ARIZONA SCIENCE CENTER
Never stop wondering.
Never stop imagining.™

A Wild Ride! Week 2: Grades 6-8

Day	Topics	Related Standards
1	Transferring Energy	**Analyze** how humans use technology to store (potential) and/or use (kinetic) energy.
2	Graphing Motion	**Construct an explanation** on how energy can be transferred from one energy store to another.
3	Ramping it Up!	**Plan and carry out an investigation** that can support an **evidence-based explanation** of how objects on Earth are affected by gravitational force.
4	Getting Loopy!	Use non-algebraic **mathematics and computational thinking** to explain Newton's laws of motion.
5	The Triple Crown!	Use non-algebraic **mathematics and computational thinking** to explain Newton's laws of motion.

A Wild Ride! Week 2

Day 1: Transferring Energy

Teacher/Parent Background:

What do scientists and engineers do when they are faced with a challenge? This week students will be introduced to the strategies of scientists and engineers by learning about the steps of the engineering design process in order to begin defining their own, week-long challenge: *How can we design an exciting and safe roller coaster using Newton's Laws?*

In previous grades students learned about using different types of energy, for example: mechanical, light, sound, electrical, and thermal energy. All types of energy can be categorized as one of two basic types of energy; kinetic energy and potential energy.

Potential energy is the energy stored in an object, or energy waiting to happen. Sometimes potential energy is described as gravitational potential energy because objects have the potential to change their position due to the force of gravity. Sometimes potential energy is described as chemical potential energy because the energy is stored within the matter itself. Sometimes potential energy is described as elastic potential energy because it is stretched or compressed within the object. Kinetic energy is the energy of motion. Only matter in motion has kinetic energy.

Example: Some apples are on the tree high above the ground. The apples have the potential to fall to the ground. The energy of the apples in this system is stored because of their position. When the apple is in free fall due to the force of gravity, the apple is in motion and has kinetic energy.

All energy can be identified as either potential or kinetic energy.

Overview:

In this activity, students will demonstrate how potential energy can be converted to kinetic energy and back again by working through the "ask" phase of the Engineering Design Process.

Related Standards:

- Analyze how humans use technology to store (potential) and/or use (kinetic) energy.

Key Terms:

- Potential Energy
- Kinetic Energy
- Energy Transformation
- Total Energy

Materials List:

- Masking Tape or Duct Tape
- Ruler
- String or fishing line
- Block of wood
- Heavy object or weight, to tie to string (preferable if mass object is known)
- Computer
- Pen/Pencil

Activity Description:

Before students jump into building a roller coaster, we want to help them develop the skill of thinking like an engineer. Students spend some time asking themselves what they need to know to solve the following problem: How can you design an exciting and safe roller coaster?

Once students have some questions, they can start the following activity to gain a better understanding of how energy is being converted during a roller coaster ride.

1. Tightly tie a piece of string to the heavy object. This object will act as the pendulum bob.
2. Tape the upper end of the string to the top of a desk or table so that the pendulum bob hangs just above the floor.
3. Test the swing of the pendulum and adjust the length of the string if needed. The pendulum should swing freely and be as close to the floor as possible.
4. Place the block of wood directly in front of the hanging bob so that they touch each other. You want the pendulum bob to strike the block at the bottom of its swing. Mark the placement of the block with a piece of masking tape labeled block-start.
5. Place the wood block at the spot where you labeled block-start. Keep the string straight while raising the pendulum bob 10 cm above the floor (use a ruler to measure the distance from the floor to the pendulum bob)
6. Release the pendulum bob. Mark the displaced position of the block with a piece of tape labeled block stop.
7. Measure the distance between block-start and block-stop. Record the measurement on the data table 1.
8. Leave the piece of tape labeled block-start in place and then move on to repeat the rest of the process two more times. Record your results and calculate the average of the three distances.
9. Repeat the entire process for three trials starting with the pendulum bob height at 20 cm.
10. Repeat the entire process for three trials starting with the pendulum bob height at 30 cm.
11. Repeat the entire process for three trials starting with the pendulum bob height at 40 cm.

Next, students will go to [Energy in a Roller Coaster Ride interactive] on PBS Learning.

