

Momentum





Momentum : "it is defined as the product of mass and velocity of an a body"

$$\text{momentum} = \text{mass} \times \text{velocity}$$

$$p = m v$$

kg . m / s

or

N . s

→ It is a vector quantity. So it has direction.
(same as velocity)

Examples

1) a truck of mass 4000 kg



→
velocity 20 m s^{-1}

$$p = 4000 \times 20 \\ = 80000 \text{ kg m/s}$$

A car of mass 1000 kg



→
velocity 20 m s^{-1}

$$p = 1000 \times 20 \\ = 20000 \text{ kg m/s}$$

1) If two bodies are moving with same velocity, the one with greater mass will have greater momentum.

2)

A car of mass 1000 kg



velocity \rightarrow 20 m/s

$$p = 1000 \times 20 \\ = 20000 \text{ kg m/s}$$

A car of mass 1000 kg.



velocity \rightarrow 60 m/s

$$p = 1000 \times 60 \\ = 60000 \text{ kg m/s}$$

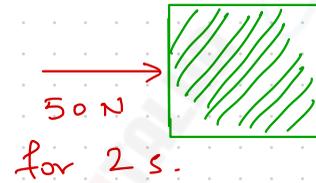
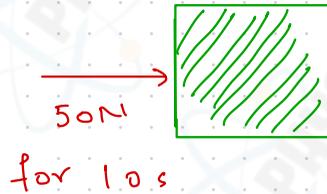
2) If we have 2 bodies of the same mass, then the one with greater velocity has greater momentum.

Impulse: "it is defined as the product of force and the time for which the force was exerted"

$$\text{Impulse} = \text{force} \times \text{time}$$

$\text{N}\cdot\text{s}$ N s

Example



$$\begin{aligned} \text{Impulse} &= 50 \times 10 \\ &= 500 \text{ N}\cdot\text{s} \end{aligned}$$

$$\begin{aligned} \text{Impulse} &= 50 \times 2 \\ &= 100 \text{ N}\cdot\text{s} \end{aligned}$$

→ If both boxes were at rest initially, which one would have a greater final velocity?

Impulse = change of momentum

$$F \times \Delta t = \Delta p$$

$$F \times \Delta t = \text{final } p - \text{initial } p$$

If a body has constant mass

$$F \times \Delta t = m v - m u$$

\swarrow final velocity \searrow initial velocity

$$F \times \Delta t = m (v - u) \longrightarrow F = m \left(\frac{v - u}{t} \right)$$

$$F \times \Delta t = m \Delta v \qquad F = m a$$

Examples



Solution

$$a) F \times \Delta t = \text{final } p - \text{initial } p$$

$$20 \times 10 = \text{final } p - 0$$

$$200 \text{ kg m/s} = \text{final } p$$

$$b) \text{final } p = m \cdot v$$

$$200 = 50 \cdot v$$

$$\frac{200}{50} = v$$

$$4 \text{ m/s} = v$$

If the box is at rest initially, what would be

a) its final momentum?

b) its final velocity?

if the 20N force pushes the box for 10 s?

The longer a force acts on a body, the more its momentum changes.

2.)



A car of mass 1000 kg was moving at a velocity of 30 m/s.

Suddenly the car crashed into a tree and it took 0.50 s for the car to come to rest.

- Calculate the initial momentum of the car.
- State the impulse on the car.
- Calculate the force that exerted by the tree on the car.

Solution

$$\begin{aligned} \text{a) } p &= m v \\ &= 1000 \times 30 \\ &= 30\,000 \text{ kg m/s} \end{aligned}$$

$$\begin{aligned} \text{b) } \text{Impulse} &= \Delta p \\ \text{Impulse} &= \text{final } p - \text{initial } p \\ &= 0 - 30\,000 \\ \text{Impulse} &= 30\,000 \text{ N}\cdot\text{s} \end{aligned}$$

$$\begin{aligned} \text{(c) } F \times \Delta t &= \text{impulse} \\ F \times 0.50 &= 30\,000 \\ F &= 60\,000 \text{ N} \end{aligned}$$

Cars have a crumple zone at their front. During accidents this zone crumples up but it increases the time for car to come to rest.

Hence, the force acting on the car is smaller.

d) Another car with a crumple zone was in the same accident, ^{same mass and velocity} what would be the force on the car if it came to rest in 1s.

Solution

$$d) \quad F \times \Delta t = \text{impulse}$$

$$F \times 1 = 30000$$

$$F = 30000 \text{ N}$$



Conservation of momentum

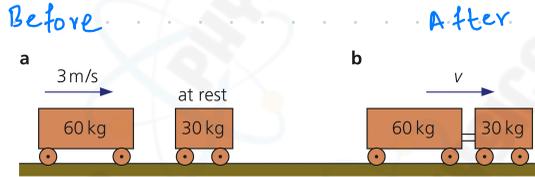
principle of conservation of momentum:

“When two or more bodies act on one another, as in a collision, the total momentum of the bodies remains constant, provided no external forces act (e.g. friction).”

Total momentum
before collision

=

Total momentum
after collision



▲ Figure 1.6.2

Suppose a truck of mass 60 kg moving with velocity 3 m/s collides and joins with a stationary truck of mass 30 kg (Figure 1.6.2a). The two move off together with the same velocity v which we can find as follows (Figure 1.6.2b).

Total momentum before collision = Total momentum after collision

$$(60 \times 3) + (30 \times 0) = (90 \times v)$$

$$2 \text{ m/s} = v$$

- 1) A trolley of mass 3kg moving with velocity 5m/s collides and joins with a stationary trolley of mass 2kg and the two move off together with the same velocity v . Assuming momentum is not lost in the collision, calculate the value of v .



$$\begin{aligned} \text{Total momentum before} &= \text{Total momentum after} \\ (3 \times 5) + (2 \times 0) &= (5 \times v) \end{aligned}$$

$$\boxed{3 \text{ m/s} = v}$$

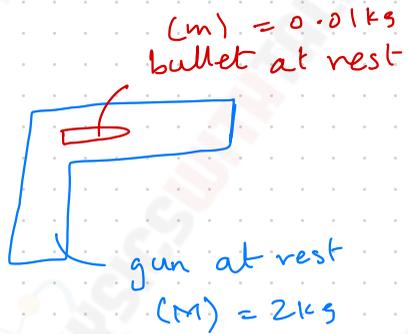
- 2) A trolley of mass 5 kg moving with velocity 5 m/s collides with a stationary trolley of mass 2kg. The 5 kg trolley stops and the 2 kg trolley moves off with velocity v . Assuming momentum is not lost in the collision, calculate the value of v .



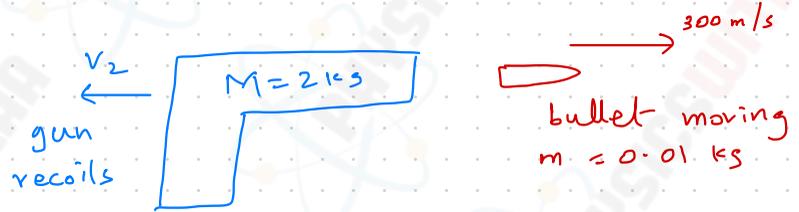
$$(5 \times 5) + (2 \times 0) = (5 \times 0) + (2 \times v)$$

$$\boxed{12.5 \text{ m/s} = v}$$

Before



After



Find the velocity at which the gun recoils?

Total momentum before = Total momentum after

$$(0.01 \times 0) + (2 \times 0) = (0.01 \times 300) - (2 \times v_2)$$

$$1.5 \text{ m/s} = v_2$$

