unit 7

# Transportation Technologies

## Chapters In This Unit:




## Unit Thematic Project Preview

### Advancing Transportation

As part of this unit, you will learn about the different types of engines and motors that make vehicles go. You will also explore the many transportation systems that allow you to move around your neighborhood, your country, and the world!

As you read this unit, use this checklist to prepare for the project at the end of this unit:

***PROJECT CHECKLIST***

✓ Look for transportation magazines and Web sites.

✓ Find out what kinds of transportation problems are in your community.

✓ Consider whether you will use materials or a computer to make a model.

## WebQuest Internet Project

Go to **glencoe.com** to this book's Online Learning Center (OLC) to find the WebQuest activity for Unit 7. Begin by reading the Task. This WebQuest activity will help you learn about space exploration, especially to the planet Mars. You will find out about past missions to Mars as well as current and future travel to that planet and beyond.

### Explore the Photo

**Moving into the Future** As operating gasoline-fueled engines becomes more expensive and causes more pollution, technologists are inventing new ways to get around. Solar, electric, and alternative fuel powers are not just science-fiction—they are real today! *What kind of transportation do you imagine you will use when you grow up?*



AFP/Getty Images

chapter 21

# Transportation Power

## Sections



## What You'll Learn

- **Explain** how an external combustion engine works.
- **Compare** a steam engine to a steam turbine.
- **Tell** how an internal combustion engine works.
- **Define** four-stroke and two-stroke engine cycles.
- **Describe** the purpose of a crankshaft.
- **Identify** differences among various engines.
- **Examine** how electric motors are used to power locomotives.
- **Discuss** how a hybrid automobile is powered.
- **Summarize** the advantages and disadvantages of hybrid and fuel cell cars.

### Explore the Photo

**Power** Until the invention of the steam engine, transportation power came directly from natural sources, such as wind and flowing water. *What might be the source of power shown in this picture?*

Launch the TECHNOLOGY LAB

## Build a Steam Turbine

At the end of this chapter, you will be asked to build a steam generator that will turn a fan-shaped turbine. Get a head start by using this checklist to prepare for the Technology Lab.

### PROJECT CHECKLIST

- ✓ Get familiar with steam turbines by looking at photos or illustrations of them.
- ✓ Ask your teacher for a list of materials you will need to build the turbine.
- ✓ Create a table to record speeds for your different designs.



Joel W.Rogers/Corbis

section 21.1

# External Combustion Engines

## Reading Guide

**Before You Read** **Preview** What are some types of transportation power?

### Content Vocabulary

- external combustion engine
- piston
- turbine

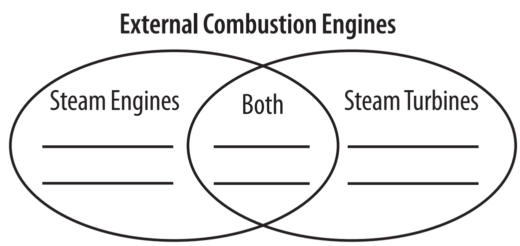
### Academic Vocabulary

You will see these words in your reading and on your tests. Find their meanings at the back of this book.

- convert
- expand

### Graphic Organizer

Draw the section diagram. Use it to organize and write down information as you read.




Go to **glencoe.com** to this book's OLC for a downloadable graphic organizer and more.

**TECHNOLOGY STANDARDS**

**STL 3** Relationships & Connections

**STL 7** Influence on History

**STL 11** Design Process

**STL 16** Energy & Power Technologies

**ACADEMIC STANDARDS**

**Science**

**NSES Content Standard E** Understandings about science and technology

**Social Studies**

**NCSS 2** Time, continuity, and change

**STL** *National Standards for Technological Literacy*

**NCTM** *National Council of Teachers of Mathematics*

**NCTE** *National Council of Teachers of English*

**NSES** *National Science Education Standards*

**NCSS** *National Council for the Social Studies*

## Engines and Motors

*How did earlier humans get power for transportation?*

Engines and motors produce the power we need to carry people and goods. Until about 300 hundred years ago, there were no engines. The only forms of transportation power came directly from nature, such as wind, flowing water, and muscle power from people and animals. Without power for transportation, how would you get to school or visit far-away relatives or friends? How would food and other products get to our stores?

**As You Read**

**Contrast** What is the difference between a steam engine and a steam turbine?

An engine is a power source that uses combustion with air to produce motion. The word *motor* is more general. A motor converts any form of energy into motion. Some examples are air motors and electric motors. People often use the words *engine* and *motor* interchangeably. You can say that a car is powered by an engine or a motor. However, there are no electric engines, only electric motors.

Reading Check **Compare** What is the difference between an engine and a motor?

## Steam Engines

*How do steam engines work?*

All steam engines are **external combustion engines**. See **Figure 21.1**. *External* means the power source is outside the engine. *Combustion* refers to burning. Steam engines use the heat from burning coal or wood to change water into steam. The fire is under a boiler outside the engine, so the power source of the engine is external.

### Pistons and Flywheels

Steam engines have a piston that moves up and down. A **piston** is a plug that just barely fits inside a closed cylinder. Expanding steam from a boiler pushes on the piston and causes it to move inside the cylinder. The piston's up-and-down movement turns a circular flywheel.

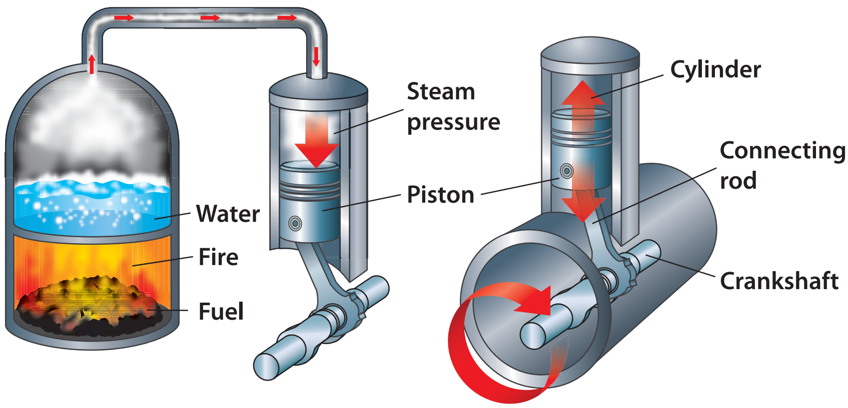
**Imagine This...**

**Personal Rocket Power**

Imagine soaring through the air with your own rocket pack. Two companies in Mexico and Colorado are in the early stages of producing rocket packs. Each weighs over 100 pounds and can propel the user to speeds over 60 mph. But each only lasts for 30 seconds and costs over $100,000. *Why do you think the flight time for rocket packs is so short?*

Go to **glencoe.com** to this book's OLC for answers and to learn more about different rocket packs.

