Crazy Coasters

GRADE LEVELS:
Grades 6^{th} – 8^{th}

CONCEPTS:
- Potential energy is stored energy
- Kinetic energy is moving energy
- Centrifugal force is a fictitious force that appears to cause objects to move outward from the center of a circle
- Kinetic energy can be changed by angle of descent, mass, and a wide variety of factors

OBJECTIVES:
- Have a thorough understanding of kinetic and potential energy
- Gain an understanding of inertia
- Relate gravity to potential and kinetic energy as well as inertia
- Apply this knowledge to roller coasters in real life as well as other objects

ACADEMIC CONTENT STANDARDS:
Science: Physical Sciences: 7.2, 8.1, 8.2, 8.3

VOCABULARY/KEY WORDS:
Kinetic Energy - The energy of motion, observable as the movement of an object, particle, or set of particles.
Potential Energy - is energy that is stored within an object not in motion but capable of becoming active.
Inertia - a body which resists change in its motion. Inertia is the name for the tendency of an object in motion to remain in motion, or an object at rest to remain at rest, unless acted upon by a force.
Centripetal Force - force acting on a moving body at an angle to the direction of motion, tending to make the body follow a circular or curved path.
G-force - a unit of force equal to the force exerted by gravity; used to indicate the force to which a body is subjected when it is accelerated. 2 Gs is equal to two times the force of gravity.

Acceleration - The rate at which an object's velocity changes with time.
Invert - To turn upside down or inside out. To reverse the position, order, or condition of.
Friction- A force that resists the relative motion or tendency to such motion of two bodies in contact

EXTENSIONS AT COSI:

Big Science Park

- Centripetal Generotor - the riders are subject to an inward, or *centripetal,* force. As the ride spins, it forces the riders to travel in a circle. According to Isaac Newton's law of inertia, objects in motion tend to travel in a straight line at constant speed unless acted on by an external force. To make an object travel along a curved path, a force must keep the object moving toward the *center of curvature* in this case the axis of rotation. The wall of the ride's cylindrical chamber accomplishes this by pushing the riders toward the center.

Atrium

- Pendulum – Notice the motion of the pendulum. At what points is it going the fastest? When is it moving the slowest? Why?
- Vortex – the angle of the vortex, along with gravity cause the penny to move toward the center of the vortex. The inertia of the penny keeps it moving, even when it is sideways within the vortex tube.

Stairway

- Rolling wheels – Notice how the position of the mass on the wheels changes the acceleration of each wheel.

Ocean

- Making Waves – Take a close look at the mechanism that makes the waves. As you raise it out of the water you are building up its potential energy. When the wave maker moves down it has kinetic energy that is transferred to the water causing it to move.

Mezzanine

- High Wire Unicycle – How is inertia important when riding the unicycle? The riders will be going slightly up hill on their way back to the platform. The riders will need to be going fast enough/have enough inertia to make it back up to the top of the hill. If they do not have enough inertia it is very hard to peddle up the incline to the platform.

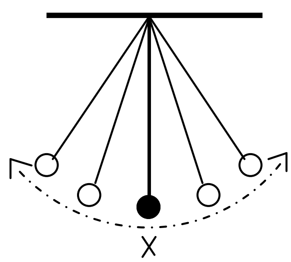
ADDITIONAL RESOURCES:

Education World - Roller Coaster Roundup
http://www.educationworld.com/a_lesson/00-2/lp2032.shtml
Teacher Vision - Roller Coaster Math
http://www.teachervision.fen.com/mathematics/lesson-plan/3705.html
Thrills and Chills Without the Spills - Roller Coaster Physics for Middle School
http://www.angelfire.com/on2/thrillsandchills/reference.html

Potential and kinetic energy, centripetal force, & free fall make roller coasters fun.
http://library.thinkquest.org/2745/data/openpark.htm
Educators Reference Desk – Downhill Discoveries
http://www.eduref.org/cgi-bin/printlessons.cgi/Virtual/Lessons/Science/Physics/PHS0014.html
Teaching Today - Rolling Balls: Mass and Kinetic Energy
http://teachingtoday.glencoe.com/lessonplans/rolling-balls-mass-and-kinetic-energy

SAMPLE TEST QUESTIONS:

1. The diagram below shows a pendulum in motion.



Which describes the potential and kinetic energy of the pendulum at position X?
A. Potential energy is at its lowest and kinetic energy is at its lowest.
B. Potential energy is at its highest and kinetic energy is at its lowest.
C. Kinetic energy is at its highest and potential energy is at its lowest.
D. Kinetic energy is at its highest and potential energy is at its highest.

