FORCE AND LAWS OF MOTION

Force: It is defined as the external effort done by a body on some other body which stops or tends to stop, move or tend to move, change the direction or tend to change the direction, change the speed or tend to change the speed, change the shape or tend to change the shape of that body.

Types of forces

1) Balanced forces
2) Unbalanced forces

Balanced forces:

If the result of all the forces acting on a body is zero than that force is known as balanced force.

- So under balanced force a body is at rest will remain at rest will remain at rest. A body is in motion will remain in that motion, a body in specific direction will remain in that direction.
- But balanced forces can change the shape of a body on which it is action.

Unbalanced force:

If the result of all the forces acting on a body is not equal to zero than it is said to be an unbalanced force.

- It can change the state of rest or motion or direction.
- But it cannot change the shape.

Newton's first law of motion:

According to Newton's first law of motion a body is in rest will remain at rest or a body in motion will remain in that motion and body is in specific direction will remain in same direction until and unless any external unbalanced force is applied to it.

Inertia and mass:

Inertia of a body is the property due to which it opposes any change in its state of rest, motion or direction. Thus Newton's first law defines inertia and is rightly called law of inertia.

And if we have greater mass it has more ability to resist its start and if it has less mass it has less ability to resist. Hence, we conclude mass of a body is a measure of inertia of the body.

Three types of inertia:

1) Inertia of rest
2) Inertia of motion
3) Inertia of direction

Inertia of rest:

It is the property of a body which resist the change in state of rest masses a body at rest will remain at rest and cannot start moving on its own. Rather a body at rest opposes the forced which try to make it move.

Inertia of motion:

It is the property of a body which resist any change in its state of motion means a body in motion will remain in motion and cannot stop by its own. Rather a body at motion opposes the force which tries to make it rest.

Inertia of direction:

It is the property of a body which resist any change in its state of direction means a body in specific direction will remain in that direction and cannot change it by its own. Rather a body in specific direction opposes the force which tries to change its direction.

Linear momentum:

It is defined as the product of mass and velocity. It is denoted as p.

Its formula:

Linear momentum = mass x velocity

- P = mv
- Its S.I. unit is Kgm/s.
- It is a vector quantity.

Newton's second law of motion:

According to Newton's second law of motion the external force applied on an object is directly proportional to the rate of change in its momentum and this change take place always in the direction of the applied force.

This above law also helps us to find the formulae for force.

So,

Let there be the force 'F' which is applied to an object whose mass is 'm' for time't'. In this time it changes its velocity 'u' to 'v'.

So, initial linear momentum $p_1 = mu$

Final linear momentum $p_2 = mv$

So, as per law,

$$\text{Force} \propto \frac{change\ in\ momentum}{time}$$

$$F \propto \frac{P2-P1}{t}$$

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

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

As we know $\frac{v-u}{t} = a$

$$F \propto ma$$

$$F = kma$$

Where *k* is proportionality constant and $k = 1$

$$\therefore F = ma\ ;$$

Hence, force acting on a moving body is product of mass and acceleration.

- Its S.I. unit is Newton denoted by 'N'.
- It is a vector quantity and its direction is same as that of acceleration's direction of body
- One Newton force is defined as a body of 1Kg mass is being accelerated by 1m/s^2.

Some applications of Newton's second law of motion:

1) Catching a cricket ball.
   To catch a fast cricket ball, a player pulls his hand backward to prevent the injury to his hand. By doing this it increases the time during which high velocity of cricket ball reduces to zero.
   By formulae,
   $$F = \frac{m(v-u)}{t}$$
   You can see force is acting inversely proportional to time.
   Therefore, we increase the time it reduces the force and hence reduces its effect on our hand.
2) High jump.

During high jump athlete are made to fall on a cushioned bed or on a sand bed. By doing this we increase the time to get athlete touch to ground or you can say time increases for high velocity of athlete to reduce to zero, because sooner he touches the ground sooner his velocity will become zero. Later his velocity will take time to get to zero. So again it would decrease the rate of change of momentum. So did the force, thus injury to the athlete is thus avoided.

3) Use of seat belts in car.
In case of accident and sudden applications of breaks in both the cases large momentum of car reduces to zero in very short interval of time and stretchable safety belts worn by the passengers of car exerts a force on their body and make forward motion slower. The time taken by passenger to fall forward increases and hence stopping force acting on passenger reduced.

Newton's first law of motion is a special case of Newton's second law of motion:

According to Newton's second law

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

So, $F \times t = m(v-u)$ … (i)

As per Newton's first law of motion. If no external force is provided to it.

$$F = 0 \quad \text{… (ii)}$$

Put (ii) into (i)

$$0 \times t = m(v-u)$$

$$0 = mv - mu$$

$$mu = mv$$

$$v = u$$

And if no external force is provided body will move with the uniform velocity.

Further, if $u = 0$ then v will be also 0. It means if body is initially at rest will continue to be at rest, when no external force is applied on the body.

SOLVED PROBLEMS

Q.1. What is acceleration produced by a force of 12N, exerted on the object of mass 3 kg?

Ans. m = 3Kg

F = 12N

F = ma

a = F/m =12/3 = 4m/s^2

Q.2. What force will be needed to produce an acceleration of 4m/s^2 on a ball of mass 6Kg?

Ans. m = 6Kg

a = 4m/s^2

F = ma = 6 x 4 = 24N

Q.3. A force of 5N gives a mass m_1 , an acceleration of 8m/s^2, and a mass m_2, an acceleration of 24m/s^2. What acceleration would it give if both the mass are held together?

Ans.

Case I	**Case II**	**Case III**
F = 5N	F = 5N	F = 5N, a = ?
$m = m_1$	$m = m_2$	$m = m_1 + m_2 = 5/8 + 5/24$
a = 8m/s^2	a = 24m/s^2	m = 20/24
F = ma	F = ma	F = ma
$5 = m_1 \times 8$	$5 = m_2 \times 24$	5 = (20/24) x a
$m_1 = 5/8$	$m_2 = 5/24$	$a = \frac{5 \times 24}{20}$ = 6m/s^2

Q.4. A motorcycle is moving with a velocity of 90 Km/h and it takes 5 seconds to stop after the breaks are applied. Calculated the force applied if the mass of motorcycle along with rider is 200Kg?

