6 Energy and Forces on Earth

At-a-Glance:

In the last unit, students focused on how environmental changes impact the ability of organisms to survive, grow, and reproduce. In this unit, students expand their understanding of the need for energy among living things to include nonliving energy systems. They use sleds to see how friction transfers energy out of systems, and then apply what they know about forces and motion to engineer a roller coaster.

Common Misconception:

- **Misconception:** Friction is always "bad" because it slows motion.
  - ✓ **Fact**: Friction isn't good or bad. It does slow motion, but it also helps us move. Friction between our feet and the ground allows us to walk easily. This is why walking on ice is so hard—there is very little friction between our feet and the ground.

A Breakdown of the Lesson Progression:

1

Friction and Motion

Students build on their knowledge of energy transfer by exploring how energy can change forms and be transferred into and out of energy systems. Students explore how sled dogs need energy to pull a sled over the snow, and how energy changes as it transfers from the dogs to the sled.

2

Engineering Roller Coasters

Once students understand how forces transfer energy into or out of objects or systems to change their motion, they apply their knowledge to solve the problem of engineering a new roller coaster for an amusement park that has specific requirements.

KnowAtom™
Focus on what matters.

Unit 6: Energy and Forces on Earth

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Energy and Forces on Earth

Unit Overview:

Martin Buser first competed in the Iditarod in 1980. Since then, he has completed the 1,609-kilometer (1,000-mile) race 29 times, winning it four times.

Martin Buser is standing on the left.

The Iditarod isn't easy. Called "the last great race on Earth," it can take anywhere from 8 to 13 days to complete. It begins in Anchorage, Alaska, and ends on the western Bering Sea coast. Successfully completing the race is an accomplishment in and of itself, and the last person to cross the finish line receives a red lantern. Mushers (the drivers of the sled) need to know about energy and forces to maximize their dog sleds.

In this unit, students use sleds and roller coasters to explore the relationship between energy, forces, and motion. Students begin by experimenting with friction, conducting an experiment to see how surface friction affects how much force is needed to pull a sled over different textured-surfaces. Students then apply what they know about energy and forces to engineer a roller coaster.

Unit Goals:

1. Describe how friction transfers energy out of objects and systems by turning mechanical energy into heat.
2. Use evidence to support an argument about the relationship between energy, force, and motion.
3. Explore the role of gravity and other forces in causing roller coasters to move.

Applying Next Generation Science Standards

This unit covers the following **Next Generation Science Standards**. Each standard includes where it is found in the unit, as well as how it applies the relevant crosscutting concepts (listed in green) and disciplinary core ideas (listed in orange). **Note: Science and engineering practices are listed separately because all of the practices are incorporated into every unit.*

Grade-Specific Standards:

5-PS2	**Motion and Stability: Forces and Interactions**
5-PS2-1.	**Support an argument that the gravitational force exerted by Earth on objects is directed down.** ▪ **Types of Interactions:** Students explore how roller coasters are designed to use the force of gravity to move around the track. Lesson 2 ▪ **Cause and Effect:** Students evaluate the cause-and-effect relationship between the position of roller coaster cars on the track and the amount of stored gravitational energy they have, and therefore the amount of mechanical energy there is available to move. Lesson 2

3-5-ETS1	**Engineering Design**
3-5-ETS1-1.	**Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.** ▪ **Defining and Delimiting an Engineering Problem:** Students use given information to define the problem of an amusement park that needs a new, exciting roller coaster to replace the roller coaster it's been operating for years. Lesson 2 ▪ **Influence of Engineering, Technology, and Science on Society and the Natural World:** Students use what they know about the role of engineering in society to describe how engineers can use scientific knowledge and advances in technologies to create new technologies that solve problems. Lesson 2

3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

- **Developing Possible Solutions:** Students come up with different possible solutions to the amusement park's problem, and then decide on the roller coaster design they think has the best chance of meeting the criteria of the problem within the constraints. Lesson 2
- **Influence of Engineering, Technology, and Science on Society and the Natural World:** Students analyze how well their prototype roller coaster solves the problem and addresses the constraints of the problem. Lesson 2

3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

- **Optimizing the Design Solution:** Students test their roller coaster prototype, evaluating possible failure points and areas it can be improved. Lesson 2
- **Cause and Effect:** Students connect the materials used and the structure of their prototypes with their effectiveness at solving the problem within the constraints. Lesson 2

Supporting Standards:

4-PS3	Energy
4-PS3-2.	**Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.** ▪ **Conservation of Energy and Energy Transfer:** Students use sleds and roller coasters to observe how energy can be transferred from place to place. Lessons 1 and 2 ▪ **Energy and Matter:** Students analyze the relationship between energy and matter as they observe motion in their sled and roller coaster. Lessons 1 and 2
4-PS3-4.	**Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.** ▪ **Conservation of Energy and Energy Transfer:** Students use what they know about forces and motion to design and test a roller coaster that causes energy to change between potential and kinetic as the cars move over the tracks. Lesson 2 ▪ **Energy and Matter:** Students analyze how matter can be used to convert energy from one form to another. Lesson 2

Science and Engineering Practices

Students use the following science and engineering practices in the unit's lessons.

Lesson 1: Friction and Motion

1. Asking questions (for science) and defining problems (for engineering)

- Students develop a question that will help guide them through an experiment into how the amount of force needed to pull a sled changes depending on the roughness of the surface it's being pulled over.

2. Developing and using models

- Students create a visual model (scientific diagram) of their experiment-in-progress. Students use the model to visualize how the materials will be used and to communicate their experiment to others.

3. Planning and carrying out investigations

- Student teams collaboratively plan and carry out a procedure that compares the amount of force needed to pull a sled across surfaces with different textures (smooth and rough) in three trials for each surface.

4. Analyzing and interpreting data

- Students collect and analyze data on the average number of washers (the force used to move the sled) needed to move a sled over smooth and rough surfaces.

5. Using mathematics and computational thinking

- Students record the number of washers needed to move their sled over two different smooth surfaces and two different rough surfaces in three separate trials. Students then calculate the average number of washers needed on each surface.

6. Constructing explanations (for science) and designing solutions (for engineering)

- Students use the quantitative data they gathered in the experiment to construct an explanation that either supports or rejects their hypothesis about how the amount of force needed to pull a sled changes depending on the texture of the surface it's being pulled over.

7. Engaging in argument from evidence

- Students come together as a class, comparing results from the experiment and analyzing possibilities for any differences in results. They use their data from the experiment to describe how forces like friction transfer energy out of systems, which affects the motion of different objects.

8. Obtaining, evaluating, and communicating information

- Students use information from the student reader and their experiment to communicate their analysis, both in writing and in class dialogue, about the connection between forces, motion, and energy.

Lesson 2: Engineering Roller Coasters

1. Asking questions (for science) and defining problems (for engineering)

- Students clarify an engineering problem that they will then design a technology to solve. Students define the problem of an amusement park that wants to attract new visitors by designing a new, exciting roller coaster.

2. Developing and using models

- Students create a visual model (diagram) of their prototype. Students use the model to visualize how the materials will be used and to communicate their prototype to others. They then build their prototype, which is a physical model of the proposed solution.

3. Planning and carrying out investigations

- Students use what they know about the criteria (safe, has two loops and at least one sharp turn) and constraints (available materials) of the problem, as well as their research, to design a possible solution to the problem, given the available materials. They then collaboratively develop a procedure for testing how well a marble could move through the roller coaster.

4. Analyzing and interpreting data

- Students collect and analyze data on how well a marble moves through their roller coaster, making adjustments and improvements based on their data.

6. Constructing explanations (for science) and designing solutions (for engineering)

- Students use the data they gather from each prototype to construct an explanation about how to improve their prototype so that it better solves the problem, or if they should replicate their prototype as is.

7. Engaging in argument from evidence

- Students use the data and observations from their prototypes to describe how their modifications positively or negatively affected how well the marble could move through the roller coaster, explain how well their prototype solved the problem, and decide if they would refine or replicate any of their designs based on the data.

8. Obtaining, evaluating, and communicating information

- Students use information from their lab manuals and class dialogue, along with their knowledge of forces and motion, to communicate with their classmates how their team used scientific knowledge to design and then modify their prototype roller coasters.

Unit 6 Pacing Guide Example

All KnowAtom units are designed to take approximately one month. Lessons may span one or two weeks. This pacing guide provides one example for how to break down the lessons in this unit over a month. **Breakdown is based on 30- to 45-minute class periods.** Communities that have longer class periods or schedules where science class occurs more frequently can modify this guide accordingly.

Any days in this guide that appear unused take into account months with holidays, vacations, times when a lab and/or investigation takes longer to complete, and/or days when science class does not occur. Note that at the beginning of the school year, when the engineering and scientific processes are new to students, labs may take an extra class period to complete.

Unit 6: Energy and Forces on Earth				
Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**
Week 1				
Lesson 1 **Start:** As a class, read Section 1 of the KnowAtom student reader. **Final Goal:** Transition to the Socratic dialogue.	**Lesson 1** **Start:** Socratic dialogue. **Final Goal:** Transition to Lab 7 question.	**Non-Science Day**	**Lesson 1** **Start:** Recap experiment question. **Final Goal:** Students develop majority of lab with check-ins.	**Non-Science Day**
Week 2				
Lesson 1 **Start:** Teams complete lab development and may begin data collection. **Final Goal:** Students complete data collection.	**Lesson 1** **Start:** Students analyze data and evaluate results. **Final Goal:** Teams complete lab conclusions.	**Lesson 1** **Start:** Lab debrief/wrap-up with class. **Final Goal:** Review an assigned assessment question (optional).	**Non-Science Day**	**Non-Science Day**

Week 3				
Non-Science Day	**Lesson 2** **Start:** As a class, read Section 2 of the KnowAtom student reader. **Final Goal:** Transition to the Socratic dialogue.	**Lesson 2** **Start:** Socratic dialogue. **Final Goal:** Transition to Lab 8 engineering scenario/problem.	**Non-Science Day**	**Lesson 2** **Start:** Recap engineering problem. **Final Goal:** Students develop majority of lab with check-ins.
Week 4				
Lesson 2 **Start:** Teams complete lab development and may begin prototype testing/ data collection. **Final Goal:** Students complete prototype testing/ data collection.	**Non-Science Day**	**Lesson 2** **Start:** Students analyze test data and evaluate results. **Final Goal:** Teams complete lab conclusions (refine or replicate).	**Lesson 2** **Start:** As a class, review team results and conclusions. **Final Goal:** Wrap-up the lab and debrief.	**Non-Science Day**

Science Words to Know:

Use the blank concept map visual to connect vocabulary once the unit is complete. An example concept map is displayed in Appendix 3.

1. **chemical energy** – energy stored in the bonds of atoms and molecules

2. **energy** – the ability to do work

3. **energy system** – a set of connected parts that change an input of energy to a different output of energy

4. **force** – a push or pull that acts on an object, changing its speed, direction, or shape

5. **friction** – a force that slows motion whenever two objects rub against each other by turning mechanical energy into heat

6. **gravitational energy** – the energy stored in an object as a result of its vertical position or height

7. **kinetic energy** – the energy of motion

8. **mechanical energy** – the energy of a substance or system due to its motion

9. **potential energy** – energy that is stored

10. **work** – any change in position, speed, or state of matter due to force

Teacher Background

Energy Makes Dog Sleds Move

Martin Buser has such a passion for the Iditarod that he named his two children after checkpoints in the race—Nikolai and Rohn. He also runs a kennel, called Happy Trails Kennel, that raises and trains dogs to race.

Preparing for the Iditarod can take months, if not years. It is physically grueling for both the dogs and the musher, and those who make it to the end are usually exhausted and sleep-deprived. There are rules that have to be followed to make sure both the musher and the dogs are safe.

Once the race begins, the dogs need an almost-constant supply of energy. **Energy** is the ability to do work. **Work** is any change in position, speed, or state of matter due to force. Remember that consumers such as dogs get energy when they eat food. Racing dogs have a diet that often includes lamb, chicken, beef, moose, or salmon. They need between 10,000 and 12,000 calories a day to help pull the sled. Calories are the measure of energy that fuels your body.

Dogs eat to gain energy.

Calories are a form of **potential energy**, which is energy that is stored. There are different forms of potential energy. For example, the energy in food is a form of potential energy called **chemical energy,** which is energy stored in the bonds of atoms and molecules. Because food is matter, it stores chemical energy.

Dogs can pull sleds because like all living things, their bodies turn the potential chemical energy stored in food into different forms of kinetic energy. **Kinetic energy** is the energy of motion. There are different forms of kinetic energy, including **mechanical energy**, which is the energy of a substance or system due to its motion.

Energy Systems

We can understand how dogs use energy by thinking of them as energy systems. An **energy system** is a set of connected parts that change an input of energy to a different output of energy. When you eat, you are getting an input of energy in the form of calories (chemical energy). Your body stores some of that energy, and it turns the rest of it into different forms of kinetic energy. This is why it is important to eat enough calories. Without enough calories, you wouldn't have enough energy for your heart to beat, your muscles to move, or your brain to regulate your body. These actions all require outputs of kinetic energy.

Not all energy systems are living things. For example, the dogs that pull the sled form another energy system that includes the dogs, the sled, and the musher.

This dog sled is an energy system, made up of the sled, the dogs, and the musher.

Picture a dog sled. When the dogs are attached to the sled and they begin to run, they pull the sled. This input of energy is a pulling force that transfers the dogs' mechanical energy to the sled. A **force** is a push or pull that acts on an object, changing its speed, direction, or shape. This transfer of energy causes the sled to move because it now also has mechanical energy. The movement of the sled is an output of energy.

Any time energy transforms (changes) from one form to another, it forms an energy system. For example, when you ride a bike, you and the bike form an energy system. You have potential energy in your body in the form of chemical energy stored in the bonds that hold food molecules together. When you move your legs, that chemical energy transforms into mechanical energy that powers your movement. The mechanical energy transfers to the bike, causing the bike's wheels to turn.

Human-Made Energy Systems

Energy systems can also be human-made. Many of the technologies that power modern society are human-made energy systems that change one form of energy into different forms that do specific kinds of work. For example, an automobile is an energy system that takes chemical energy stored in a fuel such as gasoline and changes it into mechanical energy that moves the car.

As energy changes from one form to another, it is always conserved. This means that it is never created or destroyed. Because of this, sources of energy do not create energy. A source either stores energy or releases it in a way that can be changed to more useful forms. Fossil fuels store energy in their chemical bonds. A car engine burns gasoline, converting the fuel's chemical energy into mechanical energy to make the car move. Wind turbines use the motion of the wind to turn turbines, which then produce electricity. Solar cells transfer light energy into electrical energy.

The conservation of energy means that in a perfect system, the total amount of energy will be conserved as it changes from one form to another. Let's go back to the dog sled. The conservation of energy means that in a perfect system, however much mechanical energy the dogs transfer to the sled, the sled will have the same amount as it moves over the ground.

