Linear Momentum

Momentum:

Product of mass and velocity.

Formula: $p = mv$

p: momentum

m: mass (kg)

v: velocity (ms^{-1})

unit: $kgms^{-1}$ or Ns (prove later)

P.S: vector (magnitude and direction)

Note:

- Momentum can be +ve or −ve.

By default, → +ve

$p = +ve$

$p = -ve$

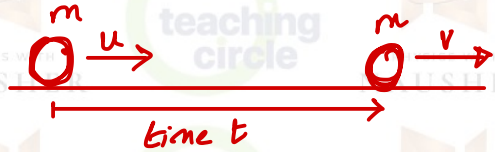
- Always check the unit of mass.

Made with GoodNotes

Define force

Force is defined as rate of change of momentum.

$$F = \frac{\Delta p}{t}$$



F: resultant force
t: time
Δp: change in momentum

units of Δp

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

Note:

$$F = \frac{mv - mu}{t}$$

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

$$\boxed{F = ma}$$

Note: Remember momentum is vector so initial and final momentum of object could have different signs if direction of object changes.

Made with Goodnotes

A tennis ball of mass 55 g is travelling horizontally with a speed of 30 $m s^{-1}$. The ball makes contact with a wall before rebounding in the horizontal direction with a speed of 20 $m s^{-1}$. The ball is in contact with the wall for a time of 5.0×10^{-3} s.
What is the average force exerted on the wall by the ball?

A 110 N **B** 220 N **C** 330 N **D** 550 N

Steps:

Calculate

i) Initial p

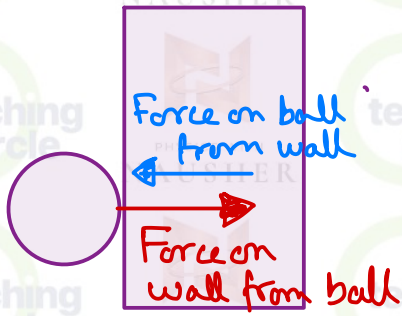
ii) Final p

iii) Change in p.

iv) Force exerted on the ball.

Made with Goodnotes

Direction of forces on the ball and the wall



$$F_{ball} = -F_{wall}.$$

The force on the object will be negative if the direction of the force opposes the direction of its initial velocity.

The force exerted by ball on wall is equal in magnitude and opposite in direction to the force exerted by the wall on the ball.

Made with Goodnotes

Time of impact

The force exerted is dependent on the time taken for the impact to occur.

The same change in momentum, over a longer period of time, will exert less force.

e.g ball collides with a cushion.

