18

Land Vehicular Systems

Basic Concepts

- Cite the types of propulsion systems used in land vehicles.
- State how drive systems function.
- Identify types of guidance systems.
- List ways in which land vehicles are controlled.
- Define and describe the components of a suspension system.
- Identify the function of automobile structural systems.
- Name the support systems of land transportation.

Intermediate Concepts

- Describe the differences between series and parallel hybrid systems.
- Explain the operation of an automatic transmission.

Advanced Concepts

- Demonstrate how magnetic levitation (maglev) systems operate.

Land transportation requires vehicles such as automobiles, trucks, locomotives, and railcars to function. These vehicles and all other land vehicles have components from each of the vehicular systems. These systems include propulsion, guidance, control, suspension, structural, and support systems.

Propulsion Systems

Land vehicles, like all forms of transportation, must be propelled in order to move from one place to another. This propulsion can occur in several ways. The first way is through the use of an internal combustion engine. The second method of propulsion is electricity. The third is a hybrid of both the internal combustion engine and electricity.

Internal Combustion Engines

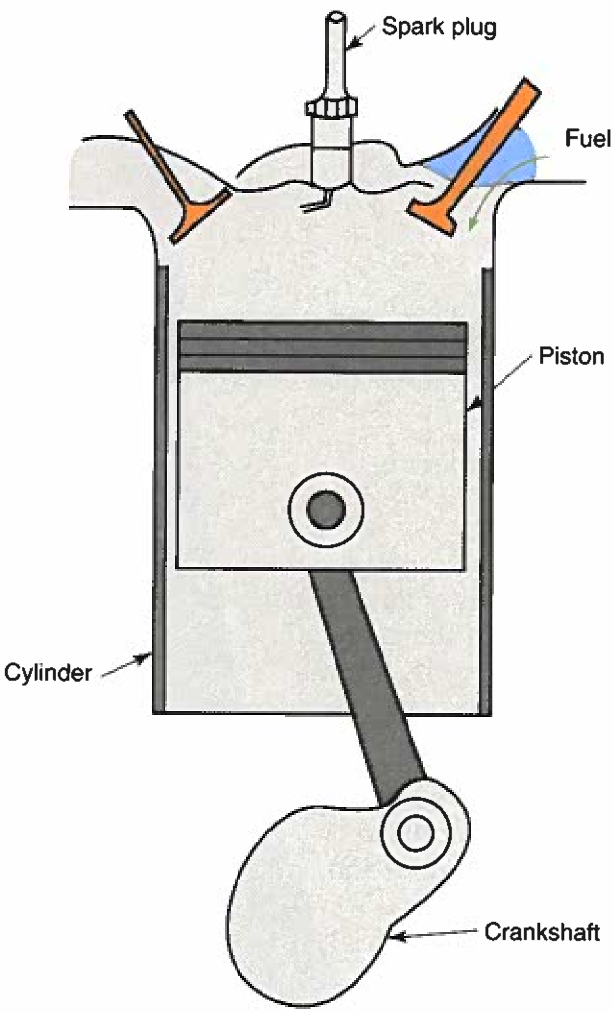
Internal combustion engines are the most commonly used type of engine in automobiles, trucks, and recreational vehicles. They are a type of heat engine. The engine functions by igniting a fuel to produce hot gases. The hot gases push either a piston or rotor to create mechanical energy. Mechanical energy is used to propel the land vehicle. In internal combustion engines, the hot gases are produced inside of a combustion chamber, or cylinder. There are three main types of internal combustion engines: gasoline piston engines, rotary engines, and diesel engines.

Gasoline piston engine: An engine found in automobiles, motorcycles, lawn mowers, and snowmobiles. These engines have five main components: a cylinder, a piston, a spark plug, a crankshaft, and fuel.

Gasoline piston engines

Gasoline piston engines can be found in automobiles, motorcycles, lawn mowers, and snowmobiles. The theory of the gasoline piston engine existed well before an efficient example of the engine was built. Sadi Carnot, in 1823, and Alphonse Beau de Rochas, in 1862, both published articles describing the function of a gasoline piston engine. It was not until 1876, however, that Nikolaus Otto built the first efficient gasoline piston engine.

Figure 18-1. The five major components of a gasoline piston engine are the cylinder, piston, spark plug, crankshaft, and fuel.

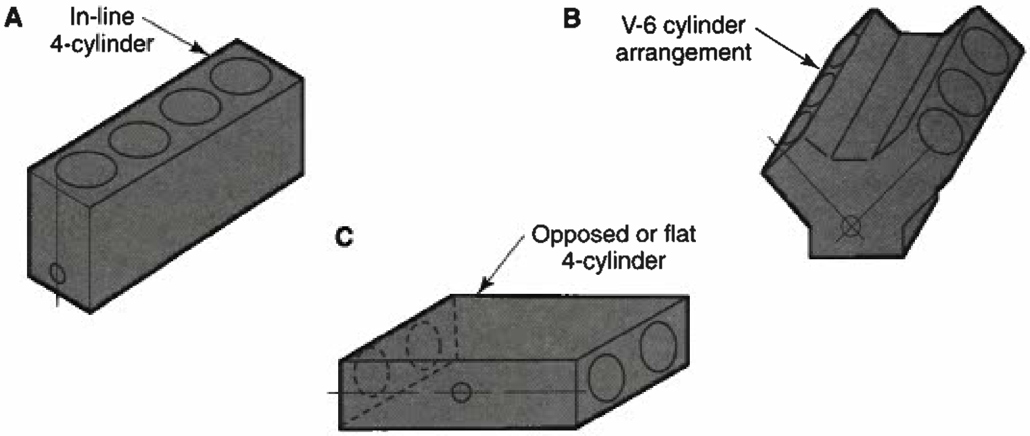


The gasoline piston engine has five main components: a cylinder, a piston, a spark plug, a crankshaft, and fuel. See **Figure 18-1.** The cylinder is an enclosed chamber with two ports. One allows fuel and air in, and the other allows exhaust to escape. The main moving part inside the cylinder is the piston. Fuel is allowed to enter the cylinder, and the piston compresses the air and fuel mixture. The compressed fuel is then ignited by a spark plug. The piston is driven down, which creates the mechanical energy. The reciprocal (up and down) motion of the piston is used to turn the crankshaft. The crankshaft is the device that transmits the power of the engine to the transmission. The function of the transmission will be discussed later.

The two ways in which gasoline piston engines operate are based on the number of strokes it takes to complete one combustion cycle. The two types of engines are known as two-stroke and four-stroke engines. The operation and advantages of each are described in greater detail in Chapter 14.

Gasoline piston engines are classified by the quantity and alignment of the cylinders. There are three main cylinder configurations. See **Figure 18-2.** The first is the in-line configuration. This configuration has all cylinders in a straight line. The second style is the flat, or opposed, engine. In this type of engine, there are two rows of cylinders arranged

Figure 18-2. Engine blocks have three different cylinder configurations. The number of cylinders varies, but it is always in multiples of two. A—In-line. B—V. C—Opposed.



horizontally. The two banks of cylinders are on opposite sides of the crankshaft. The pistons are connected to the crankshaft and push outward from the center. The last engine configuration is the V-engine. V-engines are similar to flat engines, in that they have two rows of cylinders. The difference is that, in V-engines, the cylinders are situated to form a *V*, with the crankshaft at the bottom, instead of the cylinders being directly opposed. The number of cylinders is also listed when describing a gasoline piston engine. For example, an engine with a *V* configuration and six cylinders is called a V6. The number of cylinders and the layout of the engine affect the amount of power produced. Different configurations are used in different situations.

Rotary engines

Rotary engines are internal combustion engines that use rotors in place of pistons. They are usually called Wankel rotary engines. The name comes from their German inventor, Dr. Felix Wankel. The engine is small, lightweight, powerful, and smooth running. The smoothness comes from the use of rotary, rather than reciprocal (up and down), movement of the piston. The rotor turns inside a specially shaped combustion chamber. It lets fuel and air in, compresses it, burns it, and then releases the exhaust all in one smooth rotation. The design of rotary engines decreases the amount of moving parts used in piston engines.

Rotary engine: An internal combustion engine that uses rotors in place of pistons. Also called Wankel rotary engines.

Because rotors replace the pistons, we classify these engines differently. Whereas we refer to four, six, or eight cylinders in traditional piston engines, we call out the number of rotors in the Wankel engine. Generally, one-rotor Wankel engines are used in smaller applications, such as snowmobiles. Two-rotor Wankel engines are used for automobiles. Experimental engines with more than two rotors have been developed, but they are not yet commonly used.

Figure 18-3 shows the parts of a Wankel rotary engine. The special shape of the housing is very critical. It is somewhat like a large figure eight. This shape is called an ***epitrochoidal curve***. It allows the tips of the rotor to ride against the housing as the rotor revolves.

Epitrochoidal curve: The special shape of a Wankel rotary engine housing, somewhat like a large figure eight.

Figure 18-3. A Wankel engine uses spinning rotors instead of pistons to convert heat energy to power. Note the shape of the combustion chamber. The rotor has the shape of a slightly rounded equilateral triangle. It is attached to an eccentric (off-center) shaft, which comes through the center of the housing. Special replaceable tips maintain a tight seal between the tips and the housing. If the seal is not kept tight, the engine will have a great loss of power.

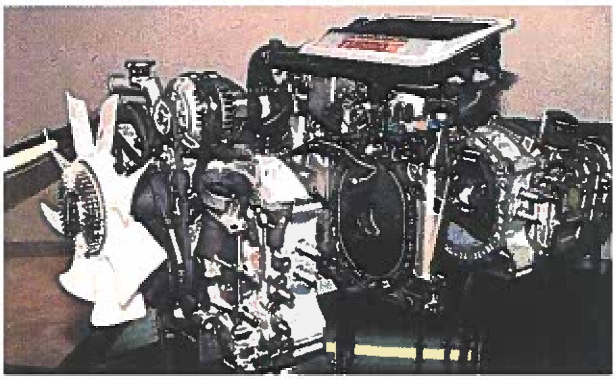
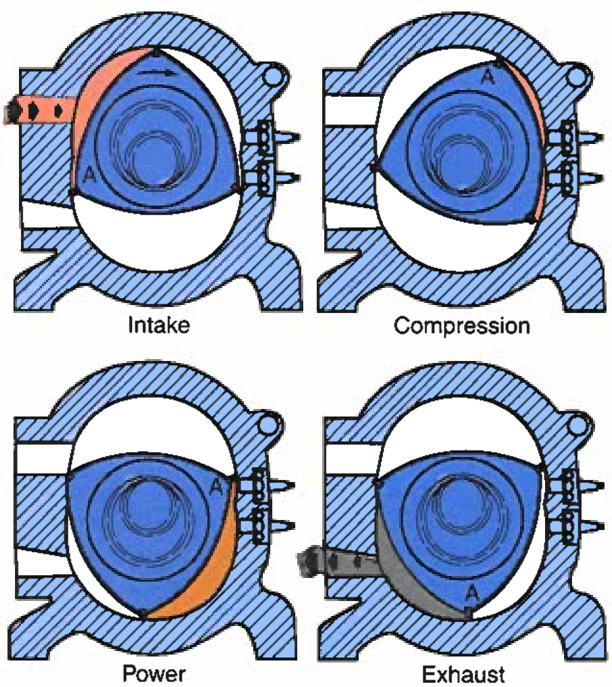


Figure 18-4. The combustion cycle of the Wankel engine. Each lobe (point) of the rotor goes through four phases in one revolution. The intake, compression, power, and exhaust stages all take place in one revolution of the rotor.



Intake and exhaust ports are located in the epitrochoidal housing. They are placed so they take advantage of the expanding and contracting spaces made by the spinning rotor. See **Figure 18-4.**

Rotary engines are typically lighter and do not cause as much vibration as gasoline piston engines. They are not, however, commonly used in automobiles. Rotary engines use more fuel than conventional engines. They are also greater pollutants than gasoline piston engines. Mazda has redesigned the original rotary engine, however, and promised that the company has improved the drawbacks to the engine. See **Figure 18-5.**

Diesel engines

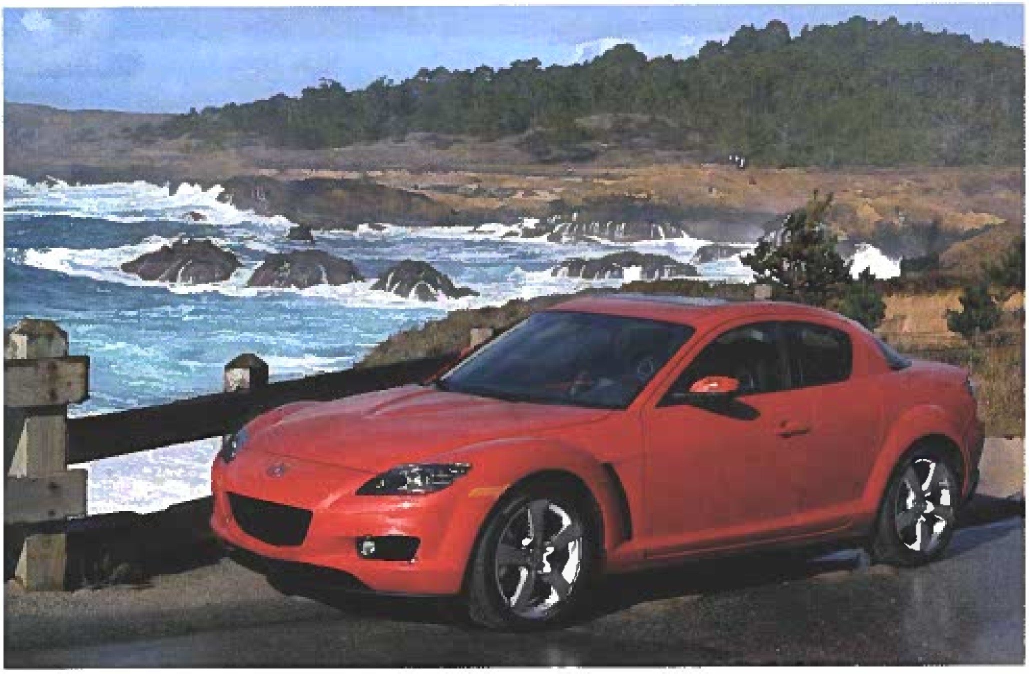
Diesel engines are internal combustion engines that use heat and pressure to ignite their fuel. Rudolph Diesel, a German automotive engineer, developed them. These engines follow the same basic power cycle as the other internal combustion engines we have discussed so far (intake, compression, power, and exhaust).

They are different from gasoline engines in several ways. For one thing, they have no spark plugs. They rely on the extreme heat of the compressed air to supply the ignition. When diesel fuel is injected into the combustion chamber, the hot compressed air causes the fuel to burn with explosive force. Because the diesel engine relies on heated compressed air for ignition, it is called a ***compression-ignition engine***. During the compression stage, diesel engines only compress air, instead of an air and fuel mixture, like in gasoline engines. The fuel is not added until the compression is complete. See **Figure 18-6.** This enables diesel engines to be more efficient. Medium-duty and heavy-duty trucks, as well as many train locomotives, use diesel engines because of their efficiency.

Another point of difference is the high compression ratio of the diesel, when compared to gasoline engine ratios. The compression ratio is the difference between the volume of the combustion chamber when the piston is at bottom dead center (BDC) and the volume at top dead center (TDC). See **Figure 18-7.**

Still another difference between diesel engines and gasoline engines is diesel engines

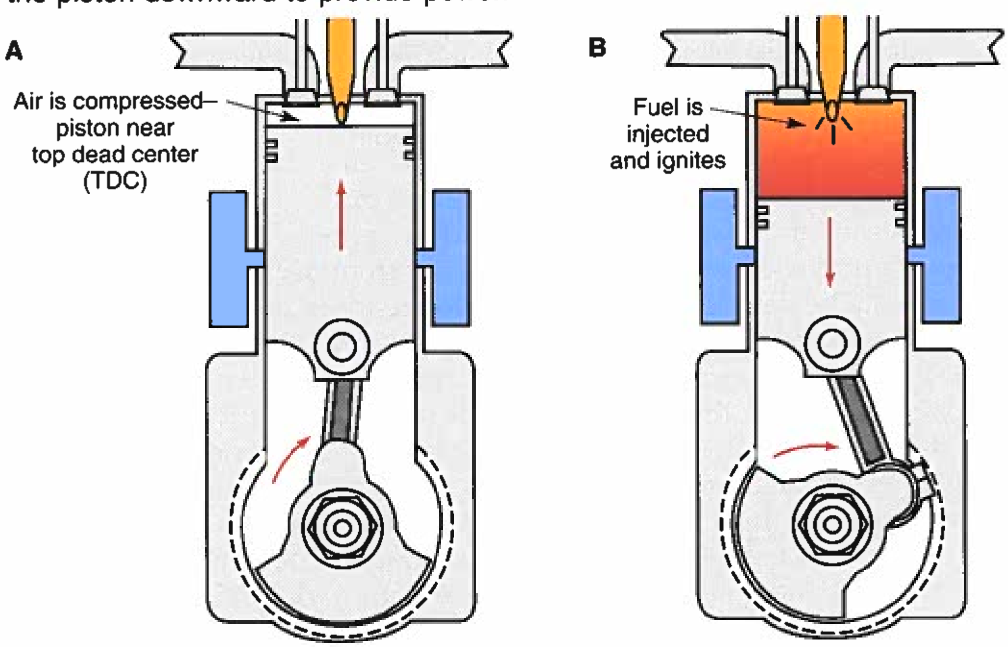
Figure 18-5. A redesigned rotary engine was introduced on the Mazda RX-8. (Mazda)



Diesel engine: An internal combustion engine that uses heat and pressure to ignite its fuel.

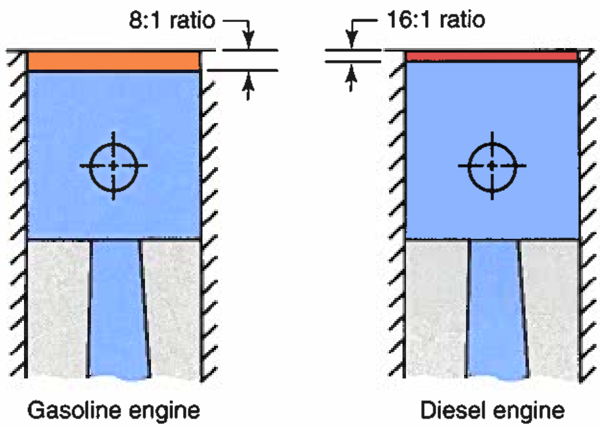
Compression-ignition engine: An engine that relies on heated compressed air for ignition.

Figure 18-6. The operating cycle of the diesel engine. A—The piston compresses the air, greatly increasing the temperature of the air. B—When diesel fuel is injected into the cylinder, the heat causes combustion, driving the piston downward to provide power.



are built to be much stronger. This added strength is necessary because of the stress the higher compression ratio places on the engine parts, especially the pistons, rods, and crankshaft. The additional weight added to diesel engines makes their use on small automobiles uncommon.

