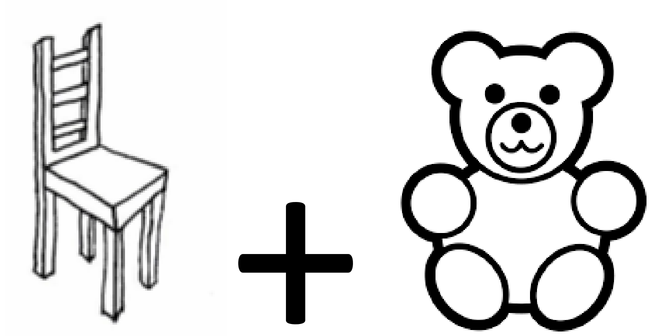
LESSON 1

Name: ___________________________ School: _________________________________

PAPER CHAIR ENGINEERING CHALLENGE

Can you make a strong CHAIR to hold a STUFFED ANIMAL, using only PAPER and TAPE?



Goal: Build the strongest chair possible, using only paper and tape

Rules:

- You must only use two materials: paper and tape (you can use any type and any amount you wish)
- Your chair must stand on its own, without taping the legs to the ground/table.
- You can rip and tear the paper, but cannot cut it (because that would require extra supplies)
- Test the chair by placing a stuffed animal on it. Can it sit comfortably without falling?
  - EXTRA CHALLENGE: Can your chair hold more than one stuffed animal?!?
- Be creative! There are many ways to make this chair work.

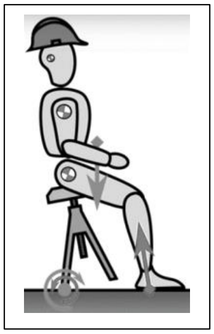
20 MINUTES TO BUILD…. SET A TIMER …. READY?… GO

QUESTIONS:

1. Were you successful with the challenge? Why or why not?

2. How did you design the physical structure of the chair?

3. What was the most difficult part of the challenge? Why?



THE PHYSICS OF FALLING BACK IN YOUR CHAIR

Excerpt From: Practical Engineering Blog:
https://practical.engineering/blog/2017/5/21/the-physics-of-falling-back-in-your-chair

Falling back in your chair is something that's happened to all of us, and there's a simple explanation to why something so clumsy can sneak up on you. I'm Grady, and this is Practical Engineering. On today's episode, we're talking about static stability, or the study of objects at rest, and how far is too far to lean back in your chair.

It all starts with Newton's Second Law, which says that **a net force on an object will cause it to accelerate**. Well, we don't want our roads, bridges, dams, and buildings to accelerate. In fact, the job description of a **structural engineer** is essentially just to make sure that acceleration doesn't occur. So to keep things static, we need we need to balance our forces. Here's a simple example of how this works. Imagine an object is floating in space… any object will do. How about a classic square? Applying a force to this object would cause it to accelerate. If you're an aerospace engineer, your job is finished here, but in civil engineering terms, acceleration is bad news. So, we can add another force to make the net force acting on the object zero. We've achieved static equilibrium, which means we keep our job for another day.

Stay with me because now it gets fun. What if I take the two forces on this object and adjust them so they are not inline with one another. The sum of the two forces is still zero, but you intuitively know that this object is not going to be static. It's going to spin. A rotational force is known as a moment or torque. If an engineer tells you they shared a moment with someone special, keep that alternate definition in mind. Here's another intuition you already have: torque is the product of the force and its distance from the center of rotation. So a small force with a long lever arm is equivalent to a large force with a small lever arm. Static equilibrium requires not only that net forces be zero, but also that the moments be zero as well. And that's really all there is to it. For an object to be at rest, you simply have to satisfy these two conditions. Static analysis involves adding up all of the forces and moments on an object and making sure they sum to zero.

