CONTENTS

➤➤➤ MOTION ➤➤➤

PHYSICAL SCIENCE

This science deals with the properties and Behaviour of nonliving things.

(a) Physics (in Greek Nature):

It is the branch of science which deals with the study of the natural laws and their manifestation in the natural phenomenon.

Mechanics (oldest branch) :

If deals with the conditions of rest or motion of the material objects around us.

Statics :

It deals with the study of object at rest or in equilibrium, even when they are under the action of several forces (measurement of time is not essential).

Kinematics : If deals with the study of motion of objects without considering the cause of motion measurement of time is essential). $\left[\text{Kinematics}\frac{\text{Greek}}{\text{Word}}\text{Kinema}\rightarrow\text{motion}\right]$

Dynamics : It deal with the study of objects taking into consideration the cause of their motion.

$\left(\text{Dnamics}\frac{\text{Greek}}{\text{Work}}\text{Dynamis}\rightarrow\text{power}\right)$

Rest : An object is said to be at rest if it does not change its position w.r.t. its surroundings with the passage of time.

Motion :A body is said to be in motion if its position changes continuously w.r.t. the surroundings (or with respect to an observer) with the passage of time.

REST AND MOTION ARE RELATIVE TERMS

Eg. : 1 A, B and C are three persons. B and C are sitting in the car and A is standing outside it. When car starts to move, B and C are changing their position with respect to A so B and C are in motion with respect to A but B is not changing its position with time with respect to C, so B is at rest with respect to C (same for C). Therefore motion depends on the position of the observer , hence motion is relative.

Eg. :2 We know that the earth is rotating about its axis and revolving around the sun. The stationary objects like your classroom, a tree and the lamp posts etc., do not change their position with respect to each other i.e. they are at rest. Although earth is in motion. To an observer situated outside the earth, say in a space ship, our classroom, trees etc. would appear to be in motion. Therefore, all motions are relative. There is nothing like absolute motion.

(a) Concept of a Point Object :

In mechanics while studying the motion of an object, sometimes it dimension are of no importance and the object may be treated as point object without much error. When the size of the object is much less in comparison to the distance covered by the object then the object is considered as a point object.

Eg. : 1 If one travels by a car from one place to another far away place, then length of the car is ignored as compared to distance traveled.

Eg. : 2 Earth can be regarded as a point object for studying its motion around the sun.

(b) Frame of Reference :

To locate the position of object we need a frame of reference. A convenient way to set up a frame of reference is to choose three mutually perpendicular axis and name them x-y-z axis. The coordinates (x, y, z) of the particle then specify the position of object w.r.t. that frame. If any one o more coordinates change with time, then we say that the object is moving w.r.t. this frame.

MOTIONS IN ONE, TWO AND THREE DIMENSIONS (TYPE OF MOTION)

As position of the object may change with time due to change in one or two or all the three coordinates, so we have classified motion as follows :

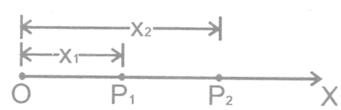
(a) Motion in 1-D:

If only one of the three co-ordinates specifying the position of object changes w.r.t. time. In such a case the object moves along a straight line and the motion therefore is also known as rectilinear or linear motion.

Eg. : (i) Motion of train along straight railway track.

(ii) An object falling freely under gravity.

(iii) When a particle moves from P_1 to P_2 along a straight line path only the x-co-ordinate changes.



(b) Motion in 2-D:

If two of the three co-ordinates specifying the position of object changes w.r.t. time, then the motion of object is called two dimensional. In such a motion the object moves in a plane.

Eg. : (i) Motion of queen on carom board.

(ii) An insect crawling on the floor of the room.

(iii) Motion of object in horizontal and vertical circles etc.

(iv) Motion of planets around the sun.

(v) A car moving along a zigzag path on a level road.

(c) Motion is 3-D:

If all the three co-ordinates specifying the position of object changes w.r.t. time, then the motion of object is called 3-D. In such a motion the object moves in a space.

Eg.: (i) A bird flying in the sky (also kite).

(ii) Random motion of gas molecules.

(iii) Motion of an aeroplane in space.

TYPES OF MOTION

(i) Linear motion (or translatory motion) : The motion of a moving car, a person running, a stone being dropped.

(ii) Rotational motion : The motion of an electric fan, motion of earth about its own axis.

(iii) Oscillatory motion : The motion of a simple pendulum, a body suspended from a spring (also called to and fro motion).

SCLALER AND VECTOR QUNTITY

Physically quantities (i.e. quantities of physics) can be divided into two types :

(i) Scalar quantity : Any physical quantity, which can be completely specified by its magnitude alone, is a scalar quantity or a scalar.

Eg.: Charge, distance, area, speed, time temperature, density, volume, work, power, energy, pressure, potential etc.

(ii) **Vector quantity :** Any physical quantity, which requires direction in addition to its magnitude is known as a vector.

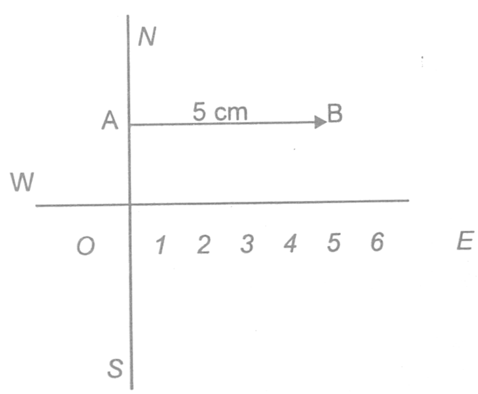
Eg. : Displacement, velocity, acceleration, force, momentum, weight and electric field etc.

(a) Representation of a vector :

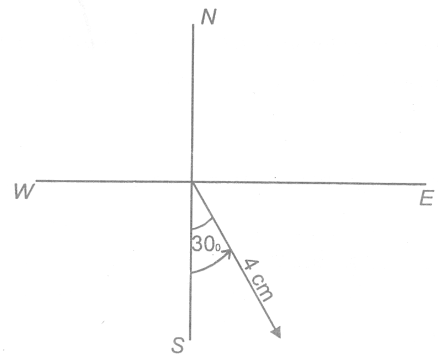
A vector is represented a directed line segment drawn in the given direction on a certain scale.

Tail ⟶ *head* (symbolic representation)

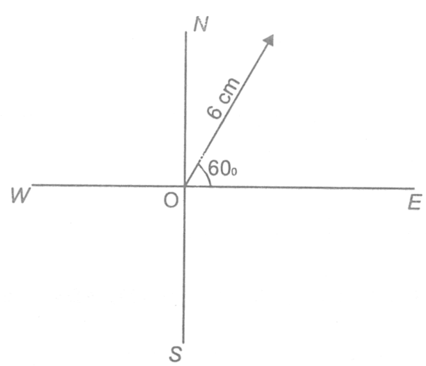
Eg.: To represent a displacement of 50 m towards east. Take 10 m = 1 cm (Scale)



Eg.: To represent a velocity of 20 k m/h towards 30^0 east of south. (Scale 5 km/h = 1 cm.)



Eg. : 6 m displacement, 60^0 north - east (north of east) (Scale 1 m = 1 cm)



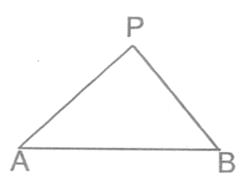
(b) Difference between Scalar and Vector :

Scalar	Vector
1. They have a magnitude only.	1. They have magnitude as well as direction.
2. They are added or subtracted arithmetically like 3 kg + 5 kg = 8 kg	2. They are added or subtracted by the process of vector addition.

DISTANCE AND DISPLACEMENT

(a) Distance :

Consider a body traveling from A to B along any path between A & B. The actual length of the path that a body travels between A and B is known as the distance. The distance traveled is different for different path between A and B. It is a scalar quantity. According to figure distance at path APB is AP + PB and at path AB is AB.



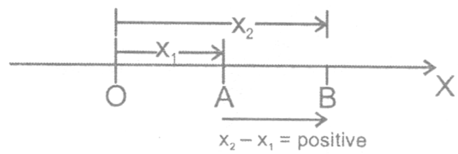
(b) Displacement :

The distance traveled in a given direction is the displacement. Thus displacement is the shortest distance between the given points. It is a vector quantity. S.I. unit of distance or displacement is metre.

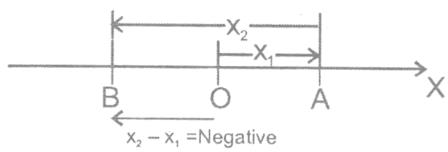
❖ **NOTE :** If a body travels in such a way that it comes back to its starting position, then the displacement is zero. However, distance traveled is never zero.

Eg. :

(i) When an object moves towards right from origin to in time t_1 to t_2, its displacement is positive.



(ii) When an object moves towards left in time t_1 to t_2, its displacement is negative.



(iii) When an object remains stationary or it moves first towards right and then an equal distance towards left, its displacement is zero.

(iv) Shifting origin causes no change in displacement.

(c) Difference between Distance and Displacement :

Distance	Displacement
1. Distance is the length of the path actually traveled by a body in any direction.	1. Displacement is the shortest distance between the initial and the final positions of a body in the direction of the point of the final position.
2. Distance between two given points depends upon the path chosen.	2. Displacement between two points is measured by the straight path between the points.
3. Distance is always positive.	3. Displacement may be positive as well as negative and even zero.
4. Distance is scalar quantity.	4. Displacement is a vector quantity
5. Distance will never decrease	5. Displacement may decrease.

EXERCISE

OBJECTIVE DPP - 1.1

1. A body whose position with respect to surrounding does not change, is said to be in a state of :

(A) Rest (B) Motion (C) Vibration (D) Oscillation

2. In case of a moving body :

(A) Displacement > Distance (B) Displacement < Distance

(C) Displacement $\geq$ Distance (D) Displacement $\leq$ Distance

3. Vector quantities are those which have :

(A) Only direction (B) Only Magnitude

(C) Magnitude and direction both (D) None of these

4. What is true about scalar quantities ?

(A) Scalars quantities have direction also. (B) Scalars can be added arithmetically.

(C) There are special law to add scalars. (D) Scalars have special method to represent.

5. A body is said to be in motion if :

(A) Its position with respect to surrounding objects remains same

(B) Its position with respect to surrounding objects keep on changing

(C) Both (A) and (B)

(D) Neither (A) nor (B)

6. A distance is always :

(A) shortest length between two points (B) path covered by an object between two points

(C) product of length and time (D) none of the above

7. A displacement :

(A) is always positive (B) is always negative

(C) may be positive as well as negative (D) is neither positive nor negative

8. Examples of vector quantities are :

(A) velocity, length and mass (B) speed, length and mass

(C) time, displacement and mass (D) velocity, displacement and force

9. Which of the following is not characteristic of displacement ?

(A) It is always positive.

(B) Is has both magnitude and direction.

(C) It can be zero.

(D) Its magnitude is less than or equal the actual path length of the object.

10. S.I. unit of displacement is :

(A) m (B) ms^{-1} (C) ms^{-2} (D) None of these

11. Which of the following is not a vector ?

(A) Speed (B) Velocity (C) Weight (D) Acceleration

12. Time is an example of :

(A) Scalar (B) Vector

(C) Scalar or vector (D) Neither scalar nor vector

13. In five minutes distance between a pole and a car changes progressively. What is true about the car ?

(A) Car is at rest (B) Car is in motion

(C) Nothing can be said with this information (D) None of the above

14. A distance :

(A) Is always positive (B) Is always negative

(C) May be positive as well as negative (D) Is neither positive nor negative

SUBJECTIVE DPP - 1.2

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1. Is absolute rest possible ?

2. Are distance and displacement equal in magnitude ?

3. Is distance a vector quantity ?

4. Define scalar quantity and give two examples.

5. Define rest and motion and give two examples of each.

6. A runner running along a circle, runs the circle completely. What is his displacement ? What distance has be run ?

7. Distinguish between rest and motion.

8. Write difference between distance and displacement.

9. Can a body be at rest and motion at the same time ? Explain.

10. When do we say that body is at rest and when do we say that it is moving ? Explain.

11. Give two examples to explain that motion is relative.

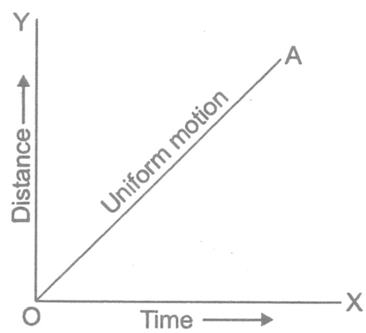
➤➤➤ MOTION ⮜⮜⮜

PL - 2

UNIFORM AND NON UNOFORM MOTION

(a) Uniform Motion :

A body has a uniform motion if it travels equal distances in equal intervals of time, no matter how small these time intervals may be. For example, a car running at a constant speed of say, 10 meters per second, will cover equal distances of 10 metres every second, so its motion will be uniform. Please note that the distance-time graph for uniform motion is a straight line (as shown in the figure).



(b) Non-Uniform Motion :

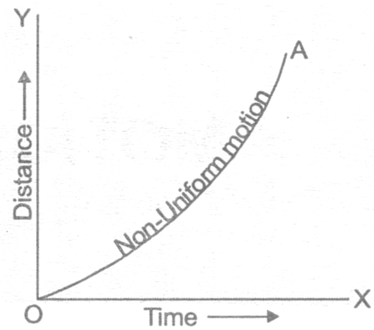
body has a non-uniform if it travels unequal distances in equal intervals of time. For example, if we drop a ball from the roof of a building, we will find that it covers unequal distances in equal intervals of time. It covers :

4.9 metres in the 1st second,

14.7 metres in the 2nd second,

24.5 metres in the 3rd second, and so on.

Thus, a freely falling ball covers smaller distance in the initial '1 second' interval and larger distance in the later '1 second' interval. From this discussion we conclude that the motion of a freely falling body is an example of non-uniform motion. The motions of a train starting from the railway station is also an example of non-uniform motion. This is because when the train starts from a s station, if moves a very small distance in the 'first' second. The train moves a little more distance in the '2nd' second and so on. And when the train approaches the next station, the distance traveled by it per second decreases.



Please note that the distance-time graph for a body having non-uniform motion is curved line (as shown in the figure). Thus, in order to find out whether a body has uniform motion or non-uniform motion, we should draw the distance-time graph for it. If the distance time graph is straight line, the motion will be uniform and if the distance -time graph is a curved line, the motion will be non-uniform. It should be noted that non-uniform motion is also called accelerated motion.

SPEED

The distance traveled by a body in unit time is called its peed. Therefore,

speed = $\frac{\text{Distance}}{\text{Time}}$ or s = $\frac{d}{t}$. S.I. unit of speed or average speed is m/sec. It is a scalar quantity,

(a) Average Speed :

For an object moving with variable speed, it is the total distance traveled by the object divided by the total time taken to cover that distance.

$$\text{Average speed} = \frac{\text{total distance travelled}}{\text{total time taken}}$$

(b) Uniform Speed (or Constant Speed):

When an object covers equal distance in equal intervals of time, it is said to move with uniform speed.

Eg. A car moves 10 m is every one second so it motion is uniform.

(c) Variable Speed (Non-Uniform Speed) :

If a body covers unequal distance in equal intervals of time, its motion is said to be non-uniform.

Eg. Falling of a apple from a tree, a cyclist moving on a rough road, an athlete running a race, vehicle starting from rest, the motion of freely falling body etc.

(d) Instantaneous Speed :

The speed of an object at any particular instant of time or at particular point of its path is called the instantaneous speed of the object. it is measure red by speedometer in an automobile.

VELOCITY

It is the rate of change of displacement.

Therefore, velocity = $\frac{\text{displacement}}{\text{time}}$ or it is the distance traveled in unit time in a given direction.

$$\text{velocity} = \frac{\text{distance travelled in a given direction}}{\text{time taken}}$$

S.I. unit of velocity is m/s. If is a vector quantity.

(Magnitude of the velocity is known as speed) 1 km/h = 5/18 m/s.

Speed	Velocity
1. It is a scalar quantity.	1. It is a vector quanity.
2. Speed = $\frac{\text{dis tan ce travelled}}{\text{time}}$	2. Velocity = $\frac{\text{displacement}}{\text{time}}$
3. It is rate of change of position of an object.	3. It is rate of change of position of an object in specific direction.

(a) Uniform Velocity (Constant Velocity) :

If a body covers equal distance in equal intervals of time in a given direction then it is said to be moving with constant velocity.

(b) Non-Uniform Velocity :

When a body does not cover not cover equal distances in equal intervals of time, in a given direction (in this case speed is not constant), then it is known as non uniform velocity. If speed is constant then also body can have a non-uniform velocity.

Eg : A car moving on a circular road with constant speed.