2. A child at a playground slides down a slide on a windless day.

Describe two forces that affect the motion of the child as she moves down the slide.

3. When you are driving a car, why is braking less effective on a wet road than on a dry road?

A. The water reduces friction.

B. Kinetic energy is increased by water.

C. Friction increases when the brakes are wet.

D. Reaction time is reduced during a rainstorm.

Coasters Pre Visit Activities

Flip

Description: Explore how exerting a force on an object can give it kinetic energy and momentum.

Key words: Levers, Fulcrums, Kinetic Energy, Momentum

Materials:
Plastic spoon

Instructions:
1. Start by placing a spoon on a table or desk cross-wise in front of you, with the curved side of the bowl resting on the table.
2. Gently push the tip of the bowl. Ask your students "What is happening to the spoon?"
3. Next, gently tap the tip of the spoon. Ask your students "Now what is happening to the spoon? If I keep increasing the force of the tapping, what will happen?" "Why is this happening?"

Further Exploration:

Make a prediction of what percentage of the time a flipped spoon will land bowl up or bowl down. Then, flip the spoon off the end of a table and see if it lands bowl up or bowl down. Graph the results of X number of tries. As each person in the class does this, you can arrive at a statistical average.

What's going on?

The spoon is acting as a simple first-class lever with the bowl of the spoon acting as the fulcrum. As you push down the tip of the bowl, the handle rises. As you increase the force of the tapping, the spoon handle moves higher and higher. If you hit the tip at the edge, the spoon may flip end over end. This is a result of giving the handle enough kinetic energy so that the handle's momentum carries it over the tip. The more force you provide, the more energetic the flip.

Relevant Ohio Science Content Standards:
Physical Sciences: 1.6, 3.2, 3.3, 7.2

Marble Challenge

Description: Try to keep a marble in a bottomless cup without touching the marble.

Key Words: Centripetal Force

Materials:

- Paper cup
- Small marble
- Ballpoint pen
- Desktop
- Goggles

Instructions:

1. Carefully remove the bottom of the cup. Use the ballpoint pen to score around the edge and to punch holes. Smooth the bottom edge on the inside of the cup.

2. Using the modified cup, a marble and a flat surface, brainstorm ways to pick up or lift the marble. No hands touching the marble allowed! Remember, a good scientific experiment can be duplicated by others. Can others in your group duplicate the successful trials?

3. What happens if the marble reaches the top of the cup? What happens when the cup is upside down?

Further Exploration:

Explain how this activity illustrates the forces you feel on many amusement park rides. What happens if you use a cup with a different diameter or slope?

What's going on?

Moving the cup back and forth provides the force that causes the marble to circle inside the cup. The faster you move the cup, the faster the marble travels. The marble tries to move in a straight line, however the inside of the cup pushes on the marble forcing it to move in a circle. This force is called centripetal force. As the marble pushes outward against the cup, it rolls up the sloped side of the cup because moving from a smaller to a larger circumference provides less resistance. A hint to moving the

marble up the cup's inside surface is that you need to move the cup back and forth at a speed that adds to the marble's speed. This is called resonance.

Relevant Ohio Science Content Standards

Physical Science: K.4, K.5, 1.6, 3.3, 3.4

Inertia

Description: Gain an understanding of Newton's first law, which states that an object at rest tends to stay at rest and an object in motion tends to stay in motion with the same speed and the same direction unless acted upon by an unbalanced force.

Keywords: Momentum, mass, velocity, inertia

Concepts:

- In physics, **momentum** is the product of the mass and velocity of an object.
- The tendency of a body to resist acceleration; the tendency of a body at rest to remain at rest or of a body in straight line motion to stay in motion in a straight line unless acted on by an outside force is known as **inertia**.

Materials:

- For Demonstration:
  - Masking Tape
  - Pencil
  - Paper
  - Meter Stick
  - Large Open Area

Instructions:

1. Put a strip of masking tape on the floor marked Point A. Measure 10 meters from Point A, and put another strip of tape on the floor marked Point B.
2. The tendency of a body to resist acceleration; the tendency of a body at rest to remain at rest or of a body in straight line motion to stay in motion in a straight line unless acted on by an outside force is known as inertia.
3. Instruct the participants to line up on Point A, run as fast as possible to Point B, and stop on Point B without slowing down.
4. Measure how far each participant went over Point B
5. Draw some conclusions from their experiences.