We all lean back in our chairs. To recline is human, and leaning back satisfies not just our need to relax, but sometimes a way to combat boredom. But occasionally the lean is mean, and chances are at least once or twice you've pushed the limits a little too far and **fallen right over backwards**. How can we be so clumsy? It turns out that leaning back in your chair has a very subtle point of no return, and we can see how it works through static analysis.

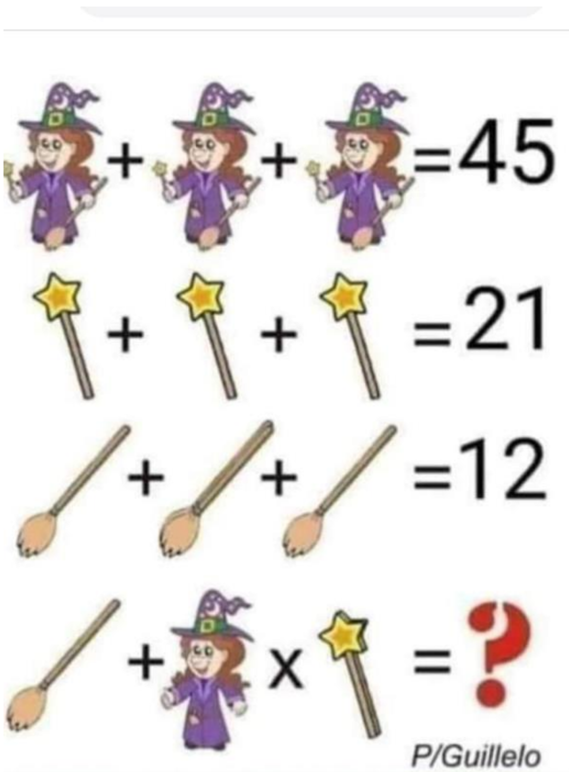
For our purposes, we can assume however hard your body pushes down on the ground, the ground pushes up to match it. So, the forces in this system are always balanced. But let's look at the moments. Your point of rotation is the back legs of the chair, and gravity pulling on your body is generating a moment about this point of rotation. A human's center of gravity while sitting is somewhere in front of their belly button. With no other forces in the system, you can see that your weight would generate a moment that would rotate you forward. But, when we lean back in our chairs, we use our feet for support. Your feet and legs create an equal but opposite moment about the point of rotation to keep you static.

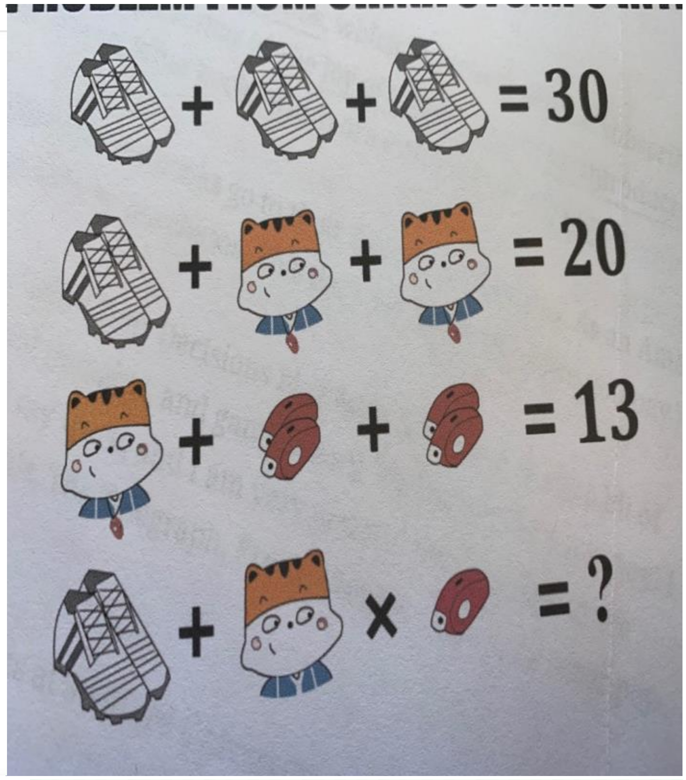
One of the first things you learn in statics is that you can't push a rope. In other words, a rope can act in tension, but it's pretty useless in compression. In exactly the same way, your feet can push on the ground, but unless you have been bitten by a radioactive spider (or recently stepped in chewing gum), they can't pull on the floor beneath you. Watch what happens in our diagram as you continue to lean back further and further. As soon as your center of gravity passes over the point of rotation, the moment that it creates reverses. But, unlike before, there is no way to use your feet to counteract this rotation because they can't pull on the ground. All of the sudden, our moments aren't balanced. You can kick your legs forward to try and move your center of gravity. You can wave your arms to try and counter-rotate using conservation of angular momentum. But more than likely, if you've made it this far, there's no going back. Well, actually there's only going back. You're going to fall.

