Friction between braking surfaces converts kinetic energy into heat.
- In drum brakes, wheel cylinders force brake linings against the inside of the drum.
- In disc brakes, pads are forced against a brake disc.

Factors that influence vehicle braking include (an effective braking system takes all of these factors into account):
- Road surface
- Road conditions
- Weight of the vehicle
- Load on the wheel during stopping
- How the vehicle is being driven
- The tires on the vehicle

Basic hydraulic braking system has two main sections:
- Brake assemblies at the wheels
- Hydraulic system that applies them

There is a brake for:
- When the vehicle is in motion—usually a foot brake—for slowing or stopping the vehicle
- When the vehicle is stationary—a park brake—usually operated by hand, but sometimes foot-activated

Varying systems:
- Some systems have all drum brakes.
- Some systems have disc brakes on the front wheels and drum brakes on the rear wheels.
- Other systems have all disc brakes.

Components of basic braking system include:
- The brake pedal
- The master cylinder to provide hydraulic pressure
- The brake lines and hoses to connect the master cylinder to the brake assemblies
- Fluid to transmit force from the master cylinder to the wheel cylinders of the brake assemblies
- Brake assemblies, either drum or disc, that stop the wheels
The driver pushes the brake pedal, and this action applies mechanical force to the piston in the master cylinder.
- The piston applies hydraulic pressure to the fluid in the cylinder.
- The brake lines transfer the pressure, which is undiminished in all directions within the confines of the brake lines, to the wheel cylinders.
- The wheel cylinders at the wheel assemblies apply the brakes.
- Force is transmitted through the fluid, and for cylinders the same size, the force transmitted from one is the same value as the force applied to the other.
- By using cylinders of different sizes, forces can be increased or reduced.

In an actual braking system, the master cylinder is smaller than the wheel cylinders, so the force at all of the wheel cylinders is increased.
- When brakes are applied to a moving vehicle, they absorb the vehicle's kinetic energy, and the friction between the braking surfaces converts this energy into heat.
- In drum brakes, the wheel cylinders force the brake linings against the inside of the brake drum.
- In disc brakes, the pads are forced against a brake disc.
- In both systems, heat spreads into other parts and the atmosphere, so the brake linings and drums, pads, and discs must withstand high temperatures and high pressures.
- On modern vehicles, this basic system has some refinements, such as a power booster, and this helps the driver apply the brakes.

Drum and Disc Brakes

Drum brakes have a drum attached to the wheel hub, and braking occurs by means of brake shoes expanding against the inside of the drum.
- With disc brakes, a disc attached to the wheel hub is clamped between two brake pads.
- On light vehicles, both of these systems are hydraulically operated, and the brake pedal operates a master cylinder, and the hydraulic lines and hoses connect the master cylinder to the brake cylinders at the wheels.
- Most modern light vehicles have either disc brakes on the front wheels and drum brakes on the rear wheels, or disc brakes on all four wheels.

Disc brakes require greater forces to operate them, and a brake booster assists the driver by increasing the force applied to the master cylinder when the brake is operated.
- The antilock braking system (ABS) is a control system that applies maximum braking force without wheel-lock or skidding and prevents wheel-lock or skidding, no matter how hard the brakes are applied or how slippery the road surface; thus steering stays under control and stopping distances are generally reduced.
- Braking systems consist of a brake pedal, a master cylinder, wheel speed sensors, the electronic control unit (ECU), and the hydraulic control unit, also called a hydraulic modulator.

Coefficient of Friction

Coefficient of friction is the measurement of friction between pairs of surfaces.
- Friction is the force that resists movement of one surface over another, and it can be desirable, but often it is not.
- Examples of a low coefficient of friction include:
  - A pair of surfaces that can move easily over each other
  - Ice and metal have a low coefficient of friction (e.g., metal ice skates slide easily on ice).

Examples of a high coefficient of friction include:
- A pair of surfaces that cannot move easily over each other
- Rubber tires and dry road surfaces have a high coefficient of friction, so they tend to grip each other (e.g., tires don’t slide easily when you apply the brakes or turn your vehicle into a corner).
Lever/Mechanical Advantage

A lever allows small efforts to overcome large loads, or vice versa, depending on the type of lever, and the ratio between load and effort for any given lever is known as the mechanical advantage.

A simple example of a lever is a bar, which is pivoted at some point called a fulcrum. A lever allows the user to overcome a large load over a small distance at one end by applying a small force at a greater distance from the other end.

