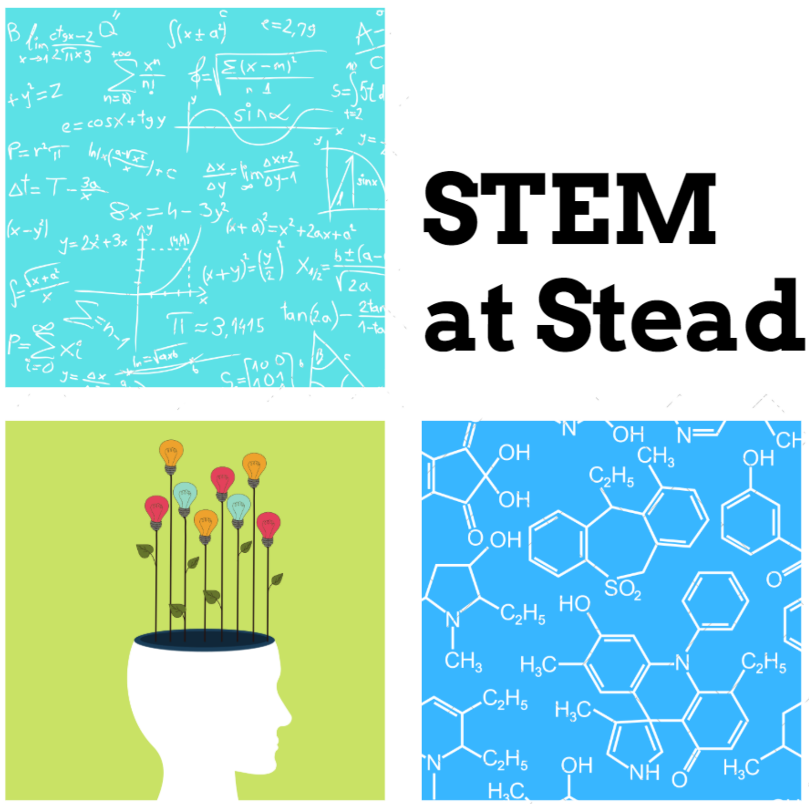
Catapult: Advanced Scientist



SCIENCE WORTH EXPLORING

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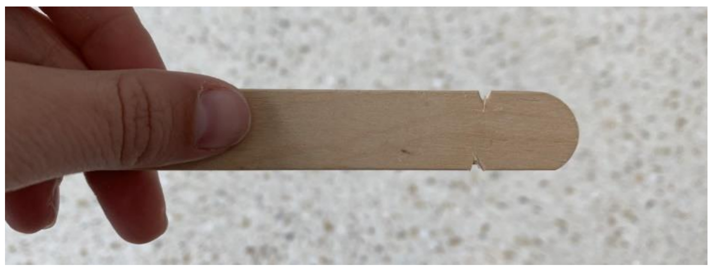
Catapult Teacher Information: Advanced Scientist

How do I prep?

1. Double check that all the necessary supplies are inside of the kit:

   - 10 Jumbo Popsicle Sticks
   - 1 Bottle Cap
   - 10 pom poms
   - Spring scale
   - 10 Rubber Bands
   - 1 Sticky Dot
   - 10 pencil erasers
   - Measuring tape

2. You need to cut notches in two of the jumbo popsicle sticks. Refer to the picture below to see where the notches should be cut.



What will they learn?

1. The discussion materials for this experiment will be based off the Iowa Core Standards for high schoolers. The student does not have to be a high schooler to complete this activity, they just need to be able to understand content at a high school level. The standards covered by this experiment are:
   a. Physical Science → Motion and Stability: Forces and Interactions
   HS-PS2-1: Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.
   b. Algebra → Reasoning with Equations and Inequalities: Solve equations and inequalities in one variable
   HAS.REI.B.3: Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters

Need extra help?

If you aren't familiar with topics covered or if the student needs extra help, consider these resources:

www.billnye.com/the-science-guy/gravity   www.billnye.com/the-science-guy/simple-machines

Setting up the catapult → https://littlebinsforlittlehands.com/popsicle-stick-catapult-kids-stem-activity/

Using a spring scale → https://www.youtube.com/watch?v=SWOmsKkP8ZY&t=33s

Catapult Instructions: Advanced Scientist

What is the experiment?

In this experiment you will be building and testing a catapult. The catapult will be made out of popsicle sticks and rubber bands. You will use a soda pop bottle cap as a bucket and place your projectile in there. Your projectile is what you will be testing! You want to use the right projectile so that your catapult launches it the farthest distance. You will be using small pom poms and pencil erasers as projectile. When you get to your trials, you can use any number of combinations of these materials. You will also be testing the force you pull down the catapult arm with. In order to measure force, you will be using a spring scale. This will let you know how much force you exert when you pull down on the handle of the scale. There is a video of how to use a spring scale listed in your teacher's materials. Ask them to watch this!