(c) Average Velocity :

If initial velocity of body is u and final velocity is v then the arithmetic means of velocity is called average velocity and is given as $v_{2v} = \frac{u+v}{2}$. Where, u = initial velocity and v = final velocity. Also for an object moving with variable velocity it is defined as the ratio of its total displacement to the total time interval in which the displacement occurs. Average velocity $= \frac{\text{Total displacement}}{\text{Total time}}$. If x_1 & x_2 are the positions of an object at times t_1 & t_2 then, $\vec{v}_{av} = \frac{\vec{x}_2 - \vec{x}_1}{\Delta t} = \frac{\vec{\Delta x}}{\Delta t}$ $\Delta t = t_2 - t_1$

(d) Instantaneous Velocity :

The velocity of an object at any given instant of time at particular point of its path is called its instantaneous velocity.

$$\vec{V} = _{\lim \Delta t \to 0} \frac{\Delta\vec{x}}{Xt} = \frac{d\vec{x}}{dt}$$

Ex. When is the average speed of an object equal to the magnitude of its average velocity ? Give reason also.

Sol. As average speed $= \frac{\text{total pathlength}}{\text{time int erval}}$ also, average velocity = $\frac{\text{Displacement}}{\text{time int erval}}$. When an object moves along a straight line and in the same direction its total path length is equal to the magnitude of its displacement. Hence average speed is equal to the magnitude of its average velocity.

FEATURE OF UNIFORM MOTION

(i) The velocity in uniform motion does not depend on the choice of origin.

(ii) The velocity in uniform motion does not depend on the choice of the time interval ($t_2 - t_1$).

(iii) For uniform motion along a straight line in the same direction, the magnitude of the displacement is equal to the actual distance covered by the object.

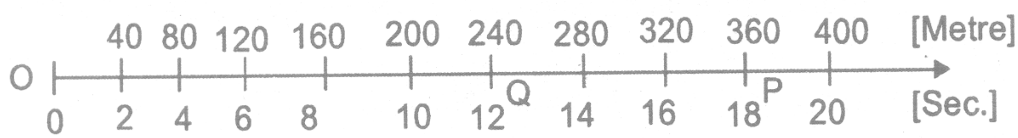
(iv) The velocity is positive if the object is moving towards the right of the origin and negative if the object is moving towards the left of the origin.

(v) For an object is uniform motion no force is required to maintain its motion.

(vi) In uniform motion, the instantaneous velocity is equal to the average velocity at all time because velocity remains constant at each instant, at each point of the path.

ILLUSTRATIONS

1. A car is moving along x-axis. As shown in figure it moves from O to P in 18 s and returns from P to Q in 6 second. What is the average velocity and average speed of the car in going from (i) O to P and (ii) from O to P and back to Q.



Sol. (i) Average velocity = $\dfrac{\text{path lenght}}{\text{time interval}} = \dfrac{360\text{m}}{18} = 20\,\text{ms}^{-1}$

Average speed = $\dfrac{\text{path length}}{\text{time interval}} = \dfrac{360\text{m}}{18} = 20\,\text{ms}^{-1}$

(ii) From O to P and back to Q

Average velocity = $\dfrac{OQ}{18+6} = \dfrac{240\text{m}}{24} = 10\,\text{ms}^{-1}$

Average speed = $\dfrac{\text{path length}}{\text{time interval}} = \dfrac{OP+PQ}{18+6} = \dfrac{360+120}{24} = 20\,\text{ms}^{-1}$

2. A car covers the 1st half of the distance between two places at a speed of 40 km h^{-1} and the 2nd half at 60 km h^{-1}. What is the average speed of the car ?

Sol. Suppose the total distance covered is 2S.

Then time taken to cover first distance with speed 40 km/h,

$t_1 = \dfrac{S}{40}\text{h}$

Time taken to cover second S distance with speed 60 km/h,

$$t_2 = \frac{S}{60} h$$

$$V_{av} = \frac{\text{total distance}}{\text{total time}} = \frac{S+S}{\left(\frac{S}{40}+\frac{S}{60}\right)}$$

$$V_{av} = \frac{2S}{\left(\frac{3S+2S}{120}\right)} = \frac{2S}{5S}\times 120$$

$$\Rightarrow \quad V_{av} = 48 km/h$$

3. A non-stop bus goes from one station to another station with a speed of 54 km/h, the same bus returns from the second station to the first station with a speed of 36 km/h. Find the average speed of the bus for the entire journey.

Sol. Suppose the distance between the stations is S. Time taken in reaching from one station to another station.

$$t_1 = \frac{S}{54} h$$

Time taken in returning back,

$$t_2 = \frac{S}{36} h$$

Total $t = t_1 + t_2$

$$t = \frac{S}{54} + \frac{S}{36} = \frac{2S+3S}{108} = \frac{5S}{108} h$$

Average speed $V_{av} = \dfrac{\text{Total distance}}{\text{Total time}}$

$$V_{av} = \frac{2S}{5S}\times 108$$

$$V_{av} = \frac{216}{5} = 43.2 \text{ km/h}$$

EXERCISE

OBJECTIVE DPP - 2.1

1. When a body covers equal distance in equal intervals of time, its motion is said to be :

(A) Non-uniform (B) Uniform (C) Accelerated (D) Back and forth

2. The motion along a straight line is called :

(A) Vibratory (B) Stationary (C) Circular (D) Linear

3. A particle is traveling with a constant speed. This means :

(A) Its position remains constant as time passes.

(B) It covers equal distance in equal interval of time

(C) Its acceleration is zero

(D) It does not change its direction of motion

4. The rate of change of displacement is :

(A) Speed (B) Velocity (C) Acceleration (D) Retardation

5. Speed is never :

(A) zero (B) Fraction (C) Negative (D) Positive

6. The motion of a body covering different distances in same intervals of time is said to be :

(A) Zig - Zag (B) Fast (C) Slow (D) Variable

7. Unit of velocity is :

(A) ms (B) ms^{-1} (C) ms^2 (D) none of these

8. A speed :

(A) is always positive (B) is always negative

(C) may be positive as well as negative (D) is neither zero nor negative

9. A particle moves with a uniform velocity :

(A) The particle must be at rest (B) The particle moves along a curved path

(C) The particle moves along a circle (D) The particle moves along a straight line

10. A quantity has value of $-6.0\ ms^{-1}$. It may be the :

(A) Speed of a particle (B) Velocity of a particle

(C) Position of a particle (D) Displacement of a particle

11. In 10 minutes, a car with speed of 60 kmh^{-1} travels a distance of :

(A) 6 km (B) 600 km (C) 10 km (D) 7 km

12. A particle covers equal distances in equal intervals of times, it is said to be moving with uniform :

(A) Speed (B) Velocity (C) Acceleration (D) Retardation

13. The SI unit of the average velocity is :

(A) m/s (B) km/s (C) cm/s (D) mm/s

14. Mere per second is not the unit of :

(A) Speed (B) Velocity (C) Displacement (D) None of them

SUBJECTIVE DPP - 2.2

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1. What is the S.I. unit of velocity ?

2. Which is vector, speed or velocity ?

3. Give the name of the physical quantity that corresponds to the rate of change of displacement ?

4. Apart from velocity name two other quantities which are vector ?

5. When is a body said to have uniform velocity ?

6. A particle is moving with uniform velocity. it is necessary moving with uniform speed ? Is it necessary that it is moving along a straight line ?

7. Write difference between sped and velocity.

8. A train covers 80 km in 2 hours. Find its average speed in kmh^{-1}, $m\ min^{-1}$ and ms^{-1}.

9. Which one of the following have maximum and the least average speed ?

(i) Sanjeev moving with 12 kmh^{-1}

(ii) Rajeev running with 5 ms^{-1}

(iii) Kabir moving with 150 $m\ min^{-1}$.

10. (a) Uniform motion (b) Non uniform motion

11. (a) Average speed (b) Velocity

➤➤➤ MOTION ➤➤➤

PL - 3

ACCELERATION

Mostly the velocity of a moving object changes either in magnitude or in direction or in both when the object moves. The body is then said to have acceleration. So it is the rate of change of velocity i.e. change in velocity in unit time to the acceleration (it is a vector quantity). Its S.I. unit is m/sec^2 and c.g.s unit is c $m/sec.^2$

$$\text{Acceleration} = \frac{\text{change in velocity}}{\text{time}} = \frac{v-u}{t} = \frac{\text{final velocity} - \text{initial velocity}}{\text{time}}$$

(a) Uniform Acceleration (Uniformly Accelerated Motion):

If a body travels in a straight line and its velocity increases in equal amounts in equal intervals of time. Its motion is known as uniformly accelerated motion.

Eg.1 Motion of a freely falling body is an example of uniformly accelerated motion (or motion of a body under the gravitational pull of the earth).

Eg.2 Motion of a bicycle going down the slope of a road when the rider is not pedaling and wind resistance is negligible.

(b) None-Uniform Acceleration :

If during motion of a body its velocity increases by unequal amounts in equal intervals of time, then its motion is known as non uniform accelerated motion.

Eg.1 Car moving in a crowded street.

Eg.2 Motion of a train leaving or entering the platform.

TYPES OF ACCELERATIO

(i) Positive acceleration : If the velocity of an object increases in the same direction, the object has a positive acceleration.

(ii) Negative acceleration (retardation): If the velocity of a body decreases in the same direction, the body has negative acceleration or it is said to be retarding.

Eg. A train slows down.

EQUATIONS OF UNIFORMLY ACCELERATION MOTION

(a) 1st Equation of Motion :

Consider a body having initial velocity 'u'. Suppose it is subjected to a uniform acceleration 'a' so that after time 't' its final velocity becomes 'v'. Now we now,

$$\text{Acceleration} = \frac{\text{change in velcity}}{\text{time}}$$

$$a = \frac{v - u}{t}$$

or $v = u + at$ or $v = at + u$ .....(i)

(b) 2nd Equation of Motion :

Suppose a body has an initial velocity 'u' and uniform acceleration 'a' for time 't' so that its final velocity becomes 'v'. The distance traveled by moving body in time 't' is 's' then the average velocity = (v + u)/2.

Distance traveled = Average velocity × time

$$s = \left(\frac{u+v}{2}\right)t \quad \Rightarrow \quad s = \left(\frac{u+u+at}{2}\right)t \qquad (\text{as } u = v + at)$$

$$s = \left(\frac{2u+at}{2}\right)t \quad \Rightarrow \quad s = \frac{2ut + at^2}{2}$$

$$s = ut + \frac{1}{2}at^2$$

(c) 3rd Equation of Motion

Distance traveled = Average velocity × time

$$s = \left(\frac{u+v}{2}\right)t \qquad \text{......(ii)}$$

from equation (i) $t = \frac{v-u}{a}$

Substituting the value of t in equation (iii), we get $s = \left(\frac{v-u}{a}\right)\left(\frac{v+u}{2}\right)$

$$s = \left(\frac{v^2 - u^2}{2a}\right) \quad \Rightarrow \quad 2as = v^2 - u^2 \text{ or } v^2 = u^2 + 2as \qquad \text{....(iv)}$$

(d) Distance covered in nth second :

$S = ut + \frac{1}{2}at^2$ is the distance covered by a body in t s.

$S_n - un + \frac{1}{2}an^2$ ....(v) [distance covered by a body along a straight line in n second.

$S_{n-1} = u(n-1) + \frac{1}{2}a(n-1)^2$ ....(vi) [distance covered by a body along a straight line in (n-1) sec.]

$\therefore$ The distance covered by the body in n^{th} second will be -

$S_{nth} = S_n - S_{n-1}$

$$\therefore \quad S_{nth} = un + \frac{1}{2}an^2 - \{u(n-1) + \frac{1}{2}a(n-1)^2\}$$

$$S_{nth} = un + \frac{1}{2}an^2 - \{nu - u + \frac{1}{2}a(n^2 + 1 - 2n)\}$$

$$S_{nth} = un + \frac{1}{2}an^2 - \{un - u + \frac{an^2}{2} + \frac{a}{2} - an\}$$

$$S_{nth} = un + \frac{1}{2}an^2 - un + u - \frac{an^2}{2} - \frac{a}{2} + an$$

$$S_{nth} = u + a\left(n - \frac{1}{2}\right)$$

$$S_{nth} = u + a\left(\frac{2n-1}{2}\right)$$

$$S_{nth} = u + \frac{a}{2}(2n-1) \qquad \text{............(vii)}$$

TO SOLVE NUMERIAL PROBLEMS

(i) If a body is dropped from a height then its initial velocity u = 0 but has acceleration (acting). If a body starts from rest its initial velocity u = 0.

(ii) If a body comes to rest, its final velocity v = 0 or, if a body reached the highest point after being thrown upwards its final velocity v = 0 but has acceleration (acting).

(iii) if a body moves with uniform velocity, its acceleration is zero i.e. a = 0.

(iv) Motion of body is called free fall if only force acting on it is gravity (i.e. earth's attraction).

MOTION UNDER GRAVITY (UNIFORM ACCELERATED MOTION)

The acceleration with which a body travels under gravity is called acceleration due to gravity 'g'. Its value is 9.8 m/s^2 (or $\approx$ 10 m/s^2). If you have to take g = 10 m/s^2 then it must be mentioned in the question otherwise take g = 9.8 m/s^2.

(i) If a body moves upwards (or thrown up) g is taken negative (i.e. motion is against gravitation of earth). So we can form the equation of motion like.

$v = u - gt$, $s = ut - \frac{1}{2}gt^2$, $v^2 - u^2 = -2gh$.

(ii) If a body travels downwards (towards earth) then g is taken + ve. So equations of motion becomes $v = u + gt$, $s = ut + \frac{1}{2}gt^2$, $v^2 - u^2 = 2gh$.

(iii) if a body is projected vertically upwards with certain velocity then it returns to the same point of projection with the same velocity in the opposite direction.

(iv) The time for upward motion is the same as for the downward motion.

ILLUSTRATION

1. A car is moving at a speed of 50 km/h. Two seconds there after it is moving at 60 km/h. Calculate the acceleration of the car.

Sol. Here u = 50 km/h = $50 \times \frac{5}{18}$ m/s = $\frac{250}{18}$ m/s

and v = 60 km/h = $60 \times \frac{5}{18} = \frac{300}{18}$ m/s

Since $a = \frac{v-u}{t} = \frac{\frac{300}{18} - \frac{250}{18}}{2} = \frac{\frac{50}{18}}{2} = \frac{50}{36} = 1.39\,m/s^2$

2. A car attains 54 km/h in 20 s after it starts. Find the acceleration of the car.

Sol. u = 0 (as car starts from rest)

v = 54 km/h = $54 \times \frac{5}{18}$ = 15 m/s

As, $a = \frac{v-u}{t} \therefore a = \frac{15-0}{20} = 0.75\,m/s^2$

3. A ball is thrown vertically upwards with a velocity of 20 m/s. How high did the ball go ? (take g = 9.8 m/s^2).

Sol. u = 20 m/s, a = - g = - 9.8 m/s^2 (moving against gravity)

s = ? v = 0 (at highest point)

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

$(o)^2 - (20)^2 = 2(-g)\,s$

$-400 = 2\,(-9.8)\,s$

$-400 = -19.6\,s$

$\frac{400}{19.6} = s \Rightarrow s = 20.4$ m.

EXERCISE

OBJECTIVE DPP 3.1

1. A car accelerated uniformly from 18 km/h to 36 km/h in 5 s. The accelerating is ms^{-2} is :

(A) 1 (B) 2 (C) 3 (D) 4

2. Out of energy and acceleration which is vector ?

(A) Acceleration (B) Energy (C) Both (D) None of these

3. C.G.S. unit of acceleration is :

(A) ms^{-2} (B) $cm\ s^{-2}$ (C) ms^{2} (D) $cm\ s^{2}$

4. A train starting from a railway station and moving with inform acceleration, attains a speed of 40 kmh^{-1} in 10 minutes, Is acceleration is :

(A) 18.5 ms^{-2} (B) 1.85 $cm\ s^{-2}$ (C) 18.5 cms^{-2} (D) 1.85 $m\ s^{-2}$

5. The brakes applied to a cap produce a negative acceleration of $6ms^{-2}$. If the car stops after 2 seconds, the initial velocity of the car is :

(A) 6 ms^{-1} (B) 12 ms^{-1} (C) 24 ms^{-1} (D) zero

6. A body is moving with uniform velocity of 10 ms^{-1}. The velocity of the body after 10 s is :

(A) 100 ms^{-1} (B) 50 ms^{-1} (C) 10 ms^{-1} (D) 5 ms^{-1}

7. In 12 minutes a car whose speed is 35 kmh^{-1} travels of distance of :

(A) 7 km (B) 3.5 km (C) 14 km (D) 28 km

8. A body is moving along a straight line at 20 ms^{-1} undergoes an acceleration of 4 ms^{-2}. After 2 s, its speed will be:

(A) 8 ms^{-2} (B) 12 ms^{-1} (C) 16 ms^{-2} (D) 28 ms^{-2}

9. A car increase its speed from 20 kmh^{-1} to 50 kmh^{-1} is 10 sec., its acceleration is :

(A) 30 ms^{-1} (B) 3 ms^{-1} (C) 18 ms^{-1} (D) 0.83 ms^{-1}

10. When the distance travelled by an object is directly proportional to the time, it is said to travel with :

(A) zero velocity (B) constant speed (C) constant acceleration (D) uniform velocity

11. A body freely failing from rest has a velocity V after it falls through a height h. The distance it has to fall further for its velocity to be come double is :

(A) 3 h (B) 6 h (C) 8 h (D) 10 h

12. The velocity of bullet is reduced from 200m/s to 100 m/s while traveling through a wooden block of thickness 10 cm. The retardation, assuming it to be uniform will be :

(A) $10 \times 10^4\ m/s^2$ (B) $1.2 \times 10^4\ m/s^2$ (C) $13.5 \times 10^4\ m/s^2$ (D) $15 \times 10^4\ m/s^2$

13. A body starts falling from height 'h' and travels distance h/2 during the last second of motion. The find of travel (in sec.) is :

(A) $\sqrt{2}-1$ (B) $2+\sqrt{2}$ (C) $\sqrt{2}+\sqrt{3}$ (D) $\sqrt{3}+2$

SUBJECTIVE DPP - 3.2

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1. Find the formula for the distance covered by a body in n^{th} s.

