# SECTION-01 - BE-01

# BASICS OF SCIENCE AND ENGINEERING

## PHYSICS

1. Units and Measurements
2. Classical Mechanics
3. Electric Current
4. Heat and Thermometry
5. Weave Motion, Optics and Acoustics

## CHEMISTRY

6. Chemical Reactions and Equations
7. Acids, Bases and Salts
8. Metals and Non-Metals

## COMPUTER PRACTICE

9. Computer Practice

## ENVIRONMENT SCIENCES

10. Environmental Sciences

# 2. Classical Mechanics

## [1] Force :

We know that to produce a motion in a football at rest, you have to kick it. The ball has to be pushed upwards to bounce high. The force has to be applied in the opposite direction of its motion to stop the ball from falling off the slope. In the same way, hitting a ball with a bat changes its direction.

From this we can define force as : External effort in the form of push or pull which (1) produces or attempts to produce motion in an object at rest, (2) stops or tries to stop the object in motion, (3) changes or tries to change the direction of motion of an object is called force. To move a body at rest as well as to change or stop its motion, an external agency that provides the force is always needed.

In all the above cases the external agency applies a force when an object is in contact. This type of force is called contact force. Friction force, Normal force , Air resistance , Tension force , spring force are examples of contact forces. But it is not necessary that the external factor is always in contact with the object. An external agency exerts a force even if it is not in contact with the object. These types of forces are called non–contact forces or field forces. Magnetic force, electrostatic force, gravitation force are examples of field forces.

**Units of Force :**

Force = Mass × Acceleration

SI unit of force is newton (N) and the cgs unit is dyne.

**Definition of 1 newton (1N) :**

1 newton = 1 kg × 1 $ms^{-2}$

One newton is that force which produces an acceleration of 1 $ms^{-2}$ in a body of mass 1 kg.

**Definition of 1 dyne :**

1 dyne = 1 gm × 1 cm $s^{-2}$

One dyne is that force which produces an acceleration of 1 cm $s^{-2}$ in a body of mass 1 gram.

**The relation between newton and dyne :**

1 newton = 1 kg × 1 $ms^{-2}$

thus newton = 1000 g × 100 cm $s^{-2}$

Thus 1 newton = 100000 g cm $s^{-2}$

i.e 1 newton = $10^5$ dyne

## [2] Linear Momentum :

The linear momentum of a body is defined as the product of the mass of the body and its velocity i.e.

Linear momentum = mass × velocity

If a body of mass m is moving with a velocity $v$, its linear momentum $p$ is define as

$$\vec{P} = m\vec{v}$$

Linear momentum is a vector quantity. Its direction is the same as the direction of velocity of the body.

The SI unit of linear momentum is kg $ms^{-1}$ and the cgs unit of linear momentum is g cm $s^{-1}$.

From $p = mv$, we find that

when m is constant, $p \propto v$

when $v$ is constant, $p \propto m$

Further, when two bodies of unequal masses $m_1$, $m_2$ have the same linear momentum

i.e. $p_1 = p_2$ or $M_1\vec{v_1} = M_2\vec{v_2}$

$$\therefore \frac{\vec{v_2}}{\vec{v_1}} = \frac{M_1}{M_2}$$

Velocities of the bodies having equal linear momentum vary inversely as their masses i.e. the heavier body has smaller velocity and the lighter body has higher velocity.

In considering the effect of force, linear momentum is very important. This can be understood from the following examples :

(i) We know that a much greater force is required to push a truck than a car to bring them to the same speed in the same time. Similarly, a greater opposing force is needed to stop a heavy body than a light body in the same time, when they are moving with the same speed. Thus, the mass of a body is an important parameter that determines the effect of force on its motion.

(ii) Speed is another important parameter to consider. A bullet fired from a gun can easily pierce through a target like human tissue, before it stops, resulting in grave injury. The same bullet, thrown with a moderate speed can be easily stopped. Thus for a given mass, greater is the speed, greater is the opposing force needed to stop the body in a certain time.

Taken together, the product of mass and velocity, i.e., linear momentum is an important quantity, when we consider effect of force on its motion.

## [3] Impulse and its Applications :

When a large force acts on a body for a short interval of time then the body is said to be subjected to impulse. e.g. Hammer struck on a nail, the ball struck by a bat.

