Physics 2

Unit- 2

Force and Laws of Motion

Force and its relation to motion

Q.1: **Define force. What are it units? Describe effects of force.**

Ans: **Force:** A force is a push or pull upon an object resulting from the object's interaction with another object. Force may be defined as an influence which tends to change state, speed, direction and shape of a body. It has both magnitude and direction and is therefore, a vector quantity. It may also be defined as an external agency, which changes the speed and direction of a body. It can also change the shape of a body.

Force is a vector quantity. It is represented by an arrow.

Units of force: In S.I system, force is measured in Newton's represented by letter "N" while as in C.G.S system its values are represented in dynes.

Newton: The force applied is said to be one Newton if it produces acceleration of $1 m/sec^2$ and in a body of mass 1Kg.

Dyne: The force applied is said to be one dyne if it produces acceleration of $1 cm/sec^2$ in a body of mass 1 gram.

Effects of force: Some of the common effects of force are:-

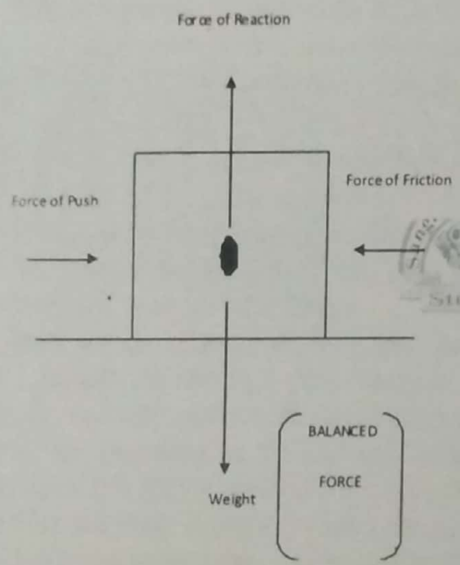
1. **A force may move a body at rest.** For example, when we kick a football kept on the ground with our foot, the football moves. The force applied by our foot moves the ball.
2. **A force may stop a moving body.** For example, when a player catches a moving cricket ball, the force applied by player's hands stops the moving ball.
3. **A force can change the speed of a body.** For example, when a ball is dropped from a certain height, the speed of the ball goes on increasing due to gravitational pull of the Earth on the ball, in the downward direction. Thus force applied by the Earth in the direction of motion of the ball increases the speed of the ball.
4. **A force may change the direction of a moving body.** For example, when a moving cricket ball is hit by a bat, the cricket ball moves in a different direction. The force applied by the bat changes the direction of the moving cricket ball.
5. **A force may change the size and shape of a body.** For example, when we press a rubber ball or a balloon between our two hands, the shape of the rubber ball or balloon changes from spherical to ablong. The forces applied by our hands change the shape of the rubber ball/balloon.

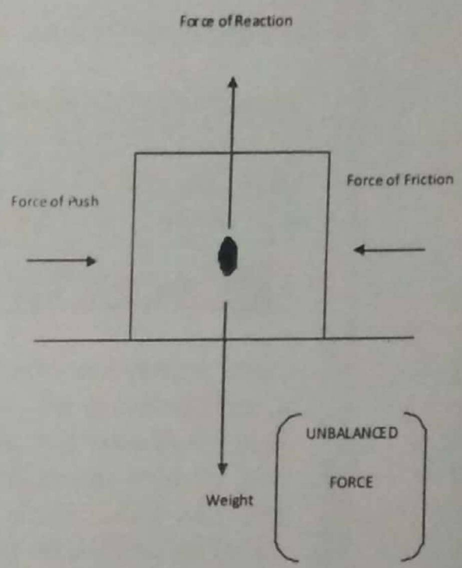
Balanced and unbalanced forces

Q.2: What is difference between balanced and unbalanced force.

Ans: **Balanced force:** A force is said to be balanced if the resultant of all the forces acting on a body is equal to 0. A body under the influence of a balanced force does not change its position of rest or uniform motion and appears as if no force is acting on it. For example: In the game of tug of war, the two teams pull each other in the opposite directions. If the two teams pull the rope with equal force i.e. $F_1 = F_2$, then the rope does not move in either direction. Under this condition, the forces acting on a rope are balanced forces.