2. How is the position of a moving particle along a straight line described by a number ? How is the direction of motion specified by the number describing position ?

3. A ball is thrown vertically upward from the ground with a velocity 39.2 ms^{-1}. Calculate :

(i) the maximum height to which the ball rises and

(ii) the time taken by the ball to reach the highest point.

4. A body standing near the edge of a cliff 125 m above a river throws a stone downward with a speed of 10 ms^{-1} Find :

(i) with what speed will the stone hit water and

(ii) how long will it take to descend ?

5. A stone is dropped from the top of a building 200 m high and at the same time another stone is projected vertically upward from the ground with a velocity of 50 ms^{-1}. Find where and when the two stone will meet.

6. A ball thrown vertically upward reached a height of 80 m. Calculate :

(i) the time to reach the highest point

(ii) the spend of the ball upon arrival on the ground.

➤➤➤ MOTION ⮜⮜⮜

PL - 4

DISTANCE (DISPLACEMENT) FROM SPEED (VELOCITY) TIME GRAPH

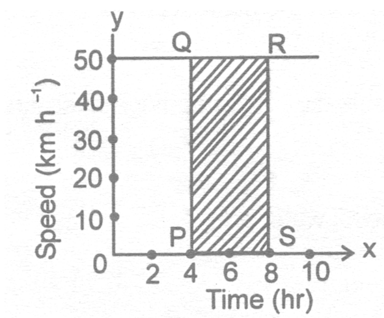
A distance (displacement = speed (velocity) x time, so the distance (displacement) can be calculated (computed) with speed (velocity) - time graph.

Case (i) : When speed (velocity) is uniform (constant):

Figure shows the speed - time graph of a car (taxi) moving with a uniform speed of 50 km h^{-1}. It is a straight line parallel to X - axis (time axis). Distance covered by this taxi from time t_1 = 4h at P to time t_2 = 8 h at S, is given by distance = 50 × (t_2 - t_1)

= 50 (8 - 4)

= 50 × 4 = 200 km

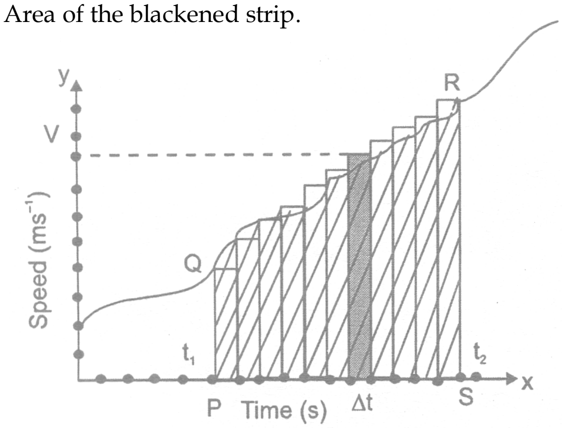


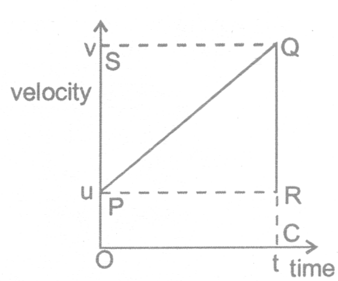
In figure, PQ = 50, SP = (t_1 - t_1)

Hence distance = PQ × SP = Area of rectangle PSRQ

Case (ii) : When speed (velocity) as well as acceleration is non-uniform (variable)

Figure shows the speed- time graph of a body moving with variable speed and acceleration. Over a small interval of time Δt, the speed can be taken as constant. For this small time interval, distance $\Delta S = v\Delta t$ = Area of the blackened strip.





For whole time-interval between t_1 and t_2

distance = sum of area of all the strips between t_1 and t_2 = Area of shaded figure PQRS.

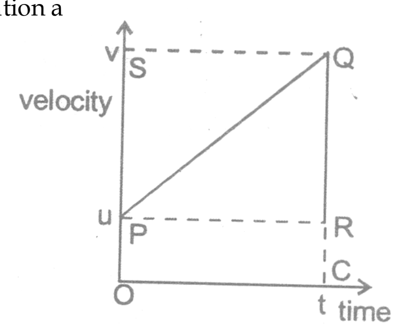
GRAPHICAL DERIVATION OF EQUATIONS OF MOTION

(a) First Equations :

v = u + at

It can be derived from v - t graph, as shown is figure

From line PQ, the slope of the line = acceleration a



$$a = \frac{QR}{RP} = \frac{SP}{RP}$$

$\therefore$ SP = v - u

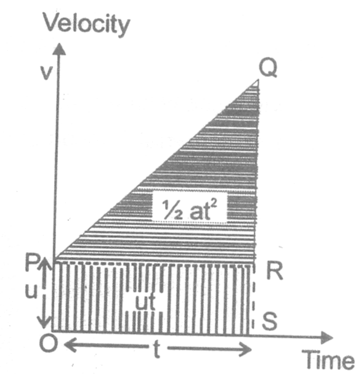
So $a = \frac{v-u}{t}$

or $v\ u + at$

(b) Second Equation :

$$s = ut + \frac{1}{2}at^2$$

It can also be derived from v - t graph as shown in figure.



From relation,

Distance covered = Area under v - graph

s = Area of trapezium OPQS

= Area of rectangle OPRS + Area of triangle PQR

$$= OP \times PR + \frac{RQ \times PR}{2}$$

Putting values,

$$S = u \times t + \frac{1}{2}(v-u) \times t \qquad (\therefore RQ = v - u \;\&\; PR = OS = t)$$

$$= u \times t + \frac{1}{2}at \times t \qquad (\therefore v - u = at)$$

Pr $s = ut + \frac{1}{2}at^2$

(c) Third Equation :

$v^2 = u^2 + 2as$

From above graph OP = um SQ = v, OP + SQ = u + v

$$a = \frac{QR}{PR} \qquad \text{or} \qquad PR = \frac{QR}{a} = \frac{v-u}{a}$$

S = Area of trapezium OPQS $= \frac{OP + SQ}{2} \times PR$

On putting the values,

$$S = \frac{u+v}{2} \times \frac{v-u}{a} = \frac{v^2 - u^2}{2a} \qquad \text{or} \qquad v^2 = u^2 + 2as$$

EXERCISE

OBJECTIVE DPP 4.1

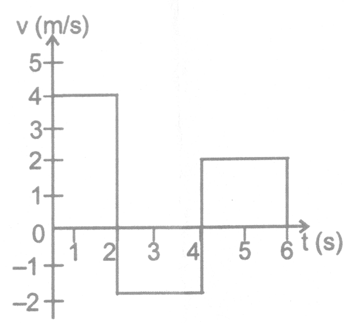
1. Area between speed - time graph and time axis gives :

(A) Distance (B) Velocity (C) Speed (D) None of these

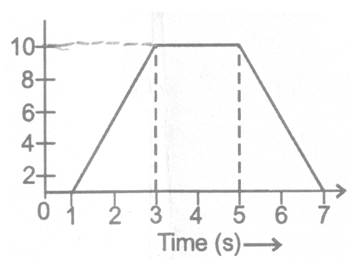
2. An object undergoes an acceleration of 8 ms^{-2} starting from rest. Distance traveled is 1 s is :

(A) 2 m (B) 4m (C) 6m (D) 8 m

3. The velocity-time graph of a body moving in a straight line is shown in figure. The displacement and distance travelled by the body is 6 seconds are respectively.

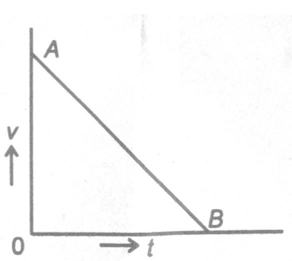


4. For the velocity time graph shown in figure, the distance covered by the body in the last two seconds of its motion is what fraction is of the total distance covered in all the seven seconds ?



(A) 1/2 (B) 1/4 (C) 1/3 (D) 2/3

5. Velocity-time graph AB (Figure) shows that the body has :



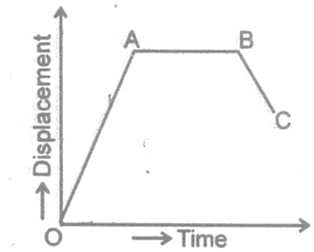
(A) A uniform acceleration

(B) A non-uniform retardation

(C) Uniform speed

(D) Initial velocity O*A* and is moving with uniform retardation

6. In figure BC represents a body moving :
(A) Backward with uniform velocity
(B) Forward with uniform velocity
(C) Backward with non-uniform velocity
(D) Forward with non-uniform velocity



7. Speedometer measures .... speeds.

SUBJECTIVE DPP - 4.2

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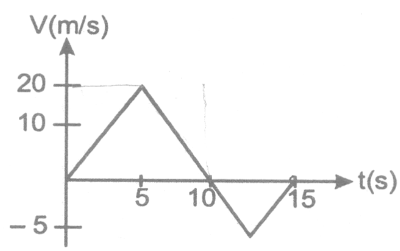
1. A stone is thrown vertically upward which takes time 't' to reach to maximum height 'h'. After next 't' seconds it reached the ground from the maximum height. Draw (i) distance-time graph and (ii) displacement time graph for the motion of the stone.
2. Draw V-t graphs in the following cases : (i) uniform retardation (ii) non uniform acceleration
3. From the following (V-t) graph find :



(i) Distance and displacement in 10 second.
(ii) Distance and displacement in 15 second.

➤➤➤ MOTION ❮❮❮

PL - 5

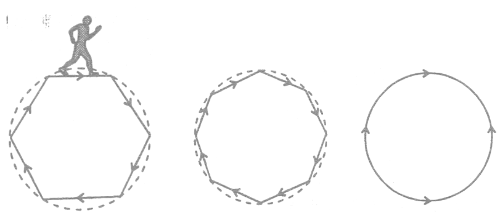
CIRCULAR MOTION

(a) Definition :

Motion of a particle (small body) along a circle (circular path), is called a circular motion. If the body covers equal distances along the circumference of the circle in equal intervals of time, the motion is said to be a uniform circular motion. A uniform circular motion is a motion in which speed remains constant but direction of velocity changes.

(b) Explanation :

Consider a boy running along a regular hexagonal track (path) as shown in figure. As the boy runs along the side of the hexagon at a uniform speed, he has to take turn at each corner changing direction but keeping the sped same. In one round he has to take six turns at regular intervals. If the same boy runs along the side of a regular octagonal track with same uniform speed, he will have to take eight turns in one round at regular intervals but the interval will become smaller.



By increasing the number of sides of the regular polygon, we find the number of turns per round becomes more and the interval between two turns become still shorter. A circle is a limiting case of polygon with an infinite number of sides. On the circular track, the turning becomes a continuous process without any gap in between. The boy running along the sides of such a track will be performing a circular motion. Hence, circular motion is the motion of a body along the sides of polygon of infinite number of sides with uniform speed, the direction changing continuously.

Eg. Example of uniform circular motion are :

(i) Motion of moon around the earth.

(ii) Motion of satellite around its planet.

(c) Nature of Circular of Motion :

Circular motion is an acceleration motion. Since, in a circular motion, velocity changes though in direction only, the motion is said to be accelerated.

DIFFERENCE BETWEEN UNIFORM LINEAR MOTION AND A UNIFOR CIRCULAR MOTION

Uniform linear motion	Uniform circular motion
1. The direction of motion does not changes	1. The direction of motion changes continuously.
2. The motion is non-accelerated.	2. The motion is accelerated.

RADIAN - (A UNIT FOR PLANE ANGLE)

It is a convenient unit for measuring angle in physics.

(a) Definition :

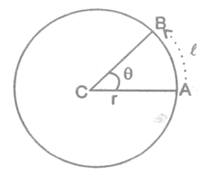
One radian is defined as the angle subtended at the centre of the circle by an arc equal in length to its radius.

Eg. In figure, the arc AB of the circle has length ℓ and subtends an angle θ at the centre C.

If $\angle ACB = \theta$ radians.

Then, $\theta = \frac{\ell}{r}$ radians.

[For $\ell = 1$, $\theta = 1$ radian]



Angle subtended by the circumference at the centre,

$\theta = \frac{2\pi r}{r} = 2\pi$ radians $\{\text{or } 2\pi^c\}$

[^{c}] is symbol for radian, just as (^{0}) is symbol for degree.

Relation

For complete circle at centre

$2\pi^c = 360^0$

Or $1^c = \left|\frac{360}{2\pi}\right| = 57.3^0$

ANGULAR DISPLACEMENT AND ANGULAR VELOCITY

(a) Definitions :

(i) Angular displacement : In a circular motion, the angular displacement of a body is the angle subtended by the body at the centre in a given interval of time. It is represented by the symbol θ (theta).

(ii) Angular velocity : The angular displacement per unit time is called the angular velocity. it is represented by the symbol ω (omega).

Eg. Let a body move along a circle of radius r and perform a uniform circular motion. Let the body be at point P to start with and reach point Q after time t. Then, angular displacement = $\angle PCQ = \theta$ and angular velocity

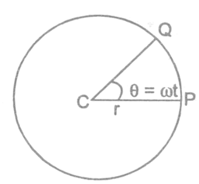
$= \omega = \frac{\theta}{t}$ (i.e. $\theta = \omega t$)

If the time period of the body is T (time taken in one complete round), the angular displacement = $2\pi^c$

Hence $\omega = \frac{2\pi}{T}$

But $\frac{1}{T}$ = N (frequency)

There $\omega = 2\pi N$



(b) Units for θ and ω :

The unit for angular displacement is radian (a supplementary quantity). The radian is defined at the angle subtended at the centre of a circle by an arc equal in length to its radius. The unit from angular velocity radian per second (rad/s).

(c) Relation between Linear and Angular Quantities :

For an arc of length ℓ

Linear displacement = ℓ

Angular displacement , $\theta = \frac{\ell}{r}$

Hence,

For a time interval t,

Linear velocity, $v = \frac{\ell}{t}$

Angular velocity $\omega = \frac{\theta}{t} = \frac{\ell}{rt} = \frac{v}{r}$

Hence $v = r\omega$

EXERCISE

OBJECTIVE DPP 5.1

1. 1^c is equal to :

(A) 57.3^0 (B) 573^0 (C) 180^0 (D) 360^0

2. An athlete complete one round of a circular track of diameter 200 m in 40 s. What will be the displacement at the end of 2 minutes 40 s.?

(A) 2200 m (B) 220 m (C) 22 m (D) Zero

3. What will be the distance in the above equation ?

(A) 2512 m (B) 2500 m (C) 2200 m (D) Zero

4. The distance traveled by a body is directly proportional to the time, then the body is said to have :

(A) Zero speed (B) Zero velocity (C) Constant speed (D) None of these

5. An athlete runs along a circular track of diameter 28m. The displacement of the athlete after he completes one circle is :

(A) 28 m (B) 88 m (C) 44 m (D) Zero

6. A boy is running along a circular track of radius 7 m. He completes one circle in 10 second. The average velocity of the boy is :

(A) 4.4 m^{-1} (B) 0.7 ms^{-1} (C) Zero (D) 70 ms^{-1}

7. A body is moving with a uniform speed of 5 ms^{-1} in a circular path of radius 5 m. The acceleration of the body is :

(A) 25 ms^{-2} (B) 15 ms^{-2} (C) 5 ms^{-2} (D) 1 ms^{-2}

8. Unit of angular velocity is :

(A) red (B) m/s (C) rad/s^2 (D) rad/s

9. The bodies in circular paths of radii 1 : 2 take same time to compete their circles. The ratio of their linear speeds is :
(A) 1 : 2 (B) 2 : 1 (C) 1 : 3 (D) 3 : 1

10. In a circular path of radius 1m, a mass of 2kg moves with a constant speed 10 ms^{-1}. The angular speed in radian/sec. is :
(A) 5 (B) 10 (C) 15 (D) 20

11. The relation among v, ω and r is :
(A) $\omega = \frac{v}{r}$ (B) $v = \frac{\omega}{r}$ (C) $\omega = \frac{r}{v}$ (D) None of these

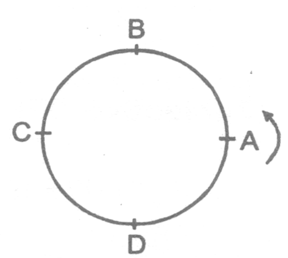
12. Uniform circular motion is an example of :
(A) Variable acceleration (B) Constant acceleration
(C) A and B both (D) None of these

13. Rate of change of angular velocity refer to :
(A) angular speed (B) angular displacement
(C) angular acceleration (D) None of these

14. A car travels $\left(\frac{1}{4}\right)^{th}$ of a circle with radius r. The ratio of the distance to its displacement is :
(A) $1; \frac{\pi}{2\sqrt{2}}$ (B) $\frac{\pi}{2\sqrt{2}} : 1$ (C) $2\sqrt{2} : \pi$ (D) $\pi 2\sqrt{2} : 1$

SUBJECTIVE DPP 5.2

1. The wheel of a cycle of radius 50 cm is moving with a speed 14 ms^{-1}. Calculate the angular velocity of the wheel.
2. An air craft completes a horizontal loop of radius 1 km with a uniform speed of 900 kmh^{-1}. Find the angular velocity of the air craft.
3. A artificial satellite takes 90 minutes to complete its revolution around the earth. Calculate the angular velocity of the satellite.
4. A particle moves along a circle of radius R as shown in figure. It starts from A and moves in anticlock-wise direction.



