Section 1

Brakes and Braking

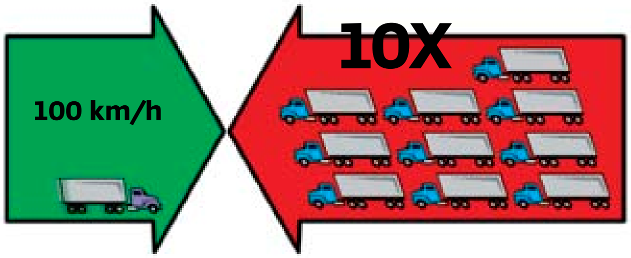
Heat–Energy–Traction–Friction

For a vehicle to move along the highway, an internal combustion engine must convert its heat energy into mechanical energy. This mechanical energy goes from the engine to the driving wheel tires by means of a system of connecting rods, shafts and gears. The final factor that moves the vehicle is the amount of traction its tires have on the road surface.

Friction is the force that resists movement between two surfaces in contact with each other. To stop a vehicle, the brake shoe linings are forced against the machined surfaces of the brake drums, creating friction. This friction produces heat.

The engine converts the energy of heat into the energy of motion; the brakes must convert this energy of motion back into the energy of heat. The friction between brake drums and linings generates heat while reducing the mechanical energy of the revolving brake drums and wheels. The heat produced is absorbed by the metal brake drums, which dissipate the heat into the atmosphere. The amount of heat the brake drums can absorb depends on the thickness of the metal. When enough friction is created between the brake lining and the drums, the wheels stop turning. The final factor that stops the vehicle is the traction between the tires and the road surface.

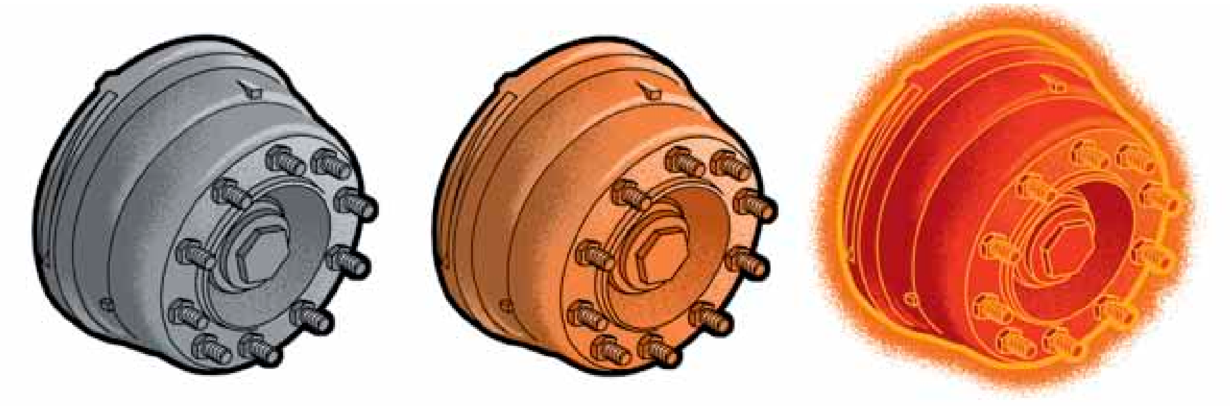
If a 200–horsepower engine accelerates a vehicle to 100 km/h in one minute, imagine the power needed to stop this same vehicle. Also, consider that the vehicle might have to stop in an emergency in as little as six seconds (just 1/10 the time it took to reach 100 km/h).



To stop the vehicle in 1/10 the time it took to accelerate would require a stopping force of 10 times the acceleration force—the equivalent of approximately 2,000 horsepower. If the vehicle had six wheels, each wheel would have to provide 1/6 the braking force. If one or two of the wheels had brakes that were not properly adjusted, the other wheels would have to do more than their share of the braking, and that might be more than their brakes were constructed to stand. Excessive use of the brakes would then result in a buildup of heat greater than the brake drums could absorb and dissipate. Too much heat results in brake damage and possible failure.