Figure 18-7. Diesel engines use a much higher compression ratio than gasoline engines. If the pistons are both at bottom dead center (BDC) in their cylinders, the volume of the cylinder in the diesel engine is greater than that in the gasoline engine. This allows a greater compression ratio. Compression ratios for diesel engines are typically 16:1–21:1, while those of gas engines are usually around 9:1–10:1. The higher compression ratio is responsible for generating the temperature needed to ignite the fuel when it is injected into the cylinder.



Electrical Propulsion

The second major type of land vehicle propulsion is electrical propulsion. Transportation vehicles that use electrical propulsion systems usually use an electric motor. The types of motors studied in Chapter 13 are similar to the ones used on vehicles. The motors need to be designed according to their applications. Mass transportation systems, such as electric buses and trains, need very strong motors. Motors used in golf carts do not need to be as powerful.

All vehicles propelled by electric motors must have a source of electricity to power the motors. There are two main ways electrically propelled vehicles get their energy. One is through direct connection to a source of electricity, and the other is using stored electricity.

Direct electric vehicles

Direct electric vehicle: A vehicle that requires a connection to electricity.

A ***direct electric vehicle*** requires a connection to electricity. This is often hard to accomplish. Imagine having an automobile that has to be plugged into a wall to operate. It would take a pretty long cord to get you to school. There are direct electric vehicles, however, that you have probably seen before. Think about bumper cars at an amusement park. Bumper cars are electrically propelled vehicles that are connected to a power source. They do not carry batteries because it would be too expensive and they would have to be recharged often. Instead, the cars have long poles that connect to an electrically charged grid in the ceiling above the cars. The grid supplies the current for the electric motors in the cars to operate.

This is similar to the system used by some light-rail systems. These electrically propelled vehicles get their power from overhead lines. See **Figure 18-8.** The vehicles can travel only where there are electric lines. If they become disconnected to the lines, they lose all power. Electric current is sent through the overhead lines, where special spring-tensioned rods or collapsible frames on the top of the vehicle pick the current up. The current is sent through these extensions to the motors inside the vehicle.

Rail: A long piece of steel that has an *I*-shaped cross section.

Other transportation vehicles, such as subway trains, receive electric current through a third ***rail***, or a long piece of steel that has an *I*-shaped cross section, located between the two main tracks. The third rail is similar to the two rails that guide the wheels of the train, except it is electrified to provide power to the train. See **Figure 18-9.** The third rail system is used in many subway systems. It requires less space above the train than the overhead line system. Third rail systems are, however, potentially very dangerous. If the rail is touched, it could be deadly.

The overhead lines and the third rail are powered by a power plant with substations along the way. The substations lower the voltage from the main power plant and ensure that the entire system is powered. The

Figure 18-8. Overhead lines are the power source for electric trains used in many light-rail systems, such as this one in Houston, Texas. (Siemens)

GREEN TECH

Newer types of electric cars must be recharged more frequently than other cars must be refueled with gasoline. However, automakers are working to improve electric vehicles to travel farther distances between charges.

trains must keep in contact with the lines or rail to be propelled. The electrical current the train receives is then used by the onboard electric motors to propel the vehicle.

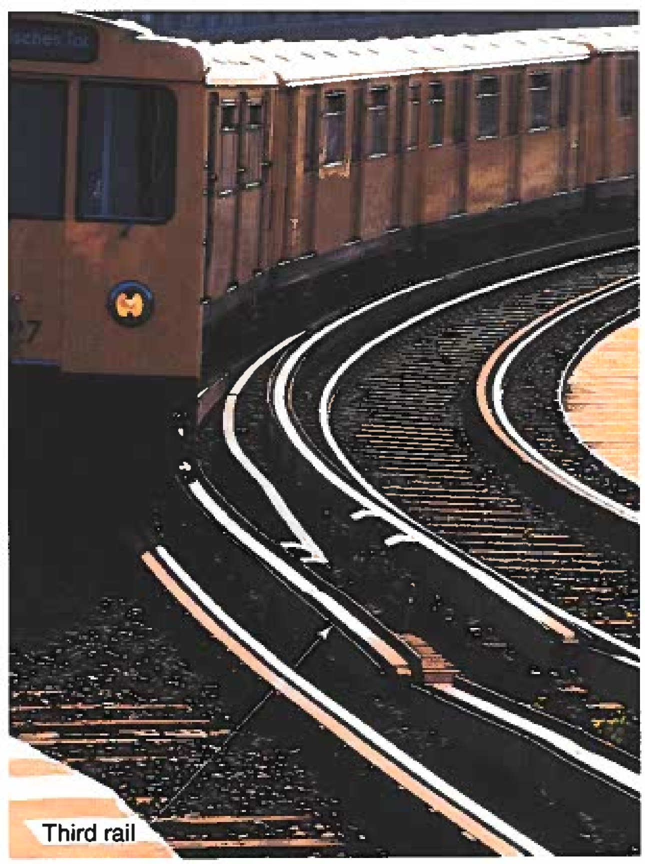
Indirect electric vehicles

In many situations, it is not possible to connect electric vehicles with a direct power source. In these cases, batteries are used to power the motors. All batteries have a specific storage capacity, rated in amp-hours, and they must be recharged when they have lost their stored power. There are several ways to recharge batteries. The first is to simply plug the battery into a power source. This is common in golf carts and other small electric vehicles. This, however, would be hard to do if you were traveling in an electric car on a cross-country trip. For this reason, several types of electricity-generating devices have been used in vehicles to create electricity that can either be directly used by the vehicle or stored in batteries for future use.

Solar propulsion

One method of supplying electric vehicles with power and recharging batteries is through the collection of solar energy. Vehicles that

Figure 18-9. Subway trains and some other rail vehicles receive their power through a special third rail. This rail runs next to or between the rails guiding the trains.



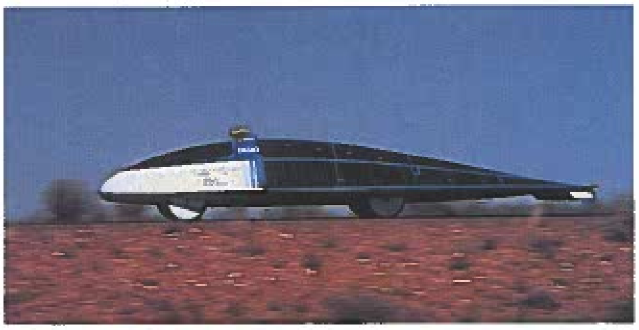


Figure 18-10. The Sunraycer is a solar-powered vehicle built to compete in a "solar challenge" race in Australia. Good design and lightweight materials helped it win. (GM-Hughes)

collect solar energy utilize photovoltaic cells to convert light energy to electrical energy. This energy is put into storage batteries, where it can be used to run electric motors.

Solar propulsion has not been popular in land transportation vehicles. The main reason is that solar cells are not highly efficient. Vehicles that rely solely on solar power have to be completely covered with photovoltaic cells. They must also be designed to be lightweight and aerodynamic, and they cannot carry many passengers.

The greatest use of solar-powered vehicles is in experimental races. See **Figure 18-10.** The GM Sunraycer is a solar-powered vehicle designed and built to participate in a "solar challenge" race in Australia. The Sunraycer proved to be a good design, as it won the race. It made good use of lightweight materials and efficiently harnessed the sun's energy.

Solar propulsion: A propulsion system that relies on the sun's energy.

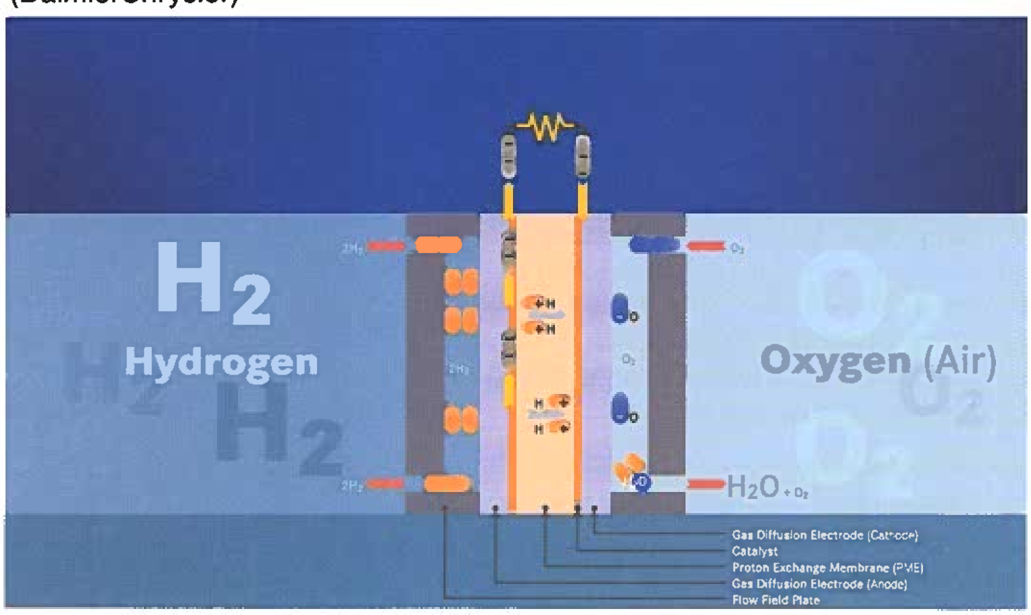
Fuel cell: A device that utilizes a chemical reaction between hydrogen and oxygen to produce electricity.

Proton exchange membrane (PEM): A common type of fuel cell that works by passing hydrogen through one end and oxygen through the other.

Fuel cell propulsion

Fuel cells are a technology also used to power electric motors in automobiles. They have been used for years in the space program, but they have only recently been designed for use in automobiles. The most common type of fuel cells used in automobiles is the ***proton exchange membrane (PEM)*** fuel cell. See **Figure 18-11.** PEM fuel cells generate electricity through a chemical process. They work by passing hydrogen through one end and oxygen through the other. An anode on the hydrogen side causes the hydrogen to break into protons and electrons.

Figure 18-11. Operation of a proton exchange membrane (PEM) fuel cell is shown in this diagram. The only outputs of a fuel cell are energy and water. (DaimlerChrysler)



The protons then pass through the membrane in the center, on the way to the cathode side of the cell. This generates electricity. The remaining hydrogen molecules are combined with the oxygen and create water. Heat and water are the only by-products of the use of fuel cells.

The electricity created is then sent to the motors for direct use or to the batteries for storage. One problem with fuel cells is the need for hydrogen. It is easy to go to a gas station and fill a car with gasoline. These types of systems do not exist for hydrogen. One potential solution to this problem is the use of fuel reformers. Reformers are able to separate the hydrogen molecules from other forms of fuel. For example, a fuel cell vehicle with a reformer could fill up with methanol or natural gas. See **Figure 18-12.** The reformer would then send only the hydrogen molecules into the fuel cell. This does create pollutants, but still not at the level of a gasoline engine.

Guideway: A railway of magnetic levitation (maglev) vehicles.

Linear motor: An induction motor that has been flattened out.

Hybrid system: A system that uses both an internal combustion engine and an electric motor.

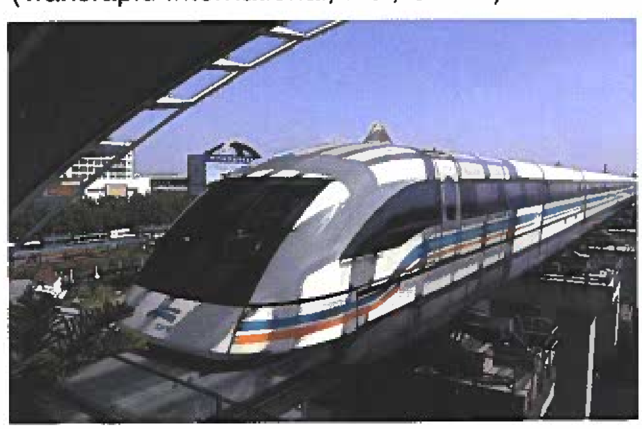
Electromagnetic propulsion

One other type of propulsion system that uses electricity is the electromagnetic propulsion system. These systems are quite different from the other electric propulsion systems. They are generally called *magnetic levitation (maglev).* These vehicles are propelled using the magnetic field generated by electromagnets. Electromagnets are devices that use electricity to create magnetic fields. The magnetic field is temporary and only present when electricity flows through the wire.

The ***guideways***, or railways, of maglev vehicles are lined with electromagnets. The magnetic fields of the electromagnets come into contact with linear motors on the maglev trains. ***Linear motors*** are basically induction motors that have been flattened out. The linear motor mounted on the train acts as the stator in a typical motor. The electromagnets on the guideway repel the linear motor on the train, which pushes it down the track, or guideway. See **Figure 18-13.** The types of guideways will be discussed later in this chapter.

Figure 18-12. The first public service station offering both gasoline and hydrogen opened in Washington, D.C., in late 2004. (Shell Energy)

Figure 18-13. Linear magnetic motors on a magnetic levitation (maglev) train work with strong magnetic fields in the guideway to move the vehicle forward or backward. This train is pulling into a station in Shanghai, China. (Transrapid International, Inc., GmbH)



Hybrid Propulsion

Some systems do not use only an internal combustion engine or electric motor. They use both. These systems are known as ***hybrid systems*** because they are a combination of two different systems. Hybrid systems are able to take advantage of the positive aspects of both internal combustion engines and electric motors, without experiencing as many of the negatives. The two most popular hybrid systems are diesel-electric propulsion and gasoline-electric propulsion.

Diesel-electric propulsion: A system in which large diesel engines turn electric generators that power a locomotive's wheels.

Gasoline-electric hybrid: A type of propulsion system used in automobiles and small trucks. These systems are configured as either series hybrids or parallel hybrids.

Diesel-electric propulsion

The diesel engines you have studied earlier are most commonly used in trucks. They may, however, also be used to create electricity. These systems are known as ***diesel-electric propulsion*** systems. Diesel-electric propulsion systems are most commonly found in train engines. See **Figure 18-14.**

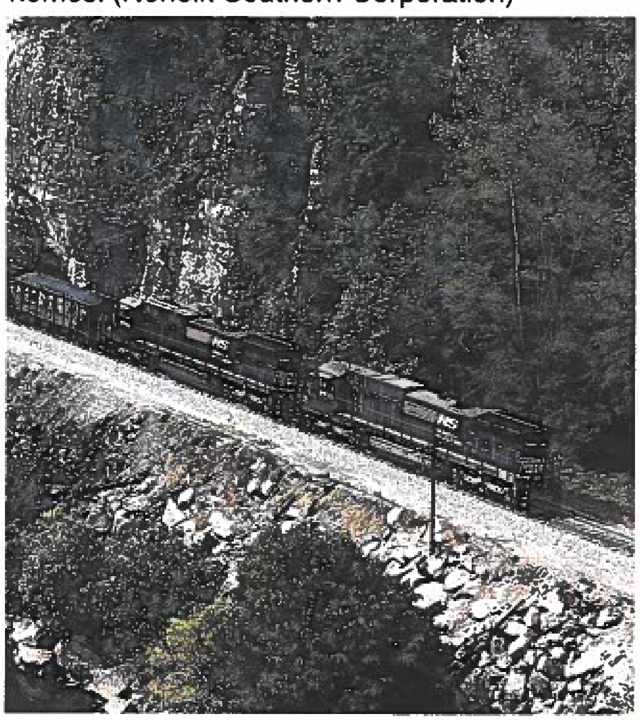
Gasoline-electric hybrid

Gasoline-electric hybrid systems are used in automobiles and small trucks. There are two main configurations in gasoline-electric hybrid systems. The first type is the series configuration. A ***series hybrid*** is like a series circuit in electricity. All the components are connected in a line. The gasoline engine is used to power a generator, which converts the engine's mechanical energy to electrical energy. The energy is then stored in batteries and used to power electric motors at the two front wheels. In these systems, the engines can be smaller than in a typical automobile. This is because the engine is only needed to power the generator. There is no link from the engine to the wheels.

The second type of configuration is parallel hybrid. ***Parallel hybrids*** use both the gasoline engine and electric motors to turn the wheels. The electric motors are used at speeds of under 15 to 25 miles per hour (mph), depending on the vehicle. This puts an end to engines idling at stoplights. Once cruising speeds of over 15–25 mph are reached, the gasoline engine is turned on to maintain the increased speed. The electric motors are used in the cruising stage when an additional burst of propulsion is needed, such as when passing cars on a highway. While the gasoline engine is in use, some of the power is used to operate a generator, and the rest recharges the batteries. An onboard computer controls the switching between the engine and motors. One other feature of gasoline-electric hybrids is the concept of regenerative braking. ***Regenerative braking*** is a process that transforms the car's kinetic energy into electrical energy by using the electric motor as a generator during braking. The electrical energy helps to power the batteries, which allows the gasoline engine to run even less.

The main advantage of the gasoline-electric hybrid system is fuel efficiency. Vehicles with hybrid engines also produce less harmful emissions. They are much quieter at low speeds. Hybrid systems are typically more expensive, however, than similar vehicles with traditional gasoline engines. As more hybrid systems are

Figure 18-14. Diesel-electric locomotives use large diesel engines to turn electric generators that power the locomotive's wheels. The majority of freight trains today have diesel-electric propulsion systems. Some of these train locomotives using diesel-electric propulsion can generate over 6000 horsepower (hp). The electricity that the engine—usually a large V12 diesel engine—generates could provide enough electricity to power a neighborhood of homes. (Norfolk Southern Corporation)



designed and built, the prices of these vehicles will fall. The original car manufacturers that created hybrid vehicles were Toyota, Honda, and Ford. Many of the other manufacturers will soon have hybrid vehicles as well.

Transmitting Power

The propulsion systems in land vehicles provide the power to move the vehicles. They must be connected to the wheels of the vehicle, however, in order for the vehicle to actually move. The drive system provides the transfer of power from the engine to the wheels.

The components of the ***drive system,*** or power train, allow the propulsion power to be sent throughout the vehicle. Even bicycles have drive systems. See **Figure 18-15.**

In automobiles, the drive systems are used to transfer the motion of the engine's crankshaft into the power that moves the vehicles. Automobiles send this constant power through transmissions, driveshafts, differentials, axles, and wheels to create movement of the vehicle. See **Figure 18-16.**

The first job of the drive system is to multiply the amount of torque the engine produces. In a drive system, the original torque is produced by the engine and present at the crankshaft. The amount of torque an engine produces is only enough to move a vehicle on a level surface and at a moderate speed.

Figure 18-15. A bicycle has a drive system consisting of pedals attached to a large gear (sprocket). A chain transmits power from the sprocket to drive gears on the rear wheel. This is a simple form of drive system. (Howard Bud Smith)

Series hybrid: A gasoline-electric hybrid system configuration in which all the components are connected in a line.

Parallel hybrid: A gasoline-electric hybrid system configuration that uses both the gasoline engine and electric motors to turn the wheels.

Regenerative braking: A process that transforms a car's kinetic energy into electrical energy by using the electric motor as a generator during braking.