However, in the real world, some of that energy transfers out of the system. Friction is one way that energy is transferred out of a system. **Friction** is a force that slows motion whenever two objects rub against each other by turning mechanical energy into heat. Friction is why your hands feel hot after you rub them together. It's important to point out that energy isn't disappearing as a result of friction. Instead, it's transferring out of the system. Heat is evidence that energy has transferred out of the system and into the surrounding environment.

Factors that Influence Motion

Friction is the main reason that dog sleds work well in the snow but not on rougher surfaces like grass or gravel. Snow and ice are much smoother than other surfaces. This means there is less friction that occurs when objects like sleds move over the snow. Think of trying to walk on ice. The reason it is so hard is that there is very little friction between your feet and the ice. This is why you slip and slide on ice, but not on rougher surfaces. We need some friction so our feet can grip the ground as we walk.

However, dog sleds are designed to take advantage of the smooth surface of ice. Because less energy transfers out of the system when a sled is pulled over snow or ice, less energy is needed to pull the sled than would be needed on grass or gravel.

Other factors also influence how fast the sled will move. For example, the more massive the sled is, the more force will be needed to move it. Remember that mass is a measure of the amount of matter that makes up an object or substance. The sun is more massive than Earth, the same way a boulder is more massive than a pebble. Mass is measured in grams.

And the more dogs there are attached to the sled, the more force they will produce to pull the sled. This means they will be able to transfer more energy to the sled and make it move faster. This is why the Iditarod has rules about how many dogs can pull a racer to make the race fair. A team of 30 sled dogs would be able to move much faster than a team of six sled dogs.

There are rules about how many dogs can pull a sled because the more dogs there are, the more force they generate and the more easily they will pull the sled.

Engineers Need to Know About Forces and Motion

When engineers design technologies that move, such as dog sleds, they apply scientific knowledge about energy transfer and forces. This is especially important when designing roller coasters because at their core, roller coasters work because they are structured with gravity in mind. Remember that gravity is the force of attraction between all matter, and Earth's gravity pulls down on all objects on Earth's surface. Roller coasters use the force of gravity to move along the track, converting energy from potential to kinetic and back again. At their heart, the design of roller coasters centers on the law of conservation of energy.

Let's begin with the basic structure of a roller coaster. All roller coasters are made up of connected cars that move on tracks. But unlike a vehicle like a train, roller coasters don't have a motor to make them move.

Instead, the cars are pulled to the top of the first hill, usually with a long chain that runs underneath the tracks. Together, the cars and the track form an energy system.

You may have noticed that the first hill of a roller coaster is always the tallest. This is done on purpose. As the roller coaster cars move up the hill, they are getting more potential energy. This form of potential energy is called **gravitational energy**, and it is the energy stored in an object as a result of its vertical position or height.

The higher up an object is, the more gravitational energy it has stored. The moment those roller coaster cars begin to move downhill, that gravitational energy changes to mechanical energy. As the cars move around the track, energy is constantly changing between potential and kinetic energy.

Gravitational potential energy changes to mechanical kinetic energy as the roller coaster cars begin to move down the hill.

Forces on Roller Coasters

The first hill on a roller coaster has to be the highest because as the roller coaster cars move over the tracks, energy transfers out of the system. Friction is one force that transfers energy out of the system as the cars rub against the track.

Drag, also called air resistance, is another force that transfers energy out of a system. Drag is similar to friction, but it occurs between a solid substance and a fluid such as air.

As the roller coaster cars move over the tracks, both friction and drag cause energy to transfer out of the roller coaster system. This means that the roller coaster has less energy at the end of the ride than it does at the beginning of the ride.

As you move over the tracks, it can feel as though forces are pulling your body in all directions. In fact, engineers design the track in a specific way so riders will feel the thrill of interacting forces. Remember that engineers use scientific knowledge and mathematics to solve problems by creating new technologies.

First, engineers know that Earth's gravity is constantly pulling down on you. In response, the ground pushes back with an equal force. This is why we don't all fall into the center of the planet. As you ride the roller coaster, gravity pulls down on you equally throughout the entire ride.

Engineers also know that objects in motion tend to stay in motion unless an outside force causes them to change their motion. This is called inertia.

For example, imagine that you are riding in one of the cars on a roller coaster. When the roller coaster accelerates, your seat pushes you forward. To accelerate means to increase your speed over time. As the roller coaster picks up speed, your body also accelerates.

Acceleration and Deceleration

When the roller coaster slows down, your body is still moving at that accelerated pace. The harness holding you in the car is the outside force that causes you to slow down. (This is the same function of a seatbelt in a car.) Roller coasters use changing accelerations and decelerations (decreases in speed over time) to make you feel weightless in one moment and extremely weighty in the next.

The feeling of weightlessness is a result of inertia and acceleration. It usually happens at the top of a hill, right at the moment when the cars begin to move downhill. At that point, the car is already moving downward, but because of inertia, your body hasn't yet changed its motion downward.

For a brief moment, your body will lift out of the seat. In that second, gravity is pulling down on you, but the opposite force of the ground (or the car in this case) isn't pushing back up. This is why you feel weightless.

Engineers also often design loop-the-loops to turn riders upside down for a few seconds in the middle of the ride. These loop-the-loops can result in the same feeling of weightlessness.

The loop-the-loops are circular parts of the track. They work because of a force called the centripetal force. Centripetal force is a force that keeps an object moving along a curved path. As the cars move up and around the track, the centripetal force pushes them inward toward their center of rotation.

Loop-the-Loops

Let's go back to inertia for a moment. Picture the beginning of the loop, as the roller coaster cars move upward toward the top. Because of inertia, those cars will keep moving upward until an outside force changes their direction.

The loop of the track is that outside force that changes the motion of the cars, causing them to begin to loop around. This is why it feels like you are being pushed into the seat at the top of the circle, when you are completely upside down. Your body would keep moving upward because of inertia, and it is this inertia that pushes you back against the seat.

As the cars move through the loop, the track forces the cars to continuously change their motion. At each point, inertia keeps your body moving in a straight line, but the track changes your motion. It is these interactions that make the loop-the-loops work.

Lesson 1: Friction and Motion

<u>Objective</u>: Students carry out an experiment to examine how surface friction affects the amount of force needed to pull a sled over surfaces with different textures.

<u>Materials</u>:

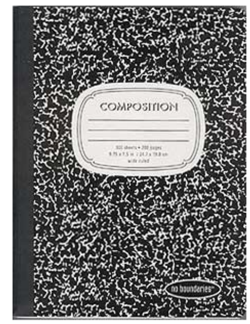
Consumable

A. Goggles – 1 per student
B. Laboratory notebooks – 1 per student
C. Paper plates – 1 per team
D. String – 60 cm per team
E. Straws – 1 per team
F. Paper clips – 1 per team
G. Paper sheets – 1 per team

Non-Consumable

H. Felt sheets – 1 per team
I. Foam sheets – 1 per team
J. Flat marbles – 5 per team
K. Metal washers – shared
L. Forms of Energy Visual – (not shown)
M. Energy Systems Visual – (not shown)
N. Forces on a Dog Sled Visual – (not shown)
O. Hole punches – shared

A


B


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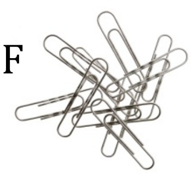

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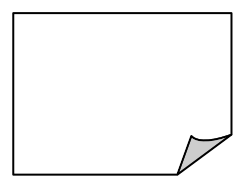

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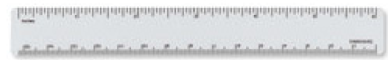
Teacher Tool Kit
P. Rulers – 1 per team
Q. Invisible tape – 1 per team
R. Scissors – 1 per team

P 

Q  R 

Teacher Preparation:

- Download the visuals from the KnowAtom Interactive website.
- To save time, prepare photocopies of the Blank Data Table and Blank Graph for each student using the copy master on page 43.
- Assemble one sled to use as a model for the classroom (see set-up procedures). Each team will need a level desk or table surface area to use during the lab.
- Arrange several pick-up stations for teams to access the materials during the lab. For example:
  - Pick-Up Station 1: paper plates, scissors, hole punches, paper clips, and string
  - Pick-Up Station 2: felt sheets, paper sheets, and foam sheets
  - Pick-Up Station 3: metal washers, flat marbles, invisible tape, and rulers

Student Reading Preparation:

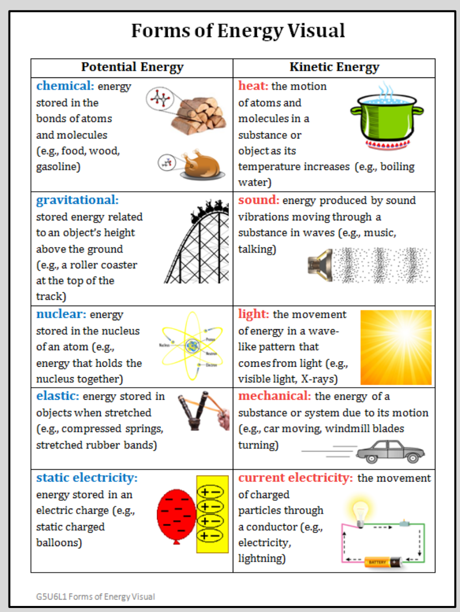
- Read Section 1 of the student reader together as a class before the Socratic dialogue and activity portion of the lesson. Model how to read closely for understanding. For example:
  - Emphasize connections between examples in the reading and broader concepts. For example, ask why a certain example was used to support the reading's main point.
  - Use "why" and "how" questions to connect ideas in the reading to student experiences.

Socratic Dialogue:

- The Socratic dialogue serves as the bridge between the nonfiction reading and the lab portion of the lesson.
- The example Socratic dialogue below describes one possible progression of ideas to engage students in higher order thinking. Blocks are used to divide the dialogue according to key organizing concepts. Note that in a Socratic dialogue, the teacher is not the only one asking questions and challenging ideas. Students should be actively engaged in proposing questions, challenging assumptions, and using evidence to support their arguments. *Not sure how to set up a Socratic dialogue? Check out www.knowatom.com/socratic for an in-depth look at how to hold a next generation Socratic dialogue in the classroom.*

Block 1-1: Different Forms of Energy

1. Display *Forms of Energy Visual*. Begin a dialogue with students that introduces students to the different categories and forms of energy.


Forms of Energy Visual

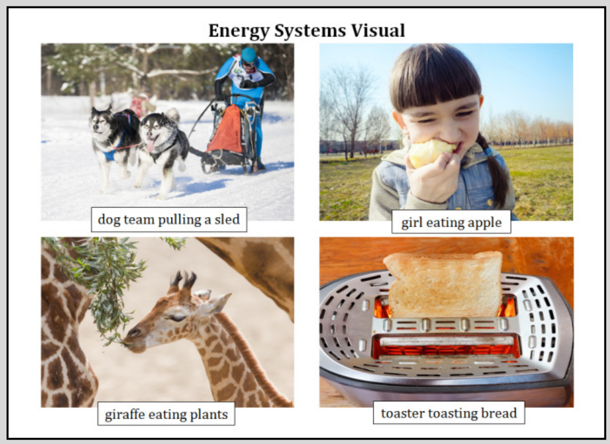
Potential Energy	Kinetic Energy
chemical: energy stored in the bonds of atoms and molecules (e.g., food, wood, gasoline)	heat: the motion of atoms and molecules in a substance or object as its temperature increases (e.g., boiling water)
gravitational: stored energy related to an object's height above the ground (e.g., a roller coaster at the top of the track)	sound: energy produced by sound vibrations moving through a substance in waves (e.g., music, talking)
nuclear: energy stored in the nucleus of an atom (e.g., energy that holds the nucleus together)	light: the movement of energy in a wave-like pattern that comes from light (e.g., visible light, X-rays)
elastic: energy stored in objects when stretched (e.g., compressed springs, stretched rubber bands)	mechanical: the energy of a substance or system due to its motion (e.g., car moving, windmill blades turning)
static electricity: energy stored in an electric charge (e.g., static charged balloons)	current electricity: the movement of charged particles through a conductor (e.g., electricity, lightning)

G5U6L1 Forms of Energy Visual

- ☐ **Big Idea 1:** Coach students toward the idea that **energy** is the ability to do **work** (any change in position, speed, or state of matter due to force), and there are different kinds of energy. For example:
  - *Ask one student to explain how kinetic energy is different from potential energy. (**Potential energy** is stored energy. It has the potential, or the ability, to do work, but it isn't actively*

*doing work. **Kinetic energy** is the energy of motion, which means it is energy that is actively doing work.)*

- *Ask another student why chemical energy is a form of potential, not kinetic, energy. (**Chemical energy** is energy stored in the bonds of atoms and molecules. It is potential energy because it is stored energy, so it isn't actively doing work.)*
- *Ask the first student why mechanical energy is an example of kinetic energy. (**Mechanical energy** is the energy of a substance or system due to its motion. Because it is energy in motion, it is kinetic energy.)*



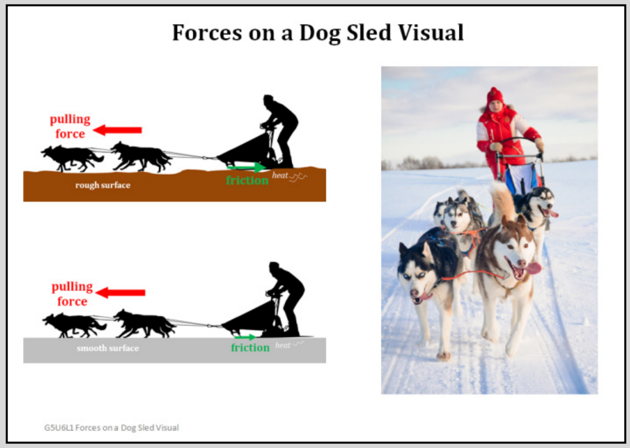
2. Display <u>*Energy Systems Visual*</u>. Have a dialogue with students that connects the last two units, which focused on the need for energy among living things, with this unit, which expands the idea of energy to nonliving things as well.

