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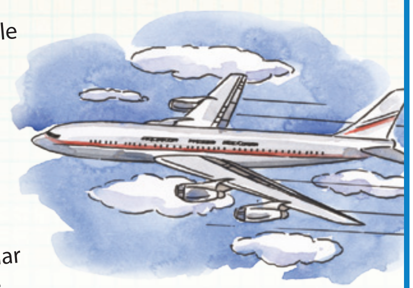
Motion and Machines

Leonardo da Vinci (1452–1519) was a man with a wide variety of talents and interests. Not only was he a talented artist and painter, but he also was interested in architecture and science. He filled many notebooks with drawings and designs of all sorts of machines. Some were weapons of war, but others were ideas of portable bridges, flying machines, or ways to move water. His designs often included many simple machines. Most of his designs were never built or tested. Some were not his original ideas but were drawings of ways to improve machines commonly known at that time. His designs were not collected and published until long after his death. By the time his sketches were well known, others had already invented many similar machines. Since da Vinci's death, many people have tried to build models of his machines. Some work and some do not. But his drawings show what a creative mind he had. God made humans creative, and He expects us to use our creativity in ways that glorify Him.



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Objectives

- Recognize that only God values creativity
- Preview the chapter content

Introduction

Walk out of the room, close the door, open the door, and return to the room.

What activities did you just observe? walking and opening the door, the door's opening and closing

Many things, such as people walking and doors moving, happen every day that we tend to ignore or pay little attention to. You may shoot a basketball or move a box without thinking much about it.

In this chapter we will learn more about the science behind many of the ordinary activities that we observe and do every day.

Teach for Understanding

Provide time for the student to complete Looking Ahead, Activity Manual page 137. For part B, encourage the student to think of things he would like to learn about the laws of motion and momentum. He should write his answers in question form, such as, "What are the three laws of motion?"

Provide the answers for part A and allow the student to check his work. After the chapter is finished, you may choose to have him look back at this page and check his understanding of the items he missed.

As time allows, discuss student questions from part B about the laws of motion and momentum. You may choose to provide trade books or other resources to help answer questions that are beyond the scope of this chapter.

Allow the student to leaf through the chapter, looking at the headings, pictures, captions, charts, etc., and discuss the things he thinks he will be learning about.

What is the title of the chapter? Motion and Machines

What is happening in the photo? Possible answers: a person is riding a zipline, or a cable ride

Activity Manual

Preview, page 137

The Looking Ahead page is intended to assess the student's prior knowledge before beginning the chapter.

SCIENCE BACKGROUND

Leonardo da Vinci (1452–1519)
Although probably not a Christian, da Vinci is an example of how all people display God-given characterisitcs. Da Vinci is known primarily for his famous paintings, but he was also a scientist and an engineer. He recorded his ideas and observations in notebooks. Today this information, along with his detailed drawings, is a resource for scientists and inventors.

TEACHER HELPS

Chapter photo
The chapter photo is of a canopy cable ride at a cloud forest in Monteverde, Costa Rica. Ziplines like this one often use a pulley system.

Chapter preview
Other preview and prereading activities may include using a K-W-L chart, a probe, or an anticipation guide.

Diagrams
Diagrams from the Student Text are included on the Teacher's Toolkit CD.

Student Text pages 212–15
Activity Manual page 138

Objectives

- Differentiate between speed and velocity
- Explain why a reference point is needed to observe motion
- Describe the relationship of mass and velocity to momentum

Vocabulary

potential energy
kinetic energy
mechanical energy
motion
reference point
distance
speed
velocity
acceleration
friction
momentum

Introduction

Do your parents have a growth chart on the wall or doorpost for them to measure and mark your height?

The chart is a type of reference point to keep track of your growth progress.

What are some characteristics of a reference point? It does not move. It does not change.

Name some other reference points that you have seen or used. Possible answers: the lights on an airport runway; the finish line of a race; a target for arrows; a lighthouse; a basketball hoop or soccer goal

A reference point is something that remains still.

Teach for Understanding

Purpose for reading

What is the difference between a moving object's speed and its velocity?

How do mass and velocity affect momentum?

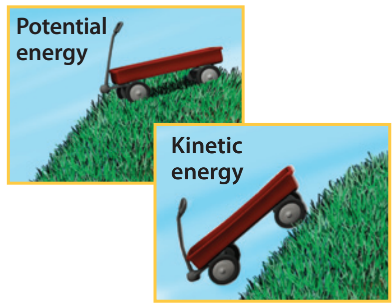
Discussion

What is energy? the ability to do work

What is the main difference between potential energy and kinetic energy? Potential energy is stored energy. Kinetic energy is due to motion.

Why are both potential and kinetic energy forms of mechanical energy? Both have the ability to make something move.

Whether they are roller coaster cars speeding down a track or leaves fluttering in the wind, objects are constantly in motion. As they move from one location to another, objects convert energy from one form to another. Perhaps you remember that scientists describe *energy* as the ability to do work. If a wagon is sitting on the top of a hill and you give it a tiny push, what happens? A force called gravity causes the wagon to move down the hill. The wagon at the top of the hill has **potential energy**, or stored energy, because of its position. But as the wagon starts to roll down the hill, its potential energy changes into **kinetic** (kuh NET ik) **energy**, or energy due to motion.

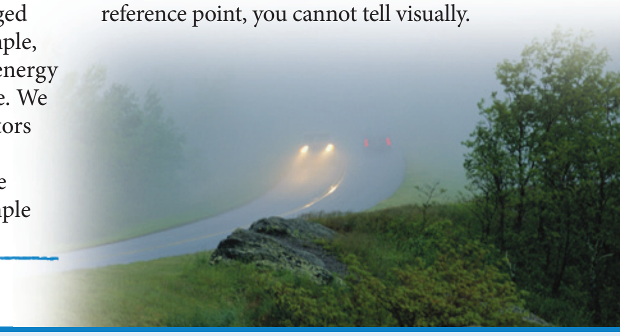


Potential and kinetic energy are forms of **mechanical energy**, or the ability to make something move. Other forms of energy can also be changed into mechanical energy. For example, our bodies convert the chemical energy from food into the ability to move. We use electrical energy to move motors to help us perform tasks. We also use machines to increase the force of mechanical energy. From a simple lever to a complex airplane, mechanical energy and machines are essential parts of our everyday lives.

For a Christian, the use of energy and machines is a way of obeying God. Learning about motion and machines can help a Christian better fulfill his job as a manager of God's creation and can also help him find ways to show love to others.

Motion

What exactly is motion? **Motion** is the change of an object's position. To determine whether an object has changed position, we need a fixed, unmoving object or location to use as a **reference point**. Think about riding in a car. You can tell the car is moving because you can see its position changing in relation to stationary objects outside of the car. However, when you look at the other people inside your car, they look like they are not moving even though they are. Your reference point inside the car is not fixed. It moves as the car moves. At night when it is hard to see reference points outside the car, another car's headlights can be very confusing. Is the other car still and your car moving? Or are both cars moving? Is one car moving faster than the other car? Without a reference point, you cannot tell visually.



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SCIENCE BACKGROUND

Writing about speed
The slash mark replaces the word *per* when abbreviating rates of speed. For example, kilometers per hour is written as km/h.

Distance and Speed

By measuring an object's position at different times, you can determine the **distance** it travels. Suppose you are in a sprint race. When the starter gun sounds, you start running. At 6 seconds, you are 48 meters from the starting line. The 48 meters is the distance that you have traveled.

To know how fast you ran those 48 meters, we need to add another factor—time. By dividing the distance traveled by the amount of time it takes to travel that distance, we can determine the **speed**, or rate, that you ran. Dividing 48 meters by 6 seconds tells us

Distance ÷ Time = Speed
48 m ÷ 6 s = 8 m/s

that your average speed was 8 meters per second (8 m/s).

Speed is measured in length units per time units, but the units are not always the same. For example, you would probably measure a runner's speed in meters per second (m/s). Your car's speed, though, is measured in kilometers per hour (km/h) or miles per hour (mi/h).

You are probably familiar with the speedometer in your family car. The speedometer registers how fast a car can go in kilometers or miles per hour. The speedometer measures the *instantaneous speed*, the car's speed at one particular moment. However, we usually use the average speed to calculate distance and time. To determine the distance a car travels, we multiply its average speed by the amount of time it travels. For example, a car going 100 km/h (62 mi/h) for 2 hours would travel 200 km (124 mi).

Speed × Time = Distance
100 km/h × 2 h = 200 km

speedometer

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Calculate average speed
MATH
Direct a student to calculate the average speed of an object by dividing the distance traveled by the amount of time the object takes to travel that distance.

If a baseball travels 100 meters in 5 seconds, what is its average speed? 20 m/sec

If a football player runs 50 yards in 6 seconds, what is his average speed? 8.3 yd/sec

Continue with other examples as time allows.

Discussion

The Second Law of Thermodynamics states that matter cannot be created or destroyed.

If energy is not created or destroyed, where does energy come from? It changes from one form to another.

Potential energy changes into kinetic energy. What are some other types of energy changes? Possible answer: Chemical energy and electrical energy can change to mechanical energy.

Why must a reference point be an object that is not moving? A moving object is unreliable as a reference point.

What happens when your reference point is a moving object? Your perception is wrong.

Read 2 Peter 1:3 and discuss the concept that the Bible speaks to every situation in life. Because God never changes, He and His Word become a "reference point" for Christians in every situation. Students should be encouraged to ask themselves, "What does the Bible say about this?

How do you determine the distance an object travels? by measuring an object's position at different times

How is speed calculated? by dividing the distance the object travels by the time it takes the object to travel that distance

What is another word for speed? rate

How is speed measured? in length units per time units

Give an example of speed. Accept any answer that demonstrates distance divided by time.

What does the speedometer in a car measure? instantaneous speed

What is the difference between instantaneous speed and average speed? Instantaneous speed is the speed of an object at any one moment, and average speed is the average speed an object travels during an entire period of movement.