1. Read the Background Reading.
2. Launch the simulation.
3. Draw a diagram that illustrates the transformation of energy, using the interactive activity as an example. Then describe the transformation. For example: When I carry a sled to the top of a snowy hill, the potential energy of the sled increases. As I stand with my sled at the top of the hill,

the kinetic energy is zero and the potential energy is at its maximum. As I slide down the hill, the potential energy of the sled decreases and its kinetic energy increases.

Closure:

Ask students the following questions:

1. Describe the pattern in the data. In other words, how did the changes in the starting height of the pendulum bob affect how far the block moved?
   - *The higher the pendulum was started, the further it moved the block after it hit it.*
2. How does raising the height of the pendulum bob affect its potential energy?
   - *The higher the pendulum bob, the greater the potential energy.*
3. As the pendulum is let go from increasing heights, how is the resulting kinetic energy affected? What is the evidence?
   - *The higher the bob, the faster it swings when released, causing the block to move farther. This shows more kinetic energy.*
   - *The swinging pendulum bob must have more kinetic energy if it starts higher because the block moves further.*

Extension:

Watch & Learn: Transfer of Energy

Watch & Learn: What is Kinetic and Potential Energy?

Student Handouts

Data Table 1

Distance of Displaced Block of Wood				
Height of Pendulum Bob	Trial 1 (cm)	Trial 2 (cm)	Trial 3 (cm)	Average (cm)
10cm				
20cm				
30cm				
40cm				

Potential to Kinetic Energy Diagram

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Day 2: Graphing Motion

Teacher/Parent Background:

All motion can be represented using graphs. There are three types of graphs used to describe how an object moves over time: Position v. Time graphs, Distance v. Time graphs or Speed v. Time graphs. What you are trying to demonstrate or measure will determine which graph is best to use.

Position v. Time Graphs

Position graphs show an object's location compared to a reference point. Imagine you are in a car with your mom, driving 30 mph (miles per hour) to your house. If you compare your body's motion to your mom's, you are not in motion. If you compare your body to a green light you drive through, you are moving at 30 mph. If you compare your motion to a jogger that is running on the street in the same direction as you, you are moving around 25 mph. These are all reference points, or objects or locations that you compare an object's motion to. Position graphs show motion relative to a specific location.

Distance v. Time Graphs

Distance graphs do not compare motion to a reference point. Instead, they show the total distance covered over time. For example, if you walk 30 meters to the water fountain, and back to your classroom another 30 meters, your total distance would be 60 meters on a Distance v. Time graph.

Speed v. Time Graphs

Speed graphs show how fast an object moves over time. For example, if you are riding your bike at 10 mph, and stop to talk to a friend, then ride off at 15 mph, a speed graph will show this motion. It will not show your total distance or compare your motion to a reference point.

Overview:

In this activity, students are introduced to ways of visualizing motion through graphs to help them understand that motion is a change in position, direction, or speed. They will continue to think like an engineer and ask more questions about motion as it relates to roller coaster design.

Related Standards:

- Construct an explanation on how energy can be transferred from one energy store to another.

Key Terms:

- Motion
- Direction
- Speed
- Force

Materials List:

- Graphing Paper
- Pen/Pencil

Activity Description:

1. Read the following story:
    - You are watching your favorite television show. During the commercials you get up to grab a snack. The commercials will last for 3 minutes. It is 100 meters to the kitchen from the couch. The kitchen is at the end of the hall. It takes you 30 seconds to get to the kitchen. You open the refrigerator and take 90 seconds to decide to grab a piece of fruit. You walk 50 meters in 15 seconds back towards the couch then stop to pet your dog for 30 seconds. You finally hurry the remaining 50 meters back to the couch in 10 seconds.
2. Fill in the data table (see student handouts) based on the story.
3. Create a position v. time graph based on the information in your table. Remember to use the couch as your reference point.
4. Create a distance v. time graph based on the information in your table. Remember to use the couch as your reference point.
5. Create a speed v. time graph based on the information in your table. Remember to use the couch as your reference point.