- **<u>Big Idea 2</u>:** Coach students toward the idea that all living things are **energy systems** because they are sets of connected parts that change an input of energy to a different output of energy. For example:
  - *Ask one student why all living things need food. (Because food is matter, it stores chemical energy in the bonds of its atoms and molecules. We need energy to carry out all life functions, including moving our muscles and having our brain regulate every body function.)*
  - *Ask another student to build on the first student's answer, adding supporting details or using evidence to respectfully contradict what has already been said.*
  - *Ask the first student how chemical energy is changed within the body of a living thing, such as a dog or a person.*

(When you eat, you are getting an input of energy in the form of calories (chemical energy). Your body stores some of that energy. It turns the rest of it into different forms of kinetic energy, including mechanical energy that powers all movement in your body.)
  - *Ask another student to describe how kinetic energy and potential energy interact. (Energy constantly changes from potential to kinetic and back to potential. Energy is never created or destroyed, but it can change forms as it moves through different energy systems.)*
  - *Ask the first student to give an example from everyday life of energy changing from potential to kinetic or from kinetic to potential. (There are many examples of this. A common example is a person on a bike at the top of a hill. At the top of the hill, the person on the bike has gravitational potential energy. When the person on the bike rolls down the hill, that gravitational energy changes to mechanical kinetic energy. Another common example is a car, which converts the stored chemical energy in gasoline into mechanical energy that makes the car move.)*
  - *One at a time, provide multiple students with the chance to respond to this question so that students are thinking about ways that energy is used and changes in their lives.*
- **Big Idea 3:** Coach students toward the idea that there are many examples of energy systems in the world. For example:
  - *Ask one student to describe why the toaster in the visual is an example of an energy system. (When a toaster is plugged in, it gets an input of electrical energy. That energy is changed to heat, which does work by toasting the bread.)*
  - *Ask another student why the dog sled is an example of an energy system. (The dogs provide the input of energy in the form of mechanical energy when they start to move. That energy transfers to the sled, causing the sled to move.)*

Block 1-2: Introduction to Forces

1. Display *Forces on a Dog Sled Visual*. Continue the dialogue with students, focusing on the relationship between energy, force, and motion.



- **Big Idea 4**: Coach students toward the idea that for an object to change its motion (such as beginning to move, stopping, or changing its direction or speed), a force has to transfer energy to or from the object. For example:
    - *Ask one student what force causes dog sleds to begin to move. (A **force** is any push or pull that acts on an object, changing its speed, direction, or shape. When the dogs are attached to the sled and they begin to run, they pull the sled. This input of energy is a pulling force that transfers the dogs' mechanical energy to the sled. This transfer of energy causes the sled to move because it now also has mechanical energy. The movement of the sled is an output of energy.)*
    - *Ask another student why force is necessary to change the motion of an object, such as a dog sled. (Objects can only move with energy. When a force is applied to the object, it transfers energy into or out of the object. This transfer of energy is what causes the movement of the object to change.)*
    - *Ask the first student to give an example of when a force would transfer energy out of an object. (Friction is an example of a force that transfers energy out of an object. It does this by turning mechanical energy into heat.)*

- *Ask another student why friction affects the motion of an object. (When two objects rub against each other, friction turns some of the mechanical energy into heat, which is released into the environment. Because the objects now have less mechanical energy, they slow down and will eventually come to a stop.)*
- *Assess student understanding of the conservation of energy by asking the same student how we can say that energy is never destroyed, even though when an object experiences friction there is less mechanical energy in the object, and energy moves out of the system as heat. (Energy doesn't disappear as a result of friction. Instead, it transfers out of the system. It still exists, but it is no longer making the object do work (moving).)*

- **Big Idea 5:** Coach students toward the idea that friction happens all around us, but different surfaces cause more or less friction. For example:
  - *Ask one student to describe what causes friction to occur. (Friction happens whenever two objects rub against one another. As they move against one another, the force of their rubbing causes energy to transfer into the environment.)*
  - *Ask another student where friction happens in everyday life. (There are many possible answers to this. For example, friction happens whenever we walk on the ground. The contact between our feet and the ground causes friction. Friction also happens when we rub our hands together, which is why they feel hot after rubbing them together.)*
  - *One at a time, provide multiple students with the chance to respond to this question so that students are thinking about examples of friction from their own lives.*
  - *Ask the first student why dog sleds work well in the snow and ice but not on rougher surfaces like grass or gravel. (Snow and ice are much smoother than other surfaces. This*

means there is less friction that occurs when objects like sleds move over the snow. Because less energy transfers out of the system when a sled is pulled over snow or ice, less energy is needed to pull the sled than would be needed on grass or gravel.)

- *Ask another student what evidence we have that ice causes less friction than grass or gravel. (It is much easier to slide across ice than it is to slide across grass or gravel. This is because ice is very smooth, so there is little friction between us and the ice.)*

Experiment: Lab 7 – Force and Motion

SAFETY: Students should wear goggles during this activity.

1. Divide students into teams of two. Students will have read and discussed how dog sleds in the Iditarod race must pull heavy sleds over snowy terrain. Use Socratic dialogue to guide students toward asking a question that they could answer with an experiment related to the concepts of friction and force, using what they learned about dog sleds. See if any students get close enough to a question that could be framed into something that is usable as the experiment question. You may need to ask several leading questions to get students thinking. For example:

- Would it be hard for a dog sled team in the Iditarod to pull the sled across rough gravel surfaces compared to smooth ice or snow? What about sand? [*Some students might point out that the dog sled might experience more friction as it moved over rough surfaces compared to smooth surface. Other students might point out that the texture of a surface might affect the amount of force the dogs would need to use to pull the sled across it.*]
- How could we test these ideas like a scientist? [*Students should recognize that they could design an experiment to answer a*

question related to the topic at hand (surface friction and force).]

2. If necessary, pull out some of the materials from your kit and point out the quantities each team has to work with. Show the class one of the pre-assembled sleds (plate with attached string and paper clip hook) and the different textured materials.

- What sort of question could we answer about friction and force using these materials?

See if any student gets close enough to a question that could be framed into something that is usable as the experiment question. For example: "Is more force needed to pull a sled across smooth or rough surfaces?" or "Does it take more force to pull a sled across a rough surface or a smooth surface?"

Question

As a class, discuss the possible questions for the experiment and decide which questions to explore for the lab. Some teams may decide to modify their questions slightly, which is fine as long as the concepts of force and friction are being explored. Once the experiment question is established for the lab, students should record it in their lab notebooks. Students create a title for the new lab entry that is relevant to the question. A relevant title for this lab could be "Force and Motion" but other titles can be used as well.

NOTE: Use the *Who is a Scientist* poster and the *Scientific Process Visual to* help students work through the scientific process.

Research

For research, students list up to three facts relevant to the experiment question, using information from the student reader and/or discussion. For example:

- *A force is a push or a pull that acts on an object, changing its speed, direction or shape.*

- *Friction is a force that slows motion whenever two objects rub against each other by turning mechanical energy into heat.*
- *Objects can only begin moving when a force acts on them, because forces transfer energy that powers movement.*

Hypothesis

Teams form their own hypothesis and record it in their lab notebooks. Team hypotheses may contain the following type of examples:

- "More force is needed to pull a sled across a rough surface than a smooth surface."
- "More force is needed to pull a sled across a smooth surface than a rough surface."
- "The same amount of force is needed to pull a sled across smooth and rough surfaces."

Checkpoint #1: After Question, Research, and Hypothesis

As teams are ready, they should check in with the teacher to review their question, research, and hypothesis. Do the lab notebooks of both team members match and meet expectations? Can both students within the team explain their reasoning? If not, ask for areas of clarification or correction before they advance further. Not all teams will arrive at the lab check-points at the same time, so teams independently receive the go-ahead to move on in their lab after they have made the necessary modifications. At this point in the year, student lab notebook entries within the class may have similar (but not identical) questions, and variations from team to team in the remaining steps of the process are expected and encouraged.

Summarize Experiment
Stand by the materials stations and explain how the materials function and the general amounts each team can use.

- It may be helpful to explain that the straw can be used to reduce friction between the string and the edge of the test area (desk or table) so the maximum friction will occur between the sled and the surface being tested.
- Identify which materials (felt, transparency, desk surface, and foam) can be used to represent smooth and rough surfaces.

If needed, facilitate a discussion that will help students arrive at a testable experiment. This may involve asking questions to connect the materials to how they could be used to generate data about how much force is needed to pull the sled (paper plate) across different surfaces. Students summarize the experiment in their lab notebooks. For example: "Our experiment will compare the number of washers needed to pull a sled across surfaces with different textures (smooth and rough) in three trials for each surface. The variables in the experiment are the different surfaces. The constant in the experiment is the number of flat marbles (load) placed in the sled."

Checkpoint #2: After Experiment Summary
As teams are ready, they should check in with the teacher to review the experiment summary of their lab. Do the lab notebooks of each team member match and meet expectations? Can students explain their reasoning? The summary should not include a detailed procedure or material quantities.

- ✓ Students describe what data will be collected to serve as evidence to address the lab question. The summary should include the basics of the data to be collected, the number of tests or trials students will conduct, the variables, and the parts of the experiment they will keep constant in each test or trial.

List Materials and Procedure

Students list materials and all relevant safety precautions in their lab notebooks.

- 60 centimeters of string
- 5 flat marbles
- 1 paper plate
- 1 paper clip
- 1 straw
- 1 ruler
- 1 roll of invisible tape
- 1 sheet of felt (rough surface)
- 1 sheet of foam (rough surface)
- 1 sheet of paper (smooth surface)
- 1 desk surface (smooth surface)
- 1 set of metal washers – shared
- 1 hole punch – shared

Safety:

- goggles

Teams develop a standardized list of steps for the procedure. The procedures may vary from team to team depending on approach. To cut back on the number of steps in the actual testing procedure, students should create a separate set-up procedure that details how they set up their sled system on their desks (see examples below). Students may need some tips to help them set-up their sled system.

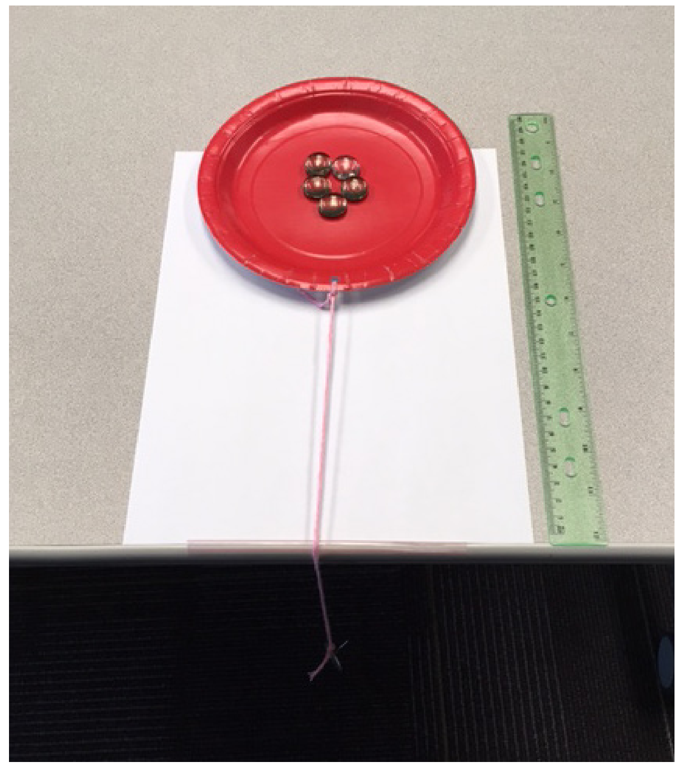
<u>Set-Up Procedure</u>:

1. Punch one hole in the rim of the paper plate (sled). Tie the string to the sled. Tie a paper clip to the opposite end of the string and open the paper clip to form a hook.
2. Clear a level test area (desk or table) to pull the sled across different surfaces. Tape a straw along the edge of the test area for the string to hang.

<u>Testing Procedure</u>:

1. Place 1 sheet of paper on the test area behind the straw.
2. Position the sled 16 centimeters behind the straw on the paper with the string over the straw, hanging off the desk/table edge.
3. Place five flat marbles on the sled. Add metal washers to the paper clip hook, one at a time, until the sled starts moving

across the paper. Record the number of the washers that moved the sled.
4. Repeat steps 2-3 for two more trials.
5. Repeat steps 1-4 with the desk, foam, and felt surfaces.

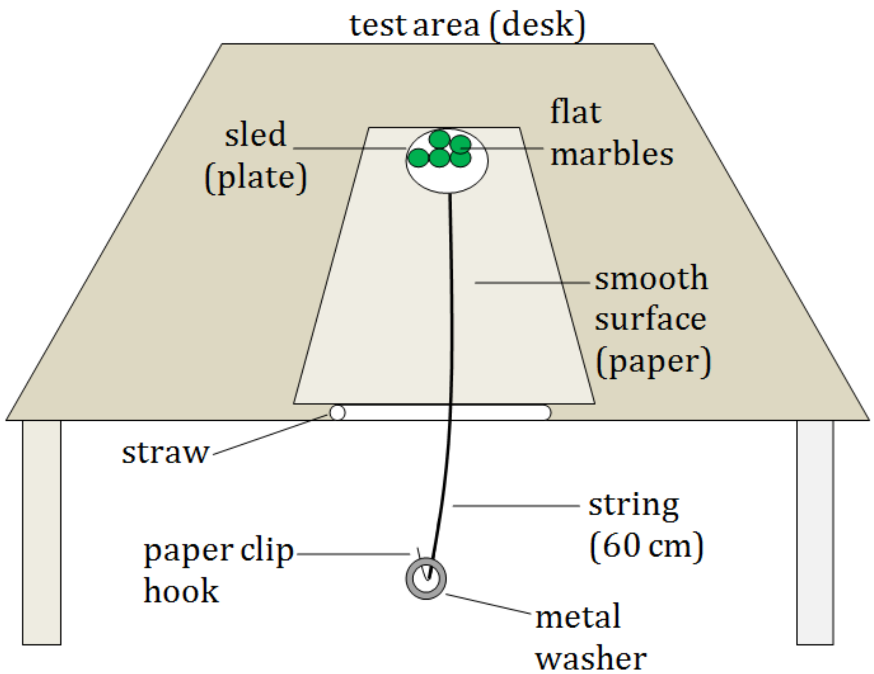


The photos show a fully assembled sled with paper clip, string, and paper plate (on left) and the sled test area (on right).

<u>Checkpoint #3</u>: After Materials and Procedure
As teams are ready, they should check in with the teacher to review the materials and procedure steps of their lab. Are the materials and procedure in vertical lists and quantities included with all materials? Can you follow each team's procedure? Are the materials and quantities under "materials" all required by the procedure? Is it clear, concise, and specific? If not, clarify expectations. Students make corrections or any modifications and return to the checkpoint for the go-ahead.

Scientific Diagram
Students draw a titled scientific diagram of their experiment-in-progress. All materials should be labeled. For example:

Testing Surfaces and Friction Diagram



Checkpoint #4: After Scientific Diagram
As teams are ready, they should check in with the teacher to review their lab scientific diagram. Are the diagrams complete? Diagrams should be titled and materials labeled. If complete, students pick up blank data tables and graphs to tape inside their lab notebooks and then proceed to collect the materials needed to conduct their experiment after meeting at this checkpoint.