Discussion

What is velocity? the speed and distance of a moving object in a certain direction

How is the velocity of an object different from its speed? Velocity is an object's speed in a certain direction.

Direct the student to determine whether the following are examples of velocity and to explain why or why not.

Dad is driving west at 105 km/h (65 mi/h). Yes, because it gives the speed in a certain direction.

Jim runs 10 km/h (6.2 mi/h). No, because it does not tell direction.

What is acceleration? a change in velocity during a period of time

Name three different ways you could accelerate while riding your bike. speed up, slow down, change direction

Discuss relationships among speed, velocity, and acceleration.

Lindy the racecar driver drives at 150 mi/h. Is 150 mi/h her speed or velocity? speed

Lindy maintains the 150 mi/h speed as she circles the track. Does her velocity remain the same during each lap? no **Why?** She changes direction at each turn.

Rodney has come alongside and matched Lindy's speed. Lindy increases her speed to get to the finish line before Rodney. What term best describes her action? acceleration **Why?** The speed changed.

Discuss *Fantastic Facts*.

How can a plane accelerate in ways that a car does not? It can move up and down.

What instrument helps pilots know whether they have adequate acceleration to turn? an accelerometer

How has this technology been developed for use in cars? It is used to activate air bags.

Velocity and Acceleration

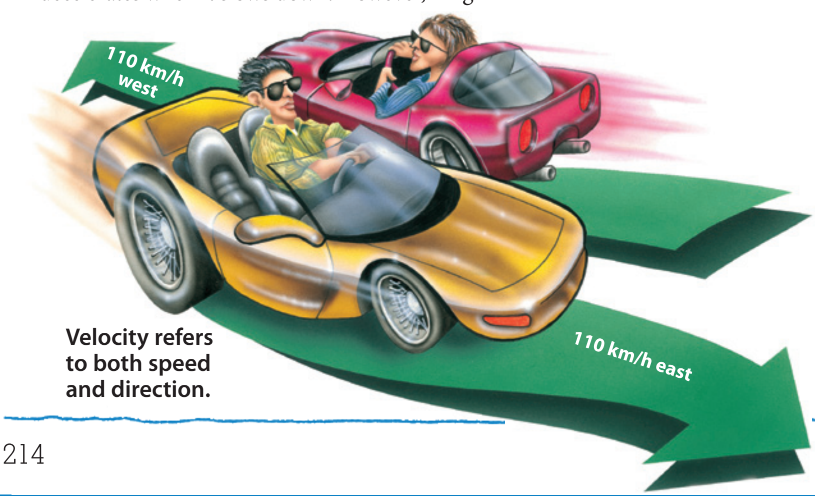
The speed of an object refers to the distance the object moves over a given amount of time. However, **velocity** refers to the distance an object moves over a given amount of time *in a certain direction.* Velocity refers to both the speed *and* direction of a moving object. Two objects may move at the same speed, but if they are going different directions, they will have different velocities. For example, a car traveling north at 80 km/h (50 m/h) has a different velocity than a car traveling south at 80 km/h (50 m/h). The velocity of an object changes if the speed or the direction changes or if both the speed and direction change. A car traveling around a curve changes velocity even if its speedometer shows a constant speed.

Acceleration is a change in velocity during a period of time. The faster the velocity changes, the greater the acceleration. Usually we say that an object accelerates when it speeds up and decelerates when it slows down. However, in scientific language, acceleration occurs whenever an object speeds up, slows down, or changes direction.

Most people like having cars that can accelerate quickly. They want the car to go faster in a shorter amount of time.

FANTASTIC FACTS

Think about all the ways that an aircraft can accelerate. In addition to the ways a car accelerates, an aircraft also moves up and down. Pilots need to maintain a certain amount of acceleration to keep a plane flying. Aircraft have instruments called accelerometers in them. Just like cars, airplanes need greater acceleration to turn than to fly straight. Accelerometers show a pilot whether he has adequate acceleration to perform a certain maneuver. Some cars also use the technology of accelerometers. When a sudden decrease in acceleration occurs, such as in a collision, an accelerometer activates the airbags that protect the occupants of the car.



Velocity refers to both speed and direction.

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SCIENCE MISCONCEPTIONS

Different meanings

Velocity, *acceleration*, and *deceleration* each has a common meaning and a scientific meaning. Thinking of the common meanings may cause confusion when trying to learn the scientific meanings.

Velocity is commonly used interchangeably with speed, leaving out direction as a factor.

Acceleration is usually thought to mean only "to go faster," rather than meaning "a change of velocity," which includes a change of speed and/or direction.

Deceleration commonly means "to slow down," but it is really a negative change in velocity, or a change opposite of acceleration.

But actually, the most important acceleration of a car is how fast it stops. Good tires and brakes help decelerate a car in a safe amount of time and distance.

In order for acceleration to occur, a *force*, a push or pull, must be applied to an object. If you want to make a wagon move, you must push or pull it. If you want to make it turn, you must apply a force to the handle. If you want to make it stop, you must also push or pull it. If you do nothing to a moving wagon, it will eventually stop because a force called friction is working on the wagon. **Friction** is a force that keeps objects from moving against other objects.

Momentum

The mass and the velocity (speed and direction) of an object determine its **momentum**. This concept sounds complicated, but you undoubtedly have experienced the results of momentum. If someone throws a baseball and a tennis ball toward you at the same speed, which one would you try hardest to avoid? The tennis ball would probably be less painful than the baseball. It has less momentum because it has less mass. For the same reason, you would try to avoid being hit by a baseball thrown by a professional baseball player. But you probably would not run too hard to avoid a baseball thrown by a little child. Although the ball's mass is the same, the velocity of the professional player's ball is much greater than that of the little child.

A train is an example of a moving object that has a lot of mass. Its great mass gives it great momentum. A train takes much longer to slow down than a car. Depending on its velocity, the train could take several kilometers to stop after it has applied its brakes.

QUICK CHECK

1. What is energy?
2. How is velocity different from speed?
3. Why would a fast-moving train not be able to stop quickly?

Accelerometer
LANGUAGE
The word combines the terms *accelerate* and *meter*.

What does the word *meter* mean in this context? Elicit that it is a device for measuring.

What other words use *meter* in this way? Possible answers: thermometer, barometer, speedometer

Since the word *meter* has to do with measuring, what would be the definition of *accelerometer*? a device that measures acceleration

Discussion

What is force? a push or a pull

Force is the main element in a game of tug of war. The game begins with the forces balanced and the rope not moving.

How does each side exert force on the rope? by pulling it

Is the force on each side usually equal? no **How do we know this?** One side wins and the other side loses.

If I pull on a wagon of bricks and it moves, are the forces equal? no **What has the greater force?** my pull

If the wagon remains stationary because I cannot move it, are the forces equal? probably

If the wagon is on a hill and it starts to roll, pulling me along with it, are the forces equal? no **What has the greater force?** the rolling wagon

What force will make a moving wagon eventually stop? friction

What is friction? a force that keeps objects from moving against other objects

Friction can also be described as the force that resists the movement of objects against each other.

What determines the momentum of a moving object? the mass and velocity of the object

What is *mass*? the quantity of matter in an object

What is the relationship between the mass of an object and its momentum? The greater the mass is, the more momentum the object will have.

What are some examples that show the relationship between mass and momentum? Possible answers: a moving train, a baseball being thrown, a tennis ball being hit

Answers

1. Energy is the ability to do work.
2. Speed is how fast an object is moving. Velocity is the distance an object moves over a given amount of time in a certain direction.
3. A fast-moving train would not be able to stop quickly because not only does its great mass give it great momentum, but the greater velocity also increases the momentum.

Activity Manual

Reinforcement, page 138

Lesson **107**

Student Text pages 216–19
Activity Manual pages 139–40

Objectives

- Identify Newton's three laws of motion
- Explain that both gravity and friction work against inertia

Vocabulary

first law of motion	second law of motion
inertia	third law of motion
gravity	

Introduction

Imagine that you are the passenger in a car that your dad is driving. Suddenly, your dad notices that the car in front of him has stopped. Your dad slams on the brakes.

How does your body respond? Does your body jolt forward, stay still, or pull backward? Show me. jolts forward

How does your body respond when you are in a stopped vehicle and all of a sudden the driver stomps on the gas pedal? Show me. pushes backward

Have you wondered why your body responds this way? Today we will learn why.

Teach for Understanding

Purpose for reading

Is friction helpful or harmful?

What is the law of action and reaction?

Discussion

What did medieval scientists observe? that all things tend to slow down and come to a rest

Were the observations of medieval scientists correct or incorrect? correct

Why did they draw incorrect conclusions? Answers will vary. Elicit that man's observations are limited. Only God knows all things and is not limited by lack of wisdom and knowledge (Rom. 11:33–36).

What is the first law of motion? An object tends to stay at the same velocity unless another force causes it to change.

Remind the student that acceleration is a change in velocity during a period of time.

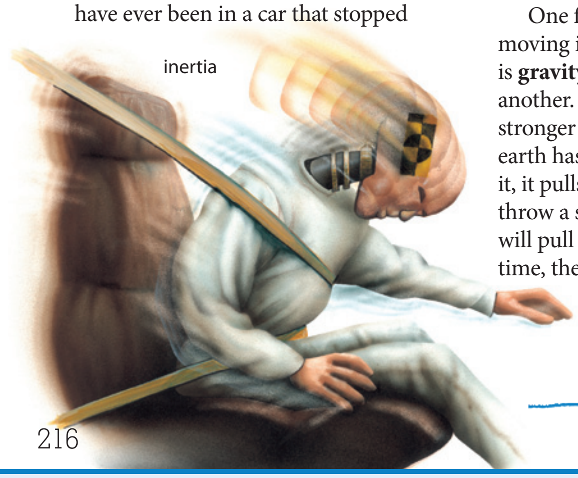
Laws of Motion

Medieval scientists believed that all things tend to slow down and come to a rest. Though these scientists made correct observations, their conclusions were wrong. Galileo Galilei (GAL-uh LEE-oh GAL-uh-LAY) (1564–1642) discovered that, contrary to what the scientists of his day believed, a moving object does not come to rest unless an outside force acts on the object. As Sir Isaac Newton (1642–1727) continued Galileo's study of how and why things move, he formulated the three laws of motion.