Using the right kind of lever in the right way allows a user to move larger loads with smaller efforts, and the effort required to move any load depends on the relative distance of each from the fulcrum. The ratio of load and effort is called the mechanical advantage.

If the effort distance from the fulcrum is greater than the load distance, then the effort required will be less than the load being moved. This is known as a positive mechanical advantage.

If the load distance is greater than the effort distance, then the effort required is greater than the load being moved. This is known as a negative mechanical advantage, which is sometimes referred to as a mechanical disadvantage.

Force is transmitted through the fluid, and for cylinders the same size, the force transmitted from one is the same value as the force applied to the other.

There are three basic types of levers.
1. Lever of the first order, in which the fulcrum is in the middle, between the load and the effort. Examples of this type of lever are crowbars and seesaws.
2. Lever of the second order, in which the load is in the middle, between the effort and the fulcrum. An example of this type of lever is a wheelbarrow.
3. Lever of the third order, in which the effort is in the middle, between the load and the fulcrum. An example of this type of lever is the human arm, where the elbow is the fulcrum, the biceps muscles are the effort, and the hand (and whatever it is holding) is the load.

Hydraulic Pressure and Force

Hydraulic pressure is transmitted through liquid and can transmit increased force.

1. When the brake pedal is pressed:
   - Force against the piston in the master cylinder applies pressure to the fluid.
   - This same pressure is transmitted throughout the fluid, but it has a different effect on each piston in other cylinders.
2. Effect on the top cylinder:
   - The top cylinder is smaller than the master cylinder, so the force it exerts will be less than the force applied to the master cylinder.
3. Effect on the middle cylinder:
   - The middle cylinder is the same size as the master cylinder, so the force from it will be the same.
4. Effect on the bottom cylinder:
   - The bottom cylinder is larger than the master cylinder, and so its force is greater.

Brake Fade

Brake fade is the reduction in stopping power caused by a buildup of heat in the braking surfaces.

1. What is “fade” or “brake fade?”
   - Reduction in stopping power caused by a buildup of heat in the braking surfaces
   - In the case of drum brakes, it is a change in dimension of components in response to heat.
2. When does brake fade occur?
   - Brake fade occurs most often during high-performance driving or when going down a long, steep hill.
3. Is brake fade more prevalent in drum or disc brakes?
   - Owing to configuration, brake fade is more prevalent in drum brakes.
   - Disc brakes are much more resistant to brake fade.
     - Disc brakes are now a standard feature in front brakes for most vehicles.
     - However, brake rotors can become warped due to excessive heating.
4. How can brake fade and rotor warping be reduced?
   • By using proper braking technique
   • By simply selecting a lower gear when running down a long downgrade that would require braking
     ° Automatic transmissions may necessitate a brief application of the throttle after selecting the gear.

5. What are the benefits of period application of the brakes?
   • Period application of the brakes allows them to cool between applications.
   • Continuous light application of the brakes can be particularly destructive in both wear and adding heat to the brake system.

Regenerative Braking
READY FOR REVIEW

- Regenerative braking is any technology that allows a vehicle to recapture and store part of the kinetic energy that would ordinarily be lost when braking. A simpler technology that can only convert the energy to heat, but which uses similar principles, is known as dynamic braking.
- Both regenerative and dynamic brakes are most commonly seen on electric or hybrid vehicles, and braking is accomplished by electrically switching motors to act as generators that convert motion into electricity instead of electricity into motion.
- Traditional friction-based brakes must also be provided to be used when rapid, powerful braking is required, and estimates currently see 30% efficiency; however, the actual efficiency depends on numerous factors, such as the state of change of the battery, how many wheels are equipped to use the regenerative braking system, and whether the topology used is parallel or serial in nature.
- Electric railway vehicles feed the recaptured energy back into the grid, while road vehicles store it for reacceleration using flywheels, batteries, or capacitors. Older dynamic brake systems generally used the electricity to provide heat or just passed it through large banks of resistors to dissipate the energy.