Closure:

Discuss the Following:

- Each graph you created showed the same story in a different way. Explain how each graph showed your motion.
    - Position v. Time
        - *Showed how my position compared to the couch. You can see the kitchen is farthest from the couch at 100m. You can also see me return to the couch after 175s.*
    - Distance v. Time

        - *Showed how I walked 200 m total on my trip to the kitchen and back to the couch.*
    - Speed v. Time
        - *Showed how my speed changed on my trip to the restroom. I was the fastest at the end of my trip because I was rushing back to the couch before the show started, again.*
- If you are going to build a roller coaster that you want to have lots of variety and be exciting what kind of data may you want to collect during prototyping. What graph would you use? Explain.
    - *I would want to collect data on how quickly the roller coaster is moving at various places on the track. The best graph would be a speed v. time graph so you can know how fast the roller coaster is moving.*

Extension:

Make your own motion story and then graph it!

Read & Watch: Roller Coaster Physics

Student Handouts

Data Table

Time (seconds)	Position (m)	Distance (meters)	Speed (m/s)
0 s	0 m	0 m	0 m/s
30 s	100 m	100 m	3.3 m/s

Position v. Time Graph

Distance v. Time Graph

Speed v. Time Graph

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Day 3: Ramping it Up!

Teacher/Parent Background:

An object has different types of energy. Kinetic energy is the energy of motion, and depends on the mass and speed of the object. Gravitational potential energy is energy an object possesses based on its position. Gravitational potential energy depends on mass, height, and the strength of the gravitational field.

As an object falls through the air or rolls down a slope, it is accelerated by gravity. During this time, the gravitational potential energy of the object is converted to kinetic energy. This conversion follows the law of conservation of energy, which states that the total energy is constant in a closed system. If there is no friction, the kinetic energy of a freely-rolling car at the bottom of the hill is equal to the gravitational potential energy of the car at the top. If friction is present, some of the potential energy is converted to heat.

As long as there is no friction in the system, the conversion from potential to kinetic energy is the same whether the object is in free fall or is rolling down a ramp. Friction slows objects down and causes energy to be lost as heat. In a real roller coaster, the car gathers potential energy as it is pulled to the top of the first hill. For the remainder of the ride, the car coasts freely, rolling up and down hills and loops as energy is converted from potential to kinetic and back again. Due to conservation of energy, the car can never go higher than the initial hill without the input of additional energy.

Overview:

In this activity, students will explore and adjust incline planes in an online simulation and then design and test their own ramps as students enter the next phase of the engineering design process and start imagining their roller coaster solutions.

Related Standards:

Plan and carry out an investigation that can support an evidence-based explanation of how objects on Earth are affected by gravitational force.

Key Terms:

- Friction

- Gravitational Potential Energy
- Kinetic Energy
- Momentum

Materials List:

- Computer
- Foam pipe insulation or foam pool noodles cut in half, lengthwise
- Masking Tape
- Marbles
- Various objects such as blocks, boxes, chairs, etc. to use as support

Activity Description:

1. Launch the Explore Learning Roller Coaster Physics Simulation.
2. Open the Student Exploration Sheet.
3. Follow the instructions found on the Student Exploration sheet to complete the Gizmo Warm-Up, Activity A and Activity C.
4. Once the online simulation and accompanying handout is complete, use the foam pipe insulation to build a ramp that will allow a marble to jump off the ramp and into a cup.
5. Try at least 3 different iterations of the ramp and use the knowledge you gained to make the marble "fly" as far as you can.
6. Now that students have explored the materials they will be using in their roller coaster build, ask them to draw out 2 possible ideas of what their roller coaster could look like based on the challenge details in the Student Handout.

