Changing momentum

Changing the momentum of a moving object—whether stopping a car or striking a tennis ball—requires a force. The greater the change in momentum or the more quickly the momentum changes, the greater the force required. Car crashes are dangerous because the very rapid change in momentum involves huge forces.

Key facts

- ✓ **Changing an object's momentum requires a force.**
- ✓ **The more momentum an object has, the larger the force needed to stop it, or the longer the stopping force must be applied.**

Force and momentum

When a car comes to a halt, its momentum falls to zero. We can calculate the force needed to change the car's momentum using the equation here. As the examples below demonstrate, a far greater force is needed to stop a car suddenly than to slow it down gradually.

$$\text{force (N)} = \frac{\text{change in momentum (kg m/s)}}{\text{time (s)}}$$

Final velocity

$$F = \frac{mv_f - mv_i}{t}$$

Initial velocity

Stopping gradually

A car with a mass of 1000 kg is traveling at 14 m/s (about 31 mph [50 km/h]). The driver brakes for 10 seconds, bringing the car to a stop. What is the force acting on the car?

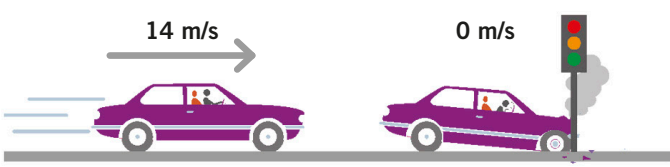
Remember to take the initial momentum away from the final momentum.

$$F = \frac{(1000\text{ kg} \times 0\text{ m/s}) - (1000\text{ kg} \times 14\text{ m/s})}{10\text{ s}}$$

$$= \frac{0 - 14\,000\text{ kg m/s}}{10\text{ s}}$$

$$= -1400\text{ N}$$

The force is negative because it acts in the opposite direction to the motion of the car.



Stopping suddenly

A car of the same mass is also traveling at 14 m/s. It hits a traffic light and decelerates to 0 m/s in 0.07 seconds. What is the force acting on this car?

$$F = \frac{(1000\text{ kg} \times 0\text{ m/s}) - (1000\text{ kg} \times 14\text{ m/s})}{0.07\text{ s}}$$

$$= \frac{0 - 14\,000\text{ kg m/s}}{0.07\text{ s}}$$

$$= -200\,000\text{ N}$$

The force that stops the car is equivalent to the weight of five elephants.

Stopping distance

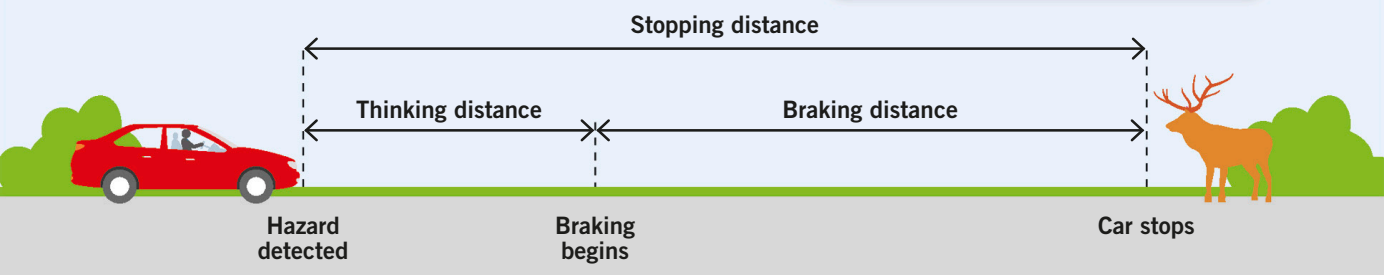
In an emergency, a driver may see a hazard and have to stop the car very quickly. The distance the car travels between the driver seeing the hazard and the car coming to a stop is called the stopping distance and is affected by the car's speed, mass, and other factors.

Key facts

- ✓ **Stopping distance is the distance covered between the driver seeing a hazard and the vehicle stopping.**
- ✓ **Stopping distance is the sum of thinking distance and braking distance.**
- ✓ **Factors affecting thinking distance include tiredness, use of drugs or alcohol, distractions, and the vehicle's speed.**
- ✓ **Factors affecting braking distance include the vehicle's speed, mass, condition, and road and weather conditions.**

Thinking and braking

Total stopping distance can be divided into two parts: thinking distance and braking distance. Thinking distance is the distance the car travels during the time a driver takes to react and use the brakes after seeing a hazard. Braking distance is the distance the car travels after braking begins.



Stopping distance and speed

The most important factor affecting stopping distance is speed; the faster a car is traveling, the longer it takes to stop safely. This is because a fast car has far more kinetic energy than a slow car, so the brakes must do much more work to bring the car to a stop.