Forces and momentum

International Baccalaureate · IB Diploma · Physics · HL

Scope and prerequisites

This handout covers selected HL topics for the course first assessed in 2025; it is not the whole syllabus.

Prerequisites: read the stated quantities and units, and use arithmetic and the model conditions below.

The examples are original and fictional: they are not real measurements or real student investigations.

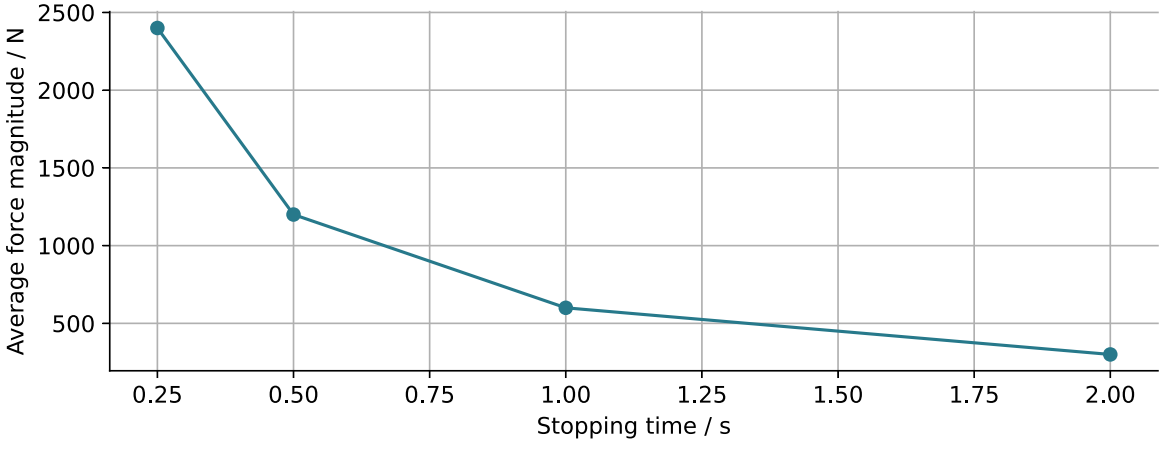
Forces, momentum and safe stopping

What would explain this observation?

- A passenger continues moving when a vehicle brakes. The seat belt provides the force needed to change the passenger **momentum**.

Build the model

- **Resultant force** causes acceleration, not motion itself.
- Momentum is mass multiplied by velocity.
- For an isolated system, total momentum is conserved even when kinetic energy is not.
- momentum: Mass multiplied by velocity.
- resultant force: The vector sum of forces on an object.



The same impulse, 600 N s, spread over a longer time needs a smaller force

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Choose evidence that can test it

- Impulse equals momentum change.
- Increasing stopping time for the same momentum change reduces average force.
- Identify external forces before applying momentum conservation.

In the lab: Draw a free-body diagram containing only forces on the selected object. For spring measurements, add loads in steps within the elastic range and measure extension from the unloaded position.

Work from known quantities

- Known: a 60 kg passenger slows from 10 to 0 metres per second in 0.50 s. $\Delta p = m(v\text{-}u) = 60(0\text{-}10) = -600$ kg metres per second.
- Average $F = \Delta p/\Delta t = -600/0.50 = -1{,}200$ N.
- The sign shows the force opposes the initial motion.

Your turn: A 2 kg trolley travels at 3 metres per second. Find its momentum.

Check the conclusion and its limits

- Balanced forces do not require the object to be at rest.
- Mass and weight have different units and meanings.

Not true: An object moving at constant velocity must have a nonzero resultant force. By Newton's first law, constant velocity - including steady motion - means zero RESULTANT force. Forces can be present, but they balance; a nonzero resultant would change the velocity.

Key:

- Resultant force causes acceleration, not motion itself.
- Impulse equals momentum change.
- Watch for: balanced forces do not require the object to be at rest.

Write from a momentum of 32 kilogram metres per second

- A 4 kg trolley travels at 8 metres per second and stops in 0.40 s.
- Find the momentum and the average force. Constant velocity needs zero resultant force.

Write from a momentum change of 6 kilogram metres per second

- A 0.50 kg ball's velocity reverses from +6 to −6 metres per second in 0.25 s.
- The momentum change is $0.50 \times (-12) = -6$ kg m s^{-1}, so the average force is $-6 \div 0.25 = -24$ N – a REVERSAL changes momentum by twice the one-way value.

■ **Write from a stopping distance split of 36 metres**

- At 20 m s^{-1} a driver reacts for 0.60 s, then brakes for 24 m.
- Reaction distance $20 \times 0.60 = 12$ m, total $12 + 24 = 36$ m – tiredness grows the first term, worn brakes the second.

■ **Write from a conserved total**

- A 2 kg trolley at 3 m s^{-1} couples with a stationary 1 kg trolley.
- Total momentum 6 kg m s^{-1} = 3 kg × v, so v = 2 m s^{-1} – the pair shares the momentum; the faster one does not keep it.