Exercise -3(C)

1. **Name the two factors on which the force needed to stop a moving body in a given time, depends.**
   Solution:
   Velocity and mass are the two factors on which the force needed to stop a moving body is dependent upon in a given time.

2. **Define linear momentum and state its S.I. unit.**
   Solution:
   Linear momentum of a body can be defined as the product of its mass and velocity. The S.I. unit of linear momentum is $kgms^{-1}$

3. **A body of mass m moving with a velocity v is acted upon by a force. Write expression for change in momentum in each of the following cases: (i) when v <<c, (ii) when v→c, and (iii) when v<<c but m does not remain constant. Here c is the speed of light.**
   Solution:
   Let Δp is the change in momentum;
   (i) When v << c ;
   $\Delta p = m\,\Delta v$
   (ii) when v→c;
   $\Delta p = \Delta(mv)$
   (iii) when v<<c;
   $\Delta p = \Delta(mv)$

4. **Show that the rate of change of momentum = mass x acceleration. Under what condition does this relation hold?**
   Solution:
   Let force 'F' be applied on a body having mass 'm' for 't' period of time because of which the velocity of the body changes from u to v.
   Hence, the initial velocity of the body is 'mu' and final velocity of the body is 'mv'

   The difference in the momentum of the body in 't' seconds is given as mv-mu=m(v-u)

   Rate of change of momentum = change in momentum/time
   = [m(v-u)] /t - equation 1

   As we know, acceleration 'a'=(v-u)/t
   Substituting this in the above equation 1, we get;
   Rate of change of momentum = mass x acceleration = ma

   The condition for this relation to hold true is that mass of the body remains constant.

5. **Two bodies A and B of same mass are moving with velocities v and 2v respectively. Compare their (i) inertia (ii) momentum.**

Solution:

(i) If 'm' is the mass of two bodies A and B,
Comparing inertia of both the bodies;
Inertia of A: Inertia of B :: m:m or 1:1

(ii) To compare momentum of bodies A and B
Momentum of A = m(v)
Momentum of B = m(2v) =2mv
Comparing momentum of bodies A and B
Momentum of A: Momentum of B :: mv:2mv or 1:2

6. **Two balls A and B of masses m and 2m are in motion with velocities 2v and v respectively. Compare (i) their inertia, (ii) their momentum, and (iii) the force needed to stop them in same time.**

Solution:

(i) Comparing inertia of two bodies A and B;
Inertia of body A: Inertia of body B :: m:2m or 1:2

(ii) Comparing momentum of both bodies
Momentum of body A = m(2v) = 2mv
Momentum of body B = (2m)v= 2mv
Momentum of body A: Momentum of body B :: 2mv:2mv or 1:1

(iii) Comparing the force needed to stop both the bodies at the same time
Rate of momentum change is directly proportional to the force applied on a body as per Newton's second law of motion. Hence;
Force required to stop A: Force required to stop B:: 1:1

7. **State Newton's second law of motion. What information do you get from it?**

Solution:

Newton's second law of motion states that:
The rate of change of momentum of a body is directly proportional to the force applied on it and the change in momentum takes place in the direction in which the force is applied.
Newton's second law of motion provides the quantitative value of force. We could relate the physical quantity force to the other measurable quantities such as mass and acceleration.

8. **How does Newton's second law of motion differ from first law of motion?**

Solution:

The differences are as given below:

Newton's First law of motion	Newton's second law of motion
The first law provides qualitative definition of force	The second law provides quantitative value of force
It demonstrates the force as cause of acceleration	It presents force as product of mass and acceleration, thereby relating force to measureable quantities such as mass and acceleration

9. Write the mathematical form of Newton's second law of motion. State condition if any.

Solution:

Newton's second law of motion can be expressed mathematically as follows:

F=ma

where 'F' is the force applied on a body having mass 'm' and acceleration 'a'. The force produces acceleration in the body due to which the velocity and hence the momentum of the body changes.

For the relation to hold well, two conditions are needed:

- Velocities must be much smaller than the velocity of light
- Mass of the body remains constant.

10. State Newton's second law of motion. Under what condition does it take the form F=ma?

Solution:

Newton's second law of motion states that:

The rate of change of momentum of a body is directly proportional to the force applied on it and the change in momentum takes place in the direction in which the force is applied.