Ans. F = ?

m = 200Kg

u = 90 Km/hr. = 25m/s

v = 0

t = 5s

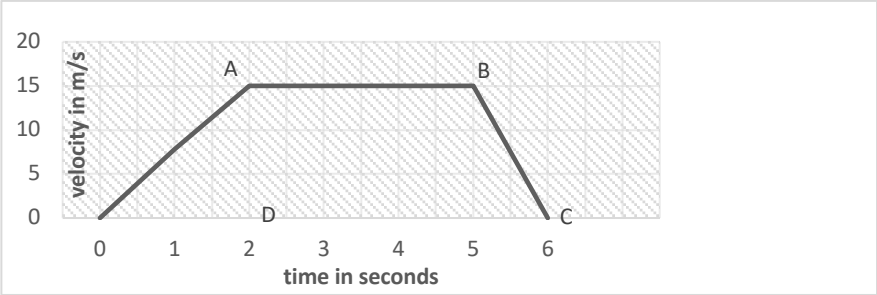
F = ma

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

$F = \frac{200(0-25)}{5}$

F = -1000N

(-) sign indicate that force applied in the opposite direction of the motion.



Q.5. Speed-time graph of a car weigh 1000Kg is given along side.

a) **What is the distance travelled by the car in first 2 second?**
b) **What is the breaking force applied at the end of 5sec to bring the car to stop in 1 sec?**

Ans.

(a) m = 1000Kg
s = ? in first two seconds
Area of triangle OAD = $\frac{1}{2} \times base \times height = \frac{1}{2} \times 2 \times 15$
= 15 m

(b) F = ?
m = 1000Kg
t = 1 sec at the end
u = 15m/s
v = 0
F = ma
$= \frac{m(v-u)}{t}$

$= \frac{1000(0-15)}{1}$

= 1000(-15)
= -15000N
(-) sign indicates that the force applied in the opposite direction of the motion.

Q.6. Calculate the force required to import a car a velocity of 30m/s in 10 seconds. The mass of car is 1500Kg.

Ans. m = 1500Kg

u = 0m/s

v = 30m/s

t = 10 sec

F = ma

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

$= \frac{1500(30-0)}{10}$

= 150 x 30

= 7500N

The direction of force is in the same direction of acceleration or motion.

SKILLS ASSESMENT - 1

Q.1) What is the momentum of a mass 75Kg when he walks with velocity of 2m/s? Ans:150kgm/s

Q.2) What would be the force required to produce on acceleration of 2m/s^2 in a body of mass 12 Kg? What would be the acceleration if the force were doubled? Ans:24N, 4m/s^2

Q.3) A man pushes a box of mass 50 Kg with a force of 80 N. what will be the acceleration if the mass were halved? Ans:3.2m/s^2

Q.4) A certain force exerted for 1.2 sec raises the speed of an object from 1.8 m/s to 4.2 m/s. later the same force is applied for 2 seconds. How much does the speed changes for 2 seconds? Ans:4m/s^2

Q.5) A constant force acts on an object of mass 5 Kg for a duration of 2 seconds. It increases the objects velocity from 3m/s to 7m/s. Find the magnitude of the applied force. Now if the force were applied for duration of 5 sec. What would be the final velocity of the object?

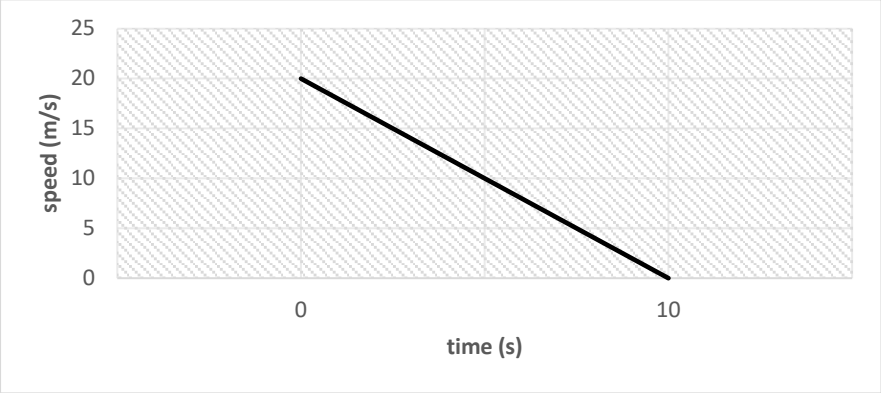
Ans:10N, 13m/s

Q.6) Which would require a greater force: accelerating 2Kg mass at 5m/s^2 or a 4 kg mass at 2m/s^2? Ans:2kg object

Q.7) A motorcar is moving with a velocity of 108Km/h and it takes 4 seconds to force exerted by the breaks on the motor car if its mass along with the passenger is 1000Kg? Ans:-7500N

Q.8) **A force of 5 N gives a mass m_1, an acceleration of $10m/s^2$ and a mass m_2, an acceleration of 20 m/s^2. What acceleration would it give if both the masses were tied together? Ans:$6.67m/s^2$**

Q.9) **The velocity time graph of a ball of mass 20g moving along a straight line on a long table is given in fig. how much force does the table exert on a ball to bring it to rest. Ans:-0.04N**



Q.10) **For how long should a force of 100N act on a body of mass 20 Kg so that it acquires a velocity of 100m/s? Ans:20s**

Q.11) **A 150g ball travelling at 30m/s strikes the palm of a player's hand and is stopped 0.06sec. Calculate the force exerted by the ball on the hand.**

Ans:-75N

Q.12) **A body of mass 1 Kg is kept at rest. A constant force 6 N starts acting on it. Find the time taken by the body to move through a distance of 12 m. Ans:2s**