Drive system: A system used to transfer the motion of the engine's crankshaft into the power that moves the vehicle.

Figure 18-16. Drive systems on automobiles have many parts that transfer power from the engine to the drive wheels. Some automobiles use the rear wheels as drive wheels, as shown here. Most current cars, however, use front-wheel drive. A few models use all four wheels.

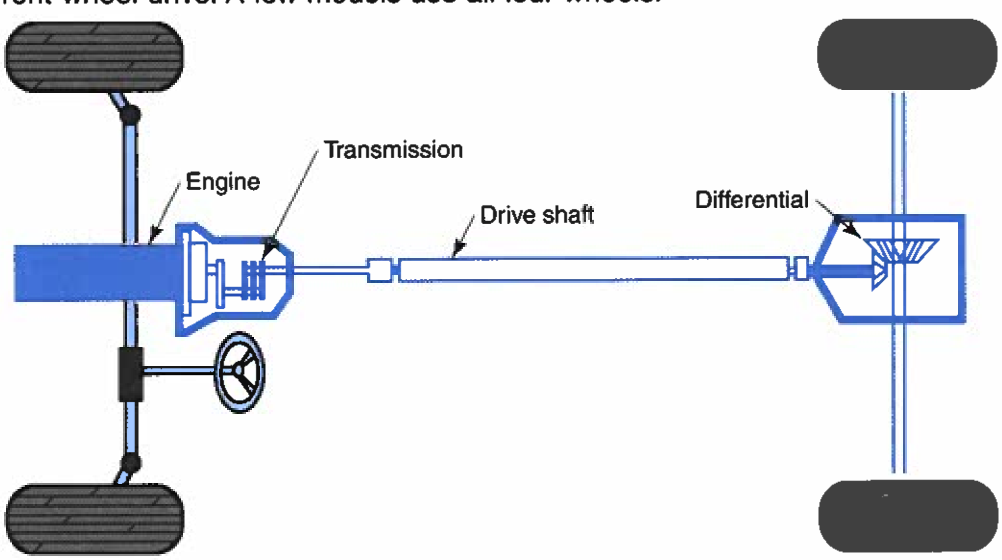
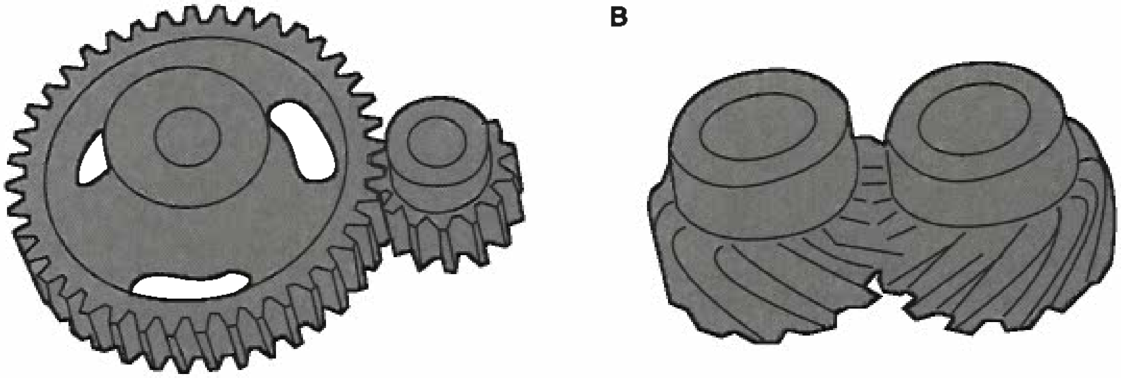


Figure 18-17. Gears are used to transmit power. Those used in transmissions are made of high-quality steel and are designed to be tough and durable. By changing gears, the transmission is able to change the amount of torque and allow the engine to operate at its most efficient speed. A—Spur gears. B—Helical gears. These are preferred because of their great strength and smooth operation.

A B



Transmission system: A device that provides for multiplying, dividing, or reversing the mechanical power and torque coming from the engine.

Manual transmission: A transmission that is totally controlled by the operator of the vehicle.

Transmission systems

Transmission systems are the devices that provide for multiplying, dividing, or reversing the mechanical power and torque coming from the engine. Two basic types of transmission gears use different arrangements of gear teeth. See **Figure 18-17.**

Manual transmissions

Manual transmissions are totally controlled by the operator of the vehicle. A lever called a stick shift controls and engages different combinations of gears. See **Figure 18-18.** In a typical five-speed manual transmission, the gears can be aligned in six different ways (five forward gears and one reverse). The gear alignments have different gear ratios. A ***gear ratio*** describes the change in the amount of torque. See **Figure 18-19.** For example, in first gear, a transmission typically has a gear ratio of 3:1. This means that, for every three revolutions of the input shaft, the output shaft makes one revolution. This slows the output shaft down and provides the torque needed to move the vehicle from a stopped position. As the vehicle gains speed, less torque is needed, and more revolutions of the output shaft are desired. Fourth gear, for example, may be a ratio of 1:1, meaning the crankshaft of the engine is spinning at the same speed as the output shaft of the transmission.

In a manual transmission, a clutch is used to disconnect the engine from the transmission. See **Figure 18-20.** Clutches allow us to do the following:

- Start the vehicle moving smoothly.
- Shift gears.
- Disengage the engine from the drive train, allowing the car to stand still with the power source still running.

Figure 18-18. A cutaway of a five-speed manual transmission. The "stick shift" lever is on the left. The clutch is contained in the "bell" housing on the right side of this drawing, opposite the stick-shift end.

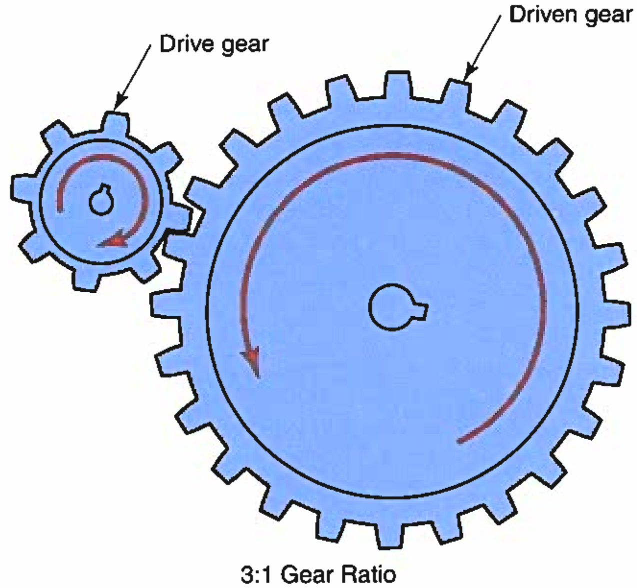
Automatic transmissions

Automatic transmissions also change the torque between the power and drive systems. They are different from manual transmissions, however, in many ways. Automatic transmissions are not dependent on the vehicle operator for control. Instead of the operator having to depress a clutch pedal and shift gears, the automatic transmission does the work itself. These transmissions use a torque converter instead of a clutch.

The ***torque converter*** is a type of fluid coupler. It uses fluid to transfer power. See **Figure 18-21.**

Automatic transmissions are also different from manual transmissions because automatic transmissions can produce an unlimited number of gear ratios. Producing a multitude of gear ratios is accomplished by using ***planetary gear sets***. See **Figure 18-22.** A planetary gear is actually composed of several gears.

Figure 18-19. How a pair of gears multiplies force. Think of the larger (driven) gear as a lever with the fulcrum at the hub, and then think of the small (drive) gear as the force moving the larger gear.

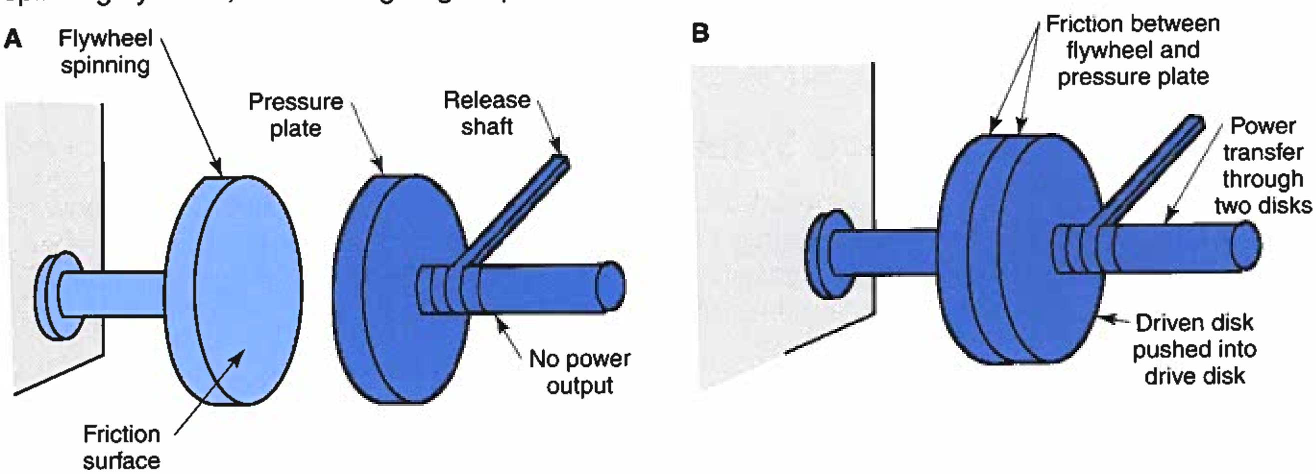


Driveshafts and axles

The output shaft of either an automatic or manual transmission is connected to either a transaxle or a driveshaft. See **Figure 18-23.** In front-wheel drive automobiles, the power is sent from the transmission to the transaxle and then to a differential. A ***differential*** takes rotational power from one source, the transaxle, and transfers it to two

Gear ratio: A ratio describing the change in the amount of torque.

Figure 18-20. A friction clutch is used in manual transmissions. This clutch uses a friction disk attached to a pressure plate on the shaft between the transmission and engine. A—The vehicle operator disengages the clutch by pressing on a foot pedal. When the clutch is disengaged, the pressure plate does not spin. The series of levers and springs that make up the clutch mechanism move the friction disk away from the flywheel. No power is transmitted between the power system and the drive system. B—When the clutch is engaged, the pressure plate is pressed against the spinning flywheel, transmitting engine power to the vehicle's driveshaft, and the vehicle moves.



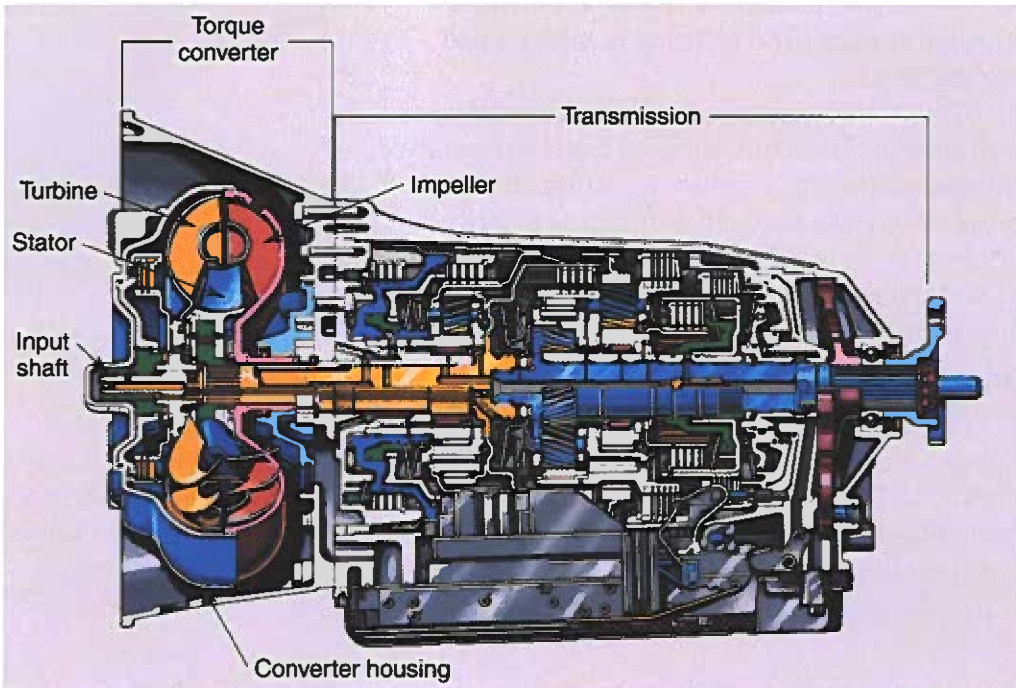
Automatic transmission: A transmission that is not dependent on the vehicle operator for control. It uses a torque converter instead of a clutch.

Torque converter: A fluid coupler used in automatic transmissions. It uses fluid to transfer power.

Planetary gear set: Several gears combined together to provide an unlimited number of gear ratios.

Differential: A component that takes rotational power from one source, the transaxle, and transfers it to two axles. It also allows the wheels to spin at different speeds, which helps make turning easier.

Figure 18-21. The torque converter is a fluid coupler used in automatic transmissions. The outer housing of the converter is attached to the flywheel and crankshaft of the engine. The inner section of the converter is a turbine that rotates within the housing and is attached to the input shaft of the transmission. The inside of the housing and turbine has blades that face each other, and the housing is partially filled with oil. As the driver accelerates the engine, the housing of the torque converter spins with the crankshaft. Oil inside the converter is set into motion and transmits power from the engine to the driven wheels. When the driver comes to a stop and the engine idles, the converter does not spin fast enough to turn the turbine and transmission shaft. This essentially disconnects the engine and transmission. In this manner, the converter serves the same function as the clutch. (DaimlerChrysler)



axles. It also allows the wheels to spin at different speeds, which helps make turning easier. In rear-wheel drive vehicles, the transmission is connected to a driveshaft. The driveshaft is a long rod that transfers the rotational power from the transmission to a rear differential.

In four-wheel drive vehicles, the power from the transmission must be sent to all four wheels. Power is typically sent to a transfer case. The transfer case then sends the power to the front and rear differentials.

Guidance Systems

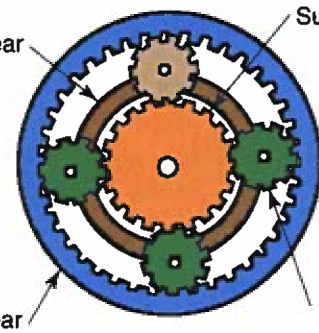
The guidance of land vehicles includes knowing where you are and where you are going. This is referred to as navigation. There is a number of different navigational aids for land transportation vehicles, including maps, signs, and electronic navigational systems.

Maps

In land transportation, the most commonly used maps are ***road maps***. See **Figure 18-24.** These maps are often sold in collections, known as ***atlases***. Road maps use different symbols to denote different types of roads, landforms, and structures. These symbols can be found in the legend located on the map.

Traditionally, maps have been printed on paper and updated yearly. Printed maps are still very common. Electronic maps, however, are gaining in popularity as well. They can come in the form of software programs, Internet Web sites, or digital videodisks (DVDs). These resources make it very easy to plan a trip. Many electronic maps allow the user to type in the addresses of the departure and arrival locations. The programs generate a map showing the best route to follow, as well as the total distance and time of the trip. These electronic maps can then be printed out or downloaded to a disk or handheld device.

Figure 18-22. Planetary gear sets in an automatic transmission can provide a multitude of gear ratios. The ring gear is the outermost gear, and the sun gear is placed in the center. Several planetary gears connect the ring and the sun gear. By engaging and disengaging the planetary gears using bands and clutches, the transmission is able to create different gear ratios. This is done automatically once the vehicle operator has placed the vehicle in the drive gear and depressed the accelerator.



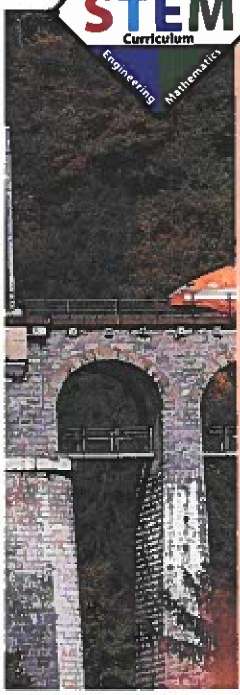
Road map: A map that uses different symbols to denote different types of roads, landforms, and structures.

Atlas: A collection of road maps.

Figure 18-23. On front-wheel-drive vehicles, the transaxle transmits power from the engine to the wheels through a differential. (Mercedes-Benz)

GREEN TECH

One of the benefits to using digital maps rather than paper maps is that when they are updated, no paper needs to be used in order to make the update available.



STEM Connection

Science: Automobiles and Friction

Friction is a force that opposes or resists motion. In automobiles, friction can be used to start or stop vehicular motion. Vehicles come to a stop using the friction generated by applying the brakes. When brakes are applied, brake pads apply force to the rotor, causing enough friction to stop the car. The friction caused by applying the brakes produces heat, which is not used as power, but instead, is typically vented.

The clutch in a vehicle with a manual transmission uses friction to transmit power from the engine to the transmission. Located between the engine and the transmission, the friction is generated between clutch plates and the flywheel. Force is applied to the clutch disc, and that friction transfers power, which is then transmitted to the transmission. By disengaging the clutch, the clutch disc is released from this pressure, which stops the transmission from receiving this type of power.

Torque converters are used in vehicles with automatic transmission. They use a method of hydraulic coupling to transmit power to the transmission. This serves the same purpose as a clutch in a manual transmission. Friction still comes into play, however, when shifting gears. In the hydraulic coupling design, the clutch pack receives fluid pressure, causing the transmission to be powered.

Figure 18-24. Road maps show highways, expressways, local streets, and such features as rivers and lakes. They may also show schools, shopping centers, and other large features along roads. State and national road maps show all the major highways between cities in a state or country. City street maps are much more detailed and focus on the streets and alleys in a small town or large city. Street maps show local parks, schools, hospitals, and points of interest.

Navigation Systems

Maps are an essential part of the newest navigation technology, onboard navigation systems. ***Onboard navigation systems*** include a liquid-crystal display (LCD) screen in the dash that is linked to an electronic map. See **Figure 18-25.**

The entire system is connected to a global positioning system (GPS) and can display your current location on the map. If the destination has been entered, the navigation system can keep the driver informed, either on the display screen or verbally through the speakers, on how to get to the destination. Advanced systems can tell the driver which way to turn as he approaches an intersection. These systems improve the safety of land transportation because the driver does not have to take his eyes off the road and flip through a map.

Signage

While operating a land vehicle, the most common type of guidance information used is signage. ***Signage*** is the information transmitted

Figure 18-25. By "locking on" to a series of navigational satellites, a global positioning system (GPS) receiver can show the vehicle's location within a few feet. If the destination has been entered, the navigation system can keep the driver informed, either on the display screen or verbally through the speakers, on how to get to the destination. Advanced systems can tell the driver which way to turn as he approaches an intersection. These systems improve the safety of land transportation because the driver does not have to take his eyes off of the road and flip through a map. GPS units are becoming a standard feature of some automobile models. This in-dash unit is part of the instrument panel.