First Law of Motion

The **first law of motion** says that an object tends to stay at the same velocity unless another force causes it to change. An object at rest, zero velocity, tends to stay at rest. An object traveling in a straight line at a constant speed tends to keep moving that way.

The resistance to a change in motion is called **inertia** (ih NUR shuh). If you have ever been in a car that stopped suddenly, you experienced inertia. You were thrown forward in the car because your body was in motion, and it stayed in motion even after the car stopped. When you push someone on a swing, it is harder to get him started than it is to keep him going. You must first overcome his body's tendency to stay at rest.



Velocity involves not only speed but also direction. If you have gone into a tight spiral on a roller coaster ride, you know that your body wants to go straight even though the track turns. You feel like you are being pushed to one side. Perhaps you have swung an object on the end of a rope around and around. When you release the rope, the object goes in a straight line from the point that you let go. It does not continue circling.

Obviously, objects in the universe do not remain still or keep moving in straight lines. If you jump up to shoot a basketball, you will not continue floating up into the air. If you roll a toy car across the carpet, it will roll for a while and then come to a stop. Certain forces are operating against inertia.

One force that keeps an object from moving indefinitely in a straight line is **gravity**, the pull of one object on another. Objects with greater mass have stronger gravitational pulls. Since the earth has more mass than anything on it, it pulls objects toward itself. If you throw a softball through the air, gravity will pull the ball to the earth. At the same time, the ball pulls the earth toward itself. But because the mass of the earth is so much greater than

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TEACHER HELPS

Newton's laws

During the teaching about each law of motion, display a statement that summarizes the law after it has been discussed. You may want to have those prepared ahead of time instead of writing them for display during the lesson.

DIRECT A DEMONSTRATION

Demonstrate inertia

Materials: a clear plastic or glass cup, a coin, a note card large enough to cover the cup opening

Place the note card on top of the cup, and place the coin on top of the note card. With your finger, flick the card off the cup so that the coin falls into the cup instead of moving with the note card.

Why did the coin fall into the cup rather than stay on the note card? The coin tended to stay at rest over the center of the cup, so it fell when the note card was moved.

Variation: Try a similar demonstration using plastic dishes on a tablecloth.

that of the ball, the pull of the ball on the earth is very, very tiny.

When we talk about the *mass* of an object, we are referring to the amount of matter in that object. However, when we talk about the *weight* of an object, we are referring to the gravitational force on that object. So weight is actually a measure of force. An object that weighs less has less gravitational force being applied to it. For example, you would weigh less on the moon because the gravitational force pulling on you would be less than that on Earth.

Friction also works against inertia and is helpful in many ways. Without the force of friction you would not be able to walk. Your foot would not be able to grip the floor and push you forward. Without friction, turning over in bed or stopping your car would be impossible.

Sometimes people increase the friction of surfaces. Rubber cutouts stuck to bathroom floors increase friction and keep people from falling. Baseball players wear batting gloves to keep their hands from slipping on the bat. Rubber tires give more friction against the road and help keep a car from sliding on the road.

In other situations, friction is not helpful, and people try to reduce it. Winter sports such as sledding, skiing, and ice-skating are fun only when there is less friction. Snow skiers wax their skis to reduce friction and to allow the skis to glide quickly along the snow. People put lubricants, such as grease and oil, on machine parts to reduce friction on the parts that rub together in movement.

FANTASTIC FACTS

Air resistance is an example of helpful friction. If raindrops met no resistance, they would be falling faster than the speed of sound by the time they reached the earth. Rain showers would be painful indeed! Gravity pulls the drops earthward, and air resistance limits their maximum speed. The two forces soon balance each other, and the raindrops fall at a constant speed.

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Discussion

According to Newton's first law of motion, what would have to happen to an object in order for it to accelerate? Answers will vary, but elicit that a force would have to be applied. Otherwise the object would continue at the same velocity (speed and direction).

Write a summary of Newton's first law for display: An object at rest tends to stay at rest, and an object in motion tends to stay in motion with the same direction and speed.

What is inertia? the resistance to a change in motion

Why is it important that you wear your seat belt in a moving car? A seat belt will keep your body from moving forward if the car stops suddenly.

What are two forces that work against a moving object? gravity and friction

Do you think gravity and friction work for or against an object that is just starting to move? against **Why?** because the object tends to resist the movement

How is mass different from weight? Mass is the amount of matter in an object. Weight is the gravitational force on an object.

Why would your mass on the moon be the same as your mass on Earth but your weight different? Your body would still have the same amount of matter on the moon, but the gravitational pull on your body would be different.

Why do moving objects not keep moving? Friction slows down a moving object and brings it to a stop.

Other than the ways listed in your book, what are some ways that friction is helpful? Possible answers: opening a jar; climbing stairs; turning a screwdriver

Other than the ways listed in your book, where would we want to reduce friction? Possible answers: on a bike chain, door hinge, pulley

Do you think a bowler would rather increase or reduce friction on a bowling lane? reduce **Why?** A lack of friction allows the bowling ball to move quickly down the lane in the direction the bowler rolls it.

Why do work crews sometimes put sand on icy roads? to increase friction

Discuss *Fantastic Facts.*

What force is air resistance? friction

What other force affects how raindrops fall? gravity

WRITING

Write a persuasive letter The student could use the information learned about momentum and inertia to write a persuasive letter encouraging others to wear seat belts.

SCIENCE BACKGROUND

Mass and Weight

Mass and weight are often used interchangeably, but they are not the same thing. Mass measures the amount of matter something has. The mass of an object stays the same unless matter is added or taken away from it. Weight measures the amount of gravity pulling on an object. On Earth, mass and weight are very close to being the same measurement. But on the moon and elsewhere in space, the pull of gravity is different, so weight changes.

Mass is usually measured in grams or kilograms. Weight is usually measured in grams, ounces, pounds, and tons.

Discussion

A formula is the mathematical sentence that shows how something works. What is the formula for the second law of motion? mass × acceleration = force

Why does it take more force to pick up a full carton of milk than it takes to pick up an empty carton? The full carton has a greater mass. **Identify the principle that supports your answer.** the greater the mass of the object, the greater the force needed to move it

Which usually travels faster—a baseball that is thrown or a baseball that is hit with a bat? the baseball that is hit with the bat **Why?** the greater the force, the greater the acceleration

Jamal and his dad were target practicing with a bow and arrows. Jamal's arrows usually flew at 45 m/sec, and his dad's flew at 60 m/sec. Whose arrows had the greater force exerted on them? his dad's **How do you know?** The arrows with the greater acceleration had the greater force.

At Saturday's game the Tigers kicked a 45-yard field goal. The Bears kicked a 20-yard field goal. Whose ball probably had the greater force exerted on it? the Tigers' ball **How do you know?** It traveled farther.

Your mom wants to rearrange some furniture. Your job is to help move the bookcase, but you want to use as little force as possible. Will you move the bookcase with or without the books on the shelves? without the books **Why?** Less mass will require less force.

Write a summary of Newton's second law for display: An increase or decrease in force is related to an increase or decrease in mass and/or acceleration.

Discuss other possible examples of the second law of motion.

Second Law of Motion

Most of us recognize that moving a 50 kg (110 lb) box is easier than moving a 500 kg (1,102 lb) box. Newton's **second law of motion** states that force is equal to an object's mass and the acceleration of the object. The following formula illustrates the second law of motion.

> mass × acceleration = force
> *(ma = F)*

Several principles result from this formula. First, *the greater the mass of the object, the greater the force needed to move it.* For example, a little bit of force can move an empty cardboard box, but moving a cardboard box filled with encyclopedias requires much more force. Moving a golf ball with a golf club is quite simple, but moving a bowling ball with a golf club would be quite difficult!

Another principle we can derive is that *the greater the force exerted on the object, the greater its acceleration will be.* Athletes use this principle often. The harder you swing a tennis racket or baseball bat, the faster the ball accelerates after you hit it.

We can also conclude from the formula that *the greater the acceleration, the greater the force exerted on an object.* This is why it takes more force to throw a fast baseball pitch than to throw a slow baseball pitch. The fast ball has more acceleration, so it requires more force.

← Force exerted

The Second Law of Motion

← Greater force exerted

MATH

Calculate force

Allow the student to practice using the formula for Newton's second law of motion: mass × acceleration = force. The following problems illustrate the formula and provide practice identifying the unknown part.

If the mass of an object is 10 kg and the acceleration is 10 km/h, how many units of force were applied? 10 kg × 10 km/h = F; F = 100

If there are 20 units of force and the object weighs 10 kg, what is the acceleration? 10 kg × a = 20; a = 2 km/h

If the acceleration of an object is 10 km/h and 5 units of force were applied, what is the mass of the object? m × 10 km/h = 5 kg; m = 0.5 kg

DIRECT AN ACTIVITY

Conduct an arm wrestling competition.

Observe various matches and discuss how force, mass, and acceleration affect the results.

Enrich the activity by charting and graphing the results.

Third Law of Motion

The **third law of motion** is sometimes called "the law of action and reaction." All forces come in pairs. When one object exerts a force on another object, the second object reacts by exerting an equal force back on the first object. For example, a person paddling in a kayak pushes the paddle backward against the water, and the water reacts by pushing the boat forward. The boat moves in the opposite direction of the force of the paddle. If you sit in a chair that has wheels and push against your desk, the desk pushes you backwards.

If you have ever ridden on bumper cars at an amusement park, you have felt Newton's third law of motion. As you bump into another car, the other car bumps you back with an equal amount of force.