Q.13) **A feather of mass 10 mg dropped from height it is found that it moves with uniform velocity. Why is not force acting on it?**

Q.14) **A force of 4 N acts on a body of mass 2 Kg for 4 sec. Assuming body to be initially at rest. Find**

(a) Final velocity and (b) its distance covered in 10 sec after the force starts acting. Ans:$8m/s^2$, 64m

SKILLS ASSESMENT - 2

Q.1. **What name is given to the product of mass and velocity of a body?**

Q.2. **Name the physical quantity which s considered to be a measure of the quantity of the motion of a body.**

Q.3. **What is the total momentum of the bullet and the gun before firing?**

Q.4. **Name the physical quantity whose unit is kgm/s.**

Q.5. **What is the usual name of the force which cannot produce motion in a body but only change its shape?**

Q.6. **Name the unbalanced force which slows down a moving bicycle when we stop paddling it.**

Q.7. State that the statement is true or false: "Unbalanced forces acting on a body changes its shape."

Q.8. When a ball is dropped from a height, its speed increase gradually. Name the force which causes this change in speed.

Q.9. Name the property of bodies to resists a change in their state of rest or of motion.

Q.10. What is the other name of Newton's first law of motion?

Q.11. With which physical quantity the speed of a running ball is multiplied so as to obtain it momentum.

Q.12. Fill in the blanks:

a. **_____ is a measure of the inertia of a body.**
b. **When a running car stops suddenly, the passengers are jerked _____.**
c. **When a stationary car starts suddenly, the passengers are jerked _____.**
d. **If there were no unbalanced forces of _____ and no _____ resistance a moving bicycle would go on moving forever.**

Q.13. Explain why, it is easier to stop a tennis ball than a cricket ball moving with the same speed.

Q.14. Explain how, a karate player can break a pile of tiles with a single blow of his hand?

Q.15. State Newton's first law of motion. Give two examples to illustrate Newton's its law of motion.

Q.16. On what factor does the inertia of a body depends? Which has more inertia a cricket ball or a rubber ball of same size?

Q.17. Why do the passengers in a bus tend to fall backward when it starts suddenly?

Q.18. Explain why, passengers in a bus fall forward when the bus stops suddenly?

Q.19. Give reason that why dust particles come out of carpet when hanging carpet is beaten with a stick.

Q.20. When tree is shaken its fruit and leaves fall down. Why?

Q.21. Explain why, it is dangerous to jump out of a moving bus?

Q.22. State various effects of forces.

Q.23. Give one example of each.

a. **A force moves a stationary body.**
b. **A force stops a moving body.**
c. **Force changes the speed of a body.**
d. **Force changes the direction of moving body.**
e. **Force changes the shape of a body.**

Q.24. Which type of forces – balanced or unbalanced, act on a rubber ball when it presses it between out bands? What effect it produces to it?

Q.25. Give reasons:

a. **What happens to a passenger travelling in a bus when it takes the sharp turn?**
b. **Why are road accidents at high speeds very much worse than road accidents at low speed?**

Q.26 A plastic ball and a clay ball of equal masses, travelling in the same direction with equal speeds, strike against a vertical wall. From which ball does the wall receive greater amount of momentum?

Q.27 A moving bicycle comes to rest after sometime if we stop paddling it. But Newton's first law of motion says that a moving body should continue to move for ever unless some external force acts on it. How do you explain the bicycle case?

Q.28 A man throws a ball weighing 500g vertically upwards with a speed of 10m/s.

a. **What will be its initial momentum?**
b. **What could be its momentum at the highest point of its flight?**

Q.29 A car is moving on a level road. If the driver turns off the engine of the car, the car's speed decreases gradually and ultimately it comes to rest. A student says that two forces act o the car which bring it to a rest. What could these forces be? Which of these two forces contributes more to down and stop the car?

Q.30 There are two types of forces X and Y. The forces belonging to type X can produce motion in a stationary object but cannot change the shape of the object. On the other hand, a forces belonging to type Y cannot produces motion in a stationary object but can change the shape of the object. What is the general name of the forces such as X and Y?

Newton's third law of motion:

According to Newton's third law of motion every action in this universe always has an equal and opposite reaction i.e., the force of action and reaction are always equal in magnitude and opposite in direction.

- These forces act on two different objects and never cancel each other. So each force, reaches its own effect.

Further, although action and reaction forces are always equal in magnitude, yet these forces may not produce acceleration of equal magnitude, because both acts on different bodies which may have different mass.

Some applications of Newton's third law of motion:

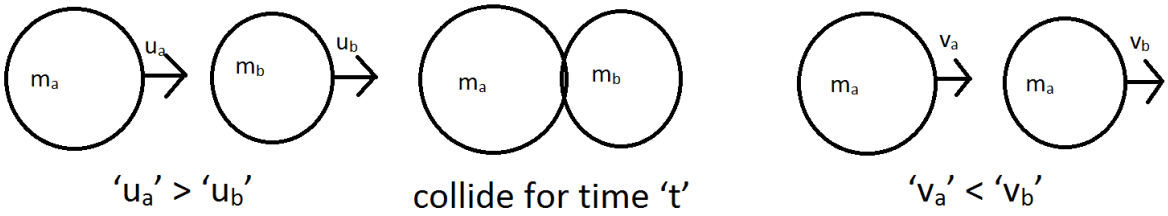
1. **Walking.**
   To walk on ground, we push the ground backward with our foot forward with the same force. So it is the forward reaction force of a ground that enables us.
2. **Swimming.**
   While trying to swim, a swimmer pushes the water backward with her hands and feet. This is the force of action. The water pushes the swimmer forward with the same force (of reaction).
3. **Recoiling of gun.**
   When a bullet is fixed from a gun, the gun recoil i.e. gun moves backward with small distance, this is because on firing, the gun exerts same force on the bullet (i.e. action) in forward direction. In turn, the bullet exerts an equal force on the gun (i.e., reaction) in with small distance because gun is much heavier than bullet.
4. **Man and boat.**
   Suppose a sailor is in a boat at rest near a river bank. As a sailor jumps from the boat to the river bank, the boat is pushed away from the bank. This happens due to equal force of action and reaction.
5. **Flying of rockets.**
   In a rocket, the final burnt appears in the force of hot and highly composed gasses. They are made to escape through the nozzle in the downward direction. As a reaction, the rocket moves upward with the same force.
6. **The case of hose pipe.**
   As water rushes out at a great spread from the hose pipe in the forward direction (action), the hose pipe tends to move backwards due to an equal force of reaction.