Most brake linings operate best at around 250°C and should not exceed 425°C. It's important to understand that the power needed to stop generates heat which could damage the brakes.

Brake Drums



250°C Normal | **425°C Maximum** | **1100°C Panic!**

Speed–Weight–Distance

The distance required to stop a vehicle depends on its speed and weight, in addition to energy, heat and friction. The braking force required to stop a vehicle varies directly with its weight and speed. For example, if the weight is doubled, the braking force must be doubled to be able to stop in the same distance. If the speed is doubled, the braking force must be increased four times to be able to stop in the same distance. When weight and speed are both doubled, the braking force must be increased eight times to be able to stop in the same distance.

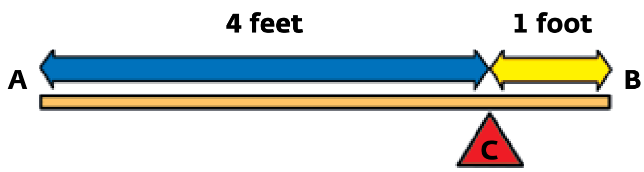
For example, a vehicle carrying a load of 14,000 kg at 16 km/h is brought to a stop in 30 metres with normal application of the brakes. If this same vehicle carried 28,000 kg at 32 km/h, it would require eight times the braking force to stop the vehicle in 30 metres. This would be more braking force than the brakes could provide. No vehicle has enough braking force when it exceeds its limitations.

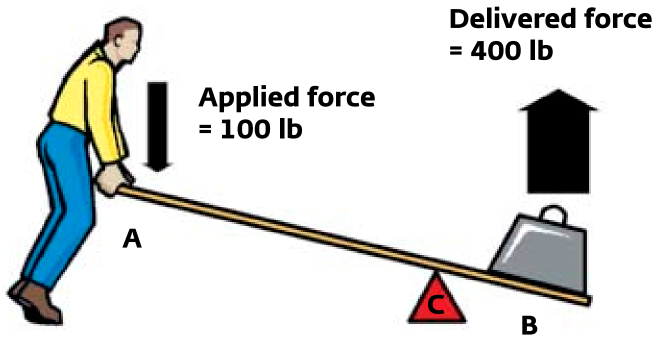
Braking Force

Mechanical

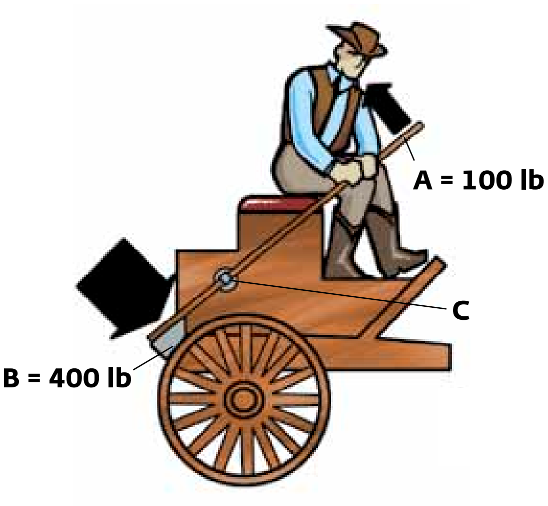
Braking systems use devices to gain a mechanical advantage. The most common device for this purpose is leverage. A lever is placed on a pivot called the fulcrum. As the distance from A to C is four feet, and from C to B is one foot, the ratio is four to one (4:1). Force has been multiplied by the leverage principle.