Onboard navigation system: A system that includes a liquid-crystal display (LCD) screen in the dash that is linked to an electronic map.

Signage: The information transmitted by the use of signs.

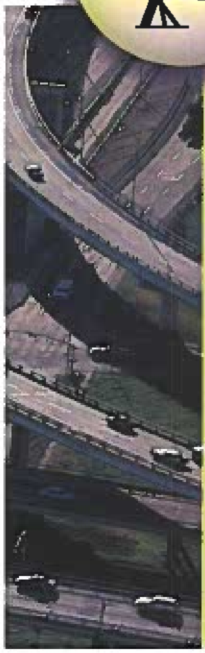
by the use of signs. See **Figure 18-26.** Regulatory signs inform drivers about what they must or must not do. Warning signs, such as "railroad crossing" and "narrow road," communicate hazards lying ahead. Information signs give drivers knowledge of directions and distances of nearby cities, as well as street names.

One other type of signage used on both roads and railroads is the signal. Signals are combinations of lights that give information to the driver or operator. See **Figure 18-27.**

Electronic Guidance Systems

There are several electronic systems used on selected land transportation vehicles to help the driver guide the vehicle. Several of the systems are used on automobiles to assist in

Figure 18-26. Traffic is controlled and directed by various signs and signals, such as this electronic, travel-time display sign on an expressway. Electronic message boards are used in many urban areas to communicate road conditions and construction information. These signs can be updated to include current information. (Wisconsin Department of Transportation)



Technology Link

Communication: Traffic Lights and Signals

In many areas of our lives, visual communication systems are used to guide and direct our actions. On the road, traffic signs help to guide drivers and control the flow of traffic. These signs are communication devices that aid transportation systems. Traffic lights are dynamic, and often, they can respond to feedback they receive. In order to best control traffic, the lights are part of a system that processes information and then communicates the output to drivers.

The signals are sent from push buttons at the crosswalk, from sensors embedded in the road, from timers, or sometimes even by radio frequency from emergency vehicles. The outputs may include either three lights (red, yellow, and green) or one flashing light (yellow or red). The processor is the computer controlling the sequencing of the lights. It receives information from the control devices and selects the appropriate action, turning each light either on or off. The control devices can be manual devices, timers, or detectors. Manual devices are handheld controllers used by police officers to direct traffic. Timers are automated devices set to trigger an electrical output at a specific sequence. Detectors are the control devices used to work along with the current traffic situation.

parallel parking and include sensors and in-dash displays. Other guidance systems are used to maintain safe distances between other cars on the road. Several car manufacturers have designed ***adaptive cruise control systems*** that use lasers or radio detecting and ranging (radar) to determine the distance of the closest car on the road. The systems then monitor the conditions and adjust the speed of the car appropriately. Similar systems use sensors to detect oncoming objects and alert the driver of potential accidents.

Figure 18-27. Block signals on a railroad line warn engineers whether to proceed normally (green light), proceed with caution (yellow light), or stop (red light). In this case, the train is heading away from the station. The red signal lights warn following trains to stop until this train enters the next block, or control section.

Control Systems

Land vehicles require more than just propulsion. They must also be able to be controlled. The speed and direction of the vehicle are both able to be controlled in land vehicles. This ensures that the correct destinations are reached at the right times.

Changing Speed

Acceleration means the changing of a vehicle's speed so the vehicle moves faster. The method of acceleration depends on the type of propulsion system used by the vehicle. Those vehicles using internal combustion engines accelerate by forcing more fuel into the engine through a throttle system. This system includes fuel injectors. See **Figure 18-28.** Giving the engine more fuel produces more revolutions per minute (rpm) from the engine. The drive components receive the extra power and use it to produce an increase in speed.

In an electric vehicle, acceleration is signaled by a potentiometer. Potentiometers are variable resistors that change the resistance of the electric circuit. A dimmer switch is an example of a potentiometer. In electric vehicles, the gas pedal is a potentiometer. The harder it is depressed, the more power is sent to the motors, which increases the speed. Vehicles that use electromagnetic levitation for propulsion, like the maglev system, are locked into a "wave" that travels through coils in a guideway. As the operator increases the frequency of the wave, he increases the speed of the vehicle. See **Figure 18-29.**

To be safe, vehicles that are able to speed up must be able to slow down. ***Deceleration*** is the slowing down or braking of a vehicle. Manufacturers design vehicles that can decelerate gradually. Gradual deceleration provides safety for the passengers and cargo onboard. Many types of braking systems have been developed for use on a variety of land vehicles.

Hydraulic braking systems

The ***hydraulic braking systems*** used on modern wheeled vehicles link a master cylinder to a brake pedal and to one or two brake cylinders at each wheel. The cylinders are connected to the master cylinder with steel tubing. The tubing carries and contains the flow of hydraulic fluid through the system. See **Figure 18-30.** When the vehicle operator steps on the brake pedal, the master cylinder is activated. Force produced at the master cylinder is transmitted to each wheel cylinder by the hydraulic fluid. The wheel cylinders expand to activate the vehicle's brakes. In this way, each wheel receives an equal amount of force to decelerate the car

Adaptive cruise control system: An electronic guidance system that uses lasers or radio detecting and ranging (radar) to determine the distance of the closest car on the road.

Acceleration: The changing of a vehicle's speed so the vehicle moves faster.

Deceleration: The slowing down or braking of a vehicle.

Hydraulic braking system: A braking system that links a master cylinder to a brake pedal and to one or two brake cylinders at each wheel.

Figure 18-28. Acceleration in an internal combustion vehicle is achieved by providing more fuel to the engine. Shown is the operation of a fuel injection system.

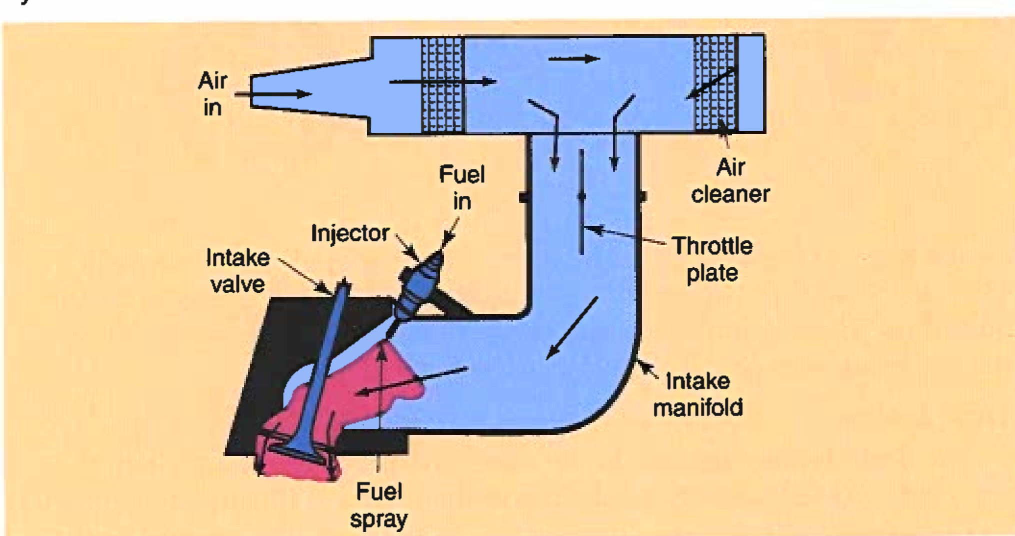
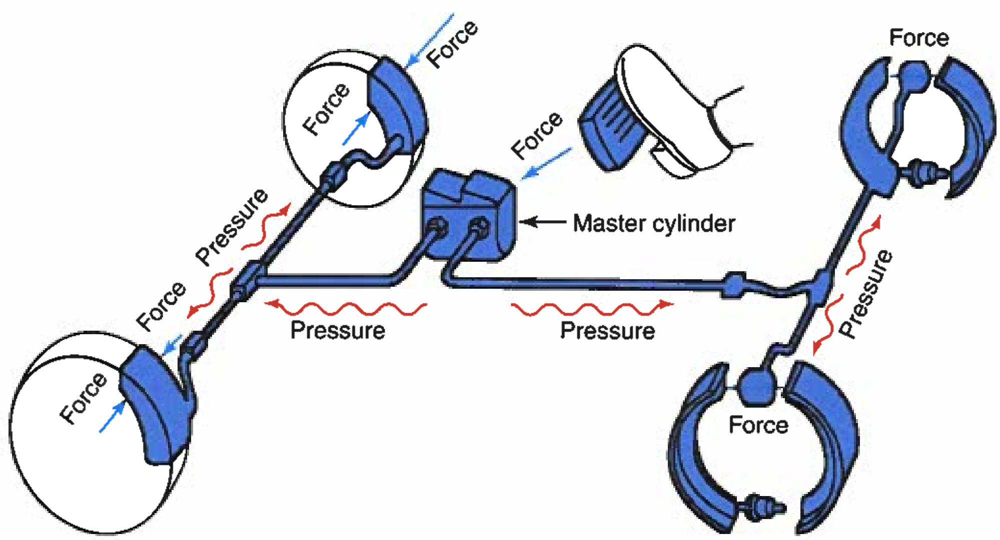


Figure 18-29. In a magnetic levitation (maglev) system, acceleration is achieved by increasing the frequency of the "wave" traveling through the guideway coils. (Transrapid International, Inc., GmbH)

Figure 18-30. Force applied to the brake pedal of a vehicle is transmitted to fluid in the master cylinder and brake lines. Fluid pressure in wheel cylinders forces the brake shoes and pads against rotating wheel components (brake drums or rotors). This reduces vehicle speed through friction.



evenly. Refer to Chapter 10 for a review of the operation of hydraulic cylinders. There are various types of mechanical brakes powered by the individual wheel cylinders. Drum brakes and disc brakes are the devices that use friction to physically slow the vehicle.

Drum brake: A brake device that uses two brake shoes shaped to fit the inside of the brake drum.

Drum brakes

The ***drum brake*** uses two brake shoes shaped to fit the inside of the brake drum. The shoes are held close to the inside of the brake drum, but they are not touching it. The brake drum is attached to the wheel of the vehicle and rotates freely around the brake shoes while the vehicle is moving. As the brake pedal is depressed, the hydraulic cylinders activate the wheel cylinders. They push the brake shoes outward against the rotating brake drum. The two surfaces rub against each other. The friction from this contact slows the vehicle.

Disc brakes

Disc brakes are another commonly used brake device. Instead of a drum, a steel disc called a rotor is mounted to the wheel assembly so it spins freely. See **Figure 18-31.** A brake caliper straddles the rotating disc, but it does not touch the disc. When the disc brake is activated through the hydraulic brake system, the caliper is squeezed against both sides of the disc. The friction of the rubbing surfaces slows the disc. This, in turn, slows the wheel.

Disc brake: A brake that makes use of a rotating disc or rotor on the wheel.

Power brake: A brake system that adds a vacuum control valve between the brake pedal and the master cylinder.

Power brakes

Power brakes are found on all modern automobiles. This brake system adds a vacuum control valve between the brake pedal and the master cylinder. When the brake is pushed, the vacuum unit uses the vacuum created by the propulsion system to activate the master cylinder. The balance between vacuum pressure and atmospheric pressure is controlled in the unit. As a result, vacuum exerts the major force on the master cylinder. This allows the driver to use less foot pressure. At the same time, the brake pedal may be positioned more comfortably.

Antilock braking system (ABS): A computer-controlled braking system that improves control of the vehicle in certain braking situations.

Antilock braking systems (ABSs)

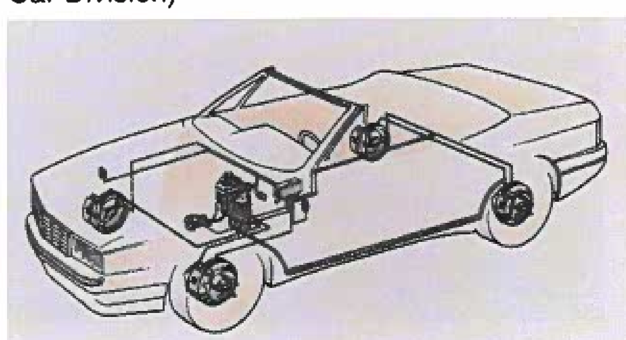
Antilock braking systems (ABSs) are computer-controlled braking systems that improve the control of the vehicle in certain braking situations. An ABS uses sensors at each wheel to monitor the speed at which the wheel is turning. If one of the wheels is operating at a completely different speed while braking, the computer connected to the sensors can detect the difference. The only reason for a wheel to rotate at a very different speed would be if the tire lost traction during braking. If this occurs, the ABS controller is able to send braking pulses to the skidding wheel to help maintain the same speed as the other wheels. An ABS helps the driver control the vehicle while braking and enables the vehicle to stop faster. These systems are only used in extreme conditions when the computer senses the skidding is occurring.

Air brake: A railroad car brake that uses compressed air to operate the brake cylinder.

Pneumatic brakes

Railroad cars use pneumatic brakes to decelerate. Pneumatic brakes, or ***air brakes***, use compressed air to operate the brake cylinder. The brake cylinder is connected to a brake shoe that is pushed against the wheel to brake. Air brake systems can be computer controlled to provide the specific amount of pressure needed for each situation. For

Figure 18-31. Disc brakes, as shown in this phantom view, make use of a rotating disc or rotor on the wheel. Brake pads on pivoting calipers are forced against the rotor to slow and stop the vehicle. (GM-Cadillac Motor Car Division)



example, more pressure is needed when the train is loaded with cargo than when it is empty. If a train car becomes detached from the locomotive, the air brakes would automatically be applied to stop the car.

Controlling Direction

It is not hard to see that, if there were no way of steering a vehicle, the vehicle would be unsafe. Drivers and other vehicle operators would have no way of avoiding obstacles. Additionally, vehicles would be almost useless. While they could move easily, they would never arrive at the desired destination.

Land vehicles on fixed pathways

Degree of freedom: Any of a limited number of ways in which a body may move.

Railroad trains, maglev vehicles, monorails, vehicles that travel through tubes and pipes, escalators, elevators, and moving sidewalks all have one ***degree of freedom***. See **Figure 18-32.** This means they can only move forward or backward, in or on their guideways. The control of direction is mostly done automatically by the arrangement of the vehicle and guideway. Wherever the guideway goes, the vehicle must go.

Trains, for example, must follow the railroad tracks. The wheels have a flange on the inner side to help keep the train on the track. They are also ground at a slight angle and fit on the tracks so there is a gap between the wheel flange and the inside of the tracks. See **Figure 18-33.** When the train approaches a turn in the track, the whole vehicle shifts over slightly, so the outside wheel has to turn more revolutions than the inside wheel. This helps the vehicle to follow the track. Just as important, it prevents the wheels from skidding or derailing. Skid prevention also means less wear on the metal parts of the vehicle and track.

Land vehicles on nonfixed pathways

There are three basic ways to control the direction of nonfixed pathway vehicles: front steer, rear steer, and all-wheel steer. Most vehicles rely on front steering for control. See **Figure 18-34.** Both front wheels act instantly with the movement of a steering wheel.

Figure 18-32. This factory towline system has one degree of freedom. A—Towline carts move materials along fixed pathways to various parts of the factory. B—The towline connects the car to a tow chain recessed below floor level. (SI Handling Systems, Inc.)

A

B

Figure 18-33. A flange on a railroad wheel holds the wheel on the rail. A slight angle on the flange helps the wheel follow curves in the track.

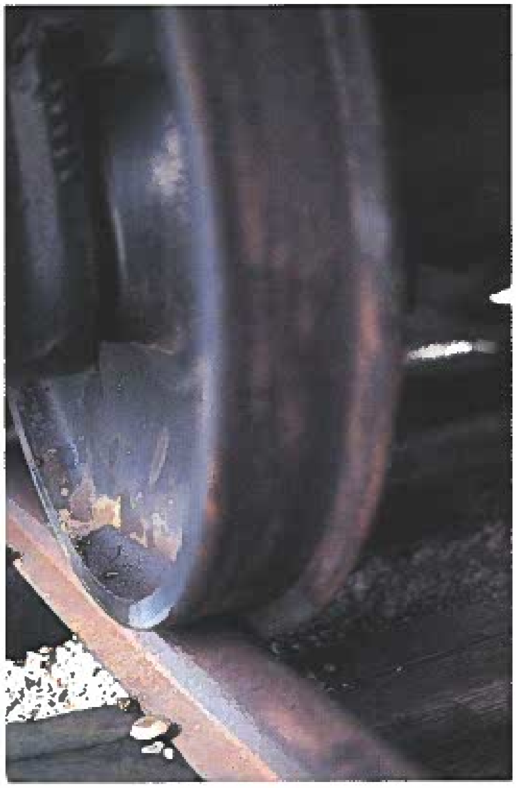


Figure 18-34. Front-wheel steering is the method used on most land vehicles, such as this tractor. (Deere & Company)

Career Connection

Locomotive Engineers

The railroad industry utilizes many types of workers. Rail yard engineers, yardmasters, switch operators, conductors, and yard laborers are all required in order for trains to operate. One of the highest paid rail occupations is the locomotive engineer.

Locomotive engineers operate trains. They begin each trip by checking the various systems on the train. The engineers are then given orders to leave the train yard. From that point on, their primary role is to monitor the status of the locomotive and train cars. They keep watch on the speed and control the throttle, as well as other system gauges. Locomotive engineers also follow all the signs along the railway and make sure the train is operating in a safe manner.

They typically work up through the ranks in a train yard. While the only initial school requirement is a high school diploma, they almost always have extensive work experience in several rail occupations before becoming an engineer. Once they are selected to become engineers, they complete an engineer training program. In the program, they spend time in the classroom, in simulators, and on a locomotive. They must also pass physical exams of their health and vision. The average salary for a locomotive engineer is just over $25 per hour. Most engineers are members of the Brotherhood of Locomotive Engineers.

Figure 18-35. Rear-steer is used on certain vehicles, such as this forklift, to permit a tight turning radius.

Forklifts, some street-cleaning machines, and other small vehicles that need to have a tight turning radius are designed with rear-wheel steering. See **Figure 18-35.** These vehicles can turn around in a very small space.

Recent improvements in the control of automobiles and trucks have led to ***all-wheel steering***. All-wheel steering is popular in larger vehicles because it increases control. Fire engines, for example, often use all-wheel steering because they need to maneuver into tight spots at the scene of a fire. All-wheel steering systems use the steering wheel to operate the front and rear wheels at the same time. There are two ways all-wheel steering systems can operate. See **Figure 18-36.** When the front and rear tires are steered in opposite directions, it is known as coordinated, or negative, steering. ***Coordinated steering*** aids in parking and decreases the turning radius of the vehicle. The opposite method of all-wheel steering is crab, or positive, mode, when all tires are turned in the same direction. ***Crab mode*** is useful in changing lanes and adding stability to the vehicle. All-wheel drive is electronically controlled, and an electronic controller selects the method of turning.

