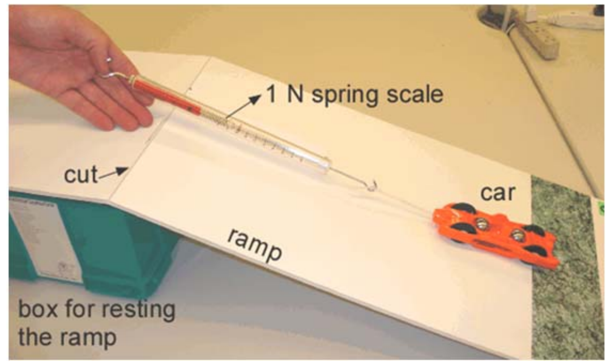
What is Work and Who Does Work? – Lab

Purpose

How is work connected to energy? How can one calculate the amount of energy transferred into a system by working?

Materials:

Frictionless cart or car
1 N Spring scale/force probe
Several ramps, 40 to 100 cm in length
1 box about 20 cm high on which to rest the top of the ramp



PART I: Exploring Work.

Pre-lab discussion:

Consider a system that consists of a cart, a frictionless ramp and the earth (the spring is not part of the system).

1. Draw a picture of the system and an energy bar graph for the system at three different positions:

	Position A: the cart is at rest at the bottom of the ramp	Position B: the cart is dragged up the ramp by a constant force applied by the spring	Position C: the cart is at rest at the top of the ramp.
Picture			
Energy bar graphs			

2. What are the energy transfers from A to B?

3. What are the energy transfers from A to C?

4. How was energy transferred into the system?

5. Think about pulling the cart along another frictionless ramp that has the same height but a longer length. In which case was more energy transferred into the system? Explain.

6. What is different about raising the cart on the longer ramp (with a lower incline) vs the shorter ramp (with higher incline) vs straight (vertically) up?

7. When you load furniture in a tall truck you use a ramp. Would you set your ramp with a low incline or a sharp incline to make your job easier? Explain why.

Directions:

Design a lab where you can measure the force it takes to pull a cart up a frictionless ramp such that the object is moving at *constant speed*. Once you set the object moving with constant speed, read the force applied at 3 or 4 different positions along the ramp. Use 3 or 4 ramps of different lengths but same height and repeat the reading of the force applied for each ramp. Discuss energy transfer for the object moving up the incline at constant speed (the spring scale is not part of the system). Make a graph of Force applied vs position of the object along the ramp (only for that part of motion that was with constant speed). Use different colors for each graph.

Experimental Question:

Hypothesis:

IV:

DV:

Constants of the experiment:

Materials List:

Procedure:

Title ____

Post-Lab discussion:

1. What is the slope of each of the F vs Δx graphs? Explain why.

2. What does the y-intercept of the graphs represent?

3. How does the length of each ramp compare to the force applied?

4. Calculate the area under each one of your graphs.

5. What is the unit for the calculated area?

6. What does 1 J (Joule) represent?

7. What do you think that the area under the force vs Δx graph represent?

8. Make a bar graph for the object moving up the inclined plane at constant speed.

9. Using your bar graph, explain what the calculated area under the F vs x graph represents.

PART II: Work to Energy Connection

Explore the connection between work and gravitational potential energy.

Pre-lab Discussion:

1. What are the energy transfers for a cart moving up an incline at constant speed under the action of a constant external force?

2. What happens if the cart is pulled straight upward (on the vertical), what forces act on the cart, and how are these forces related to the change in energy for the cart?

Directions:

- Slowly pull the cart vertically up at *constant speed* using a spring scale. Move the cart vertically upward on a distance equal to the height of the ramps used in part I of this lab. Record the amount of force that you apply to the cart at different heights (when the cart is moving with constant speed). Ignore the values of the force at the beginning or end of the motion (while the cart is accelerating).
- Make a graph of Force vs height (Δy).