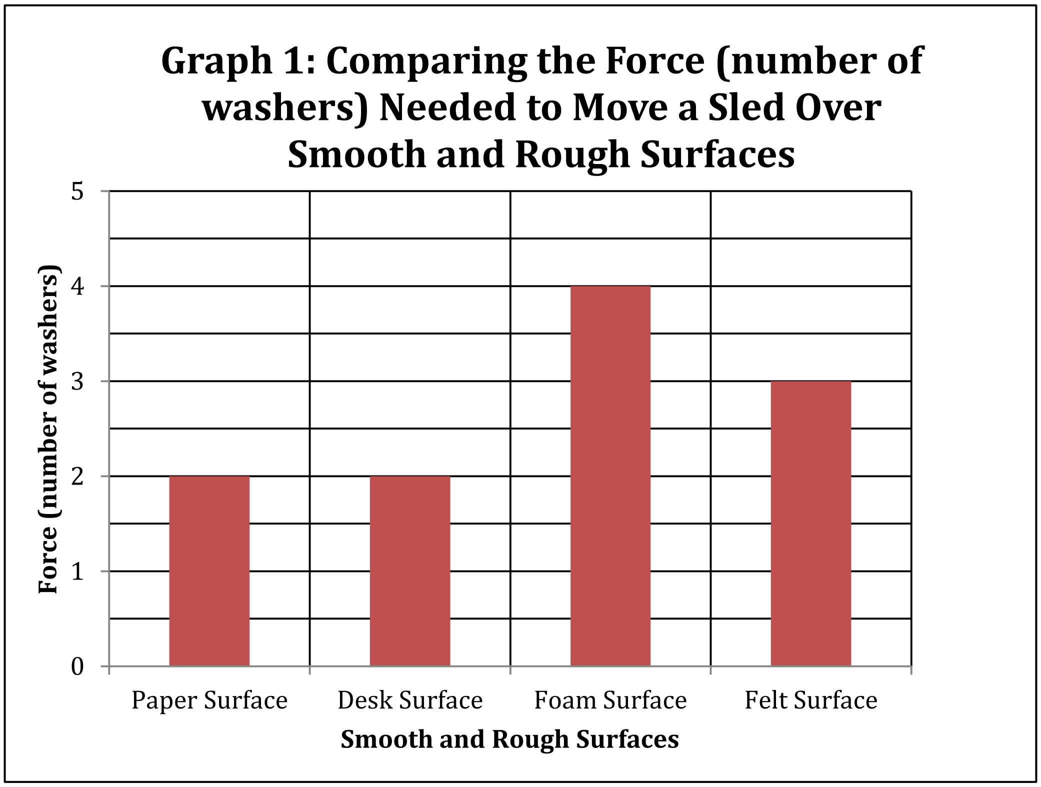
Data

Each team collects any materials they need from the pick-up stations to carry out their procedures. Students record data in their data tables as the experiment progresses. Students graph average number of washers needed to move the sled over each surface type in a bar graph. Photocopy and distribute blank data tables and bar graphs to save time.

Table 1: Comparing the Force (number of washers) Needed to Move a Sled Over Smooth and Rough Surfaces

	Smooth Surface		**Rough Surface**	
	Paper Surface	Desk Surface	Foam Surface	Felt Surface
Trial 1	2	2	4	3
Trial 2	2	2	4	3
Trial 3	2	2	4	3
Average Number of Washers (applied force used to move the sled)	2	2	4	3

NOTE: Example data represent one possible outcome.



Conclusion

Each student writes a conclusion that summarizes their findings and tells how the data did or did not support the hypothesis. For example: "Our hypothesis that the same amount of force is needed to pull a sled across smooth and rough surfaces is false. Our data show that it took 1-2 more washers on average to pull the sled over the rough surfaces (foam and felt) than over the smooth surfaces (desk and paper). We can conclude that more force is required to pull objects across rough surfaces compared to smooth surfaces."

<u>Final Checkpoint</u>: After Data and Conclusion
As teams are ready, they should check in with the teacher to review the data and conclusion steps of their lab. One team member reads the team's conclusion aloud to you while you review the other team member's lab notebook. Do they restate the hypothesis? Have they made a true/false/inconclusive claim? Look for key data points that students used to form their conclusion. Is it clear? Is it persuasive? Do the data support the claim? If the results are contrary to their research, what might be responsible? How could they test for that in the future?

<u>Wrap-Up</u>:

1. Have a dialogue with students to review their results from the experiment. For example:

- Ask a student from one team to present their conclusion to the class, including the key data points.
- Were the data consistent with all teams in the class? If not, what may have caused some teams to have different data? [*Answers will vary. One at a team, ask student teams to compare their results and analyze possibilities for any differences, including differences in experimental design.*]
- Were there any challenges in the experiment? [*Answers may vary. One at a time, provide student teams with a chance to describe their process and any difficulties they faced, as well as how they overcame those difficulties. Other teams can add to student answers based on their own procedure and experiment.*]
- Ask another student why it was important to use the same number of flat marbles in each test. [*It is important to keep everything in the experiment the same except for what it being tested. In this experiment, the number of washers needed to pull the sled was what was being tested, so it was important to keep*

the load (number of marbles) the same in each test, otherwise it would be impossible to know what caused the sled to move.]

- Ask the first student why different numbers of washers were able to move the sled across different surfaces. [*The more washers there were, the more force they applied to the sled, causing it to move. On smooth surfaces, less force was needed to move the sled because there was less friction between the surface of the material and the surface of the sled.*]

2. Continue the dialogue with students to review how energy can be transferred into or out of objects or systems. For example:

- Ask one student why having the washers apply a force to the sled was important for making the sled move. [*Force is necessary for motion. Without force, an object won't change its motion.*]
- Ask another student why the washers needed to hang over the edge of the desk in order to pull on the sled, causing it to move. [*Gravity pulled down on the washers hanging over the desk. It was because of this downward pull on the washers that the washers were able to transfer energy through the string to the sled, which caused the sled to move.*]
- Ask the first student how the results from the experiment support the argument that it is easier to pull sleds across snow than across sand or gravel. [*Like the smooth surfaces in the experiment, there is much less friction between a sled and smooth snow. The sand and the gravel are much rougher, like the rough surfaces in the experiment, so we know that a sled would require a lot more force to pull it over the sand or the gravel than the snow.*]

This complete lab notebook entry is intended to be used as an exemplar only.
It is not intended for student use.

Page

Force and Motion, Date, Partner Name

Lab 7: Force and Motion

Question: Is more force needed to pull a sled across smooth or rough surfaces?

Research: A force is a push or a pull that acts on an object, changing its speed, direction or shape. Friction is a force that slows motion whenever two objects rub against each other by turning mechanical energy into heat. Objects can only begin moving when a force acts on them, because forces transfer energy that powers movement.

Hypothesis: The same amount of force is needed to pull a sled across smooth and rough surfaces.

Summarize Experiment: Our experiment will compare the number of washers needed to pull a sled (paper plate) across surfaces with different textures (smooth and rough) in three trials for each surface. The variables in the experiment are the different surfaces. The constant in the experiment is the number of flat marbles (load) placed in the sled.

Materials:

- 60 centimeters of string
- 5 flat marbles
- 1 paper plate
- 1 paper clip
- 1 straw
- 1 ruler
- 1 roll of invisible tape
- 1 sheet of felt (rough surface)
- 1 sheet of foam (rough surface)
- 1 sheet of paper (smooth surface)
- 1 desk surface (smooth surface)
- 1 set of metal washers (shared)
- 1 hole punch (shared)

Safety:

- goggles

Unit 6: Lesson 1 – Sample Laboratory Notebook

This complete lab notebook entry is intended to be used as an exemplar only.
It is not intended for student use.

Set-Up Procedure:

Step 1: Punch one hole in the rim of the paper plate (sled). Tie the string to the sled. Tie a paper clip to the opposite end of the string and open the paper clip to form a hook.

Step 2: Clear a level test area (desk or table) to pull the sled across different surfaces. Tape a straw along the edge of the test area for the string to hang.

Testing Procedure:

Step 1: Place 1 sheet of paper on the test area behind the straw.

Step 2: Position the sled 16 centimeters behind the straw on the paper with the string over the straw, hanging off the desk/table edge.

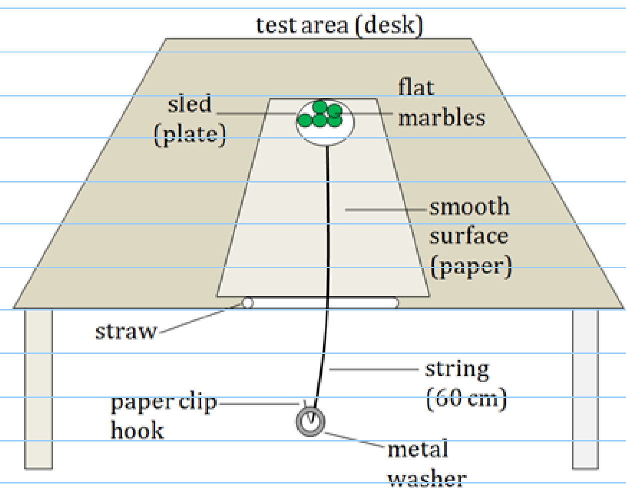
Step 3: Place 5 flat marbles on the sled. Add metal washers to the paper clip hook one at a time until the sled starts moving across the paper. Record the number of washers that moved the sled.

Step 4: Repeat steps 2-3 for two more trials.

Step 5: Repeat steps 1-4 with the desk, foam, and felt surfaces.

Scientific Diagram:

Testing Surfaces and Friction Diagram



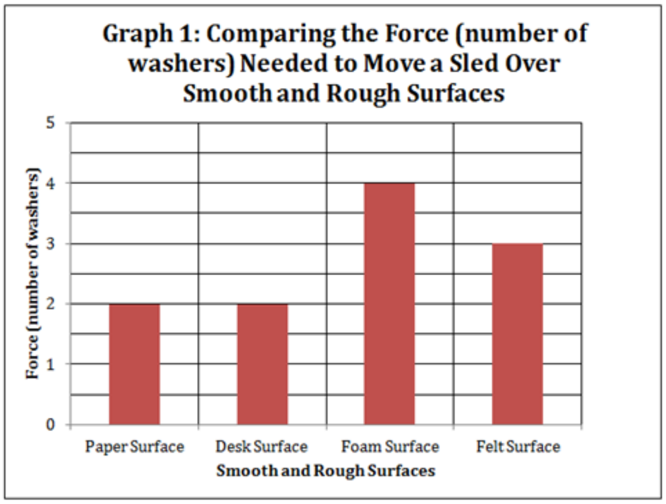
Unit 6: Lesson 1 – Sample Laboratory Notebook

This complete lab notebook entry is intended to be used as an exemplar only. It is not intended for student use.

Data:

Table 1: Comparing the Force (number of washers) Needed to Move a Sled Over Smooth and Rough Surfaces

	Smooth Surface		Rough Surface	
	Paper Surface	Desk Surface	Foam Surface	Felt Surface
Trial 1	2	2	4	3
Trial 2	2	2	4	3
Trial 3	2	2	4	3
Average Number of Washers (applied force used to move the sled)	2	2	4	3



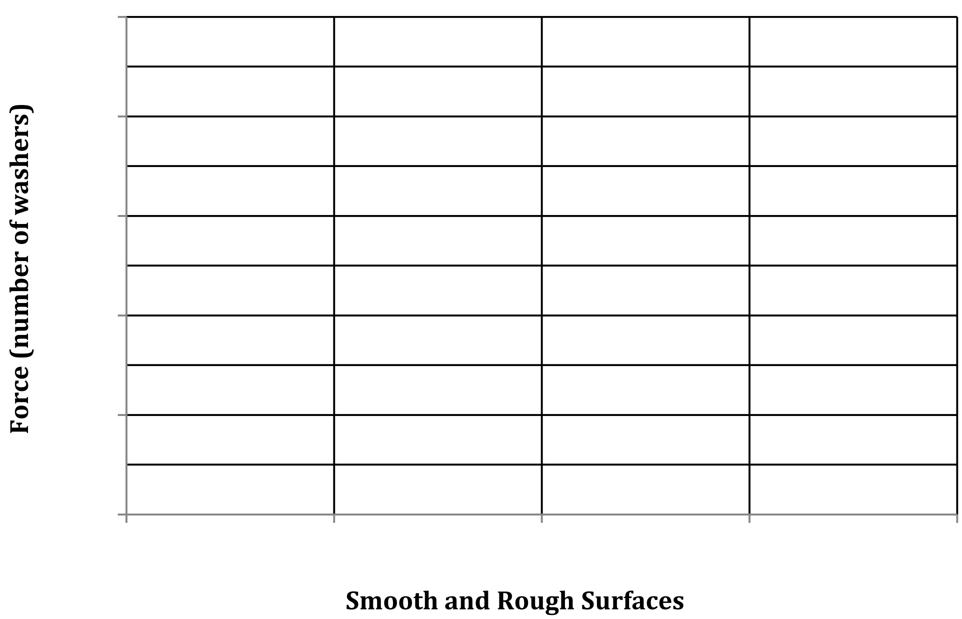
Conclusion: Our hypothesis that the same amount of force is needed to pull a sled across smooth and rough surfaces is false. Our data show that it took 1-2 more washers on average to pull the sled over the rough surfaces (foam and felt) than the smooth surfaces (desk and paper). We can conclude that more force is required to pull objects across rough surfaces than smooth surfaces.

Unit 6: Lesson 1 – Blank Data Table and Blank Graph

Table 1: Comparing the Force (number of washers) Needed to Move a Sled Over Smooth and Rough Surfaces

	Smooth Surface		**Rough Surface**	
	Paper Surface	Desk Surface	Foam Surface	Felt Surface
Trial 1				
Trial 2				
Trial 3				
Average Number of Washers (applied force used to move the sled)				

Graph 1:



Lesson 2: Engineering Roller Coasters

Objective: Students apply what they know about energy transformation to solve the problem of engineering a new roller coaster for an amusement park ride that has specific requirements.

Materials:

Consumable

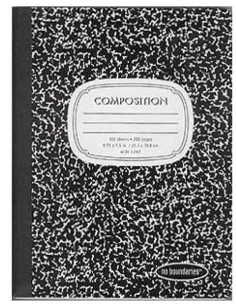
A. Goggles – 1 per student
B. Laboratory notebooks
– 1 per student
C. Roller coaster tracks
(pipe insulation)
– 10 sections per team
D. Dowels
– 2 per team

Non-Consumable

E. Marbles – shared
F. Measuring tape – shared
G. Gravity on Roller Coasters Visual
– (not shown)
H. Interacting Forces Visual
– (not shown)

Teacher Tool Kit

I. Duct tape – shared
J. Scissors – 1 per student

B


A


C


D


E


F


I


J


Teacher Preparation:

- Download the visuals from the KnowAtom Interactive website.