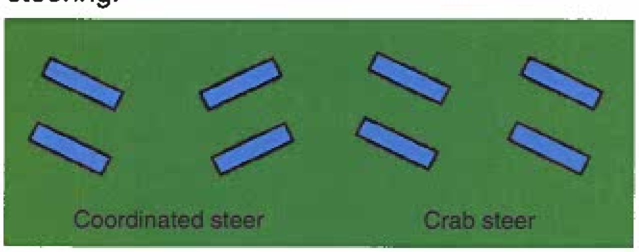
All-wheel steering: A steering system that uses the steering wheel to operate the front and rear wheels at the same time.

Coordinated steering: Negative steering, in which the front and rear tires are steered in opposite directions.

There are several types of mechanical ways that automobile and truck wheels are physically turned. One of the more common ways in small cars is by using a ***rack and pinion*** system. Racks and pinions are both types of gears. Rack gears are flat gears, and pinion gears are round. When used together, rack and pinion gears change rotary motion into linear motion. See **Figure 18-37.**

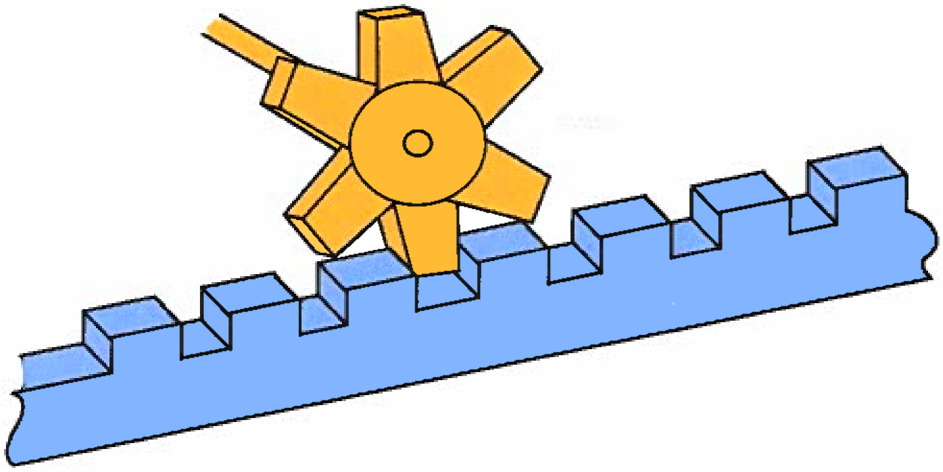
The pinion gear is mounted to the end of the steering wheel column. The teeth of the pinion gear and the rack gear mesh together. As the steering wheel is turned, the pinion gear moves the rack gear in the opposite direction. Both ends of the rack gear are connected to tie rods. The tie rods connect to the wheels. As the rack gear is moved in one direction, the wheels are turned in the opposite direction.

Figure 18-36. The two types of all-wheel steering are coordinated steering and crab steering.



Car manufacturers are working on a new method of steering that does not use rack and pinion gears. It actually does not even use a steering column. This new method of steering is known as *drive-by-wire*. It is an electronic system that uses sensors in the steering wheel. The sensors can detect the rotation of the steering wheel and send that information to the steering system at the wheels. Electric motors at the wheels are then activated to turn the wheels.

Figure 18-37. Rack-and-pinion steering uses a round gear (pinion) and a flat gear (rack) to change rotary motion to linear motion.



Crab mode: Positive mode, in which all tires are turned in the same direction.

Rack and pinion: Types of gears. Rack gears are flat gears, and pinion gears are round.

Articulated frame steering

Some vehicles designed for mass transit, farm operation, and construction have an ***articulated*** (hinged) section in the middle of the vehicle. See **Figure 18-38.** Steering is then controlled by swiveling the trailing wheels along with the front wheels. This system allows a small turning radius on very long vehicles.

Articulated: Hinged.

Tracked land vehicles

Tanks, bulldozers, some logging equipment, and other off-road vehicles use tracks. The tracks improve traction on difficult terrain. To change the direction of such a vehicle, the operator must vary the speed of one of the tracks. By decelerating one track and accelerating the other, she can pivot the vehicle. See **Figure 18-39.** Tracked vehicles are able to turn around in one spot by moving one track forward and one track backward.

Suspension Systems

Suspension systems include the components that link the vehicle to the guideway or path. In land vehicles, suspension systems can include tires, wheels, shocks, springs, and even magnets. Automobiles, trains, and maglev trains share some of the same suspension system components, but they each have unique pieces as well.

Automobile Suspension Systems

Automobile technology is at the forefront of suspension system design. Systems for many land vehicles have used the basic designs used for car suspensions. Trucks use the same components, but they are stronger

Figure 18-38. Hinged, or articulated, sections of this bus allow a shorter turning radius, an advantage in city mass transit. This very large bus has two hinged sections. (French Technology Press Office)

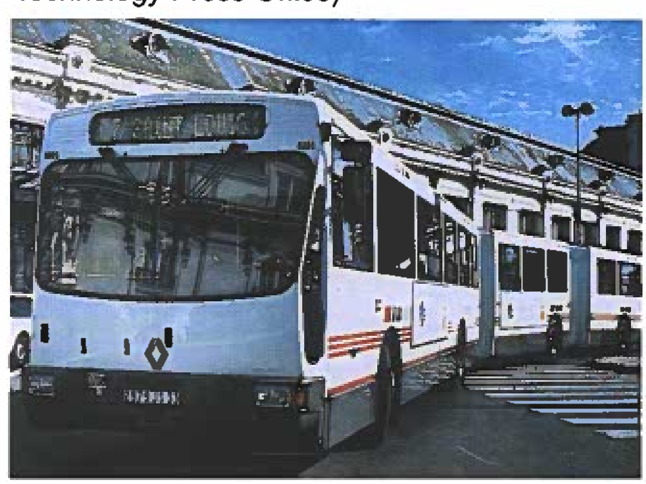


Figure 18-39. A tracked vehicle, such as this huge mining shovel, changes direction by altering the speed and direction of the two tracks. (P&H Construction Equipment)

Pneumatic tire: A tire filled with air.

Contact patch: The part of the tire actually touching the road as the tire spins.

Bias tire: A tire made of many layers of fabric, called plies.

Steel-belted radial tire: A tire constructed with wide strips of steel mesh called belts. It improves durability, wear resistance, and gas mileage.

and more heavy-duty. Even golf carts and tractors have borrowed components from car suspension technology. The main suspension components are the tires.

Pneumatic tires

Pneumatic tires (air-filled tires) are an important part of suspension systems. They provide the contact points between the vehicle and the surface on which it travels. See **Figure 18-40.** Tires actually have two important functions:

- Providing a cushioning effect as the vehicle travels over bumps and ruts. The air inside the tire compresses, and the sidewalls help to absorb the shock.
- Providing traction. This enables the car to "grip" the road surface for greater safety and better handling. The ***contact patch*** is the part of the tire actually touching the road as the tire spins.

The structure of a tire is constructed of various rubber compounds and fabric. A typical ***bias tire*** has many layers of fabric, called plies. The cords of each ply run in a different direction.

Steel-belted radial tires are the most common type of tire today. See **Figure 18-41.** These tires provide better traction and a longer tread life and permit a softer ride than other tires.

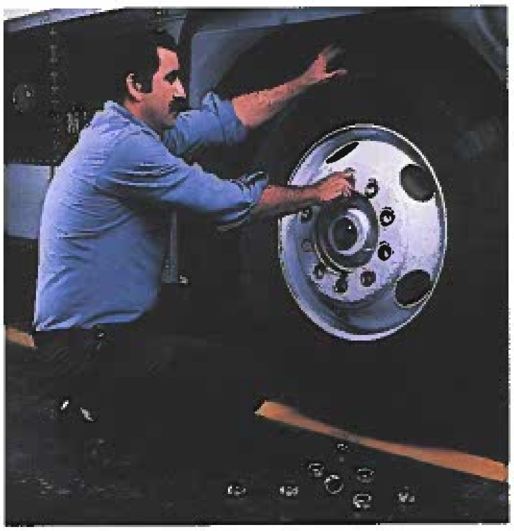


Figure 18-40. Air-filled tires are mounted on a wheel called a rim. The assembly is then bolted to the axle of the vehicle. Each modern tire can support 50 times its own weight when it is properly inflated. Air holds 90% of the weight. The structure of the tire supports the other 10%. Keep in mind, however, that the tire must also contain and withstand the pressure of the air it holds. This large tire is being mounted on a bus. (Greyhound)

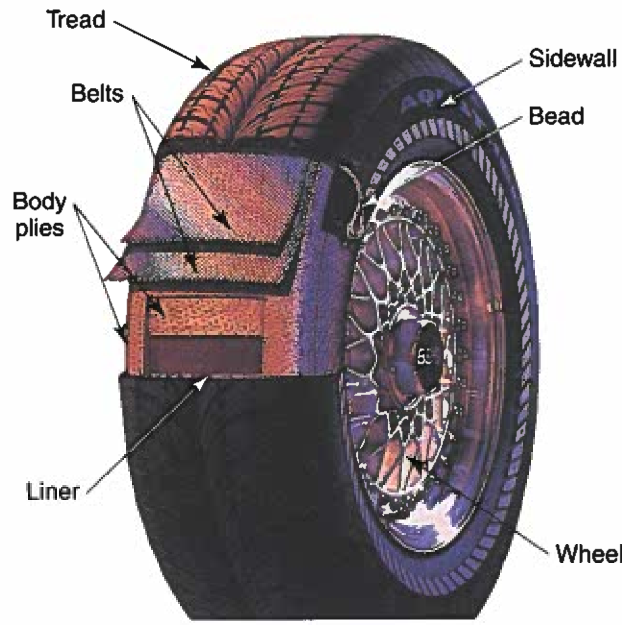


Figure 18-41. Wide strips of steel mesh called belts are key construction elements in a radial tire. They improve durability, wear resistance, and gas mileage. The plies on radial tires are placed so the cords run perpendicular to the centerline of the tread. Steel-belted radial tires also provide a softer ride than other tire types. (The Goodyear Tire & Rubber Company)

There is a thin rubber coating, or liner, on the inside of the tire, as well as a thick rubber exterior covering. The tread pattern is formed on the exterior of the tire. See **Figure 18-42.**

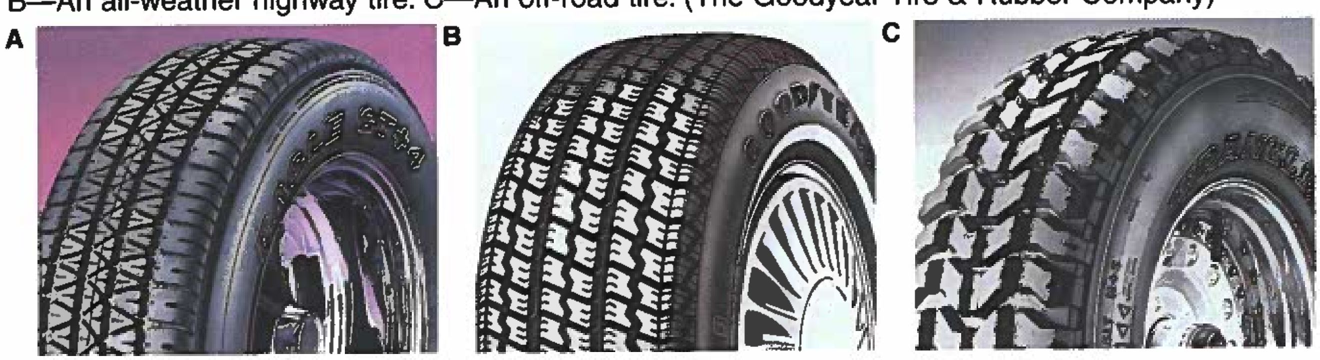
Springs

Springs are devices that are able to temporarily store energy and then use the energy. The springs used on automobiles are relatively large and heavy-duty. They need to support a heavy weight.

One type of automotive spring is called a ***coil spring***. It is made by taking long steel rods and forming them around a cylinder into a helix.

Spring: A device that is able to temporarily store energy and then use the energy.

Figure 18-42. Tread designs vary depending on their purpose. A—An all-season performance tire. B—An all-weather highway tire. C—An off-road tire. (The Goodyear Tire & Rubber Company)



STEM Connection

Technology: Reading the Tire Code

All tires have several sets of markings. See **Figure 18-A.** In this drawing, *P* signifies the type of tire and stands for "passenger." *LT* stands for "light truck." If no letter is used, the tire is meant for use in large trucks, motorcycles, tractors, or other land vehicles. *195* is the width of the tire in millimeters. *75* is the aspect ratio, which is the height of the tire, compared to the width. This means the height of the sidewall is 75% of the width. *R* signifies the type of tire construction and stands for "radial." *B* is used for bias constructed tires. *14* is the diameter, in inches, of the rim the tire is designed to fit.

Other markings include load and speed ratings. Load ratings are the amount of weight the tire can support. Speed ratings use letters to describe the maximum speed the tire can withstand. There are also quality markings. Tread-wear is graded on a scale on which 100 is average. Traction and temperature are rated on an A, B, and C scale.

Figure 18-A. Tire information, such as its pressure rating, size, construction type, and maximum inflation, are molded into the sidewall.

Coil spring: An automotive spring made by taking long steel rods and forming them around a cylinder into a helix. It is taken off the cylinder and heat-treated. The spring then retains its shape and gives the proper tension.

The springs are taken off the cylinder and heat-treated. They then retain their shape and give the proper tension. See **Figure 18-43.**

Another type of automotive spring is the ***leaf spring***. It is made of a series of steel strips, each one shorter than the next. A bolt that runs through the centers of each strip holds the leaves together. See **Figure 18-44.**

Torsion bars are another commonly used "spring" on modern land vehicles, such as trucks and automobiles. These bars do not resemble normal springs. They look more like metal rods. See **Figure 18-45.**

When a spring compresses and then rebounds, it will spring past its normal position. As it rebounds, it will compress past its normal position again. This is called ***spring oscillation***.

Figure 18-43. Coil springs are placed between the vehicle frame and axle to support the weight of the body. When the wheel goes over a bump, the spring compresses and stores potential energy. As the wheel moves off the bump, the spring uses the energy to expand and push the wheel back onto the road. This way, the wheel and spring move over the bump, but the vehicle frame can keep moving in a straight line. (GM-Cadillac Motor Car Division)

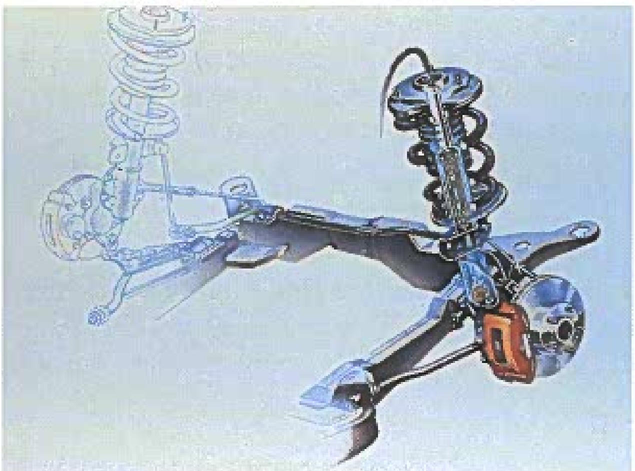
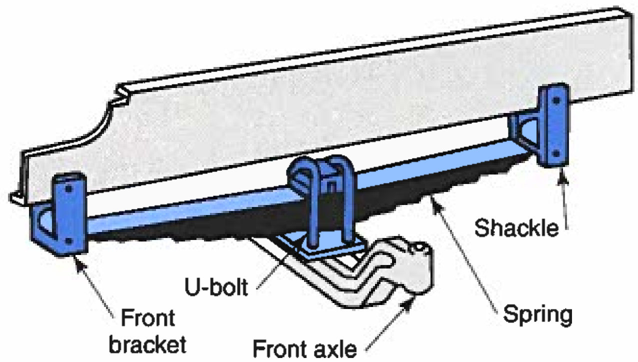


Figure 18-44. Leaf springs attach to the axle and two points on the vehicle frame. As a wheel hits a rut or bump, the leaf spring flexes up and down, storing potential energy. By returning to its original shape, the spring forces the axle up or down, to force the wheel firmly onto the road surface. This lets the wheel go over the obstacle, while the vehicle continues to travel in a straight line.



Leaf spring: An automotive spring made of a series of steel strips, each one shorter than the next.

Torsion bar: A metal rod used as a spring on modern land vehicles.

Shock absorbers

Shock absorbers absorb a road's unevenness so it is not transferred to the vehicle structure. The job of a shock absorber is to control spring oscillation. This system consists of shock absorbers connected between the car frame and the axle. There is one for each spring, usually one at each wheel. When the spring compresses and tries to oscillate, the shock will resist this motion. See **Figure 18-46.**

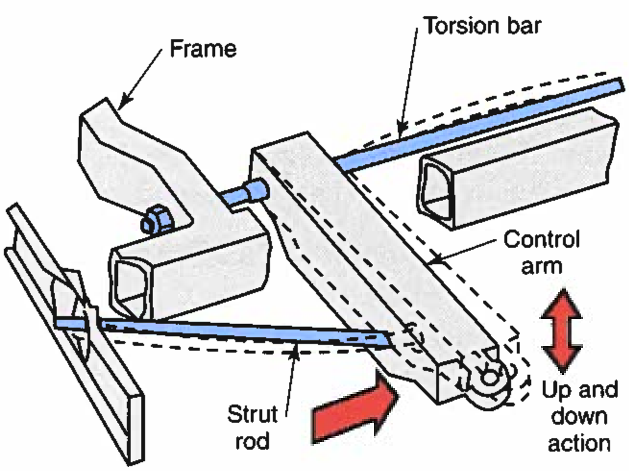


Figure 18-45. Torsion bar suspension uses the tension, or flex, in a steel bar to support the load of the vehicle. One end of the bar is attached to the wheel assembly through a lever arm. The other end is attached to a cross member of the car frame. When the wheel hits a bump or rut, the lever arm will swing up or down. The torsion bar will resist this movement and force the wheel assembly back to its normal position. Torsion bars are more stable than coil springs because they will not let the car sway from side to side as much.

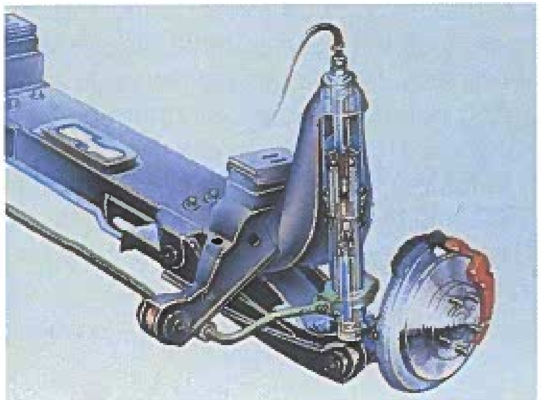


Figure 18-46. Shock absorbers smooth the vehicle's ride on bumpy roads by controlling the bounce from coil and leaf springs. A shock absorber looks like two pipes, one fitting inside the other. One end is attached to a piston rod that moves inside the other pipe. The piston on the end of the rod is made so it creates a seal between itself and the inside of the shock. On the piston, there is a two-way valve arrangement or simply ports (holes). When the shock is compressed, the hydraulic fluid in it is put under pressure too. The fluid is allowed to escape slowly through the valve or ports at a fixed rate, and so, the oscillation of the shock is slowed. This cutaway view shows the interior of a typical telescoping shock absorber. (GM-Cadillac Motor Car Division)

Spring oscillation: The compression and rebounding of a spring, in which the spring will spring past its normal position.