Calculate the distance traveled and displacement :
(i) From A to B (ii) From A to C (iii) From A to D
5. Name a physical quantity that (i) varies (ii) remains same in a circular motion.
6. Define angular speed write its S.I. unit.
7. Define the time period and find the relation between v and ω.

ANSWER KEY

(Objective DPP # 1.1)

Qus.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Ans.	A	D	C	B	B	B	C	D	A	A	A	A	B	A

(Objective DPP # 2.1)

Qus.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Ans.	B	D	B	B	C	D	B	A	D	B	C	A	A	C

(Subjective DPP # 2.2)

8. 40 kmh^{-1}, 666.7 m min^{-1}, 11.1 ms^{-1}

(Objective DPP # 3.1)

Qus.	1	2	3	4	5	6	7	8	9	10	11	12	13
Ans.	A	A	B	B	B	C	A	D	D	B	A	D	B

(Subjective DPP # 3.2)

3. (i) 78.4 m (ii) 4 s **4.** (i) 5.5 ms^{-1} (ii) 4.13 s

5. After 4 second, it will be at a height of 121.6 m from the ground.

6. (i) 4.04s (ii) 39.59 ms^{-1}

(Objective DPP # 4.1)

Qus.	1	2	3	4	5	6
Ans.	A	B	A	B	D	A

7. **Instantaneous speed**

(Subjective DPP # 4.2)

3. (i) 100 m, 100 m (ii) 112.5 m, 87.5 m

(Objective DPP # 5.1)

Qus.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Ans.	A	D	A	C	D	C	C	D	A	B	A	B	C	B

(Subjective Dpp # 5.2)

1. 28 rad/s **2.** 0.25 rad/s **3.** $\frac{\pi}{2700}$ rad/d

FORCE AND LAWS OF MOTION

PL-6

FORCE

Consider a ball kept on a table, we can move it by pulling or pushing. We can increase its speed by pushing it in the direction of motion. If we push it opposite to the direction of motion its speed will decrease. If the ball is in motion towards east, we push it towards north, the direction of will change.

Take a soft rubber ball between your palms and push the ball from both sides, the shape of the ball is distorted. In all the above cases we have applied the force on the ball.

So force in a push or pull which can move the object. It can change the speed of the object, it can change the direction of motion, it can change the shape of the object. In all the above cases we have applied the force on the ball and the ball is accelerated so we can define force as follows :

"Force is the cause which can produce acceleration in the body on which is acts".

(a) Effects of Force :

The force or a set of forces acting on a body, can do three things :

(i) A force or a set of forces can change the speed of the body.

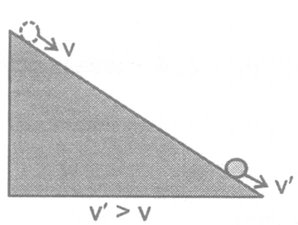
(ii) A force or a set of forces can change the direction of motion.

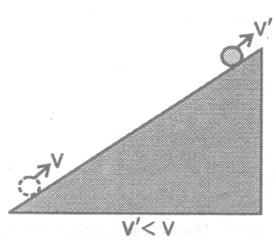
(iii) A force can change the shape of the body.

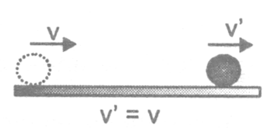
GALILEO'S EXPERIMENTS

Experiment 1 :

It was observed by Galileo that when a ball is rolled down on an inclined plane it speed increases, whereas if it is rolled up an inclined plane its speed decreases. If it is rolled on a horizontal plane the result must be between the cases describe above i.e. the speed should remain constant. If can be explain as -



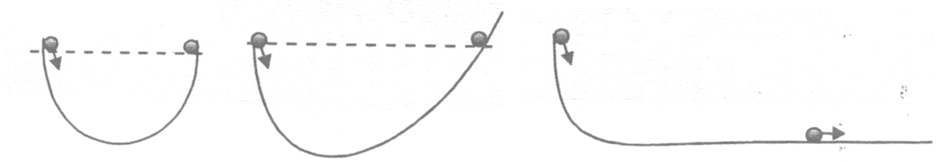




moving down : speed increase **moving up : speed decreases** **moving horizontal : speed remains constant**

Experiments 2 :

When a ball sin released on the inner surface of a smooth hemisphere, it will move to the other side and reach the same height before coming to rest momentarily. If the hemisphere is replaced by a surface shown in figure (b) in order to reach the same height ht ball will have to move a larger distance.



(a) (b) (c)

if the other side is made horizontal, the ball will never stop because it will never be able to reach the same height, it means its speeds will not decrease. It will have uniform velocity on the horizontal surface. Thus, if unbalances forced do not act on a body, the body will either remain at rest or will move with a uniform velocity. It will remain uncelebrated.

(a) Conclusion of Galileo's Experiments :

(i) A body is at rest and no unbalanced forced acts on it, remains at rest.

(ii) A body is moving and no unbalance force acts on it, it will continue to move at constant speed in a fixed direction.

(iii) If unbalance forces act on a body the body will accelerated. The idea was suggested by Galileo and was later formulated into laws by Newton.

NOWTON'S FIRST LAW OF MOTION

We have learnt so far that :

(i) If a body is at rest and no unbalanced force acts on it, it remains at rest.

(ii) If a body is moving and no unbalanced force acts on it, it will continue to move at constant speed in a fixed direction.

(iii) If an unbalanced force acts on a body, the body will accelerated.

These facts are taken together from Galileo's law of inertia on Newton's' first law of motion. The idea was suggested by Galileo and was later formulated into a law by Newton. We can state Newton's first law motion as follows :

(a) Statement of Newton's First law of Motion :

A body at rest will remain at rest and a body in motion will remain in uniform motion unless acted upon by an unbalanced force.

This law also be stated as follows :

A body remain uncelebrated if and only if, the resultant force on it is zero.

In such a case the body is said to be in equilibrium.

INERTIA

Description :

If follows from first law of motion that is absence of any eternal force, a body continues to be in its state of rest or of uniform motion along a straight line. In other words, the body cannot change by itself its position of rest or of uniform motion.

The inability of the body to change by itself its states of rest or uniform motion is a straight line is called inertia. Newton's' first law of motion is also called law of inertia.

(a) Inertia Depends upon Mass :L

We know that it is difficult to move a heavier body than the lighter one. Similarly it is difficult to stop a moving heavier body that a lighter body moving with the same velocity. Thus, we conclude that mass of the body is the measure of inertia, more the mass, more the inertia.

TYPES OF INERTIA

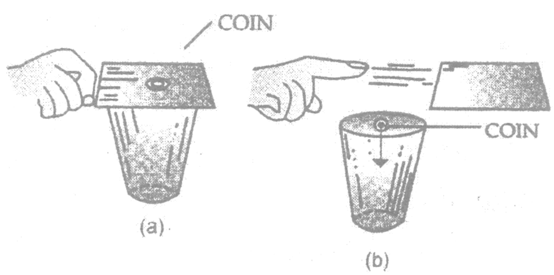
Inertia is of the three types :

(a) Inertia of Rest :

The tendency of the body to continue is state of rest even when some external unbalance force is applied on it, is called the inertia of rest.

Description :

(i) A person sitting in a bus falls backwards when the bus suddenly starts. The reason is the lower part of his body begins to move along with the bus but the upper part of his body tends to remain at due to inertia of rest.



(iii) We beat a carpet with a stick to remove dust particles. When the carpet is beaten, it is suddenly set into motion. The dust particles tend to remain at rest due to inertia of rest and hence fall off.

(iv) When a branch of tree is shaken the fruits get separated from the tree due to inertia of rest.

(b) Inertia of Motion :

The tendency of the body to continue in its state of motion even when some unbalance forces are applied on it, is called in the inertia of motion.

Description :

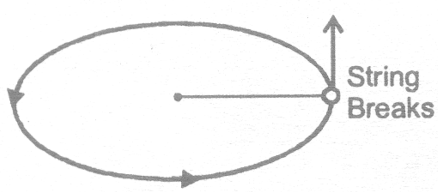
(i) A man carelessly getting down a moving bus falls forward, the reason being that his feet come to rest suddenly, whereas the upper part of his body retains the forward motion.

Man jumping carelessly from a moving bus falls forward.

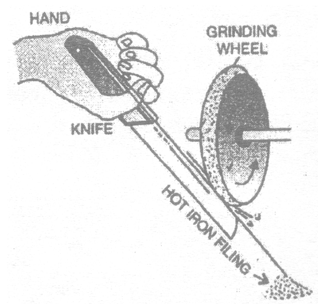
(ii) An athlete runs a certain distance before taking a leap so that the inertia of motion of his body at the time of leaping may help him in his muscular efforts.
(iii) We remove snow or mud from our shoes by striking them against wall. On striking the wall, the feet comes to rest whereas the snow which is still in motion separates from the shoes.

(c) Inertia of Direction :

The tendency of a body to oppose any change in its direction of motion is known as inertia of direction.
(i) If a car takes a turn along a curved track, the passengers experience a force acting away from the centre of the curved track. This is the result of tendency of the passenger to continue moving along a straight path.
(ii) Tie a stone to one end of a string and holding other end of the string in hand. rotate the stone in a horizontal circle. if during rotation, the string breaks at certain stage, the stone is found to fly off tangentially at that point of the circle.



String breaks, stone goes away tangentially



Sparks produced during sharpening of knife go tangential.

(iii) The water drops sticking to cycles tyre are found to fly off tangentially.
(iv) The sparks produced during sharpening of a knife or a razor against a grinding wheel, leave the rim of the wheel tangentially.

DEFINITION OF FORCE FROM FIRST LAW OF MOTION

Description :

A according to first law of motion, if there is no force, there is no change in state of rest or of uniform motion. In other words, if a force is applied, it may change the state of rest or of uniform motion. If the force is not sufficient, it may not produce a change but only try to do so.
Hence force is that which changes or tries to change the state of rest or of uniform motion of a body in straight line.

EXERCISE

OBJECTIVE DPP - 6.1

1. If A and B two objects with masses 10 kg and 30 kg respectively then :

(A) A has more inertia than B (B) B has more inertia than A

(C) A and B have the same inertia (D) none of the two have inertia

2. First law of motion defines :

(A) inertia (B) force

(C) both inertia and force (D) neither inertia nor force

3. Newton's first law of motion is :

(A) qualitative (B) quantitative

(C) both qualitative and quantitative (D) neither qualitative nor quantitative

4. Inertia depends upon :

(A) acceleration of the body (B) velocity of the body

(C) shape of the body (D) mass of the body

5. Which of the following has largest inertia ?

(A) A pin (B) An in pot

(C) Your physics book (D) Your body

6. When a bus starts suddenly the passengers standing on it, lean backwards in the bus. This is an example of :

(A) Newton's first law (B) Newton's second law

(C) Nekton's third law (D) none of Newton's law

7. The law which defines force is :

(A) Newton's third law (B) Newton's first law

(C) Newton's second law (D) none of these

8. Inertia of rest is the property by virtue of which the body is unable to change by itself :

(A) the state of rest only

(B) the state of uniform linear motion

(C) the direction of motion only

(D) the steady state of rest

9. An iron ball and aluminium ball has same mass :

(A) inertia of iron is greater than aluminium (B) both the ball have same inertia

(C) inertia of iron is less than that on Aluminium (D) none of these

10. Mass measure amount of ____ in a body :

(A) inertia (B) motion (C) velocity (D) acceleration

SUBEJCTIVE DPPT - 6.2

1. Name the property of the bodies to resist the change in their velocities.

2. With which law of motion, the same of Galileo is associated ?

3. A ball is moving on a frictionless horizontal surface and no force is applied on it. Will its speed decrease, increase or remain same.

4. What causes motion ?

5. Define force.

6. Define inertia and name its three types.

7. State Newton's first law of motion.

8. Which of the following has more inertia ? Explain :

(a) A rubber ball and stone of the same size.

(b) A bicycle and a train.

(c) A five rupee coin and a one rupee coin.

9. Why do you fall in forward direction when a moving bus brakes to stop and fall backward when it acceleration from rest ?

➤➤➤ FORCE AND LAWS OF MOTION ◄◄◄

PL – 7

MOMENTUM

Description :

It is the combined effect of mass and velocity of the body. Mathematically, momentum of the body is defined as the product of mass and the velocity of the body. If m is the mass of the body and v is its velocity then momentum, p = mv

Momentum is a vector quantity and its direction is in the direction of velocity.

Unit of momentum :

(In **C.G.S. system**) $\rightarrow p = mv \rightarrow$ gram × cm/s = dyne × s

(In **M.K.S. system**) $\rightarrow$ p = mv $\rightarrow$ kg × m/s = Newton × s

NEWTON'S SECOND LAW OF MOTION

The rate of change of momentum of a body is directly proportional to the applied unbalanced forces i.e. Rate of change of momentum $\propto$ Force applied

Let a body is moving with initial velocity u and after applying a force F on it, its velocity becomes v in time t.

Initial momentum of the body $p_1 = mu$

Final momentum of the body $p_2 = mv$

Change in momentum in time t is mv - mu

So rate of change of momentum = $\frac{mv - mu}{t}$

But according to Newton's second law, $\frac{mv - mu}{t} \propto F$

Or $F \alpha \frac{m(v-u)}{t}$ Here, $\frac{v-u}{t} = a$ (acceleration)

So $F \ \alpha \ ma$

or $F = kma$ Here is proportionality constant.

if 1N force is applied on a body of mass 1 kg and the acceleration produced in the body is 1 ms/^{2}, then 1 = k × 1 × 1 or k = 1.

So the magnitude of the resultant force acting on body is equal to the product of mass of the body and the acceleration produced. Direction of the force is same as that of the acceleration.

UNITS OF FORCE

(a) In C.G.S. System :

$\therefore$ F = ma $\rightarrow$ gm × cm/s^2 = Dyne

Definition of one dyne :

If m = 1 gm, a = 1 cm/s^2, then F = 1 dyne.

When a force is applied on a body of mass 1 gram and the acceleration produced in the body in 1 cm/s^2 then the force acting on the body will be one dyne.

(b) In S.I. System :

F = ma $\rightarrow$ kg × m/s^2 = Newton

Definition of one Newton :

If m = 1 kg and a = 1 m/s^2 then by, F = ma

F = 1 × 1 = 1 kg m/s^2 = 1 N.

If a force is applied on a body of a mass 1 kg and acceleration produced in the body in 1 m/s^2, then the force acting on the body will be one Newton.

Other units :

There are two other units of force called gravitational units.

(c) Kilogram Force (kgf) :

Kilogram force (kf) or Kilogram weight (kg. wt.) is force with which a mass of 1 kg is attracted by the earth towards its centre.

1 kgf = 9.8 N

(d) Gram Force (gf) :

Gram force or gram weight is the force with which a mass of 1 gram is attracted by the earth towards its centre.

1 gf = 981 dyne

Relation between Newton and dyne.

We know :

1 N = 1kg = 1 ms^{-2}

or 1 N = 1000 g × 100 cms$\rightarrow$

or 1 N = 10^5 g cms$\rightarrow$ = 10^5 dyne

$\therefore$ 1 N = 10^5 dyne

FIRST LAW OF MOTION BY SECOND LAW OF MOTION

Description :

According to first law of motion, if there is no force, there is no change in state of rest or of uniform motion. In other words, if a force is applied, it may change the state of rest or of uniform motion. If the force is not sufficient, if may not produce a change but only try to do so. Hence force is that which changes o tries to change the state of rest or of uniform motion of a body in straight line.

Hence we get the definition of force from Newton's first law of motion.

Newton's first law of motion can be deduced from Newton's' second law of motion.

According to second law of motion,

$F = ma$

if $F = 0$, then $a = 0$

Since $m \neq 0$

So $a = \frac{v-u}{t} = 0$

or $mv = mu$

or $v - u = 0$ or $v = u$

or $v = u$ [after more time]

Which means that the velocity of the body cannot change in absence of external force. If the body is initially at rest i.e., if $u = 0$, $v = 0$ and if $u = 5\ ms^{-1}$, $v = 5ms^{-1}$.