Title ____

Post-lab Discussion:

1. Make a bar graph for the cart moving at constant speed under the applied force.

2. What happens to the total energy of your system (cart + earth)?

3. The cart is pulled up at constant speed. How can you determine/calculate the external force applied to the cart knowing its mass?

4. Calculate the work done by the applied force for the case where the cart was moved vertically upward on a distance equal to the height of the ramps used in part I. Compare this value to the values calculated in part I. Remember, work represents the area under the F vs x graph.

5. What does the work done by the applied force represent?

6. Determine the change in energy for your system.

7. How can you calculate the change in energy for the cart?

8. What does that change in energy depend on?

How much energy is stored in a spring? – Elastic Potential Energy Lab

Purpose

What is the relationship between the amount of force applied to the spring and the amount of deformation? What is the relationship between the amount of deformation of the spring and the amount of energy stored in the spring? What is the connection between the amount of work done by the spring and the amount of energy stored in the spring?

Materials

Hooke's law apparatus
meter stick

Pre lab discussion

1. What is the relationship between the force in a spring and the stretch of the spring?

2. When a force applied to a spring stretches the spring, that force does work. How would you calculate that work if you knew how the force is related to the stretch?

3. What happens to the work done by the applied force in stretching a spring?

4. If you can find the work done in stretching a spring, can you also find the elastic energy stored in that stretched spring?

Directions

Design an experiment to determine the relationship between the amount a spring stretches and the force used to stretch the spring. You will have to measure the amount of force vs stretch for a spring. Hint: force is the dependent variable and stretch is the independent variable. After collecting the data for one spring, repeat the experiment with a different spring. Your documentation should contain:

Experimental Question:

Hypothesis:

IV:

DV:

Constants of the experiment:

Materials List:

Procedure:

Data table:

Graph with smooth line through data points. (hint: plot force on the vertical axis)

Title ____

Analysis of Data and Conclusions

1. By looking at the graph, what is the relationship between the stretching force, F, and the stretch of the spring, x? Note: the stretch of the spring is always measured from 0 (no stretch).

2. Do both graphs have the same slope? Why or why not?

3. What does the slope of the F vs x graph represent?

4. Calculate the slope of each graph.

5. Which spring is harder to stretch the same amount?

6. What else can one calculate from an F vs x graph and what does that represent?

7. What do you know about work done in stretching the spring and energy stored in the spring?

8. Calculate the amount of energy stored in spring 1 when it is stretched 2 cm starting from the unstretched position.

9. Calculate the amount of energy stored in spring 2 when it is stretched 2 cm starting from the unstretched position.

10. Develop a mathematical formula for calculating the energy stored in a stretched spring.

11. How much energy is stored in spring 1 when stretched from 0 cm to 2 cm?

12. How much energy is stored in spring 1 when stretched from 2 cm to 4 cm?

13. What is the change in elastic potential energy of spring 1 when stretched from 2 cm to 4 cm?

14. Using your graph, calculate the work required to stretch spring 1 from 2 cm to 4 cm.

15. Compare the work required to stretch spring 1 from 2 to 4 cm to the change in the elastic potential energy of spring 1 when stretched from 2 cm to 4 cm.

16. Write three most important things you learned from this lab about elastic potential energy.

Exploring Energy – Lab

Purpose

What types of energy and energy transformations can you identify?

Materials

Baking soda, film canister, vinegar, tissue paper, jar, cheetos, aluminum pie pan, lighter wand, squeeze flashlight, LED flashlight, wind up toys, steel spheres, astroblaster, jumping disks, spring toy car.

Pre-lab discussion:

1. What do you think is the definition of energy?

2. List as many types of energy as you know.

3. What do you think can happen to energy?

Directions:

Definitions

System: The part of the station we want to focus our attention on

Initial State: This is how the system starts off (a snapshot in time)

Final State: What happens to the system after an action (also a snapshot in time). action is described at each station.

Observe what happens at each station and write a description of the initial state and final state of the system. Describe the process it underwent. Fill out the table below.

Station 1 ____

System	Initial State	A main form of energy in initial state	Final State	A main form of energy in final state	Is the main form of energy the same in initial and final states?