The product of force and time during which force acts is called impulse of force.

Impulse of force = $F \cdot dt$

According to newton's second Law of motion

$$F = \frac{dp}{dt}$$

$$\therefore \quad F \cdot dt = dp = M_2V_2 - M_1V_1$$

Impulse of force = Change in momentum

When a large force acts for a very short duration producing a final change in the momentum of the body it is difficult to measure force and time separately. But change in momentum can be measured.

The forces which act on bodies for short time are called impulsive forces.

Thus, impulse of force = force × time.

The S.I. unit of impulse of a force is newton–second (Ns). or kg ms$^{-1}$.

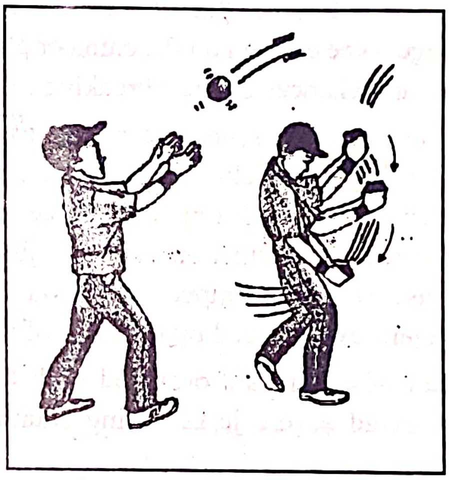
In c.g.s. system its unit is dyne–second. impulse is a vector quantity.

- **Applications of Impulse of a Force :**

1. A cricket player lowers his hands while catching a cricket ball. As you may have noticed, the player draws in his hands backward in the act of catching the ball, Fig. Thus he allows a longer time for his hands to stop the ball.

$$\therefore \quad \text{force} = \frac{\text{Change in linear momentum}}{\text{time}}$$

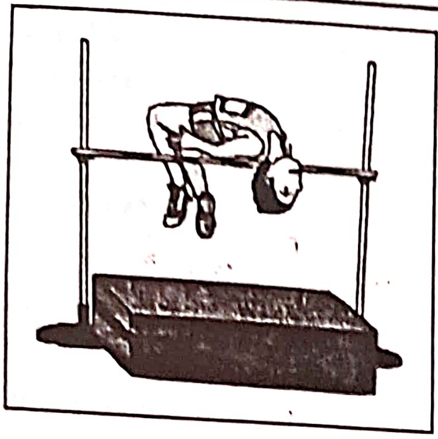
therefore by increasing the time of a catch, the player has to apply a smaller force against the ball in order to stop it. The ball in turn, exerts a smaller force on his hands and his hands are not injured.



It should be clearly understood that force depends not only on the change in momentum, but also on how fast the change is brought about. The same change in momentum brought about in a shorter time needs a greater force and vice–versa.

2. When a person falls from a certain height on a cemented floor, the floor does not yield. The total change in linear momentum is produced in a smaller interval of time. Therefore, as explained above, the floor exerts a much larger force. Due to it, a person gets more injury.

On the other hand, when a person falls on a heap of sand or a cushion, the sand yields. The same change in linear momentum is produced in much longer time. The average force exerted on the person by the heap of sand or cushion, is therefore, much smaller and hence the person is not hurt.



3. Chinawares and glasswares are wrapped in paper or straw pieces while packing. In the event of fall, impact will take a longer time to reach the glass/ chinawares through paper/straw. As a result, the average force exerted on the china or glasswares is small and chances of their breaking reduce.
4. The vehicles like scooter, car, bus, truck etc. are provided with shock-absorber When they move over an uneven road, impulsive forces are exerted by the road. The function of shock-absorber is to increase the time of impact. This would reduce the force/jerk experienced by the rider of the vehicle.
5. Bogies of a train are provided with the buffers. They avoid severe jerks during shunting of the train.

Due to presence of buffers, time of impact increases. Therefore, force during jerks decreases. Hence the chances of damage decrease.

**Example-1 : By Appling a force on an object of 5 kg mass, its velocity increases from 2 $ms^{-1}$ to 3.5 $ms^{-1}$ in 2 second. Find applied force.**

**Solution :**

Mass m = 5 kg

Initial velocity $u = 2\ ms^{-1}$

Final velocity $v = 3.5\ ms^{-1}$ .