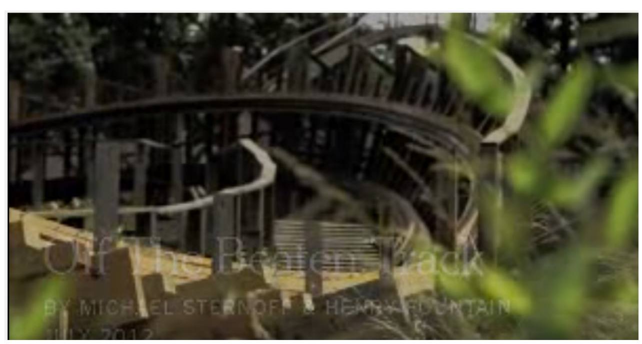
- To save time, prepare photocopies of the Materials Survey Chart and the Blank Data Table for each student using the copy masters on page 65.
- Arrange several pick-up stations for students to access the prototyping materials during the lab. For example:
  - <u>Pick-Up Station 1</u>: roller coaster tracks and dowels
  - <u>Pick-Up Station 2</u>: duct tape, measuring tape, and scissors
  - <u>Pick-Up Station 3</u>: marbles

<u>Student Reading Preparation</u>:

- Read Section 2 of the student reader together as a class before the Socratic dialogue and activity portion of the lesson. Model how to read closely for understanding. For example:
  - Emphasize connections between examples in the reading and broader concepts. For example, ask why a certain example was used to support the reading's main point.
  - Use "why" and "how" questions to connect ideas in the reading to student experiences.

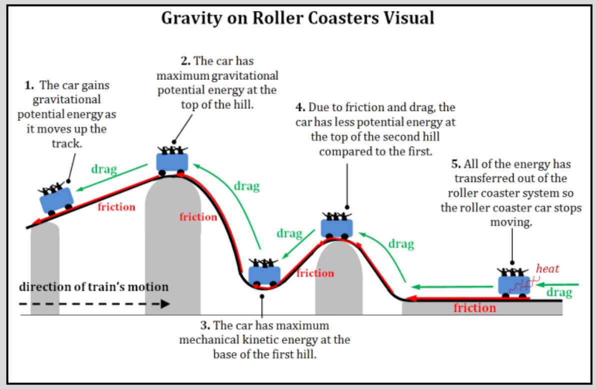
<u>Socratic Dialogue</u>:

<u>Block 2: Designing Roller Coasters</u>



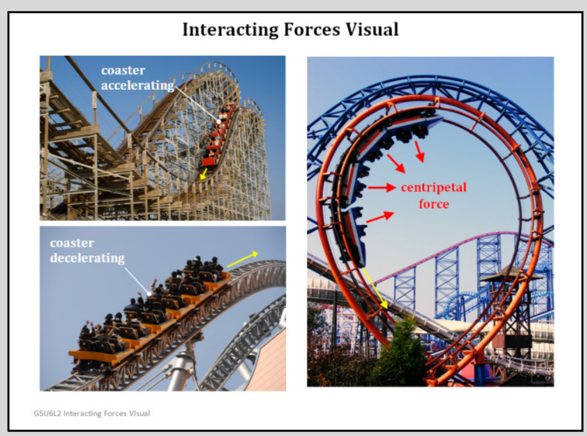
* **Note to teachers**: If time and resources permit, the following video can be watched as a class as a jumping off point for the dialogue. The video describes a roller coaster designer. It can be found at: https://www.youtube.com/watch?v=Xyei8OgXsY4

1. Display _Gravity on Roller Coasters Visual_. Continue the dialogue from the last lesson, focusing on how engineers can apply what they know about forces and motion to design technologies such as roller coasters.



- ☐ **Big Idea 6**: Coach students toward the idea that at their core, roller coasters work because they are designed with gravity in mind. For example:
  - *Ask one student why gravity is a force. (Gravity is the force of attraction between all matter. It pulls two different objects or substances toward one another. For example, Earth's gravity pulls all objects on or near Earth's surface down toward the center of Earth.)*
  - *Ask another student to use evidence to support the idea that gravity is a force because it changes motion. (One way to show the effect of gravity would be to hold a pen above the ground and drop it. It is gravity's attractive pull that causes the pen to drop to the ground.)*
  - *Ask one student how the force of gravity acts on you when you are riding a roller coaster. (Earth's gravity is constantly pulling down on you, so as you ride the roller coaster, gravity pulls down on you equally throughout the entire ride.)*
  - *Ask another student why we don't all fall into the center of Earth since gravity is constantly pulling down on us. (The ground pushes back with an equal force.)*
  - *Ask the first student how roller coasters use gravity. (The first hill of a roller coaster is always the tallest because as the roller coaster cars move up the hill, they are getting more potential **gravitational energy**, which is the energy stored in an object as a result of its vertical position or height.)*

- *Ask another student to describe the cause-and-effect relationship between the height of the roller coaster cars and the amount of energy they have stored. (The higher up the cars are, the more gravitational potential energy they have stored.)*
- *Ask the first student to use the visual to trace how that gravitational potential energy changes as the cars move over the tracks. (As the cars move around the track, energy is constantly changing between potential and kinetic energy. The moment those roller coaster cars begin to move downhill, that gravitational potential energy changes to mechanical kinetic energy. As the cars move up another hill, the energy is stored as gravitational potential energy, and it changes back to mechanical kinetic energy as the cars move down the hill on the other side.)*
- *Ask another student why the first hill on any roller coaster has to be the highest. (As the roller coaster cars move over the tracks, energy transfers out of the system because of friction and drag. This means there is less energy as the cars move over the track because some of the energy has transferred out of the roller coaster and into the environment.)*



2. Display *<u>Interacting Forces Visual</u>*. Have a dialogue with students about how engineers design the track in a specific way so riders will feel the thrill of interacting forces.

- ☐ **<u>Big Idea 7</u>:** Coach students toward the idea that gravity and inertia are important concepts for engineers designing roller coasters. For example:

- *Ask the first student to describe the relationship between inertia and an object's motion. (Inertia means that objects in motion tend to stay in motion and objects at rest will stay at rest unless an outside force causes them to change their motion.)*
- *Ask another student to apply inertia to the dog sled example from the last lesson, explaining why dogs are needed to pull the sled. (Because of inertia, a dog sled that isn't moving won't suddenly start moving unless an outside force acts on it. The dogs provide that outside force that changes the dog sled's motion, making it start to move.)*
- *Ask the first student what causes roller coasters to accelerate. (To accelerate means to increase your speed over time. Whenever the roller coaster moves downhill and gravitational potential energy changes to mechanical kinetic energy, it accelerates.)*
- *Ask another student what causes roller coasters to decelerate. (To decelerate means to decrease in speed over time. As the roller coaster moves up hills, mechanical kinetic energy changes to gravitational potential energy, so it decelerates.)*
- *Ask the first student how roller coasters use inertia, along with accelerations and decelerations, to make the ride feel exciting. (When the roller coaster accelerates, your seat pushes you forward. As the roller coaster picks up speed, your body also accelerates. When the roller coaster decelerates, your body is still moving at that accelerated pace because of inertia. The harness holding you in the car is the outside force that causes you to slow down. Roller coasters use changing accelerations and decelerations to make you feel weightless in one moment, and extremely weighty in the next.)*
- *Ask another student why there is a moment in a roller coaster ride when you feel weightless. (It usually happens*

at the top of a hill, right at the moment when the cars begin to move downhill. At that point, the car is already moving downward, but because of inertia, your body hasn't yet changed its motion downward. For a brief moment, your body will lift out of the seat. In that second, gravity is pulling down on you, but the opposite force of the ground (or the car in this case) isn't pushing back up. This is why you feel weightless.)

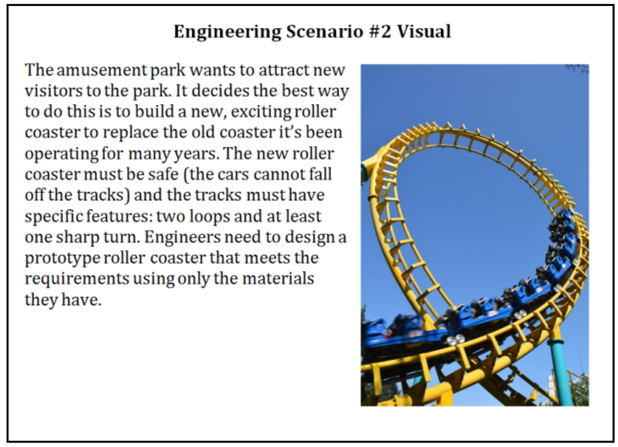
- **Big Idea 8**: Coach students toward the idea that loop-the-loops are another common feature on many roller coasters because they provide riders with the thrill of being upside down for a few seconds in the middle of the ride. They work because of a force called centripetal force. For example:
  - *Ask one student to describe how centripetal force acts on the roller coaster cars and the riders. (Centripetal force is a force that keeps an object moving along a curved path. As the cars move up and around the track, centripetal force pushes them inward from the track toward the center of the loop.)*
  - *Ask another student how roller coaster tracks produce centripetal force. (It has to do with inertia. As the cars move upward toward the top of the loop, inertia would cause them to keep moving upward. But the track forces them to begin to turn as they begin the loop. As the cars move through the loop, the track forces the cars to continuously change their motion. At each point, inertia keeps your body moving in a straight line, but the track changes your motion. It is these interactions that make the loop-the-loops work.*
  - *One at a time, provide multiple students with the chance to respond to this question as students explore the different forces that interact on a roller coaster ride. Redirect if misconceptions arise before moving onto the engineering lab.*

<u>Engineering</u>: Lab 8 – Engineering Roller Coasters

SAFETY: Students should wear goggles during this activity.

Engineering Scenario

Display the engineering scenario visual *<u>Engineering Scenario #2 Visual</u>*. Read the engineering scenario with the class: "The amusement park wants to attract new visitors to the park. It decides the best way to do this is to build a new, exciting roller coaster to replace the old coaster it's been operating for many years. The new roller coaster must be safe (the cars cannot fall off the tracks) and the tracks must have specific features: two loops and at least one sharp turn. Engineers need to design a prototype roller coaster that meets the requirements using only the materials they have."


Engineering Scenario #2 Visual

The amusement park wants to attract new visitors to the park. It decides the best way to do this is to build a new, exciting roller coaster to replace the old coaster it's been operating for many years. The new roller coaster must be safe (the cars cannot fall off the tracks) and the tracks must have specific features: two loops and at least one sharp turn. Engineers need to design a prototype roller coaster that meets the requirements using only the materials they have.

Problem

Divide students into teams of two. Students collect their lab notebooks to begin a new lab entry. Students summarize the problem presented in the engineering scenario in their lab notebooks, based on what they learned from the scenario. As part of their summary of the problem, students define the criteria (the needs or requirements the solution must meet) and constraints (ways the solution is limited) in their own words. Identifying the criteria and constraints is a critical step in the engineering process because prototype solutions will be compared on the basis of how well each one meets the specified criteria for success, along with how well each takes the constraints into account. It's important for students to be able to identify this information from the scenario so they know what their prototype needs to accomplish and the limitations they need to consider. If needed, use leading questions to guide students toward identifying the criteria and constraints of the problem.

- What are the requirements the solution must meet?
- What are the restrictions to the solution?

For example: "An amusement park needs to attract new visitors to its park with a new, exciting roller coaster."

Criteria:

- The new roller coaster must be safe (the cars cannot fall off the tracks).
- The roller coaster must have two loops and at least one sharp turn.

Constraints:

- materials

When teams are finished recording the problem, including its criteria and constraints, have students briefly share what they recorded with the class to clear up any misunderstandings related to the specific criteria and constraints they identified in the scenario. When complete, students create a new title for the engineering lab that is relevant to the problem. In this example, a relevant title would be "Engineering Roller Coasters."

NOTE: When students are finished summarizing the problem, display the *Engineering Process Visual* in place of the *Engineering Scenario #2 Visual* to help guide them through the lab process.

Research

For research, students list up to three facts relevant to the problem, using information from the student reader and/or discussion. For example:

- *Gravity, friction, and drag are three forces that act on a roller coaster car.*
- *As the roller coaster cars move up a hill, they gain gravitational energy. That energy changes to mechanical energy as the cars begin to move down the hill.*
- *Friction and drag are two forces that transfer energy out of the roller coaster system as it moves over the track, causing the cars to slow down.*

Survey Available Materials
As a class, survey the available materials. Stand by the pick-up stations and explain that each team will have access to the following for building their prototypes:
- 10 sections of roller coaster track (pipe insulation)
- 2 dowels

Teams also have access to the following tools and materials for assembling and testing their prototypes. These items are not included in the materials survey chart:
- duct tape (shared)
- 1 scissors
- 1 tape measure
- 1 marble
- additional books, chairs, or desks to support the roller coaster structure (classroom provides)

Students collect a sample of the materials from the pick-up stations (optional) according to the materials listed on their materials survey chart to evaluate as they fill out their Materials Survey Chart. Photocopy and distribute blank survey charts to save time. The name and quantity of each material are pre-filled in the survey chart. Students record:
- sketch of each material

- description of what each material is made from
- 1-2 physical properties of each material (e.g., thickness, flexibility, shape)

Materials Survey Chart				
Name	**Quantity**	**Sketch**	**Made From**	**Properties**
roller coaster track	10		foam	bendable, hollow with grooves
dowels	2		wood	long, thin, and rigid

Checkpoint #1: After Problem, Research, and Materials Survey
As teams are ready, they should check in with the teacher to review their problem, research, and materials survey. Do the lab notebooks of both team members match and meet expectations? Can both students within the team describe the criteria and constraints of the problem? Are the research questions relevant to the problem? Are the properties of the materials included in the survey chart? If not, ask for areas of clarification or correction before they advance further. Not all teams will arrive at the lab check-points at the same time, so teams independently receive the go-ahead to move on in their lab after they have made the necessary modifications. Student lab notebook entries within the class will have the same problem, but variations from team to team in the remaining steps of the process are expected and encouraged.

Possible Solutions
Students use what they know about the criteria and constraints of the problem, as well as their research, to list at least three possible

solutions to the problem, given the available materials. To do this, students identify three different ways to configure a roller coaster track so the car can navigate the required features (two loops and a sharp turn while remaining on the track). Students should be thinking about how they might design their track in such a way that the coaster car converts the most potential energy to kinetic energy as it moves over the track. The following are three possible examples students might come up with:

- Build a roller coaster with one lift hill followed by two loops and a sharp turn.
- Build a roller coaster with a lift hill between two loops.
- Build a roller coaster with two loops followed by the lift hill for the sharp turn at the end.

