Catapults

Preparation

Grade Level: 5-12	Group Size: 20-30
Time: 45-60 Minutes	Presenters: 3-5

Objectives

Students will be able to:

- Work as a team to solve a problem.
- Generate and test hypotheses.
- Record and analyze data.
- Draw conclusions based on findings generated by experimentation.

Standards

This lesson aligns with the following National Science Content Standards

- Unifying Concepts and Processes in Science, K-12
- Science as Inquiry, 5-8 and 9-12
- Physical Science, 5-8 and 9-12
- Science and Technology, 5-8 and 9-12
- History and Nature of Science, 5-8 and 9-12

Materials

- 4-8 Catapults
- Masking tape to mark position
- Ping-pong balls
- Tape measures - one per group
- Pencils
- Targets (industrial-sized coffee filters make good targets)
- "Scientific Method" handout (Appendix A)
- "Catapult Challenge" overhead (Appendix B)
- "Catapult Variables" drawing (Appendix C)
- "Catapult Challenge" data sheet (Appendix D)
- "Engineering: Is it You?" handout (http://www.micron.com/k12/resources.aspx)

Preparation

Request a large room for the lesson – a cafeteria or gym is ideal. A white board and overhead projector are needed for the introduction and conclusion. Each student will need a pencil for recording information during the lesson. Print copies of the diagrams, handouts, and worksheets for each student. Prepare overhead transparency.

Introduction

Today we are going to use catapults to learn how engineers solve problems. The scientific method is used to solve all kinds of problems and to improve processes and products. Scientists, engineers, and researchers need to be very systematic and record all their results carefully so that when an experiment or process is repeated, the results will be the same or can be "replicated." The scientific method usually follows these steps:

Distribute "Scientific Method" handout (Appendix A) and describe the steps. This information can be covered in more detail as students are working on the challenges with the catapults. Use the overhead transparency "Catapult Challenge" (Appendix B) to guide students through a discussion of the Scientific Method.

1. **State the Problem**: The first step in the scientific process is to state the desired outcome so you know exactly what you are trying to discover or solve.
    - What is your goal?

Tell the students that their goal in the activity is to determine which combination of the variables will result in shooting a ball the greatest distance.

2. **Research the Topic**: Understand your topic and gather information related to your experiment to best approach a solution. In this experiment you will shoot a few balls at different settings and make some preliminary observations.
    - Ask Questions.
    - Investigate past experiments.
    - Define your *variables,* things in the experiment you can control or change. What are the variables in this experiment?
    - Define your *constants,* things in the experiment you can't control or change. What might be some constants in this experiment?

    The uncontrolled variables may be:
    - Air thickness/density
    - Wind
    - Human factors (human error)

3. **Develop a Hypothesis**: Your *hypothesis* is an educated, scientific guess. This guess, or hypothesis, is based on your research with the goal of achieving the desired outcome. In other words, what do you think will happen when you try your experiment?
    - A hypothesis is measurable through science.
    - Answering the question stated in the problem is your hypothesis.

Give an example of a hypothesis.

4. **Perform an Experiment**: You need to set up an experiment that can prove whether your hypothesis is true or false. The experiment will consist of trials, variables, constants and an outcome.
    - Trials are the number of experiments you try.
    - Replication is an important part of experimentation. Can the results be repeated?
    - Variables can be changed or adjusted.
    - Constants are recorded.
    - The outcome of each trial is recorded.

5. **Gather and Record Data**: Carefully record both the variables and the results you achieve from each trial.

6. **Analyze Your Results**: When you have completed your experiment, determine if your hypothesis was correct by analyzing the data.
    - What do the numbers mean?
    - Did you achieve your main goal?
    - Was the experiment conducted properly and consistently?
    - If not, how can you change a variable, or the experiment, to achieve the desired results?

7. **Draw Your Conclusion**: After you have performed your experiment and analyzed your results, determine whether your original hypothesis was correct. If your experiment has shown your hypothesis to be incorrect, you should have sufficient data to develop a new hypothesis getting you closer to a solution.
    - Did your experiment prove your hypothesis?
    - Do you need to perform a different experiment?
    - Do you need to conduct more trials?
    - Can you change a variable to get you closer to your desired results or outcome or do you need a new experiment?

