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# Energy and Forces on Earth

UNIT 6

## Student Reader

## Front Cover:

The front cover shows a photograph of a team of dogs pulling a dog sled across the snow.

 

# Unit 6: Energy and Forces on Earth

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# 1 Forces Make Things Move

## *Sledding Across Alaska*


***Martin Buser is standing on the left.***

Martin Buser is a champion dog sled racer. Since 1980, he has competed in the Iditarod (pronounced eye-DIT-a-rod). The Iditarod has been called "the last great race on Earth." It covers 1,609 kilometers (1,000 miles) of wild, snowy trails. It begins in Anchorage, Alaska. The race is intense. It can take 8 to 13 days. Racers may face blizzards and below-zero temperatures.

***This team of dogs is racing in the Iditarod.***

Martin has finished 29 Iditarod races. He has such a passion for the race that he named his two children after checkpoints in the race: Nikolai and Rohn. He also runs a kennel, called Happy Trails Kennel. This kennel raises and trains dogs to race.

# *Eating on the Trail*

Both the driver of the dog sled and the dogs have to prepare for months before they are ready to run in the Iditarod.

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.

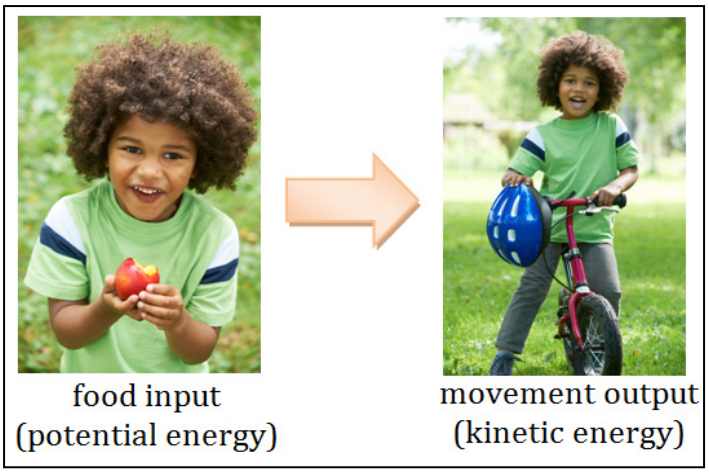
Dogs need between 10,000 and 12,000 calories a day to help pull the sled. Calories are the measure of energy that fuels your body.

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

***This dog eats to gain chemical energy from the food.***

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. For example, mechanical energy is one form of kinetic energy. **Mechanical energy** is the energy of a substance or system due to its motion.

We can understand how dogs use energy by thinking of all animals 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 potential energy). Your body stores some of that energy. 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 or your muscles to move. These actions are all outputs of kinetic energy.

# *Making the Sled Move*

The dogs that pull the sled form are part of an energy system that includes the dogs, the sled, and the driver of the sled. This person is called a musher.

The number of dogs on a team is important. Every sled is pulled by a team of 12 to 16 dogs. It takes a large amount of force to pull a grown adult, as well as their supplies, across the ground. A **force** is a push or pull that acts on an object, changing its speed, direction, or shape. Force is always necessary to transfer energy into or out of a system.

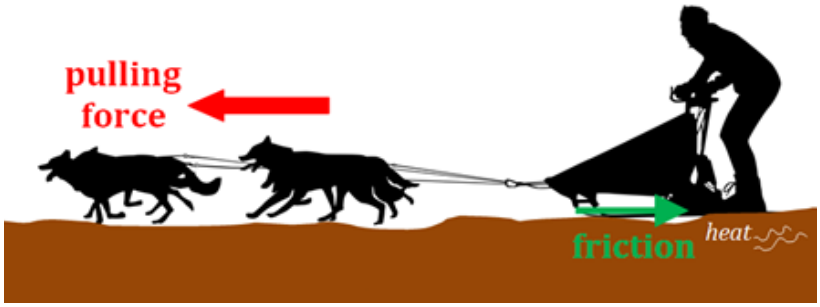
***These dogs apply a force to the sled, causing it to move.***

Picture a dog sled. If nothing pushes or pulls the sled, it cannot move. 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.