**Figure 21.1** Steam Engines




**Blowing Off Steam** Steam engines (left) produce power when steam pressure pushes on a piston similar to the one shown at the right. *What three types of fuels have been commonly used with steam engines?*

SuperStock

By connecting the spinning flywheel to a vehicle's wheels, steam was used to power land transportation. The first steam engine was built in England in 1712. It operated pumps to remove water from coal mines. This is a good example of how engineers can adapt a technology that was developed for one setting and then use it for another setting.

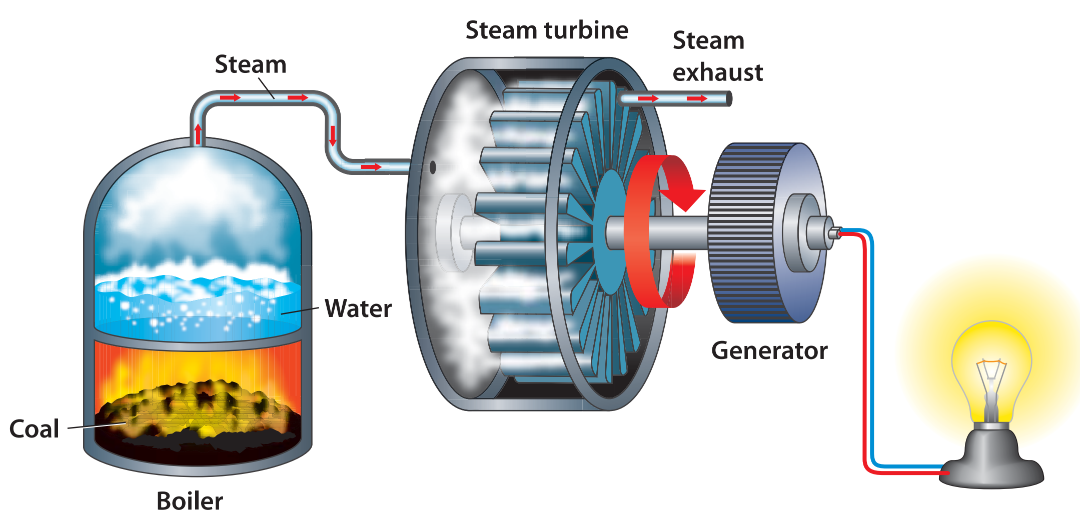
**Gathering Steam** Huge locomotives like this one once crisscrossed the country. They were powered by steam engines. *What noise did steam trains make when they ran?*

Almost any type of fuel can be used to produce steam, and many types of engine designs are available. However, steam is dangerous. Also, boilers require a lot of maintenance and space, and so they are used mainly for large vehicles.

## Transportation Power

Steam engines powered huge locomotives and ships that transported passengers and cargo. The engines made a loud chuffing noise and produced clouds of steam. Steam engines were also used in some early cars like the Stanley Steamer.

**Figure 21.2** **Steam Turbines**




**Generating Electricity** In one type of electrical power plant, burning coal heats water and makes steam. The steam pressure spins a turbine that is connected to a generator (alternator). The generator produces electricity. *What do steam engines and steam turbines have in common?*

Richaro Hutchings/PhotoEdit

In modern-day America, steam engines are not used very much. Their efficiency is low, and they do not produce much power for their size. People's needs have changed. However, you can better understand today's technologies by studying those used in the past.

**Reading Check** **Describe** How does an external combustion engine work?

**Round and Round** Steam turning a turbine is similar to blown air turning a pinwheel. *Why are steam turbines external combustion engines?*

## Steam Turbines

*What are steam turbines?*

Steam turbines operate from steam pressure, just like steam engines. That is where the similarity ends, however. Steam engines produce their power by pistons moving up and down. Steam turbines develop power from spinning disks. The two kinds of power sources are very different.

A **turbine** is a continually spinning disk that resembles a pinwheel. Blow on a pinwheel, and it spins. You could call the pinwheel a "breath turbine" because your breath makes it spin. Steam from a boiler spins steam turbines, as shown in **Figure 21.2**. Steam turbines power oceangoing ships and are also used in electrical plants to produce electricity.

## section 21.1 assessment

**After You Read** **Self-Check**

1. Identify where and when the first steam engine was built and its purpose.
2. Explain why steam engines are considered *external* combustion engines.
3. Compare a steam turbine to a steam engine.

### Think

4. List some safety problems that you think early steam engines might have caused.

### Practice Academic Skills

**Social Studies**

5. Look up improvements made on steam engines by James Watt (1736–1819). Make sketches illustrating his changes and write captions explaining them.

**STEM** **Mathematics**

6. Jaden wants a new mp3 player. There is one on sale for $95.99 that comes with a 20% mail-in rebate. How much will the player cost Jaden after the rebate?

**Math Concept** **Percents** A percent is a part of the whole. You can find the price after a discount in two ways.

1. Find 20% of $95.99, and then subtract that amount from the selling price.
2. You can also subtract the discount percent from 100, and then calculate that percentage of the selling price.

For help, go to **glencoe.com** to this book's OLC and find the Math Handbook.

