Catapults and Trebuchets (Catapulting, Trebuchets and Physics, Oh My!)

GRADE LEVELS:
This workshop is for 9th through 12th grade

CONCEPTS:
- A lever is a rigid object that can multiply the force of an another object
- Levers are made of different parts such as the fulcrum, effort arm, and load
- Levers are made of three classes
- Data from experiments can be translated into graphs for further study
- Experiments must be constantly modified for optimum results

OBJECTIVES: Create catapult from various components
- Identify kinetic and potential energy
- Identify various parts of levers
- Use deductions made from trial runs and adjust catapult for better results
- Identify different classes of levers.
- Collect data from catapult launches and graph results

ACADEMIC CONTENT STANDARDS:
Science: Physical Sciences 9.21, 9.22, 9.24, 9.25, 12.5

VOCABULARY/KEY WORDS:
Lever: a simple machine used to move a load using a board/arm, and fulcrum
Fulcrum: the point on which a lever rotates
Board/Arm: the part of the lever that force is applied to and that supports the load
Force: the effort used to move the board/arm and the load
Load: the **mass to be moved**
Counterweight: a weight that balances another weight
Kinetic energy: energy of motion as an object moves from one position to another
Potential energy: stored energy due to an object's position or state of matter
Trebuchet: a form catapult that utilized a counterweight and sling to throw a load
Catapult: a large lever used as a military machine to throw objects

EXTENSIONS AT COSI:
Big Science Park: Giant Lever
Progress: Identify various levers used in the 1898 portion of the exhibition.
Gadgets: Experience how simple machines utilize force first hand by using the pulley chair

ADDITIONAL RESOURCES:
Build a virtual trebuchet. Test your skill at accuracy and length.
http://www.globalspec.com/trebuchet/
Virtual trajectory calculator
http://hyperphysics.phy-astr.gsu.edu/Hbase/traj.html
Gravity launch on-line demonstration
http://www.sciencenetlinks.com/interactives/gravity.html
All-around interesting site with answers and activities surrounding physics
http://www.physics.org/

SAMPLE TEST QUESTIONS:

1. Which of the following a force that can change or oppose the motion of an object?
    a. Gravity
    b. Air resistance
    c. Friction
    d. All of the above

2. What word describes the principal that an object in rest will stay in rest unless acted on by an unbalanced force?
    a. Gravity
    b. Inertia
    c. Entropy
    d. Friction

3. A catapult launches a rock with a mass of 45 kg. The rock's acceleration is 40 m/s^2. What force was exerted on the rock?
    a. 1800 newtons
    b. 1.125 kg
    c. 1.125 newtons
    d. 45 m/s^2

Catapults and Trebuchets-Pre Visit Activities

3 Classes of Levers

Objective: The learner will move a load using 3 classes of levers.

Materials:

- Brick per group
- 2 bamboo skewers per group
- Small pebbles
- Newspaper

Procedures:

1. Explain and draw the 3 classes of levers.
    - Class 1 lever: fulcrum located in the middle, like a see-saw
    - Class 2 lever: fulcrum located at one end of the lever, load is in the middle and effort from underneath. This is how a wheel barrel works.
    - Class 3 lever: fulcrum and load are at opposite ends, effort is in the middle. This is how a canoe paddle functions- the hand at the top of the paddle is the fulcrum, the hand on the shaft is the effort and the water on the blade is the load.

2. Divide students into small groups. Provide each group with a newspaper page, cup of pebbles, brick, and 2 bamboo skewers. Spread newspaper over work surface. Place the brick on top of a pile of pebbles.

3. Challenge the students to use the 3 classes of levers to lift and move the brick from the pile of pebbles without using their hands. Record which levers were most efficient for various tasks.

Possible Interactive Questions:

- Which class of lever was most effective for lifting the brick? For moving the brick out of the rubble?
- Which how does the height of the fulcrum affect the ability to lift in a

class 1 lever?

- What purpose would a lever serve in construction projects?

What Happened/What's Going On:

Levers are not only used in warfare. They also serve a very practical purpose in moving large masses. Archimedes, an ancient mathematician, is credited for saying "Give me a lever long enough and a place to stand, and I will move the earth." Despite the exaggeration, levers were used throughout history to help assemble massive construction projects. It is hypothesized that levers were used in the construction of the moai on Easter Island, in raising stones at Stone Hedge, and to lift stones to build the great pyramids.

Lever Computer Demo

CONCEPTS:

Show how levers can be manipulated to support various weights

OBJECTIVES:

- Gain a solid understanding of the functionality of levers
- Show how less weight at a further position can have the same or a greater effect than more weight at a closer position

MATERIALS:

- Computers (one per student or pair of students)
- Internet connection: http://library.thinkquest.org/27948/lever.html

PROCEDURES:

- Give a basic introduction to levers
- Allow the students to experiment with the levers
- Suggest balancing 9 against 1 or other ratios

POSSIBLE INTERACTIVE QUESTIONS:

- Why can nine and one balance with each other?
- What explains the diffusion of force?
- How can this be applied to make life easier for us?

WHAT HAPPENED/WHAT'S GOING ON?

Since each of the weights are the same, it seems counterintuitive that nine can balance with one. However, the positioning determines how many Nm will be on each side. As Newtons (force) are multiplied by meters (distance), the work necessary to pull the lever will increase or decrease accordingly.