Possible Interactive Questions:

- Did you overrun Point B by more or less than you expected? Why or how so?

- How can this phenomenon assist athletes, such as long jumpers?

What's Going On?

The principle of inertia is the tendency of a body in motion to stay in motion unless acted on by an outside force. The participants start their bodies in motion, but when they try and stop on a point traveling at the same speed their bodies want to continue moving. This is similar to how a roller coaster travels after being released from the first hill. The train will continue to move forward until, gravity, wind resistance, or physical contact (brakes) stops its movement.

Further Exploration:

To experiment further with this activity, teams should explore why some participants went farther past Point B than others. Does velocity factor into this equation? How about the mass of the participant?

Relevant Ohio Science Content Standards:

Sciences: Physical Sciences 9.22, 9.23

Coasters Post Visit Activities

Rollback

Description: Make a can that will roll back to you after you have rolled it away.

Key Words: Energy, Potential, Kinetic

Materials:

- Rubber band
- 10 quarter sized washers
- String
- 2 large paper clips
- 18 oz. oatmeal container
- Hammer
- Nail

Instructions:

1. Using the hammer and nail, gently pound a hole through the center of the bottom and top of the container. (Wear your safety goggles!)

2. Thread 10 washers together with a piece of string then tie the string. Then, tie the string around the rubber band.

3. Thread the rubber band through the hole in the bottom of the can. Place a paper clip through the rubber band on the outside of the can so the rubber band will not slip through the hole.

4. Center the washers in the container and thread the remaining end of the rubber band through the hole in the lid, securing it with a paper clip.

5. Roll the can away from you on a smooth level surface. What happens? Why?

What's Going On?

When you roll the can the rubber band twists and creates **potential energy** (stored energy). The can stops rolling after the initial energy generated by the push has been expended. The stored energy in the rubber band then unwinds, changing the potential energy to **kinetic energy** (energy of motion). The can then rolls back toward the starting point. Once the energy is completely used, the rubber band has unwound and the can stops rolling.

Further Exploration:

What would happen if the washers were not centered? What if you used more or less than 10 washers? Try using a see-through container to watch the science in action (a peanut butter jar works great). Experiment with the placement of the holes in the top and bottom of the can. Can you use 2 rubber bands to create a car that will carry an apple? Think about how you might use your knowledge of potential and kinetic energy to construct a successful model.

Relevant Ohio Science Content Standards:

Physical Sciences: 7.2

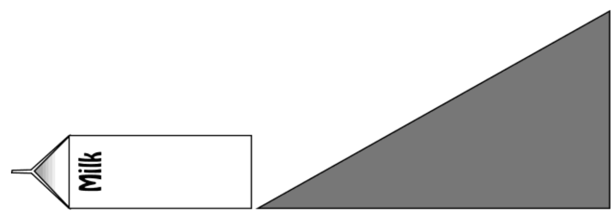
Rollin' Rollin' Rollin'

DESCRIPTION: To understand and observe the difference between potential and kinetic energy and the different amount of work done by each.

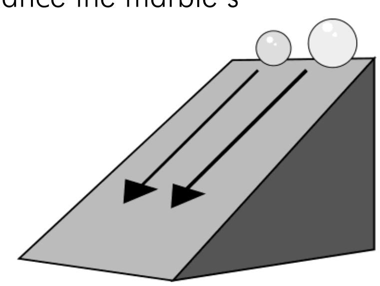
MATERIALS: Three (3) marbles of different sizes
Ruler
Inclined Plane
Milk Carton

PROCEDURE:

1. Set up inclined plane and place the bottom section of a milk carton at the bottom of the ramp. This will be used to measure the distance that the marble moves the carton.



2. Set marbles on top of the ramp. What kind of energy is being used now?
3. Decide which marble has the most potential energy.
4. Hypothesize how many centimeters each marble will move the carton.
5. Roll each marble down the inclined plane and find the distance the marble's energy moved the carton.
6. Try different heights, different drops, and different planes to see other outcomes.



WHAT HAPPENED?