Station 2 ____

System	Initial State	A main form of energy in initial state	Final State	A main form of energy in final state	Is the main form of energy the same in initial and final states?

Station 3 ____

System	Initial State	A main form of energy in initial state	Final State	A main form of energy in final state	Is the main form of energy the same in initial and final states?

Station 4 ____

System	Initial State	A main form of energy in initial state	Final State	A main form of energy in final state	Is the main form of energy the same in initial and final states?

Station 5 ____

System	Initial State	A main form of energy in initial state	Final State	A main form of energy in final state	Is the main form of energy the same in initial and final states?

Station 6 ____

System	Initial State	A main form of energy in initial state	Final State	A main form of energy in final state	Is the main form of energy the same in initial and final states?

Station 7 ____

System	Initial State	A main form of energy in initial state	Final State	A main form of energy in final state	Is the main form of energy the same in initial and final states?

Station 8 ____

System	Initial State	A main form of energy in initial state	Final State	A main form of energy in final state	Is the main form of energy the same in initial and final states?

Station 9 ____

System	Initial State	A main form of energy in initial state	Final State	A main form of energy in final state	Is the main form of energy the same in initial and final states?

Station 10 ____

System	Initial State	A main form of energy in initial state	Final State	A main form of energy in final state	Is the main form of energy the same in initial and final states?

Station 1: Acids and Bases (goggles required, one trial per group).
Please read all directions before starting. Place 1/3 of a teaspoon of baking soda (base) in a small facial tissue wrapper. Have the film canister lid ready. Pour 20 mL of Vinegar (acid) into the film canister. Add the tissue packet with the baking soda into the film canister and quickly replace the cap. Drop the closed film canister into the clear jar. You need to move quickly on this one. Stay clear of the jar opening. Make observations (please view from the side).

Station 2: Fire Cheetos on Fire (goggles required, one trial per group).
Place one piece of Cheeto into the aluminum pie pan. Using the lighter wand, attempt to ignite the Cheeto. You may find it easier to ignite the Cheeto by maneuvering the flame to an internal surface of the Cheeto. Make observations.

Station 3: Squeeze Flashlight
Hold the flashlight in your hand and watch the light bulb. Squeeze the handle slowly at first, then more quickly. Make observations.

Station 4: Squeeze LED
Hold the LED in your hand and watch the light bulb. Squeeze the handle once. Make observations.

Station 5: Wind Up Toy
Wind the toy. Be gentle. It only takes a few twists. Place the toy on the tabletop and release. Make observations.

Station 6: Colliding spheres
Hold a piece of paper between the two steel spheres and make them collide such that the paper is between the two spheres. Make observations.

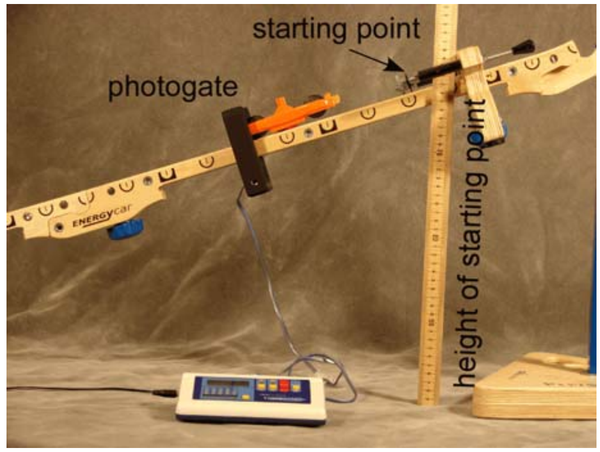
Station 7: Astroblaster (goggles required).
Drop the smaller ball from chest height. Observe. Drop the bigger ball from chest height. Observe. Please stack the smaller ball on top of the bigger ball. Release the balls simultaneously so that they may fall together. Make observations.

Station 8: Jumping Disks
Take the plastic half ball and invert it (bend it the other way around). Either place it on the table and watch it or release it such that it falls perpendicularly on the ground with the curved side down. Watch and make observations.