# section 21.2 Internal Combustion Engines

## Reading Guide

**Before You Read** **Connect** Where does burning take place in a car's engine?

### Content Vocabulary

- internal combustion engine
- reciprocating motion
- rotary motion
- crankshaft
- ignition system
- emissions
- ethanol
- maintenance
- jet engine
- thrust
- propellant

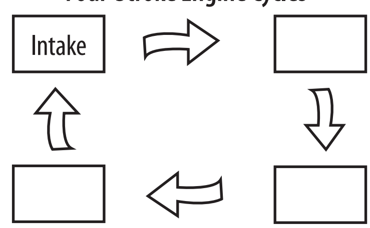
### Academic Vocabulary

- transfer
- regulate

### Graphic Organizer

Draw the section diagram. Use it to organize and write down information as you read.

**Four-Stroke Engine Cycles**




Go to **glencoe.com** to this book's OLC for a downloadable graphic organizer and more.

**TECHNOLOGY STANDARDS**

**STL 5** Environmental Effects

**STL 16** Energy & Power Technologies

**STL 18** Transportation Technologies

**ACADEMIC STANDARDS**

**Mathematics**

**NCTM Algebra** Use mathematical models to represent and understand quantitative relationships.

**Science**

**NSES Content Standard F** Science and technology in society

**STL** *National Standards for Technological Literacy*

**NCTM** *National Council of Teachers of Mathematics*

**NCTE** *National Council of Teachers of English*

**NSES** *National Science Education Standards*

**NCSS** *National Council for the Social Studies*

## Internal Combustion

*What is an internal combustion engine?*

Did you know that there is a fire inside most car engines? You cannot see the flames because they are deep inside. This internal fire makes these engines internal combustion engines. Gasoline, diesel, and rocket engines are all this kind of engine.

Most engines we use create power from a piston sliding inside a cylinder. Fuel and air are placed inside the cylinder. See **Figure 21.3**. An electric spark causes the mixture to ignite, burn, and build up high pressure quickly.

**As You Read**

**Predict** What kinds of vehicles use internal combustion engines?

## Engine Cycles

*How are engine cycles like other types of cycles?*

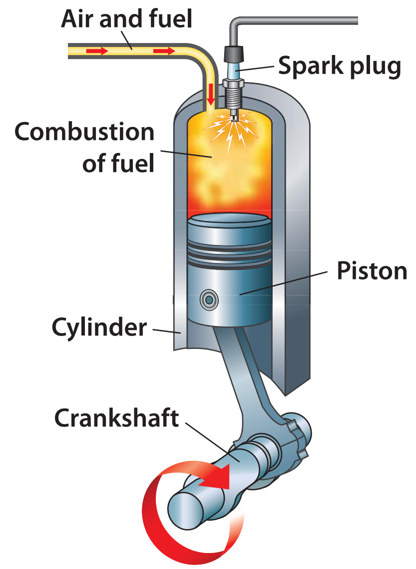
When you pedal a bicycle, your legs go up and down, repeating the motions over and over again. One motion of your leg makes a downward stroke. Lifting your leg creates an upward stroke. Your legs make two strokes before repeating the same motions. We could say that your bicycle is operated by a two-stroke human power plant.

### Four-Stroke Cycles

Much like your legs pedaling a bicycle, the pistons inside an engine move up and down. The most popular type of engine is the four-stroke cycle engine. The pistons make four strokes before they repeat themselves. See **Figure 21.4**. These strokes are the intake, compression, power, and exhaust strokes. Most cars and lawn mowers have four-stroke cycle engines.

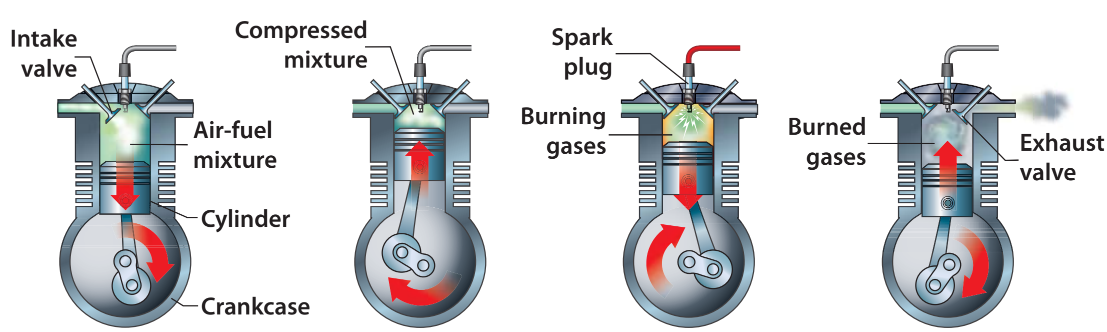
- **Intake stroke—**The piston moves down. The intake valve is open and fuel and air flow into the cylinder.
- **Compression stroke—**The intake valve closes, and the piston moves up. It squeezes the air-fuel mixture to about ⅛ of its original volume in the top of the cylinder.
- **Power stroke—**An electric spark from a spark plug ignites the mixture. The fuel and air mixture burns very rapidly and increases the pressure inside the cylinder. This pressure forces the piston down.
- **Exhaust stroke—**The exhaust valve opens. The piston moves up and pushes out the exhaust gases. The cycle repeats.

**Figure 21.3 Internal Combustion**




**Explosive Force** In a typical engine, fuel is ignited in the cylinder. The explosive force from the burning fuel moves the piston. *What keeps the explosive force from leaking around the outside of the piston?*

**Figure 21.4 Four-Stroke Cycle**




**Different Strokes** This is what happens during each stroke of a four-stroke cycle gasoline engine. *How many strokes do your legs make when you ride a bicycle?*


Dennis MacDonald/PhotoEdit

**Stroke Power** Two-stroke engines power chain-saws, string trimmers, and some motorcycles. *Which is more efficient: a two-stroke cycle engine or a four-stroke cycle engine?*

## Two-Stroke Cycles

Some small gasoline engines operate with two strokes. The intake and compression strokes are combined, as are the power and exhaust strokes. Such engines operate on a two-stroke cycle. The piston makes two strokes before it begins to repeat itself. These engines power some off-road motorcycles, chain saws, and other devices. Two-stroke cycle engines are less efficient and emit more pollutants. In two-stroke engines, the fuel and oil are mixed together.