Unbalanced force:- A force is said to be unbalanced if the resultant of all the forces acting on a body is not equal to 0. A body under the influence of unbalanced force changes its position of rest and uniform motion. For example. In the tug of war, if the force applied by a team is greater than that applied by the other team. Then the members of the weaker team will be pulled towards the stronger team. Thus, the unbalanced forces produce motion.





Q.3: 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 conditions that must be placed on the magnitude and direction of the velocity. If no, provide a reason. **(T.B.Q. 1; page 36)**

Ans: Yes. Even when an object experiences a net zero external unbalanced force, it is possible that the object is travelling with a non-zero velocity. This is possible only when the object has been moving with a constant velocity in a particular direction. Then, there is no net unbalanced force applied on the body. The object will keep moving with a non-zero velocity. To change the state of motion, a net non-zero external unbalanced force must be applied on the object.

Concept of inertia and its relation with mass

Q.4: Give the concept of inertia. What is its relation with mass?

Ans: There is a resistance offered by an object to change its state of motion. If it is at rest, it tends to remain at rest. If it is moving it tends to keep moving. This property of an object is called inertia. Therefore the *inability of a body to change its state of rest or of uniform motion by itself is called inertia.*

Inertia of body depends mainly upon its mass. If we kick a foot ball, it flies away. But if we kick a stone of the same size with equal force, it hardly moves. We may, in fact get an injury in our foot. A force, that is just enough to cause a small carriage to pick up a large velocity, will produce a negligible change in the motion of a train. We say that train has more inertia than the carriage. Clearly, more massive objects offer larger inertia. The inertia of an object is measured by its mass.

Q.5: Which of the following has more inertia: (a) a rubber ball and a stone of the same size? (b) a bicycle and a train? (c) a five-rupees coin and a one-rupee coin? **(T.B.Q. 1; page 25)**

Ans: Inertia is the measure of the mass of the body. The greater is the mass of the body; the greater is its inertia and vice-versa.

(a) Mass of a stone is more than the mass of a rubber ball for the same size. Hence, inertia of the stone is greater than that of a rubber ball.

(b) Mass of a train is more than the mass of a bicycle. Hence, inertia of the train is greater than that of the bicycle.

(c) Mass of a five rupee coin is more than that of a one-rupee coin. Hence, inertia of the five rupee coin is greater than that of the one-rupee coin.

Q.6: In the following example, try to identify the number of times the velocity of the ball changes:

"A football player kicks a football to another player of his team who kicks the football towards the goal. The goalkeeper of the opposite team collects the football and kicks it towards a player of his own team".

Also identify the agent supplying the force in each case. **(T.B.Q. 2; page 25)**

Ans: The velocity of the ball changes four times.

As a football player kicks the football, its speed changes from zero to a certain value. As a result, the velocity of the ball gets changed. In this case, the player applied a force to change the velocity of the ball. Another player kicks the ball towards the goal post. As a result, the direction of the ball gets changed. Therefore, its velocity also changes. In this case, the player applied a force to change the velocity of the ball. The goalkeeper collects the ball. In other words, the ball comes to rest. Thus, its speed reduces to zero from a certain value. The velocity of the ball has changed. In this case, the goalkeeper applied an opposite force to stop/change the velocity of the ball. The goalkeeper kicks the ball towards his team players. Hence, the speed of the ball increases from zero to a certain value. Hence, its velocity changes once again. In this case, the goalkeeper applied a force to change the velocity of the ball.

Q.7: Explain why some of the leaves may get detached from a tree if we vigorously shake its branch. **(T.B.Q. 3; page 25)**

Ans: Some leaves of a tree get detached when we shake its branches vigorously. This is because when the branches of a tree are shaken, it moves to and fro, but its leaves tend to remain at rest. This is because the inertia of the leaves tend to resist the to and fro motion. Due to this reason, the leaves fall down from the tree when shaken vigorously.

Q.8: Why do you fall in the forward direction when a moving bus brakes to a stop and fall backwards when it accelerates from rest? **(T.B.Q. 4; page 25)**

Ans: Due to the inertia of the passenger.