$$F = \frac{\Delta p}{t} \Rightarrow \Delta p = F \times t$$

Δp : remains constant

As $t \uparrow$, $F \downarrow$

As $t \downarrow$, $F \uparrow$

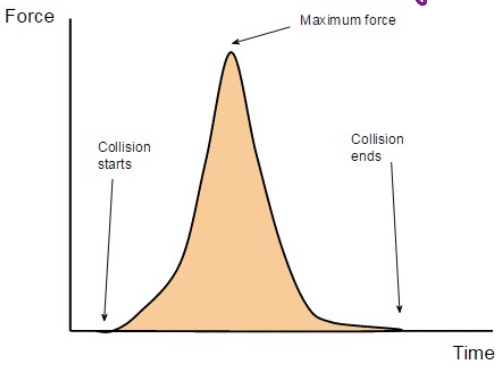
Made with Goodnotes

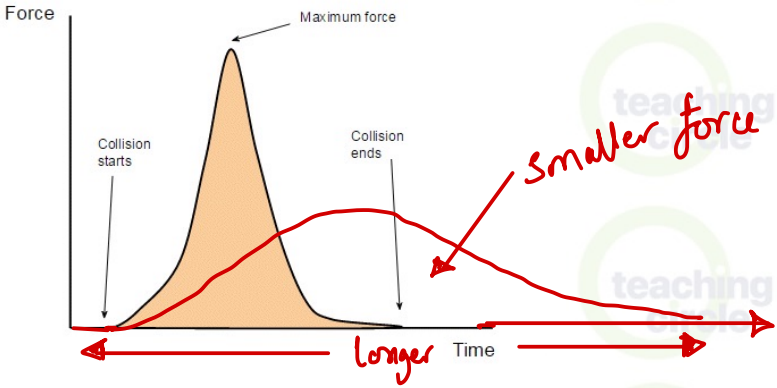
Force v/s time graphs

Force ⇒ Y-axis
time ⇒ x-axis

$\Delta p = F \times t$

(Y-axis) (x-axis)



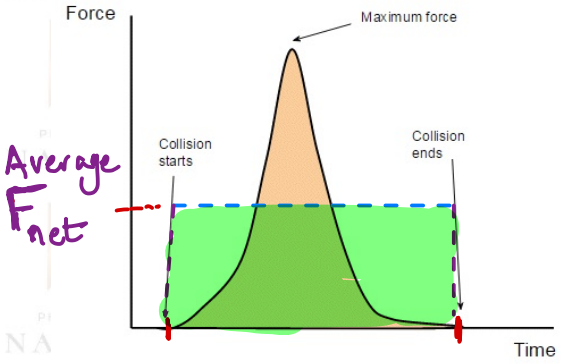


State the similarity and difference between the two graphs.

How will the force on second object look like?

Made with Goodnotes

Average net force



Area under the curve which represents the time varying force is equal to the area under the rectangle.

Note:- since force varies in an actual collision, the average net force is used in the equations to calculate change in momentum.

- To calculate change in momentum from graph, use the formula of the shape being formed by that area.

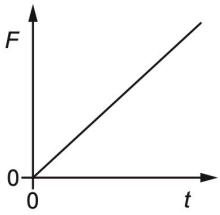
e.g rectangle $= l \times w$

triangle $= \frac{1}{2} \times b \times h$.

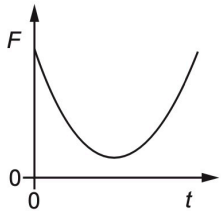
Made with Goodnotes

6 A rubber ball is dropped onto a table and bounces back up. The table exerts a force F on the ball. Which graph best shows the variation with time t of the force F for the short time that the ball is in contact with the table?

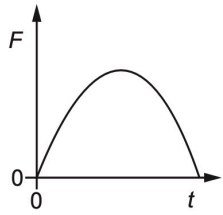
A



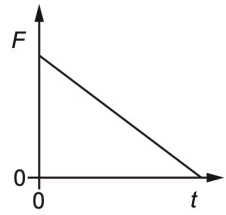
B



C



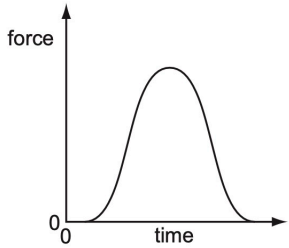
D



7 A resultant force causes an object to accelerate.
What is equal to the resultant force?

A the acceleration of the object per unit mass
B the change in kinetic energy of the object per unit time
C the change in momentum of the object per unit time
D the change in velocity of the object per unit time

A golf ball is hit by a club. The graph shows the variation with time of the force exerted on the ball by the club.

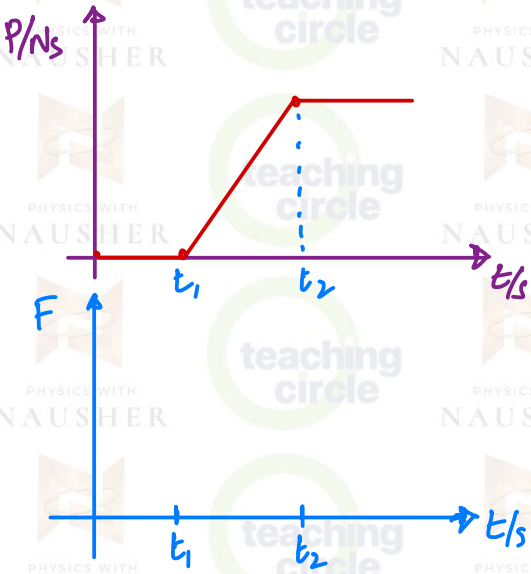


Which quantity, for the time of contact, **cannot** be found from the graph?