For the relation to hold well, two conditions are needed:

- Velocities must be much smaller than the velocity of light
- Mass of the body remains constant.

11. How can Newton's first law of motion be obtained from the second law of motion?

Solution:

To obtain Newton's first law of motion from second law of motion:

From Newton's second law, F=ma

If F=0, then a =0;

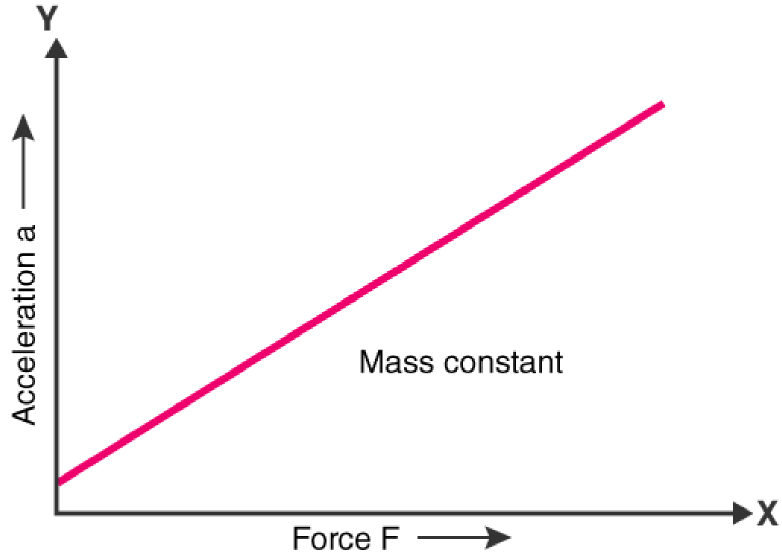
This implies that when force is not applied on a body, the acceleration will be zero. If the body is at rest, it will continue to stay at rest, when it is moving, it will continue to move in the same direction with the same speed.

Hence, a body not acted upon by an external force, does not change its state of rest or motion which is the statement of Newton's first law of motion.

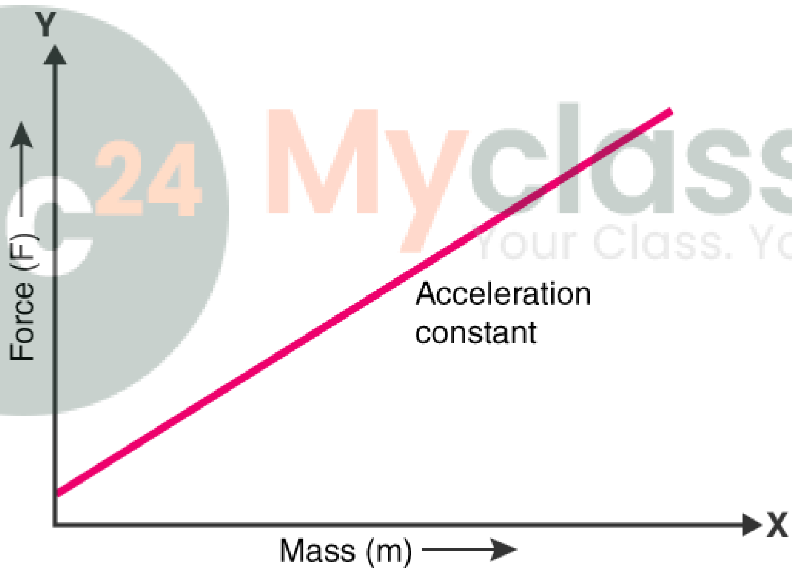
12. Draw graphs to show the dependence of (i) acceleration on force for a constant mass, and (ii) force on mass for a constant acceleration.