Predict what you think will happen in this experiment. For example, which of the projectile (pom poms or pencil erasers) will travel farther? What will be the optimal force?

Research Newton's Second Law of Motion. Define the variables of the equation and write the equation out.

a = F_{net} = m =

You should have found that Newton's Second Law of motion is Force = Mass * Acceleration (F = m*a). Where Force is the force applied to the projectile, mass is the mass of the projectile, and acceleration is the resulting acceleration of the projectile when it is airborne. This can be rewritten three different ways depending on which variable you want to solve for:

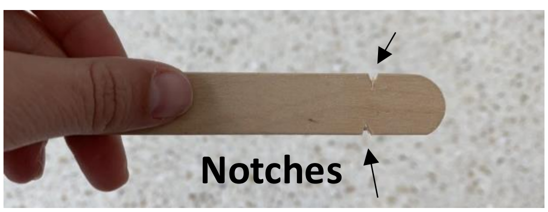
$$F = m*a \rightarrow a = F/m \rightarrow m = F/a$$

Specifying F_{net} compared to F means that all forces acting on the object are taken into consideration, not just the force you apply to it to move it forward. Since you cannot calculate F_{net} in this experiment (you would have to be able to measure the force of gravity simultaneously to measuring the force you applied to the projectile), we will just use the force applied by the projectile in order to solve for the other variables.

Solve for the missing value below:

#1	a = ____________	F_{net} = 10 N	m = 2 kg
#2	a = 5 m/s/s	F_{net} = ____________	m = 2 kg
#3	a = 10 m/s/s	F_{net} = 10 N	m = ____________

Catapult Instructions: Advanced Scientist



Materials Needed:

10 Jumbo Popsicle Sticks	Rubber Bands
Bottle Cap	Sticky Dots
Projectiles (pom poms and pencil erasers)	Spring Scale

Instructions:

1. 8 of the jumbo popsicle sticks should be regular. 2 of the jumbo popsicle sticks should have notches cut out on the side. If there aren't 2 with notches cut out on the side, you will need to ask the teacher for scissors, so you can cut them. The sticks should look like the picture second from the bottom.
2. Take 8 of the popsicle sticks and stack them on top of one another. Secure the stack together with two rubber bands. The second picture from the top show what the stack will look like.
3. Slide one of the jumbo sticks with small pieces cut out of the sides (shown in the picture second from the top) through the stack of the eight sticks, between the bottom two sticks.
4. Take the remaining jumbo stick with notches and secure it with a rubber band to the other jumbo stick with pieces cut out within the stack. Refer to the bottom left picture for guidance. The rubber band holding these two sticks together should rest within the notch from the missing pieces in the two sticks.
5. Place a sticky dot on the angled stick outside of the stack. Place the sticky dot on the opposite end from the rubber band about one inch from the end of the stick.
6. Place the bottle cap on the sticky dot to create a small bucket. The bucket should be placed 0.5 inches from the end of the popsicle stick. There is a small ring attached to the opening of the cap, remove that.
7. Your catapult is now ready to launch. Fill out the table in part A on the next page for each of the five trials you complete, as well as an average of all the trials.
8. After your trials are finished, fill out section B.
9. After section B is filled out, graph your results from part A with the graph paper provided in part C.
10. Read through the science behind catapults to learn about what was happening during the experiment.
11. Read the questions for sections D and E and write your answers in the space provided to you.
12. Once you have completed your discussion materials, clean up your experiment area and give your worksheet to the teacher.

Catapult Discussion Materials: Advanced Scientist

A. Calculate the acceleration for each trial:

First… rearrange Newton's Second Law of Motion (F_{net} = m * a) to solve for acceleration (a). Write the rearranged equation below:

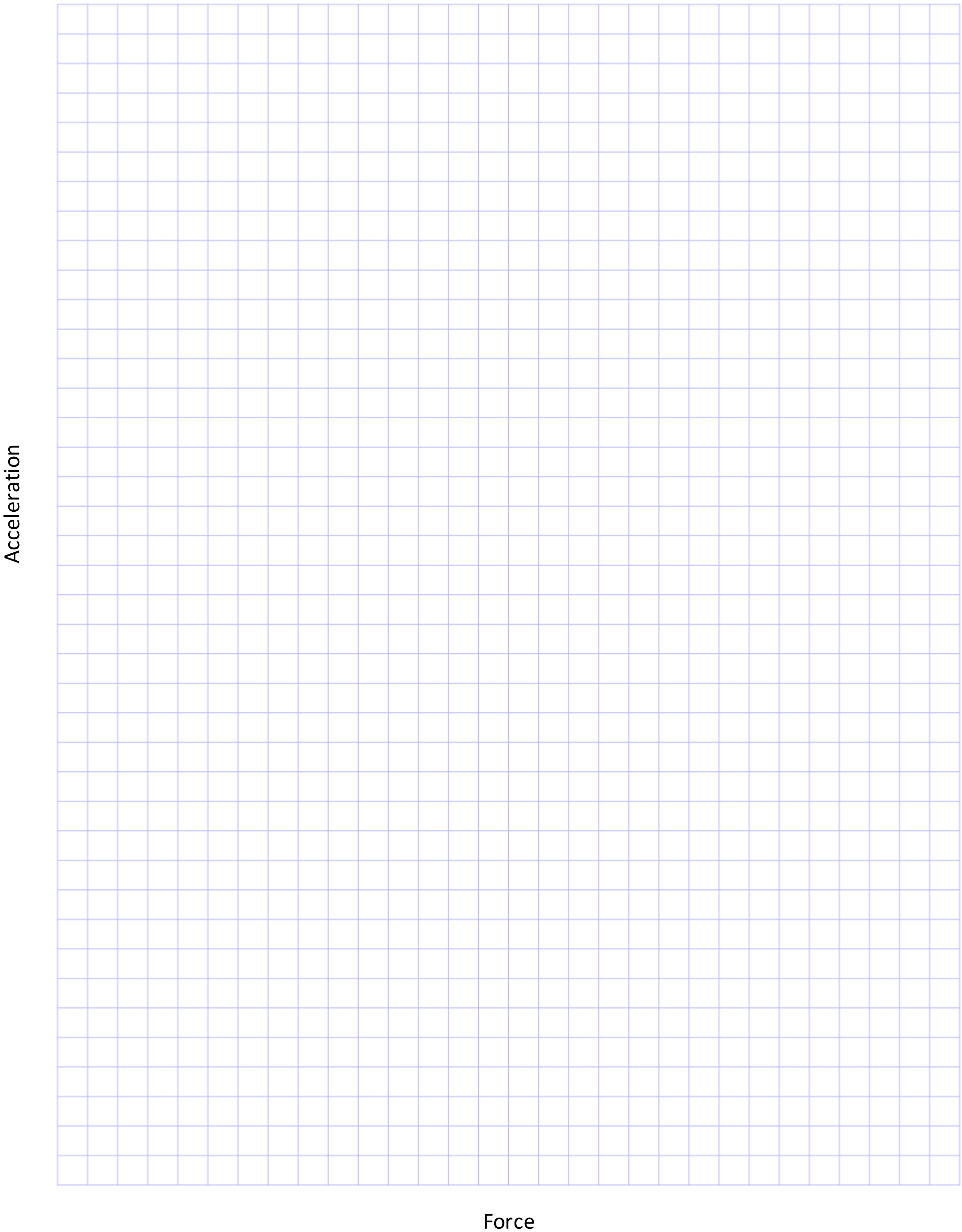
Now record the mass of the projectile in kilograms and the force you pulled down on the catapult arm with in the middle two columns of the table. Mass should be measured using the electronic scale and the force should be measured using the spring scale provided. Use your rearranged equation to solve for acceleration in the last column. You may need to convert lbs to kg → 1 lb = 0.453592 kg

Trial	Mass (kg)	Force (N)	Acceleration (m/s/s)
1			
2			
3			
4			
5			
Average			

B. Is there a pattern you can see from your trials? Is there a relationship between the acceleration and how far you think the projectile traveled?

Catapult Discussion Materials: Advanced Scientist

C. Graph the results from your trials below:



Catapult Discussion Materials: Advanced Scientist

The science behind catapults

The reason the projectile launches through the air and eventually hits the ground can be explained by physics. Sir Isaac Newton discovered the physics behind a catapult back in 1687. He describes this in what he called the first law of motion:

"An object at rest stays at rest, until a force is applied, and an object in motion stays in motion, at the same speed, until a force acts upon it"

An object at rest stays at rest- this means that the projectile will always sit in the bottle cap if we don't apply a force to it. Until a force is applied- the force we applied was the arm of the catapult. When we pull back the arm it stores up a lot of energy, but when we let go of the arm it changed the form of energy and applied a force to the projectile. This change in energy created a force that launched the projectile forward. But why did the projectile not stay in the air at the same speed if we didn't apply a force to it? Gravity. It's the force that keeps you and me from floating off into space. Gravity is the downward force acting on the projectile that eventually brought it back down to the ground.

Newton's second law, commonly referred to as the law of acceleration, states:

"The acceleration produced by a net force on an object is directly proportional to the net force, is in the same direction as the net force, and is inversely proportional to the mass of the object"

This translates to the equation $F = m * ((V_t - V_0)/ (t_t - t_0))$. Since we know that the change in velocity over a period of time is acceleration, we rewrite the equation as $F = m * a$. An assumption this equation makes is that the mass will remain constant throughout the trajectory. This means that the projectile will not get lighter or heavier after it is launched. Now why do we refer to the force as a net force? Because this is what acceleration is based on. It is not merely the force we applied with the catapult arm, but it is a sum of all forces acting on the projectile. This is why the acceleration we calculated wasn't quite accurate.

D. How do you think adding in the force of gravity to our calculations would affect acceleration?

E. Do the results match your prediction? Why or why not?