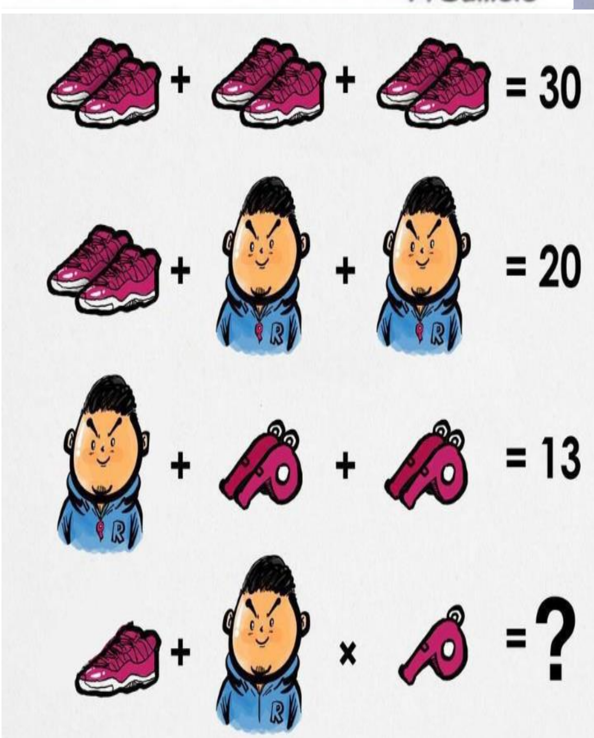
It might seem silly, but this is the exact same type of analysis engineers use every day to design anything that's meant not to move. A perfect example is a crane. Lifting heavy objects and moving them about is just like leaning back in a chair because they both have the same effect of shifting the system's center of gravity. Some cranes even have sensors to monitor to the pressure on the outriggers and make sure that center of gravity never gets on the wrong side of the point of rotation. Statics is a fundamental skill that is broadly applicable not only to engineers, but anyone who has anything that needs to stay put.