Terms and Definitions
READY FOR REVIEW

- **Application time** is the time elapsed between the depression of the brake pedal (treadle) and the engagement of the linings with the drums.
- **Asbestos** is the class of magnesium-silicate minerals that occur in fibrous form.
- **Asbestosis** is the permanent, untreatable lung scarring caused by exposure to asbestos and causes shortness of breath.
- **Bleeding** is the process by which air and contaminants are removed from the hydraulic system.
- **Brake fluid** is the substance used to transmit force in hydraulic brake systems.
- **To contaminate** is to make unfit for use by contact with foreign material.
- **To corrode** is to weaken or destroy gradually by chemical means.
- **A defect** is an imperfection that impairs value or usability.
- **Failure** is the inability to perform the desired function, and usually occurs prematurely or unexpectedly.
- **Flushing** is the process of removing all the old fluid from the hydraulic system and replacing it with new fluid.
- **Foreign material** is any extraneous material not intended to be present; examples include particles of steel, dirt, rust, carbon, acid, and condensation (water).
- **Hydraulic** is relating to the use of fluid to transmit force.
- **Indicator** is the symptom that helps identify a product, operation, or maintenance problem.
- **Physics** is the scientific study of matter and energy and how they interact.
- **Pneumatic** is relating to the use of air to transmit force.
- **Release time** is the time between the release of the brake pedal and the total disengagement of the brake linings and the brake drums.
- **Root cause** is the specific condition that started the problem.
- **Stopping distance** is the distance a vehicle travels from the time force is applied to the brake control until the vehicle reaches a full stop.
- **Wear** is the undesirable removal of material from the surface of a part.
Purposes of the Brake System

There are four purposes of the brake system in a vehicle:
1. To slow the vehicle
2. To stop the vehicle
3. To hold the vehicle when stopped
4. To provide an emergency means of stopping the vehicle

Scientific Principles That Affect Brake Systems (the Physics of Braking)

Energy is the ability to do work, and types of energy include mechanical, electrical, light, heat, and nuclear energy.
Force is applied to energy that causes a change in the motion or shape of an object. An example would be the pressing of the brake pedal, which then starts a series of mechanical energy conversions that stop the movement of the vehicle and also produce heat and sound energy.
Work is the movement as a result of an applied force.
Power is the rate at which work is done or energy is transmitted and is measured in horse power, torque, or watts.

Types of Brake Systems

Mechanical systems use gears, levers, cables, and similar devices to transfer force through the brake system.
Electrical systems use electromagnetic force to transfer force through the brake system.
Hydraulic systems use brake fluid to transfer force through the brake system.

Operations of a Hydraulic Brake System

Brake fluid is stored in a reservoir called a master cylinder and in brake lines connecting the master cylinder to the wheel cylinders.
Depressing the brake pedal forces a pushrod to move one or more pistons in the master cylinder to seal the fluid between the master cylinder and the wheel cylinders.
Additional pressure on the brake pedal pushes the pistons in the wheel cylinders, which then causes the brake shoes/pads to press against the wheels. This increased friction causes the wheels to slow and eventually stop if pressure continues to be applied.
When the brake pedal is released, springs return the master cylinder pistons to their open position, so that the brake fluid is no longer under pressure.
With the pressure released, the pistons in the wheel cylinders move back into their cylinders, with the force returning to zero pressure.
Operation of an Air Brake System

READY FOR REVIEW

- An air compressor pressurizes air and stores it in air tanks.
- Depressing the brake pedal releases pressurized air from the tanks, which is then applied to the piston in the air brake chamber.
- Movement of the piston actuates a lever (slack adjuster), which rotates the s-cam.
- This causes the brake shoes to make contact with the brake drum, and friction between the shoes and the drum causes the wheels to slow and eventually stop if pressure continues to be applied.
- When the brake pedal is released, air is exhausted from the air brake chambers, and the springs return the shoes to their released position.

Comparison of the Hydraulic and Air Brake Systems

READY FOR REVIEW

- Application time (time to engage): hydraulic brakes—faster; air brakes—slower (due to the time needed for the air to move through)
- Release time: hydraulic brakes—faster; air brakes—slower
- Pressure leak: hydraulic brakes—will lead to loss of braking; air brakes—will not lead to loss of braking
- Maintenance: hydraulic brakes—require little maintenance; air brakes—require moderate maintenance
- Adaptability: hydraulic brakes—difficult to expand; air brakes—fairly easy to expand and to tie
- Fail-safe (back up): hydraulic brakes—available; air brakes—available

Types of Brake Fluid and their Descriptions

READY FOR REVIEW

- DOT 3
  - Glycol-based fluid that is clear or amber tinted
  - Lowest boiling point of the three types described
  - When exposed to air, it absorbs moisture very quickly.
- DOT 4
  - Glycol-based fluid that is clear or amber tinted
  - Higher boiling point than DOT 3
- DOT 5
  - Synthetic, silicon-based fluid that is purple tinted
  - Highest boiling point of the three types described
  - Does not absorb moisture when exposed to air
  - Incompatible with other fluids; therefore, do not mix it with DOT 3 or 4.