Rockets ascend because of Newton's third law. As the rocket expels gases downward, an equal and opposite reaction occurs. The gases exert a force that causes the rocket to move upward.

QUICK CHECK

1. What is the difference between mass and weight?
2. What is Newton's second law of motion?
3. Why is the third law of motion sometimes called the "law of action and reaction"?

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SCIENCE MISCONCEPTIONS

Cause and effect
Newton's third law of motion deals with the action and reaction of force. Sometimes examples of cause and effect not relating to force are incorrectly identified as action and reaction.

An example of action and reaction
Two marbles bounce away from each other when one is rolled into the other.

An example of cause and effect
You shout when your finger is hit with a hammer.

BIBLE

Actions and reactions
In the Bible, Jesus gives examples of how God desires Christians to respond to the words and actions of others. Christ's reactions to harsh words, beatings, and ultimately death were filled with love and compassion for those mistreating Him. [BATs: 3c Emotional control; 5a Love; Bible Promise D. Identified in Christ]

How do you react when someone wrongs you? Answers will vary.

Discussion

What does the third law of motion say? When one object exerts a force on a second object, the second object reacts by exerting an equal force back on the first object.

What is another name for Newton's third law of motion? the law of action and reaction

Each backstroke competitor at a swim meet waits in the water at the end of his lane. When the starting gun sounds, each uses his feet to push off from the side of the pool. How does this demonstrate Newton's third law of motion? The action of pushing against the wall produces the reaction of moving the swimmer forward as the wall exerts an equal force against the feet of the swimmer.

Remind the student of the discussion on balanced and unbalanced forces.

What would happen if you exerted pressure on a chair by sitting in it, and instead of exerting equal force back, the chair exerted less force back? The chair would collapse or break, and you would fall.

Can you think of other examples of Newton's third law in everyday life? Possible answers: bouncing a ball; swinging on a swing set; rowing a boat; recoil from firing a gun

Write a summary of Newton's third law for display: For every force exerted there is an equal force exerted back; the "law of action and reaction."

Answers

1. Mass is the amount of matter in an object. Weight refers to the amount of gravitational force on that object.
2. Newton's second law states that force is equal to an object's mass and the acceleration of the object.
3. Newton's third law is called the "law of action and reaction" because forces work in pairs. If an object exerts a force on another object, the second object reacts by exerting an equal force back on the first object.

Activity Manual

Review, pages 139–40
These pages review Lessons 106 and 107.

Assessment

Quiz 9-A
The quiz may be given any time after completion of this lesson.

Lesson 108

Student Text pages 220–21
Activity Manual pages 141–42

Objectives

- Plan a demonstration to illustrate the laws of motion
- Experiment to show each of the laws of motion with toy cars
- Identify the laws of motion in real-life situations

Materials

- See Student Text page

Introduction

Have you ever wondered how a policeman determines what happened at an accident scene? Today you will study and practice one of the ways a policeman can discern what happened.

Teach for Understanding

Purpose for reading

The student should read all of the pages before beginning the activity.

Discussion

What do we call people who try to figure out what happened at an accident scene? accident reconstructionists

What skills do they use? math and physics (mainly Newton's laws of motion)

Physics is the branch of science that deals with matter and energy and their relationships to each other.

God's laws of motion are consistent. Because the laws do not change, we can build cars and evaluate accident sites based on the laws that we know will always be the same.

ACTIVITY

Mini Cars in Motion

Have you ever passed a car accident and wondered how the cars ended up where they were? Eyewitnesses often help sort out the events of accidents, but what if there are no eyewitnesses? People called accident reconstructionists use skills such as mathematics and physics (mainly Newton's laws of motion) to try to figure out what happened at an accident scene. A few engineering firms even specialize in accident reconstruction. Most of these people use very advanced computers to recreate accident scenes.

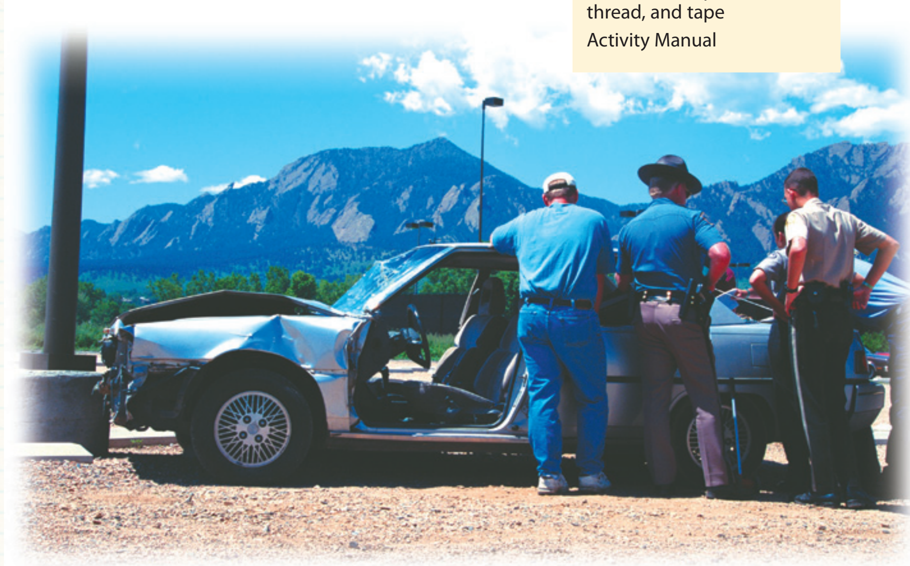
In this activity you will use small objects, including toy cars, to demonstrate each of Newton's laws of motion. Then you will apply each law to a simulated accident to try to analyze what happened at the accident scene.

Process Skills
- Experimenting
- Making and using models
- Observing
- Communicating

Problem

How can I use models to demonstrate Newton's laws of motion?

Materials
2 small toy cars
other items, such as books, pennies, rubber bands, blocks, ruler, spools of thread, and tape
Activity Manual



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TEACHER HELPS

Car selection
To eliminate additional variables, choose cars that are as alike as possible. They should be the same mass, body shape, and have the same ease of rolling.

Demonstrating inertia
If a student chooses to demonstrate Newton's first law by placing the toy car on the table and saying that inertia keeps it from moving, acknowledge that he is correct, but encourage a more active demonstration.

Time allotment
You may choose to limit the amount of time available for the student to produce demonstrations.

No hypothesis
Although experimenting usually involves proving a hypothesis, in this activity the students will be experimenting to show the laws of motion.

TECHNOLOGY

The teacher may want to record the experiment and show it to the class in slow motion in order that each student may see the demonstration clearly.

Procedure

1. Draw a plan for your demonstration of Newton's first law of motion. (Remember: You are not trying to demonstrate the accident scenario. You are trying to show how the law of motion works.)
2. Choose and list the materials you need for your demonstration.
3. Test your demonstration. Continue experimenting until the demonstration shows Newton's first law of motion adequately.
4. Read the first simulated accident scenario in your Activity Manual. Complete the accident report by using your knowledge of Newton's first law of motion.
5. Repeat the procedure for the other laws of motion.
6. Be prepared to share your demonstration and conclusions.

Conclusions

- Which of the laws of motion was the easiest to demonstrate? Which was the hardest to demonstrate?

Follow-up

- Do additional research about accident reconstructionists.

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SCIENCE PROCESS SKILLS

Experimenting

What was the purpose of this experiment? to show the laws of motion

Do all the demonstrations for the first law of motion have to be the same in order to show the first law of motion? no

Is it harder to conduct an experiment or to plan and set up an experiment? Answers will vary, but probably to plan and set up an experiment is harder.

What part of an experiment is the hardest to set up? Answers will vary, but probably controlling the variables is hardest.

Procedure

Guide the student as he sets up each demonstration. Ask leading questions that will encourage the student to identify what he is trying to do. A real-life example may help him visualize what he needs to try.

If needed, use these possible solutions to demonstrate each law.

First law—Place a thin book on a table several inches away from the toy car. The spine of the book should face the car. Place a penny on top of the toy car. Roll the car into the book. The car will hit the book and stop moving, but the penny will continue moving. Although the car had an outside force acting on it (the book), the penny did not, so it continued to move even when the car stopped. Gravity eventually stopped the penny.

Second law—Increase the mass of car A by taping four pennies to the top. Line up cars A and B side by side at the edge of a table so that the back of each car extends about ¼ inch beyond the edge. Hold a ruler parallel to the edge of the table and hit the back of both cars at the same time. Car B should accelerate more because it has less mass.

Third law—While holding car A still with one hand, roll car B into car A. After hitting car A, car B will roll backward. The action of hitting car A caused the reaction of it hitting car B back.

Conclusions

Discuss the accident scenarios. The student's answers may vary. Allow time for the student to explain the reasons for the answers he chose.

Use the questions in the Science Process Skills to discuss experimenting.

Activity Manual

Activity, pages 141–42

Assessment

Rubrics

Select the prepared rubric, or design a rubric to include your chosen criteria.

Objectives
- Design and make a model roller coaster
- Discover relationships between slope, speed, and momentum

Materials
- photos, pamphlets, or books about roller coasters
- See Student Text page

Introduction
Discuss roller coasters the students may have seen or ridden. Discuss the photos or other materials to see the variety of roller coasters and their use of hills and loops.

Teach for Understanding
Purpose for reading
The student should read all the pages before beginning the exploration.

What to do
What are some forces that cause a car to roll along a roller coaster? gravity, inertia, and momentum

If the student has difficulty making a successful model, ask the following questions.

Problem with the "car" hitting a dead space and slowing or stopping:

Is the slope steep enough to keep the "car" moving?

Is the slope too steep, causing the "car" to drop and stop rather than roll?

Problem with the "car" making it through a loop:

Is enough distance given along the slope for the "car" to gain enough momentum and speed?

Is the slope steep enough or too steep for the "car" to gain enough momentum and speed?

