Changing Momentum

Indicates a Flash activity.
Indicates an accompanying worksheet.
Indicates a virtual experiment.
Indicates that there are teacher’s notes.
Indicates content on a required practical.
Indicates maths skills practice.
Changing Momentum

- What is a change in momentum?
- Changing momentum safely
- Summary activities
What is a change in momentum?

All moving objects have **momentum**.

\[
\text{momentum} = \text{mass} \times \text{velocity}
\]

The **heavier** an object is and the **faster** it moves, the more momentum it will have and the harder it will be to stop.

When a force acts on an object that is moving, or able to move, a **change** in momentum occurs.

1. The cube is **stationary** and has no momentum.
2. Force is applied.
3. The cube’s momentum changes; it **gains** momentum.
Force and change in momentum

The change in momentum depends on the size of the force and the time for which it is applied. The relationship between these values is shown by this equation:

\[ \text{force} = \frac{\text{change in momentum}}{\text{time}} \]

- Momentum, \( p \), is measured in kilogram metres per second (kg m/s).
- Time, \( t \), is measured in seconds (s).
- Force, \( F \), is measured in newtons (N).
Where does the formula for change in momentum come from?

First, remember that Newton’s second law of motion states:

\[ F = \frac{\Delta p}{t} \]

\[ F = ma \]

The formula for acceleration is:

\[ a = \frac{\Delta v}{t} \]
Substituting the formula for acceleration into Newton’s second law:

\[ F = ma = \frac{m\Delta v}{t} \]

Remember the formula for momentum:

**momentum** = mass \( \times \) velocity

\[ p = mv \]

Substitute it into the equation:

\[ F = \frac{m\Delta v}{t} = \frac{\Delta p}{t} \]

Success! Again, we find that the **force** is equal to the **rate of change** in momentum.
A rugby ball of mass **0.5 kg** is kicked from stationary to a velocity of **8 m/s**. The kicker’s foot is in contact with the ball for **0.1 seconds**.

What force does the kicker use?

\[
\text{force} = \frac{\text{change in momentum}}{\text{time}}
\]

\[
= \frac{(0.5 \times 8) - (0.5 \times 0)}{0.1}
\]

\[
= \frac{4}{0.1}
\]

\[
= 40 \text{ N}
\]
A tennis ball is rolled at a stationary toy car of mass 0.1 kg. After the collision, the car then moves with a velocity of 0.5 m/s. The ball and car are in contact for 0.05 seconds.

With what force does the tennis ball hit the toy car?

\[
\text{force} = \frac{\text{change in momentum}}{\text{time}} = \frac{(0.1 \times 0.5) - (0.1 \times 0)}{0.05} = \frac{0.05}{0.05} = 1 \text{ N}
\]
Relating force, acceleration and velocity

Sam is a tennis player practising her serve. If she increases the force she uses, what will happen to the acceleration of the ball?

Sam’s coach shows her a new technique that increases the amount of time her racket is in contact with the tennis ball. If she still hits the ball with the same force, what will happen to the velocity of the tennis ball?

Sam buys new tennis balls that are heavier than before. Assuming that she still hits them in the same way with the same force, what will happen to the speed of her serve?
Relating force and momentum

These two cars have the same mass.

If the blue car is travelling at 50 mph, and the yellow car is travelling at 75 mph, which has the most momentum?

Both cars brake at the same time and both travel 10 m before stopping.

Which driver experiences the most force? Why?
Changing Momentum

What is a change in momentum?

Changing momentum safely

Summary activities
Car crashes and momentum

What happens if two cars travelling very quickly collide?

Both cars come to a stop in a short space of time. This means that the cars and their occupants experience a large change of momentum very quickly.

How can changes in momentum cause a serious injury?

A very large change of momentum in a short space of time means that the car occupants will experience a large force.

How could you use this principle to make cars safer?
Reducing force in car crashes

One way to **reduce** the forces acting on a person in a collision is to **increase** the time it takes for the person to decelerate.

A longer deceleration means that the same change in momentum occurs over a **longer** time. There is therefore a **smaller** force acting on the person.

Explain how rate of change of momentum is relevant for…

- …seatbelts.
- …airbags.
- …crumple zones.
How do car safety features work?

How do car safety features reduce the risk of injury?

Cars are much safer than they were 10 or 20 years ago.

Press the buttons below to find out how these safety features reduce the forces experienced by car occupants and help prevent injury.

seatbelts

airbags

crumple zones
Increasing collision time calculation

A 90 kg driver with no seatbelt crashes at 12.5 m/s, impacting against the steering column in 0.04 seconds. What is the force on the driver?

momentum = mass × velocity
= 90 × 12.5
= 1125 kg m/s

force = change in momentum / time
= 1125 / 0.04
= 28,125 N

With a seatbelt, the driver would have stopped in 0.2 seconds.

What would the force on the driver been if they had worn a seatbelt?
Motorcycle helmets

Motorcycle helmets are designed to **prevent injury** to the head and brain.

They generally contain a layer of **crushable foam**.

In a collision, the foam part of the helmet crushes, extending the head's stopping time by about six thousandths of a second. This **reduces the peak force** on the brain.

The hard outer casing holds the foam in place and prevents objects piercing the helmet.
Falling over safely

Increasing the time it takes for a change in momentum to occur is a very useful way of making collisions safer. Many different safety features use this principle.

For instance:

- cushioned surfaces in children’s playgrounds.
- crash mats for athletes.

Can you think of any other examples?
Changing Momentum

- What is a change in momentum?
- Changing momentum safely
- Summary activities
You will need this equation to answer the following questions about force, change of momentum and time:

\[
\text{force} = \frac{\text{change in momentum}}{\text{time}}
\]

Click "start" to begin.