Everybody tries to maintain its state of motion or state of rest. If a body is at rest, then it tries to remain at rest. If a body is moving, then it tries to remain in motion. In a moving bus, a passenger moves with the bus. As the driver applies brakes, the bus comes to rest. But, the passenger tries to maintain his state of motion. As a result, a forward force is exerted on him. Similarly, the passenger tends to fall backwards when the bus accelerates from rest. This is because when the bus accelerates, the inertia of the passenger tends to oppose the forward motion of the bus. Hence, the passenger tends to fall backwards when the bus accelerates forward.

Q.9: When a carpet is beaten with a stick, dust comes out of it. Explain. **(T.B.Q. 2; page 36)**

Ans: Inertia of an object tends to resist any change in its state of rest or state of motion. When a carpet is beaten with a stick, then the carpet comes to motion. But, the dust particles try to resist their state of rest. According to Newton's first law of motion, the dust particles stay in a state of rest, while the carpet moves. Hence, the dust particles come out of the carpet.

Q.10: Why is it advised to tie any luggage kept on the roof of a bus with a rope? **(T.B.Q. 3; page 37)**

Ans: When the bus accelerates and moves forward, it acquires a state of motion. However, the luggage kept on the roof, owing to its inertia, tends to remain in its state of rest. Hence, with the forward movement of the bus, the luggage tends to remain at its original position and ultimately falls from the roof of the bus. To avoid this, it is advised to tie any luggage kept on the roof of a bus with a rope.

Q.11: 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 come to rest. **(T.B.Q. 4; page 37)**

Ans: (c) A batsman hits a cricket ball, which then rolls on a level ground. After covering a short distance, the ball comes to rest because there is frictional force on the ball opposing its motion.

Frictional force always acts in the direction opposite to the direction of motion. Hence, this force is responsible for stopping the cricket ball.

Newton's Laws of motion

Q.12: Define Newton's First law of motion.

Ans: *A body at rest will remain at rest and a body in motion will continue in motion in a straight line with a uniform speed, unless it is compelled by an external force to change its state of rest or uniform motion.* Example a book lying on a table is at rest, it will not move by itself i.e. it cannot change its position of rest by itself. It can change its state of rest when compelled by the force of our hands i.e. when we lift the book from the table.

Q.13: Define Newton's Second law of motion. Give the mathematical formulation of Newton's second law of motion.

Ans: According to Newton's second law of motion: *The rate of change of momentum of a body is directly proportional to the applied force, and takes place in the direction in which the force acts.* i.e.

$$Force \propto \frac{\text{Change in momentum}}{\text{Time taken}}$$

Mathematical formulation of Newton's second law of motion: Consider a body of mass m having an initial velocity u, the initial momentum of the body will be 'mu'

Suppose a force F acts on this body for the time t and causes the final velocity to become v, the final **momentum** of this body will be 'mv'. Now the change in momentum of this **body is** $mv - mu$ and the time taken for this change is t. So according to Newton's **second law** of motion:

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

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

But $\frac{v-u}{t}$ represent change in velocity with time which is known as acceleration 'a'.

So, by writing 'a' in pace of $\frac{v-u}{t}$ in the above relation, we get:

$F \propto m \times a$

Thus, force acting on the body is directly proportional to the product of '*mass*' of the body and '*acceleration*' produced in the body by the action of force, and it acts in the direction of acceleration.

Thus $F = k\,m \times a$ (where k is the constant)

The value of k in SI units is 1, so the above equation becomes:

$F = m \times a$

or Force = mass × acceleration

The S.I. unit of force is Newton denoted by N. A Newton is that force which when acting on a body of mass 1kg produces an acceleration of 1 m/s^2 in it.

$F = m \times a$

Putting m = 1 kg and a = 1 m/s^2, F becomes 1 Newton

So, 1 Newton = 1kg × 1m/s^2.

Q.14: Define Newton's Third law of motion?