Problem with the "car" making it through several loops in a row:

Should the size of each loop increase or decrease along the ride?

If the loops stay the same size, is more distance needed between them for the "car" to gain momentum and speed before entering the next loop?

Activity Manual
Exploration, pages 143–44

Assessment
Rubrics
Select the prepared rubric, or design a rubric to include your chosen criteria.

EXPLORATION

Roller Coaster

Many roller coasters are called gravity coasters because once the car is at the top of the first hill, the main force causing it to roll is gravity. The height and placement of hills, loops, and turns make use of inertia and momentum that cause the car to continue to the end of the ride. In this activity you will use gravity, inertia, and momentum to cause your BB "car" to complete your "roller coaster."

What to do
Plan your roller coaster with the following requirements.
- *The start must be 1 meter above the finish.*
- *The roller coaster must contain at least 1 loop.*
- *A plastic bag must be attached to the end of the roller coaster to catch the BBs.*

Materials
10 ft of plastic tubing
masking tape
plastic bag
BBs
Activity Manual

1. In your Activity Manual, draw and label a diagram of your idea for a "roller coaster."
2. List the materials you will use.
3. Make your roller coaster by taping the tubing to the wall according to your diagram.
4. Test your roller coaster with a BB "car."
5. Record the results. Adjust your roller coaster as needed to get the BB to the end of the ride and into the plastic bag.
6. When you have made the roller coaster work as you want it to, draw a diagram of the completed roller coaster.


Cedar Point, Ohio

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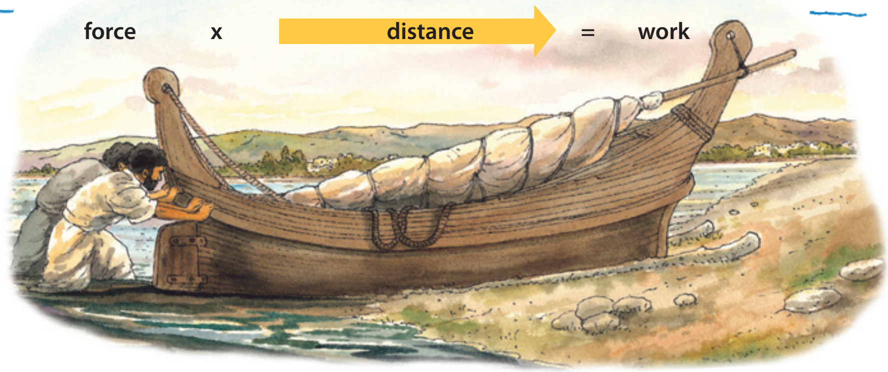
TEACHER HELPS

Attaching tubing
This activity is designed to have the tubing attached to a smooth surface, such as a wall or chalkboard. You may choose to have the student hold the tubing or use other means of support.

Drawing conclusions
Once successful models are made, you may choose to have the student time the "cars." Compare results and draw conclusions as to the reasons for slower and faster times.

Factors for speed
Discuss the places along the roller coaster where gravity and momentum give the "car" the greatest speed. Decide where gravity and friction slow the "car."



Machines

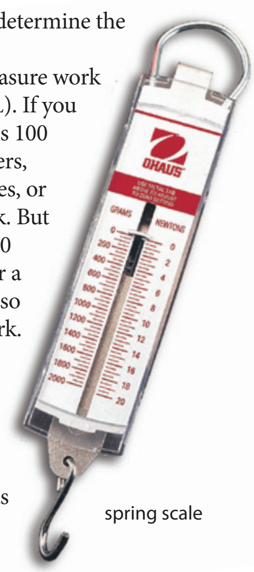
Work

Suppose you push as hard as you can on a brick wall. Have you done any work? You might be sweating and exhausted, but you have not really done any work unless you have moved the wall. **Work** is defined as a force acting on something as it moves a certain distance. Applying a force to an object is not enough. You must make the object move.

force (newtons) × distance (meters) = work (joules)

Force is measured in **newtons** (N). Suppose we say that an object weighs 3 newtons. We are saying that 3 newtons of gravitational force are being exerted on the object. So newtons are a measure of both force and weight. A spring scale can measure an object's force in newtons. If you multiply the object's force by the distance the object travels, you will determine the amount of work done.

The unit used to measure work is called the **joule** (JOOL). If you lift an object that weighs 100 newtons upward 5 meters, you have done 500 joules, or newton-meters, of work. But pushing a box against 20 newtons of friction over a distance of 25 meters also equals 500 joules of work. Because work equals force times distance, applying a greater force over a shorter distance involves the same amount of work as applying a lesser force for a greater distance.


spring scale

100 newtons (N) × 5 meters (M) = 500 joules (J)

20 N × 25 m = 500 J

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SCIENCE BACKGROUND

Weight and force
The words *weight* and *force* can be used interchangeably when measuring in newtons.

Joules
When multiplying *newtons* times *meters* to find the amount of work, the answer is in *newton-meters*, or *joules.*

Objectives
- Explain that *work* equals *force* times *distance*
- Describe a lever
- Identify several common levers
- Differentiate among the three classes of levers

Materials
- ruler
- chalkboard/whiteboard eraser
- cardboard tube or other object to use as a fulcrum

Vocabulary

work	effort force
newton	resistance force
joule	lever
machine	fulcrum

Introduction

How hard do you think you are working while reading a page of your textbook? Accept any answer.

Scientifically speaking, you are not doing any work when you read your textbook. Today we will learn what work is and what it is not.

Teach for Understanding

Purpose for reading

Why is playing basketball considered work but doing homework is not always work?

What is a fulcrum?

Discussion

What is the definition of work? a force acting on something and moving it a distance

What is the formula for determining how much work is done? force × distance = work, or newtons × meters = joules

Which unit measures force? newton

Which unit measures work? joule

How much work is done if you lift a box that weighs 4 newtons from the floor onto a shelf that is 2 meters off the ground? 8 joules

Discussion

What is a machine? any object that makes work easier

How does a simple machine make work easier? It strengthens the force used to do the work or changes the direction of the applied force.

What does not change when using a simple machine? the amount of work done

If it takes 10 newtons of force to lift 1000 grams without a simple machine, would it take more or less force to lift 1000 grams with a simple machine? Why? Elicit that it should take less force because a simple machine strengthens the force. A simple machine makes it possible to do more work using less force.

What is the difference between effort and resistance? Effort is the force that is applied to a simple machine. Resistance is the force that works against the effort.

What is often the resistance force? the weight or the object being moved

What are the six simple machines? lever, pulley, wheel and axle, inclined plane, wedge, screw

Why are these called simple machines? because all machines are usually made of one or more of these machines

What is a lever? any bar that turns on a point

What is the fulcrum? the spot where the bar turns, or pivots

What are some common levers? Possible answers: seesaws, wheelbarrows, brooms, paint can openers, hinges

How are levers classified? by where the effort and resistance are located in relation to the fulcrum

Discuss *Creation Corner*.

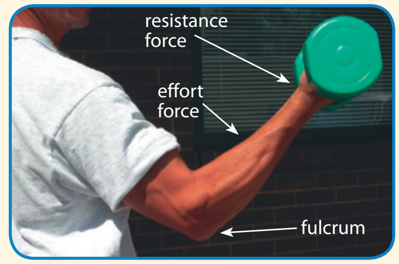
Who originally designed levers? God

The joints and muscles in our bodies are so complex that often the same joint can function as different classes of levers, depending on which muscles are providing the effort.

How do the the levers in our bodies point to an all-wise Creator? Without the levers, we could not move and do many of our daily tasks.

CREATION CORNER

Man has used mechanical levers for thousands of years. But God created the original design. Many of the joints in the human body are levers. Your head pivots on a first-class lever. If you drop your head down, the resistance is your head, the fulcrum is the top of your spine, and the muscles in your back provide the effort. Your toe joints provide the fulcrums for second-class levers. The resistance is your weight, and the effort is your leg muscles. Your elbow is an example of a third-class lever. The joint is the fulcrum, the lower arm muscles provide the effort, and whatever you carry or throw is the resistance. It takes only a small movement at the joint to give a great force. Without these God-given levers, our bodies would not be able to perform many of the tasks that they normally perform.



Simple Machines

A **machine** is any object that makes work easier. Simple machines do not reduce the amount of work done. However, a simple machine makes the work easier by strengthening the force used to do the work or by changing the direction of the applied force.

Remember, a force is a push or a pull. The force applied to a simple machine is called the **effort force**, or effort. The **resistance force**, or resistance, is the force that works against the effort. Sometimes the resistance force is an actual push or pull, but often it is the weight of the object being moved.

There are six simple machines: lever, pulley, wheel and axle, inclined plane, wedge, and screw. All machines, even complex ones, are usually made of one or more of these simple machines.

Lever

A **lever** is any bar that turns on a point. The spot where the bar turns, or pivots, is called the **fulcrum**. Some common levers include seesaws, wheelbarrows, and brooms.

We use levers to lift objects that are otherwise too heavy for us. Archimedes, a mathematician who lived more than two hundred years before Christ, was one of the first men to study simple machines. He once said that if he had a long enough lever and a fixed fulcrum, he could move the earth. Of course, Archimedes could never prove his statement, but he understood that levers make work easier.

Scientists classify levers into three categories, depending on where the effort and resistance are located in relation to the fulcrum. On a *first-class lever*, the fulcrum is located between the effort and the resistance. Seesaws

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TEACHER HELPS

Demonstrate levers
You may want the student to do his own demonstration of each type of lever.

LANGUAGE

Scientific or common usage
Words such as *work* and *machine* have scientific definitions as well as common use definitions. Direct the students to come up with different sentences using either meaning of each word, and call on another student to identify whether the word is used in its scientific context or in its common usage context.

First-class lever

and crowbars are both first-class levers. If you use a paint can opener, you are using a first-class lever. The fulcrum is the rim of the can. The lid provides the resistance force, and your pushing down on the other end produces the effort force. A pair of scissors is an example of two first-class levers working together.