**Reading Check** **Summarize** What are engine cycles?

# Gasoline Engines

***How do gasoline engines produce power?***

There are more gasoline engines in the world than any other type. They start easily, are inexpensive to make, and can be made in almost any size. Automobile engines operate with a four-stroke cycle. Many modern engines have four cylinders, but others may have six or eight cylinders.

## Pistons

The piston in a gasoline engine moves only up and down. This up-and-down, straight-line motion is called **reciprocating motion**. Unless we travel by pogo stick, reciprocating motion cannot be used for transportation. It must be converted to **rotary motion**, or circular motion. All of our transportation vehicles and methods, except rocket-powered spacecraft, require rotary motion to turn wheels or propellers.

## Crankshaft

Reciprocating motion is changed to rotary motion by a **crankshaft**. See **Figure 21.5**. The pedals on your bicycle are also attached to a crankshaft. The crankshaft converts your reciprocating leg motion to the circular motion of the wheels. Your legs move up and down, but the wheels rotate to move you forward.

An automobile has a crankshaft inside the engine. Each piston is joined to it by a connecting rod. The rotating crankshaft transfers power to the driving wheels.

**Reading Check** **Explain** What is the purpose of a crankshaft on a bicycle?

# Diesel Engines

*How are diesel engines different from gasoline engines?*

Diesel engines power trucks, buses, locomotives, ships and some automobiles. They operate smoothly with heavy loads, which would cause a gasoline engine to stall. Diesel engines last longer and require less maintenance.

## Parts of a Diesel Engine

The internal parts of a diesel engine are like the parts inside a gasoline engine. Diesels have pistons, cylinders, and a crankshaft. They come in four-stroke and two-stroke cycle versions, which are a bit more efficient and use less fuel than four-stroke engines.

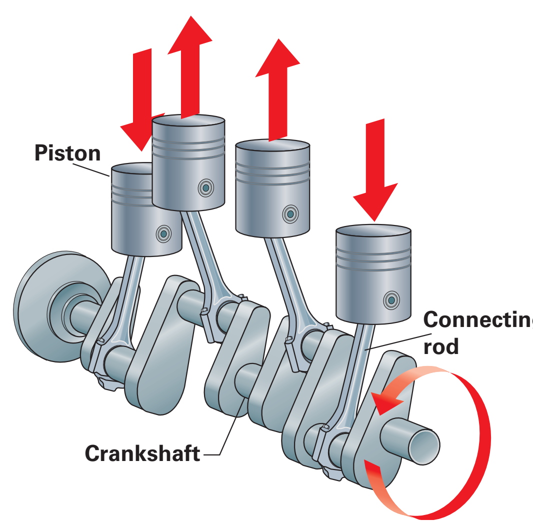
The major differences between diesel and gasoline engines are in the diesel's fuel system and **ignition system**. Since diesel fuel cannot be easily ignited with a spark plug, diesel engines use hot air.

## Diesel Engine Cycles

The engine's four strokes are the same as those in a gasoline engine. However, there are some operating differences.

- **Intake stroke—**Only air enters the cylinder. It is not an air-fuel mixture.
- **Compression stroke—**The air is squeezed to about 1⁄22 of its original volume, causing its temperature to rise to about 1,000°F.
- **Power stroke—**Diesel fuel is squirted directly into the cylinder. The high air temperature ignites the fuel immediately. Pressure builds up very quickly and pushes the piston down.
- **Exhaust stroke—**The piston moves up. Burned gases are pushed out.

**Figure 21.5 Crankshaft**




**Change in Motion** A crankshaft is a strong, heavy piece of metal that converts reciprocating motion to rotary motion. *Where have you seen something that works like a crankshaft?*

**Reading Check** **Contrast** How are gasoline and diesel engines different?

# Emissions and the Environment

*Why does the government control emissions from cars?*

When an engine burns fuel, it creates **emissions**. Emissions are gases released into the air because of combustion. A small part of this gas contains pollutants, which are harmful to the environment.

## Ethics in Action

### Fuel Economy

One important thing to consider when choosing a car is how much fuel it uses, or its "fuel economy." This is measured in miles per gallon. If your car gets more miles per gallon, you spend less on gas and cause less pollution.

**Extreme Efficiency** The average new vehicle sold in the United States gets less than 30 miles per gallon. However, a French team has built an experimental car called *Microjoule* that can travel 10,705 miles per gallon!

**English Language Arts/Writing**

**Higher Standards** Many people want to make fuel economy laws stricter. They want new automobiles to get at least 35 miles per gallon. Others say this would be unfair to automakers and would hurt their business.

1. Research both sides of the issue.
2. Write your own opinion in one paragraph.

## Fuel Efficiency

The Environmental Protection Agency of the U.S. government **regulates** the emissions and miles per gallon for all cars sold in the United States. The emissions must be low to reduce pollution. The miles per gallon must be high to burn less fuel.

Manufacturers are trying to reduce emissions by designing more fuel-efficient automobiles, including electric and hybrid cars (see Section 21.3). They are also trying to reduce harmful emissions by experimenting with cleaner sources of fuel.

## Ethanol

Some engines can use **ethanol**, a liquid fuel made from corn. Ethanol burns more cleanly than straight gasoline. Americans usually use ethanol as an "additive," which means that they mix it with gasoline. Cars that can use ethanol are called flex-fuel vehicles. Flex-fuel vehicles in Brazil use ethanol made from sugar.

## Natural Gas

Natural gas heats half the homes in America. Scientists are also testing it as a fuel for automobiles. Suppliers compress it to make a liquid. It is compressed natural gas, or CNG. These CNG cars cause less pollution than cars that use straight gasoline.

## Biodiesel

Biodiesel is a mixture of soybean oil and diesel fuel. Called B20 because it is 20 percent soybean oil, biodiesel can be used in any diesel engine. Its greenhouse gas emissions are reduced.

**Reading Check** **Explain** Why is it important to control emissions from automobiles?

# Gas Turbine Engines

***Why do commercial airplanes use gas turbine engines?***

Gas turbine engines power many large airplanes and ships. They are complicated, but they are the most reliable internal combustion engine. A reliable engine requires less **maintenance** because it rarely stops working or breaks.