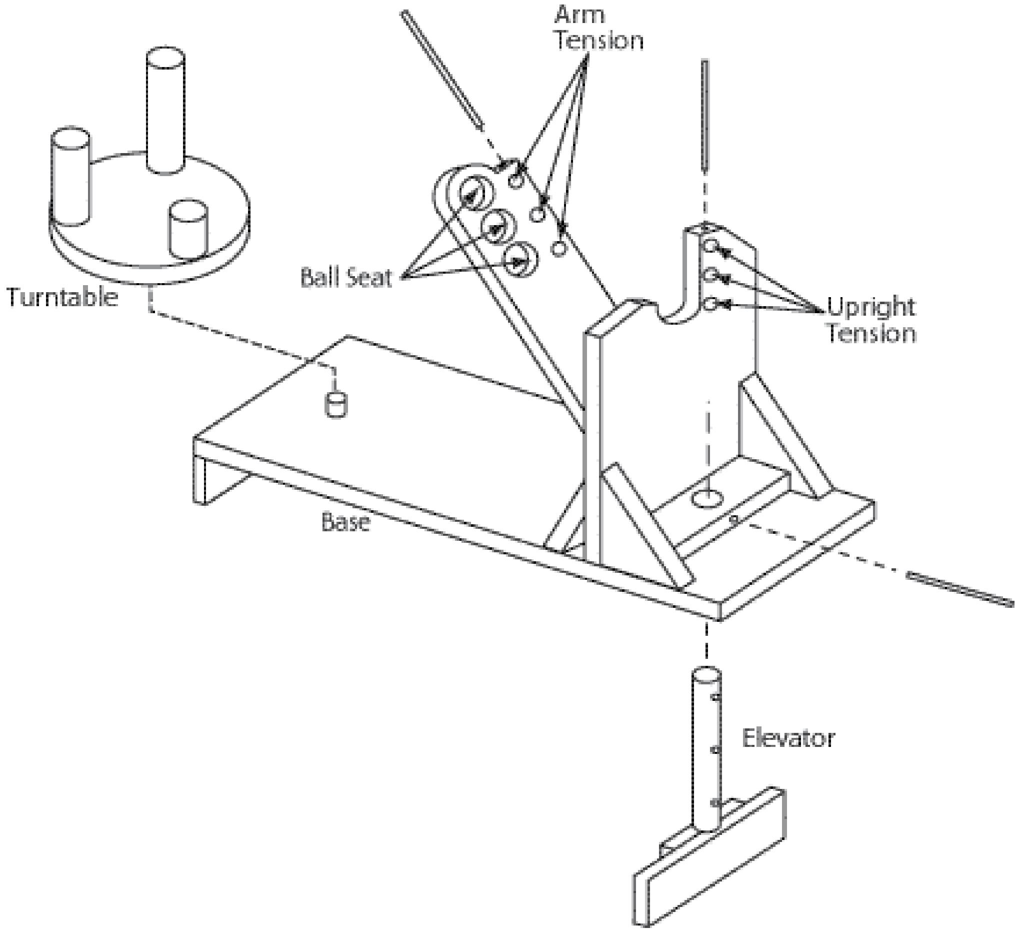
8. **Report Your Results and Conclusion**: Your results and conclusion should be reported for others to see and use. Reporting your results will help you to remember what you did and can aid in future research for others.

Show the Scientific Method poster to reinforce the steps.

Catapult challenge

Distribute catapult drawing (Appendix C). Divide the class into small groups to work with the catapults. Explain and demonstrate each factor and level to students. Depending on the age of the students and the time available, the activities can be adapted. For example, you could limit the variable settings to high and low, or you could allow adjustments to only three or four of the factors.

As seen in the sketch, each factor has three discreet levels, all easily adjustable.



Your first task or problem to solve is to find the combinations on the catapult that will result in shooting a ball the greatest distance. The catapults have five components and three levels of each that affect the distance the ball is thrown, which is also the response variable.

The controllable variables are:

- **Elevator height** – affects the initial angle at which the ball is thrown. It is important to note that two different elevator heights can actually produce the same distance if the launch angles are equally offset from 45 degrees. The maximum distance is typically produced at 45 degrees.