Law of conservation of linear momentum.

When two or bodies interact with one another the vector sum of their linear momentum remains constant (i.e. is conserved), and is not affected due to their mutual action and reaction. The only condition is that no external unbalanced force should be acting on the system of bodies.

We can prove the above law by taking the ideal collision scenario.

Let there are two bodies of mass 'm_a' and 'm_b' respectively moving with initial velocity 'u_a' and 'u_b' where 'u_a' is greater than 'u_b' in straight line in same direction after some time they will collide for time 't' and then again start moving with final velocities 'v_a' and 'v_b' where 'v_a' is greater than 'v_b' in straight line in same direction respectively.



Mass of a is 'm_a'.

Initial velocity 'u_a'.

Final velocity 'v_a'.

Time taken to change velocity to collide at time that is 't'.

Force exerted on 'a'.

$F_a = m_a(v_a - u_a)/t$

According to Newton's third law of motion, force of action is equal and opposite to force of reaction.

So,

$F_a = -F_b$

$m_a(v_a - u_a)/t = -m_b(v_b - u_b)/t$

$m_av_a - m_au_a = - m_bv_b + m_bu_b$

$m_av_a + m_bv_b = m_au_a + m_bu_b$

Total final momentum of two bodies = total initial momentum of two bodies

Hence, law of conservation is satisfied.

SOLVED PROBLEMS

Q.1. When two bodies A and B interact with each other, A exerts a force of 10N on B, towards east. What force exerted by B on A?

Ans. Force exerted by B on A i.e. F_{BA} = 10N (towards east)

Force exerted by B on A i.e. F_{AB}=?

$F_{BA} = - F_{AB}$

$10 = - F_{AB}$ i.e. $F_{AB} = -10N$.

(-) sign indicates the opposite direction means towards west.

Q.2. A 10g bullet is sot from a 5 kg gun with a velocity of 400 m/s. What is the speed of recoil of gun after it fires?

Ans. $m_b = 10g = 0.01kg$

$m_a = 5kg$

u_b = initial velocity of bullet before it fires = 0 m/s

v_b = final velocity of gun before it fires = 0 m/s

v_g = final velocity of gun after it fires = ?

(Recoiling speed of gun)

1st way.

Total momentum of gun and bullet of her firing = total momentum of gun and bullet before firing

(i.e. by law of conservation of momentum)

$M_g v_g + m_b v_b = m_g u_g + m_b u_b$

$(0.01)(400) + 5v_g = (0.01)(0) + 5(0)$

$4 + 5v_g = 0$

$V_g = -4/5 = -0.8m/s$

(-) sign indicates that gun moves in opposite direction to the bullet after firing.

Or you can recoil of gun is in opposite direction to bullet.

2nd way, just ask me in class.

Q.3. A man weighing 60 kg runs along the rails with a velocity of 18 km/hr and jumps into a car of mass 1 quintal standing on the rail calculate with which velocity car will starts travelling along the rails?

Ans. $m_m = 60kg$

m_c = 1 quintal = 100kg

$u_m = 18km/hr = 5m/s$

$u_c = 0m/s$

$v_m = v_c = v$

By law of conservation of momentum.

Total initial momentum of car and man = total final momentum of car and man

$m_m v_m + m_c v_c = m_m u_m + m_c u_c$

$60(5) + 100(0) = 60\ v + 100v$

$300 = 160\ v$

$V = 300/160$

$v = 1.88 m/s$

So it will move with above magnitude. And (+) sign indicates that in the same direction in which man was moving.

Q.4. The car A of mass 1500 kg, travelling at 25m/s collide with another car B of mass 1000 kg travellingat 15m/s in the same direction. After collision the velocity of car A becomes 20m/s. Calculate the velocity of car B after collision.

Ans. $m_a = 1500$ kg

$m_b = 1000$ kg

u_a = initial velocity or velocity of 'a' before collision = 25m/s

u_b = initial velocity or velocity of 'b' before collision = 15m/s

v_a = final velocity or velocity of 'a' after collision = 20m/s

v_b = final velocity or velocity of 'b' after collision = ?

Law of conservation of momentum.

Total momentum of 'a' and 'b' before collision = total momentum of 'a' and 'b' after collision.

$m_a u_a + m_b u_b = m_a v_a + m_b v_b$

$1500(25) + 1000(15) = 1500(20) + 1000\ (v_b)$

$37500 + 15000 = 30000 + 1000 v_b$

$v_b = (52500 – 30000)/1000$

$v_b = 22500/1000$

$v_b = 22.5 m/s$

Q.1) **A bullet of mass 50g is fixed from a gun of mass 6kg with a velocity at 400m/s. Calculate the recoil velocity of the gun. Ans:-3.34m/s^2**

Q.2) **A machine gun fires 25g bullet at the rate of 600 bullets per minute with a speed of 200m/s. Calculate the force required to keep the gun in position. Ans:50N**

Q.3) **A boy pushes a wall with a force of 20N. What is the magnitude and direction of the force experienced by the boy? Ans:-20N**

Q.4) **A bullet of mass 20g moving with a velocity of 300m/s gets embedded in a freely suspended wooden block of mass 880g. What is the velocity acquired by the block? Ans:6.67m/s^2**

Q.5) **A girl of mass 50kg jumps out of a rowing boat of mass 300kg on the bank with a horizontal velocity of 3m/s. With what velocity does the boat begin to move backward? Ans:0.5m/s^2**