Shock absorber: A suspension system component that absorbs a road's unevenness so it is not transferred to the vehicle structure.

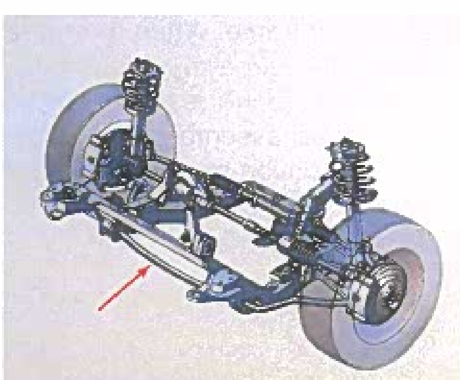
Stabilizer bars

A ***stabilizer bar***, or sway bar, is a long steel rod mounted between the two front wheel assemblies. See **Figure 18-47.** This bar helps to keep the vehicle from leaning out too far when the vehicle is going around corners.

Train Suspension Systems

Electric and diesel-electric trains use suspension components similar to those in automobiles. Wheels, springs, and shock absorbers are all used in trains. The entire suspension system of a train is contained on a ***bogie***, or truck. See **Figure 18-48.** Most train cars have two bogies, one at the front and one in the rear. The bogies are attached to the bottom of the train cars on swivels so the bogies are able to turn with the tracks. They consist of steel frames to which the suspension components are attached. Each bogie contains two axles, with a total of four steel wheels. Coil springs are used on a bogie to support the weight of the train car. Shock absorbers are used to ensure a smooth ride. Some bogies are equipped with air suspension systems that help create an even better ride. In most locomotives and electric trains, the bogies also carry the propulsion motors. The increased weight actually helps the suspension system create a smooth ride.

Figure 18-47. A stabilizer (indicated by the arrow) keeps the vehicle from leaning to the outside on tight turns. When the centrifugal force caused by the turn causes the vehicle's body to dip on the outside and lift on the inside, the bar is twisted. The stiffness of the bar resists this twisting and helps to keep the car level. This makes for a more comfortable ride. It also makes the vehicle easier to control. (Saturn Corporation)

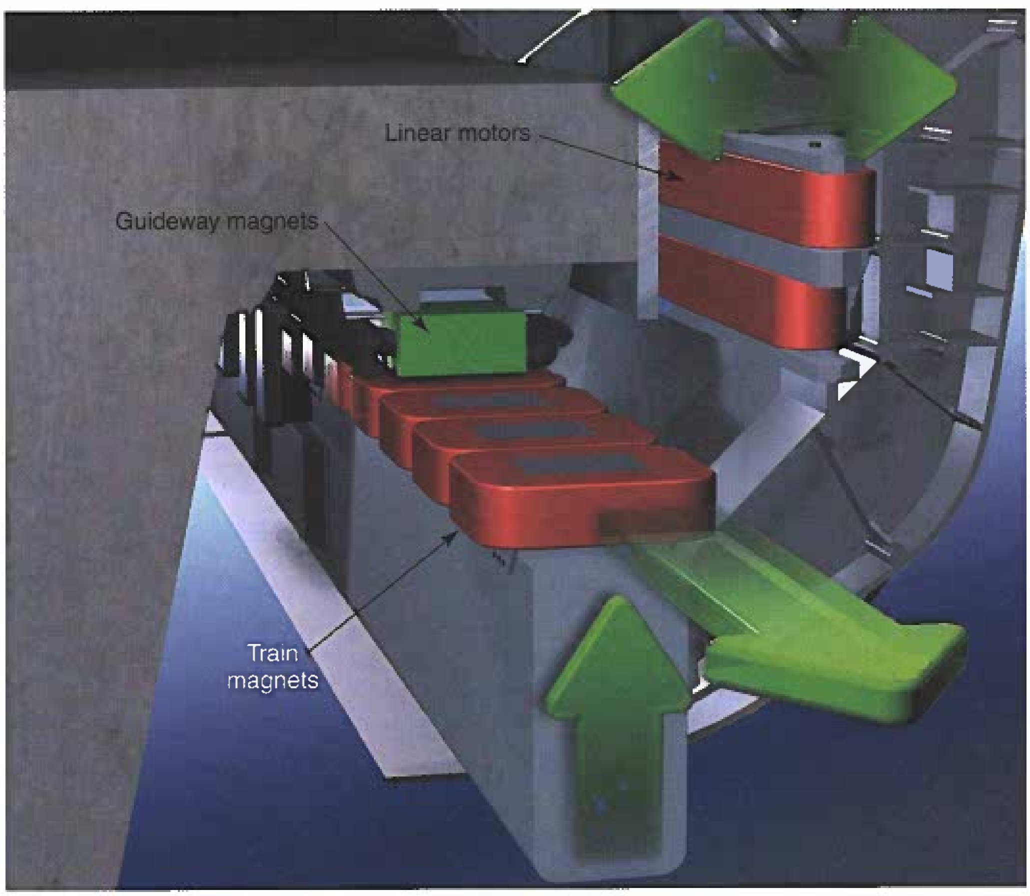


Magnetic Levitation (Maglev) Suspension Systems

Magnetic levitation (maglev) trains have an entirely different suspension system. They are not suspended by shocks, tires, or springs. Magnetic forces suspend them in air. There are two methods of using maglev as a suspension system. The first method is by repulsion. In repulsion systems, the train levitates above the track. The magnets lining the track and those along the bottom of the train have the same polarity. Since magnets with the same polarity repel, the train floats above the track. The other method of suspension acts in the opposite manner. In attraction systems, the train wraps around the guideway. Magnets line the underneath of the guideway and the top of the lip of the train. See **Figure 18-49.** The two sets of magnets have opposite polarity and are attracted to each other. The magnetic fields are controlled so the two magnets come close to touching, but never actually touch. Both of these suspension methods create a gap between the guideway and the train that enables the train to move almost without any friction.

Figure 18-48. A train bogie holds two sets of wheels and is attached to the bottom of the car with a swivel. Note the heavy coil springs that help support the weight of the train.

Figure 18-49. Magnetic forces suspend a magnetic levitation (maglev) train. In this diagram of an attraction maglev system, the magnets on the train and the magnets on the guideway are of opposite polarity and are attracted to each other. The tiny gap between the two sets of magnets allows the train to be propelled with virtually no friction. Linear motors built into each side of the train work with matching magnets in the guideway to move the train forward or backward. (Transrapid International, Inc., GmbH)



Stabilizer bar: A long steel rod mounted between the two front wheel assemblies to keep the vehicle from leaning out too far when the vehicle is going around corners.

Bogie: A part of the suspension system of a train. It is attached to the bottom of the train car on a swivel and consists of a steel frame to which the suspension components are attached. Each bogie contains two axles, with a total of four steel wheels.

Structural Systems

Structural systems in land vehicles typically serve several purposes. They allow for a structure that contains the rest of the vehicle. These systems also form the exterior of the vehicle.

Automobile Structural Systems

Body: The enclosed part of a vehicle.

Chassis: The frame of a vehicle.

Unibody construction: A type of automobile construction that combines the body and frame in one unit.

Convertible: An automobile that has a removable roof.

The main parts of an automobile structure are the ***body*** (the exterior of the vehicle) and the ***chassis*** (the frame). The two parts historically have been made separately and then joined with bolts. Rubber blocks (spacers) are usually inserted between the body and frame to reduce vibrations from the engine and the road surface.

Unibody construction is very common on many automobiles today. See **Figure 18-50.** It is also called integral frame, or unit body, construction. This type of structure combines the body and frame in one unit. Suspension parts may be attached directly to the unibody. Sometimes, a partial frame may be attached. Partial frames are made to carry the weight of the propulsion system. They also withstand the stress put on the suspension system.

This type of construction is almost universal for all subcompact, compact, and midsize automobiles. Manufacturers, however, have kept the frame and body construction, known as body-on-frame, for many larger cars. The conventional style is better at reducing road noise.

Automobile bodies

Automobile bodies may be placed in classes by the number of doors or the type of roof. Two-door and four-door cars are clearly different and easily recognized. The roofs of many automobiles are solid sheet metal. Usually, six columns—three on each side—support them. This arrangement provides relative safety if the vehicle should roll over. One method of roof support eliminated the middle column on each side. The roof was supported only at each corner. This style improved visibility, but the roof crushed easily in rollover accidents. Many modern cars have gone back to the six-support system for safety. Designers pay special attention to placement and shape of the middle column to improve visibility.

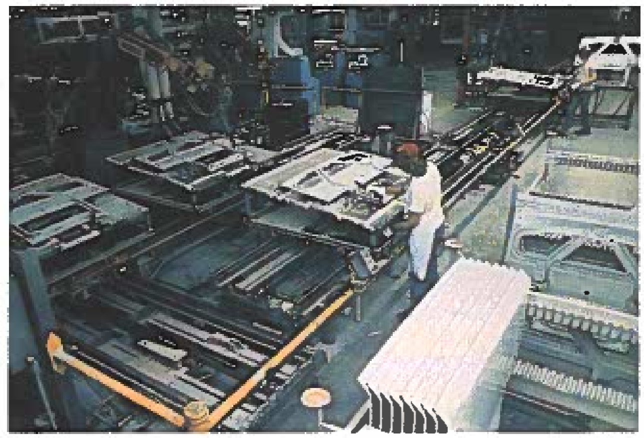
Figure 18-50. In unibody construction, the frame and body are combined in a single unit. (GM-Cadillac Motor Car Division)

Convertibles are automobiles that have a removeable roof. The tops may be made of fabric, steel, or aluminum. Fabric tops fold down behind the passenger compartment for storage. Convertibles with metal roofs have special latches that secure them onto the body. These cars are popular, but they also have obvious safety disadvantages.

Most car bodies are made of sheet steel. Many times, special additives help the steel withstand manufacturing processes. Body parts are usually pressed, or stamped, into shape with large hydraulic presses. See **Figure 18-51.**

Some designers and manufacturers are using aluminum and fiberglass reinforced plastic for body parts. These materials are lighter and allow vehicles to have higher fuel efficiencies. The manufacture of body parts from plastic is relatively easy. One drawback, however, is plastic does not withstand impact as well as steel. Designers must keep this in mind when designing the total automobile. They do not want to reduce the level of safety for buyers of their cars.

Figure 18-51. Automotive body parts are typically stamped from sheet steel. (SI Handling Systems, Inc.)



Automobile frames

Automobile chassis are the main "skeletons" of the vehicles. They are made to support and hold together the vehicle. As was explained earlier, frames may be separate from or an integral (inseparable) part of a unibody construction.

Conventional automotive frames are made of steel. The metal sheets are pressed or rolled into a box or channel shape. The frame usually consists of two long pieces running the length of the car. Steel cross members join them. The parts are usually welded, but they may also be cold riveted. Either way, the frame members must be securely joined so they provide a rigid structure.

Truck Structural Systems

Highway cargo transportation requires the use of special vehicles. Trucks are the vehicles of the trade. There are many types. The basic vehicular systems are the same for many trucks. There are different designs, however, to suit the type of cargo the truck will be hauling. See **Figure 18-52.** Single-unit trucks have one-piece structures. They are relatively short so they can maneuver easily in tight places.

Tractor-trailers are the large two-piece vehicles you see on highways. The tractor is the workhorse with a propulsion system capable of producing a great amount of horsepower (hp). These vehicles usually have more than 12 speeds in their transmissions. This enables them to start out while pulling heavy loads and to shift up to a more efficient gear when hauling on the open road and over modern expressways.

Trailers are made in various shapes and sizes. Depending on the type of cargo, bulk or break-bulk, trailers will take on many different appearances. (***Bulk cargo*** is loose material, such as grain or oil. ***Break-bulk cargo*** is a single unit or cartons of freight.) See **Figure 18-53.**

Bulk cargo: Loose material, such as grain or oil.

Break-bulk cargo: A single unit or cartons of freight.

Rail Vehicle Structural Systems

Rail vehicles have taken on many shapes, according to their purposes. Ones used for passengers are obviously different from those used for cargo. The basic framework or structure of all rail cars is steel. Most passenger cars are covered with aluminum alloy to save weight. Some passenger trains use a fiberglass-reinforced plastic body. Railcar builders are starting to use this material more because of its manufacturing ease and good appearance.

Figure 18-52. Truck bodies come in different designs, often determined by the type of cargo they will carry.

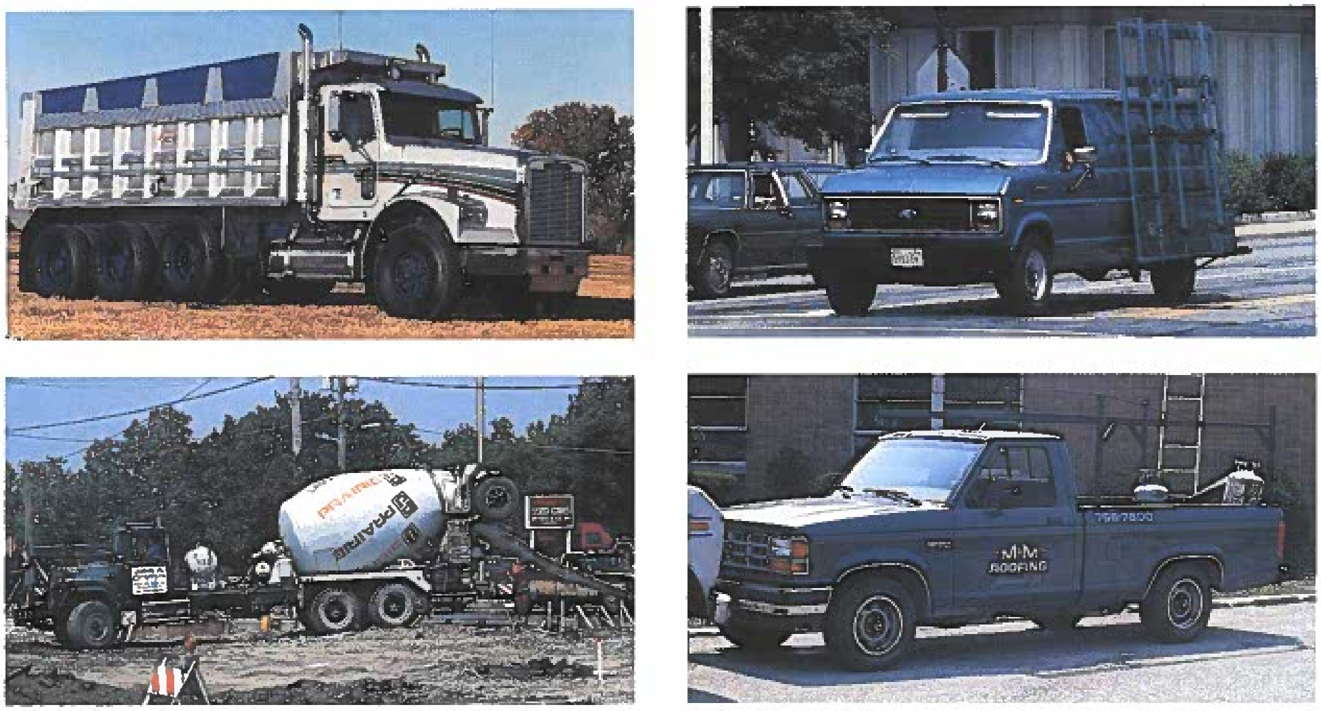
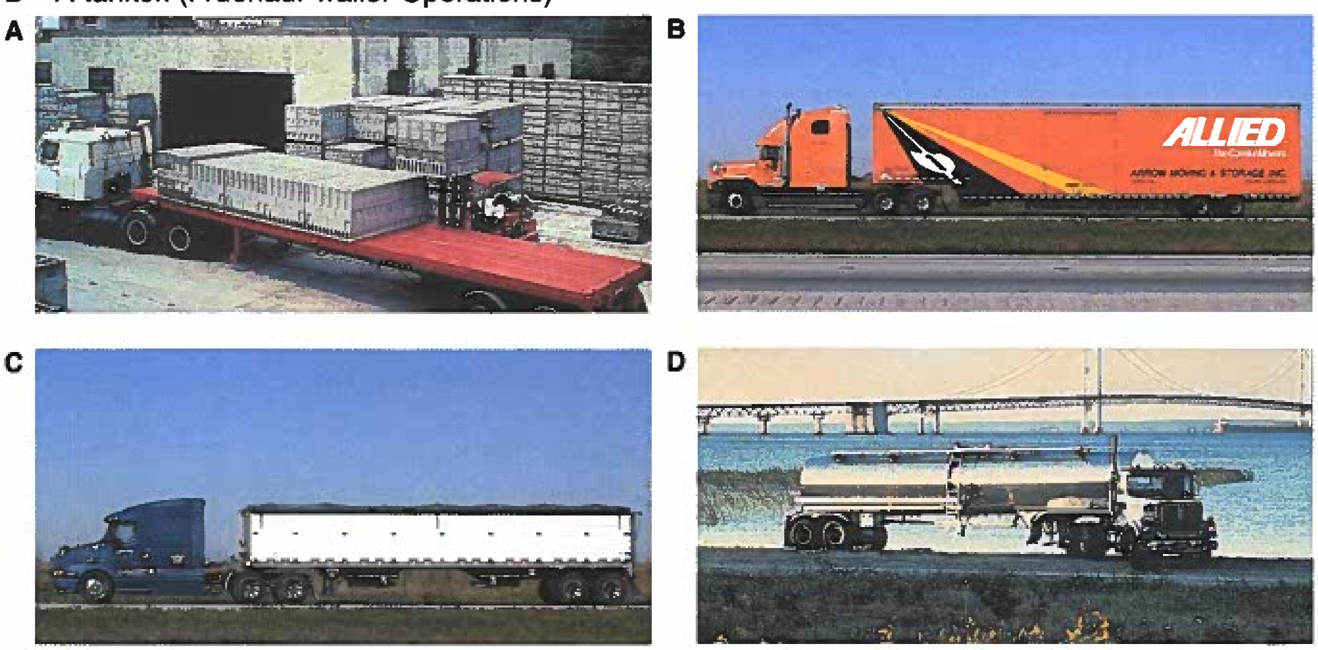


Figure 18-53. These trailers represent different types of cargo haulers found on the highways. A—A flatbed. (Fruehauf Trailer Operations) B—A closed (moving) van. C—A loose-cargo hauler. D—A tanker. (Fruehauf Trailer Operations)



Passenger trains have a variety of cars with flexible coverings between them. See **Figure 18-54.** The coverings between cars permit passenger movement between the cars. At the same time, they offer protection from the environment.