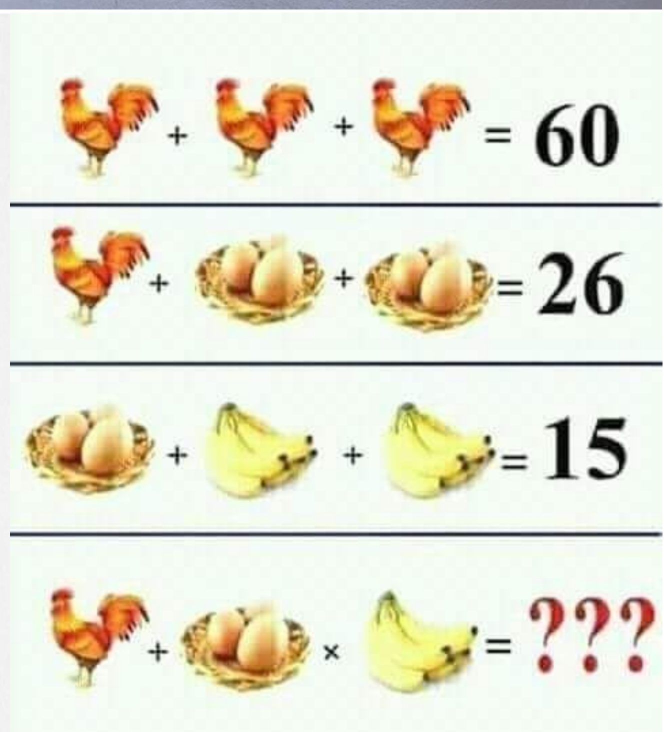
LESSON 2

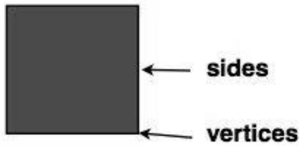
COMPLETE THE FOLLOWING QUESTIONS. Remember Order of Operations (PEMDAS). But that's not all!
Hint: Don't miss the little details in the pictures.





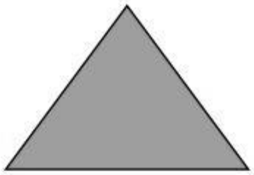
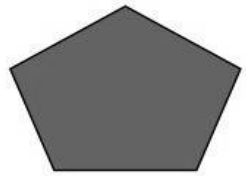
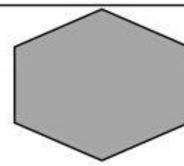
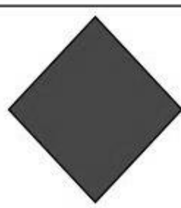
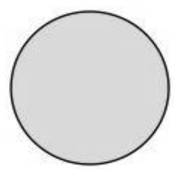
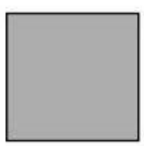
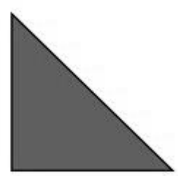






Sides and Vertices

Write how many sides and vertices each shape has.

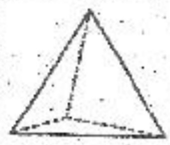
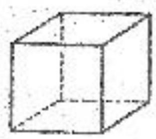
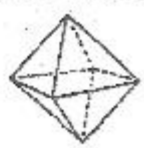
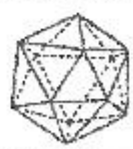
 _______ sides _______ vertices	 _______ sides _______ vertices
 _______ sides _______ vertices	 _______ sides _______ vertices
 _______ sides _______ vertices	 _______ sides _______ vertices
 _______ sides _______ vertices	 _______ sides _______ vertices

LESSON 3

LESSON 3

POLYHEDRON PATTERNS

Count and record the number of faces (F), vertices (V), and edges (E) for each polyhedron. Then calculate the values for F + V – E.

NAME	FIGURE	FACES (F)	VERTICES (V)	EDGES (E)	F + V – E
Tetrahedron		4	4	6	4 + 4 – 6 = 2
Hexahedron (cube)		____	____	____	____
Octahedron		____	____	____	____
Dodecahedron		____	____	____	____
Icosahedron		____	____	____	____

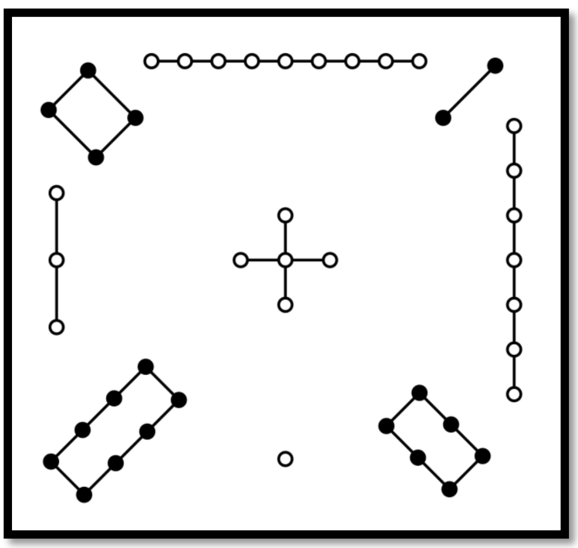
1. What pattern did you observe in the last column?
2. Determine whether or not this relationship holds with an ordinary box (rectangular prism).
3. Explore this relationship with another polyhedron that has faces, vertices, and edges but is not a rectangular prism.