Q.6) **A boy of mass 60kg running at 3m/s jumps on to the trolley of mass 140kg moving with a velocity of 1.5m/s in the same direction. What is their common velocity? Ans:1.95m/s**

Q.7) **A bullet of mass 29g is fixed horizontally with a velocity of 150m/s from a pistol of mass 2kg. What is the recoil velocity of the pistol?**
Ans:2.175m/s

Q.8) **A truck of mass 2500 kg moving at 15m/s collide with a car of mass 1000kg moving with a velocity 5m/s in the opposite direction. With what velocity would the two moves together. Ans:9.29m/s**

Q.9) **A man wearing a bullet proof vest stands still on roller skater. The total mass is 80kg. A bullet of mass 20g is fixed at 400m/s. It is stopped by the vest and falls to the ground. What is then the velocity of the man?**
Ans:0.1m/s

Q.10) **A heavy car A of mass 2000kg travelling at 10m/s has a head-on collision with a sports car B of mass 500kg. If both the car stops dead on colliding. What was the velocity of car B.? Ans:40m/s**

Q.11) **A ball X of mass 1kg travelling at 2m/s has a head on collision with an identical ball Y at rest. X stops and Y moves off. Calculate the velocity of Y after the collision. Ans:2m/s**

Q.12) **An unloaded truck weighing 2000kg has a maximum acceleration of 0.5m/s^2. What is the maximum acceleration when it is carrying 2000kg load? Ans:0.25m/s^2**

Q.13) **A girl of mass 40kg jumps with a horizontal velocity of 5m/s onto a stationary cart with frictionless wheels. The mass of the cart is 3kg. What is her velocity as the cart starts unbalanced force working in the horizontal direction. Ans:200/43m/s**

Q.14) **Two hockey payers of opposite team while trying to hit a ball on the ground collide and immediately become entangled. One has a mass of 60kg and was moving with velocity 5m/s while other of mass 55kg and was moving with velocity 6m/s towards the first player. In which direction and with what velocity will they move**

after they become entangled?
Ans:0.27m/s

SKILLS ASSESMENT - 4

Q.1) **Which physical quantity corresponds to the rate of change of momentum?**
Q.2) **Define one Newton's force?**
Q.3) **What is the relationship between force and acceleration?**
Q.4) **If the mass of the body and the forceacting on it are both doubled, what happens to the acceleration?**
Q.5) **Which physical principle is involved in the working of jet aeroplane?**
Q.6) **Is the following statement true or false?**
A rocket can propel itself in vacuum.
Q.7) **Name physical quantity which makes it easier to accelerate a small car than a large car.**
Q.8) **Fill in the blanks.**
- **a) Newton's second law of motion can be written as force = mass x _____ or force = _____ of change of _____.**
- **b) In collision and explosion the total _____ remains constant, provided that an external _____ acts.**

Q.9) **Explain the meaning of the following equation**
F = m x a
Where the symbols have their usual meanings.
Q.10) **To take a boat away from the blank with an oar, why?**
Q.11) **Why does a gunman get a jerk on firing a bullet?**
Q.12) **If action is always equal to reaction, explain why cart pulled by a horse can be moved?**
Q.13) **Explain how a rocket works?**
Q.14) **Do actions and reactions act on the same body or different bodies? How are they related in magnitude and direction? Are they simultaneous or not?**
Q.15) **If a man jumps out from a boat, the boat moves backward. Why?**
Q.16) **Why it is difficult to walk on sleepy road?**
Q.17) **Explain why runner presses the ground with his feet before he starts his race?**
Q.18) **Name the laws involved in the following statements:**
- **a) The sum of product of mass and velocity of two moving bodies before and after their collision remains constant.**
- **b) A body of mass 5kg can be accelerated more easily by a force than another body of mass 5kg under similar condition.**
- **c) If there were no friction and no resistance in air then a moving bicycle would go on moving forever.**
- **d) When personA standing on a roller skates pushes another person B (also stands on same) make him move to the right side, then person A himself moves to the left side by an equal distance.**

Q.19) **State and explain Newton's second law of motion.**

Q.20) Explain why a cricket man moves his hands backwards wile catching a fast cricket ball.

Q.21) State Newton's third law of motion and give two examples to illustrate the law.

Q.22) Explain why, when a fireman directs a powerful stream of water on a fire from a hose pipe, the hose pipe tends to go backward.

Q.23) Explain:

a) State the law of conservation of momentum.

b) Discuss the conservation of momentum in each of the following cases:

i. The rocket taking off from ground.

ii. Flying of a jet aeroplane.

Q.24) If a balloon filled with air and its mouth is untied, is released with its mouth in the downward direction, it moves upwards. Why?

Q.25) Why are car seat belts designed to stretch somewhat in a collision?

Q.26) The troops (soldier) equipped to be dropped by parachutesfrom an aircraft are called paratroops. Why do paratroops roll on landing?

Q.27) Why would an aircraft be unable to fly on the moon?

Q.28) Explain why it is possible for a small animal to fall from a considerable height without any injury being caused when it reaches the ground?

N.C.E.R.T Exercise Questions & Answers

Q.1. An object experiences a net zero external unbalanced force. Is it possible for the object to be travelling with a non zero velocity? If yes, State the condition that must be placed on the magnitude and direction of the velocity. If no. provide a reason.

Ans. Yes, when external unbalanced force on an object is zero, the object can be travelling with a non zero velocity. The necessary conditions are : (i) The object should already be moving with a uniform speed along straight line. (ii) There should be no change in magnitude of velocity and also no change in the direction of motion. (iii) The resistance to motion due to air must be zero. (iv) The resistance to motion due to friction between the object and the ground must be zero.

If any of the four conditions stated above is not met with, the answer will be 'No'. This is because external unbalanced force is needed for initiating the motion and also for any subsequent change (decrease/increase) in the velocity.

Q.2. When a carpetis beaten with a stick, dust comes out of it. Explain.

Ans. When a carpet is beaten with a stick, it comes in motion. The dust particles in the carpet tend to remain at rest due to inertia of rest. That is why these particles fall down.