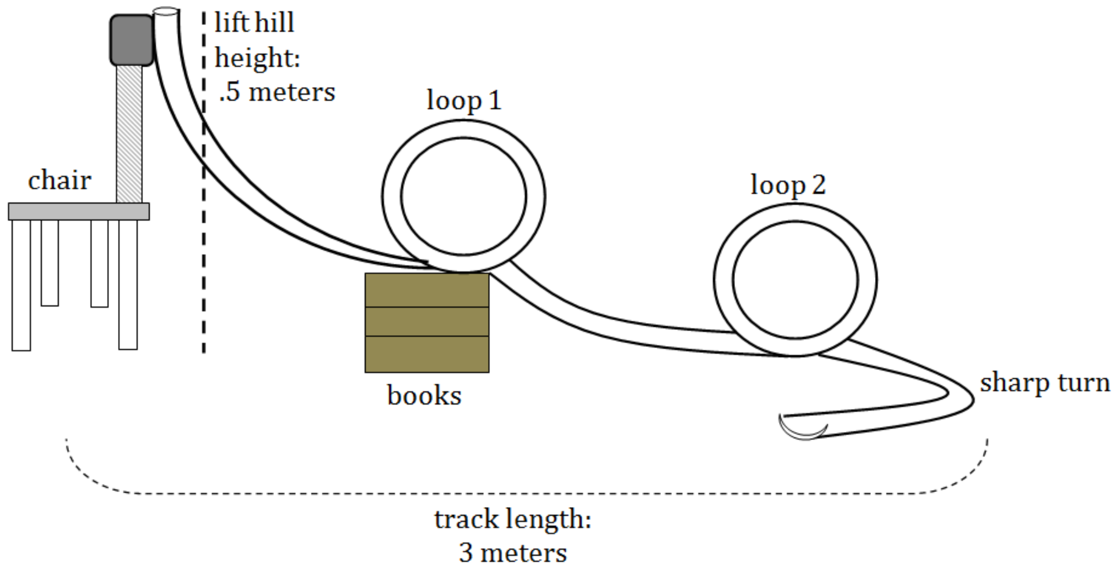
If teams have difficulty choosing a course of action based on their possible solutions, discuss the possible solutions together as a class to help the class group-think which types of solutions would have the greatest likelihood of success and why. If teams feel confident with the possible solutions they have generated, teams independently choose which of their ideas would have the greatest likelihood of success as their solution before proceeding.

Checkpoint #2: After Possible Solutions
As teams are ready, they should check in with the teacher to review the possible solutions for the problem. Do the lab notebooks of each team member match and meet expectations? Can students explain their reasoning for the possible solution they chose given the available materials? If not, ask for areas of clarification or correction before they advance further.

Diagram and Build Prototype

Students draw a scientific diagram of their prototype roller coaster. All diagrams should be titled and include labels of materials used. Students follow their prototype diagram when building.

Roller Coaster Prototype 1



<u>Checkpoint #3</u>: After Diagram (Before Materials Are Collected to Build)
As teams are ready, they should check in with the teacher to review their prototype diagram before accessing materials to build. Are the diagrams complete? Diagrams should be titled and materials labeled. Can you understand the diagram? Could you follow it to build the prototype? If not, clarify expectations. Students make corrections or any modifications and return to the checkpoint for the go-ahead. After meeting this checkpoint, students collect the materials they need and then build their prototype based on their diagram.

Notes for Materials: Teams can bend the track sections and should avoid cutting them unless necessary. Use duct tape to hold pieces together. Teams may be allowed the use of books, chairs, and/or desks to achieve the desired height for their prototype coasters to build the most potential energy. It may be helpful for students to begin by assembling a simple coaster with one loop using 2-3 tracks before attempting a prototype with all features (2 loops and 1 sharp turn). Differences in team designs and approach are expected and encouraged.

Test

Teams test their prototype roller coasters using one marble and measuring tape. Teams develop a simple test procedure for their coaster. An example test procedure is shown below:

1. Measure the length and height of the roller coaster.
2. Release a marble (roller coaster car) at the starting point of the track and observe how the marble moves through the loops and the sharp turn.
3. Repeat Step 2 several times for continued observation.

Checkpoint #4: After Test Procedure

As teams are ready, they should check in with the teacher to review their prototype test procedure. Can you follow each team's test procedure? Is it clear, concise, and specific? Will it test the prototype to see how well it solves the problem? If not, clarify expectations. Students make corrections or any modifications and return to the checkpoint for the go-ahead. Students pick up blank data tables and graphs (if applicable) to tape inside their notebooks at this checkpoint.

Teacher Tips: If some teams find their marbles are running out of speed, ask questions to help them examine where their designs may be losing energy (areas of the track that are long and straight, climbing track, many loops in a row, etc.). Ask teams what they could do to add more potential energy to the marble at the start of the track (they would need to raise the maximum height of the coaster track where the marble is first released).

The photo shows a track length with two loops taped to a table surface.

Data

Students record observational data for their prototype roller coasters. Photocopy and distribute blank data tables to save time.

Table 1: Prototype Roller Coaster Test Data				
Prototypes	Track Length (meters)	Track Height (meters)	Features	Observations
1	3	.5	2 loops 1 sharp turn	The marble did not have enough speed to complete the second loop.
2	5	1.25	2 loops 1 sharp turn	The marble completed both loops but was too slow to complete the sharp turn.
3	5	2.5	2 loops 1 sharp turn	We increased the height of the top of the track to give the marble more potential energy. We made the loops smaller in diameter. The extra potential energy from the track height and the small loops helped the marble move through each loop and the turn at the end without falling off the track.

NOTE: Example data represent one possible outcome. Team data will vary.

Refine or Replicate

Teams revise their prototypes to make modifications if their first prototype became damaged, unstable during testing, or did not meet the feature requirements. Teams can test and record results for up to three different prototypes. Teams can collaborate with other teams to share ideas if needed and revise their first prototype diagram to make the necessary changes. Students use their new diagram as a guide for building their second prototype.

When the prototype testing is complete, students should be prepared to explain how well their prototypes met the criteria of the problem within the constraints. Their explanation should include how their modifications positively or negatively affected their prototype's ability to safely carry the marble through the features of the track, and it should be supported with data (evidence) from their data table. This information should then be used to explain how well the prototype solved the problem, and if students would refine or replicate any of their prototype designs based on the data.

For example: "We engineered a new prototype roller coaster to help the amusement park attract new visitors. Our first prototype had a maximum height of .5 meters at the top of the track and a length of 3 meters. The track had two loops and one sharp turn, but the marble (roller coaster car) did not have enough kinetic energy to complete the second loop in the track. In our second prototype, we increased the height of the top of the track to 1.25 meters to give the marble more potential energy and increased the length of the track to 5 meters. In this prototype, the marble completed both loops but had very little speed to complete the sharp turn at the end of the track. In our third and most successful prototype, we changed the track in several ways to give the marble the most potential energy: we made the loops a smaller diameter and increased the height of the track to 2.5 meters. The marble had more potential energy to complete the loops and the sharp turn without falling off the track. Given the test results, we would recommend our third prototype for replication because it met the criteria of the problem with the available materials."

<u>Final Checkpoint</u>: After Data and Refine or Replicate
As teams are ready, they should check in with the teacher to review the data and refine or replicate steps of their lab. One team member reads the team's refine or replicate conclusion aloud to you while you review the other team member's lab notebook. Do they restate the problem and describe the prototype technology? Did they make a claim about whether the technology should be refined or replicated? Look for key data points that students gathered from their test data to support their recommendation to refine or replicate. Is it clear? Is it persuasive? Do the data support the claim?

<u>Wrap-Up</u>:

1. Have a dialogue with students to review results of their roller coaster prototypes. For example:

- Ask students from one team how their roller coaster prototype addressed the problem presented by the amusement park. [*The prototype should have met the criteria—the marble could safely travel around the track and the track had the specific requirements of two loops and one sharp turn.*]
- Ask students from another team to present their prototype and conclusion to the class, including their key test data that supports their recommendation to refine or replicate.
- Ask students from the same team what challenges they faced in designing their roller coaster prototypes. [*Answers will vary. Students should reflect on the cause-and-effect relationship between the structure of their prototype and how well the*

marble could travel through it. One common challenge is not making the first hill high enough so the marble has enough energy to carry through the rest of the track. One at a time, provide students from other teams the opportunity to discuss their own challenges and how they overcame them.]

2. Continue the dialogue with students, reviewing how engineers can design solutions that fill a societal need. For example:

- Ask one student why engineers who design roller coasters like to include the loop-the-loops. [*The loop-the-loops are exciting and fun for riders, which is why they are popular designs for roller coasters.*]
- Ask another student what causes the loop-the-loops to feel so exciting. [*The loop-the-loops use inertia and a steady change of direction to make riders feel excited.*]

Unit 6: Lesson 2 – Sample Laboratory Notebook
This complete lab notebook entry is intended to be used as an exemplar for teacher use only. It is not intended for student use.

Page
Engineering Roller Coasters, Date, Partner Name

Lab 8: Engineering Roller Coasters

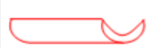
Problem: An amusement park needs to attract new visitors to its park with a new, exciting roller coaster.

Criteria:
- The new roller coaster must be safe (the coaster cannot fall off the tracks).
- The roller coaster must have two loops and at least one sharp turn.

Constraints:
- materials

Research: Gravity, friction, and drag are three forces that act on a roller coaster car. As the roller coaster cars move up a hill in the track, they gain gravitational energy. That energy changes to mechanical energy as the cars begin to move down the hill. Friction and drag are two forces that transfer energy out of the roller coaster system as it moves over the track, causing the cars to slow down.

Survey Available Materials:

Materials Survey Chart				
Name	**Quantity**	**Sketch**	**Made From**	**Properties**
roller coaster track	10		foam	bendable, hollow with grooves
dowels	2		wood	long, thin and rigid

List Possible Solutions:
- Build a roller coaster with one lift hill followed by two loops and a sharp turn.
- Build a roller coaster with a lift hill between two loops.
- Build a roller coaster with two loops followed by a lift hill for the sharp turn at the end.

Unit 6: Lesson 2 – Sample Laboratory Notebook

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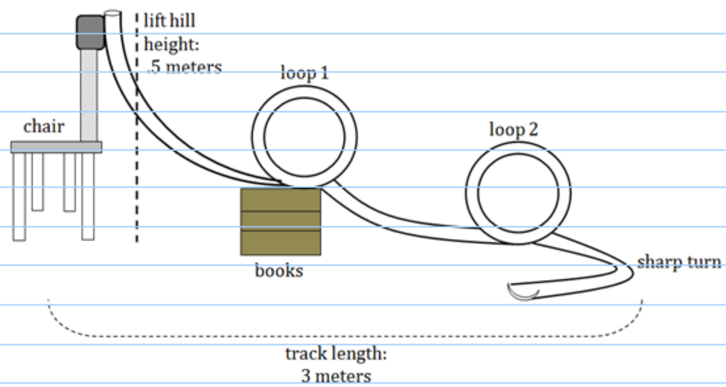
Scientific Diagram:

Roller Coaster Prototype 1



Test:

1. Measure the length and height of the roller coaster.
2. Release a marble at the starting point of the track and observe how the marble moves through the loops and the sharp turn.
3. Repeat Step 2 several times for continued observation.

Data:

Table 1: Prototype Roller Coaster Test Data

Prototypes	Track Length (meters)	Track Height (meters)	Features	Observations
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Unit 6: Lesson 2 – Sample Laboratory Notebook

This complete lab notebook entry is intended to be used as an exemplar for teacher use only. It is not intended for student use.

Refine or Replicate: We engineered a new prototype roller coaster to help the amusement park attract new visitors. Our first prototype had a maximum height of .5 meters at the top of the track and a length of 3 meters. The track had two loops and one sharp turn, but the marble (roller coaster car) did not have enough kinetic energy to complete the second loop in the track. In our second prototype, we increased the height of top of the track to 1.25 meters to give the marble more potential energy, and increased the length of the track to 5 meters. In this prototype, the marble completed both loops but had very little speed to complete the sharp turn at the end of the track. In our third, and must successful prototype, we changed the track in several ways to give the marble the most potential energy: we made the loops a smaller diameter and increased the height of the track to 2.5 meters. The marble had more potential energy to complete the loops and the sharp turn without without falling off the track. Given the test results, we could recommend our third prototype for replication because it met the criteria of the problem with the available materials.

Unit 6: Lesson 1 – Blank Survey Chart and Blank Data Table

Materials Survey Chart				
Name	**Quantity**	**Sketch**	**Made From**	**Properties**
roller coaster track	10			
dowels	2			

Table 1: Prototype Roller Coaster Test Data				
Prototypes	Track Length (meters)	Track Height (meters)	Features	Observations
1				
2				
3				

Name: ______________________________ Date: ____________

Unit 6: Energy and Forces on Earth

Vocabulary Check

Directions: For questions 1-5, circle the best answer.

1. Energy stored in the bonds of atoms and molecules is called ________________________.

A. chemical energy　　B. mechanical energy

C. gravitational energy　　D. potential energy

2. ________________________slows motion because it transfers energy out of an object or system, turning mechanical energy into heat whenever two objects rub against each other.

A. Energy　　B. Potential energy

C. Mechanical energy　　D. Friction

3. ________________________ is a form of kinetic energy because it is the energy of a substance or system due to its motion.

A. Gravitational energy　　B. Chemical energy

C. Mechanical energy　　D. Potential energy

4. Any change in position, speed, or state of matter due to force is called ________________________.

A. work　　B. potential energy

C. friction　　D. mechanical energy

5. Any push or pull that acts on an object, changing its speed, direction, or shape, is called a(n) ________________________.

A. force　　B. friction

C. drag　　D. energy

Name: ____ Date: ______________

Unit 6: Energy and Forces on Earth

Concept Check

Part I: For questions 1-2, circle the best answer.

1. A ball is thrown into the air. In a perfect system, if no outside forces acted on the ball, how would you describe the ball's motion after it's thrown? (Outside forces include gravity, drag, and friction.)

A. A force would have to act on the ball to keep it moving in the air.
B. The ball will continue to move in the same direction and speed until another force acts on it.
C. The ball will continue to move in the same direction and speed until the force from the throw wears out.
D. none of the above

2. Once a ball is thrown in the air, it always falls back to the ground. What is the cause of this?

A. Gravity causes the ball to fall to the ground.
B. Inertia causes the ball to fall to the ground.
C. The ball eventually falls to the ground because it runs out of energy.
D. none of the above

Part II: Use the space below each question for your answer.

3. Jaylen likes to ride her skateboard with her friends in the neighborhood. One of her friends set up a ramp on the street to ride down. When Jaylen and her friends ride down the ramp, they can travel half way down the street without pushing off the ground. When Jaylen rides down a flat street, she has to push off the ground with her feet to keep moving forward.

3a. How does Jaylen form an energy system with her skateboard when she rides down a <u>flat</u> street in her neighborhood? Include inputs and outputs of energy in your answer.