Thus, it follows that a body will continue to be in the state of rest or of uniform motion along a straight line if no external force acts on it and this is the first law. thus, first law can be deduced from second law of motion.

ILLUSTRATIONS

1. A force F_1 acting on a body of 2 kg produces an acceleration of 2.5 ms^2. An other force F_2 acting on the another body of mass 5 kg produces an acceleration of 2 m/sec^2. Find the ratio $\frac{F_2}{F_1}$.

Sol. For fist body $F = ma$

$F_1 = 2 \times 2.5 = 5N$

For second body $F_2 = 5 \times 2 = 10N$

So $\frac{F_2}{F_1} = \frac{10}{5} = 2.$

2. A force of 20N acting on amass m_1 produces an acceleration of 4 ms^{-2}. The same force is applied on mass m_2 then the acceleration produced is 0.5 ms^{-2}. What acceleration would the same force produce, when both masses are tied together ?

Sol. **For mass m_1 :** F = 20N, a = 4 ms^{-2}

then $m_1 = \frac{F}{a} = \frac{20}{4} = 5\,kg$

For mass m_2 : F = 20N, a = 0.5 ms^{-2}

then $m_2 = \frac{F}{a} = \frac{20}{0.5} = 40\,kg$

When m_2 and m_2 are tied together :

Total mass = $m_1 + m_2$ = 45 kg. F = 20N

then $a = \frac{F}{(m_1 + m_2)} = \frac{20}{45} = 0.44\,ms^{-2}$

IMPULSES OF FORCE

(a) Introduction :

In previous article, we leant that a moving body has momentum and that on effect (a force) is needed to stop it. It is our common experience that a smaller force takes more time to stop the body whereas a bigger force does the same in lesser time. This observation gives concept of a new quantity, force × time, which is named a impulse.

(b) Definition :

The product of the magnitude of a force applied on a body and the time for which it is applied, is called impulse of the force. It is represented by the symbol (I).

i.e., Impulse = Force × Time

or $I = F.\,t$

The S.I. unit of impulse is Newton-second (N-s) and the C.G.S unit is dyne - second (dyne -s)

(c) Impulse and Momentum :

From Newton's second law of motion

Force, $F = \frac{p_2 - p_1}{t}$ or $F.t = p_2 - p_1$

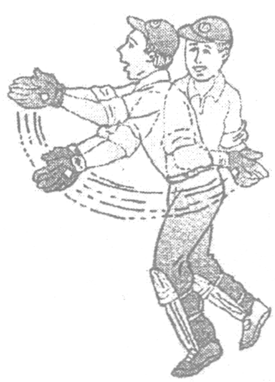
i.e., Impulse = Change in momentum

This relation is called impulse equation or momentum-impulse theorem. It has an important application in our everyday life.

APPLICATIONS OF IMPULSE EQUATION IN DAILY LIFE

(i) Catching the ball by a cricketer :

While catching a fast moving cricket ball, the player moves his hands backward after catching the ball. By moving his hands, the cricketer increases the time. As a result he has to apply a small force on the ball. In reaction, the ball also applies lesser force and the hands of the player are not injured.



(ii) Jumping on heap of sand :

If someone jumps from a height on a heap of sand below, his feet move inside the sand very slowly. His momentum changes slowly requiring a lesser force of action from the sand. The man is not injured.

(iii) Jumping down of a passenger from a moving train or bus :

A passenger sitting in a moving train or bus has momentum, When the jumps down and stands on platform or road, his momentum becomes zero.

If he jumps down suddenly from the moving train or bus and tries to stand on his feet, his body will fall forward due to inertia of motion. He will be injured.

He is advised to run over some distance on the platform or road along with (in direction f) the train or bus. This will slow down his rate of change of momentum and lesser force will be involved.

(vi) Springs in vehicles :

The vehicles are fitted with springs to reduce the hardness of the shock. When vehicles more over an uneven road, they experience impulses exerted by the road. The springs increase the duration of impulse and hence reduce the force.

(v) Springs in seats :

The seats are also fitted with springs to reduce their hardness. When we sit on them all of a sudden, the seats are compressed. The compression increases duration of our coming to rest of the seat. They reaction force of seats become negligible.

(vi) Soft material packing :

China and glass wares are packed with soft material when transported. They collide during transportation but soft packing material slows down their rate of change of momentum. The force of impact is reduced and the items are not broken.

(vii) Atheists :

Athletes are advised to come to stop slowly after finishing a fast race. In general, all changes of momentum must be brought slowly to involve lesser force of action and reaction to avoid injury.

IMPULSE DURING AN IMPACT OR COLLISION

The impulsive force acting on the body produces a change in momentum of the body on which it acts. We know, Ft = mv - mu, therefore maximum force needed to produce a given impulse depends upon time. If time is short, the force required in a given impulse or the change in momentum is large and vice - versa.

EXERCISE

OBJECTIVE DPP - 7.1

1. Newton's second law of motion :

(A) defines force (B) defines inertia

(C) gives measure of force (D) none of these

2. Newton's second law of motion is :

(A) qualitative (B) quantitative

(C) both qualitative and quantitative (D) neither qualitative nor quantitative

3. Momentum measures amount of _______ in a body :

(A) inertia (B) motion (C) velocity (D) acceleration

4. Force measures rate of change of ____ of a body :

(A) mass (B) inertia (C) velocity (C) momentum

5. C.G.S. unit of force is :

(A) m/s (B) s/ m (C) dyne (D) Newton

6. Momentum has same unit as :

(A) impulse (B) torque (C) moment of force (D) couple

7. When force of 1N acts on mass of 1kg. which is able to move freely, the object moves with a /an:

(A) speed of 1 ms^{-1} (B) speed of 1 kms^{-1}

(C) acceleration of 10 ms^{-2} (D) acceleration of 1ms^{-2}

8. The net force acting on a body of mass of 1 kg moving with a uniform velocity of 5 ms^{-1} is :

(A) 5N (B) 0.2 N (C) 0 N (D) None of these

9. A body of mass 20 kg moves with an acceleration of 2ms^{-2}. The rate of change of momentum is S.I. unit is :

(A) 40 (B) 10 (C) 4 (D) 1

10. A body of mass M strikes against wall with a velocity v and rebounds with the same velocity. Its change in momentum is :

(A) zero (B) Mv (C) -Mv (D) -2 Mv

11. Gram weight is a unit of :

(A) mass (B) weight (C) A and B both (D) neither A nor B

12. 9.8 N is equal to :

(A) 1 kgf (B) 1 kgwt (C) A and B both (D) Neither A nor B

13. A body of mass 5 kg undergoes a change in speed from 20 m/s to 0.20 m/s. The momentum :

(A) increases by 99 kgm/s (B) decreases by 99 kgm/s

(C) increases by 101 kgm/s (D) decreases by 101 kgm/s

14. The combined effect of mass and velocity is taken into account by a physical quantity called :

A) torque (B) moment of force (C) momentum (D) all of them

15. How many dynes are equal to 1N ?

(A) 10^8 (B) 10^4 (C) 10^5 (D) 10^3

16. Choose correct relation :

(A) $a = \frac{F}{m}$ (B) aF = m (C) m = F × a (D) none of these

SUBJECTIVE DPP - 7.2

1. Name of quantities on which momentum of a body depends.
2. What is S.I. unit of momentum ?
3. Is momentum vector or scalar ?
4. Two similar trucks are moving with same velocities on a road. One of them is loaded while another one is empty. Which of the two ill require a larger force to stop it in same time ?
5. Explain meaning of the following equation F = ma. Symbol have their usual meaning.
6. Explain how Newton's second law of motion can be explained to define the unit of force and also name the unit.
7. A 1000 kg vehicle moving with a speed of 20 ms^{-1} is brought to rest in a distance of 50 metre by applying brakes :
   (i) Find the acceleration.
   (ii) Calculate the unbalanced force acting on the vehicle.
   (iii) The actual force applied by the brakes will be slightly less than that calculated in, why ? Give reasons.
8. Write the expression for impulse.
9. Name a quantity which has same unit as that of impulse.
10. Derive relation between impulse and momentum.
11. A 5 quintal car is moving with a velocity of 54 kmh^{-1}. What is its impulse if it is stopped within 0.5s by application of backward force ? Also determine the force applied.

➤➤➤ FORCE AND LAWS OF MOTION ◄◄◄

PL – 8

NEWTON'S THIRD LAW

(a) Introduction :

When a force is applied to stop a moving body, we ourselves experience some force from the body being stopped. When a cricketer used his hands to stop a moving ball, his hands also experience some force from the ball and sometimes the force is unbearable. When we jump on a cemented road from some height, our feet get injured by the impact of the road.

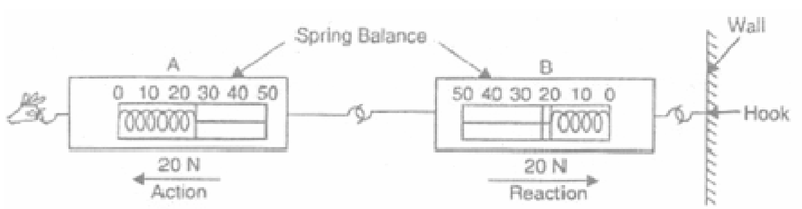
From above examples we find that whenever one body exerts a force on another body, the second body exerts an equal and opposite force on the first body. The force exerted by the first body on the second body is called 'action' and the force exerted by the second body on the first body is called 'reaction'/

(b) Statement :

The law states the "To every action there is an equal and opposite reaction". Moreover, action and reaction act on different bodies.

(c) Demonstration :

Two similar spring balances A and B joined by hook as shown in the figure, The other of the spring balance B is attached to a hook rigidly fixed in a rigid wall.



Demonstration - Newton's third law of motion.

The other end of the spring balance A is pulled out to the left. Both the balances show the same reading (20 N) for the force.

The pulled balance A exerts a force of 20N on the balance B. It acts as action, B pulls the balance A in opposite direction with a force of 20 N. This force is known as reaction.

We conclude that action-reaction forces are equal and opposite and act on two different bodies.

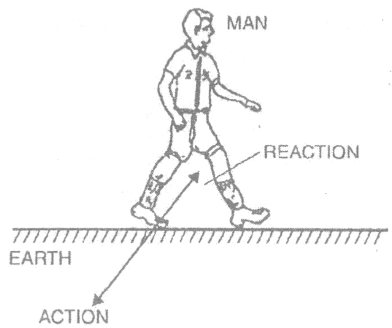
(b) Explanation :

If may be noted that action and reaction occur simultaneously. Action and reaction never act on same body. Had this been the case, there would have been no (accelerated) motion, Since action and reaction occur in pairs and act on two different bodies, it is impossible to have single isolated force.

(e) Examples :

(i) Swimming of a man : The man swims because he pushes water behind (action), water pushes man forward (reaction).

(ii) Walking of man : man pushes the earth behind from right foot (action). Earth pushes the man forward (reaction). Then the man walks.



Walking man

(iii) Flight of jet or rocket : The burnt gases are exhausted from behind with high speed giving the gases backward momentum (action). The exhausted gages impart the jet or rocket a forward momentum (reaction). Then jet or rocket moves.

(iv) Gun and bullet : A loaded gun has a bullet inside it. When the gun's trigger is pressed, the powder inside cartridge explodes. A force of action acts on the bullet and makes the light bullet come out of the barrel with a high velocity. The heavy gun moves behind (recoils) with a small velocity due to force of reaction.

This is also an example of law of conservation of linear momentum.

(v) Man and boat : A man is boat near river bank is at rest. To reach the bank, the man pushes the boat behind (action), the boat pushes the man forward (reaction). The man lands on the bank.

(vi) Hose pipe : Water rushes out of the hose pipe with a large velocity due to force of action of the compressor from behind. The rushing out jet of water pushes the hose pipe behind due to force of reaction. Then pipe has to be held tightly.

NO ACTION IS POSSIBLE WITHOUT REACTION

Examples :

(i) A nail cannot be fixed on a suspended wooden ball.

(ii) A paper cannot be cut by scissors of single blade.

(iii) A hanging piece of paper cannot be cut by blade.

(iv) Writing on a hanging page is impossible.

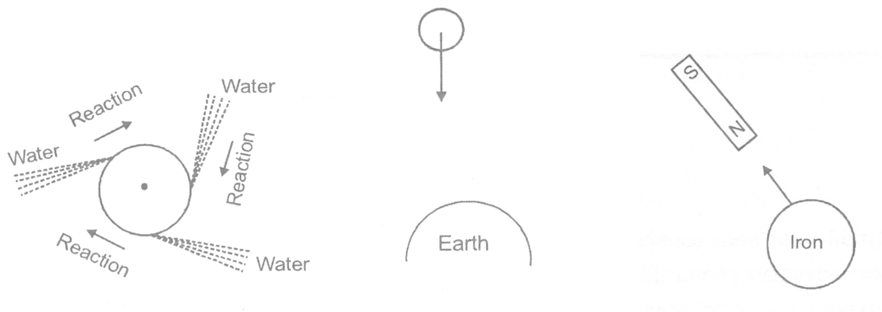
(v) Hitting on a piece of sponge does not produce reaction. You do not enjoy hitting.

ACTION AND REACTION ARE NOT BALANCED

Action and reaction, through equal and opposite are not balanced because they act on two different bodies. If case when they act on two different bodies forming a single system, they become balanced.

INTERACTION BETWEEN BODOIS AT A DISTANCE

We have uptill now considered examples where the two bodies are in direct contact with each other but. But interaction takes place even when the two bodies are not in actual contact with each other. For example, a comb rubbed with dry hair can interact with a piece of paper from a distance. Similarly a magnet can interact with an iron piece from a distance. Interaction between a falling stone and the earth also takes place although these are not in actual contact with each other. Thus when one body influences another body by applying force with or without contact, we say that the first body is interacting with the second body.



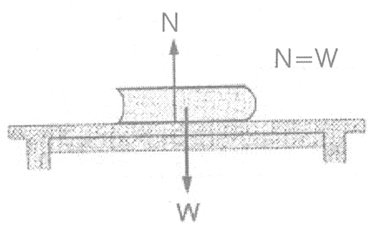
Lawn Sprayer

(a) Earth attracts a body at a distance

(b) Magnet attracts iron at a distance

ANY PAIR OF EQUAL AND OPPOSITE FORCES IN NOT AN ACTION - REACTION PAIR

Consider a book kept on a table. We have seen that the table pushes the book in the upward direction. They why does not the book fly up ? It does not fly up because there is another force on the book pulling it down. This is the force exerted by the earth of the book, which we call the weight of the book. So, there are two forces on the book-the normal force, N acting upwards, applied by the table and the force, W acting downwards, applied by the earth. As the book does not accelerate, we conclude that these two forces are balanced. In other words, they have equal magnitudes but opposite direction.



Can call N the action and W the reaction ? We cannot. This is because, although they are equal and opposite, they are not forces applied by two bodies on each other. The force N is applied by the table on the book, its reaction will be the force applied by the book on the table. Weight W is the force applied by the earth on the book, its reaction will be the force applied by the book on the earth.
So, although N and W are equal and opposite, they do not form an action - reaction pair.

PRINCIPLE OF CONSERVATION OF LINEAR MOMENTUM

By Newton's second law, the rate of change of momentum is equal to the applied force.

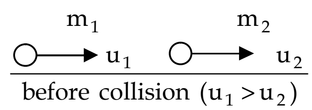
$$\frac{\text{Change in momentum}}{\text{time}} = \text{Force}$$

Change is momentum = F × t
If F = 0 then,
Change is momentum = 0
If the force applied on the body is zero then its momentum will be conserved, this law is also applicable on the system. If in a system the momentum of the objects present in the system are P_1 , P_2, P_3 .... and external force on the system is zero, then -
$P_1 + P_2 + P_3 + \ldots\ldots\ldots\ldots = \text{Constant}$

❖ **NOTE :** If only internal forces are acting on the system then its linear momentum will be conserved.

(a) The Law of Conservation of Linear Momentum by Third Law of Motion :

Suppose A and B are two objects of masses m_1 and m_2 are moving in the same direction with velocity u_1 and u_2 respectively ($u_1 > u_2$). Object A collides with object B and after time t both move in their original direction with velocity v_1 and v_2 respectively.



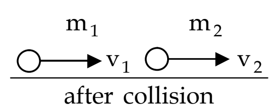
The change in momentum of object A = $m_1v_1 - m_1u_1$

The force on B by A is $F_1 = \dfrac{\text{Change in momentum}}{\text{time}}$

$F_1 = \dfrac{m_1v_1 - m_1u_1}{t}$ ....(1)

The change is momentum of object B = $m_2 v_2 - m_2u_2$

The force on A by B is $F_2 = \dfrac{\text{Change in momentum}}{\text{time}} = \dfrac{m_2v_2 - m_2v_2}{t}$ .....(2)



By Newton third law, $F_1 = - F_2$

$$\frac{m_1v_1 - m_1u_1}{t} = -\left(\frac{m_2v_2 - m_2u_2}{t}\right) \Rightarrow m_1v_1 - m_1u_1 = -m_2v_2 + m_2u_2$$

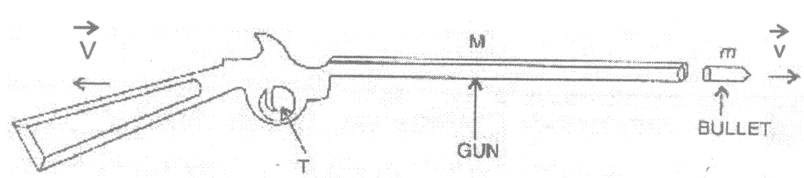
or $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

or Initial momentum = Final momentum

SOME ILLUSTRATION ON CONSERVATION OF MOMENTUM

(a) Recoil of Gun :

A loaded gun (rifle) having bullet inside it forming one system is initially at rest. The system has zero initial momentum.