Balancing Act

Key Words/Concepts:

Class 1 lever
Mass
Distance
Fulcrum

Objectives:

The learner will represent balanced objects mathematically.
The learner will hypothesis and test the distances from the fulcrum required to balance two objects.
The learner will build a class 1 lever.

Materials:

Meter sticks (1 per student group)
Yarn
Washers (1 per student group)
Paper, pencil

Procedures:

1. Tie a string around the middle of the meter stick. Tie the washers into two equal bundles, making sure that there is a loop at the top that will slide along the meter stick.
2. One student will suspend the meter stick by holding onto the string. The other will add the weights.
3. Allow students to test and find a point on the meter stick at which there is balance. Record the number of washers and the distance each set of washers is from the center (fulcrum).
4. Add 2 washers to one of the existing sets. Test to find the positions on the meter stick required to balance the washer loads. Record the number of washers and the distance each washer is from the fulcrum.
5. Multiple the force (number of washers) by the distance from the fulcrum. If the lever was balanced, both resultants should be equal.

Possible Interactive Questions:

How long would the bar need to be to balance 50 washers using only 5 washers?

What would need to be done to raise 50 washers using only 5 washers?

How can this equation be used to find an unknown number of washers if the distances and one set of washers is known? Example: On one side of the lever there are 9 washers suspended 21 centimeters from the fulcrum. The other load is 63 centimeters from the fulcrum. How many washers are on the other end?

How could you use what you experienced to build a more enjoyable teeter totter?

Where else are levers used to balance or raise objects?

What Happened/What's Going On:

The equation $d_1m_1=d_2m_2$ can be used to determine the distance from the fulcrum or the mass required to balance two loads on a class one lever. In order to lift an object, one side of the equation must have a greater resultant. The side with the greater resultant will lift the side with the lower resultant.

This experiment can also be used to determine the mass or an unknown object. Replace one set of washers with an unknown mass. Solve the equation by substituting m_2 with x.

Academic Content standards:

Science, Forces and Motion: 12.5, 8.1

Catapults and Trebuchets-Post Visit Activities

Big Science Park! Giant Lever

Key Words/Concepts:
Lever
Fulcrum
Work
Using a formula to solve for an unknown

Objectives:
The learner will create and test a hypothesis.
The learner will represent results mathematically.

Materials:
Pen, paper
Calculators (optional)
Giant Lever in Big Science Park!
People

Procedures:

6. Go to Big Science Park at COSI.
7. Estimate how much force it will take to lift the car at the rope closet to the fulcrum and the rope farthest from the fulcrum. Keep in mind that the force will be a combination of weights of your classmates.
8. Test your hypothesis. Add students until the car is raised and the bar is in equilibrium (parallel to the ground). Record the results. To convert pounds to kilograms, divide by 2.2. 1 kilogram=2.2 lbs.
9. Test again with a different combination of students. Find an average of the weights needed to bring the bar to equilibrium.
10. Use the average in the formula to find the weight of the car and its cradle.

$$C \times d_1 = (F \times d_2) + 6{,}913\text{kg}$$

d1= distance from the cradle attachment to the fulcrum, 4 meters

d2= distance from the rope attachment to the fulcrum, 12.8 meters for the farthest rope and 4 meters for the closest rope
C= weight of the car and the cradle
F= the amount of force needed to bring the lever into equilibrium
6,913 kg= the weight of the lever, ropes, and other factors

6. Compare results to the estimation.

Possible Interactive Questions:

Did your results come close to your estimation? Why do you think they were/ were not accurate?
Why was it important to include the weight of the lever, ropes, and other factors?
How could this lever be made more efficient?
What could be done so that one person could lift the car by their self?
Is a simple lever a realistic way to raise and lower heavy objects? Why or why not?

What Happened/What's Going On:

A lever is a simple machine with a rigid bar free to turn around a pivot point called the fulcrum. The general formula for a balanced lever is: the weight (or force) on one side multiplied by its distance from the fulcrum, equals the weight on the other side multiplied by its distance from the fulcrum. In most situations, the weight of the lever is disregarded. However, the weight of this lever is rather high in comparison to the rest of the system and must be included.

The actual weight of the 1961 Mercury Comet is 1105.4 kilograms, or 2,437 pounds.

Academic Content standards:

Math, Use Algebraic Representations 10.3, 9.11

History of Siege Weapons

CONCEPTS:
Explain the historical progression of siege weapons to gain an understanding of how the addition and modification of parts can change the efficiency of catapults and trebuchets.

OBJECTIVES:
- Gain an understanding of modifications in siege weapons
- Be able to identify the parts of each siege weapon shown
- Be able to identify the classes of levers

MATERIALS:
- Computer
- Projector

Or

- Pictures

PROCEDURES:
- Show the class the simplest weapon – a sling shot
- Ask for the fulcrum, load, arm, and resistance
- Continue up in a progression of siege weapons including but not limited to ballistas, catapults, onagers, mangonels, and trebuchets

POSSIBLE INTERACTIVE QUESTIONS:
- How has the technology progressed? What has replaced these weapons?
- Did the amount of work required to get one to work decrease over time? What does this say about the efficiency of levers?

WHAT HAPPENED/WHAT'S GOING ON?
Over time, levers were modified to create ruthlessly efficient machines of war. Unfortunately for countless nations, but fortunately for the sake of science, these levers had practical applications that can be seen today.