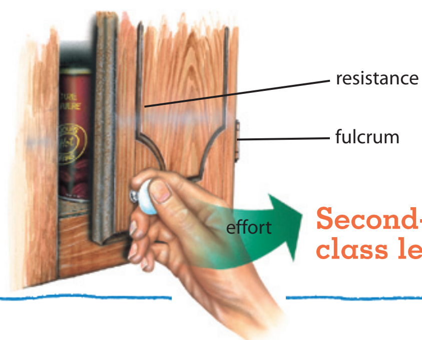
A *second-class lever* has the resistance between the effort and the fulcrum. Some examples of second-class levers are a door and a wheelbarrow. Almost everything that has a hinge is a second-class lever. An example of two second-class levers working together is a nutcracker.

In a *third-class lever*, the effort is between the resistance and the fulcrum. In these levers, a little movement by the effort gives greater movement at the resistance. Some examples of third-class levers are a broom and a fishing pole. You can move the end of a broom a little, but at the floor the broom moves much more than the little that you moved it. An example of two third-class levers working together is a pair of tweezers.

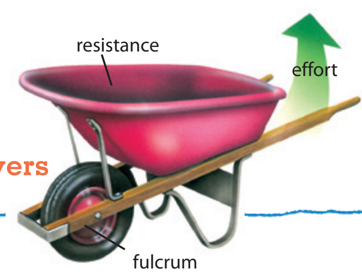
Third-class lever

QUICK CHECK

1. What is work?
2. What is the function of a machine?
3. Describe the location of the effort, resistance, and fulcrum of each class of lever.



Second-class levers



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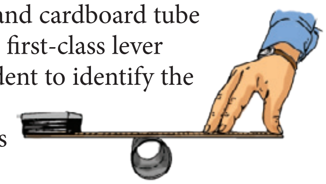
DIRECT A DEMONSTRATION

Test various levers

Have several examples of levers available for the students to see and touch. Levers you could use are a broom, boat oar, scissors, crowbar, nutcracker, fishing pole, or tweezers. Direct the student to demonstrate the movement of each lever, identify its effort, fulcrum, and resistance, and then classify it.

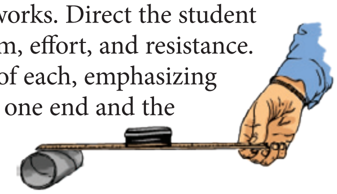
Discussion

Use the ruler, eraser, and cardboard tube to demonstrate how a first-class lever works. Direct the student to identify the fulcrum, effort, and resistance, and discuss the position of each.



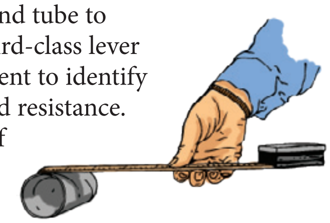
Name some examples of first-class levers. Possible answers: seesaw, balance scale, crowbar, boat oar, scissors, head movement, some automobile jacks, pry bar

Use the ruler, eraser, and tube to demonstrate how a second-class lever works. Direct the student to identify the fulcrum, effort, and resistance. Discuss the position of each, emphasizing that the fulcrum is at one end and the resistance is in the middle. Compare the second-class lever to the first-class lever.



Name some examples of second-class levers. Possible answers: wheelbarrow; door on a hinge; lower-leg movement when standing on toes; other types of hinges; paper cutter; garlic press; bottle opener; pocket knife

Use the ruler, eraser, and tube to demonstrate how a third-class lever works. Direct the student to identify the fulcrum, effort, and resistance. Discuss the position of each and compare to first- and second-class levers.



Name some examples of third-class levers. Possible answers: tweezers; broom or most long-handled tools; fishing pole; baseball bat; most joints in the body

Answers

1. a force acting on something as it moves a certain distance
2. to make work easier
3. A first-class lever has the fulcrum between the effort and the resistance. A second-class lever has the resistance between the effort and the fulcrum. A third-class lever has the effort between the fulcrum and the resistance.

Activity Manual

Reinforcement, pages 145–46

Lesson
111

Student Text pages 226–29
Activity Manual pages 147–51

Objectives

- Describe a pulley, wheel and axle, inclined plane, wedge, and screw
- Discern between a fixed pulley, a moveable pulley, and a block and tackle
- Explain what a compound machine is

Materials

- simple machines, such as a pulley, can opener, wedge, screw, and screwdriver

Vocabulary

pulley	wheel and axle
fixed pulley	inclined plane
moveable pulley	wedge
block and tackle	screw
mechanical advantage	compound machine

Introduction

Display and identify the types of simple machines and their uses.

Today you will learn how each of these objects makes work easier.

Teach for Understanding

Purpose for reading

What is mechanical advantage?

What is a compound machine?

Discussion

What is a pulley? a grooved wheel with a chain or rope wrapped in the groove

How does a pulley make work easier? by changing the direction of the force or by reducing the amount of force needed

What are three types of pulleys? fixed pulley, moveable pulley, and block and tackle (combined pulleys)

Look up the word *fixed* in the dictionary and read aloud the definition that applies to a fixed pulley. nonmoving

Which type of pulley changes the direction of the force without reducing the amount of work? fixed pulley

Which type of pulley reduces the amount of force needed to move an object or produce a gain in force? moveable pulley

Pulley

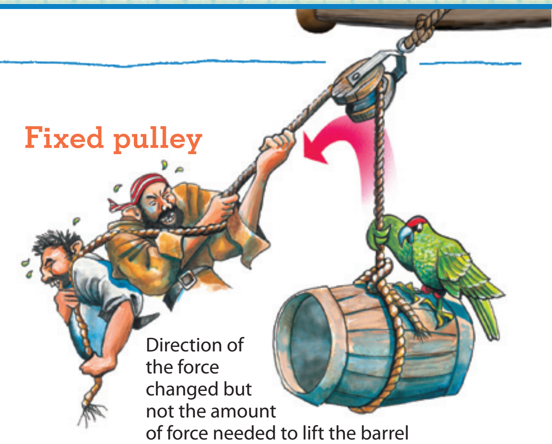
A **pulley** is a grooved wheel with a chain or rope wrapped in the groove. Pulleys are used to raise and lower things. To pull something up, you pull down on the rope. If you want to lower something, you release the rope. Pulleys make work easier by changing the direction of the force or by reducing the amount of force needed to move an object.

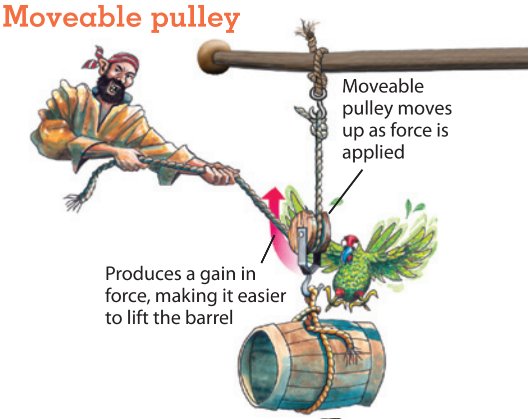
A **fixed pulley** is attached to something, so it does not move. It makes work easier by changing the direction of the force but does not reduce the amount of force needed to move the object. Flagpoles use fixed pulleys.

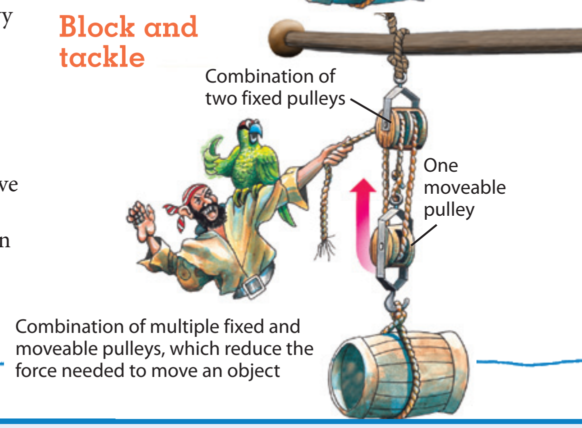
A **moveable pulley** moves with the load or resistance. It produces a gain in force but does not change the direction of the force.

A **block and tackle** combines multiple fixed and moveable pulleys. The fixed pulleys change the direction of the force, while the moveable pulleys produce a gain in force. People use block and tackle pulleys to raise sails on sailboats. Big construction cranes often use a block and tackle to lift heavy pieces of equipment.

Multiple fixed and moveable pulleys combined provide greater mechanical advantage. **Mechanical advantage** is the decrease in effort that is needed to move an object. All simple machines give some mechanical advantage. However, remember our definition of work. When you apply less force, you must apply it







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SCIENCE BACKGROUND

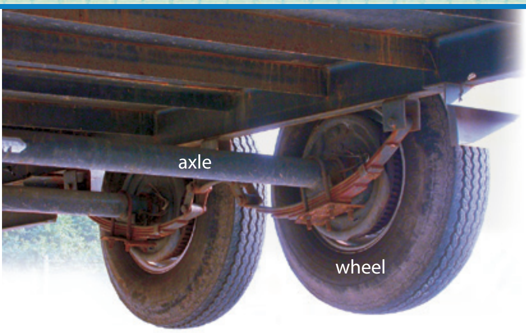
Pulleys
The three classes of pulleys are fixed, moveable, and compound pulleys. Compound pulleys are often called block and tackles.

A fixed pulley changes the direction of the force but does not decrease the effort force needed. However, a moveable pulley decreases the effort needed (produces a gain in force). A moveable pulley multiplies the effort force being applied (gives a mechanical advantage), so less effort is actually needed to lift or move the object. Compound pulleys provide an even greater mechanical advantage but require more space since the object has to move over a longer distance. Whenever force is decreased, the distance increases.