The railcars in passenger trains average about 85′ in length and are fitted with many luxuries. Coach cars are set up for comfortable passenger travel, with rows of upholstered, adjustable seats. Windows surround these cars so passengers may have full view of the countryside. Sleeping cars are divided into private berths, or bedrooms. Windows have shades to make sleeping easier and more comfortable. Dining cars have tables set for comfortable, and sometimes luxurious, dining. Other cars are set up as coffee shops and lunch counters.

Cargo railcars are designed to be functional, not comfortable. They are usually constructed of steel for strength and durability. The structures of cargo haulers are varied to suit the types of cargo they will be hauling. Cargo haulers are designed to carry weights from 50 to 150 tons. See **Figure 18-55.**

The four basic types of freight cars are the open-top gondola car, boxcar, flatcar, and tank car. Variations include refrigeration units and special designs for material handling. For example, the structures (boxes) of some gondola cars can be tipped so the contents can be dumped. Tank cars may be fitted with pumps, and boxcars may have extralarge doors so forklifts can move in and out easily. Special railcars called auto conveyors may have two or three levels. Sheet metal coverings protect the autos.

Designers have found a few advantages to creating special railcars. One is that when a railcar is designed for a particular product, it can be made so the product can be stacked on the car more efficiently. This allows each car to carry more. It also reduces the need for special dunnage. ***Dunnage*** includes the straps, blocks, and special rigging needed to securely fasten freight to a vehicle.

Figure 18-54. Passenger trains include various types of cars, such as coaches, sleepers, baggage, and dining. Flexible, accordion-type shields between cars allow passengers to safely and comfortably move from car to car.

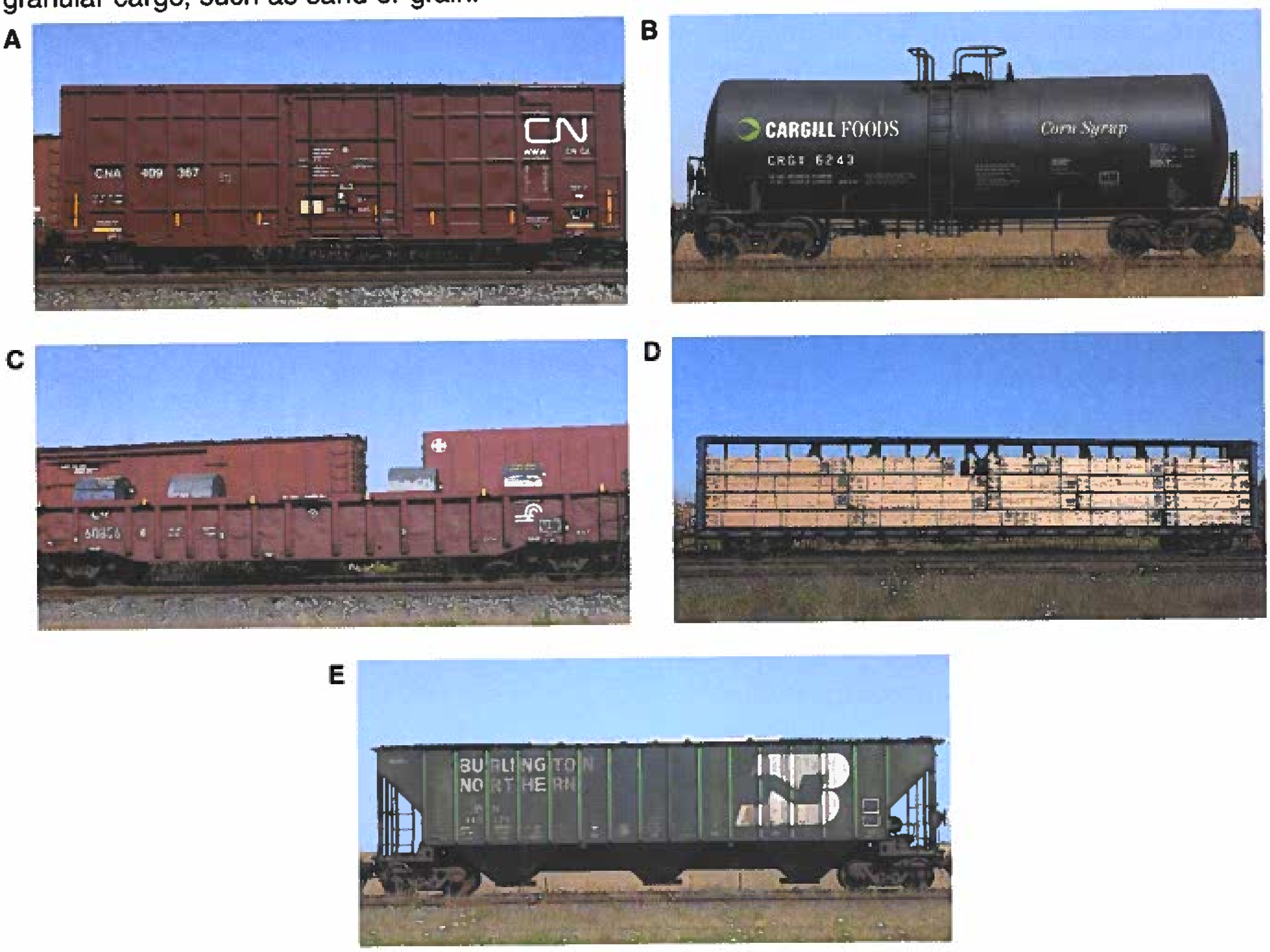
Dunnage: The straps, blocks, and special rigging needed to securely fasten freight to a vehicle.

Support Systems

Support systems are those structures that provide services to land transportation passengers and cargo. They also help to maintain the vehicles and provide pathways for transportation. Land transportation support systems can be divided into five categories, or types, of facilities. The categories are the following:

- **Related construction.** This includes the structures on which vehicles travel.
- **Passenger facilities.** These are the buildings and facilities that provide comfort and services to passengers.

Figure 18-55. Rail cars for cargo are built for strength and designed for various types of materials. A—A boxcar with large, sliding doors for loading and unloading. B—A tank car for liquid hauling. Usually, tank cars are dedicated to a specific type of liquid cargo. C—A gondola is an open-topped car that can be used to carry various types of loads. D—A center-beam flatcar designed to haul stacked lumber. E—A hopper car has unloading chutes at the bottom and typically carries dry granular cargo, such as sand or grain.



- **Cargo facilities.** These are the buildings and facilities that provide loading, unloading, and storage for various types of cargo.
- **Vehicle maintenance.** This includes those facilities designed to maintain and repair vehicular systems.
- **Other support systems.** These include any other systems needed for safe transportation, such as life support and rescue operations, communications systems, and regulatory agencies.

Roads and Highways

Roadbed: The foundation supporting the road surface and vehicles.

Roads and highways are constructed structures that should be included in the study of transportation technology. Improved construction designs and techniques can benefit both construction and transportation technology. Roads and highways begin with the clearing of land to make way for a ***roadbed***. This is the foundation supporting the surface and vehicles. Once the route is chosen, surveyed, and staked, hills and valleys are "moved" to level the roadbed. Construction workers on road-building equipment make cuts and fills. See **Figure 18-56.** ***Cuts*** remove excess earth from hills. This earth is usually moved to low spots, or valleys, along the route where fills are needed. A ***fill*** is the addition of material, such as rock and soil, to build up low-lying areas. By cutting and filling, construction engineers form a relatively level roadbed that will provide a safe and comfortable path for vehicle travel.

Figure 18-56. Road construction frequently involves moving large quantities of earth and rock to make the road as level as possible. This bulldozer is working in a cut, where earth has been removed. (Caterpillar, Inc.)

The soil in the roadbed is then compacted and covered with a gravel or stone subbase. This provides a strong foundation for the road surface. The road surface is usually made of asphalt or concrete. These materials make a hard, durable driving surface. Often, the road receives a surface texture that gives vehicles extra traction, especially in wet weather.

Cut: The removal of excess earth from hills.

Fill: The addition of material, such as rock and soil, to build up low-lying areas.

Once the road is built, shoulders are made along its sides to provide emergency and stopping lanes. Guidance systems in the form of road signs, traffic lights, and highway markers are then placed. All this leads to a finished support system essential for car and truck travel.

The United States has an excellent system of interstate highways that began to develop in the 1950s. These highways have smooth and wide surfaces. Many of them have four lanes, two in each direction, to promote safety and speed. The highways connect cities, usually by the shortest route possible.

Traffic planners have a major role in the design of highway and road networks. They have come up with many ways to make these systems safer and more efficient. Beltways are constructed around larger cities so all traffic does not have to go through the center of town.

Cloverleafs are used where two highways intersect. See **Figure 18-57.** They have been so named because the ramps that connect the highways are looped and look somewhat like the leaves of a clover plant. One highway actually goes over the other on a bridge, or overpass. At the ends of the ramps are acceleration or deceleration lanes that run along the edge of the highway. They make it possible to leave and enter each highway while maintaining a safe rate of speed.

Traffic planners have improved on the cloverleaf design by extending the lanes where vehicles enter and exit the main highways. Where an on-ramp and an off-ramp are close to each other, highway engineers have added extra safety lanes separate from the main highway. This provides a safer area for drivers to enter and exit the highway.

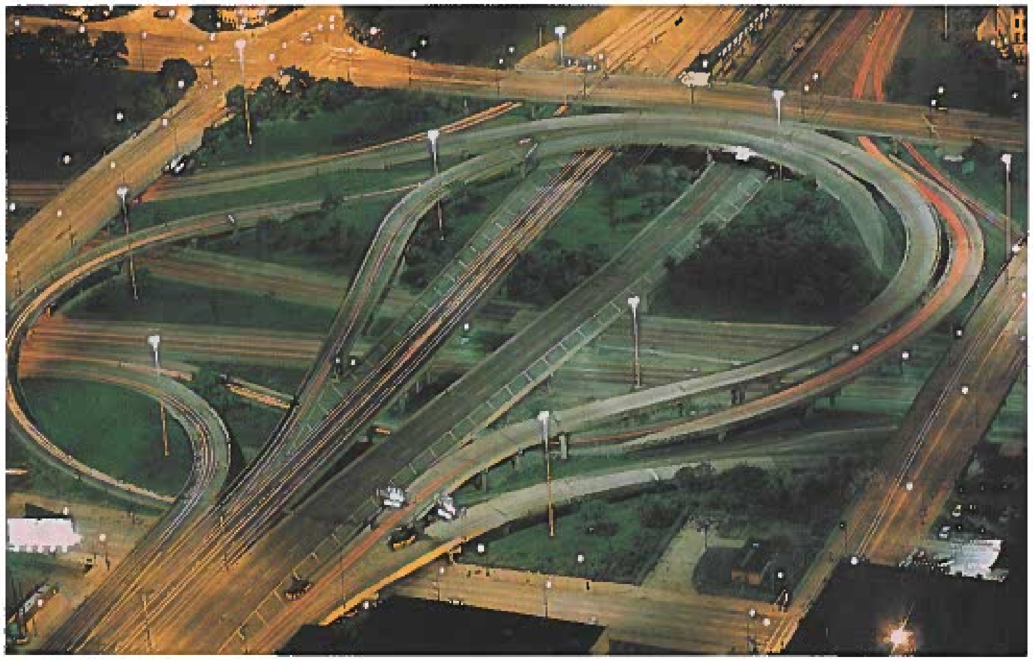
The network of roads and highways in the United States includes many types of roads. Each type of road has different specifications. For example, a country road may only have to be 15′ wide and can be constructed with gravel. On the other hand, highways must be constructed as described above and must be over three times as wide as a

Grade: The percentage of the change in height every 100′ of track.

Rail bed: Several layers of stone designed to spread the weight of the trains evenly over the compacted surface.

GREEN TECH
In recent years, it has been found that using railroads to haul cargo has less of an environmental impact than using trucks. Freight trains can have more fuel efficiency and emit less carbon.

Figure 18-57. Cloverleaf intersections are used to bring together two major roadways without stoplights and speed the safe movement of vehicles from one road to the other. This photo was taken with a long time exposure at night, resulting in red "trails" from the taillights of moving vehicles.



country road. All the country roads, city streets, state highways, and interstate highways work together to form a system of roads that connects virtually any starting point with any destination.

Railroads

Railroad construction has some similarities to the construction of highways. First the route is planned, and then the land is obtained. Because locomotives are made to pull heavy loads and ride on smooth iron wheels, they cannot climb hills like highway vehicles can. For this reason, cuts and fills must be made accurately. There can be no steep grades anywhere on the line. The ***grade*** is the percentage of the change in height every 100′ of track. Most grades are kept below 1.5%, which would be 1.5′ change in height over a 100′ section of track. Trains are most efficient when the track is flat (0% grade) and straight. There can be no sharp turns on a rail bed. Trains are not designed to make sharp turns. The tracks must be laid so there are gradual, large-radius turns. See **Figure 18-58.** Large-radius turns are often less than 5°, while tight turns are around 10°.

Figure 18-58. Because trains are not able to make sharp turns, tracks must be laid in wide, gradual curves. Trains move along this industrial siding at low speeds, so the curves can be sharper than those where trains move at high speeds. (Howard Bud Smith)

After the land is cleared and the soil compacted by earth-moving equipment, the ***rail bed*** is put down. This is made up of several layers of stone designed to spread the weight of the trains evenly over the compacted surface. The first is a layer of crushed stone called the ***subballast***. A thick layer of ***ballast*** is then added. It is composed of larger stones. The cross-ties, usually made of wood, are then laid on top of the ballast. Their purpose is to secure the rails that are later fastened to them. More ballast is added to fill the spaces between and around the ties. The ballast holds the cross-ties in place.

Rail construction crews, in the next step, lay the track on top of the ties. A track consists of two parallel rails. The wheels of a train ride on the rails. The distance between them must be kept at a constant width (gauge). This keeps the train from derailing (jumping off the track). The standard gauge for railroads in North America is 4′ 8 1/2″ wide. Rails are long pieces of steel that have an *I*-shaped cross section. See **Figure 18-59.** Modern railroad construction techniques use continuous rails instead of jointed ones. Long sections of rail are welded together so the ride is smoother and quieter.

Subballast: Crushed stone that forms the first layer of a rail bed.

Ballast: A layer of large stones placed on top of the subballast in a rail bed.

Bridge: A structure that spans a waterway, a ravine, or another barrier.

Maglev Guideways

Maglev trains run on a different type of railway than typical locomotives do. The guideways are elevated and are either shaped like a *T* or *U*. See **Figure 18-60.** In the *T*-shaped guideway systems, the train is actually wrapped around the guideway. The maglev trains used in *U*-shaped guideways are contained within the walls of the guideway. Both systems are elevated and built on concrete piers. Maglev guideways take up much less space and are not nearly as destructive as roads or rail beds. Since the tracks are elevated, there is no need to cut and fill the land. Instead, the lengths of the piers are changed to accommodate the landscape.

Bridges

Bridges are those all-important structures that span waterways, ravines, and other barriers. They have been around for a long time. Over time, bridges have undergone many changes to make them easier, safer, and more efficient to build.

The beam bridge is the oldest type. This type is currently made of steel and concrete. Beam bridges are commonly seen connecting short spans in cloverleaf interchanges or overpasses. A variation of the beam bridge is the truss bridge. Truss bridges were often used as railroad bridges.

Arch bridges are commonly seen connecting roads over long spans, such as over rivers. The road deck may either be built on top of the arch or suspended from the arch. Cantilever bridges are noted for their strength. See **Figure 18-61.** These bridges are able to span longer lengths than beam and arch bridges. Because of their strength and

Figure 18-59. Railroad rails are long strips of steel formed into an *I* shape. Sections once were bolted together, but today, they are most often welded into a continuous length of track.

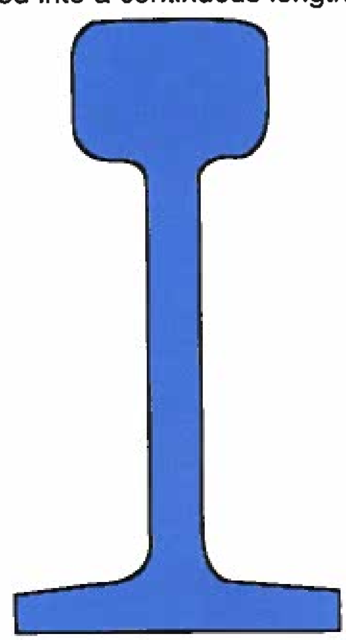
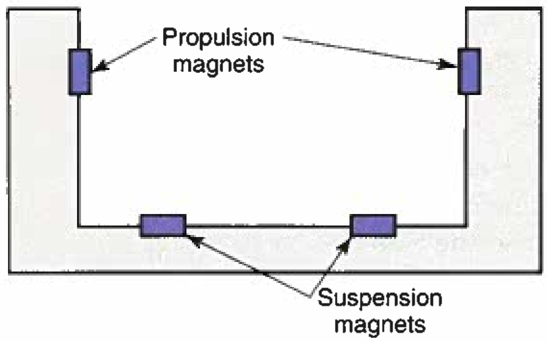


Figure 18-60. Two types of magnetic levitation (maglev) guideways. A—A *U*-shaped guideway encloses the train and is used with repulsion-type suspension systems. B—A *T*-shaped guideway is used with attraction-type suspension systems. The train rides atop the guideway. The lower section on each side of the train wraps around the guideway.

A



B

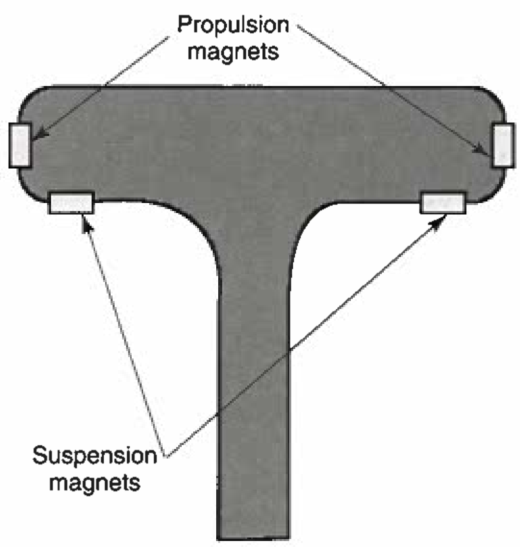
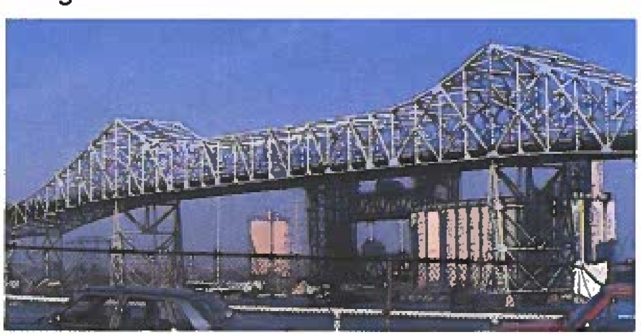


Figure 18-61. Cantilever bridges are strong in relation to material weight and can span long distances. They are often used as railroad bridges, although this example is a highway bridge.



spanning ability, they are often used as railroad bridges over large rivers. These bridges are basically made of two first-class levers. Their ends are secured firmly to the ground so the middle will not fail when heavily loaded. The large concrete and steel supports provide the fulcrum for each lever.