Q.3. Why is it advised to tie any luggage kept on the roof of the bus with a rope?

Ans. Any luggage kept on the roof of a bus should be tied with a rope. This is because when the bus stars suddenly, the luggage pieces may fall down due toinertia of rest. Similarly, when the moving bus stops suddenly, the luggage pieces may fall due to inertia of motion**.**

Q.4. A batsman hits a cricket ball which then rolls on a level ground. After covering a short distance, the ball comes to rest. The ball slows to a stop because (a) the batsman did not hit the ball hard enough, (b) velocity is proportional to the force exerted on the ball, (c) there is a force on the ball opposing the motion, (d) there is no unbalanced force on the ball, so the ball would want to came to rest.

Ans. (c) The cricket ball comes to rest after covering a short distance, because there is a force on the ball, opposing the motion. This is due to resistance of air and also due to friction between the ball and the ground.

Q.5. A truck stats from rest and rolls down a hill with a constant acceleration. It travels distance of 400 m in 20 s. Find its acceleration. Find the force acting on it if its mass is 7 metric tonnes.

Ans. Here, u = 0, s = 400m, t = 20s, m = 7 metric tonnes = 7x1000 kg = 7000kg;

a = ?, F = ?

from, $s = ut + \frac{1}{2} at^2$, $400 = 0 + \frac{1}{2} a (20)^2 = 200a$

or, $a = 400/200 = 2 m/s^2$

$F = ma = 7000 \times 2 = 14000$ N

Q.6. A stone is thrown with a velocity of 20 m/s across the frozen surface of a lake and comes to rest after travelling a distance of 50 m. What is the friction between the stone and the ice?

Ans. Here, m = 1 kg, u = 20 m/s ; v = 0, s = 50 m, F = ?

From, $v^2 - u^2 = 2as$, $0 - (20)^2 = 2 a \times 50 = 100 a$

Or $a = -400/100 = -4 m/s^2$

Thus, $F = ma = 1 (-4) = -4$ N

Negative sign indicates that force of friction is opposing the motion of the ball.

Q.7. An 8000 kg engine pulls a train of 5 wagons, each of 2000 kg, along a horizontal track. If the engine exerts a force of 40000 N and the track offers a frictional force of 5000N, then calculate :

a. The net accelerating force
b. The acceleration of the train
c. The force of wagon 1 on wagon 2.

Ans. Here, mass of engine, m_1 = 8000 kg

Mass of 5 wagons, m_2 = 5 x 2000 kg = 10000 kg

Force exerted by the engine, F = 40000 N; frictional force, f = 5000 N

(a) Net acceleration force = F – f = 40000 – 5000 = 35000 N

(b) The acceleration of the train = a = $\frac{\text{net force}}{\text{total mass of engine and wagon}} = \frac{F-f}{m_1+m_2} = \frac{35000}{18000} = 1.94 m/s^2$.

(c) Force of wagon 1 on wagon 2 = mass of 4 wagons (behind wagon 1) x acceleration

= 4 x 2000 x 1.94 = 15420 N

Q.8. An automobile vehicle has a mass of 1500 kg. What must be the force between the vehicle and road if the vehicle is to be stopped with a negative acceleration of 1.7 m/s^2?

Ans. Here, m = 1500 kg, a = -1.7 m/s^2, F = ?

Clearly, F = ma = 1500 (-1.7) N = -2550 N

Negative sign indicates that force is opposing the motion of the vehicle.

Q.9. What is the momentum of an object of mass m, moving with the velocity v?
(a) $(mv)^2$ (b) mv^2 (c) ½ mv^2 (d) mv

Ans. (d) Momentum = mass x velocity = m x v = mv

Q.10. Using a horizontal force of 200 N, we intend to move a wooden cabinet across a floor at a constant velocity. What is the frictional force that will be exerted on the cabinet?

Ans. Force applied, F = 200 N, force of friction, F =?

As the wooden cabinet is to move across the floor with a constant velocity, no force (f) is spent in accelerating the cabinet, i.e., f = P – F = 0

Or F = P = 200N

Q.11. Two objects, each of mass 1.5 kg are moving in the same straight line but in the opposite direction. The velocity of each object is 2.5 m/s before the collision during which they stick together. What will be the velocity of the combined object after collision?

Ans. Here, $m_1 = m_2$ = 1.5 kg, u_1 = 2.5 m/s, u_2 = - 2.5 m/s

Negative sign for opposite direction of motion.

If v is velocity of combined object after collision, then applying the principle of conservation of momentum, we get

$(m_1 + m_2)v = m_1u_1 + m_2u_2$

$(1.5 + 1.5)v = 1.5\ (2.5) + 1.5\ (-2.5) = 0$

Or $v = 0$

Q.12. According to the third law of motion, when we push on an object, the object pushes back on us with an equal and opposite force. If the object is the massive truck parked along the roadside, it will probably not move. A student justifies this by answering that the two opposite and equal forces cancel each other. Comment on this logic and explain why the truck does not move.

Ans. When we push a massive truck parked along the roadside, it does not move. The justification given by the student that the two opposite and equal forces cancel each other is totally wrong. This is because forces of action and reaction never act on one body. There is no question of their cancellation. The truck does not move because the push applied is far less than the force of friction between the truck and the road.

Q.13. A hockey ball of mass 200g travelling at 10m/s is struck by a hockey stick so as to return it along its original path with a velocity of 5m/s. Calculate the change i the momentum of the hockey ball by the force applied by the hockey stick.

Ans. Here, m = 200g = 200/1000 kg = 1/5 kg

Initial velocity, u = 10 m/s

Final velocity, v = -5m/s, negative sign is used because the ball returns along the original path.

Change in momentum = final momentum – initial momentum

$= mv - mu = 1/5(-5) - 1/5\ (10) = -3$ kg m/s

Q.14. A bullet of mass 10g travelling horizontally with a velocity of 150 m/s strikes a stationary wooden block and comes to rest in 0.03 s. Calculate the distance of penetration of the bullet into the block. Also, calculate the magnitude of the force exerted by the wooden block on the bullet.