Solution:

(i) The following graph shows the acceleration on force for a constant mass



(ii) The following graph shows force acting on mass for a constant acceleration



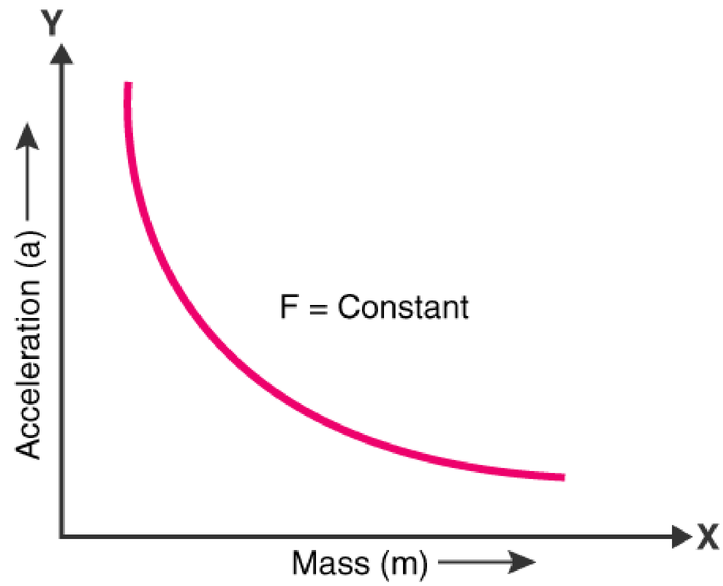
(iii)

13. How does the acceleration produced by a given force depend on mass of the body? Draw a graph to show it.

Solution:

If a force is applied on two bodies that have different masses, then the acceleration that is produced by them varies inversely to their individual masses.

When a graph for mass against acceleration is sketched, a hyperbola is obtained.



14. Name the S.I. unit of force and define it.

Solution:

The S.I unit of force is newton.

One newton is the force which when acts on a body of mass 1kg, produces an acceleration of $1 m/s^2$. i.e., 1 newton=1 kg x $1 m/s^2$

15. What is the C.G.S unit of force? How is it defined?

Solution:

The C.G.S unit of force is dyne. One dyne is the force which when acts on a body of mass 1g, produces an acceleration of $1 cm/s^2$. i.e., 1 dyne=1gx$1 cm/s^2$

16. Name the S.I. and C.G.S units of force. How are they related?

Solution:

S.I. unit of force is newton, C.G.S. unit of force is dyne.

Relationship between newton and dyne:

1 newton = 1 kg x $1 m/s^2$

= 1000g x $100 cm/s^2$ = 10^5 g x cm/s^2

= 10^5 dyne

17. Why does a glass vessel break when it falls on a hard floor, but it does not break when it falls on a carpet?

Solution:

The glass vessel comes to rest almost immediately when it falls from a height on a hard floor. Hence the floor applies a huge force on the vessel causing it to break. But, if the glass vessel falls on a carpet, the time period at which the vessel comes to rest escalates hence the carpet applies lesser force in the vessel and hence it does not break.

18. Use Newton's second law of motion to explain the following:
(a) A cricketer pulls his hands back while catching a fast moving cricket ball.
(b) An athlete prefers to land on sand instead of hard floor while taking a high jump.

Solution:

(a) It is because while doing so, time of catching the ball can be increased. In other words, to increase the time to bring about a given change in momentum consequently rate of change of momentum decreases. Hence the ball exerts a small amount of force on our hands.

(b) When an athlete is landing from a height on a hard floor, his feet immediately come to rest which causes a very large force to be exerted on his feet by the floor. In case he lands on sand, for some distance, his feet pushes the sand hence the time period in which the feet comes to halt increases. Consequently, he is saved from getting hurt as the force exerted on his feet decreases.

Multiple choice type

1. The linear momentum of a body of mass m moving with velocity v is:
(a) v/m
(b) m/v
(c) mv
(d) 1/mv

Solution:

(c) mv

Linear momentum can be defined as the product of mass and velocity of an object.

2. The unit of linear momentum is:
(a) Ns
(b) kg ms^{-2}
(c) Ns^{-1}
(d) kg^2 ms^{-1}

Solution:

(a) Ns

3. The correct form of Newton's second law is:
(a) $F = \frac{\Delta p}{\Delta t}$
(b) $F = m\frac{\Delta}{\Delta t}$
(c) $F = v\frac{\Delta m}{\Delta t}$
(d) F = mv

Solution:

(a) $F = \frac{\Delta p}{\Delta t}$

Where motion or momentum changes either due to change in velocity or change in mass or both.