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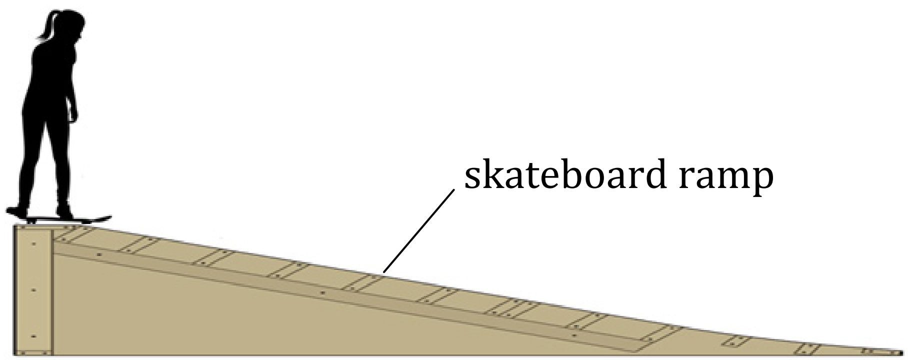
3b. Jaylen and her friends want to improve their skateboard ramp. They want to use the ramp to ride the full length of the street, without having to push off the ground with their feet to stay in motion. Use what you know about potential and kinetic energy to describe what Jaylen and her friends should do to the ramp to help them travel a farther distance down the street on their skateboards.



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4. During a technology class, Eric was asked to design and make his own roller coaster using foam tubes and duct tape. After making his roller coaster, Eric was asked to record how he made it so that another student could make the same type of roller coaster following the same design.

4a. Describe two different methods that Eric could use to record how he made his roller coaster so that another student could make the same type of roller coaster.

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4b. Explain how each method you described in part (a) could help another student replicate Eric's roller coaster design.

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5. Snakes do not have legs so they must use their muscles to move along the ground on their smooth underbellies.

5a. Which type of surface would you expect a snake to move faster on, a smooth, plastic floor or a rough, sandy beach? Why?

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5b. After looking at snakes with very fast cameras, scientists discovered that snakes create friction with their scales to help them move. Why would friction help a snake move?

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Part III Teacher Note

This assessment asks students to investigate how the mass of a winter sled affects how much force is needed to move it. This assessment is applying the concepts of force and motion to a new context, using a similar structure to the scientific process. This type of assessment may be new to your students. Materials and pre-assembled paper plate sleds from Lesson 1 can be reused in the assessment to help students visualize how the data was collected in the scenario, if needed.

There are several ways for students to complete this assessment depending on the level of your students. For example, the assessment can be worked through as an entire class, using the materials from Lesson 1 to replicate the experiment, with students just graded on specific questions. Or students can use materials from Lesson 1 to model the experiment presented in the assessment with a partner, or individually, and then answer the remaining questions independently.

Part III: Read the Winter Sleds scenario, and then answer the questions that follow.

Word Bank
mass - a measure of the amount of matter that makes up an object; measured in grams (g)
force - a push or pull that acts on an object, changing its speed, direction, or shape

Winter Sleds

In the winter, Roger and his friend Harry like to sled down a tall hillside in their neighborhood. Roger likes to use an old wooden sled that belonged to his grandfather. The wooden sled is very heavy. Harry uses a light, plastic sled to slide down the hill.

Roger's wooden sled

Harry's plastic sled

One day while they were sledding, Roger noticed that in order to travel the same distance down the hillside, he needed several people to push his sled at the top of the hill to get it moving. Harry could get his sled moving on his own. Roger was curious if the mass of his sled had something to do with the amount of force needed to move it.

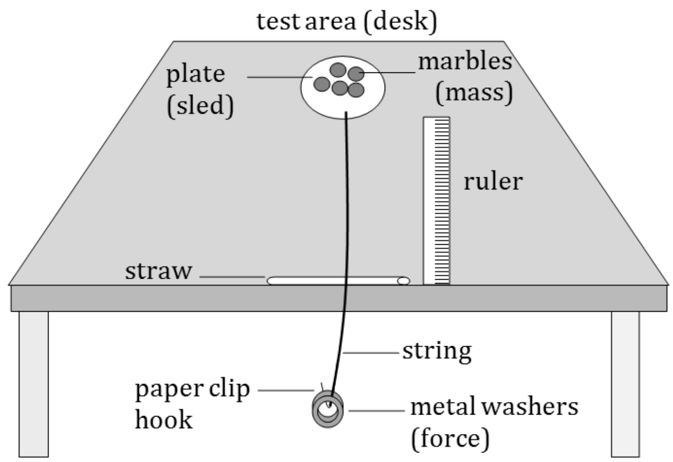
Roger shared his observations with his science class. Some of the students thought that the mass of his sled was responsible for how much force was needed to move it down the hill, but some students did not agree.

Roger's science teacher asked the class to think of a question they could investigate like scientists to help them find out if the mass of the sled affected the amount of force needed to move it. So the class came up with the following question for their experiment.

How does the mass of a winter sled affect how much force is needed to move it?

Roger's class used the following materials to set up a model to investigate the question:

- 15 marbles
- 10 washers
- 1 desk surface
- 1 paper plate (sled) with string and paper clip hook attached
- 1 ruler
- 1 straw



experiment set-up diagram

Making a Prediction

1. Use information from the story and what you know about forces and motion to write a prediction for the question in the spaces below. TIP: This question is most similar to the hypothesis in the scientific process.

Question: How does the mass of a winter sled affect how much force is needed to move it?

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2. Explain your reasoning for your prediction in the spaces below.

Testing the Model

Roger's experiment compared how many washers it takes to move a plate with 5, 10, and 15 marbles across his desk, using the experiment set-up diagram shown earlier. He tested each plate for three separate trials.

Here is Roger's test procedure:

1. Position the plate 16 centimeters behind the straw on the desk with the string over the straw, hanging off the desk edge.
2. Put 5 marbles on the plate. Add metal washers to the paper clip hook on the string, one at a time, until the plate starts moving across the desk. Record the number of washers that moved the plate to the edge of the desk.
3. Repeat steps 1-2 for two more trials.
4. Repeat steps 1-3 for two more tests, first with 10 marbles on the plate and then 15 marbles on the plate.

Analyze Data

The data Roger collected from the experiment is listed on the following page.

Table 1: Comparing the Force Needed to Move a Sled With Different Masses (marbles)			
	Number of Washers to Move Plate		
	Plate with 5 Marbles	**Plate with 10 Marbles**	**Plate with 15 marbles**
Trial 1	2	3	4
Trial 2	2	3	4
Trial 3	2	3	4
Average Number of Washers	2	3	4

3. Describe any patterns you notice in Rogers's data.

4. Look at the prediction and explanation you wrote for Questions 1 and 2. Now look at the data in Table 1.

Do Roger's data support your prediction and explanation?

☐ Yes ☐ No

Explain how the data did or did not support your explanation. TIP: This question is most similar to the **conclusion** in the scientific process.

5. Roger asked Harry if he had any ideas for ways he could make his wooden sled move faster down the hill. Harry told Roger to rub the bottom of his sled with rough sand paper to make it smoother. Explain why Harry's suggestion could help Roger's sled move faster down the hill.

Unit 6: Appendix 1
Answer Keys

Vocabulary Check

1. A. chemical energy [Energy stored in the bonds of atoms and molecules is called chemical energy. Because it is a kind of stored energy, chemical energy is one kind of potential energy. Gravitational energy is another form of potential energy because it is the energy stored in an object as a result of its vertical position or height. Mechanical energy is a form of kinetic energy because it is the energy of a substance or system due to its motion.]
2. D. Friction [Friction slows motion because it transfers energy out of an object or system, turning mechanical energy into heat whenever two objects rub against each other. Energy is the ability to do work. Mechanical energy is the energy of a substance or system due to its motion and potential energy is energy that is stored.]
3. C. Mechanical energy [Mechanical energy is a form of kinetic energy because it is the energy of a substance or system due to its motion. Gravitational energy is the energy stored in an object as a result of its vertical position or height. Chemical energy is energy stored in the bonds of atoms and molecules. Potential energy is any form of energy that is stored.]
4. A. work [Any change in position, speed, or state of matter due to force is called work. Friction slows motion because it transfers energy out of an object or system, turning mechanical energy into heat whenever two objects rub against each other. Mechanical energy is the energy of a substance or system due to its motion. Potential energy is any form of energy that is stored.]
5. A. force [Any push or pull that acts on an object, changing its speed, direction, or shape, is called a force. Drag is a kind of force similar to friction, but it occurs between a solid substance and a fluid such as air. Friction slows motion because it transfers energy out of an object or system, turning mechanical energy into heat whenever two objects rub against each other. Energy is the ability to do work.]

Concept Check

Part I

1. B. The ball will continue to move in the same direction and speed until another force acts on it. [If a ball is thrown into the air and friction and drag did not exist, the ball would continue to move in the same direction and speed until another force acts on it. This scenario could never happen on Earth because there are multiple forces that act on the ball all the time. Gravity is constantly pulling down on it, and drag transfers energy out of the ball, causing it to slow down. However, this question assesses how well students understand the basics of inertia, which states that an object in motion will remain in motion and an object at rest will remain at rest unless acted on by an outside force. Students sometimes think that a constant force has to be applied to an object for it to maintain its motion, but this isn't true.]
2. A. Gravity causes the ball to fall to the ground. [When a ball is thrown in the air, it always falls back to the ground because of gravity, which is a force of attraction between all matter. Earth's gravity pulls all objects on or near Earth's surface down to Earth's center. Inertia doesn't cause the ball to fall to the ground. Inertia isn't a force, so it doesn't cause an object's motion to change. Instead, it describes the tendency of objects to keep doing what they're doing until an outside force changes their motion.]

Part II

3. This question assesses how well students understand basic energy systems and how energy can change from one form to another within an energy system.

3a. [Jaylen forms an energy system with her skateboard because they make up a set of connected parts that change an input of energy to a different output of energy. When Jaylen pushes off the ground with her foot, she applies a force to the ground that transfers an input of mechanical kinetic energy from her leg to the skateboard. This causes the skateboard to move forward, which is an output of mechanical kinetic energy.]

3b. [Jaylen and her friends could increase the height of their ramp in order to increase how far they travel down the road. The higher the ramp is, the more gravitational potential energy Jaylen has at the top of the ramp. When Jaylen moves down the ramp, that potential energy is transferred to mechanical kinetic energy, which allows her to travel farther than she did before when the ramp was lower.]

4. This question assesses how well students understand the purpose of the engineering process.
4a. [The answer should describe steps in the engineering design process, such as making a prototype diagram and listing the steps for testing.]
4b. [Using the same examples as above, the prototype diagram would provide information about where each material should go, as well as measurements and how the materials fit together. The testing procedure would allow the student to determine if the replicated roller coaster works as well as Eric's original.]
5a. [This question asks students to make a prediction about whether a snake can move faster on a smooth plastic floor or a rough sandy beach. The most important part of this response is that students come up with an argument that supports their claim. For example: The snake should travel faster on the smooth plastic floor because there would be less friction between the smooth underbelly of the snake and the surface. Or the student could argue: The snake should travel faster on the rough sand in the same way that it's easier for people to walk across sand than ice.]
b. [The answer should explain that friction can help the snake hold onto many kinds of surfaces or have better control over its movement. Students may also explore how when they try to walk across a smooth surface like ice, they slip and slide a lot, making it much harder to move.]

Part III

This assessment asks students to investigate how the mass of a winter sled affects how much force is needed to move it. This assessment is applying the concepts of force and motion to a new context, using a similar structure to the scientific process. This type of assessment may be new to your students. Materials from Lesson 1 can be reused in the assessment to help students visualize how the data was collected in the scenario if needed.

There are several ways for students to complete this assessment depending on the level of your students. For example, the assessment can be worked through as an entire class, using the materials from Lesson 1 to replicate the experiment with students just graded on specific questions. Or students can use materials from Lesson 1 to model the experiment presented in the assessment with a partner, or individually, and then answer the remaining questions independently.

1. By developing a prediction about how the mass of a winter sled affects how much force is needed to move it, students are partially assessed on the science and engineering practice of **Asking Questions and Defining Problems**. Students are also partially assessed on the disciplinary core idea of **Forces and Motion** and the crosscutting concept of **Cause and Effect**.
   - Student answer should demonstrate an understanding of how questions guide an investigation. In this example, the prediction should demonstrate that students understand what the investigation is seeking to show—how the mass of an object affects how much force is needed to move it. It should also demonstrate an awareness of the scientific principles that will help to answer the question. The prediction is most similar to the hypothesis in the scientific process, which is a clear and concise statement that can be proved true or false, and it should be a declarative sentence that does not include personal pronoun words like "my" or "I think."
     - For example: "The more massive a winter sled is, the more force will be needed to move it."
     - "The more massive a winter sled is, the less force will be needed to move it."
     - "The mass of a winter sled has no effect on the amount of force needed to move it."
2. Students are partially assessed on the science and engineering practice of **Constructing Explanations and Designing Solutions**, as well as the disciplinary core idea of **Forces and Motion** and the crosscutting concept of **Cause and Effect** as they explain their prediction, using what they know about the relationship between forces and motion. There is no "right" answer here. The goal is to have students thinking through their prediction and applying their scientific knowledge about forces and motion to support their prediction.
     - For example: It is harder to move more massive objects than it is to move less massive objects. This is because more force is required to move objects with more mass.

3. By analyzing whether the data reveal any patterns, students are partially assessed on the science and engineering practices of **Using Mathematics and Computational Thinking** and **Analyzing and Interpreting Data**, and the crosscutting concept of **Patterns**.
     - For example: There is a predictable pattern in the data showing a relationship between the mass of the plate and the number of washers needed to move the plate. The more massive the sled is

(the more marbles it has), the more washers are needed to move it.

4. By using the data provided in Table 1 to analyze their prediction and explanation, students are partially assessed on the science and engineering practices of **Constructing Explanations and Designing Solution** and **Engaging in Argument from Evidence**.
   - Student response should demonstrate an understanding of how to use evidence (data) to support or refute a prediction or claim.
   - Student response should restate their prediction (from Question 1), identify whether the results of the experiment support or do not support the prediction, and explain their reasoning, using key data points from the tables. The response should demonstrate a similar level of detail and reasoning:
     - "**The data supported the prediction**: Our hypothesis—that the more massive a winter sled is, the more force will be needed to move it—is true. Our data show that as the mass of the sled increases, the number of washers needed to move the sled also increases. The sled with 5 marbles moved with 1-2 fewer washers on average than the more massive sled with 10 and 15 marbles. We can conclude from this investigation that the amount of force needed to move an object depends on the object's mass."
     - "**The data did not support the prediction**: Our hypothesis—that the more massive a winter sled is, the less force will be needed to move it, ***or*** that the mass of a winter sled has no effect on the amount of force needed to move it—is false. Our data show that as the mass of the sled increases, the number of washers needed to move the sled also increases. The sled with 5 marbles moved with 1-2 fewer washers on average than the more massive sled with 10 and 15 marbles. We can conclude from this investigation that the amount of force needed to move an object depends on the object's mass."
5. By analyzing how sanding the bottom of the wooden sled to make it smoother would make the sled faster, students are partially assessed on the science and engineering practice of **Engaging in Argument from Evidence**, as well as the disciplinary core idea of **Types of Interactions** and the crosscutting concept of **Cause and Effect**.
   - Student response should demonstrate an understanding of how forces affect motion, specifically how friction slows motion by turning mechanical energy into heat.