## Advantages and Disadvantages

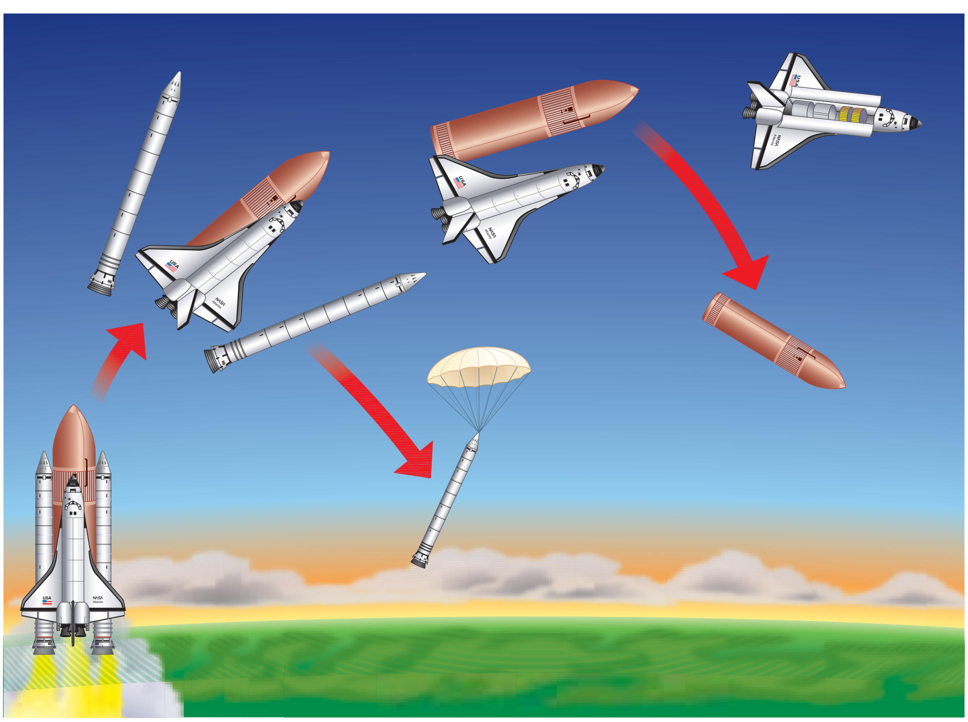
Gas turbines are smaller and lighter than other engines of the same power rating and have a long engine life. Their biggest disadvantage is high cost. The gas turbine has parts that spin at high speeds and are kept at high temperatures. Such parts must be carefully made from special materials.

## Types of Gas Turbine Engines

There are three basic types of gas turbine engines: the turbojet, the turbofan, and the turboshaft (or turboprop). Turbojets and turbofans are also called "jet engines." **Jet engines** push airplanes through the air with a jet of high-pressure exhaust gas. Have you ever blown up a balloon and then let it go? The pressurized air escapes through the end, making the balloon dart around. This force is known as **thrust**.

Reading Check **Recall** What are three gas turbine engines?

**Figure 21.6 Space Shuttle Launch**



**Blast Off!**
During the launch of the space shuttle, the two solid rocket boosters are released first. The liquid propellants are carried in the big center tank that drops away and is later picked up in the ocean. *Where might the thrust occur in a rocket?*

**Academic Connections**
**Social Studies**

**Lift Off!** America's *Saturn V* rocket put Neil Armstrong and Edwin Aldrin on the moon in 1969. It remains the largest and most powerful production rocket ever built. It was 363 feet tall and developed about 7.5 million pounds of thrust at liftoff.

**Apply** Do some research at the library on famous astronauts. Write a paragraph describing the effects of the space program on the families of astronauts.

# Rocket Engines

*Why are rocket engines used in space?*

A rocket engine carries its own oxygen for combustion. The oxygen and fuel form a **propellant** producing a high-speed exhaust gas. The gas rushes out the rear to produce thrust. Jet engines depend on oxygen from the air, but there is no air in outer space so only rocket engines can travel in space.

## Solid Propellants

The simplest rocket engines use a solid propellant. Solid propellants do not need a special combustion chamber. They are ignited, and then burn. The combustion, however, cannot be stopped once it has begun. The thrust from five powerful rocket engines lifts the space shuttle off the launching pad. Two are solid-propellant rocket engines strapped to each side. See **Figure 21.6** on page 457. They are solid rocket boosters (SRBs) that boost the shuttle into orbit, burning out in two minutes. Then they drop into the ocean.

## Liquid Propellants

The three middle engines on the space shuttle are called space shuttle main engines (SSMEs). They do not drop away. They use liquid propellants: liquid oxygen (LOX) and liquid hydrogen (LH2). The propellants are carried in a large external tank covered with insulation. When empty, the tank drops away.

## section 21.2 assessment

### After You Read — Self-Check

1. Explain the difference between a stroke and a cycle.
2. Name the device that turns reciprocating motion into rotary motion.
3. Identify what ignites the fuel inside a diesel engine.

### Think

4. The SRBs on the space shuttle use up their propellant in two minutes. Explain why this is good.

### Practice Academic Skills

**Science**

5. Simulate an engine with a small plastic bottle, baking soda, and vinegar. Place the baking soda and vinegar in the bottle. Place the bottle in a basin of water. The acid-base reaction will form a gas that pushes the bottle across the water's surface.

**STEM Mathematics**

6. Tatyana's car gets 22.5 miles per gallon. Her parents live 144 miles away. If gas costs $2.85 a gallon, how much would it cost her to drive to her parents' home?

**Math Concept** **Algebra** Write an algebraic equation based on the information in a word problem to solve it. Use $x$ to stand for an unknown quantity.

1. You can write this equation: $x = (144 \div 22.5) \times 2.85$. $x$ stands for the cost of gas.
2. Use the equation to divide the total miles by the miles per gallon to figure out the number of gallons she will need. Then multiply the number of gallons by the cost per gallon to determine the cost.