Look at this simple lever system:

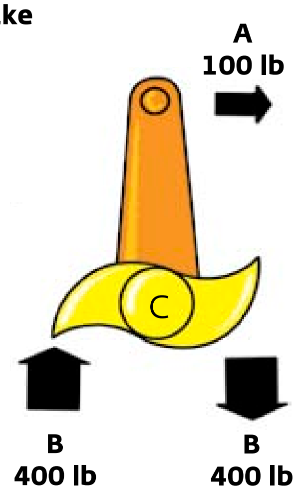




If a 100 lb downward force is applied at point A, then the upward force at point B is 400 lb.



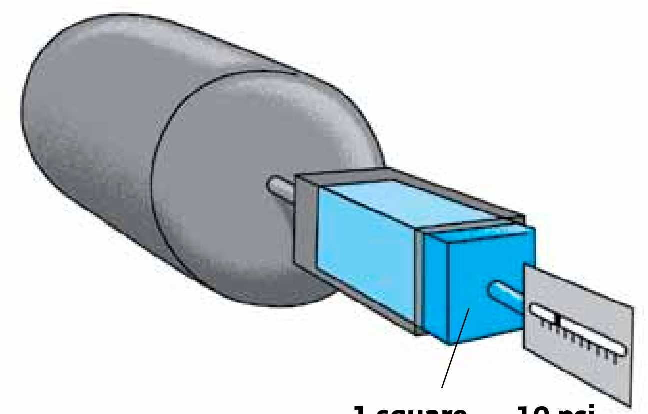
S-cam brake



Use of Air Pressure

Force can also be multiplied by the use of air to gain further mechanical advantage. Everyone has felt the force of air on a windy day. Air can be compressed (squeezed) into a much smaller space than it normally would occupy, for instance, air compressed in tires to support the weight of a vehicle. The smaller the space into which air is squeezed, the greater the air's resistance to being squeezed. This resistance creates pressure, which is used to gain mechanical advantage.

If a constant supply of compressed air is directed through a pipe that is one inch square, and if a one inch square plug were placed in the pipe, the compressed air would push against the plug. A scale can be used to measure how many pounds of force are being exerted by the air against the plug.

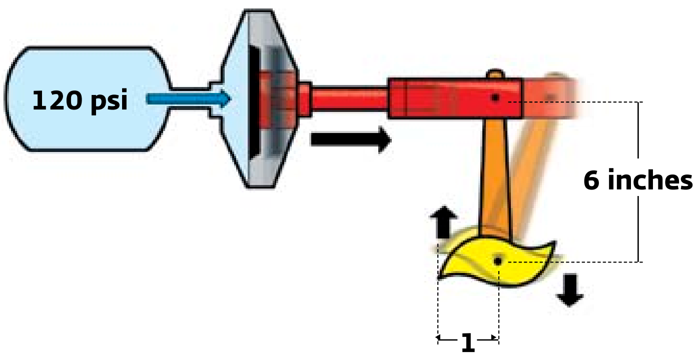


If the scale registers 10 pounds, for example, then it could be said the force is 10 pounds on the one square inch surface of the plug or 10 pounds per square inch (psi).

The more compressed the air in the supply reservoir, the greater the force exerted on the face of the plug.

Leverage and Air Pressure

In actual operation, pipes are round and plugs are diaphragms of flexible material acting against push rods. If compressed air of 120 psi acts on a diaphragm of 30 square inches, 3,600 lb of force is produced (120 x 30). Apply this force to a push rod to move a 6–inch slack adjuster operating a cam and the total force equals 21,600 inch pounds torque (3,600 x 6), or 1,800 foot pounds torque (21,600 ÷ 12). It requires 25 to 30 foot pounds of torque to tighten the wheel on a car. This comparison illustrates the force obtained from using mechanical leverage and air pressure combined.



Stopping Distance

Stopping distance consists of three factors:

- driver's reaction time
- brake lag
- braking distance

Driver's reaction time: Reaction time is often called "thinking time". The time it takes from the moment a hazard is recognized to the time the brake is applied, approximately ¾ of a second.

