

20 Momentum Conservation

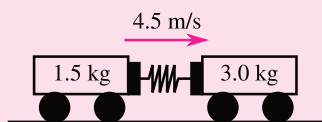
momentum (kg m/s) = mass (kg) \times velocity (m/s) $p = mv$

change in momentum (kg m/s) = force (N) \times time (s) $p_{\text{after}} - p_{\text{before}} = Ft$

The sign of the momentum (plus or minus) tells you the direction.

In these one dimensional problems, positive momentum means 'travelling East' and negative momentum means 'travelling West'.

Example 1



Two motion trolleys are moving East. The spring expands, and pushes the trolleys apart. It pushes the 3.0 kg trolley forwards with a 2.5 N force for 1.2 s. What is the change in momentum change of each trolley?

Momentum change of 3.0 kg trolley = $Ft = 2.5 \text{ N} \times 1.2 \text{ s} = 3.0 \text{ kg m/s}$

By **Newton's 3rd Law**, force on 1.5 kg trolley must be 2.5 N West (-2.5 N).

Momentum change of 1.5 kg trolley = $Ft = -2.5 \text{ N} \times 1.2 \text{ s} = -3.0 \text{ kg m/s}$.

The momentum gained by the 3.0 kg trolley is **equal** to the momentum lost by the 1.5 kg trolley. So the total momentum **stays the same**.

So, when forces act between objects, their total momentum is conserved.

Example 2 – Calculate the new velocity of the 1.5 kg trolley.

Momentum = old momentum + change = $1.5 \times 4.5 - 3 = 3.75 \text{ kg m/s}$

New velocity = momentum / mass = $3.75 / 1.5 = 2.5 \text{ m/s}$ (2.5 m/s East)

Example 3 – A 2.5 kg mass travelling at 2.5 m/s collides with and sticks to a 7.5 kg mass which is stationary. Calculate the velocity afterwards.

Total initial momentum: $2.5 \text{ kg} \times 2.5 \text{ m/s} + 7.5 \text{ kg} \times 0 \text{ m/s} = 6.25 \text{ kg m/s}$

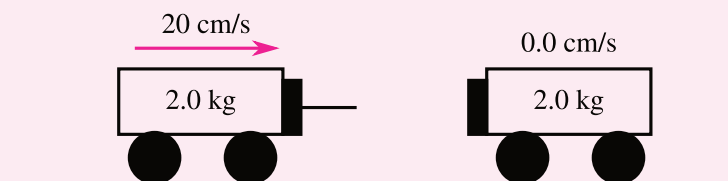
Total final momentum must be the same = 6.25 kg m/s

Final velocity = momentum / mass = $6.25 / 10.0 = 0.63 \text{ m/s}$ (2 sf)

20.1 Calculate the momentum of:

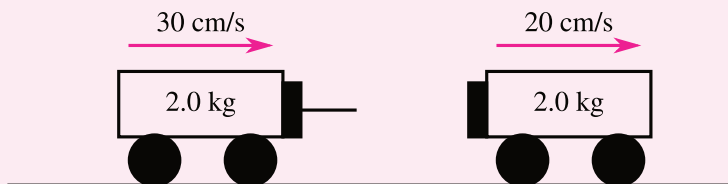
- (a) a 3.0 kg trolley moving at 2.0 m/s to the East;
- (b) a 700 kg car moving at 6.0 m/s to the West;
- (c) a 50 g mass moving at 50 cm/s to the East;
- (d) a 10 000 kg bus moving Eastwards at 3.0 m/s.
- (e) What is the total momentum of the car in (b) and the bus in (d)?
- (f) If the car and the bus were to collide and stick together in a crumpled mess, what would the total mass of the wreckage be just after the impact?
- (g) What would the total momentum of the crumpled mass be?
- (h) Calculate the initial velocity of the wreckage.

20.2 Two 2.0 kg trolleys collide and stick together on a smooth, horizontal surface. One trolley is at rest before the collision.



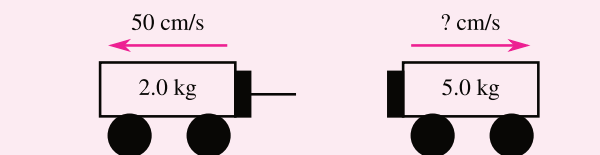
Calculate the combined velocity of the trolleys after the collision.

20.3 Two trolleys are moving in the same direction along a smooth surface. One is moving faster and catches up on the other. The trolleys collide and stick together.

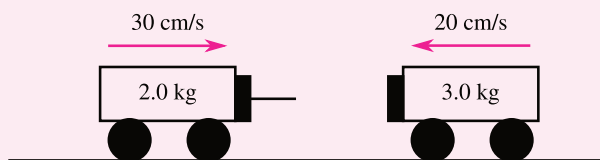


Calculate the combined velocity of the trolleys after the collision.

- 20.4 Two trolleys are at rest and in contact on a smooth, level surface. A coiled spring in one trolley is released so that they 'explode' apart. The lighter trolley moves off at 50 cm/s.



- (a) Calculate the speed of the other trolley.
- (b) Calculate the minimum energy which was stored in the coiled spring before the release. [Hint: see Kinetic Energy P34]
- 20.5 Two trolleys are moving in opposite directions along a smooth surface. The trolleys collide and stick together.



- (a) What is the total momentum of the trolleys before and after the collision?
- (b) What is the trolleys' combined velocity after the collision?
- 20.6 Complete the following table for two objects A and B , travelling together until pushed apart by explosions. ' m_A ' means 'mass of A '.

m_A (kg)	m_B (kg)	Initial combined velocity (m/s)	Final v_A (m/s)	Final v_B (m/s)
2.5	2.5	0.0	(a)	+2.0
2.5	5.0	0.0	-6.8	(b)
2.5	7.5	5.0	-4.0	(c)
9.0	(d)	-4.0	-5.0	+6.0

- 20.7** A 10 g bullet (0.010 kg) is fired at 250 m/s Eastwards towards a 10 kg sandbag.
- (a) Calculate the momentum of the bullet.
 - (b) What is the total momentum before the collision?
The bullet enters the sandbag and stops inside it:
 - (c) What is the total momentum now?
 - (d) Calculate the speed of the sandbag.
- 20.8** A 70 kg astronaut has a 20 kg backpack, and is stranded, stationary, in space 30 m to the West of her spacecraft. To get back to safety, she hurls the backpack at a speed of 4.2 m/s.
- (a) Which way does she need to throw the backpack?
 - (b) What is the total momentum before she throws it?
 - (c) What is the momentum of the backpack after throwing?
 - (d) What will the astronaut's momentum be after she has thrown the backpack?
 - (e) What is the astronaut's velocity after she has thrown the backpack?
 - (f) How much time does it take her to get back to the spacecraft?
- 20.9** The exhaust from a rocket on a test rig leaves the engine at 2 800 m/s. How many kilograms of propellant (fuel and oxidizer) need to be burnt every second to provide a force of 3.5×10^8 N?
- 20.10** A conveyor belt is used to move coal along a horizontal shaft in a coal mine. How much force needs to be applied horizontally to the belt to keep it moving at 1.2 m/s if 40 kg of coal is dropped onto it every second? Assume that the coal has no horizontal velocity before it touches the belt and the belt's turning mechanism is well lubricated.