- **Upright tension position** – adjusts the amount of force used to throw the ball. It works in combination with the arm tension.

- **Arm tension position** – works in combination with the upright tension. Different rubber band settings may change how hard the ball is thrown. The highest on both adjustments won't necessarily throw the ball the hardest.

- **Ball seat position** – determines how hard or fast the ball is thrown. The farther a ball is from the center point of rotation, the faster the ball will be traveling.

- **Turntable stop position** – determines how much stored or potential energy is created. Stretching the rubber band is stored potential energy waiting to be released. Once it is released, it becomes kinetic energy or energy of motion.

- **Ball size, type, and weight** – the more compact and dense a ball is, the further it will travel once thrown. A smaller heavy ball, such as a steel marble, will travel farther than a large light ball like the ping-pong ball. The air acts to resist or slow the ball while the weight acts to continue carrying the ball. The act of carrying the ball forward is known as momentum.

- Note: This is not a variable we will be adjusting for this activity. We will use only ping-pong balls in this particular experiment.

Q: Which variable do you think will have the most affect on the distance of the ball? Why?

Q: Which one will have the least affect on the ball? Why?

Background information

The following information is background for the presenters. Depending upon the grade level and subject, it may be shared with the students.

The general trajectory equations can tell you just about anything about the position of the ball when it is launched from a catapult.

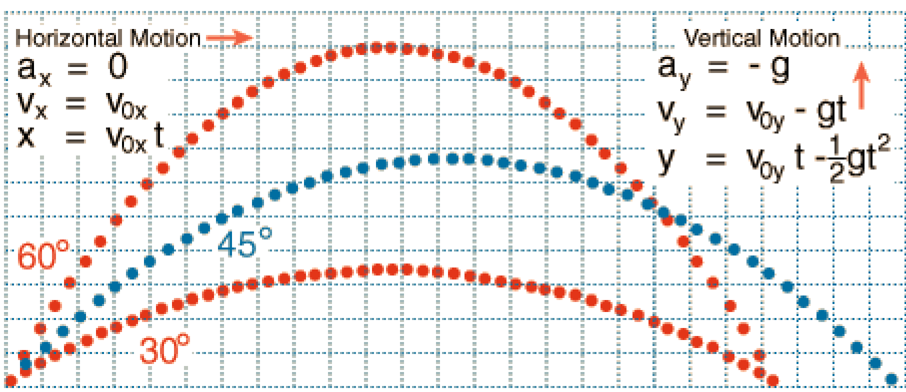
The equations for distance are:

$X = (V_{ox})\ (t)$
$Y = (V_{oy})\ (t - ½\ gt^2)$

X – This will tell you the position of the ball in the horizontal position for a given initial velocity in the “x” direction, as represented by “V_{ox}” in the equation above.

Y – This will tell you the position of the ball in the vertical position for a given initial velocity in the “y” direction, as represented by “V_{oy}” in the equation above.

Voy is affected by the upright tension and arm tension adjustments on the catapult.



The Challenge

Distribute data sheet (Appendix D) to each team.

For this challenge, your controlled factors are the catapult, the type of ball, and the placement (your catapult elevator must always rest on the designated starting place).

Before you begin, assign someone in your group to be the recorder, another to mark and measure the distances you achieve, and others to adjust the various factors. You will rotate through the roles. Try each setting 3 times, to obtain consistency and determine if your data is valid. Remember, this is not a race to see how many balls you can shoot, but rather to see how well you can test and adjust your hypothesis to solve the problem. Accuracy, not speed, is what counts in science. However, for this challenge you will have a time limit: 10 minutes from the time I tell you to begin.

Your first step will be to shoot a few balls and observe what the different settings produce. Record your observations on the data sheets.

Using these observations, establish a hypothesis and write it down. For example, you might believe that to launch the ball the greatest distance the elevator must be set HIGH, the arm tension HIGH, the ball in the HIGH seat, and the turntable set LOW. Then, establish your procedures to test and modify your hypothesis. Begin your experiments, being careful to record all your variables and results on the handout.

Allow students 10 minutes or more, if time is available. Then, move on the Accuracy Challenge.

Accuracy Challenge

Now your task is to find the combinations on the catapult that will result in shooting a ball the closest to a specified target. You should be able to use the data you recorded and your observations from the distance challenge to develop your hypothesis.

