

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.

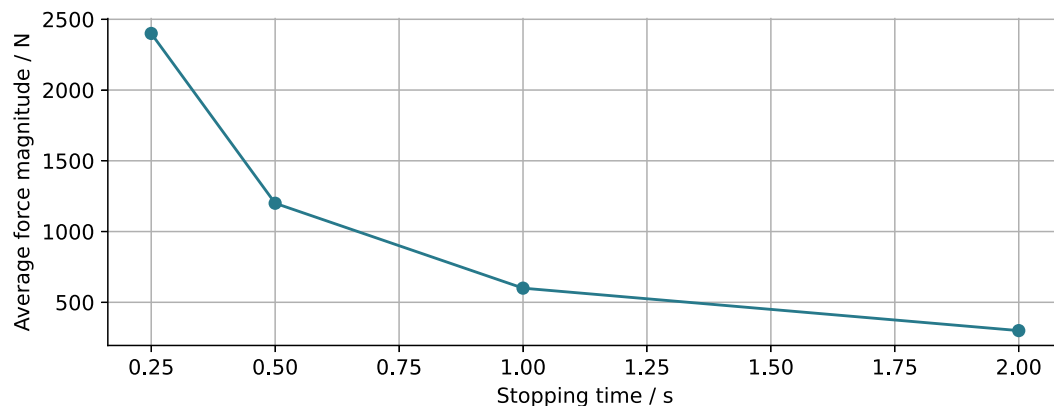
Forces, momentum and safe stopping

■ 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

■ 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. $\Delta p = m(v-u) = 60(0-10) = -600$ 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 $20 \times 0.60 = 12 \text{ m}$, total $12 + 24 = 36 \text{ m}$ – 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 $6 \text{ kg m s}^{-1} = 3 \text{ kg} \times v$, so $v = 2 \text{ m s}^{-1}$ – the pair shares the momentum; the faster one does not keep it.