Momentum

Definitions

Linear momentum is the product of the mass and velocity of an object. It is a vector quantity, possessing a magnitude and a direction.

Conservation of momentum

The total momentum of a group of interacting objects remains constant in the absence of external forces. In a simple collision or explosion, this equates to:

Momentum before = momentum after

Momentum Change

Newton's second law states that the rate of change of a body's momentum is equal to the net force acting on it.

$$F = \frac{dp}{dt}$$

We experience a force when struck by a moving object created by a change in momentum. The bigger the momentum change, the greater the force.

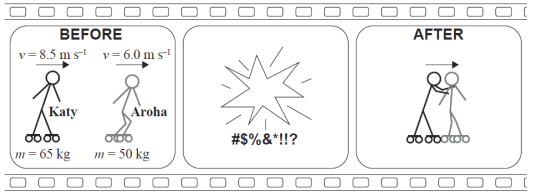
Equations

$p = mv$	Momentum	p	kg m s^{-1}
	mass	m	kg
	velocity	v	m s^{-1}
$\Delta p = F\Delta t$	Momentum	p	kg m s^{-1}
	Force	F	N
	time	t	s

Questions

ROLLER SKATING (2017;1)

Katy, 65.0 kg, and Aroha, 50.0 kg, are roller skating. Aroha is moving to the right at a constant velocity of 6.0 m s^{-1} and Katy is also moving to the right, behind Aroha, at a constant velocity of 8.5 m s^{-1}. Katy collides with Aroha, holds her shoulders, and they move together to the right at a constant velocity.



(a) What physical quantity is conserved during the above inelastic collision between Katy and Aroha? State any assumptions you have made.

(b) Calculate the combined velocity of Katy and Aroha as they skate together after the collision.

(c) As Katy collides with Aroha, they both experience a force due to the collision. The duration of the collision is 2.5 s. Calculate the size of the force experienced by Aroha.

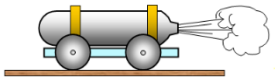
Terms

Inertia: The tendency of objects in motion to stay in motion, and objects at rest to stay at rest, unless another force causes its speed or direction to change

Elastic collision: Kinetic energy is conserved.

Inelastic collision: Kinetic energy not conserved, and some energy is converted to other types of energy (e.g., heat, sound)

Tips



A rocket works because:

- The action and reaction forces are equal and opposite.
- Momentum is conserved.

Memorise the short version of the law of conservation of momentum "total momentum before = total momentum afterwards unless an external force is applied" – it is almost always required.

Answers

(a) Total momentum of the system is conserved, assumption, no external forces.

(b)
$$p_i = m_{Katy}\,v_{Katy} + m_{Aroha}\,v_{Aroha}$$
$$p_i = (65 \times 8.5) + (50 \times 6.0) = 552.5 + 300 = 852.5 = 850 \text{ Kg m s}^{-1}$$
$$p_i = p_f = v_{combined} \times (m_{Katy} + m_{Aroha})$$
$$852.5 = v_{combined} \times (65 + 50)$$
$$v_{combined} = 7.4 \text{ m s}^{-1}$$

(c) Solved using impulse:
$$\Delta P = P_f - P_i$$
$$\Delta P = (50 \times 7.4) - (50 \times 6)$$
$$\Delta P = 370 - 300$$
$$\Delta P = 70 \text{ kg m s}^{-1}$$
$$F = \frac{\Delta P}{\Delta t}$$
$$F = \frac{70}{2.5}$$
$$F = 28 \text{ N}$$