Guidelines for Handling and Storing Brake Fluid

READY FOR REVIEW

- Change the brake fluid at each major brake repair.
- Take care not to spill the brake fluid on brake linings or any chrome or painted surfaces as it will damage these finishes.
- Always keep the brake fluid clean, and do not allow any foreign material or petroleum products (gasoline, kerosene, oil, grease, etc.) to get into the fluid.
- Do not use the brake fluid as a substitute for other fluids, such as power steering fluid or automatic transmission fluid (ATF).
- Never use containers that could be contaminated with grease, oil, dirt, rust, etc.
- Always clean off the top of the fluid reservoir before refilling it in order to avoid contamination.
- Keep the exposure time to air as short as possible for glycol-based brake fluids as this will prevent moisture from being drawn from the air, which can deteriorate the fluid’s boiling point properties.
  - Note: Moisture contamination and a reduced boiling point can lead to vapor lock.
- To prevent absorption of moisture, tightly cap fluid containers after use, and keep the master cylinder tightly covered. Reinstall the cover immediately after filling the master cylinder with new fluid, and also keep the fluid reservoir in the pressure brake bleeder tightly closed except when refilling.
- Always replace the brake fluid when you suspect moisture contamination in the hydraulic brake lines.
Use the smallest possible can of brake fluid to fill the master cylinder, and use two small cans rather than half a large can.

Store brake fluid away from heat or flame, as it is highly flammable.

Avoid skin and eye contact, and wash with soap and water if skin contact occurs. In case of eye contact, immediately wash eyes for 15 minutes, and call a physician or poison control for additional instructions.

**Purposes of Troubleshooting and Failure Analysis**

**Troubleshooting example:**
- While inspecting a wheel bearing, a cracked race is found, so the bearing is replaced.

**Failure analysis example:**
- While inspecting a wheel bearing, a cracked race is found.
- After examining the service records and the internal parts of the wheel bearing, the root cause of the problem is traced to be improper installation of the bearing by the previous service technician. The same technician installed the two previous bearings, which failed prematurely. A new bearing is installed, and the instructor/supervisor is notified so the other technician’s installation methods can be corrected.

**Steps in Failure Analysis**

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**Steps in Failure Analysis**
Signs of Brake Failure

- No braking occurs when the driver activates the brakes and there is no evidence of the vehicle slowing or stopping.
- Improper brake pedal feel is when the driver presses the brake pedal, and its movement or response is not normal. Examples include when the pedal goes to the floor or when the pedal does not move.
- Improper vehicle motion is when the brakes are applied and the vehicle vibrates excessively, pulls to one side, lunges, or otherwise handles erratically.
- Audible signs are when the brakes are applied and unexpected noises occur or when expected noises do not occur.
- Visible signs are cracks, leaks, smoke, or other indications that can be seen by the operator or the service technician.
- Instrument indicators are warning lights and displays in the vehicle that alert the driver to malfunctions.

Most Common Causes of Brake Failure

- Defective or incorrect parts installed, such as hoses that expand during brake application, weak diaphragm return springs, or the wrong size piston seals
- Improper service of the brake system, such as poor bleeding, improper shoe adjustment, or loose fittings
- Improper service of related systems such as an improperly tuned engine on vacuum power assist unit, or low power steering fluid level on hydraulic power assist unit
- Overheating due to heavy braking, excessive braking, or clogged rotor ventilators
- Improper or inadequate brake fluid (hydraulic brakes) due to improper brake fluid, low brake fluid, or contaminated brake fluid (including air bubble contamination)
- Contaminants (air brakes) in the air system or air leaks, such as dirty or moisture-laden air in the system

Safety Procedures to Follow When Working on Brakes—General Rules

- Read and follow the manufacturer’s instructions for servicing the vehicle.
- Use only the recommended tools and replacement parts or supplies specified by the manufacturer.
- Follow all safety precautions identified by the manufacturer, and wear personal protective equipment (safety glasses, gloves, hearing protection, etc.) as required.
- Use proper lifting techniques and lifting devices, such as wheel dollies and stands, when moving or holding heavy components.