Ans. Here, m = 10 g = 10/1000 kg = 10^{-2}kg

Initial velocity, u = 150m/s, final velocity, v = 0, time taken, t = 0.03 s

Distance of penetration, s= ?, force applied, F = ?

Acceleration, a = $\frac{v-u}{t} = \frac{0-150}{0.03}$ = -5 x 10^{-3} m/s^2

From, $v^2 - u^2 = 2as$, $0 - (150)^2 = 2 (- 5 \times 10^3) s$

Or $s = \frac{-150 \times 150}{-10 \times 10^3} = 2.25$ m

As, $F = ma = 10^{-2} (-5 \times 10^3) = - 50$ N

Magnitude of force, F = 50 N

Q.15. An object of mass 1 kg travelling in a straight line with a velocity of 10m/s collides with, and sticks to, a stationary wooden block of mass 5 kg. Then, they both move ff together in the same straight line. Calculate the total momentum just before the impact and just after the impact. Also, calculate the velocity of the combined object.

Ans. Here, $m_1 = 1$ kg, $u_1 = 10$ m/s ; $m_2 = 5$kg, $u_2 = 0$

Before impact, total momentum = $m_1u_1 + m_2u_2$

Or $p_1 = 1 \times 10 + 5 \times 0 = 10$ kg m/s

Just after impact, total momentum remains the same, i.e.,

$p_2 = p_1 = 10$ k m/s

If v is the velocity of the combined object.

Then from $p_2 = (m_1 + m_2) v$, $v = p_2/(m_1 + m_2) = 10/(1 + 5) = 1.67$ m/s

Q.16. An object of mass 100 kg is accelerated uniformly from a velocity of 5m/s to 8m/s in 6 s. Calculate the initial and final momentum of the object. Also, find the magnitude of the force exerted on the object.

Ans. Here, m = 100 kg, u = 5 m/s, v = 8 m/s, t = 6 s

Initial momentum of object, $p_1 = mu = 100 \times 5 = 500$ kg m/s

Final momentum of object, $p_2 = mv = 100 \times 8 = 800$ kg m/s

Force exerted, $F = \frac{\text{change in momentum}}{\text{time taken}} = \frac{(p_2 - p_1)}{t} = \frac{800-500}{6} = 50$ N

Q.17. Akhtar, Kiran and Rahul were riding in a motorcar that was moving with a high velocity on an expressway when an insect hit the windshield and got stuck on the windscreen. Akhtar and Kiran started pondering over the situation. Kiran suggested that the insects suffered a greater change in momentum as compared to the change in momentum of the motorcar (because the change in the velocity of the insect was much more than that of the motorcar). Akhtar said that since the motorcar was moving with a lager velocity, it exerted a larger force on the insect. As a result, the insect died. Rahul while putting an entirely new explanation said

that both the motorcar and the insect experienced the same force and a change in their momentum. Comment on these suggestions.

Ans. The suggestion made by Kiran that the insect suffered a greater change in momentum as compared to the change in momentum of the motor car was wrong. The suggestion made by Akhtar that motor car exerted a larger force on the insect because of large velocity of motor car is also wrong. The explanation put forward by Rahul is correct. On collision of insect with motor car, both experienced the same force as action and reaction are always equal and opposite. Further, change in momenta of the two occur in opposite directions, though magnitude of change in momentum of each is the same.

Q.18. How much momentum will a dumb-bell of mass 10 kg transfer to tithe floor if it falls from a height of 80 cm? Take its downward acceleration as 10 m/s^2.

Ans. Here, m = 10 kg, s = 80 cm = 0.8 m, a = 10 m/s^2

u = 0, v = ?, p = ?

from, $v^2 - u^2 = 2as$, $v^2 - 0 = 2 \times 10 \times 0.8 = 16$, v = 4 m/s, p = mv = 10 * 4 = 40 kgm/s

N.C.E.R.T Exemplar Problems & Answers

Multiple choice questions

1. Which of the following statement is not correct for an object moving along a straight path in an accelerated motion?

a. Its speed keeps changing
b. Its velocity always changes
c. It always goes away from the earth
d. A force is always acting on it

Ans. (c)

2. According to the third law of motion, action and reaction

a. Always act on the same body
b. Always act on different bodies in opposite direction
c. Have same magnitude and directions
d. Act on either body at normal to each other

Ans. (b)

3. A goalkeeper in a game of football pulls his hands backwards while holding the ball shot at the goal. This enables the goal keeper to

a. Exert larger force of the ball
b. Reduce the force exerted by the ball on hands
c. Increase the rate of change of momentum
d. Decrease the rate of change of momentum

Ans. (b, d)

4. The inertia of an object tends to cause the object

a. To increase its speed
b. To decrease its speed
c. To resists any change in its state of rest or motion
d. To decelerate due to friction

Ans. (c)

5. A passenger in a moving train tosses a coin which falls behind him. It means that motion of the train is

a. Accelerated **b. Uniform**

c. Retarded **d. Along circular tracks**

Ans.(a)

6. An object of mass 2 kg is sliding with a constant velocity of 4 m/s on a frictionless horizontal table. The force required to keep the object moving with the same velocity is

a. 32 N **b. 0 N**

c. 2 N **d. 8 N**

Ans. (b)

7. Rocket works on the principle of conservation of

a. Mass **b. Energy**

c. Momentum **d. Velocity**

Ans. (c)

8. A water tanker filled up to 2/3 of its height is moving with a uniform speed. On sudden application of the brake, the water in the tank would

a. Move backward **b. Move forward**

c. Be unaffected **d. Rise upwards**

Ans. (b)

Short answer questions

9. There are three solids made up of aluminium, steel and wood, of the same shape and same volume. Which of them would have highest inertia?

Ans. Out of these solids of same shape and same volume, mass of steel solid is maximum as destiny of steel is maximum. As mass is a measure of inertia, therefore, steel solid would have heist inertia.