Station 9: Spring Car
Place the toy car on the floor. Please wind the toy car by gently pressing down on the car and rolling it backwards just a few centimeters and release. Make observations.

Station 10: Rubbing Hands
With your palms together, compress your palms and fingers. Rub your hands, alternating up and down for several seconds. Place your hands on your cheeks. Make observations.

How much energy do we have when moving? – Kinetic Energy Lab



Purpose

What is the relationship between the kinetic energy stored in a moving object and the speed of the object?

Materials

CPO track
CPO timer (photo gates)
CPO energy car (+ marbles)
ruler
scale

Pre lab discussion:

Set up the track as shown in the picture at right.
Determine a starting point from where the car will be released to roll down the incline. Set up the CPO timer along the track. Answer the following questions:

1. If you want to study the energy transformations during the motion of the car down the track, how do you need to define your system? Specify which objects must be included in your system such that your study is easy to do. Justify your answer.

2. What will be the initial and final state of your system?

3. For a system that consists of the car + earth + track, draw an energy bar graph diagram for the initial and final state. Consider that friction is negligible.

4. Write the mathematical expression for the conservation of energy between the initial and final state of the system.

5. What quantities can you measure for the initial and final state?

6. How can you find the kinetic energy of the car when passing through the photo gate?

7. How can you calculate the speed of the car when passing through the photo gate?

8. If you know how find the kinetic energy and the speed when the car passes through the photo gate, how would you find a connection between them? What would you need to do?

Directions for taking data

1. Set up the track at an incline as shown in the picture above. Determine a starting point from where the car will be released to roll down the incline. Position the starting point (using the long screw) such that the flag of the car is at a marked point. This will make measurements easy.

2. Measure the height of the release point (with respect to the table) using your ruler and record it.

3. Measure the mass of the car you are using (you may use a car with steel balls; in that case the steel balls are considered part of the car) and record its value.

4. Set up the first CPO timer close to the point of release for the car (at the next mark for example) and if you want to be efficient, use a second CPO timer set up 5 cm behind the first one. When using two timers, you can record two different times simultaneously, one for each position of the photo gate. For example, the first photo gate can be set up 5 cm and the second one 10 cm along the track from the release point. This will allow you to measure time it takes the car to pass through the photo gates for two different positions. Make sure you read the time it took that car to pass through each photo gate and not the time from one photo gate to the other.

5. You will also have to measure the height of each photo gate with respect to the table and record your measurements. The two timers will be moved down the track together such that each one is set at a different height than previously (each should be moved 10 cm down along the track with respect to their previous position).

6. Release the car at the top of the track so that it travels along the track. Start taking measurements and record them in the table below. When calculating the speed of the car, remember that the flag is 1 cm wide.

Height of photo gate (cm)	Time through photo gate(s)	Speed = distance (1 cm)/time

Analyzing your data:

1. Calculate the initial gravitational potential energy of the car and fill in the table below.

2. Calculate the gravitational potential energy of the car when passing through each photo gate and fill in the table below.

3. How can one calculate the kinetic energy of the car when passing through the photo gate knowing the gravitational potential energy at the release point and at the photo gate? Remember: What is the connection between the gravitational potential energy of the car + earth system in the initial and final state and the kinetic energy of the system? Go back to your energy bar graphs if you can't figure this out.

H = Height of starting point (m)	E_g = mgH at the top (J)	h = Height of the photo gate (m)	E_g=mgh at the photo gate (J)	E_k = kinetic energy (J)	V= Speed of car (m/s)	Mass of car (kg)

4. What does the kinetic energy of the car depend on? Make a graph of the kinetic energy vs speed.

Title ____

5. What type of graph does one get when plotting kinetic energy vs. speed? Is it linear? Can you calculate anything from this graph?

6. What do you need to do with this graph so that you can read something from it?

7. How can you make this graph into a line? Build a new table and plot the new graph on the graph paper provided. Make sure to fit a line through your new graph.