SCIENCE MISCONCEPTIONS

Reducing work?
Simple machines make work easier but do not reduce the amount of work. Work is a result of force and distance. Simple machines can reduce the amount of force required by moving the object a longer distance, or they can reduce the distance as more force is applied.

Pulleys working together
Moveable pulleys are seldom used alone, but the fixed pulley that is usually used with a moveable pulley is not necessary to produce an increase in force. The fixed pulley makes the work easier only because pulling down is easier than pulling up.

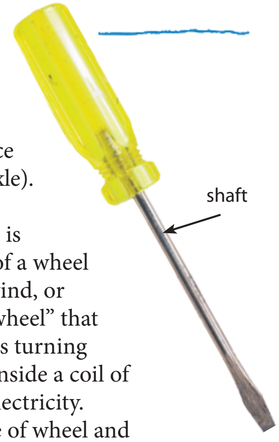


through a greater distance to get the same amount of work. Although a block and tackle requires less effort than a simple fixed pulley does, it takes a much longer piece of rope to lift a load.

Wheel and axle

A **wheel and axle** consists of a wheel and a rod, or axle, running through the wheel. Sometimes we apply force to the axle to make the wheel move a greater distance. This is how the wheels on a car work.

At other times people turn the wheel to make the smaller axle turn with greater force. Have you ever tried unscrewing a screw holding just the shaft rather than the handle of a screwdriver? You can get very little force and probably cannot move the screw very much. But when you turn the handle (the wheel), you can get greater force on the shaft (the axle).



Think about a turbine. A turbine is another example of a wheel and axle. Water, wind, or steam turns the "wheel" that turns the axle. This turning rotates a magnet inside a coil of wire to generate electricity.

A *gear* is a type of wheel and axle. A gear has toothlike projections around the wheel. Some gears have teeth that interlock with the teeth on another gear. When one gear turns, it moves the other gears that it touches in the opposite direction. However, on a bicycle the gears are connected with a chain, and both move the same direction. Gears are used in many mechanical devices. People use them in simple things, such as can openers, and also in things as complex as automobiles.

Types of Gears

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Discussion

What is a block and tackle? a combination of moveable and fixed pulleys

What is mechanical advantage? a decrease in effort needed to move an object

Why does a block and tackle require a longer piece of rope in order to use less force? Answers will vary, but elicit that work is equal to force times distance, so less force requires a greater distance for the same work.

Remind the student of the formula for work, force × distance = work.

Discuss the pictures of the pulleys.

What is a wheel and axle? a wheel with a rod, or axle, running through it

Why do large items such as refrigerators and pianos have wheels? to make moving them easier

What other simple machine is a type of wheel and axle? a pulley

What are two ways work is done using a wheel and axle? One way is to apply force to the axle to make the wheel move a greater distance. Another way is to turn the wheel to make the axle turn with greater force.

What part of a wheel and axle is a screwdriver handle? the wheel

What is a gear? a type of wheel and axle that has toothlike projections around the wheel

A car has wheels and axles that help it move. Where else in a car or truck is a wheel and axle? the steering wheel

What are some common wheels and axles? Possible answers: screwdriver, turbine, gears, car wheels, bike pedals, some pencil sharpeners, windlasses

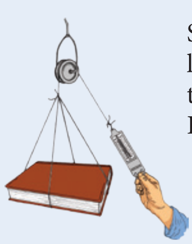
Tools such as bicycle pedals, windlasses, and hand drills are examples of wheels and axles, but the round wheel shape is replaced by a crank. Wheels and axles are considered to be variations of a lever or a pulley.

DIRECT A DEMONSTRATION

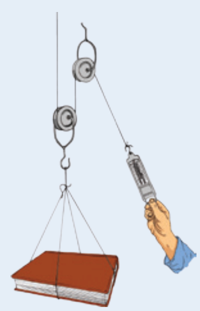
Compare the amount of work done with pulleys

Materials: book, spring scale, pulley, string or thin rope, place to attach pulley

Direct a student to lift the book 30 cm using the spring scale. Record the measurement.



Set up a fixed pulley as illustrated. Direct a student to lift the book 30 cm. Record the measurement.



Set up moveable and fixed pulleys as illustrated. Direct a student to lift the book 30 cm. Record the measurement. Compare the measurements.

Why are the measurements without a pulley and with the fixed pulley the same (similar)? A fixed pulley gives no mechanical advantage. It only changes the direction of the force.

Was more or less work used with the moveable and fixed pulleys working together? less

Discussion

What is an inclined plane? a flat, slanted surface, such as a ramp

Is more force required to push an object up a steep slope or push the same object up a gradual slope? up a steep slope

For an inclined plane, what is the relationship between the steepness of the slope, the distance of the plane, and the amount of work done? A more gradual slope requires less force to move an object, thus making the work easier; however, it has a longer distance for the object to travel.

What do we call the decrease in effort needed to move an object? mechanical advantage

Discuss and compare the inclined plane pictures.

Which action requires the most force? lifting straight up

Which action requires the least force? pushing up the longest ramp

Guide the student in drawing the conclusion that in each picture the mass of the object being moved is the same, but as the distance increases, the amount of effort decreases.

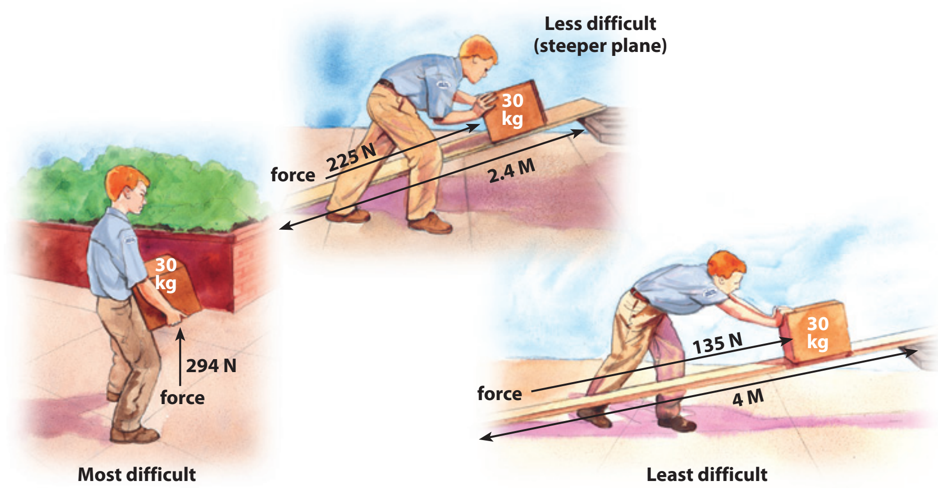
What is a wedge? two inclined planes back to back

What is the purpose of a wedge? It splits or lifts objects.

Which force helps a wedge do work? friction **Why?** It keeps the wedge from sliding.

Give examples of common types of wedges. Possible answers: knives, hatchets, axes, nails

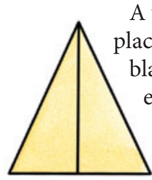
What activities would be impossible without a wedge? Possible answers: cutting meat with a knife; digging in the dirt with a shovel to plant flowers



Inclined plane

An **inclined plane** is a flat, slanted surface, such as a ramp. This type of simple machine makes moving an object up a distance easier than lifting the object straight up. The mechanical advantage of an inclined plane is based on its slope and the length of the inclined plane. A more gradual slope requires less force to move the object, thus making the work easier. A more gradual slope, however, has a longer distance for the object to travel.

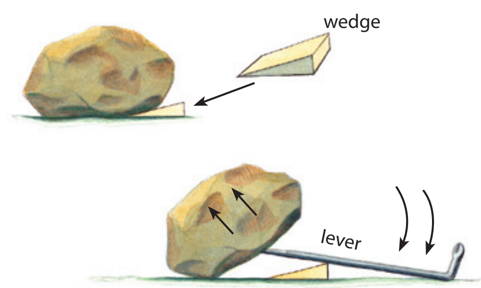
Wedge



A **wedge** is two inclined planes placed back-to-back. Knife blades, axes, hatchets, and even the ends of nails are all wedges. A wedge splits or lifts objects. Long, thin wedges cut and split better than short, fat ones. This is why a sharpened blade works better than a dull blade.

Friction keeps wedges in place. Without friction, a wedge would slide off the object that it is trying to split or lift.

Sometimes people pound wedges under objects to separate the objects from their surroundings. A wedge may be used to lift a heavy object just a little so that a lever can be used to move it farther.



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Simple machines in Egypt

HISTORY

Many historians believe that the Egyptians used inclined planes to help in the building of the pyramids. A ramp wound around the outside perimeter of a pyramid would have allowed huge stones to be pushed up the incline. Historians also think that levers may have been used to raise the huge obelisks in Egypt.

Although there may not be documentation that ancient Egyptians actually used these simple machines in these ways, there seems little doubt that ancient civilizations knew how to use simple machines to build enormous structures.

Access ramps

TECHNOLOGY

As a result of the Americans with Disabilities Act of 1990, businesses, crosswalks, and other public places now have access ramps instead of or in addition to steps. Government-established guidelines mandate the slope of the ramps. These inclined planes allow people with disabilities to have easier access to buildings and public places.

Wedge

LANGUAGE

Discuss the uses of the term *wedge* that do not mean the physical simple machine. Ask the student to list sentences and phrases that use the term. Elicit that it means “to separate or divide.” Examples include the following: He wedged his way into the line. Their disagreement has formed a wedge between them. Sin is a wedge that separates a person from God.

Screw

A **screw** is an inclined plane wound around a cylinder or a cone. The ridges in the screw are called *threads*. As these threads are turned, they cut into a material and hold the screw firmly in place. Pulling a screw out of a piece of wood without turning the screw is very difficult. Screws depend on friction to stay in place. Without friction, you could remove a screw easily, since it would not grip the material it was screwed into.

You have probably seen screws holding together wood or metal pieces many times. Another example of a screw is the top of a jar. The lid also has a screw, and the two parts fit together to close the jar. Some winding mountain roads are also types of screws. Instead of going straight up a mountain, the road has a slight incline that goes around and around. It is easier to travel than a sharp incline, but it takes a lot longer.