- For example: If Harry sands the bottom of the sled, it will make it smoother. This will reduce the amount of friction produced as the sled moves over the snow. This will help the sled move faster because friction is a force that transfers energy out of the object or system. Friction causes mechanical energy to transfer out of the sled, which makes the sled move slower because it has less mechanical energy. If the bottom of the sled is smoother and there is less friction, the sled will have more mechanical energy so it can move faster.

Student Reader Answer Key

The section review questions at the end of each section in the reader are designed to use Common Core ELA standards to advance student comprehension of the student reader. Students can answer these questions independently or they can be discussed as a class before the Socratic dialogue portion of the lesson.

Section 1 Reading Comprehension Questions

1. [The main idea of Section 1 is to describe how energy changes as it moves through different energy systems.]
2. [The text goes into detail about the Iditarod, using the dogs that pull the sleds as an example of one energy system, and the dogs plus the sled and the person as another energy system.]
3. [The text explains that the Iditarod has rules about how many dogs can pull a sled because the more dogs there are attached to the sled, the more force they will produce to pull the sled. This means they will be able to transfer more energy to the sled and make it move faster. A team of 30 dogs would be able to move the sled much faster than a team of 6 dogs.]
4. [A dog is a complete energy system because it needs inputs of energy, which it gets from food, to carry out its life functions. These life functions need energy, and the dog's body stores some of that energy. It turns the rest of it into different forms of kinetic energy, such as mechanical energy to move. A dog is also part of a larger energy system made up of other dogs, the sled, and a person because the dogs together provide the input of mechanical kinetic energy that transfers to the sled and causes the sled to gain mechanical kinetic energy as it begins to move.]
5. [The text explains the connection between forces and motion because an object can only change its motion when a force transfers energy into or out of it.]

Section 2 Reading Comprehension Questions

1. [One main idea of Section 2 is that roller coasters use the force of gravity to move. This idea is supported with a detailed description of the roller coaster track and how it is designed so that gravitational energy can change into mechanical energy as the cars move over the track.

Another main idea is that engineers design roller coasters with inertia in mind. Inertia causes changes in acceleration and deceleration throughout the ride.]

2. [This section connects back to the first section's main idea of forces and motion because roller coasters have different forces acting on them, and it is how these forces interact that give riders the thrills of a roller coaster.]
3. [The text talks about Chris Gray because he is an engineer who designs roller coasters, and that is the main point of the section.]
4. [Roller coasters are a kind of technology because they are designed by humans to fulfill a need or want. Roller coasters are designed to give people an exciting ride.]
5. [Engineers who design roller coasters need to know about forces because nothing can move without forces. Also, as the roller coaster cars move over the track, different forces act on them in different ways, and it is these interactions that make the roller coaster exciting and thrilling to the riders.]

Unit 6: Appendix 2
Common Core Connections

The following Common Core standards are covered in this unit. Questions for the *Reading Informational Texts* standards provide an example of a question that links to a specific ELA standard. Additional questions are included in the section reviews. These types of questions can also be used with other texts. Other ELA and math standards are covered as students work through the reading, class dialogue, and hands-on portion of the lessons.

ELA Standards	Applying ELA Connections to the Student Reader
Reading Informational Texts	
RI.5.1. Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from the text.	• What does Section 1 say explicitly about the relationship between force and energy? What can you infer about how force relates to motion? [*The text says explicitly that force is needed to transfer energy into or out of a system. Given that energy is needed to change matter in any way, we can infer that force is necessary to cause motion.*]
RI.5.2. Determine two or more main ideas of a text and explain how they are supported by key details.	• What are two main ideas in Section 1: Forces Make Things Move? [*One main idea is that all animals form energy systems, and food provides an input of energy that their bodies change to do work, which requires an output of energy. The text uses dogs and people to support this idea. Another main idea is that forces are needed to transfer energy into or out of objects or system. The text gives the example of the dogs pulling the sled. This pulling action is a force that transfers energy to the dog sled, making the sled move.*]
RI.5.3. Explain the relationships or interactions between two or more individuals, events, ideas, or concepts in a historical, scientific, or technical text based on specific information in the text.	• How does Section 1, which discusses the relationship between forces and energy, connect to Section 2, which focuses on engineering roller coasters? [*Engineers who design roller coasters need to know all about how energy can change forms in an energy system, and the role of forces in transferring energy into or out of systems. For example, engineers need to know that friction is a force that slows motion because it transfers energy out of the system.*]

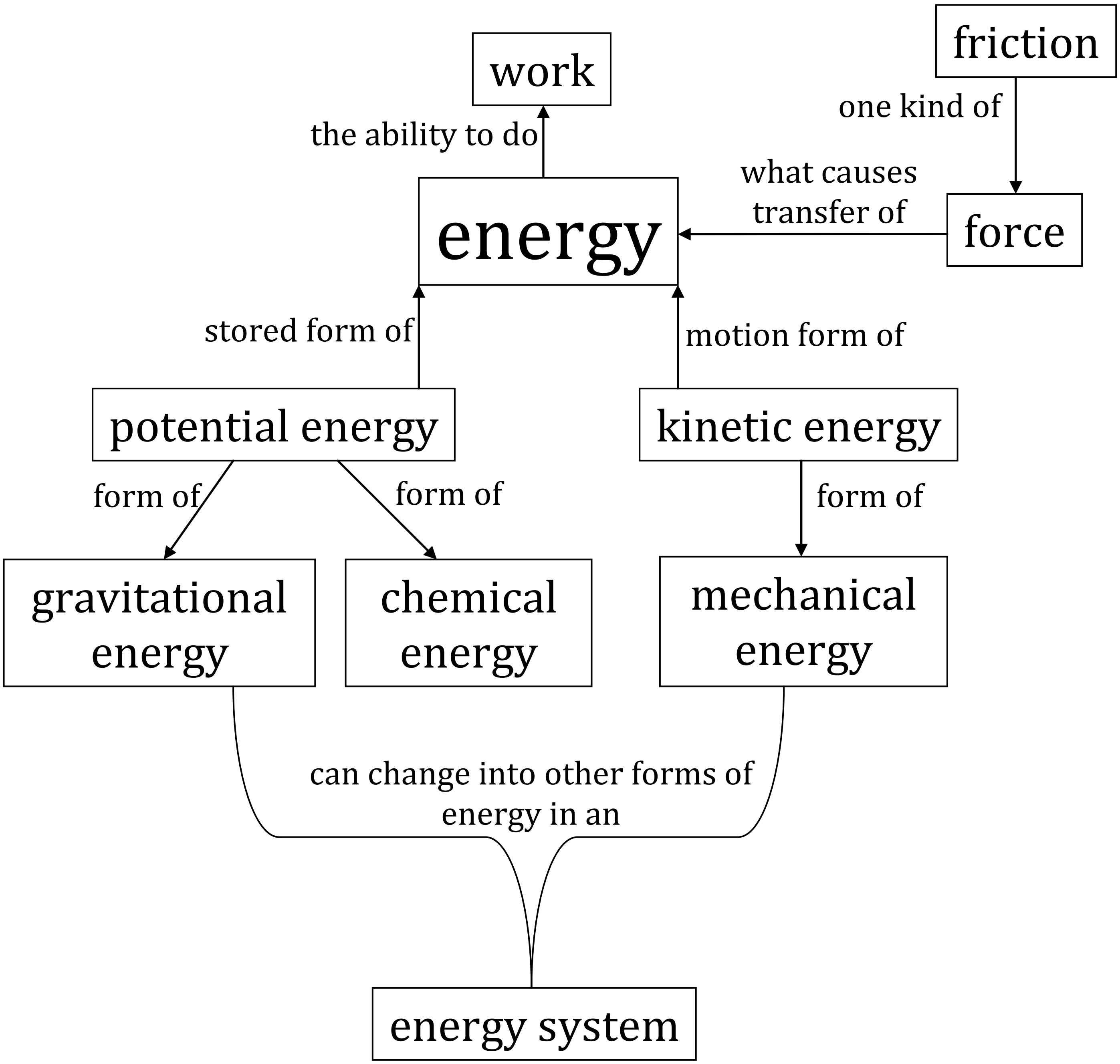
Writing	
W.5.2.E. Use precise language and domain-specific vocabulary to inform about or explain the topic.	• In Lessons 1 and 2, students use precise language and specific vocabulary in their analysis of the experiment and the engineering investigation. In Lesson 1, students use precise language as they develop the sled experiment in their lab notebooks, creating a written record of their experiments. In Lesson 2, students use precise language as they develop the roller coaster engineering lab in their lab notebooks, creating a written record of developing their roller coaster prototype.
W.5.5. With guidance and support from peers and adults, develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach.	• In Lessons 1 and 2, students practice writing in complete sentences as they communicate their findings and write a conclusion to the experiment and the engineering investigation. Because clarity and precision are essential in scientific writing, students must follow conventions of standard English grammar and usage.
W.5.9. Draw evidence from literary or informational texts to support analysis, reflection, and research.	• In both of the lessons, students use information from their readers and class dialogue to analyze the relationship between forces and motion, including evidence from the reading or their data to support their arguments.
Language	
L.5.2. Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.	• In Lesson 1, students use standard English capitalization, punctuation, and spelling as they work through the sled experiment and the roller coaster engineering investigation.
L.5.4. Determine or clarify the meaning of unknown and multiple-meaning words and phrases based on grade 5 reading and content, choosing flexibly from a range of strategies.	• Students read the student reader, expanding their scientific vocabulary and using that vocabulary to communicate with others precisely and clearly.

Speaking and Listening	
SL.5.1.A. Come to discussions prepared, having read or studied required material; explicitly draw on that preparation and other information known about the topic to explore ideas under discussion.	• In Lessons 1 and 2, students engage in Socratic dialogue before beginning the experiment and investigation. As a class, students read the reader, and then apply what they have read to new situations or real-life scenarios.
SL.5.1.B. Follow agreed-upon rules for discussions and carry out assigned roles.	• In Lessons 1 and 2, students follow agreed-upon rules during the Socratic dialogue portion of the class, as well as during the activity portion of the lesson.
SL.5.1.C. Pose and respond to specific questions by making comments that contribute to the discussion and elaborate on the remarks of others.	• In Lessons 1 and 2, students actively engage in dialogue and in the activity portion of the lesson.
SL.5.1.D. Review the key ideas expressed and draw conclusions in light of information and knowledge gained from the discussions.	• In Lessons 1 and 2, students contribute to the Socratic dialogue and the wrap-up portion of the lesson, explaining their experiences and understandings.

Use this chart to keep track of how you are connecting science to the rest of your curriculum.

Unit Connections to ELA Common Core	Unit Connections to Math Common Core	Unit Connections to History/Social Studies

<u>Unit 6: Appendix 3</u>
Sample Concept Map



Unit 6: Appendix 4
Support for Differentiated Instruction
Next Generation Science Standards

Core Expectation	Assessment Strategies	Possible Primary Evidence
5-PS2-1. Support an argument that the gravitational force exerted by Earth on objects is directed down.	Low Entry Point • Conduct simple experiments involving gravity (e.g., falling objects). At Grade-Level Entry Point • Identify gravity as the force that makes objects fall toward Earth. • Describe how an investigation could provide evidence for gravity's downward pull.	• engineering roller coasters lab notebook entry completed by student • video of student observing the downward pull of gravity by dropping different objects toward the ground
3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.	Low Entry Point • Identify a problem that needs to be solved. • Recognize that scientific knowledge can be used to solve problems. At Grade-Level Entry Point • Define the constraints of a particular problem. • Define the criteria of a particular problem. • Describe how the solution will solve the problem.	• engineering roller coasters lab notebook entry completed by student • written explanation of what the problem is • video of student verbally describing the criteria and constraints of the problem

<table>
<tr><th>Core Expectation</th><th>Assessment Strategies</th><th>Possible Primary Evidence</th></tr>
<tr><td>3-5-ETS1-2.
Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.</td><td><u>Low Entry Point</u>
Recognize that for any problem, there exist multiple solutions that could potentially solve the problem.
Recognize that some solutions will be more effective than others at solving the problem.
<u>At Grade-Level Entry Point</u>
Use a systematic method for evaluating multiple solutions.</td><td>engineering roller coasters lab notebook entry completed by student
photos of student making improvements on an existing roller coaster design so that it meets the criteria of the problem within the constraints</td></tr>
<tr><td>3-5-ETS1-3.
Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.</td><td><u>Low Entry Point</u>
Test and collect data from multiple, iterative design solutions.
<u>At Grade-Level Entry Point</u>
Identify relationships among the data collected to determine which characteristics worked well and which didn’t.</td><td>engineering roller coasters lab notebook entry completed by student
video of student testing their roller coaster prototype and deciding what works and what needs to be improved</td></tr>
</table>

Unit 6: Appendix 5
Materials Chart

	Lesson	Quantity	Notes	Used Again
Unit Kit Consumable				
Goggles	all	1 per student	safety	✓
Paper plates	1	1 per team of 2	for sled models	
String	1	60 cm per team of 2	for attaching paper clips to sleds	
Straws	1	1 per team of 2	for lab test area	
Paper sheets	1	1 per team of 2	for smooth test surface	
Paper clips	1	1 per team of 2	for hooking washers	
Roller coaster tracks (pipe insulation)	2	10 per team of 2	for designing roller coaster track	
Dowels	2	2 per team of 2	for roller coaster prototypes	
Non-Consumable				
Felt sheets	1	1 per team of 2	for rough lab test surface	
Foam sheets	1	1 per team of 2	for rough lab test surface	
Flat marbles	1	5 per team of 2	for lab sled load	
Metal washers	1	shared set	for simulating force	
Hole punches	1	shared	for assembling sled models	
Marbles (round)	2	shared set	for testing roller coasters	
Measuring tape	2	shared	for measuring roller coasters	
Teacher Tool Kit				
Rulers	1	1 per team of 2	for measuring sled test area	✓
Scissors	1, 2	1 per team of 2	for cutting materials	✓
Invisible tape	1	1 per team of 2	for test area set-up	✓
Duct tape	1	shared rolls	for building roller coasters	✓
Hand-outs				
Laboratory notebooks	1	1 per student	for Lab 7 and Lab 8	
Student readers	1, 2	1 per student		
Visuals	Download			
Lesson 1	Forms of Energy Visual, Energy Systems Visual, Forces on a Dog Sled Visual			
Lesson 2	Gravity on Roller Coasters Visual, Interacting Forces Visual			