# *Transferring Energy*

Energy is never created or destroyed. But it can be changed from one form to another. It can also transfer into or out of an object or system.

For example, in a perfect system, a moving sled will have the same amount of energy as the energy that the dogs transferred to the sled. But 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 when two objects rub against each other by turning mechanical energy into heat. Friction is why your hands feel hot after you rub them together.




***Friction is a force that turns mechanical energy into heat.***

We know that energy is not destroyed as a result of friction. Instead, it transfers out of the system. The heat around the object tells us that energy has transferred out of the system.

# *The Speed of the Sled*

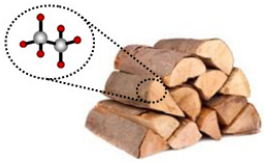
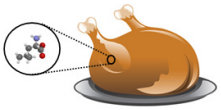
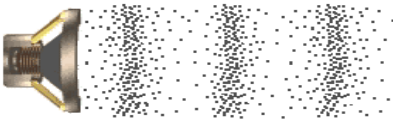
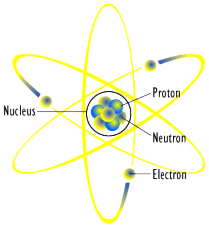
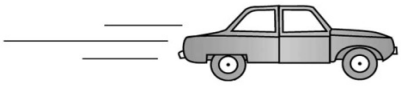
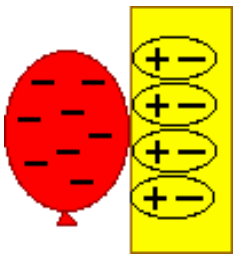
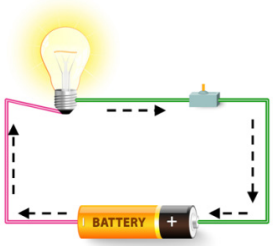
Friction is the main reason that dog sleds work well in the snow but not on rougher surfaces like grass or gravel. Snow and ice are much smoother than other surfaces. This means there is less friction that occurs when objects like sleds move over the snow.

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.

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 dogs would be able to move the sled much faster than a team of 6 dogs.

# Forms of Energy

| Potenial 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)   |

# Section 1 Review

**<u>Reading Comprehension Questions</u>:**

**1.** What is the main idea of Section 1?

**2.** What key details does the text provide to support the main idea of the text?

**3.** How does the text explain why the Iditarod has rules about how many dogs can pull a sled?

**4.** How can a dog be a complete energy system and also part of a larger energy system that includes other dogs and a sled?

**5.** How does the text explain the connection between forces and motion?

# 2 Engineering a Roller Coaster

## *Designing Roller Coasters*

From the time he was 8 years old, Chris Gray knew what he wanted to do. He wanted to design and build roller coasters that would be so thrilling people would scream as they moved up and down on the ride.

As a young person, Chris started out building model roller coasters. Today, he is a mechanical engineer. He designs roller coasters that are built around the world. He was involved in 7 of the world's top 25 wooden roller coasters.

***Engineers design roller coasters.***

# *Using Forces in a Ride*

People who design a roller coaster need to know about forces and motion. Roller coasters work because of gravity. Remember that gravity is a force that attracts all matter, and Earth's gravity pulls down on all objects on Earth's surface.

Let's begin with the basic structure of a roller coaster. All roller coasters are made up of connected cars that move on tracks, like trains do. But unlike 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. **Gravitational energy** is the energy stored in an object as a result of its vertical position or height.

***At the top of the hill, the roller coaster cars have the most gravitational energy.***

The higher up an object is, the more gravitational potential energy it has stored. As soon as those roller coaster cars begin to move downhill, that gravitational energy changes to mechanical kinetic energy.