Of all the bridge designs, suspension bridges are capable of spanning the longest distances. The Golden Gate Bridge in California is a suspension bridge. The road deck is suspended with smaller cables from strong main cables running from one end of the bridge to the other. These cables are anchored firmly to the ground at both ends. Two towers provide support for the main cables. The height of the towers is directly related to the length of the bridge. Taller towers are needed as the span increases.

Tunnels

Where road builders have encountered mountains, they have borrowed from mining technology. ***Tunnels*** are dug or bored so straight, level paths can be maintained for vehicle travel. They are often more cost-efficient than building roads over or around mountains. See **Figure 18-62.** A tunnel-boring machine (TBM) can bore through soil and soft rock with ease. The largest TBMs are 9 1/2 yards (about 9 m) high and about the length of two football fields. Operators control them with the aid of computers and television monitors.

Tunnels are also used under bays and other bodies of water. Instead of digging the tunnel underwater, prefabricated tubes are often sunk in the water. Once the tubes are anchored and connected, they are pumped out and ready for completion. This type of tunnel technology is now commonly used.

The Chesapeake Bay Bridge Tunnel is an ambitious project that was undertaken on the East Coast of the United States. It is a series of bridges and tunnels allowing vehicles to drive from Maryland to Virginia, over and under the Chesapeake Bay. The bridges consist of a series of beam bridges. The tunnels were constructed using the sunken tube method.

Tunnel: A covered passageway.

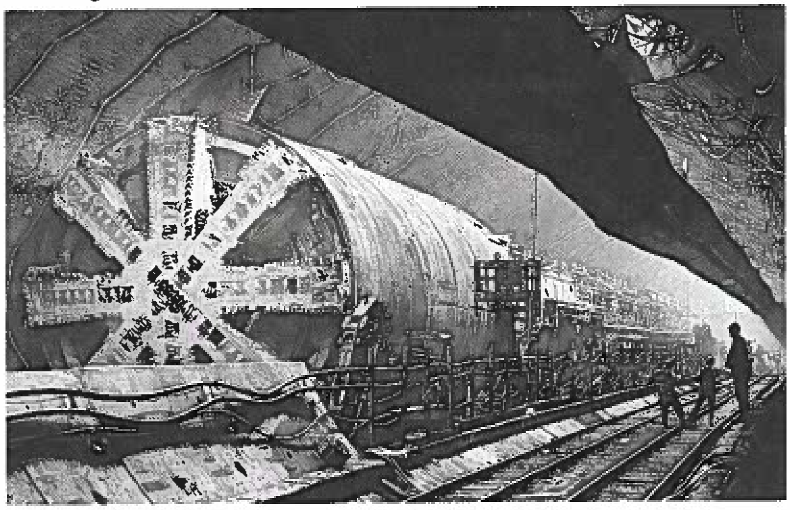


Figure 18-62. Tunnel-boring machines (TBMs) easily burrow through soil and rock. This machine was used to bore tunnels between England and France, beneath the English Channel. (British Information Services)

The Eurotunnel links Great Britain with the European continent. It was lined with curved segments of reinforced concrete behind the TBM. Cement grout was used to seal and strengthen the joints between the segments.

Passenger Facilities

Transportation companies that move passengers need special buildings and spaces for travelers. Bus stations, airport terminals, and train stations provide comfort and services for people who are traveling. See **Figure 18-63.** Here, passengers can buy tickets and wait in sheltered areas.

Figure 18-63. Bus companies, railroads, and airlines need passenger facilities. This passenger gate at the Baltimore-Washington International Airport provides a check-in desk, a waiting area with seating, and access to the ramp used to load and unload passengers for an aircraft.

Many times, goods and services are offered, as well. Passengers can eat, shop, have their shoes shined, or read a newspaper while waiting for their rides. Planners of passenger terminals consider the special needs of people who have disabilities. These facilities must be built so everyone can use them.

Safety must be built into structures. Waiting platforms are special areas where passengers can stand before boarding their vehicle. Here, there must not be any danger of being in the path of vehicles that are arriving or leaving. Usually, these areas are out of the way of regular traffic flow. They are located so the vehicles can enter and exit easily.

Many successful businesses have been founded on providing services to motorists. As car transportation grew in popularity, people were able to travel farther from home. Families and businesspeople began to take road trips that lasted several days. This led to the creation of motels. Motels are given their name because they were first referred to as motor hotels. Besides a place to sleep, motels offer travelers other services. Relaxation by a pool or in front of a television awaits weary travelers. Today, you can probably name a number of major motel chains.

Rest stops are another type of transportation support system. Many states build structures along their major highways so travelers can stop and rest. The structures may include parklike surroundings for comfortable walks. Picnic tables are often placed so meals can be eaten in quiet, peaceful surroundings. Rest rooms and information centers are also part of highway rest stops.

Truck stops are a type of physical facility for over-the-road (OTR) cargo haulers. These facilities offer services for both vehicles and operators. The services include fuel and maintenance services, restaurants, and motels. Some facilities even have special truck-washing services.

Cargo Facilities

When you realize everything in your house, including the materials of which it is made, was carried on a truck, you have an idea of the scope of cargo hauled over the road. It should be no surprise then that trucking companies need special cargo facilities. Cargo terminals are not as comfortable as passenger terminals. These facilities do, however, have well-designed spaces for storage and movement of freight. Some sections may even be refrigerated for perishables, such as meats, fruits, and vegetables.

Loading dock: A cargo facility built next to large paved areas for trucks to back up to.

Depending on the type of vehicles they are made to serve, cargo facilities have different designs. For cargo arriving on trucks, ***loading docks*** are built next to large paved areas. Trucks can back up to the loading docks. See **Figure 18-64.** The docks are built at a height that permits forklifts easy access into the trucks.

Cargo terminals that handle rail freight must be built near rail lines. Trains must be able to pull up next to the platforms. Cargo terminals also must have elevated loading docks so forklifts can easily move on and off the railcars. Some rail cargo facilities have pits located in the ground between the tracks. Cars are positioned over the pits. Bulk (loose) cargo can be dumped from the bottoms of the cars. Conveyors carry the cargo out of the pit and move it into storage tanks or bins.

Figure 18-64. Loading docks are designed to match the floor levels of the truck and building, so cargo can easily be moved into or out of the truck. This truck is backing down a ramp built to match the two floor levels.

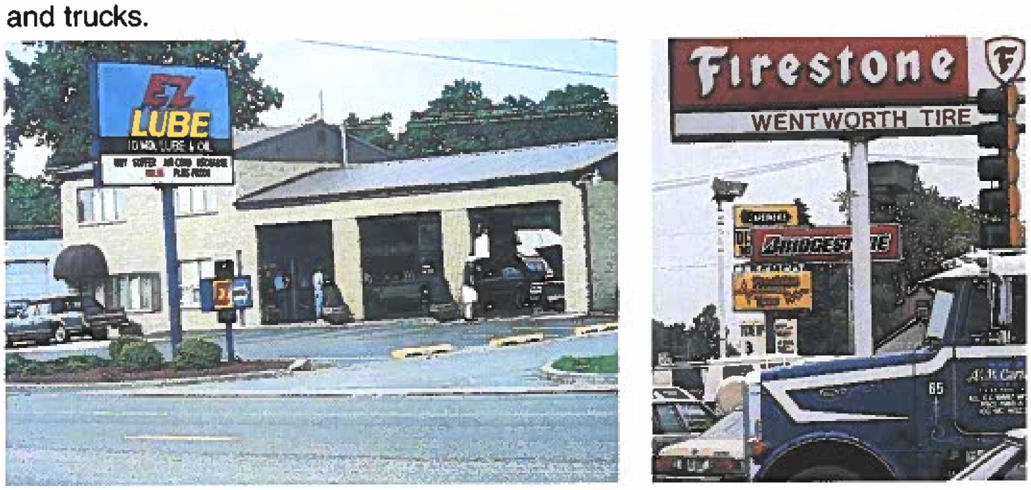
Vehicle Maintenance Facilities

Proper maintenance helps vehicles last longer and give better service. Many people enjoy working on their own cars. Private car owners can perform regular maintenance themselves. For convenience, however, some owners take their vehicles to commercial service facilities. Fast oil changes, "lube jobs," and tune-ups are available so car owners can maintain their vehicles without doing the work themselves. See **Figure 18-65.**

There are other types of maintenance that occasionally must be performed on automobiles. Engines are mechanical devices prone to wear and breakdowns. Other vehicular systems, such as the electrical, fluid, or mechanical system, could fail at any time. No matter how well a vehicle is designed, there are always things that can go wrong. When a car does not work properly, the problem must be found and fixed.

Early car engines could be fixed by almost anyone with mechanical ability. Modern auto engines, however, are complex pieces of machinery. It takes special training and equipment to diagnose and repair problems.

Figure 18-65. Many businesses perform maintenance tasks on automobiles and trucks.



GREEN TECH
Several states in the U.S. require vehicle emissions tests. These tests determine whether the devices in vehicles are preventing excess amounts of pollutants to be emitted.

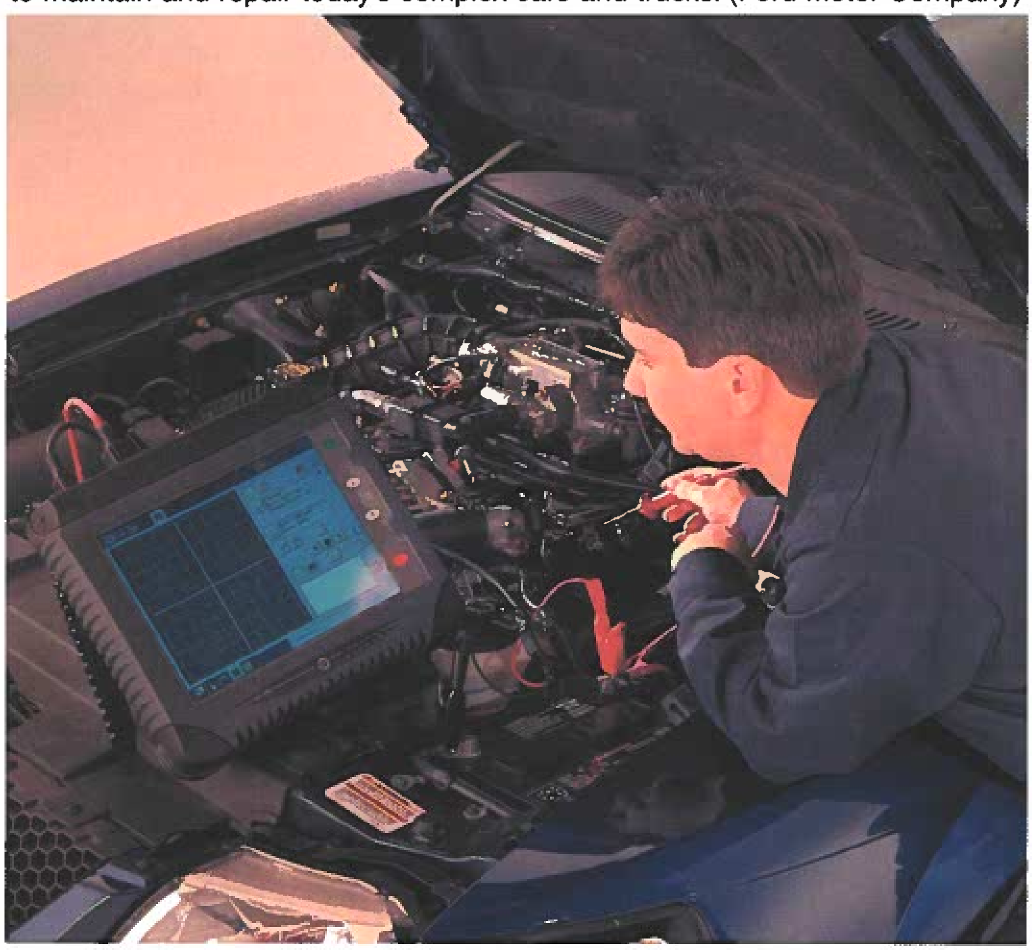
Automotive technicians are people who have that training, and they work on other people's vehicles. Large businesses and small shops all over the country employ them. Mechanics are capable of servicing every part of an automobile. Along with their repair businesses, they provide a very important support service for transportation technology. See **Figure 18-66.**

Passenger bus services hire mechanics to service their vehicles. Bus companies usually own and operate their own maintenance facilities. There, they can concentrate on keeping every part of their vehicles in top condition. Cleaning crews also wash the buses inside and out. All this is aimed at providing safe, comfortable service for paying passengers.

For large vehicles, such as trains, special support facilities need to be set up. Mechanics are able to work on the locomotives, but sometimes other parts of trains break down. When this happens, cranes are needed to lift the heavy vehicles so they can be worked on.

When metal train wheels become worn, they often need to be reground. Special grinders built into the tracks at maintenance areas do this. They regrind the small angle on train wheels so the wheels can go around curves easily. These grinders also true the wheels so they ride smoothly on the rails. All this can be done without lifting the railcar off its tracks.

Figure 18-66. Automotive technicians have the specialized tools and training to maintain and repair today's complex cars and trucks. (Ford Motor Company)



Summary

Land vehicles are propelled by internal combustion engines, electrical propulsion, or a hybrid of both. The main types of internal combustion engines include the gasoline piston, rotary, and diesel engines. Electrical propulsion systems include direct electric, indirect electric, and electromagnetic propulsion. The two types of hybrid systems are gasoline-electric and diesel-electric.

The propulsion system provides the power, and the drive train sends the power throughout the vehicle. The main component of the drive train is the transmission, which multiplies the torque of the engine. This is a part of the control system. Brakes are also part of the control system and provide the stopping power using friction.

Land vehicle guidance is assisted with the use of road maps. These maps show the location of roads, cities, and points of interest. Onboard navigation systems also help to guide drivers. Vehicular guidance systems include adaptive cruise controls and parking assist systems.

The suspension systems of land vehicles rely heavily on the tires. Tires provide both cushioning and traction. Along with the tires, springs, shock absorbers, and stabilizer bars provide for a smooth ride in nearly all land vehicles. Magnetic levitation (maglev) trains have a suspension system that relies on the support of magnetic fields.

The structure of land vehicles is comprised of a body and frame. In many automobiles, these two pieces are one, which is known as unibody construction. Unibody construction saves weight, which can increase fuel economy. The structure of vehicles can come in many forms, depending on the passengers or cargo the vehicles are designed to carry. Trucks, trailers, and train cars are specially designed with different types of cargo in mind.

Lastly, a number of facilities support land transportation. Pathways, such as roads and railways, are constructed for land vehicles. Passenger and cargo facilities provide places to unload and load vehicles. Support systems also include vehicle maintenance facilities. All the systems work together and make land transportation as safe and efficient as possible.

Key Words

All the following words have been used in this chapter. Do you know their meanings?

acceleration
adaptive cruise control system
air brake
all-wheel steering
antilock braking system (ABS)
articulated
atlas
automatic transmission
ballast
bias tire
body
bogie
break-bulk cargo
bridge
bulk cargo
chassis
coil spring
compression-ignition engine
contact patch
convertible
coordinated steering
crab mode
cut
deceleration
degree of freedom
diesel-electric propulsion
diesel engine
differential
direct electric vehicle
disc brake
drive system
drum brake
dunnage
epitrochoidal curve
fill
fuel cell
gasoline-electric hybrid
gasoline piston engine
gear ratio
grade
guideway
hybrid system
hydraulic braking system
leaf spring
linear motor
loading dock
manual transmission
onboard navigation system
parallel hybrid
planetary gear set
pneumatic tire
power brake
proton exchange membrane (PEM)
rack and pinion
rail
rail bed
regenerative braking
roadbed
road map
rotary engine
series hybrid
shock absorber
signage
solar propulsion
spring
spring oscillation
stabilizer bar
steel-belted radial tire
subballast
torque converter
torsion bar
transmission system
tunnel
unibody construction

Test Your Knowledge

Write your answers on a separate sheet of paper. Do not write in this book.

1. *True or False?* Internal combustion engines are a type of heat engine.
2. List and describe three of the main components of a gasoline engine.
3. Describe how a rotary engine works.
4. *True or False?* Rotary engines are more commonly used in automobiles than piston engines.

5. Explain the main difference between gasoline and diesel engines.
6. *True or False?* The compression ratio of a diesel engine is greater than that of a gasoline piston engine.
7. Why are direct electric vehicles not always feasible?
8. Bumper cars are an example of a(n) _____ vehicle.
   A. indirect electric
   B. direct electric
   C. diesel
   D. solar
9. *True or False?* The two by-products of fuel cells are heat and water.
10. *True or False?* Linear motors are round induction motors.
11. Summarize the difference between parallel and series hybrid systems.
12. Write two or three sentences describing how the parts of the drive system function to transmit power from the engine to the wheels.
13. State the purpose of a transmission system.
14. A _____ is a manual device that separates the transmission from the engine.
   A. torque converter
   B. differential
   C. clutch
   D. driveshaft
15. Discuss in two or three sentences how an automatic transmission operates.
16. Cite several ways manual and automatic transmissions are different.
17. *True or False?* Torque converters use the movement of fluid to transmit power.
18. The most common type of map used in land transportation is the _____ map.
   A. political
   B. road
   C. topographical
   D. geological
19. *True or False?* The map legend lists the symbols and markers used in the map.
20. Recall and describe the three types of roadway signs.
21. Describe the function of adaptive cruise control systems.
22. *True or False?* Carburetors create a fuel-air mixture necessary for combustion within the engine.
23. *True or False?* Magnetic levitation (maglev) vehicles are accelerated by increasing the flow of fuel to the gasoline engines.
24. Paraphrase how drum and disc brakes operate.
25. Identify several rear-wheel steered vehicles.

26. Name the two types of all-wheel steering.
27. Write the two purposes of tires.
28. *True or False?* Steel-belted radial tires are the most common type of tire today.
29. Interpret what the marking "LT 225/75 R 15" means.
30. What is the difference between springs and shock absorbers?
31. *True or False?* In a repulsion maglev system, the polarities of the magnets are opposite.
32. *True or False?* The chassis is the body of an automobile.
33. What is meant by the term *unibody construction*?
34. *True or False?* Vehicles that haul bulk and break-bulk cargo use the same types of trailers.
35. List several types of support systems for rail vehicles.

STEM Activities

1. Build a working model of an indirect electric vehicle.
2. Create a model of a maglev vehicle.
3. Create a display showing how a hybrid system operates.