4. The acceleration produced in a body by a force of given magnitude depends on

(c) Size of the body
(d) Shape of the body
(e) Mass of the body
(f) None of these

Solution:
(c) Mass of the body
F=ma; Force applied on a body depends on the mass of the body.

Numericals:

1. **A body of mass 5kg is moving with velocity 2m/s. Calculate its linear momentum.**
   Solution:
   Given: velocity=2m/s; mass=5kg
   Linear momentum = mv = 5x2 =10kg m/s

2. **The linear momentum of a ball of mass 50g is 0.5kg m/s. Find its velocity.**
   Solution:
   Given: mass=50g or 0.05kg; linear momentum =0.5 kg m/s, v=?
   Linear momentum = mv
   0.5=0.05 x v
   v=0.5/0.05
   v=10m/s

3. **A force of 15N acts on a body of mass 2kg. Calculate the acceleration produced.**
   Solution:
   Given: F=15N, m=2kg, a=?
   F=ma => a = F/m
   = 15/2 = 7.5m/s^2

4. **A force of 10N acts on a body of mass 5kg. Find the acceleration produced.**
   Solution:
   Given: F=10N, m=5kg, a=?
   F=ma => a=F/m
   =10/5=2 m/s^2

5. **Calculate the magnitude of force which when applied on a body of mass 0.5kg produces an acceleration of 5m/s^2.**
   Solution:
   Given: F=? m=0.5kg, a=5m/s^2
   F=ma
   = 0.5 x 5
   = 2.5N

6. **A force of 10N acts on a body of mass 2kg for 3s, initially at rest. Calculate: (i) the velocity acquired by the body, and (ii) change in momentum of the body.**
   Solution:

Given: F=10N, m=2kg, t=3s; initial velocity u=0m/s

(i) To find final velocity v;
F=ma
$a=F/m = 10/2=5m/s^2$
We know the 1st equation of motion;
v=u+at
=0+(5x3)
v=15m/s

(ii) To find change in momentum
Momentum change = final momentum – initial momentum
Δp=m(v-u)
=2(15-0) = 30 kg m/s

7. A force acts for 10s on a stationary body of mass 100kg after which the force ceases to act. The body moves through a distance of 100m in the next 5s. Calculate: (i) the velocity acquired by the body, (ii) the acceleration produced by the force, and (iii) the magnitude of the force.

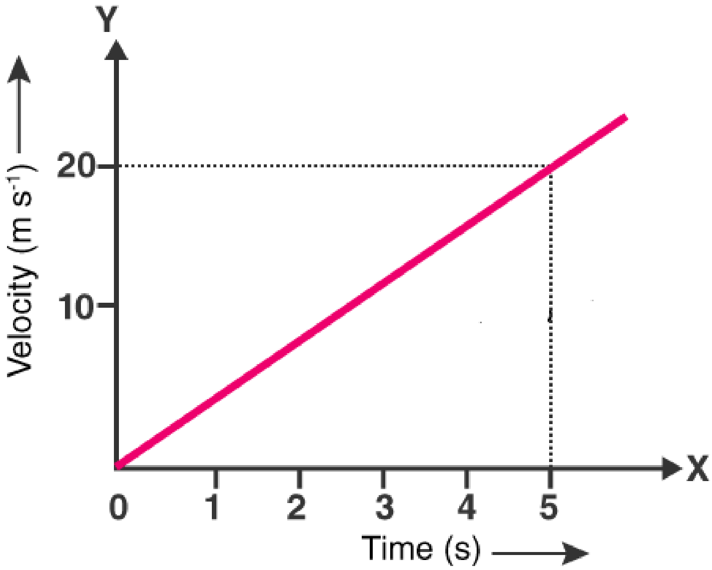
Solution:
Given: m=100kg, initial velocity u =0, distance covered s=100m;

(i) Velocity of the body= distance covered/time
= 100/5 = 20m/s

(ii) Acceleration can be found using the equation of motion,
$v^2-u^2=2as$
$a=(v^2-u^2)/2s$
$= (20^2 – 0^2)/ 2 \times 100$
$a= 2m/s^2$

(iii) Force = ma
= 100 x 2
= 200N

8. Figure shows the velocity-time graph of a particle of mass 100g moving in a straight line. Calculate the force acting on the particle.