Ans. According to this law whenever one body exerts a force on another body, the second body exerts an equal and opposite force on the first body. The force exerted by the first body on the second body is known as "action" and the force exerted by the second body on the first body is called "reaction". This law states: *To every action there is equal and opposite reaction.*

Examples:

1. When we walk on the ground, our foot pushes the ground backward and in return the ground pushes our foot forward.
2. When a bullet is fired from a gun the force sending the bullet forward is equal to the force sending the gun backward (i.e. recoiling of gun).
3. The flying of jet aeroplanes and rockets is due the Newton's third law of motion.

Q.15: If action is always equal to the reaction, explain how a horse can pull a cart. **(T.B.Q. 1; page 35)**

Ans: A horse pushes the ground in the backward direction. According to Newton's third law of motion, a reaction force is exerted by the Earth on the horse in the forward direction. As a result, the cart moves forward.

Q.16: Explain, why is it difficult for a fireman to hold a hose, which ejects large amounts of water at a high velocity. **(T.B.Q. 2; page 35)**

Ans: Due to the backward reaction of the water being ejected

When a fireman holds a hose, which is ejecting large amounts of water at a high velocity, then a reaction force is exerted on him by the ejecting water in the backward direction. This is because of Newton's third law of motion. As a result of the backward force, the stability of the fireman decreases. Hence, it is difficult for him to remain stable while holding the hose.

Q.17: Using a horizontal force of 200 N, we intend to move a wooden cabinet across a floor at a constant velocity. What is the friction force that will be exerted on the cabinet? **(T.B.Q.10; page 37)**

Ans: A force of 200 N is applied in the forward direction. Thus, from Newton's third law of motion, an equal amount of force will act in the opposite direction. This opposite force is the fictional force exerted on the cabinet. Hence, a frictional force of 200 N is exerted on the cabinet.

Momentum

Q.18: Define momentum?

Ans: The momentum of a body is defined as the product of its mass and velocity. The force required to stop a moving body is directly proportional to its mass. Thus, the quantity of motion in a body depends on mass and velocity of body.

Momentum= Mass × Velocity

$P = m \times v$

When a body is at rest its velocity is zero and hence its momentum is zero. Momentum is a vector quantity. The S.I unit of momentum is kg.m/s.

Q.19: What is the momentum of an object of mass *m*, moving with a velocity *v*?

(a) $(mv)^2$ (b) mv^2

(c) $\frac{1}{2} mv^2$ (d) mv **(T.B.Q. 9; page 37)**

Ans: Mass of the object = m

Velocity = v

Momentum = Mass × Velocity

Momentum = mv

Q.20: A hockey ball of mass 200 g travelling at 10 m s^{-1} is struck by a hockey stick so as to return it along its original path with a velocity at 5 m s^{-1}. Calculate the change of momentum occurred in the motion of the hockey ball by the force applied by the hockey stick. **(T.B.Q.13; page 37)**

Ans: Mass of the hockey ball, m = 200 g = 0.2 kg

Hockey ball travels with velocity, v_1 = 10 m/s

Initial momentum = mv_1

Hockey ball travels in the opposite direction with velocity, v_2 = −5 m/s

Final momentum = mv_2

Change in momentum = $mv_1 - mv_2 = 0.2\,[10 - (-5)] = 0.2\,(15) = 3$ kg m s^{-1}

Hence, the change in momentum of the hockey ball is 3 kg m s^{-1}.

Q.21: How much momentum will a dumbbell of mass 10 kg transfer to the floor if it falls from a height of 80 cm? Take its downward acceleration to be 10 m s^{-2}. **(T.B.Q.18; page 38)**

Ans: Mass of the dumbbell, m = 10 kg

Distance covered by the dumbbell, s = 80 cm = 0.8 m

Acceleration in the downward direction, a = 10 m/s^2

Initial velocity of the dumbbell, u = 0

Final velocity of the dumbbell (when it was about to hit the floor) = v

According to the third equation of motion:

$v^2 = u^2 + 2as$ $\quad v^2 = 0 + 2\,(10)\,0.8$ $\quad v = 4$ m/s

Hence, the momentum with which the dumbbell hits the floor is $= mv = 10 \times 4 = 40$ kg m s^{-1}