Time = 2 second

F = ?

Acceleration

$$a = \frac{v-u}{t} = \frac{3.5-2}{2} = \frac{1.5}{2} = 0.75\ ms^{-2}$$

$$F = ma = 5 \times 0.75 = 3.75\ N$$

**Example-2 : Find the acceleration produced by applying a force of 15 N on an object of mass of 3 kg.**

**Solution :**

Mass m = 3 kg

Force F = 15 N

F = ma

$$\text{So } a = \frac{F}{M} = \frac{15}{3} = 5\ ms^{-2}$$

**Example-3 : Applying a force of 20 N on an object it produces 5 $ms^{-2}$ acceleration, then find the mass of the object.**

**Solution :**

F = 20 N

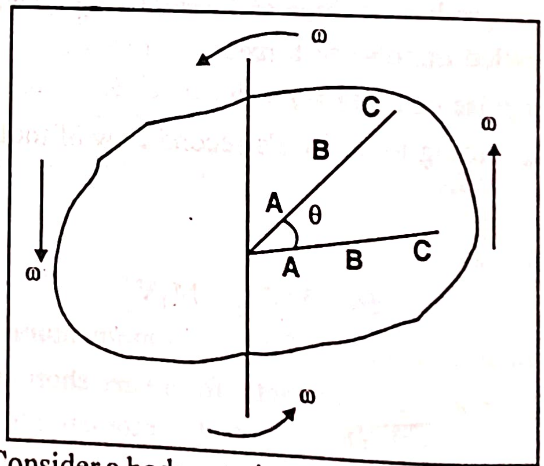
a = 5 $ms^{-2}$

F = ma

$$M = \frac{F}{a} = \frac{20}{5} = 4\ kg$$

## [4] Angular Velocity :

The angle described by a rotating body per unit time is called its angular velocity and is denoted by the Greek letter ω (omega)




Consider a body rotating about a fixed axis passing through its centre. Assume this body to be consisting of small particles such as at A, B and C. All the particles will complete one rotation in the same time i.e. the angular velocity of all such particles is the same. However, it may be noted that the linear velocity will differ from particle to particle, but will remain same for a chosen particle or body throughout the motion along the circle.

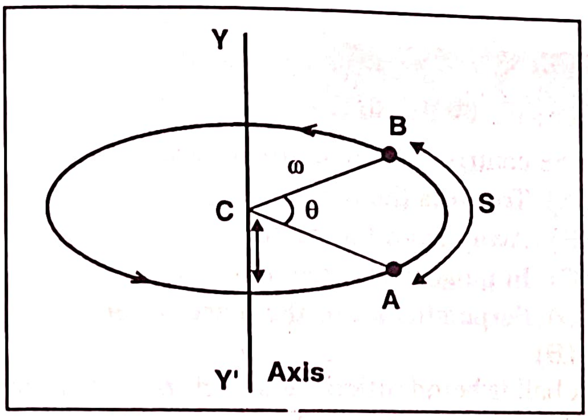
Consider an object moving about an axis Y Y' passing through a point O. If the centre of the body is at A as shown in Fig. and in t seconds the body moves from A to B and describes an angle θ, we have

Angular velocity of the body,

$$\omega = \frac{\text{Angular displacement}}{\text{time}} = \frac{\theta}{t}\ \frac{\text{rad}}{\text{s}}$$

The angle is measured in radians i.e.

$$\theta = \frac{\text{arc AB}}{\text{radius of circle}} = \frac{S}{r}\ \text{radians}$$




**Time Period (T) :**

Time period (T) is the time taken by the object performing circular motion to complete one revolution. It is denoted by 'T'.

**Frequency (f, η) :**

The number of revolutions an object completes in one second is the frequency of revolution.

Frequency is denoted by $f$ or η and $f = 1/T$. The unit of frequency is Hertz (Hz). One Hz means one revolution per second.

