NSF GK-12 Graduate Fellows Program
Award # DGE-0139171
University of North Carolina at Wilmington

Forces and Motion

Activity Instructions

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Forces and Motion Stations

Station 1, 2, and 4 activities modified from Smithsonian/National Academics *National Science Resources Center* book, Energy, Machines, and Motion

Objectives:

4.01 Analyze gravity as a universal force.

4.02 Demonstrate ways that simple machines can change force.

4.04 Determine how the force of friction retards motion

4.06 Describe and measure quantities that characterize moving objects and their interactions within a system:

- Time
- Distance
- Mass
- Force
- Velocity
- Center of mass

Time required: Four 50-minute class periods

Materials needed:

Station 1:

- K’NEX™ Mousetrap Car (instructions for building on page 188 of Energy, Machines, and Motion book)
- K’NEX™ Fan Car (instructions for building on page 175 of Energy, Machines, and Motion book)
- Stopwatch
- Meter stick
- Tape

Station 2:

- K’NEX™ Pulley System with Sled (instructions for building on page 109 of Energy, Machines, and Motion book)
- Meter sticks (2)
- Spring scale

Station 3a:

- V-shaped ramp made with cardboard strips taped together – the wide end should be ~ 2cm higher than the point
- Double cone shape (e.g. two funnels taped together at the mouth, longer than the wide end of the ramp)
- Sphere shape smaller than the wide end of the ramp
- Cylinder shape wider than the ramp

Station 3b:

- Meter stick
- Wooden ball
- Two-liter bottle caps (2)
- Masking tape

Station 3c:

- Forces pictures

Station 3d:

- Computer with internet access

Station 4:

- K'NEX™ Sled (instructions for building on page 73 of <u>Energy, Machines, and Motion</u> book) or a wooden block with a hook on one end
- K'NEX™ Cart (sled with wheels) (instructions for building on page 101 of <u>Energy, Machines, and Motion</u> book) or any object with wheels of the same size, weight, and material as above
- Inclined plane
- Meter stick
- Spring scale
- Coarse sand paper

Procedure:
Students should follow the instructions given and write answers to all questions.

(Half the students should do station 1a, the other half should do 1b)
<u>Station 1a: Motion of a Mousetrap Car</u>

1. Set the car on the floor and spring the mousetrap. **a) Describe how the car is propelled. b) How does Newton's 1st law of motion apply to the movement of the car?**
2. **a) Is the speed of the car constant as it moves across the floor? b) List all the forces acting on the car as it moves across the floor.**
3. Design and carry out an experiment to measure the average speed of your car. **a) Describe your experiment. b) What is the average speed of your car?**
4. Now measure the speed of your car at different places along its path from start to finish. **Record your measurements and graph your data.**

<u>Station 1b: Motion of a Fan Car</u>

1. Set the car on the floor and turn on the fan. **a) Describe how the car is propelled. b) How does Newton's 3rd law of motion apply to the movement of the car?**

2. **a) Is the speed of the car constant as it moves across the floor? b) List all the forces acting on the car as it moves across the floor.**
3. Design and carry out an experiment to measure the average speed of your car. **a) Describe your experiment. b) What is the average speed of your car?**
4. Now measure the speed of your car at different places along its path from start to finish. **Record your measurements and graph your data.**

<u>Station 2: Work of a Pulley System</u>

1. Lift the moveable pulley-sled assembly 0.5m off the floor using the spring scale. **Record the load force (LF), load distance (LD), effort force (EF), and effort distance (ED) in a table.**
2. Thread a cord through the pulley system to make a single fixed pulley, and lift the pulley-sled to 0.5m using the fixed pulley and the spring scale. **Record the LF, LD, EF, and ED in your table** (LF and LD should be the same as in step 1). **Draw a diagram of the entire system, clearly labeling LF, LD, EF, and ED.**
3. Now lift the pulley-sled to the same height using:
   a. Single fixed, single moveable pulley
   b. Double fixed, single moveable pulley
   c. Double fixed, double moveable pulley

   Record LF, LD, EF, and ED for each of these pulley combinations (LD and LF should be the same as in step 1).
4. **a) Describe what happens to the EF and ED with each additional loop of the cord around the pulley system.**
   b) Why do you think this happens?
5. Make another column in your results table and **a) calculate the actual mechanical advantage of each pulley system** (M.A. = LF/EF). **b) Explain what these numbers tell you.**

(Each team should complete all sections of Station 3.)
<u>Station 3a: Gravity I</u>

1. Set the cardboard ramp on a flat surface so that its wide end sits about 2cm higher than its point. Now place the double cone shape at the bottom of the V, and release it. **a) Describe what you observed. b) Did the object roll uphill? c) Does the double cone actually end up higher above the table?**
2. Now place the double cone at the top of the hill (wide end of the V) and give it a slight push toward the bottom. **Describe what you observed.**
3. **a) What force made the double cone roll toward the higher end of the V? b) Would a cylinder roll up or down the ramp? Why? c) What would a sphere do? Why?**

Station 3b: Gravity II

1. Place the wooden ball in the end cup on the meter stick and lift the cup-end to about a 30° angle from the table, holding the other end steady on the tabletop.
2. Suddenly release the cup-end of the meter stick, allowing it to fall to the table. **a) What did you observe when the meter stick fell? b) Name the force that causes this to happen.**
3. Now explain why this happens by answering the following questions: **a) Does the end of the meter stick fall faster, slower, or at the same speed as the center of the meter stick? Why? b) Does the end fall straight down or at an angle? Why? c) How do your answers from a) and b) affect the position of the ball when the meter stick is dropped?**

Station 3c:

1. Look at the 'Forces' pictures and answer the questions in your science journal.

Station 3d:

1. Use the internet to find another example of a sport where gravity plays a role. a**) Name the sport. b) What is the effect of gravity in this sport? c) Describe all other forces that act in the sport.**

Station 4:

1. Pull the sled at a steady rate across a tabletop with the spring scale. **a) Record the force needed to pull the sled. b) Why does it take this force to move the sled?**
2. Pull the cart at a steady rate across the tabletop. **a) Record the force needed. b) Why is the force different?**
3. **How do you think pulling a) the sled and b) the cart across sand paper would change the effort force?** Try it! **Record your results.**
4. Set up the inclined plane so that you can pull the sled or cart (your choice) to a vertical height of 0.5m. **a) Record the force needed to do this. b) Why is this force different than the force needed to pull the sled/cart across the table?**
5. Predict what will happen to the effort force required to move the sled/cart up the inclined plane as its slope changes. **Write your prediction in your science journal.**
6. Develop and carry out an experiment to test your prediction. **a) Write your procedure in your science journal. b) Record your results in a data table with a column for load force (LF)** (this is the force required to lift the load straight up off the table using the spring scale), **load distance (LD)** (this is the vertical height the load is raised), **effort force (EF)** (this is the force required to pull the load up the inclined plane using the spring scale), **and effort distance (ED)** (this is the distance the load has actually moved along the inclined plane).
7. Make another column in your results table for mechanical advantage, and **calculate the actual mechanical advantage of the inclined plane for each height** (M.A. = LF/EF). **What conclusions can you make from this experiment?**