As the cars move around the track, energy is constantly changing between potential and kinetic energy.

The first hill on a roller coaster has to be the highest. This is 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 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 system. This means that the roller coaster has less energy at the end of the ride than it does at the start of the ride.

# *Designing the Tracks*

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 so riders will feel the thrill of the forces. Remember that engineers use scientific knowledge and mathematics to solve problems by creating new technologies.

First, engineers know that Earth's gravity always pulls 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 the same 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 as it moves down the hill, your body also accelerates.

When the roller coaster slows down as it begins to climb the next hill, your body is still accelerating. The harness holding you in the car is the outside force that causes you to slow down. (This is the same function of a seat belt in a car.) Roller coasters use changing accelerations and decelerations (decreases in speed over time) to make you feel weightless in one moment, and very weighty in the next.


Feeling weightless 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.

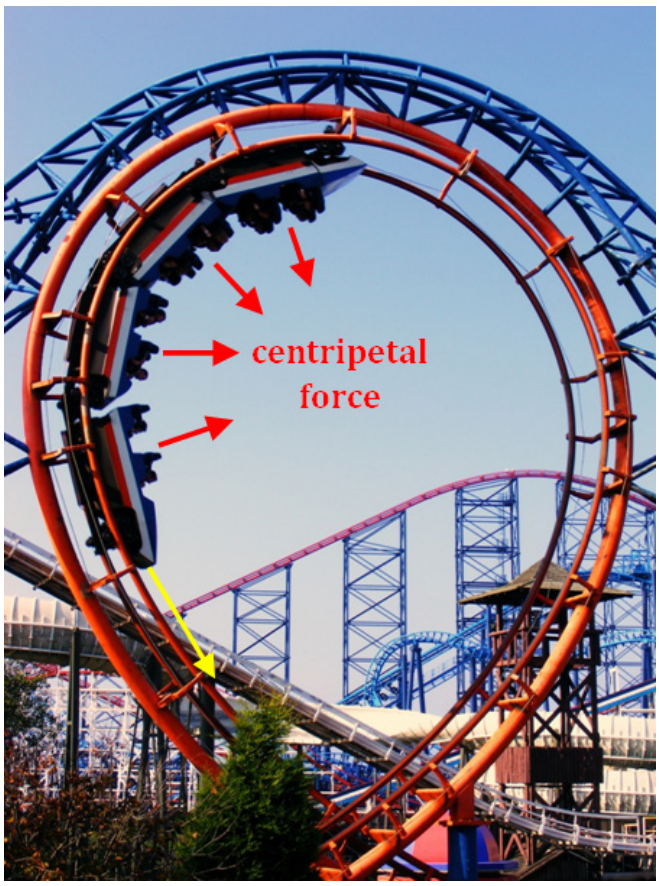
For a brief moment, your body will lift out of the seat. In that second, gravity is pulling down on you, but the opposite force of the ground (or the car in this case) isn't pushing back up. This is why you feel weightless.

# *Loop-the-Loops*

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 being weightless.

The loop-the-loops work because of a force called 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, centripetal force pushes them inward from the track toward the center of the loop.



Let's go back to inertia for a moment. Picture the start 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. The track causes the cars 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 upside down. Your body would keep moving upward because of inertia. It is this inertia that pushes you back against the seat.

As the cars move through the loop, the track makes the cars constantly 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.

# Section 2 Review

**<u>Reading Comprehension Questions</u>:**

**1.** What are two main ideas of Section 2, and how are these ideas supported by key details?

**2.** How does Section 2 connect to Section 1?

**3.** Why does the text talk about Chris Gray?

**4.** Why are roller coasters a kind of technology?

**5.** Why do engineers who design roller coasters need to know about forces?

# Science Words to Know

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

**energy** – the ability to do work

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

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

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

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

**kinetic energy** – the energy of motion

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

**potential energy** – energy that is stored

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