When object completes one revolution the angle traced at its axis of circular motion is $2\pi$ radian. It means $t = T$ and $\theta = 2\pi$.

$$\therefore \quad \text{Angular velocity } \omega = \frac{\theta}{t} = \frac{2\pi}{T} \text{ and } \frac{1}{T} = f$$

So, $\omega = 2\pi f$

## [5] Relation Between Angular and Linear Velocity :

Let us assume that the body travels on circular path with uniform speed v. If the angle described is θ and the distance traversed is S in time t i.e., if the body takes t seconds for going from A to B, we have

$$\text{Speed } v = \frac{\text{distance}}{\text{time}} = \frac{S}{t}$$

Substituting the values $S = r\theta$, in above equation

$$v = \frac{r\theta}{t}$$

By definition $\theta / t = \omega$, therefore

$$\therefore \quad v = r\omega$$

In the above equation ω is the angular velocity in radians per second.

**Angular Acceleration :**

If a body is not rotating with a uniform angular velocity it is said to possess angular acceleration.

The angular acceleration of a rotating body is defined as the rate of change of angular velocity. Thus, if a body moving with an angular velocity $\omega_1$ changes its velocity from $\omega_1$ to $\omega_2$ in t second we have

Angular acceleration

$$\alpha = \frac{d\omega}{dt} = \frac{\omega_2 - \omega_1}{t}\ \text{rad/s}^2$$

Now if the distance of the body from the axis of rotation is r, the linear velocity in the beginning will be $r\omega_1$ and will be changed to $r\omega_2$ in t second. Thus, the liner acceleration of the body will be

$$a = \frac{r\omega_2 - r\omega_1}{t} = \frac{r(\omega_2 - \omega_1)}{t}$$

$$\text{or} \quad a = r\frac{d\omega}{dt}$$

i.e., $a = 2\alpha$ linear acceleration = distance from the axis of rotation × angular acceleration.

## [6] Centrifugal force :

When any object moves at a constant speed, in a circular path, a centripetal force is experienced towards its centre, due to which it is not thrown away. According to Newton's third law of motion, this centrifugal force has the same force in the opposite direction as the centripetal force, which tries to move the object away.

The outward pushing force on an object in a circular motion called centrifugal force.

It is not a real force and directed away from the centre. It is result of the inertia of the object which resists the circular motion. The centrifugal force depends on the mass of the object, the velocity of the object, and the distance between the centre and the object.

## [7] Examples of Centrifugal and Centripetal Forces :

(1) The force of friction between the road and the tire provides the desired centripetal force when the motor car moves on a circular road. This frictional force balances the centrifugal force. Friction seems to be less if the road is too smooth. As a result, the motorcar skids off. For this the inner edge of the road is kept slightly lower than the outer edge. Thus, curved roads are made sloping.

(2) Mudguard in bicycle (mud guard) : When a bicycle is moving on the road, mud, dust etc. stick the tire and it flies tangentially as the speed increases. As a result, the rider's clothes get spoil. That's why Mudguards are kept on the tires.

(3) Bending of cyclists at curved roads are also examples of centripetal force and centrifugal force.

## Multiple Choice Questions (MCQs)

1. In order to keep a body moving in a circle, there exists a force on it that is directed toward the center of the circle. This force is known as...
(A) Centrifugal force (B) Centripetal force
(C) Gravitational Farce (D) Magnetic force

**Ans. : (B)**

2. The angular velocity of a body moving with a constant speed v in a circle of radius r is given by
(A) $v^2/r$ (B) v r
(C) v/r (D) r/v

**Ans. : (C)**

3. The force that keeps the body moving in circular motion is.....
(A) Centripetal force (B) Centrifugal force
(C) Force of gravity (D) Reaction forces

**Ans. : (A)**

4. The mathematical expression for centripetal force is....
(A) $mv^2/r$ (B) mv/r
(C) $v^2/r$ (D) $mv^3/r$

**Ans. : (A)**

5. A body of mass 10 kg is moving with a velocity of 5 m/s in a circle of radius 5 m, what is the centripetal acceleration of the body ?
(A) 5 $m/s^2$ (B) 25 $m/s^2$
(C) 0.5 $m/s^2$ (D) 50 $m/s^2$

**Ans. : (A)**

6. The centrifugal force always acts
(A) Towards the center
(B) Away from the center
(C) In tangential direction.
(D) Perpendicular to the plane of motion

**Ans. : (B)**

7. A ball is being rotated in a circle of radius 5 m with a constant tangential velocity of 20 m/s. A stone is also being rotated in a circle of radius 4 m with a constant tangential velocity of 16 m/s. Which one of the following choices is true about both the circular motions ?
(A) Both have same angular velocity
(B) Both have different angular velocity
(C) Angular velocity of ball > angular velocity of stone
(D) Angular velocity of stone > angular velocity of ball