Closure:

Ask students the following questions:

- What factors seem to determine whether the car will break the egg?
    - *The mass and speed of the car (determined by the height of the hill)*
- When there is no friction, what is the only factor that affects the final speed of a roller coaster?
    - *The only factor that affects the final speed is the total height lost*

Extension:

Read and Learn: Energy Screams

Student Handouts

Challenge Details

Dear Student,

Arizona Science Center is interested in adding a new exhibit to its *Get Charged Up!* gallery. Since *Get Charged Up!* is all about force and motion, staff members would like to introduce guests to the science behind roller coasters! You have been tasked with designing a roller coaster to be reviewed by Arizona Science Center's Exhibit Technicians for their new exhibit. Please closely follow all details outlined below:

1. **Use the steps of the Engineering Design Process to design the best possible roller coaster. This includes:**
    a. Imagining possible solutions - there are many possible solutions to this one challenge; think big!
    b. Planning your chosen solution
    c. Creating and testing your solution
    d. Improving your solution to make it even better

2. **You may only use the following materials:**
    a. Foam tubes, paper plates, paper, etc. - for the roller coaster track
    b. Making tape - to secure parts of the track or to help create roller coaster design features
    c. Scissors - to cut the tape
    d. Marbles - for the roller coaster's train/cart
    e. Paper cups, blocks, boxes, books - to support the roller coaster and to catch rolling marbles
    f. Measuring tape/ruler - to measure the length of the track

3. **Your roller coaster must include/stay within the following design requirements:**
    a. At least one hill
    b. At least one vertical loop
    c. At least one turn

We eagerly await your design proposals. Best of luck!

Arizona Science Center, Head Exhibit Technician

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Never stop imagining.

Imagine

Possible Solution #1 (include a diagram with labels)

Possible Solution #2 (include a diagram with labels)

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Day 4: Getting Loopy!

Teacher/Parent Background:

Inertia is a property of objects and substances. Newton's first law of motion, also known as the law of inertia, tells us that due to inertia, an object at rest will remain at rest. Also, due to its inertia, an object will stay in motion with the same speed and direction if there are no unbalanced forces at work upon it. You have that experience when your car is moving forward and then slows down or stops suddenly. Your body continues to move with the same speed in the same direction, or keeps moving forward. The reason your body stops or slows down is due to the constraint of the seat belt. It gives the resisting force to prevent you from moving in the same direction and at the same speed.

Friction is another source of the resisting force. Newton's second law of motion, also known as the law of force and acceleration, gives us the mathematical expression of how force can influence an object's motion. Force is equal to the mass multiplied by the acceleration, or F = ma. If an equivalent force acts upon two objects, the acceleration will be less for the object with greater mass. In other words, more force is necessary to act upon heavier objects than upon lighter ones. If the mass is a constant, the bigger the force is, the higher the acceleration will be.

Finally, Newton's third law of motion, or the law of action-reaction, tells us that whenever a force acts, there is an equal and opposite reaction happening together on both sides of the objects. The launching of rockets makes use of the action-reaction principle. They utilize a downward stream of fast, hot gases. The force of the hot gases pushing out of the open end causes the rocket to move forward. The force of the escaping gases is the "action,and the motion of the rocket is the "reaction, illustrating Newton's third law of motion.

Overview:

In this activity, students will explore the variables that affect kinetic and potential energy with an online simulation and then dive into the plan and the create phase of the engineering design process as they build a roller coaster with one complete vertical loop.

Related Standards:

- Use non-algebraic mathematics and computational thinking to explain

Newton's laws of motion

Key Terms:

- Friction
- Gravitational Potential Energy
- Kinetic Energy
- Momentum
- Inertia

Materials List:

- Computer
- Foam pipe insulation or foam pool noodles cut in half, lengthwise
- Masking Tape
- Marbles
- Various objects such as blocks, boxes, chairs, etc. to use as support

Activity Description:

Have students do the following:

1. Download the Energy Skate Park: Basics PhET simulation.
2. Before beginning the simulation, think about some factors of a ramp's design that will have an effect on the speed and momentum of an object.
3. Select "Playground" and then check grid and speed.
4. Set the friction to zero and set the mass to the maximum amount.
5. Use the ramp generator at the bottom to create ramps of different shapes and heights.
6. Observe the maximum speed of the skater on each ramp design.
7. Record your ramp designs by drawing the shape of each ramp labeled with its starting height in the data table (on Student Handout).
8. Record the maximum speed of the rider on each ramp by drawing a line on the speedometer in the max speed column.
9. Record data on the three different designs.
10. After students complete the online simulation, they will use the materials to build a mini roller coaster with just a ramp and a vertical loop.
11. Once students make a successful mini roller coaster that keeps the marble on the track, direct them to the Plan instructions on the Student Handout.