When the trigger (T) is pressed, the bullet is fired due to internal force of explosion of powder in cartridge inside.

The bullet moves forward with a high velocity and the gun move behind (recoils) with a lesser velocity.

Let the bullet and the gun have masses m and M respectively. Let the bullet move forward with velocity v and the gun recoils with velocity V.

Then final momentum of the gun and bullet is MV + mv
By the law of conservation of momentum :
Initial momentum of the system = Final momentum of the system.

$0 = MV + mv \quad \text{or} \quad V - \frac{mv}{M}$

Hence the recoil velocity of gun = $\frac{mv}{M}$

and the velocity of the gun is = - $\frac{mv}{M}$

(a) Flight of Jet Rocket :

Jet planes and rockets are provided with chemical fuels. Combustion of these fuels produces a high velocity blast of hot gases. These gases move outward and escape through nozzle (a narrow opening) with very high velocity and large momentum. (they escape horizontally backward in case of jet planes and vertically downwards in case of rocket). The escaping gases impart their momentum to the jet plane and the rocket. They move forward or upward with a high velocity.

In general, all cases involving action and reaction, are examples of law of conservation of momentum. Action and reaction being equal and acting simultaneously for same duration, have equal and opposite impulses. They produce equal and opposite changes of momentum in the pair of bodies involved. It keeps the total momentum of the two body system constant (conserved).

ILLUSTRATIONS

1. A field gun a mass 1.5 t fires a shell of mass 15 kg with a velocity of 150 m/s. Calculate the velocity of the recoil of the gun.

Sol. Mass of gun = 1.5 t = 1.5 × 1000 kg = 1500 kg
Mass of shell = 15 kg
Velocity of shell = 150 m/s.
Velocity of recoil of the gun = ?
Momentum of gun = Mass of gun × velocity of recoil of the gun = 1500 V kg m.s
Momentum of shell = Mass of shell × velocity of shell = 15 × 10 kg m/s.
By the law of conservation of momentum :
Momentum of gun = Momentum of shell

$1500\ V = 15 \times 150 \qquad \text{or} \qquad V = \frac{15 \times 150}{1500} = 1.5\,\text{m/s}.$

The recoil velocity of gun = 1.5 m/sec.

2. A hunter of 45 kg is standing on ice fires a bullet on 100 gram with a velocity of 500 ms^{-1} by a gun of 5 kg. Find the recoil velocity of the hunter.

Sol. The initial momentum of the system, P_1 = Momentum of hunter + momentum of gun + momentum of bullet
or $P_1 + 45 \times 0 + 5 \times 0 + 0.1 \times 0 = 0$ .... (1)
Final momentum of the system, P_1 = Momentum of hunter + Momentum of gun + momentum of bullet
$P_2 = 45\ V + 5\ V + 0.1 \times 500$ (Here V is the recoil velocity of gun with hunter).
$P_2 = 50\ V + 50$ ......(2)
By the conservation of momentum
$P_1 = P_2$
$0 = 50\ V + 50$ or $V = -1$ m/s.
The recoil velocity of gun with hunter is 1 m/s.

EXERCISE

OBJECTIVE DPP - 8.1

1. If a moving ball A collides with another moving ball B, then :

(A) momentum of A = momentum of B

(B) (momentum + A + momentum of B) before collision = (momentum A + momentum of B) after collision

(C) neither A nor B

(D) A or B both are possible

2. When a bullet is fired from a gun. The gun recoils to :

(A) conserve mass

(B) conserve momentum

(C) conserve K.E.

(D) none of these

3. A bullet is motion hits and gets embedded in a solid resting on a frictionless table. What is conserved ?

(A) Momentum and K.E. (B) Momentum alone (C) K.E. alone (D) None of these

4. A bullet of mass 0.01 kg is fired from a gun weighing 5.0 kg. If the initial speed of the bullet is 250 m/s, calculate the speed with which the gun recoils :

(A) -0.50 m/s (B) -0.25 m/s (C) + 0.05 m/s (D) + 0.25 m/s

5. Forces of action and reaction are :

(A) equal and in same direction

(B) equal and in opposite direction

(C) unequal and in same direction

(D) unequal and opposite.

6. Forces of action and reaction act :

(A) one after the other on same body

(B) simultaneously on same body

(C) one after the other on different bodies

(D) simultaneously on different bodies

7. A man is standing on a boat in still water. If he walks towards the shore the boat will :

(A) more away from the shore (B) remain stationary

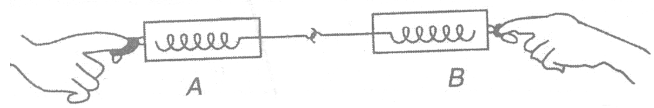
(C) move towards the shore (D) sink

8. In the action and direction were to act on the same body :

(A) the resultant would be zero (B) the body would not move at all

(C) both A and B are correct (D) neither A nor B is correct

9. Consider two spring balances hooked as shown in the figure. We pull them in opposite directions. If the reading shown by A is 1.5 N, the reading shown by B will be :



(A) 1.5 N (B) 2.5 N (C) 3.0 N (D) Zero

10. Newton used, quantity of motion' for :
(A) momentum (B) force
(C) acceleration due to gravity (D) none of these

11. A cannon after firing recoils due to :
(A) conservation of energy (B) backward thrust of gases produced
(C) Newton's first law of motion (D) Newton's' third law of motion

12. A Diwali rocket is ejecting 0.05 kg of gases per second at a velocity of 400 ms^{-1}. The accelerating force on the rocket is :
(A) 20 dyne (B) 20 Newton (C) 20 kg wt. (D) sufficient data not given

13. The forces of action and reaction have ____ magnitude but _____ direction :
(A) same, same (B) same, opposite (C) opposite, same (D) opposite, opposite

14. Choose correct statement :
(A) Action and reaction forces act on same object.
(B) Action and reaction forces act on different objects.
(C) A and B both are possible.
(D) Neither A nor B is correct.

SUBJECTIVE DPP - 8.2

1. What is total momentum of the gun and bullet just before firing ?
2. Explain of application of law of conservation of momentum.
3. State Newton's third law of motion.
4. Explain why it is difficult for a fireman to hold a hose, which ejects large amount of water at a high speed.
5. State third law of motion. Give two examples in support of this law.
6. If someone jumps to the shore from boat, the boat moves in the opposite direction. Explain why ?
7. (i) What is the physical principle involved in the working of a jet plane ?

   (ii) Do the action and reaction act on the same body or direction bodies ? How are they related in magnitude and direction ? Are they simultaneous or not ?
8. Two cars A and B are moving towards each other on a horizontal surface. The can A has mass 60 g and moves towards the right with speed of 60 cms^{-1} The car B has a mass of 100 g and moves towards the left with a speed of 20 cms^{-1}. The two cars collide and get stuck to each other. With what velocity will they move after the collision ?

ANSWER KEY

(Objective DPP # 6.1)

Qus.	1	2	3	4	5	6	7	8	9	10
Ans.	B	C	A	D	D	A	B	D	B	A

(Objective DPP # 7.1)

Qus.	1	2	3	4	5	6	7	8	9	10
Ans.	C	B	B	D	C	A	D	C	A	D
Qus.	11	12	13	14	15	16				
Ans.	B	C	B	C	C	A				

(Subjective DPP # 7.2)

7. (i) - 4 m/s^2 (ii) 4000 N (iii) Because friction also apply force in opposite direction of motion.

11. Impulse = 7500 N-second
Backward Force = 1500 N

(Objective DPP # 8.1)

Qus.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Ans.	B	B	B	A	B	D	A	C	A	A	D	B	B	B

(Subjective DPP # 8.2)

8. 10 cms^{-1}

GRAVITATION AND FLUID

PL - 9

INTRODUCTION

Besides developing the three laws of motion, Sir lssac Newton also examined the motion of the heavenly bodes - the planets and the moon. Newton recognized that a force of some kind must be acting on the planets to keep them in nearly circular orbits, otherwise their paths would be straight lines. A falling apple is attracted by the earth by the apple attracts the earth as well (Newton's third law of motion). Extending this idea, Newton proposed that every body in this universe attracts every other body. This led to the discovery of the famous law of universal gravitation i.e. each object in this universe attracts every other object. Note that gravitational force is attractive. Newton concluded that it was the gravitational force that acted between the sun and each of the planets to keep them in their orbits. In this chapter, we shall discuss the role of gravitational force of the earth of the objects, on or nor the surface of the earth.

(a) Gravitation or Gravitational Force :

It was Newton, who said that every object in this universe attracts every other object with a certain force. The force with which two objects attract each other is called the force of gravitation. The force of gravitation acts even if the two objects are not connected by the any means. If, however, the masses of the objects are small, the force of gravitation between them is small and cannot be detected easily.

The force of attraction between any two particles in the universe is called gravitation or gravitational force.

NEWTON'S LAW OF GRAVITATION

The magnitudes and the direction of the gravitational force between two particles are given by the universal law of gravitation, which was formulated by Newton.

Universal law of gravitation :

The gravitational force of attraction between two particles is directly proportional to the product of the masses of the particles and is inversely proportional to the square of the distance between the particles. The direction of the force is along the line joining the two particles.

Mathematical derivation :

Let A and B be two particles of mass m_1 and m_2 respectively. Let the distance AB = r. By the law of gravitation, the particle A attracts the particle B with a force F such that,

$F \propto m_1m_2$ (for a given pair of particles)

and $F \propto \frac{1}{r^2}$ (for given separation between the particles)

So $F \propto \frac{m_1 m_2}{r^2}$

or $F = G\frac{m_1 m_2}{r^2}$

Here G is a constant known as the universal constant of gravitation.

(a) Universal Gravitational Constant :

(i) Introduction :

Force of gravitation between two bodies of mass m_1 and m_2 kept with distance r between their centres, is given by :

$$F = \frac{Gm_1 m_2}{r^2}$$

where constant of proportionality G is called universal gravitational constant (U.G.C.).

(ii) Definition :

In relation $F = \frac{Gm_1 m_2}{r^2}$

If $m_1 = m_2 = 1$, $r = 1$, then $F = G$ Hence, universal gravitational constant may be defined as the force of attraction between two bodies of unit mass each, when kept with their centres a unit distance apart.

(iii) Units of G:

$$F = \frac{Gm_1 m_2}{r^2}$$

We have, $G = \frac{Fr^2}{m_1 m_2}$

In S.I. $G = \frac{Nm^2}{kgkg} = Nm^2 kg^{-2}$

In C.G.S. $G = \frac{dyne\,cm^2}{g.g.} = dyne\,cm^2\,g^{-2}$

(iv) Values of G :

In S.I. $G = 6.67 \times 10^{-11}\ Nm^2\ kg^2$

In C.G.S. $G = 6.67 \times 10^{-8}\ dyne\ cm^2\ g^{-2}$

(b) Important Characteristics of Gravitational Force :

(i) Gravitational force between two bodies form an action and reaction pair i.e., the forces are equal in magnitude but opposite in direction.

(ii) Gravitational force is a central force i.e., it acts along the line joining the centres of the two interacting bodies.

(iii) Gravitational force between two bodies is independent of the nature of the intervening medium.

(iv) Gravitational force between two bodies does not depend upon the presence of other bodies.

(v) Gravitational force is negligible in case of light bodies but becomes appreciable in case of massive bodies like starts and planets.

(vi) Gravitational force is a long range force i.e., gravitational force between two bodies is effective even if their distance of separation is very large. For example, gravitational force between the sun and the earth is of the order of 10^{22} N, although distance between them is 1.5×10^{8} km.

(vii) Gravitational force is a conservative force.

(c) Experimental Support for the Law of Gravitation :

(i) All the planets including the earth, rotate around the sun due to gravitational force between the sun and the planet.

(ii) Tides are formed in oceans due to gravitational force between the moon and the earth.

(iii) It is the gravitational force between the planet and its satellite which makes the satellite to move around the planet.

(iv) The atmosphere of the earth is due to the gravitational force of the earth.

NEWTON'S THRID LAW OF MOTION AND GRAVITATION

Newton's third law of motion says that : If an object exerts a force on another object, then the second object exerts an equal and opposite force on the first object. The Newton's third law of motion also holds good for the force on the earth in the opposite direction. Thus, even a falling object attracts the earth towards itself. When an object, say a stone, is dropped from a height, it gets accelerated and falls towards the earth and we say that the stone comes down due to the gravitational force of attraction exerted by the earth. Now, the stone also exerts and equal and opposite force on the earth, then why don't we see the earth rising up towards the stone.

From Newton's second law of motion, we know that :

Force = Mass × Acceleration

So, $\text{Acceleration} = \dfrac{\text{Force}}{\text{Mass}}$

or $a = \dfrac{F}{M}$

It is clear from this formula that the acceleration produced in a body is inversely proportional to the mass of the body. Now, the mass of a stone is very small, due to which the gravitational force produces a large acceleration in it. Due to large acceleration of stone, we can seen the stone falling towards the earth. The mass of earth it, however, very-very large. Due to the very large mass of the earth, the same gravitational force produces very-very small acceleration in the earth. Actually, the acceleration produced in the earth is so small that it cannot be observed. And hence we do not see the earth rising up towards the stone.

ILLUSTRATIONS

1. Two persons having mass 50kg each, are standing such that the centre of gravity are 1m apart. Calculate the force of gravitation and also calculate the force of gravity on each.

Sol. Given : $m_1 = m_2 = 50$kg.

$r = 1$m. , $G = 6.67 \times 10^{-11}$ N. m^2/kg^2

Force of gravitation $F = \dfrac{Gm_1m_2}{r^2}$

$$F = \frac{6.67\times10^{-11}\times50\times50}{(1)^2} = 1.67\times10^{-7}\text{ N.}$$

Force of gravity,

$F' = \dfrac{GMm}{r^2}$ Here r = R, radius of the earth

and $m_1 = M$ = mass of earth, $m_2 = m$ = mass of object

$$F' = \frac{6.67\times10^{-11}\times6\times10^{24}\times50}{\left(6.4\times10^{6}\right)^2} = 0.48\times10^{3}\text{ N} \quad \text{…. (ii)}$$

F′ is much greater than F so the persons will not move towards each other but each of them moves towards the earth.

ESTI MATION OF GRAVITATIONAL FORCE BETWEEN DIFFERENT OBJECTS

(a) Between Sun and Earth :

Mass of earth, $m_1 = 6 \times 10^{24}$ kg

Mass of the moon, $m_2 = 7.4 \times 10^{30}$ kg

Distance between the sun and the earth, $r = 1.5 \times 10^{11}$m

Gravitation force between the sun and the earth,

$$F = \frac{Gm_1m_2}{r^2}$$

$$F = \frac{6.67\times10^{-11}\,\text{Nm}^2\text{kg}^{-2}\times6\times10^{24}\,\text{kg}\times2\times10^{30}\,\text{kg}}{\left(1.5\times10^{11}\,\text{m}\right)^2}$$

$F = 3.6 \times 10^{22}$ N

The gravitational force between the sun and the earth is very large (i.e. 3.6×10^{22} N). This force keeps the earth bound to the sun.

(b) Between Moon and Earth :

Mass of the earth, m1 = 6×10^{24} kg

Mass of the moon, m2 = 7.4×10^{22} kg

Distance between the earth and the moon, $r = 3.8 \times 10^{8}$ m

$\therefore$ Gravitational force between the earth and the moon,

$$F = \frac{Gm_1m_2}{r^2}$$

$$F = \frac{6.67\times10^{-11}\,Nm^2kg^{-2}\times6\times10^{24}\,kg\times7.4\times10^{22}\,kg}{(3.8\times10^8\,m)^2}$$

$F = 2.05 \times 10^{20}$ N

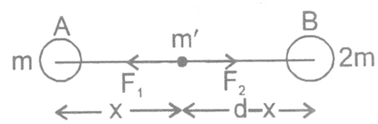
This large gravitational force keeps the moon to move around the earth. This large gravitational force is also responsible fort the ocean tides.

2. Two bodies A and B having mass m and 2m respectively are kept at a distance d apart. Where should a small particle be placed so that the net gravitational force on it due to the bodies A and B is zero ?

Sol. it is clear that the particle must be placed on the line AB, suppose it is at a distance x from A.

Let its mass is m′.

The force on m′ due to A,



$F_1 = \frac{Gmm'}{x^2}$ towards A

and that due to B is -

$F_2 = \frac{G(2m)m'}{(d-x)^2}$ towards B.