Compound Machines

A **compound machine** combines two or more simple machines to make work even easier. Scissors are an example of a compound machine. The blades are two levers working together, and the cutting edges are wedges. A screw and screwdriver working together make another compound machine. The screw itself is a simple machine, and the screwdriver is a wheel and axle. Most machines we use daily are made up of at least two simple machines.

QUICK CHECK

1. In what two ways can pulleys make work easier?
2. What is mechanical advantage?
3. How is a wedge different from an inclined plane?

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Discussion

What is a screw? an inclined plane wound around a cylinder or a cone

What is another name for the ridges in a screw? threads

What is the purpose of these threads? They cut into a material and hold the screw firmly in place.

How are some winding mountain roads types of screws? They are slight inclined planes with a gradual (slight) incline that wind around the mountain.

Why would engineers design roads this way? because it is easier to travel on a slight incline on a winding mountain road than on a steep incline

What is a compound machine? A machine that combines two or more simple machines.

What are some examples of compound machines? Identify the simple machines in each compound machine. Possible answers: scissors: levers and wedges; screw and screwdriver: screw and wheel and axle; wheelbarrow: levers and wheel and axle

Answers

1. They can change the direction of the force or reduce the amount of force needed.
2. the decrease in effort that is needed to move an object
3. A wedge is two inclined planes placed back to back. An inclined plane is a single, flat, slanted surface.

Activity Manual

Reinforcement, pages 147–48

Review, pages 149–50

These pages review Lessons 110 and 111.

Expansion, page 151

This page discusses some historical uses of simple machines.

Assessment

Quiz 9-B

The quiz may be given any time after completion of this lesson.

WRITING **Simple machines in ancient civilizations** Direct the student to choose an ancient civilization (Greece, Rome, Aztec, Maya, Inca, Babylon, etc.) and research how simple machines may have been used to construct some of its monuments.

Student Text pages 230–31
Activity Manual page 152

Objectives
- Experiment to show that an inclined plane reduces the amount of force needed to do work
- Measure metrically in newtons and centimeters
- Define operationally the results of the activity

Materials
- See Student Text page

Introduction

What is work? a force acting on something and moving it a distance

What is the formula for work? force × distance = work

Today we will be measuring and calculating the work required to move an object a distance.

Teach for Understanding

Purpose for reading
The student should read all the pages before beginning the activity.

Procedure
Guide the student in measuring the board and placing the pieces of tape. Remind him of the importance of measuring accurately. As needed, check the setup of his inclined plane and spring scale before he begins step 3.

Explain the importance of pulling the object carefully. If the movement is not slow and steady, the scale may give an incorrect reading.

Emphasize that the bottom of the object should start at the bottom of the board. The reading is taken when the bottom of the object crosses the designated mark. To measure accurately, establish set conditions and expect them to be followed carefully.

ACTIVITY

How Much Force?

Process Skills
- Measuring
- Observing
- Defining operationally
- Recording data

Work is a force acting on something and moving it a distance. We calculate the amount of work by multiplying the amount of force on the object and the distance the object is moved.

Force *(newtons)* × **Distance** *(meters)* = **Work** *(joules)*

In this activity you will calculate the amount of work needed to move an object along an inclined plane. The force will be measured using a spring scale. You will measure distance in centimeters and convert the measurements to meters before calculating the amount of work done.

Problem
How can an inclined plane reduce the amount of force needed to do work?

Materials
- board approximately 30 cm × 80 cm
- meter stick
- masking tape
- stack of books 15 cm high
- object, such as a book or bag of candy
- string 1 meter long (optional)
- spring scale (newton)
- calculator (optional)
- Activity Manual

Procedure
1. Measure from the end of the board. Place pieces of tape at 20 cm, 40 cm, and 60 cm from the end of the board. Place the stack of books (15 cm high) under the board at the place marked 60 cm. Make sure the books are straight. The board will be acting as an inclined plane.
2. Attach the string to the object being used as the weight if needed.
3. With the spring scale attached to the object or string, place the bottom of the object at the bottom of the board. Slowly and steadily pull the object up the board until the bottom of the object passes the 60 cm mark. As it passes the mark, read the spring scale to see how many newtons of force are being exerted. Record this measurement in the *Force in newtons* column on the chart in your Activity Manual.

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TEACHER ✱HELPS✱

Grams to newtons
If your spring scale measures in grams rather than newtons, convert the grams to newtons. One newton equals about 100 grams.

Group jobs
If the students are working in groups, you may want to assign each person in the group a particular job. This will keep all students on task during the activity. All students should observe each step and work together cooperatively in the group. Here are suggested job assignments for a group of four students.

Job 1: Measure and mark the board with tape.

Job 2: Stack the books and adjust the board each time.

Job 3: Pull the spring scale and observe the newton measurements.

Job 4: Record the measurements. Do the calculator calculations.

4. Move the stack of books to the 40 cm mark. Repeat step 3, reading your force measurement as the object passes the 40 cm mark.
5. Move the stack of books to 20 cm and repeat again. Read the force measurement as the object passes the 20 cm mark.
6. Convert the number in the *Length of inclined plane* column to meters and record the answer in the *Distance in meters* column.
7. Calculate the amount of work done. Your answer will be in newton-meters (N•m), or joules.

Conclusions

- Why was the amount of work done at each distance about the same?
- At which distance was the most force required to do the work?

Follow-up

- Set up an experiment to show how much work is done rather than how much force is needed to do the work.
- Change a different variable such as the height of the books.

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Conclusions

Provide time for the student to evaluate his results and answer the questions.

Why was the amount of work done at each distance about the same? The shorter the distance, the steeper the slope is. Thus the amount of work done at each distance was about the same.

How does the amount of force change as the length of the inclined plane decreases? A shorter plane requires a greater amount of force.

At which distance was the most force required to do the work? 20 cm

How would this information be helpful if you were using a ramp to load a truck or were pulling a wagon up a hill? Answers will vary but should include the idea that work will be easier if the ramp is longer and the slope is smaller.

Use the questions in the Science Process Skills to discuss defining operationally.

Activity Manual

Activity, page 152

Assessment

Rubrics

Select the prepared rubric, or design a rubric to include your chosen criteria.

SCIENCE PROCESS SKILLS

Defining operationally

In order to define operationally, the student should use terms correctly to explain his observations or conclusions in his own words.

What was the purpose of the activity? to discover whether an inclined plane reduced the amount of force needed to do work

What did you discover? Answers will vary but should include the idea that less force was needed for the object to move a greater distance.

Help the student explain his results in his own terms. The key is that he understands what is happening and is able to use the scientific terms accurately.

Student Text page 232
Activity Manual pages 153–56

Objectives
- Recall concepts and terms from Chapter 9
- Apply knowledge to everyday situations

Introduction
Material for the Chapter 9 Test will be taken from Student Text page 232 and Activity Manual pages 139–40, 149–50, and 155–56. You may review any or all of the material during the lesson. Questions similar to Solve the Problem or the ones in Thinking It Through, Activity Manual pages 155–56, may appear on the test.

You may choose to review Chapter 9 by playing "Moving Along" or a game from the Game Bank on the Teacher's Toolkit CD.

Teach for Understanding
Diving Deep into Science
Information on this page reflects the vocabulary and concepts the student should know for the test.

Solve the Problem
In order to solve the problem, the student must apply material he has learned. The student should attempt the problem independently. The answer for this Solve the Problem is based on the material on Student Text pages 224–29. Answers will vary and may be discussed.

Activity Manual
Expansion, pages 153–54
Students examine and design imaginative inventions.

Review, pages 155–56
These pages require written responses to application questions.

Lesson 114

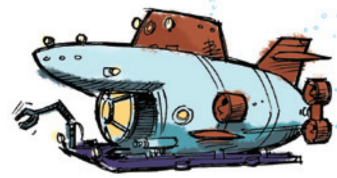
Objective
- Demonstrate knowledge of concepts taught in Chapter 9

Assessment
Tests, Chapter 9

DIVING DEEP INTO SCIENCE

Words to Know

mechanical energy	gravity	fixed pulley
motion	work	moveable pulley
reference point	newton	block and tackle
distance	joule	mechanical advantage
speed	machine	wheel and axle
velocity	effort force	inclined plane
acceleration	resistance force	wedge
friction	lever	screw
momentum	fulcrum	compound machine
inertia	pulley	



Key Ideas
Difference between potential and kinetic energy
Newton's three laws of motion
Effects of friction and gravity on motion
Formula for work
Location of effort, resistance, and fulcrum for each kind of lever
Examples of each kind of simple machine
Relationship of distance and effort in inclined planes
Examples of compound machines

Solve the Problem
Your family just bought a new washing machine. When you are getting ready to bring it home, you remember that the washing machine will need to be lifted up three tall steps. Then it will have to be moved down a narrow hallway to get to the laundry room. What simple machines might you use to help you move the washing machine into your family's house with less effort?

Possible answers: an inclined plane (a ramp); pulleys arranged as a block and tackle; an applicance dolly is a second-class lever; wheel and axle; a wedge (bottom plate)

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Review Game
Moving Along

Prepare 25 index cards by labeling 5 cards *Friction*, 5 cards *Gravity*, 5 cards *Force-1*, 5 cards *Force-2*, and 5 cards *Force-3*. Display a number line numbered from 0 to 15. Divide the class into two teams. Shuffle the cards and assign each team a symbol or marker to use with the number line.

Each time a team answers a question correctly, a member of the team draws one of the cards. If a type of force card is drawn, the team moves their marker forward 1, 2, or 3 spaces as indicated by the number on the card. If a gravity or friction card is drawn, the team's inertia is stopped and the team does not move that turn. The team cannot move again until they draw a force card to overcome their zero velocity. The first team to reach 15 wins.

Teacher Notes