8. Calculate the slope of the graph obtained.

9. Write a direct proportionality expression between the kinetic energy and the speed of the car using the value of the slope calculated above.

10. What are the units for the constant of proportionality?

11. What does the slope of the graph represent? Can you connect the value obtained for the slope to anything else that you have measured?

12. How would a general formula for calculating the kinetic energy look like?

Human Power – Lab

Purpose

How can one measure or calculate the power output of a person? What is the connection between energy, work and power?

Materials:

Bathroom scale
metric tape
stopwatch
tennis shoes

Pre lab discussion:

1. Monday morning you come to school all eager to get to your classroom on the fourth floor. You go up all those stairs in 2 minutes. Draw a bar graph for you + earth when you are already moving up the stairs at the bottom, and when you are moving up the stairs and are almost at the top of the stairs. Assume you are moving up the stairs at a constant speed.

2. By Friday morning you are tired and it takes you 5 minutes to get your classroom on the fourth floor. Draw a bar graph for you + earth when you are already moving up the stairs at the bottom, and when you are moving up the stairs and are almost at the top of the stairs. Assume you are moving up the stairs at a constant speed.

3. What is the same in both bar graphs and situations?

4. What is different in both bar graphs and situations?

5. When did you feel more powerful and what should you take in consideration when deciding this?

6. From your previous knowledge of power, what is the connection between power and energy?

Directions:

1. Locate a staircase at least 1.5 meters in vertical height, preferably with a railing. There should also be a clear area of at least 2 meters squared at the top and bottom of the stairs. Measure the vertical height of the staircase, from the bottom of the first step to the top of the last step.

2. Use a bathroom scale to measure your weight. Convert this weight from pounds to newtons using the conversion factor 1 lb = 4.45 N

3. The premise of your calculations is that if you get a running start and run (walk, crawl) up the stairs at a constant speed there will be no change in your kinetic energy and therefore the energy "expended" while climbing the stairs will be equal to your increase in gravitational energy.
4. Set the stopwatch to zero. Your partner should run up the stairs as fast as it is safely possible. You do not have to use each step. It is not necessary to run if you are not interested in a peak power value. Start the watch when your partner's foot passes the plane of the first step, and stop the watch when both feet are on the top floor. If time permits you may repeat the trials.

Post lab discussion:

1. Determine the energy "used" by you and three other classmates in climbing the stairs (measured in joules). Convert your energy to the units of calories, Calories, kilowatt-hours, ft-lbs, BTU's, ergs, and MeV. Show all "work" done in each calculation and conversion. Arrange the results of your calculations in an easy-to-follow data table.

2. Determine the power output of yourself and three other classmates in watts. Convert each of these values to kilowatts and horsepower. Show all "work" done in each calculation and conversion. Arrange the results of your calculations in an easy-to-follow data table.

Energy Skate Park – Simulation Lab

Purpose

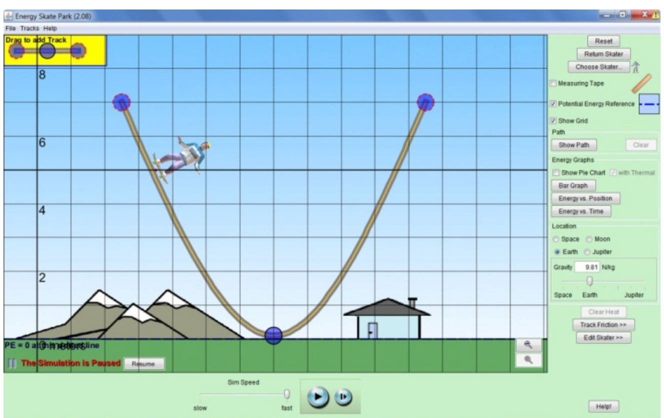
The purpose of the energy skate park simulation is to see how energy gets transferred/transformed in a real world application and verify the conservation of energy theorem. In this simulation you will manipulate the skater, will change the track, add or take away friction, gravity, and other factors to see the effect of these on a skater who behaves according to the laws of physics.