Closure:

Have students discuss the following question:

- What variables in a ramp's design have the most effect on the speed and hence momentum of a skateboarder on a ramp?
    - *Answers should include assertions about greater height and a steeper incline, causing greater speed hence greater momentum*

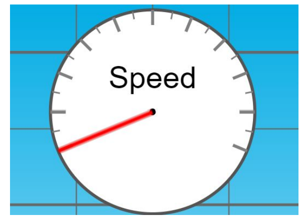
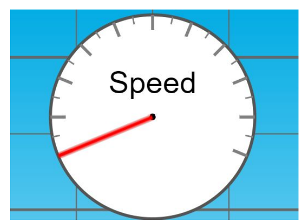
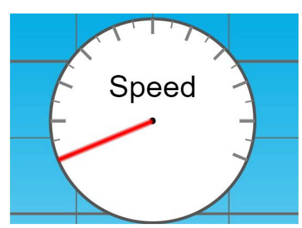
Extension:

Watch & Learn: How do Roller Coasters Work?

Interesting Engineering!: Why don't Roller Coasters Fly off their Tracks?

Student Handout

Data Table 1:

Ramp Design	Max Speed
	
	
	

Plan

After some experience building a ramp and a vertical loop go back to your 2 imagined solutions and choose the one you think is the best. You will build this design tomorrow.

Chosen Solution

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Day 5: The Triple Crown!

Teacher/Parent Background:

To help your child learn more about Newton's three laws of motion, begin with a review of each law:

- Newton's first law of motion states that an object at rest tends to stay at rest, and an object in motion tends to stay in motion at a constant speed in a straight line. That is, the state of motion of an object does not change unless it is acted upon by an unbalanced force. Therefore, if the net force is 0, nothing happens.
- Newton's second law of motion states that the relationship between force (Fmass (mand acceleration (a) is F = ma. More force makes things accelerate at a greater rate, and more mass slows the rate of acceleration.
- Newton's third law of motion states that for every action force, there is an equal and opposite reaction force. Forces always occur in pairs, never alone. When you push on something, it pushes back with an equal amount of force in the opposite direction.

Overview:

In this activity, students will design and build their own roller coasters that include at least 1 hill, 1 loop and 1 turn.

Related Standards:

- Use non-algebraic mathematics and computational thinking to explain Newton's laws of motion

Key Terms:

- Friction
- Gravitational Potential Energy
- Kinetic Energy
- Momentum
- Inertia

Materials List:

- Foam pipe insulation or foam pool noodles cut in half, lengthwise
- Masking Tape
- Marbles
- Various objects such as blocks, boxes, chairs, etc. to use as support

Activity Description:

- Using the knowledge gained in the past 4 days about roller coaster design, students will build a roller coaster using foam pipe insulation that must meet the constraints given in the challenge details from day 3.

Closure:

Discuss the following with students:

Where on your roller coaster do you see evidence for each of Newton's Laws?

First Law

Most roller coasters run by the Law of Inertia. Since an object at rest stays at rest, all roller coasters have to be pushed or pulled to get started. The student's roller coaster started at the top of a big hill. At the top, the marble has the largest amount of gravitational potential energy. Gravity pulled on the marble and put it in motion. Once put into motion, the marble stayed in motion but friction slowed it down.

Second Law

The second law states that the acceleration of an object depends on the object's mass and magnitude of the force acting upon it (F=ma). The marble could probably feel this second law when it went down the hills. The marble has mass. The gravity provides acceleration. That causes force. The rider feels the force as it moves the cars along the coaster track. The track directed the force and the marble.

Third Law

Newton's third law of motion says, "For every action there is an equal and opposite reaction." So that applied to the student's roller coaster, between the marble and the track. When the marble went up and down the hill, it created different forces onto the track. Those forces were applied back into the track and students may have noticed the track moving as the marble ran through it.

Extension:

Instagram!: Students can record an instagram video of their roller coaster in action and tag @azscience

Read & Learn: Newton's Laws and Roller Coasters