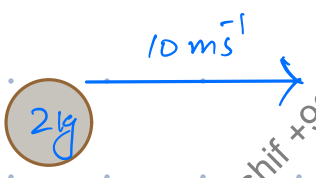
Momentum

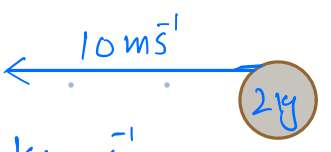
"The product of mass and velocity"

$$p = mv$$

- SI unit of momentum is $kg\,ms^{-1}$ or Ns
- Momentum is a vector quantity



$$p = 2 \times 10 = 20\ kg\,ms^{-1}$$



$$p = -20\ kg\,ms^{-1}$$

* Momentum changes sign when object reverses direction

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Impulse (change of Momentum)

The momentum of an object changes when an external force is exerted on it

* Change of momentum is also called Impulse

Thus

$$\text{Force} = \frac{\text{Impulse}}{\text{time}}$$

or

$$\text{Force} = \frac{\text{Change in momentum}}{\text{time}}$$

Important

- Change in momentum $= mv - mu$ (if objects keeps same direction)
- Change in momentum $= mv + mu$ (if object reverses direction

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Mathematically,

$$\frac{\text{Change in momentum}}{\text{time}} = \frac{mv - mu}{t}$$

$$= \frac{m(v-u)}{t}$$

$$= ma$$

$$= \text{net for}$$

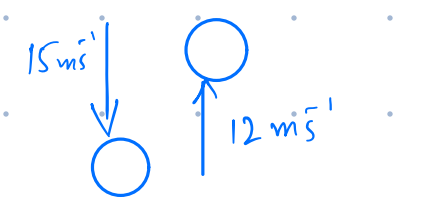
Definition of force

" Net force is equal to rate of change of momentum "

Example

A ball of mass 2 kg hits the ground at $15\ ms^{-1}$ and bounces back at $12\ ms^{-1}$, calculate its Impulse :

Sol



$$\text{Impulse} = 2(12) + 2(15)$$

$$= 54\ kg\ ms^{-1}$$

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- If time of Impact is 20 ms, Calculate force exerted by the ball on the ground.

$$\therefore \text{Force} = \frac{\text{Impulse}}{\text{time}} = \frac{54}{20\times10^{-3}} = 2700\ N$$

* This impact follows Newton's 3rd Law of motion, thus force exerted by the ground on ball is also equal and opposite. (−2700 N)

- **Law of Conservation of Momentum**

"The total momentum of a closed (Isolated) System remains constant"

Before Collision:



After Collision:



$$m_1 U_1 + m_2 U_2 = m_1 V_1 + m_2 V_2$$

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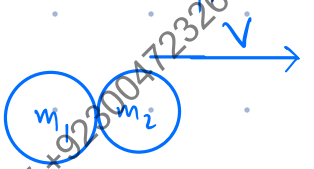
* Collisions in different directions

(1)



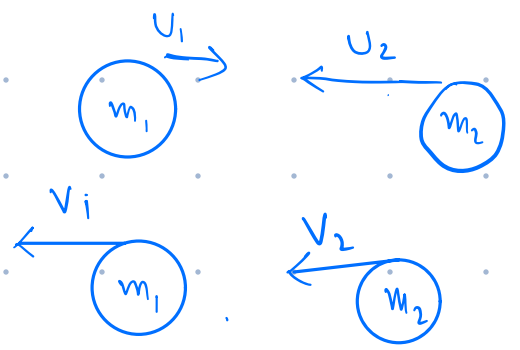
Total momentum = $m_1 U_1 - m_2 U_2$

* objects stick together after collision:



Total momentum = $(m_1 + m_2) V$

(2)



$$m_1 U_1 - m_2 U_2 = -m_1 V_1 - m_2 V_2$$

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Past Paper questions

Fig. 2.1 shows two railway trucks on a track.

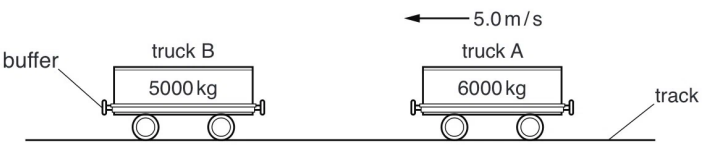


Fig. 2.1

Truck A of mass 6000 kg is moving at 5.0 m/s. It is approaching truck B of mass 5000 kg, which is stationary.

(a) Calculate the momentum of truck A.

$6000 \times 5 = 30,000$ kg m/s

momentum = ... 30,000 kg m/s ..... [2]

(b) The trucks collide, their buffers compress and then they bounce off each other, remaining undamaged.

After the collision, truck B has a momentum of 27 000 kg m/s.

(i) Determine the impulse applied to truck B.

Impulse of Truck B = 27000 − 0

impulse = ... 27000 kg m/s ..... [2]

(ii) The trucks are in contact for 0.60 s.

Calculate the average force on truck B.

$$\text{force} = \frac{\text{Impulse}}{\text{time}} = \frac{27000}{0.60} = 45000\ \text{N}$$

(iii) Calculate the final speed of truck A.

Total momentum before collision = Total momentum after collision

$30,000 + 0 = 27000 + 6000V$

$3000 = 6000V$

speed = ... $0.5\ \text{m s}^{-1}$ ..... [3]

[Total: 9]

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A footballer kicks a ball vertically upwards. Initially, the ball is stationary.

(a) His boot is in contact with the ball for 0.050 s. The average resultant force on the ball during this time is 180 N. The ball leaves his foot at 20 m/s.

Calculate

(i) the impulse of the force acting on the ball,

Impulse = force x time

= 180 x 0.050 sec

impulse = ... 9.0 kg m s^{-1} .....[2]

(ii) the mass of the ball,

$mv = 9$

$m \times 20 = 9$

$m = \frac{9}{20} = 0.45$ kg

mass = ... 0.45 kg .....[2]

(iii) the height to which the ball rises. Ignore air resistance.

Change in K.E = gain in P.E

$\frac{1}{2} m v^2 = mgh \Rightarrow h = \frac{20^2}{2(9.8)}$

$\Rightarrow \frac{v^2}{2g} = h$

height = ... 20 m .....[3]

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