The energy in the marble before it is dropped onto the plane is called potential energy, or energy stored at the point of release. When the marble is dropped, it is called Kinetic energy. Potential energy changes to Kinetic energy as it rolls down the plane.

Extension:

Try other sizes of marbles with this activity. Also, try other round objects; such as a high bounce ball, a grape, and softball. Have students continue to hypothesize which objects will have the most kinetic energy. This is a very open-ended activity. Students and teachers may extend this project to many levels and many test scenarios for energy. Feel free to encourage students to take this a step further.

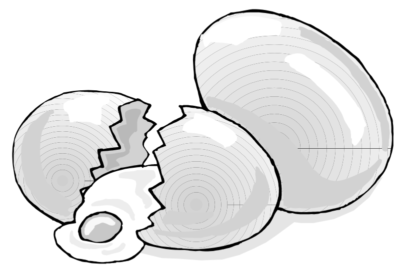
Academic Standards: Physical Sciences K-2 C, 3-5 C,

Eggshell Inertia

Description: Gain a better understanding of how friction and mass affect objects.

Keywords: Inertia, Newton's Laws of Motion

Concepts: The tendency of a body to resist acceleration; the tendency of a body at rest to remain at rest or of a body in straight line motion to stay in motion in a straight line unless acted on by an outside force is known as **inertia**.



Materials:

- Hard-Boiled Eggs (Labeled "H.B." for Hard-Boiled)
- Raw Eggs (Labeled "R.E." for Raw Eggs)
- Newspaper (For Easy Clean-Up)

Instructions:

1. Place a hard-boiled egg and a raw egg on a table close to each other.
2. Spin the eggs at exactly the same time with similar forces.
3. Make observations about the eggs.

Possible Interactive Questions:

- Make a hypothesis…which egg will stop first?
- What forces are acting on the egg?
- How do friction, mass, and inertia affect such amusement park rides as roller coasters or bumper cars?

What's Going On?

The shell on each egg was spun by the participant's hand. Because the egg white and egg yolk of the hard-boiled egg are solid just as the shell is, they both spin together. The inertia of motion keeps the hard-boiled egg spinning longer until the friction, or resistance, of the table and air against the egg stops it.

The raw egg spins for less time because liquids have more inertial drag than solids. Inside the raw egg, it is liquid and moves very little compared to the outside solid shell. The shell was forced to stop spinning first because the lack of motion of the liquid interior (egg white and egg yolk).

The concept of inertia is today most commonly defined using Isaac Newton's First Law of Motion, which states that every body at a state of rest or motion will stay in that state until acted upon by another force.

In amusement parks, inertia is utilized to propel rides as well as safely execute a maneuver such as a loop or incline. Can you think of other instances where inertia is utilized? Are there examples of when too little inertia affected the outcome of a ride? (Top Thrill Dragster not making the incline and having to restart.)

Further Exploration:

1. Instruct students to consistently spin the eggs in the same direction and speed for an extended period of time. After a few minutes, have the students release the eggs and make observations. Was it the hard-boiled or raw egg that continued to spin for a longer period of time, in this instance?
2. Place a large, sealed jar full of pickles (with pickle juice) at the center of a rotating table. Rotate the table back and forth with your hands. Observe what happens, or doesn't happen, to the pickles inside the jar. Pickles at rest tend to stay at rest. Now rotate the table steadily in one direction until the pickles start to rotate along with the jar and the table. Once the pickles are in motion, reach out and grab the pickle jar with both hands and pick it off the table. Observe the motion of the pickles. Pickles in motion tend to stay in motion.

Relevant Ohio Science Content Standards:

- Physical Sciences 9-10: Explain the movement of objects by applying Newton’s three laws of motion.
  - 9.22: Demonstrate that any object does not accelerate (remains at rest or maintains a constant speed and direction of motion) unless an unbalanced (net) force acts on it.
  - 9.23: Explain the change in motion (acceleration) of an object. Demonstrate that the acceleration is proportional to the net force acting on the object and inversely proportional to the mass of the object. ($F_{net}=ma$. Note that weight is the gravitational force on a mass.)
  - 9.24: Demonstrate that whenever one object exerts a force on another, an equal amount of force is exerted back on the first object.
  - 9.25: Demonstrate the ways in which frictional forces constrain the motion of objects (e.g., a car traveling around a curve, a block on an inclined plane, a person running, an airplane in flight).