For help, go to **glencoe.com** to this book's OLC and find the Math Handbook.

section 21.3

# Electric Motors

## Reading Guide

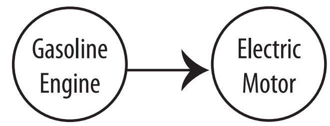
**Before You Read** **Preview** What vehicles use electric motors?

### Content Vocabulary
- hybrid
- fuel cell

### Academic Vocabulary
- environment
- alternative

### Graphic Organizer
Draw the section diagram. Use it to organize and write down information as you read.

**Hybrid Automobiles**




Go to **glencoe.com** to this book's OLC for a downloadable graphic organizer and more.

**TECHNOLOGY STANDARDS**

**STL 4** Cultural, Social, Economic & Political Effects
**STL 5** Environmental Effects
**STL 6** Role of Society
**STL 12** Use & Maintenance
**STL 16** Energy & Power Technologies

**ACADEMIC STANDARDS**

**Social Studies**
**NCSS Content Standard 8** Science, technology, and society

**Science**
**NSES Content Standard F** Science and technology in society

**STL** *National Standards for Technological Literacy*
**NCTM** *National Council of Teachers of Mathematics*
**NCTE** *National Council of Teachers of English*
**NSES** *National Science Education Standards*
**NCSS** *National Council for the Social Studies*

## Electric Transportation

Many transportation vehicles use electric motors. Subways and electric trains are two examples. Trains that use electric motors help reduce air pollution and are quieter than diesel-powered trains or buses. Other electric-powered transportation devices are:

- Segway transporters
- Elevators
- Escalators
- Amusement park rides

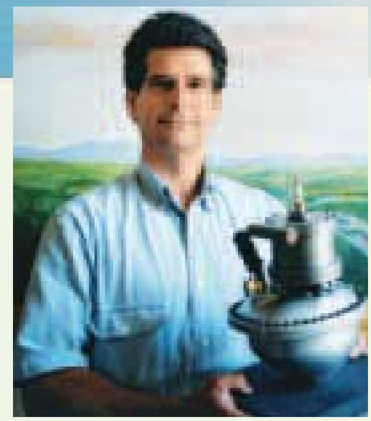
**As You Read**

**Think** What are the advantages and disadvantages of hybrid and fuel-cell cars?

## Tech Stars

### Dean Kamen

***Inventor of Segway Transporter***



Rob Howard/Corbis

Inventor Dean Kamen was born in New York in 1951. While still in college, he invented the wearable infusion pump, a medical device that led to the first insulin pump for diabetics. By age 30, Kamen founded DEKA Research and Development Corporation to be able to further generate inventions in the worlds of science and technology.

Kamen holds more than 440 U.S. and foreign patents. He is perhaps best known as the inventor of the Segway Human Transporter. Introduced in 2001, the two-wheeled, battery-operated vehicle uses sophisticated computer programming. The rider stands while operating the machine. Gyroscopes help the rider maintain balance.

**Inspiration** Kamen's Segway actually grew out of a prior invention, the Independence IBOT ™ Mobility System. After seeing a man in a wheelchair struggling to get over a curb, Kamen and his team created a self-balancing mobility device. This device allows users to climb stairs and maneuver difficult surfaces, such as rocky areas and sand.

**English Language Arts/Writing** Write an article for your school's newspaper about what you see as the future of the Segway.

Go to **glencoe.com** to this book's OLC to learn about young innovators in technology.

# Locomotives

***What engines do locomotives use?***

One common type of locomotive uses a diesel-electric drive system. A diesel engine turns a generator to produce electricity. The electricity is sent by wires to electric motors directly connected to the driving wheels. Diesel-electric locomotives can develop over 6,000 horsepower and pull 200 railroad cars.

## All-Electric Locomotives

Another type of locomotive is all electric. It has no diesel engine. It usually draws its electrical power from an overhead cable. The stainless steel *Acela Express* is a high-speed all-electric locomotive used for intercity passenger travel. It moves along the popular Washington-to-New York-to-Boston corridor at speeds over 150 mph. Its travel time between Washington, D.C. and New York City is under 2½ hours.

**Reading Check** **Discuss** How are electric motors used to power locomotives?

Car Culture/Corbis

# Electric Cars

***Will we ever drive cars powered by electricity?***

For almost 100 years, automobile companies have experimented with electrically powered cars. They are hoping to find a technology that does less harm to the **environment**. Their biggest problem has been the distance you can drive on a single battery charge. It tends to be around 50 miles, which means you can drive only about 25 miles away from a power source.

Reading Check **Predict** How do you think hybrid automobiles are powered?

## Hybrid Automobiles

Although there are few all-electric cars currently available, hybrids are extremely popular with the general public. A **hybrid** is a combination of different elements. The hybrid car combines an electric motor with a gasoline engine.

A hybrid's electric motor is used at low speeds around town and limits exhaust emissions. The small gasoline engine is used for higher speeds on freeways and on the open highway where emissions do not tend to collect. The gasoline engine also operates a generator that in turn recharges the batteries that power the electric motor.

**Pure Electricity** The Tesla Roadster looks, feels, and drives like many other high-end sports cars, but is a 100% electric vehicle. *Why are companies and consumers interested in developing electric cars?*

## EcoTech

### All Aboard

The East Japan Railway introduced a hybrid train in 2007. It has a diesel engine, two electric engines under each car, and batteries on the roof. It is 20 percent more fuel efficient than the previous generation of trains and 60 percent cleaner.

**Try This** Take public transportation, ride your bike, or walk instead of riding in an automobile.

Hybrid cars get very good mileage, often between 45 and 50 miles per gallon of gasoline. They produce only about half the greenhouse gas emissions of an ordinary car that gets about 30 miles per gallon or less.

## Fuel-Cell Automobiles

Fuel cells offer another alternative to gasoline-powered transportation. A **fuel cell** combines hydrogen with oxygen to create electricity. The astronauts who operate the space shuttle use three of these fuel cells when travelling in space. For use in transportation, fuel-cell electricity is converted to mechanical power. Some cities are testing fuel-cell-powered buses.

Fuel cells do not pollute the atmosphere because their only emission is water. They also do not have to be recharged, just refilled with hydrogen. In the future, you might drive a car powered by fuel cells. So far, however, they are only experimental. There are none available to the public, partly because they are so expensive to manufacture.