(Hint: acceleration = slope of v-t graph)

Solution:
Given: m=100g or 0.1kg
Value of acceleration can be obtained by the slope of velocity-time graph.
Acceleration = Slope = 20/5 = 4ms^{-2}
Force = ma
= 0.1 x 4 = 0.4N

9. A force causes an acceleration of 10m/s^2 in a body of mass 500g. What acceleration will be caused by the same force in a body of mass 5kg?

Solution:
Given: a=10m/s^2, m=500g or 0.5kg
We know that; F=ma
= 0.5 x 10
= 5N
To find acceleration caused by 5N force on a body having mass=5kg
a=F/m
=>5/5 = 1m/s^2

10. A force acts for 0.1s on a body of mass 2kg initially at rest. The force is then withdrawn and the body moves with a velocity of 2m/s. Find the magnitude of force.

Solution:
Given: u=0, t=0.1s, m=2kg, final velocity v = 2m/s; F=?
We know that acceleration is the rate of change of velocity
Acceleration = (v-u)/t
= (2-0)/0.1
= 20m/s^2
Force = ma
= 2 x 20

= 40N

11. A body of mass 500g, initially at rest, is acted upon by a force which causes it to move a distance of 4m in 2s, Calculate the force applied.

Solution:

Given: m=500g or 0.5kg, u=0; s=4m; t=2s, F=?

We know that, $S=ut+1/2\ at^2$

$4=(0)(2)+1/2(a)(2)^2$

$4=0+2a$

$a=2m/s^2$

Force = mass x acceleration

=0.5 x 2

= 1N

12. A car of mass 480kg moving at a speed of 54km/h is stopped by applying brakes in 10s. Calculate the force applied by the brakes.

Solution:

Given: m=480kg, initial velocity, u=54km/h or 15m/s, final velocity, v=0m/s, t=10s, F=?

We know that acceleration is the rate of change of velocity

∴ acceleration = (v-u)/t

= (0-15)/10

= $-1.5m/s^2$

The negative sign shows that it is retardation.

Force = m x a

= 480 (-1.5)

= 780N

13. A car is moving with a uniform velocity of 30m/s. It is stopped in 2s by applying a force of 1500N through its brakes. Calculate: (a) the change in momentum of car, (b) the retardation produced in car, and (c) the mass of the car.

Solution:

Given: t=2s, F=1500N, u=30m/s, v=0m/s,

acceleration = (v-u)/t

= (0-30)/2 = $-15m/s^2$

The negative acceleration just indicates retardation.

Force = mass x acceleration

⇨ Mass = force/acceleration

⇨ = 1500/(15)

= 100kg

(a) To find change in momentum

Change in momentum = final velocity – initial velocity or Δp = m(v-u)

Δp = 100(0-30)

= 3000 kg m/s

(b) Retardation produced in car

We know that retardation is negative acceleration

∴acceleration = (v-u)/t

= (0-30)/2 = $-15m/s^2$

Retardation is $15m/s^2$

(c) Mass of the car

As per newton's second law of motion,

Force = mass x acceleration

⇨ Mass = Force/acceleration

⇨ = 1500/15

⇨ = 100kg

14. A bullet of mass 50g moving with an initial velocity of 100m/s , strikes a wooden block and comes to rest after penetrating a distance 2cm in it. Calculate : (i) initial momentum of the bullet (ii) final momentum of the bullet, (iii) retardation caused by the wooden block, and (iv) resistive force exerted by the wooden block

Solution:

Given: m=50g or 0.05kg, u=100m/s, v=0m/s, s=2cm or 0.02m

(i) Initial momentum of the bullet = mu

= 0.05 x 100 = 5m/s

(ii) Final momentum of the bullet = mv

= 0.05 x 0 = 0 m/s

(iii) Retardation caused by the wooden block

Retardation is negative acceleration.

We know from the equation of motion that,

$v^2-u^2=2as$

$0^2 - (100)^2 = 2a(0.02)$

(100 x 100)/0.04= 0.04a

$a = -2.5 \times 10^5\ m/s^2$

(iv) Force = mass x acceleration

$= 0.05 \times (2.5 \times 10^5)$

= 12500N