Directions:

Go to the Physics Education Technology website. Select the "Energy Skate Park" simulation.
http://phet.colorado.edu/en/simulation/energy-skate-park
You have the option of running the simulation online (Run Now!) or download the simulation to your computer (Download) and then run it. The online version requires Adobe Flash Player to be installed on your computer. The downloaded version requires a Java runtime environment.

ACTIVITY 1

Start the simulation and click Pause. Select Potential Energy Reference and Show Grids. Click and drag the blue dot at the bottom of the track until it reaches the ground (reference line). Click and drag to place the skater on the track at the 6 m mark (see the image below). Click "Clear Heat" before every single run.



Click Start and look at the motion of the skater. Your system is skater + earth.

a) What type of energy does the skater have at the starting point?

b) What type of energy does the skater have the at the lowest point on the track?

c) What type of energy does the skater have at any point between the starting point and the lowest point on the track?

d) Draw a bar graph for your system. Consider the initial state when the skater starts from a height of 6 m and the final state when he reaches the lowest point on the track.

e) Write the conservation of energy using your bar graph.

f) Calculate the gravitational potential energy of the skater at a height of 6 m.

g) What is the kinetic energy of the skater when the skater is at the lowest point on the track?

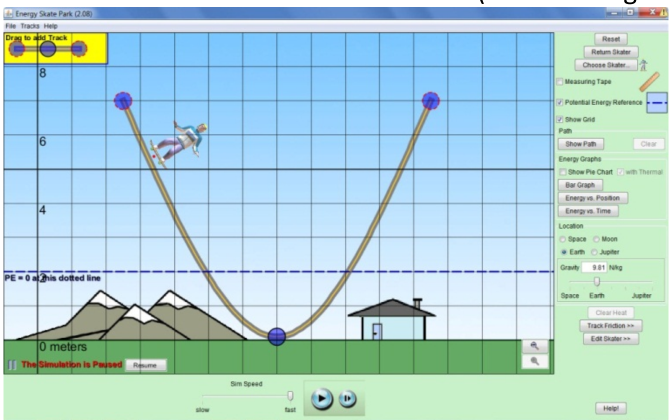
h) What is the speed of the skater at the lowest point on the track?

i) Describe how you can calculate the speed of the skater at 4 meters above the ground. (hint: you can read distances directly on the grid or use the “Measuring tape” by clicking the button for it).

j) What is the speed of the skater when at a height of 4 m above the ground?

ACTIVITY 2

Click and drag the blue reference line until it is at a height of 2 m above the ground. Click and drag to place the skater on the track at the 6 m mark (see the image below). Click “Clear Heat” before every single run.



a) At what height is the gravitational potential energy zero now?

b) What is the gravitational potential energy of the skater at the bottom of the track?

k) Draw a bar graph for your system (skater + earth). Consider the initial state when the skater starts from a height of 6 m and the final state when he reaches the lowest point on the track.

l) Write the conservation of energy using your bar graph.

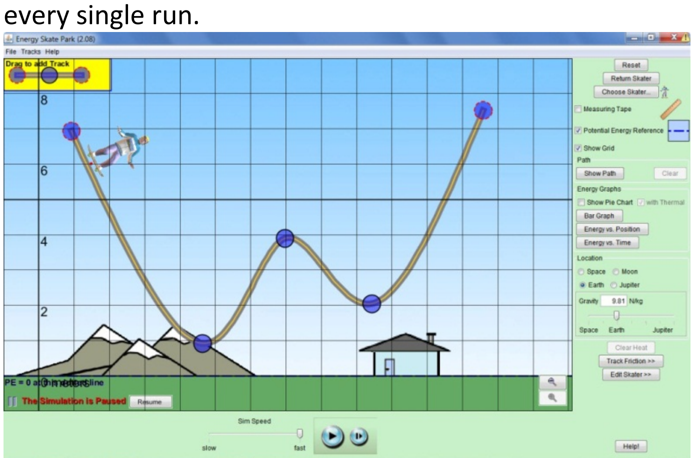
c) Calculate the kinetic energy of your system when the skater is at the bottom of the track.

d) Calculate the speed of the skater at the bottom of the track.

e) Compare this speed with the one calculate in Activity 1. How do they compare? Explain your answer.