As a team, examine your data from the distance challenge to see what differences each setting of the factors made. You will be assigned a distance to place your target. Your team will need to adjust the variables to determine which combination will reach the target.

Assign different target distances for each team. Have the teams determine the best settings for the catapult and attempt to hit the target. Once they hit the target, have them repeat the test at least three times to determine if it was a valid test.

Record all your observations on the handout. Your time limit for this challenge will be 10 minutes. If you are successful with your shot, try it multiple times to test for repeatability.

Now begin.

Conclusion

We now want each group to report their findings for both challenges. For the Distance Challenge, let's compare your settings to see if they are the same. If each catapult were exactly identical, the settings for the greatest distance should also be identical.

Q: Which combination of settings launches the ball the farthest?

Q: How is the path of a projectile altered when the catapult settings are altered?

Q: Which catapult settings(s) alters the projectile path the most?

Q: Did you get the same results with each trial?

You may want to have the recorders post their distance settings on the board.

Now let's discuss your settings for accuracy. Here we should see more variety, especially if the targets for each team are different.

Q: When you tackled the accuracy problem, was it valuable to have a record of your previous tests?

Review the process they used to solve the problems.

Q: How many possible combinations did you find? *On the board demonstrate a 3x3 matrix to establish the process for determining the number of combinations possible. Students should arrive at* 3^5 *or 243 possible combinations.*
A: 3 x 3 x 3 x 3 x 3 (Three (3) variables for each of 5 factors)

Q: Was the experiment performed consistently and correctly?
A: Answers to all the questions will vary

Q: Is all the data valid?

Q: What are the advantages of working as a team to solve problems?

Q: What issues did your team have to resolve to work together efficiently?

Q: What did you learn about the scientific method?
Distribute and discuss the "Engineering: Is it You?" handout available at: http://www.micron.com/k12/resources.aspx .