**Ans. : (A)**

8. The angular velocity of a stone being rotated is 11 rad/s. What is the angular displacement covered in 0.5 s ?
(A) 5.5 rad (B) 0.55 rad
(C) 55 rad (D) 0.5 rad

**Ans. : (A)**

9. A body is moving in a vertical circular motion. Which one of the following forces does not experience ?
(A) Force of gravity (B) Centripetal force
(C) Friction force (D) Centrifugal force

**Ans. : (C)**

10. A body of mass 2 kg moving vertical circular motion with the help of string radius 1 m and with velocity of 2 m/s. What is tension in string at lowest point ? $g = 10\ m/s^2$
(A) 28
(B) 20
(C) 8
(D) 15

**Ans. : (A)**

11. A body of mass 2 kg moving vertical circular motion with the help of string radius 1 m and with velocity of 5 m/s. What is tension in string at highest point ? $g = 10\ m/s^2$.
(A) 30
(B) 50
(C) 20
(D) 25

**Ans. : (A)**

12. At which position in vertical circular motion is the tension in the string minimum ?
(A) At the highest position
(B) At the lowest position
(C) When the string is horizontal
(D) At an angle of 35° from the horizontal

**Ans. : (A)**

13. While taking turn on a curved road, a cyclist has to bend through a certain angle. This is done______
(A) to reduce his speed
(B) to decrease the friction between the tyres and the road
(C) to get the necessary centripetal force
(D) to reduce his weight

**Ans. : (C)**

14. A car takes a turn on a slippery road at a safe speed of 9.8 m/s. If the coefficient of friction is 0.2, the minimum radius of the arc in which the car takes a turn is______.
(A) 20 m
(B) 49 m
(C) 80 m
(D) 24.5 m

**Ans. : (B)**

15. The circumference of a circular track is 1.256 km. What is the tangent of the angle of banking of the track if the maximum speed, at which a car can be safely driven along it is 20 m/s and g = 10 m/s ?
(A) 1/2
(B) 1/3
(C) 1/4
(D) 1/5

**Ans. : (D)**

16. An aeroplane is taking a turn in a horizontal plane. While taking the turn______
(A) it remains horizontal
(B) it inclines outwards
(C) it inclines inward
(D) it makes its wings vertical

**Ans. : (C)**

17. While taking a sharp turn, a car moving on a horizontal road, may be thrown out of the road. This happens ...............
(A) due to frictional force between the tyres and the road
(B) due to gravitational force
(C) due to lack of sufficient centripetal force
(D) due to the reaction of the ground.

**Ans. : (C)**

18. When a car takes a circular turn on a banked road, the Centripetal force is provided by______
(A) gravitational force
(B) frictional force
(C) horizontal component of normal reaction
(D) vertical component of normal reaction

**Ans. : (C)**

19. A cyclist moves in a circular track of radius 100 m. If the coefficient of friction is 0.2, then the maximum velocity with which the cyclist can take the turn without leaning inward is______
(A) 4.9 m/s
(B) 14 m/s
(C) 1.4 m/s
(D) 140 m/s

**Ans. : (B)**

20. Without changing the angle of banking, if we want to increase the maximum safe speed, with which a car can travel on the curved road by 10%, then we have to increase the radius of curvature of the road from 20 m to______
(A) 12.1 m
(B) 24.2 m
(C) 6 m
(D) 48 m

**Ans. : (B)**

21. Maximum safe speed does not depend upon.....
(A) radius of curvature
(B) angle of inclination with the horizontal
(C) mass of the vehicle
(D) acceleration due to gravity

**Ans. : (C)**

22. The angular speed of a flywheel making 180 r.p.m. is....
(A) $2\pi$ rad/s
(B) $4\pi$ rad/s
(C) $6\pi$ rad/s
(D) $3\pi/2$ rad/s

**Ans. : (C)**

23. The angular velocity of a wheel is 70 rad/sec. If the radius of the wheel is 0.5 m, then linear velocity of the wheel is .....
(A) 10 m/s
(B) 20 m/s
(C) 35 m/s
(D) 70 m/s

**Ans. : (C)**

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