The net force will be zero if $F_1 = F_2$

Thus, $\frac{Gmm'}{x^2} = \frac{G(2m)m'}{(d-x)^2}$

of $(d - x)^2 = 2x^2$

$d - x = \pm\sqrt{2}\,x.$

$d = (1 \pm\sqrt{2})\,x$

$x = \frac{d}{(1+\sqrt{2})}$ or $\frac{d}{(1-\sqrt{2})}$

As x cannot be negative

So $x = \frac{d}{(1+\sqrt{2})}$

FORCE OF GRAVITATION OF THE EARTH (GRAVITY)

Gravitation and gravity :

Attraction between two bodies having mass of same order, is called gravitation and the force is called gravitational force. Forces involved are very small and the attracting bodies do not move towards each other.

Attraction between a planet (earth) or its satellite and a body, having masses of widely different order is called gravity and the force is called force of gravity. Forces involved are large and body moves towards the planet.

Thus, gravity becomes a special case of gravitation in which small bodies move towards huge planets. Then force of gravity

$$F = \frac{GMm}{r^2}$$

EXERCISE

OBJECTIVE DPP - 9.1

1. When an apple falls from a tree :

(A) only earth attracts the apple (B) only apple attracts the earth

(C) both the earth and the apple attract each other (D) none attracts each other

2. Force of attraction between two bodies does not depend upon :

(A) the shape of bodies (B) the distance between their centres

(C) the magnitude of their masses (D) the gravitational constant

3. When the medium between two bodies changes, force of gravitation between them :

(A) will increase (B) will decrease

(C) will change according to the environment (D) remains same

4. S.I. unit of G is :

(A) $Nm^2 kg^{-2}$ (B) $Nm\ kg^{-2}$ (C) $N\ kg^2 m^{-2}$ (D) $Nkg\ m^{-2}$

5. The value of universal gravitational constant :

(A) changes with change of place (B) does not change from place to place

(C) becomes more at night (D) becomes more during the day

6. The value of G in S.I. unit is :

(A) 6.67×10^{-9} (B) 6.67×10^{-10} (C) 6.67×10^{-11} (D) 6.67×10^{-12}

7. The gravitational force between two bodies varies with distance r as :

(A) $\frac{1}{r}$ (B) $\frac{1}{r^2}$ (C) r (D) r^2

8. The value of G in year 1900 was $6.673 \times 10^{-11}\ Nm^2 kg^{-2}$. They value of G in the year 2007 will be :

(A) $6.673 \times 10^{-9}\ Nm^2 kg^{-2}$ (B) $6.673 \times 10^{-10}\ N\ m^2 kg^2$

(C) $6.673 \times 10^{-2}\ Nm^2 kg^{-2}$ (D) $6.673 \times 10^{-11}\ Nm^2 kg^{-2}$

9. Value of G on surface of earth is $6.673 \times 10^{-11}\ Nm^2 kg^{-2}$, then value of G on surface of Jupiter is :

(A) $12 \times 6.673 \times 10^{-11}\ Nm^2 kg^{-2}$ (B) $\frac{6.673}{12} \times 10^{-10}\ Nm^2 kg^{-2}$

(C) $6.673 \times 10^{-11}\ Nm^2 kg^{-2}$ (D) $\frac{6.673}{6} \times 10^{-11}\ N\ m^2 kg^{-2}$

10. The earth attracts the moon with a gravitational force of 10^{20}N. Then the moon attracts the earth with a gravitational force of :

(A) 10^{-20}N (B) 10^2 N (C) 10^{20} N (D) 10^{10} N

11. The orbits of planets around the sun are :

(A) circular (B) parabolic (C) elliptical (D) straight

12. Law of gravitation is applicable for :

(A) heavy bodies only (B) medium sized bodies only

(C) small sized bodies only (D) bodies of any size

13. The universal law of gravitation was proposed by :

(A) Copemicus (B) Newton (C) Galileo (D) Archimedes

14. Choose the correct statement :

(A) All bodies repel each other in the universe. (B) Our earth does not behave like a magnet.

(C) Acceleration due to gravity is 8.9 ms^{-2}. (D) All bodies fall at the same rate in vacuum.

SUBJECTIVE DPP - 9.2

1. What is the unit of gravitational constant ?

2. Which force is responsible for the earth revolving round the sun ?

3. What type of force is involved in the formation of tides in the sea ?

4. Write mathematical expression for gravitational force between two bodies of masses m_1 and m_2 separated by a distance r. All quantities are in S.I. units.

5. State the universal law of gravitation.

6. Two masses 50 kg and 100 kg are separated by a distance of 10 m. What is the gravitational force of attraction between them ? $G = 6.67 \times 10^{-11} \frac{Nm^2}{kg^2}$

7. State two applications of universal law of gravitation.

8. What happens to the forces between two objects, it :

(i) The mass of the one object is doubled ?

(ii) The distance between the objects is doubled ?

(iii) The masses of both objects are doubled ?

9. (i) Name the scientist who gave the universal law of gravitation.

(ii) Define universal Gravitational constant.

(iii) What is the value of G in S.I. unit ?

10. Newton's law of gravitation states that every object exerts a gravitational force of attraction on every other object. If this is true, then why don't we notice such forces, when the two objects in a room move towards each other due to the force ?

GRAVITATION AND FLUID

PL - 10

BODIES FALLING NER THE SURFACE OF THE EARTH

(a) Galileo's Observations on Falling Bodies :

The speed of falling body increases as it comes down. This means that the body accelerates, when i t falls freely. Suppose we drop a coin and a feather from the same height simultaneously. Which will reach the ground first ? The answer is obvious, the coin will reach earlier than lighter feather or we can say that the heavier objects comes down more faster than lighter ones but such a generalization is not correct. If we take two slid balls of different masses, say, one of 1 kg and the other of 2kg, and drop them from the same height, we will find that they reach the ground almost simultaneously.

It is said that Galileo dropped two stones of different masses from the Leaning Tower of Pisa (in Italy) and founded that they reached the ground simultaneously. Galileo argued that the air resist on object traveling through it. If the material is dense and its surface area is small, the resistance due to air is quite small compared to the force of gravity. Thus one can neglect the effect of air resistance while studying falling stones, metallic blocks, coins etc. But the effect of air resistance is very important for small pieces of paper, feather, leaves etc. each of which ahs a large surface area and low density. When a coin and a feather fall through air, air offers greater resistance to the motion of the feather and les resistance to the motion of the coin, According to Galileo's argument, if air is totally removed, the coin and the feather will fall simultaneously.

Newton was born in the year Galileo died. Galileo died not have access to the equations for gravitational attraction and the acceleration resulting from a force. Still, he correctly predicted something from his observations that was contrary to everyday experience.

Galileo's prediction was tested by the British scientist Robert Boyle. He kept a coin and a feather in a long glass tube and evacuated the air from inside the tube by using a vacuum pump. When the tube was inverted, the coin and the feather fell together.

(b) Acceleration due to Gravity :

if we drop a ball from a height, its speed increases as time passes. If we throw a ball upwards, its speed decreases till it reached the highest point. If we throw the ball at an angle to the vertical, its direction of motion changes. In all these cases, the velocity of the ball changes, i.e., the all is accelerated, whenever an object moves near the surface of the earth with no other object pushing or pulling it, it is accelerated. This acceleration is caused due to the force of gravity and is called the acceleration due to gravity. Consider an object of mass m moving freely near the earth's surface. Neglecting air resistance, the only force on it, is due to gravity. The force has magnitude :

$$F = \frac{GM_6 m}{R_e^2} \qquad ....(i)$$

where M = mass of the earth, m = mass of the object, and R_e = radius of the earth.

As the earth's radius R_s (6400 km) is large as compared to distance of the object from the earth's surface. We use R_e in Equation (i) to denote the distance of the object from the centre of the earth. As the force given by equation (i), is the resultant force on the object, its acceleration is

$$a = \frac{F}{m} = \frac{GM_e}{R_e^2}$$

Note that this acceleration does not depends on the mass of the object. Thus we have the following :

if gravity is the only acting force (meaning that air resistance is neglected), all objects move with the same acceleration near the earth's surface. This acceleration is called the acceleration due to gravity, whose magnitude 'g' is given by

$$g = \frac{GM_e}{R_e^2}$$

$$g = \frac{\left(6.67 \times 10^{-11} \frac{Nm^2}{kg^2}\right) \times \left(6 \times 10^{24}\ kg\right)}{\left(6.4 \times 10^6\ m\right)^2} = 9.8\,ms^{-2}$$

The direction of this acceleration is towards the centre of the earth, i.e., in the vertically downward direction. The acceleration has the same value, both in magnitude (9.8 m/s^2) and direction (towards centre of earth), whether the particle falls, moves up or moves at some angle with the vertical. In all these cases, we say that the particle moves freely under gravity.

(c) Value of 'g' on the Surface of the Moon :

$g = \frac{GM}{R^2}$ where M is the mass of a heavenly body like earth and R is its radius. As all heavenly bodies (like planets, the sun and the moon) are of different masses and different radii, so the value of g is different on different heavenly bodies.

We know, $$g_{moon} = \frac{GM_m}{R_m^2} \quad .....(i)$$

M_m (mass of the moon) = 7.4 × 10^{22} kg

R_m (radius of the moon) = 1.75 × 10^6 m

G = 6.673 × 10^{-11} $Nm^2\,kg^{-2}$

Then, from equation (i), $$g_{moon} = \frac{6.673 \times 10^{-11}\,Nm^2\,kg^{-2} \times 7.47 \times 10^{22}\,kg}{\left(1.75 \times 10^6\ m\right)^2}$$

$$g_{moon} = 1.63\,ms^{-2}$$

Now, $$\frac{g_{moon}}{g_{earth}} = \frac{1.663\,ms^{-2}}{9.8\,ms^{-2}} = \frac{1}{6}$$

or $$g_{moon} = \frac{1}{6} g_{earth}$$

Thus acceleration due to gravity on the surface of moon is $\frac{1}{6}$ times the acceleration due to gravity on the surface of the earth.

MASS OF EARTH AND MEAN DENSITY OF EARTH

(a) Mass of the Earth :

The mass of the earth can be calculated by using Newton's law of gravitation. Consider a body of mass m lying on the surface of the earth, then force of gravity acting on the body is given by

$$F = \frac{GMm}{R^2} \quad .....(i)$$

where, M = mass of the earth

R = radius of the earth

Also, F = mg ....(ii)

From (i) and (ii), we have $mg = \frac{GMm}{R^2}$ or $M = \frac{gR^2}{G}$

Now g= 9.8 ms^{-2}, R = 6400 km = 6.4 × 10^5 m

G = 6.67 × 10^{-11} Nm^2 kg^{-2}

$$M = \frac{9.8 \times (6.4 \times 10^6)^2}{6.67 \times 10^{-11}} = 5.98 \times 10^{24} \text{ kg}$$

Thus, the order of the mass of earth is 10^{25} kg

(b) Mean Density of Earth :

We know, $g = \frac{GM}{R^2}$

Let ρ be the means density of the earth. Since earth is assumed to be a homogeneous sphere of radius R, therefore, mass of the earth is given by

$$M = \text{Volume} \times \text{density} = \frac{4}{3}\pi R^3 \rho$$

Substituting this value in equation (i), we get

$$g = \frac{G}{R^2} \times \frac{4}{3}\pi R^3 \rho = \frac{4}{3}\pi G R \rho$$

$$\therefore \rho = \frac{3g}{4\pi GR}$$

Since, g = 9.8 ms^{-2}, G = 6.67 × 10^{-11} N m^2 kg^{-2}, R = 6400 km = 6.4 × 10^6 m

$$\therefore \quad \rho = \frac{3 \times 9.8}{4 \times 3.142 \times 6.67 \times 10^{-11} \times 6.4 \times 10^6} \quad \text{or} \quad \rho = 5478.4 \text{ kgm}^{-3}$$

$$\frac{\text{Density of earth}}{\text{Density of water}} = \frac{5478.4 \text{ kg m}^{-3}}{1000 \text{ kg m}^{-3}} \simeq 5.5$$

Thus, density of earth is about 5.5 times the density of water.

EQUATIONS OF MOTION FOR FREELY FALLING OBJECT

Since the freely falling bodies fall with uniformly accelerated motion, the three equations of motioning derived earlier for bodies under uniform acceleration can be applied to the motion of freely falling bodies. For freely falling bodies, the acceleration due to gravity is 'g' so we replace the acceleration 'a' of the equations by 'g' and since the vertical distance of the freely falling bodies is known as height 'h', we replace the distance 's' in our equations by the height 'h'. This gives us the following modified equations for the motion of freely falling bodies.

General equations of motion		**Equations of motion for freely falling bodies**
(i) $v = u + at$	changes to	$v = u + gt$
(ii) $s = ut + \frac{1}{2}at^2$	changes to	$h = ut + \frac{1}{2}gt^2$
(iii) $v^2 = u^2 + 2as$	changes to	$v^2 = u^2 + 2gh$

We shall use these modified equations to solve numerical problems. Before we do that, we should remember the following important points for the motion of freely falling bodies.

(i) When a body is dropped freely from a height, its initial velocity 'u' becomes zero.

(ii) When a body is thrown vertically upwards, its final velocity 'v' becomes zero.

(iii) The time taken by a body to rise to the highest point is equal to the time it takes to fall from the same height.

(iv) The distance traveled by a freely falling body is directly proportional to the square of time of fall.

(a) Sign Conventions :

(i) g is taken as positive when it is acting in the same direction as that of motion and g is taken as negative when it is opposing the motion.

(ii) Distance measured upward from the point of projection is taken as positive, while distance measured downward from the point of projection is taken as negative.

(iii) Velocity measured away from the surface of earth (i.e. in upward direction) is taken as positive, while velocity measured towards the surface of the earth is taken as negative.

EXERCISE

OBJECTICE DPP - 10.1

1. The value of acceleration due to gravity (g) on earth's surface is :

(A) 6.67×10^{-11} Nm^2 kg^{-2} (B) 8.9 m/s^2

(C) 9.8 m/s^2 (D) none of these

2. The acceleration due to gravity :

(A) has he same value everywhere is space (B) has the same value everywhere on the earth

(C) varies with the latitude on the earth (D) is greater on moon because it has smaller diameter

3. When a space ship is at a distance of two earths radius from the centre of the earth, the gravitational acceleration is :

(A) 19.6 ms^{-2} (B) 9.8 ms^{-2} (C) 4.9 m/s^2 (D) 2.45 ms^2

4. If planet existed whose mass and radius were both half of the earth, the acceleration due to gravity at the surface would be :

(A) 19.6 m/s^2 (B) 9.8 m/s^2 (C) 4.9 ms^{-1} (C) 2.45 m/s^2

5. A stone is dropped from the top a tower. Its velocity after it has fallen 20 m is [Take g = 10 ms^{-2}]

(A) 5 ms^{-1} (B) 10 ms^{-1}

(C) 15 ms^{-1} (D) 20 ms^{-1}

6. A ball is thrown vertically upwards. The acceleration due to gravity :

(A) is the direction opposite to the direction of its motion

(B) is in the same direction as the direction of its motion

(C) increases as it comes down

(D) become zero at the higher point.

7. The acceleration due to gravity on the moon's surface is :

(A) approximately equal to that near the earth's surface

(B) approximately six times that near the earth's surface

(C) approximately one-sixth of that near the earth's surface

(D) slightly greater than that near the earth's surface

8. The force acting on a ball due to earth has a magnitude F_b and that acting on the earth due to the ball has a magnitude F_e Then :

(A) $F_b = F_e$ (B) $F_b > F_e$ (C) $F_b < F_e$ (D) $F_e = 0$

9. Force of gravitation between two bodies of mass 1 kg each kept at a distance of 1m is :

(A) 6.67 N (B) 6.67×10^{-9} N (C) 6.67×10^{-11} N (D) 6.67×10^{-7} N

10. The force of gravitation between the bodies does not depend on :

(A) their separation

(B) the product of their masses

(C) the sum of their masses

(D) the gravitational constant

11. The ratio of the value of g on the surface of moon to that on the earth's surface is :

(A) 6 (B) $\sqrt{6}$ (C) $\frac{1}{6}$ (D) $\frac{1}{\sqrt{6}}$

12. Order of magnitude of G is S.I. unit is :

(A) 10^{-11} (B) 10^{11} (C) 10^{-7} (D) 10^{7}

13. The S.I. unit of g is :

(A) m^2/s (B) m/s^2 (C) s/m^2 (D) m/s

14. If the distance between two masses be doubled then the force between them will become :

(A) $\frac{1}{4}$ times (B) 4 times (C) $\frac{1}{2}$ times (D) 2 times

15. The type of force which exists between charged bodies is :

(A) only gravitational

(B) neither gravitational nor electrical

(C) only electrical

(D) both electrical and gravitational

SUBJECTIVE DPP - 10.2

1. What is the value of g on the surface on moon ?

2. What is average density of the earth ?

3. What is mass of he earth ?

4. What is unit of g is C.G.S. and S.I. system ?

5. The earth's gravitational force causes and acceleration of 5 ms^{-2} on a 1 kg mass somewhere in the space. How much will be the acceleration of 3 kg mass at that place ?