Safety Procedures—Special Rules for Servicing Pressurized Systems

- Both hydraulic and air brake systems operate under pressure; therefore, use great care around either system, as compressed springs and pressurized lines can deliver great force.
- Always block the truck-tractor and trailer wheels prior to working on the vehicle, and do not rely on the brake system to hold the vehicle.
- Release the pressure from pressurized lines (air or hydraulic) gradually and completely before working on the vehicle.
- Follow the manufacturer’s special disassembly procedures for pressurized components and systems, and note any warning tags on the brake components, especially the spring brake.
  **Caution:** If used improperly, the spring brake can release enough pressure to cause property damage, severe personal injury, and/or death!
Safety Procedures—Rules for Moving/Driving a Vehicle

- Be sure the vehicle is out of gear before starting it.
- Use extreme caution when moving a vehicle in the shop, and check around the vehicle and the planned path to make sure there are no obstacles in the way.
- Make sure you have a current commercial driver’s license (CDL) and/or other state and school requirements before driving a vehicle on the road.
  
  Note: Most schools require a current CDL and documented safety tests of your driving ability; however, some schools will not allow students to test drive a vehicle under any circumstances.

Before driving any vehicle, check the fluid levels, adjust the seat and mirror, and fasten your seat belt.

Do not road test the vehicle if the brake warning light is lit.

Overview of Asbestos and Safety Guidelines to Follow When Working Around Asbestos

- Because some brake linings contain asbestos, it is important that you know the potential hazards of asbestos and the precautions to take to protect yourself.
- Exposure to airborne asbestos dust can cause serious and possibly fatal lung diseases, especially asbestosis and lung cancer. The damage accumulates over the years, and the symptoms are usually not seen for 15 or more years.
- Most new brake linings do not contain asbestos. However, other materials used (glass, ceramics, mineral wool, and carbon) still pose health hazards to your lungs, and long-term hazards are not known. Therefore, follow the same safety guidelines as with asbestos.
- The most important things to remember are:
  - Avoid creating asbestos (or nonasbestos) dust when working on brakes.
  - Avoid breathing any dust accidentally created.
- The rule that follows will help you accomplish these most important goals.
  - Always use Occupational Safety and Health Administration (OSHA)-approved brake cleaning equipment.
- In the diesel technology shop, there are two preferred methods that should be used for all brake and clutch inspection, disassembly, repair, and assembly:
  - Negative pressure enclosure vacuum system with high-efficiency particulate air (HEPA) filters; also used with air-purifying respirators
  - Low pressure/wet cleaning brake cleaning equipment (more common)

- Never use compressed air or dry brushing to clean brake parts or assemblies.
- Read the material safety data sheets for any products containing asbestos, as required by OSHA, and follow any additional safety precautions they recommend.
- When cleaning the brake work area, use a damp mop on the floor and a damp rag on all countertops to remove any remaining dust, as this helps prevent asbestos fibers from becoming airborne.
- Do not grind or machine brake linings, as this is specialty work that requires additional precautions because contact with fiber dust is higher during these operations.
- Wash your hands before eating, drinking, or smoking.
- Do not wear asbestos-contaminated work clothes home, as these should be cleaned with special vacuums and then laundered separately.
- To protect others in the shop, brake work areas should be separated from other operations if possible.
Specialty Brake Tools and Equipment and Their Functions

- An asbestos removal system is used to prevent contamination from asbestos or nonasbestos dust.
- A bearing packer is used to force grease into the wheel bearings.
- A bearing race installer is used to drive the bearing race into the wheel hub.
- A brake adjusting tool is used to adjust the clearance between the brake drum and the brake shoe.
- A brake bleeder is used as a pressure tank to automatically bleed the hydraulic system.
- A brake rotor gauge is used to measure the thickness of the rotor.
- A brake shoe retaining spring tool is used to remove and install retaining spring clips.
- A brake spring tool is used to remove and install shoe return springs on drum brakes.
- A disc caliper tool is used to compress the disc caliper pistons.
- A drum brake gauge is used to determine the proper clearance between the brake lining and the drum.
- A metering valve tool holds the metering valve open to allow pressure bleeding of the front disc brakes.
- A pressure gauge is used to check the operation of a proportioning valve.
- A seal installer is used as a driver to install the wheel seal into the hub.
- A seal ring installer is used to drive the wear ring on the axle.
- A tube flaring set is used to form the ends of tubing to allow the installation of connector fittings.
- A tubing bender allows the bending of metal tubing without kinking.
- A wheel cylinder hone is used to resurface wheel cylinders in order to remove corrosion and slight pitting.
- A wheel dolly is used to lift, move, or hold heavy wheel components.