## Section 21.3 Assessment

### After You Read — Self-Check

1. Describe how a diesel-electric locomotive works.
2. Discuss hybrid automobiles and how they work.
3. Identify the emission a fuel cell produces.

### Think

4. Electric trains are sometimes designed to draw power from overhead wires or from a protected high-voltage rail on the ground. They have two electrical pickup locations. Explain why you think this is so.

### Practice Academic Skills

#### Social Studies

5. The city of Curitiba, Brazil, has one of the most successful mass transportation systems in the world. Consisting entirely of buses, the system is convenient, efficient, and affordable. More than 85% of the population uses it. As a result, Curitiba has the lowest rates of pollution and gas consumption in Brazil. Do some research on Curitiba's bus system at the library or on the Internet. Write a few paragraphs describing its design and how it works.

#### STEM Science

6. While the concept of using fuel cells in cars is relatively new, fuel cell technology has been around for some time. Fuel cells have been used in the space program for many years. Research the development of fuel cells and their uses. Write a few paragraphs about what you find. Include a discussion of the advantages and disadvantages of fuel cells.

# Exploring Careers in Technology

## Ben Hunter

**MECHANICAL ENGINEER, MENTOR**

**Q:** *What got you interested in mechanical engineering?*

**A:** I began college majoring in aerospace engineering. I've always had a curiosity about how things worked and a love for airplanes. My dad is an air-traffic-control specialist, and my grandfather was a pilot for American Airlines, so aerospace is in the family. I decided to double-major in mechanical engineering. It offered opportunities that otherwise would not be available.

**Q:** *What do you do for your company?*

**A:** I am a product development engineer in my company's Aircraft Engine Systems Group. When a company decides to design a new jet turbine engine, we provide components that make that engine work. It's my job to take one of those components from concept, through design, to manufacture, and finally testing and certification. I also mentor the on-the-job work experience of our engineering interns.

**Q:** *What advice do you have for young people who are considering an engineering career?*

**A:** Get involved with clubs for hands-on experience in different kinds of projects. Maybe your school has a math or science club or even an engineering club. Of all the classes, math is the most important. It provides the foundation for what you will study in high school and college—courses on differential equations and thermodynamics.

**English Language Arts/Writing**

**Hands-On Experience** List the skills you might develop by joining a math, science, or engineering club. How are these skills similar or different?

1. Talk to a teacher, use the Internet, or check the message boards at your school to find out what kinds of clubs are available.
2. Using a spreadsheet program, make a chart of the different clubs and what skills and experiences you can gain from them.
3. How could joining each club affect your future career choices? Write your answers in one paragraph.

Go to **glencoe.com** to this book's OLC to learn more about this career.

**Real-World Skills**

Problem-solving, observation, speaking, listening

**Academics and Education**

Mathematics, science, English language arts

**Career Outlook**

Growth as fast as average for the next ten years

**Source:** *Occupational Outlook Handbook*



Stockbyte/SuperStock

# chapter 21 Review and Assessment

## Chapter Summary

**Section 21.1** Much of our useful power comes from engines. Engines use fuel as an energy source. The world's first engine was a steam engine used to pump water from coal mines. Steam engines are external combustion engines.

**Section 21.2** Gasoline engines are internal combustion engines. They use pistons that slide up and down inside a cylinder. Each up or down motion of the piston is a stroke. This motion is converted to rotary motion by a crankshaft. Diesel engines are best suited for heavy work. Rocket engines carry oxygen as well as fuel so they can travel in space.

**Section 21.3** Many trains are powered by electric motors. Some locomotives use diesel engines to turn generators that produce electricity. The hybrid car runs on an electric motor and a gasoline engine. Fuel cell cars convert hydrogen to electricity. Their emission is water.

## Review Content Vocabulary and Academic Vocabulary

1. On a sheet of paper, use each of these terms and words in a written sentence.

**Content Vocabulary**

- external combustion engine
- piston
- turbine
- internal combustion engine
- reciprocating motion
- rotary motion
- crankshaft
- ignition system
- emissions
- ethanol
- maintenance
- jet engine
- thrust
- propellant
- hybrid
- fuel cell

**Academic Vocabulary**

- convert
- expand
- transfer
- regulate
- environment
- alternative

## Review Key Concepts

2. **Explain** how an external combustion engine works.
3. **Describe** the difference between a steam engine and a steam turbine.
4. **Explain** how an internal combustion engine works.
5. **Describe** a four-stroke and a two-stroke engine cycle.
6. **Explain** the purpose of a crankshaft.
7. **Identify** differences among various engines.
8. **Describe** how electric motors are used to power locomotives.
9. **Explain** how a hybrid automobile is powered.
10. **List** the advantages and disadvantages of hybrid and fuel cell cars.

## Real-World Skills

**11. Human-Powered Transportation** The most environmentally friendly types of transportation run off of human-power, such as a bicycle. Research other forms of human-powered transportation and write a few paragraphs describing what you find. Discuss the pros and cons.

**STEM Technology Skill**

**12. Space Travel** The materials that go into space have to be able to withstand the environment of space. There are many different suppliers of such materials.

- **a.** Conduct research to determine what materials are sent into space.
- **b.** Locate some companies that supply materials to the space program. Look for companies in your state that supply such materials. Write a summary of what you find.

## Academic Skills

**Social Studies**

**13.** You can find engines and motors almost everywhere. Make a list of every motor you see. Examples might include lawn equipment, appliances, and toys.

**STEM Mathematics**

**14.** Heather is traveling in Europe and rents a car. The speeds are all in kilometers per hour, not miles per hour. How fast will she be going, in miles per hour, at 120 kilometers per hour? Round your answer to the nearest whole number.

**Math Concept** **Unit Conversion** One mile per hour (mph) equals 1.61 kilometer per hour (kph). To convert from mph to kph, multiply by 1.61. Divide by that amount to convert from kph to mph.

## TSA WINNING EVENTS

### Automotive Engineer

**Situation** You and your team will design and build an electrically powered all-terrain vehicle. Develop sketches and a working, battery-powered model of the vehicle. Your teacher will determine the model's dimensions.