Brake lag: As air is highly compressible, it requires a relatively large volume of air to be transmitted from the reservoir to the brake chamber before there is enough pressure for the brakes to apply. It can be said that brake lag is the time it takes the air to travel through a properly maintained air brake system (approximately 4⁄10 of a second).

Braking distance: The actual distance the vehicle travels after the brake is applied until the vehicle stops.

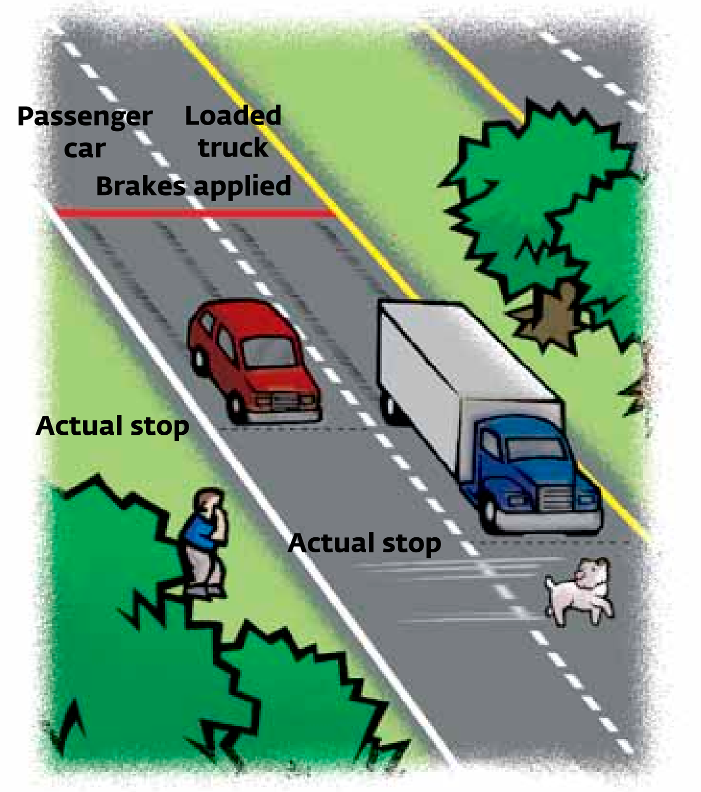
The distance depends on the ability of the brake lining to produce friction, the brake drums to dissipate heat and the tires to grip the road.

Drivers should never take their brakes for granted. The braking system must be tested and the adjustment checked before placing the vehicle into service. Drivers must understand the braking system, realize its capabilities and limitations, and learn to use them to the best advantage.

Heavy vehicles require powerful braking systems that are obtained by use of mechanical leverage and air pressure. Brakes must be used keeping in mind the heat generated by friction. If the heat becomes too great, braking effectiveness will be lost. The heavier the load and the faster the speed, the greater the force needed to stop.

It is important to remember that an air brake equipped vehicle, even with properly adjusted brakes, will not stop as quickly as a passenger car.

Comparative Stopping Distances



Section Summary Questions

1. What is the final factor that will determine if the vehicle will move?
2. What is the final factor that will determine if the vehicle will stop?
3. How is the heat that is generated by the brakes dissipated?
4. If one set of brake shoes is poorly adjusted, what effect could it have on the remaining sets of brake shoes in the system?
5. What is meant by the term “friction”?
6. If the weight of the vehicle is doubled, how many times must the stopping power be increased?
7. If the speed of the vehicle is doubled, how many times must the stopping power be increased to be able to stop at the same distance?
8. If both weight and speed of the vehicle are doubled, how many times must the stopping power be increased to stop at the same distance?
9. What is compressed air?
10. What does the abbreviation “psi” stand for?
11. If 40 psi is exerted against a diaphragm of 30 square inches in area, what are the total pounds of force that could be exerted?
12. Stopping distance consists of what three factors?
13. Define the following terms?
    - Driver’s Reaction Time
    - Braking Distance
    - Brake Lag

Notes