Scientific Method

1. State the Problem

2. Research Your Topic

3. Develop a Hypothesis

4. Perform an Experiment

5. Gather and Record Data

6. Analyze Your Results

7. Draw Conclusions

8. Report Your Results and Conclusion

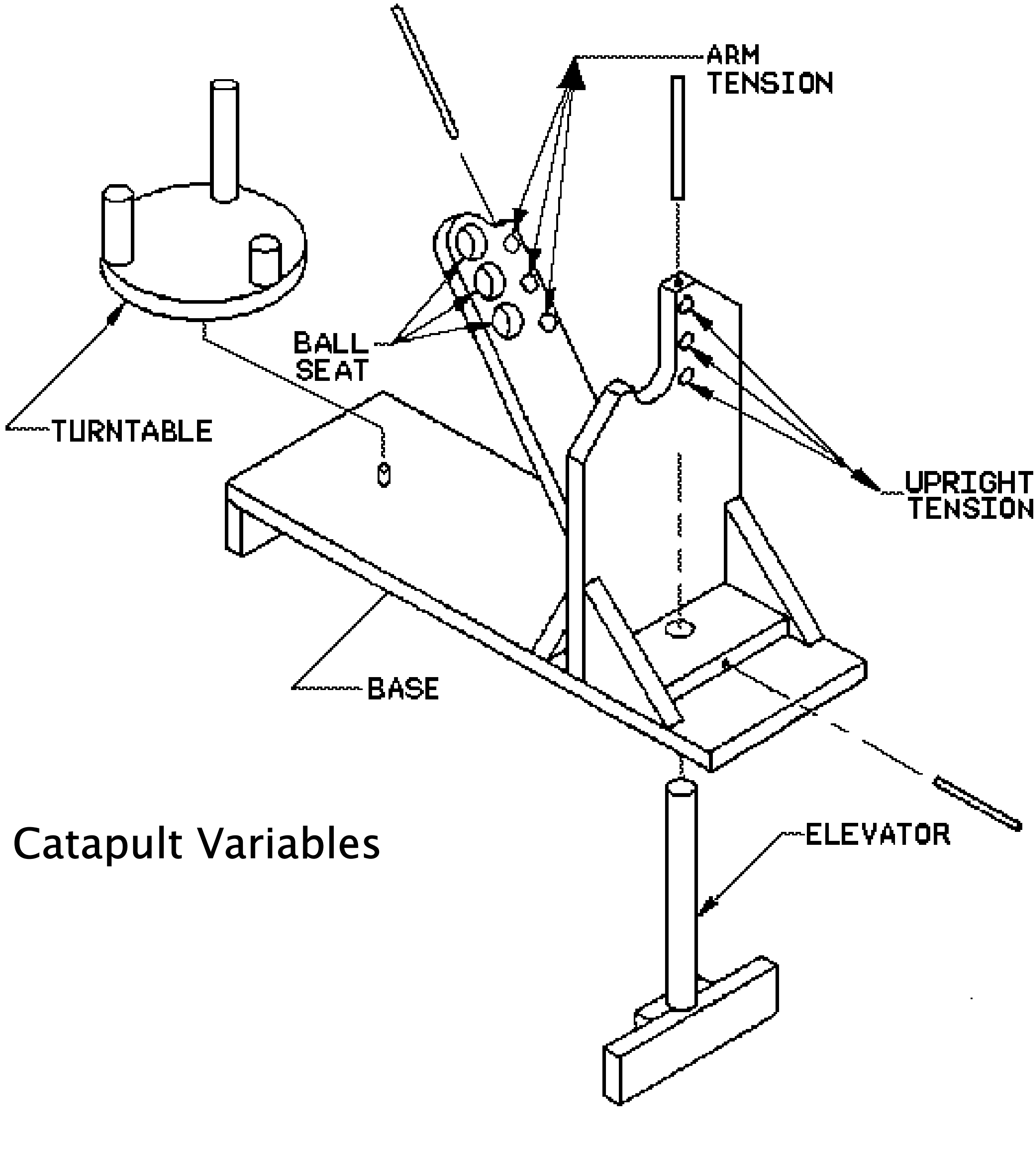
Catapult Challenge Overhead

Part One: Distance

State the Problem: ____
____

Hypothesis:
____
____

Variables (factors)	**Levels/settings**	
Elevator	low	HIGH
Arm Tension	low	HIGH
Ball Seat	low	HIGH
Turntable	low	HIGH



Catapult Variables

Catapult Challenge

Team Members: ____________________________

____

Part One: Distance

____

State the Problem: ____

____

Hypothesis:____

____

Factors (variables)	Levels/settings	
Elevator	low	HIGH
Arm Tension	low	HIGH
Ball Seat	low	HIGH
Turntable	low	HIGH

Perform an experiment:

Check the 5 options in the table below that you will use to evaluate your hypothesis.

Gather and record data:

Run each test three times and record the distance in the appropriate box.

	Option	Elevator	Arm Tension	Ball Seat	Turntable		Distance Shot		
							1	2	3
	1	HIGH	HIGH	HIGH	HIGH				
	2	HIGH	HIGH	HIGH	low				
	3	HIGH	HIGH	low	HIGH				
	4	HIGH	HIGH	low	low				
	5	HIGH	low	HIGH	HIGH				
	6	HIGH	low	HIGH	low				
	7	HIGH	low	low	HIGH				
	8	HIGH	low	low	low				
	9	low	HIGH	HIGH	HIGH				
	10	low	HIGH	HIGH	low				
	11	low	HIGH	low	HIGH				
	12	low	HIGH	low	low				
	13	low	low	HIGH	HIGH				
	14	low	low	HIGH	low				
	15	low	low	low	HIGH				

	16	low	low	low	low				

Analyze the results:

Which combination shot the ball the furthest? ____

Which factors influenced the distance the most? ____
____

Was your hypothesis correct? __________ Why or why not? ___________________________________

Part Two: Accuracy

Problem #2: What are the catapult settings that will shoot the ball the closest to the target?

Record the setting for each variable: L (low) M (medium) H (high). You will be assigned a distance to place your target.

Assigned Distance	Elevator	Arm Tension	Upright Tension	Turntable	Ball Seat	Success	Test 1	Test 2	Test 3

How many times did you have to try before you hit your first target? _____________________

What was your overall success rate for hitting the targets? ___________________________________

Which factors influenced the accuracy the most? ____
____

Explain how your group zeroed in on the correct settings for the distance assigned. __________
____
____