10. Two balls of the same size but of different materials, rubber and iron are kept on the smooth floor of a moving train. The brakes are applied suddenly to stop the train. Will the balls start rolling? If so, in which direction? Will they move with the same speed? Give reasons for your answer.

Ans. Yes, both the balls will start rolling due to inertia of motion. The train stops due to brakes. But the balls continue to move in the direction of the train. The two balls will not roll with the same speed. In fact, the iron ball being heavier than the rubber ball shall move at a lower speed.

11. Two identical bullets are fired one by a light rifle and another by a heavy rifle with the same force. Which rifle will hurt the shoulder more and why?

Ans. As momentum of light rifle and heavy rifle in opposite direction is same (being equal to momentum of identical bullets), the lighter rifle will move faster hurting the shoulder more.

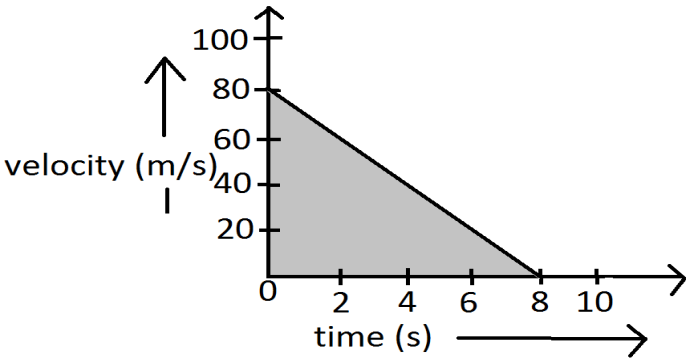
12. A horse continues to apply a force in order to move a cart with a constant speed. Explain why?

Ans. In order to move a cart a constant speed, a horse continues to apply the force to overcome friction between the cart and the ground.

13. Suppose a ball of mass m is thrown vertically upward with an initial speed u, its speed decreases continuously till it becomes zero. Therefore, the ball begins to fall downward and attains the speed v again before striking the ground. It implies that the magnitudes of initial and final momentums of the ball are same. Yet, it is not an example of conservation of momentum. Explain why?

Ans. Law of conservation of linear momentum applies only to isolated systems where there is no external force. In this case, change in velocity of ball (upward and backwards) is due to attraction pull of earth. That is why this motion of ball is not an example of conservation of momentum.

14. Velocity versus time graph of a ball of mass 50 g rolling on a concrete floor is shown. Calculate the acceleration and frictional force of the floor on the ball.



Ans. From the graph, we find that

u = 80 m/s, v = 0, t = 8 s

From v = u + at

0 = 80 + a x 8, a = -80/8 = -10 m/s

As m = 50 g = 50/1000 kg = 1/20 kg

Thus, F = ma = 1/20 (-10) = -0.5 N

Negative sign is for opposing frictional force of the floor on the ball.

15. A truck of mass M is moved under a force F. If the truck in then loaded with an object equal to the mass of the truck and driving force is halved, then how does the acceleration change?

Ans. As mass of loaded truck becomes 2 times and driving force is halved, therefore, from

F = am, a = $\frac{\mathrm{F}}{\mathrm{m}} = \frac{\frac{1}{2}time}{2times} = \frac{1}{4}time$

i.e acceleration would become 1/4 th.

16. Two friends on roller skates are standing 5 m apart facing each other. One of them throws a ball of 2 kg towards the other, who catches it. How will this activity affect the position of the two? Explain your answer.

Ans. In the process, separation between the two friends on the roller skates will increase.

To start with, both are at rest. When one throws the ball, he acquires momentum (equal to momentum of the ball) in opposite direction and move in opposite direction. The other friend who catches the ball acquires the momentum of the ball and moves away from his friend in the direction of the motion of the ball.

17. Water sprinkler used for grass lawn begins to rotate as soon as the water is supplied. Explain the principle on which it works.

Ans. The rotation of the sprinkler is explained on the basis of Newton's 3rd law of motion. As soon as water comes out of the nozzle of the sprinkler, it exerts an equal force on the nozzle in opposite direction. And the sprinkler starts rotating.

Long answer questions

18. Using second law of motion, derive the relation between force and acceleration. A bullet of 10 g strikes a sand bag at a speed of 10^3 m/s and gets embedded after travelling 5 cm. Calculate

a. The resistive force exerted by the sand on the bullet

b. The time taken by the bullet to come to rest

Ans. The required relation is F = am

Mass of bullet, m = 10 g = 10^{-2} kg

Speed of bullet, v = 10^3 m/s

Distance travelled, s = 5 cm = 5 x 10^{-2} m

As work done = K.E of the bullet

Therefore, F x s = $\frac{1}{2}$ x mv^2

$$F = \frac{mv^2}{2s} = \frac{10^{-2}(10^6)}{2\times5\times10^{-2}} = 10^5 \text{ N}$$

From v = u + at

$0 = 10^3 + (\frac{-10^5}{10^{-2}})$ x t,

$t = 10^3/10^7 = 10^{-4}$ s

19. Derive the unit of force using the second law of motion. A force of 5 N produces an acceleration of 8 m/s^2 on a mass m_1 and an acceleration of 24 m/s^2 on mass m_2. What acceleration would the same force provide if both the masses are tied together?

Ans. From, F = ma, $m_1 = F/a_1 = 5/8$ kg

And $m_2 = F/a_2 = 5/24$ kg

Total mass, $m = m_1 + m_2 = 5/8 + 5/24 = \frac{15+5}{24} = 20/24$ kg

Net acceleration, a = F/m = $\frac{5}{\frac{20}{24}}$= 6 m/s^2

20. What is momentum? Write its SI unit. Interpret force in terms of momentum. Represent the following graphically

a. Momentum versus velocity when mass is fixed.

b. Momentum versus mass when velocity is fixed.

Ans. force is equal to rate of change of momentum of the body.

As p = mv, therefore, when mass (m) is fixed, p ∝ v.

When velocity v is constant, p∝ m.

Therefore, p versus v graph and p versus m graph, both are straight lines as shown.