LESSON 4

THE LO SHU SQUARE

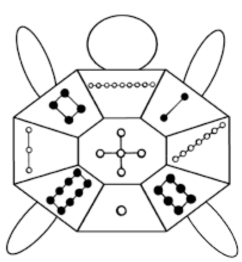
There was a pervasive fascination with numbers and mathematical patterns in ancient China, and different numbers were believed to have cosmic significance. In particular, magic squares - squares of numbers where each row, column and diagonal added up to the same total - were regarded as having great spiritual and religious significance.

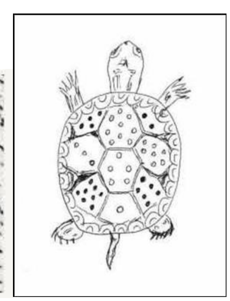
The Lo Shu Square, an order three square **where each row, column and diagonal adds up to 15,** is perhaps the earliest of these, dating back to around 650 BCE (the legend of Emperor Yu's discovery of the the square on the back of a turtle is set as taking place in about 2800 BCE). But soon, bigger magic squares were being constructed, with even greater magical and mathematical powers, culminating in the elaborate magic squares, circles and triangles of Yang Hui in the 13th Century (Yang Hui also produced a trianglular representation of binomial coefficients identical to the later Pascals' Triangle, and was perhaps the first to use decimal fractions in the modern form).



4	9	2
3	5	7
8	1	6

Legend says an ancient Chinese emperor name Yu happened to be down by the Yellow River one evening when he noticed a turtle swim at his feet. The turtle had unusual marks on his shell which formed a magic square where all columns, rows, and diagonals summed to the same amount.





There is a way to calculate the sum you need to find for each row, column, and diagonal in your grid. Add all your available numbers and divide by the number of rows in your grid:

1 + 2 + 3 + 4 + 5 + 6 + 7 + 8 + 9 = 45 / 3 = 15

A three cell square grid, therefore, must sum to 15 for all its rows, columns, and diagonals. The dot pattern Yu saw on the turtle's back sum to 15.

DO YOUR OWN LO SHU SQUARE!

To solve a math squares puzzle, the sum of all rows, columns, and diagonals must be the same. You can only use each number once. **Here's a blank 3 cell by 3 cell grid you can print out to try and solve:**

LESSON 5

The Chinese numeration system

0	zero	零	10	ten	十
1	one	一	100	one hundred	百
2	two	二	1,000	one thousand	千
3	three	三	10,000	ten thousand	萬
4	four	四	100,000	one hundred thousand	十萬
5	five	五	1,000,000	one million	百萬
6	six	六			
7	seven	七			
8	eight	八			
9	nine	九			

Activity 1: Complete the table below.

Number	Expanded Form	Chinese System
(a) 398	300 + 90 + 8	三百九十八
(b) 751	700 + 50 + 1	
(c) 576		
(d) 307	300 + 0 + 7	
(e)	4,000 + 500 + 80 + 2	
(f) 7,500		
(g) 80,427		
(h) 38,074		

Activity 2: Use Chinese characters to write your answers.

Questions	Answers
(a) What is the value of “8” in 4,834?	
(b) What year were you born?	
(c) What year did Arizona become a state?	
(d) What is the weight in ounces of an object weighing 1,032 pounds?	
(e) How many times does your heart beat in three minutes?	