**Activity** Design the safest, most reliable, and fastest vehicle you can. Make a series of sketches. Then make a working model and conduct "field" tests. Make changes as needed. Race your vehicles against others.

**Evaluation** Sketches will be evaluated based on how well they communicate your ideas. Models will be evaluated based on these criteria:

- Safety, reliability
- Utility, speed

Go to **glencoe.com** to this book's OLC for information about TSA events.

## Standardized Test Practice

**Directions** Choose the letter of the best answer. Write the letter on a separate piece of paper.

**1.** What is 53.8% of $42,540?

- **A** $22,886.52
- **B** $32,437.08
- **C** $21,436.52
- **D** $21,270.00

**2.** Reciprocating motion is circular.

- **T**
- **F**

**Test-Taking Tip** Read each test question carefully, no matter what kind of test you take.

chapter 21

# TECHNOLOGY LAB

## Build a Steam Turbine

In a steam power plant, steam is directed toward a fan-shaped turbine. The pressure from the steam causes the turbine to spin. The turbine's rotary motion turns an alternator that generates electricity for use in your home and school.

### Tools and Materials

- ✓ Copper tube, 1 inch in diameter and 4 inches long
- ✓ Two corks that fit tightly into the ends of the copper tube
- ✓ Aluminum beverage can
- ✓ Plastic bead
- ✓ Small nail
- ✓ Two metal clothes hangers
- ✓ Propane torch
- ✓ Scissors
- ✓ Razor knife
- ✓ Heavy wire cutters
- ✓ Metal file
- ✓ Safety glasses or goggles
- ✓ Stopwatch

### Set Your Goal

For this activity, you will build a steam generator that will turn a fan-shaped turbine.

### Know the Criteria and Constraints

In this lab, you will:

1. Build turbine blades that are uniform in size and shape.
2. Keep a record of turbine speeds and how different designs affect speed.

### Design Your Project

Follow these steps to complete this lab.

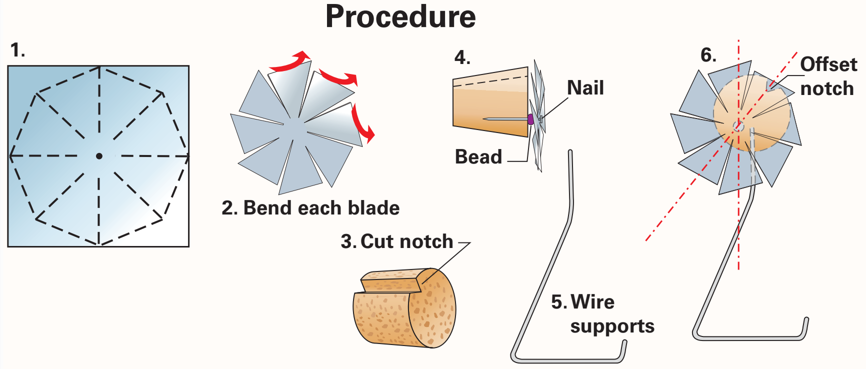
1. Review the drawing of the completed steam turbine.
2. Cut out an octagon-shaped disk from the aluminum can using scissors and the template in picture 1.
   - Punch a hole in the center of the aluminum disc with a nail.
   - Bend the blades. This will be your spinning turbine disk.
   - Color one blade with a permanent marker to help you judge how fast the disk spins.
3. Use the razor knife to cut a notch in one cork. The notch will direct steam from the tube to the turbine disk causing the disk to spin.

### SAFETY

#### Tool Safety

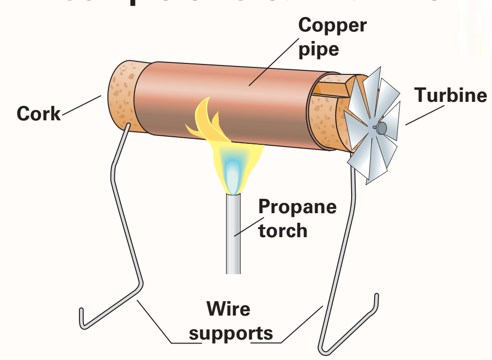
In this activity, you will be using dangerous tools, such as a propane torch. Be sure to always follow appropriate safety procedures and rules so you and your classmates do not get hurt.

**Procedure**



4. Slide the turbine disk onto the nail. Then slide on the plastic bead, which will act as a bearing. Push the nail into the notched cork at a spot across from the notch.
5. Place the cork in each end of the copper tube. Your copper tube is now a completed boiler.
6. Use the heavy wire cutters to make two supports out of clothes hanger wire.
   - Sharpen one end of each piece of wire with a metal file.
   - Then stick the sharpened end of each wire support into the edge of a cork. Your steam turbine is now ready to operate.

**Completed Steam Turbine**




7. Remove a cork and fill the copper tube about two-thirds full of water. Replace the cork.
8. Devise a method for measuring turbine speed. For example, one person can count rotations while another uses a stopwatch.
9. Put on the safety glasses, then light the propane torch.
   - Carefully and evenly heat the copper tube.
   - Steam will come out through the notch and will spin the turbine.
10. Measure and record turbine speed using the stopwatch.
11. Try twisting the turbine blades to greater or lesser angles. What effect, if any, does this have on their rotating speed?

## Evaluate Your Results

After you complete the lab, answer these questions on a separate piece of paper.

1. Could you tell how fast the disk was rotating? Would it spin faster if the boiler was two-thirds full of water or only one-third full? Why?
2. Would the disk spin faster or slower if you cut a smaller notch in the cork? Why?

***Academic Skills Required to Complete Lab***

| Tasks | English Language Arts | Math | Science | Social Studies |
|---|---|---|---|---|
| Review safety rules. | ✓ | | | |
| Build steam turbine. | ✓ | ✓ | ✓ | |
| Devise method for measuring turbine speed. | ✓ | | ✓ | |
| Measure and record turbine speed. | | ✓ | ✓ | |
| Modify turbine blades and repeat. | | ✓ | ✓ | |