A the average force on the ball
B the change in momentum of the ball
C the contact time between the ball and the club
D the maximum acceleration of the ball

Made with Goodnotes

Momentum - time graphs



gradient = rise / run

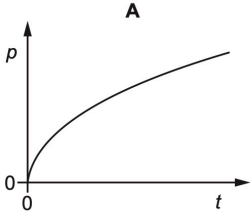
$= \frac{\Delta p}{\Delta t}$

$= F$

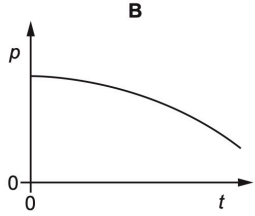
comment on the force

1 The resultant force acting on an object is slowly increased.
Which graph could show the variation with time t of the momentum p of the object?

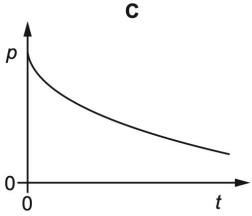
A



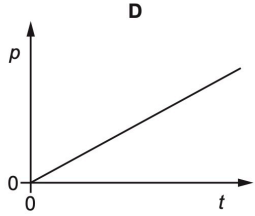
B



C

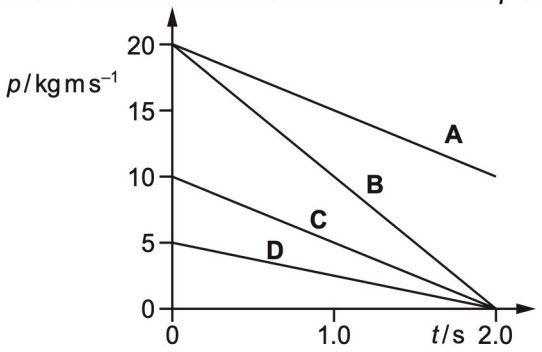


D

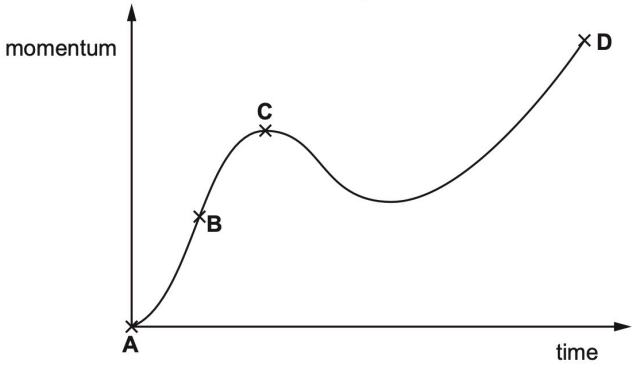


Made with Goodnotes

A resultant force of 10 N acts on a body for a time of 2.0 s.
Which graph could show the variation with time t of the momentum p of the body?



A body experiences a varying resultant force that causes its momentum to vary, as shown in the graph.
At which point does the resultant force have the largest value?



A ball falls vertically onto horizontal ground and rebounds, as shown.

The ball has momentum p_1 downwards just before hitting the ground. After rebounding, the ball leaves the ground with momentum p_2 upwards. The ball is in contact with the ground for 0.020 s. During this time interval, an average resultant force of 25 N acts on the ball.
What is a possible combination of values for p_1 and p_2?

	p_1 / kg m s^{-1}	p_2 / kg m s^{-1}
A	0.15	0.65
B	0.20	0.30
C	0.30	0.20
D	0.65	0.15

Made with Goodnotes

PHYSICS WITH NAUSHER
teaching circle
Made with Goodnotes