teacher who always assisted in anything the team need. From the written portion of the competition to the display and to the actual building of the multi-purpose vehicle.

[redacted] who assisted the team in writing the report for the competition. He also assisted with some of the construction and gave great ideas when needed.

And to

The friendly neighborhood Ace Hardware Store had all the necessary supplies and was helpful finding all the parts to the car.

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3) http://www.docfizzix.com/help.htm Legal Notice © 1998-2003 Dr. Fizz; All Rights Reserved

4) http://gpss.wrdsb.on.ca/academics/tech/student/designwork/mouse/11%20work%20mouse.htm GPSS; Copyright © 2004

5) http://www.mousetrap-vehicles.com/ Copyright © Doc Fizz; Web Production: Hypography

3/17/2004

MESA

TECHNICAL PAPER SCORING CRITERIA

[redacted] MESA USA National Engineering Design Competition

TEAM: **SCHOOL:** [redacted] **LEVEL: MS or HS**

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Score 9 /40	Score 6 /20 15	Score 8 /15 23	Score 9 /15 32	Score 10 /10
Judge	[redacted]		Total	42

397

HS-1

12/18

3/17/2004

MESA

TECHNICAL PAPER SCORING CRITERIA

[redacted] MESA USA National Engineering Design Competition

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Score 8 /40	Score 1 /20	Score 8 /15	Score 4 /15	Score 3 /10
Judge			Total	24

398

HS-1

12/18

The Multi Purpose Vehicle

[redacted]
Tucson, Arizona
[redacted]

HS-1

Abstract

The multi purpose vehicle is a four-person project. The teams consist of two girls and two boys. The purpose of the vehicle is to be able to do several different things. It requires some knowledge of physics and mechanical engineering skills. The vehicle is required to run on only mousetrap power, no other power sources are allowed and the spring cannot be altered.

Table of Contents

Introduction

The purpose of the multi purpose vehicle is to build a mousetrap-powered vehicle that can go a certain distance fastest, stop in a given area, and climb a slope. The vehicle proves to be quite a challenge. This report basically explains the design behind ours and it's unique look.

This report describes the important parts of our Multi purpose vehicle, why it looks the way it does, and what was tested to get it there. Because of the cone differential the vehicle had to be tested a lot, due mainly to slacking the testing was not completed, meaning the car was potentially more than was shown.

The multi purpose vehicle was designed to be able to do a variety of things. First it has to get through 10 meters in the fastest amount of time. It also has to be able to be targeted to stop in a certain area. Probably the most challenging task for the multi purpose vehicle team is getting it to climb a 30-degree slope. The teams have to consist of 2 boys and 2 girls. Our team has one member who retained some experience from last year in making it climb.

Discussion

Cone Differential

The main part in the design for our multi-purpose vehicle is the cone differential.

The cone differential is simple enough; it's just a cone on the axel. The purpose of the cone differential is to distribute the power of the mousetrap across the entire path of the vehicle.

The ideal for the cone differential is for it to keep the wheels spinning all the way across the line, but no further.

The cone differential works because the cone shape changes the thickness of the axel while the mousetrap loses power. As the amount of power decreases the amount of power needed to turn the wheels also decreases.

Long lever arm

By making the lever arm long, we were able to place the end of it and the beginning of the string directly over the side of the axel. The most force is exerted from a 90-degree angle, or tangent to the axe. An interesting note is that the mousetrap also makes it's Most power from 90 degrees.

But in order to accomplish that the mousetrap had to be sitting above the axel. Our solution was to sink the axel into the chassis. We cut a hole into the back of the chassis to make room for the cone differential. There was no problem elevating the mousetrap given the mousetrap's base was thicker than most of the balsa wood chassis. The obvious problem with this is that the thin chassis wasn't very durable which actually led to a problem in itself. Aerodynamics wasn't really a big issue in our design. We figured considering the size and speed of our vehicle, the added weight of making it aerodynamic Would actually hurt the speed.

Wheels.

The plan for our wheels was to make them as light as possible. That was the reason they were so thin. Because the vehicle is so light the wheels don't need to be wide, to obtain the traction needed to overcome inertia, since there is so little of it. To give it the little traction it needed to move, rubber bands were put around the wheels to prevent slippage.

Experimentation

Our experimentation showed that the cone differential did in fact spread the power over a longer distance, but with some costly consequences. The differential had to make the mousetrap power run the car for 10 meters, so the vehicle ended up moving very slowly. The better thing to do is release the string from the differential and gives the vehicle a boost at the end.

Further testing of the vehicle resulted in a structural collapse that caused it to fold up on itself. The newer version was just the old one rebuilt and reinforced.

Conclusion

The cone differential allows the MPV to supply power to the wheels the entire time the vehicle is in motion. The extended trap arm allows the string to start off tangent to the axel or cone differential. The wheels are thin so they weigh less, and have rubber touching the road so they will have the necessary traction.

Recommendations

It would probably be beneficial for us to do more testing so we can actually know exactly what size and length the cone differential should be. A good way to get more power is to keep the string tangent, which right now it doesn't do. We also haven't tested the accuracy, which would be a good thing to do since that is part of the competition. We also should try to set dates and work better as a team; these are the main reasons our necessary testing is not already done. Next time it would be a good idea to do some research before beginning the vehicle that way we can already know what someone else has learned.

References

We have none. Seriously this is a possible reason for all the mistakes made in the construction of our vehicle.

Acknowledgements

These people helped with the development of our vehicle. [redacted] helped with the design for the cone differential. [redacted] is our mesa advisor, who without him nothing in [redacted] Mesa program would be possible. [redacted] helped explain a few things and gave all Mesa members support. A few people from our own Mesa group also assisted in the design and building.