ACTIVITY 3

From the “tracks” button in the left upper corner of your window, select “Double Well”. Make sure your reference line for the zero of the gravitational potential energy is on the ground. Click “Clear Heat” before every single run.



a) Where do you have to place the skater to have it pass the bump and not leave (fly off) the track? Explain.

b) What is the highest point that the skater returns to? Explain why.

c) Click the “Bar Graph” button and run the simulation. Explain what you see happening.

d) Calculate the gravitational potential energy of your system when the skater starts its motion. (hint: read distances directly from the grid or use the “Measuring tape” to find the height of the bump).

e) Calculate the gravitational potential energy of your system when the skater is at the bottom of the second loop.

f) Draw a bar graph for your system (skater + earth). Consider the initial state when the skater starts from a certain height and the final state when he reaches the bottom of the second loop.

g) Write the conservation of energy using your bar graph.

f) Calculate the kinetic energy of your system when the skater is at the bottom of the second loop.

g) Calculate the speed of the skater at the bottom of the second loop.

Exploring Energy Transfers and Transformations – Lab

Purpose

What happens to a well defined physical system when external forces act on it?

Materials:

Block with a flat bottom
Modeling clay
Horizontal track and cart/car
Tape
Slingshot
Rope

Directions: For each station fill out the table below.

Station 1:

A lump of modeling clay sits on the table. A block with a flat bottom is dropped from a height of approximately 0.5 m on top of the clay. Observe what happens when the block hits the clay. Consider the systems selected below. For each one of them identify the energy transformations within the system, if there are external forces acting on the system, and the effect of the external forces acting on the system.

System	Initial State	Final State	Energy Transformations	External Forces	Effect of external force
block + clay + earth + air	Just when the block starts falling	Just before the block hits the clay			
block + clay + earth + air	Just before the block hits the clay	After the block hits the clay			
block	Just when the block starts falling	Just before the block hits the clay			
block	Just before the block hits the clay	After the block hits the clay			
Clay	Just before the block hits the clay	After the block hits the clay			

1. What happens to the energy stored in each system?

2. What is the effect of the external force acting on the system?

Station 2:

A cart rolls on a horizontal, low friction track. A ball of clay is placed at the end of the track. Observe what happens when the cart hits the clay. Consider the systems selected below. For each one of them identify the energy transformations within the system, if there are external forces acting on the system, and the effect of the external forces acting on the system.

System	a	b	c	d	e
cart + track + earth + clay	Cart is moving toward the clay	Just before the cart reaches the clay			
cart + track + earth + clay	Just before the cart reaches the clay	After the cart hits the clay			
cart	Cart is moving toward the clay	Just before the cart reaches the clay			
cart	Just before the cart reaches the clay	After the cart hits the clay			
clay	Just before the cart reaches the clay	After the cart hits the clay			

3. What happens to the energy stored in each system?

4. What is the effect of the external force acting on the system?

Station 3:

Place a small ball of clay into the slingshot. Pull the slingshot back and release it, shooting the clay toward a wall. Observe what happens when the clay hits the wall. Consider the systems selected below. For each one of them identify the energy transformations within the system, if there are external forces acting on the system, and the effect of the external forces acting on the system.

System	a	b	c	d	e
slingshot + wall + earth + clay	Slingshot stretched, clay not moving	Slingshot unstretched, clay moving toward the wall			
slingshot + wall + earth + clay	Slingshot stretched, clay not moving	Clay stuck to the wall			
clay	Slingshot stretched, clay not moving	Clay moving toward the wall			
clay	Clay moving toward the wall	Clay stuck to the wall			
slingshot	Slingshot unstretched	Slingshot stretched, clay not moving			

1. What happens to the energy stored in each system?

2. What is the effect of the external force acting on the system?