6. In what sense does the moon fall towards the earth ? Why does not it actually fall on earth's surface ?

7. What is the acceleration due to gravity at height $\frac{R}{5}$ from the surface of earth (radius R) ?

8. Using Newton's universal law of gravitation and second law of motion, find the mathematical expression for acceleration due to gravity on the surface on any planet.

9. Derive a relation for acceleration due to gravity. How its value vary with :

(i) mass of the planet (ii) Size of the planet ?

GRAVITATION AND FLUID

PL - 11

MASS AND WEIGHT

(a) Mass :

Definition :

Quantity of matter possessed by a body, is called the mass of the body. It is represented by the symbol m. It is a clear quantity.

Nature :

A body with more mass, needs a greater effort (force) to move it from rest or stopping it from motion. The body exhibits inertia. Thus, mass offers inertia. This mass is called inertial mass (m_1).

A body never has a zero mass.

Measurement of mass :

Mass of a body is measured by a beam balance by comparing the mass with bodies of known mass. At one place, bodies of same mass have same pull of gravity on them.

A beam balance works on the principle of moments (Bodies of equal masses, having equal weights, have equal and opposite moments about fulcrum of the balance, when suspended at equal distances from the fulcrum, and made the beam horizontal).

(b) Weight :

Definition :

The force with which a body is attracted towards the centre of the earth, is called the weight of the body. It is represented by the symbol W.

It is a vector quantity having direction towards the centre of the earth.

Expression for weight :

If mass of a body = m

Acceleration due to gravity of the earth = g

Then from relation ,

Force = Mass × Acceleration i.e., $W = mg$

This is the required expression.

Nature :

As $W = mg$, the weight of a body will vary from place to place due to variation in value of g. A body has zero weight at the centre of the earth (where $g = 0$).

Measurement of weight :

Weight of a body is measured by a spring balance.

(C) Difference between Mass and Weight :

Mass	Weight
1. Mass is quantity of matter possessed by a body?	1. Weight is the force with which a body is attracted towards the centre of the earth.
2. It is a scalar quantity.	2. It is a vector quantity.
3. Its S.I. units is kilogram (kg.)	3. Its S.I. unit is Newton (N).
4. Mass of a body remains constant at all places	4. Weight of the body changes from place to place.
5. Mass of a body is never zero.	5. Weight of a body becomes zero at the centre of the earth.
6. Mass of measured by a beam balance.	6. Weight is measured by a spring balance.

(d) Weight to object on Moon :

A body of mass m has weight, W = mg

For calculation

For earth $g_e = 9.8\ ms^{-2}$

For moon $g_m = 1.7\ ms^{-2}$

Hence,

For earth, $W_e = mg_e$

For moon $W_m = mg_m$

Ratio $\frac{W_m}{W_e} = \frac{mg_m}{mg_e} = \frac{g_m}{g_e} = \frac{1.7}{9.8} \approx \frac{1}{6}$

i.e. Weight ton moon = $\frac{1}{6}$th weight on earth.

kg. wt. is a unit of force:

From relation, W = mg

If m = 1kg W = 9.8 N

Hence a 1 kg body has weight of 9.8 N

It means that 9.8 N becomes equal to a force of 1 kilogram weight (kg. wt.)

(e) Variation in the weight of a body :

Weight of the body is given by,

W = mg

So the weight of a body depends upon (i) the mass of the body and (ii) value of acceleration due to gravity (g)at a place.

The mass of a body remains the same throughout the universe, but as the value of 'g' is different at different places. Hence, he weight of a body is different at different planes.

(i) The value of 'g' is more at poles and less at the equator. Therefore, weight of a body is more at the poles and less at the equator. In other words, a body weighs more at the poles and less at the equator.

(ii) The value of 'g' on the surfaces of different planet of the solar system is different, therefore, the weight of a body is different on different planet's

(iii) The value of 'g' decreases with height from the surface of the earth. Therefore, the weight of a body also decreases with height from the surface of the earth. That is why, the weight of a man is less on the peak of Mount Everest that the weight of the man at Delhi.

(iv) The value of 'g' decreases with depth from the surface of the earth. Therefore, the weight of a body decreases with depth from the surface of the earth.

(v) The value of 'g' at the centre of the earth is zero hence weight (=mg) of the body is zero at the centre of the earth.

DIFFERENCE BETWEEN 'g' AND 'G'

Acceleration due to gravity (g)	Universal gravitational constant (G)
1. The acceleration produced in a body falling freely under the action of gravitational pull of the earth is known as acceleration due to gravity.	1. The gravitational force between two bodies of unit masses separated by a unit distance is known as universal gravitational constant.
2. The value of 'g' is different at different points on the earth.	2. The value of 'G' is same at every point on the earth.
3. The value of 'g' decreases as we go higher from the surface of the earth or as we go deep into the earth.	3. The value of 'G' does not change with height and depth from the surface of the earth.
4. The value of 'g' at the centre of the earth is zero.	4. The value of 'G' is not zero at the centre of the earth or anywhere else.
5. The value of 'g' is different on the surface of different heavenly bodies like the sun, moon, and the planets.	5. The value of 'G' is same throughout the universe.
6. The value of 'g' on the surface of the earth is 9.8 ms^{-2}.	6. The value of G = 6.673×10^{-11} Nm^2 kg^{-2} throughout the universe.

WEIGHTLESSNESS

(a) Introduction :

When a man stands on weighing machine at rest, his weight compressed its spring downwards. Due to upward reaction, the pointer of the machine moves over the scale and the machine records the weight of the man.

But when the same machine starts falling down freely, there is no reaction and the pointer stays at zero recording a zero weight.

The man falling freely under the action of gravity has become weightless.

Definition :

Weightlessness may be defined as the state in which a body its weight due to free fall.

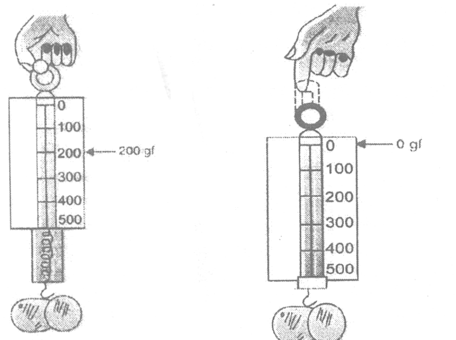
(d) Demonstration :

Let a stone piece be suspended from a spring balance suspended by a hand finger. The balance shows the actual weight of the stone.

When the balance is released from h and finger, the balance falls freely with the hanging stone piece. The balance shows a zero reading. This proves that the freely falling stone is weightless.

(i) The spring balance shows the weight of the stone.

(ii) Freely falling spring balance with the stone showing a zero reading.



Spring balance showing weight of a stone.
(a)

Freely falling spring balance shows zero weight.
(b)

(c) Weightlessness of an Astronaut in a Satellite (Space Ship):

A satellite is a freely falling body orbiting round the earth. It tries to reach the earth but its path being parallel to earth's surface. It does not reach the earth. Hence the satellite and all the bodies inside it become weightless.

It is due to this situation of weightlessness of astronauts that they are shown floating in spaceship in films on television.

EXERCISE

OBJECTIVE DPP - 11.1

1. The acceleration due to gravity is 9.8 m/s^2 :

(A) Much above the earth's surface (B) Near the earth's surface

(C) Deep inside the earth (D) At the centre of the earth

2. A particle is taken to a height R above the earth's surface, where R is the radius of the earth. The acceleration due to gravity there is :

(A) 2.45 m/s^2 (B) 4.9 m/s^2 (C) 9.8 m/s^2 (D) 19.6 m/s^2

3. When a body is thrown up, the force of gravity is :

(A) in upward direction (B) in downward direction

(C) zero (D) in horizontal direction

4. Mass of an object is :

(A) amount of matter present in the object (B) same as weight of an object

(C) measure of gravitational pull (D) none of these

5. The weight of an object is :

(A) the quantity of matter it contains

(B) refers to its inertia

(C) same as its mass but is expressed in different units

(D) the force with which it is attracted towards the earth

6. Weight of an object depends on:

(A) temperature of the place

(B) atmosphere of the place

(C) mass of an object

(D) none of these

7. The mass of body is measured to be 12 kg on the earth. Its mass on moon will be :

(A) 12 kg (B) 6 kg (C) 2 kg (D) 72 kg

8. A heavy stone falls :

(A) faster than a light stone

(B) slower than a light stone

(C) with same acceleration as light stone

(D) none of these

9. A stone is dropped from the roof of a building takes 4s to reach ground. The height of the building is :

(A) 19.6 m (B) 39.2 m (C) 156.8 m (D) 78.4 m

10. A ball is thrown up and attains a maximum height of 19.6 m. Its initial speed was :

(A) 9.8 ms^{-1} (B) 44.3 ms^{-1} (C) 19.6 ms^{-1} (D) 98 ms^{-1}

11. The value of g at pole is :

(A) greater than the value at the equator

(B) less than the value at the equator

(C) equal to the value of the equator

(D) none of these

12. Two bodies A and B of mass 500 g and 200 g respectively are dropped near the earth's surface. Let the acceleration of A and B be a_A and a_B respectively, then :

(A) $a_A = a_B$ (B) $a_A > a_B$ (C) $a_A < a_B$ (D) $a_A \neq a_B$

13. A body is thrown up with a velocity of 20 m/s. The maximum height attained by it is approximately :

(A) 80 m (B) 60 m (C) 40 m (D) 20 m

14. The weight of a body is 120 N on the earth. If it is taken to the moon, its weight will be about :

(A) 120 N (B) 60 N (C) 20 N (D) 720 N

15. Two iron and wooden balls identical in size are released from the same height in vacuum. The time taken by them to reach the ground are :

(A) not equal (B) exactly equal (C) regularly equal (D) zero

SUBJECTIVE DPP - 11.2

1. How does the acceleration due to gravity depends on the mass of planet ?

2. Is g vector or scalar ? Write is SI unit.

3. What is acceleration under free fall ?

4. What is the S.I. unit of mass ?

5. What is S.I. unit of weight ?

6. How many Newton's make 1 kg. wt. ?

7. Name of device to measure weight :

8. Which is greater : The force of attraction of earth for 1 kg of tin or the force of attraction of earth for 1 kg of lead.

9. The mass of the mass on the surface of earth is 100 kg. Does the weight on the surface of moon increase or decrease ? Explain.

10. A ball thrown up vertically returns to the thrower after 12 second. Find (Take g = 10 m/s) :

(i) velocity with which it was thrown up.

(ii) the maximum height it reaches.

(iii) its position after 4s

GRAVITATION AND FLUED

PL - 12

FLUID

Fluid is a substance that flows under the action of an applied force and does not have a shape of its own. For example, liquids and gases. They take the shape of container in which they are stored.

The study of fluids at rest is known as hydrostatic or fluid static's. The study of fluids in motion is termed as hydrodynamics. In this chapter, we will discuss the study of liquids only.

PRESSURE IN A FLUID

In case of solids, the force can be applied in any direction with respect to the surface, but in liquids, the force must be applied at right angles to the liquids surface. This is because fluids (liquids and gases) at rest cannot sustain a tangential force. Therefore, we state the pressure acting on the fluid instead of force.

The pressure (P) is defined at the magnitude of the normal force acting on a unit surface area of the fluid. It a constant force of magnitude F acts normally on a surface area A, then pressure acting on the surface is given by $P = \frac{F}{A}$. The pressure is a scalar quantity. This is because hydrostatic pressure is transmitted equally in all directions when force is applied, which shows that a definite direction is not associated with pressure.

THRUST

The total force exerted by a liquid on any surface in contact with it is called thrust of the liquid.

Thrust = Pressure × Area of surface

UNITS OF PRESSURE

In C.G.S. system, unit of pressure is dyne/cm^2. S.I. unit of pressure is Nm^{-2} or Pascal (PA). The unit of pressure, Pascal (Pa) has been named in the honour of great French scientist and philosopher Blasie Pascal. Another unit of pressure is atmosphere (atm).

1 atm = 1.013×10^5 Nm^{-2} (or Pa)

1 atm. or one atmosphere is the pressure exerted by our atmosphere on earth surface due to the weight of atmosphere.

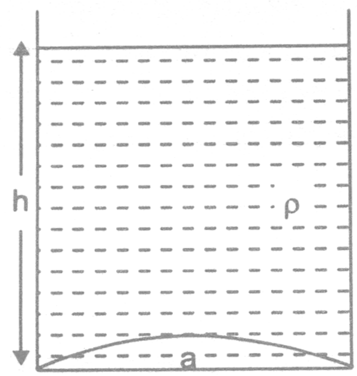
(a) Pressure is a Scalar Quantity :

Scalar quantities are those which do not have any direction. The physical quantities which have both magnitude and direction are called vector quantities. Pressure is a scalar quantity because at one level inside the liquid, the pressure is exerted equally in all direction, which shows that a direction is not associated with hydrostatics pressure or pressure due to a static fluid.

(b) Pressure Exerted by a Liquid Column :

Consider a liquid of density ρ contained in a cylindrical vessel of cross sectional area a. Let h be the height of liquid column and g be the acceleration due to gravity. The weight of liquid will exert a downward thrust on the bottom surface of the vessel. Therefore, pressure due to liquid acts on that surface.

Weight of liquid inside the vessel = volume × density of liquid × acceleration due to gravity



Thrust of liquid on area a = weight of liquid = a h ρ g

Liquid pressure on the base of vessel is

$$P = \frac{\text{thrust}}{\text{area}} = \frac{ah\rho g}{a} = h\rho g \qquad .....(i)$$

❖ **NOTE :**

(i) The liquid at rest exerts equal pressure in all direction s at a point inside the liquid.

(ii) The liquid at rest exerts equal pressure at all those points which are in one level inside the liquid.

(iii) Liquid pressure is independent of shape of the liquid surface, but depends upon the height of liquid column.

(iv) Total pressure at a depth h below the liquid surface = $P_0 + h\rho g$ where P_0 = atmospheric pressure.

(v) Pressure is a scalar quantity.

(vi) Mean pressure on the walls of a beaker containing liquid upto height is $(= h\rho g/2)$, where ρ is the density of liquid.

(vii) Thrust exerted by liquid on the walls of the vessel in contact with liquid is normal to the surface of vessel.

(C) Some Facts Involving Thrust and Pressure :

(i) Nails have a flat top but pointed end:

A small pressure applied on the flat to through falling hammer becomes a large thrust. The same thrust acts on the wooden board through the pointed end of the nail. It result in a large pressure. The nail can easily be fixed in the wooden board.

(ii) **Sewing needle have pointed tips :**

A small force of fingers makes the needle pierce into the cloth easily and sewing becomes quicker.

(iii) Cutting items (knives and blades) have sharp edge. Cutting becomes easier.

(d) Reducing Pressure :

(i) **Vehicle brakes have flat surface :**

This reduces pressure on the vehicle tyres and avoid their tearing.

(ii) Broad sole shoed :

Broad sole shoes make walking easier on a soft land.

(iii) Wide steel belt on army tank :

Wide steel belt over the wheels of an army taken, makes its movement easier over marshy land.

(vi) Tractor tyres are broad : Tractors do not sink in the soft land of the field while operating them.

(v) Camel foot are broad and soft : They walk swiftly on sand.

(vi) Hanging bags have wide straps : They reduce pressure on the shoulders.

BUOYANCY AND FORCE OF BUOYANCY (BUOANT FORCE)

Introduction :

When a body is immersed in a fluid (liquid or gas), it displaced the fluid whose volume is equal to the volume of the body immersed in the fluid. This displaced fluid exerts an upward force on the body.

Definition :

This tendency of the displaced fluid (exerting an upward force) is called **buoyancy.** The upward applied force, is called the force of buoyancy or up thrust. It is equal to the weight of the fluid displaced by the body.

Examples :

(i) When a bucket is pulled out of a well, it is felt lighter so long as it remains immersed in water, inside the well. It acquires its actual weight when out of water.

(ii) Ladies carrying water in a pitcher from a village pond, enter the pond, fill the pitcher and lift it on to their shoulder keeping it immersed in water.

Factors on which up thrust or buoyant force depends :

Let us perform the following two activates :

(i) Take two wooden blocks of different sizes. Push the small block inside the water in a tub and release it. You will find that the wooden block rises up and come to the surface of water. It rises up because upthrust or buoyant force acting on it is more than its weight.

Now push the large wooden block inside the water and release it. You will find that the large block rises up faster than the small block. It means, the upthurst or buoyant force acting on the large block is more than on the small block.

(ii) Now add some salt in water so that the density of solution (water + salt) increases. Push a wooden block inside the solution and release it. You will find that the block rises up faster in a solution than in pure water. It means, the upthrust or buoyant force acting on a body is more in a liquid having more density than in a liquid having less density.

Conclusion :

From the above mentioned actives, we conclude that upthrust or buoyant force depends on :

(i) The size or volume of the body immersed in a liquid.

(ii) The density of the liquid in which the body is immersed.

Buoyancy :

The tendency of an object to float in a liquid or the power of liquid to make an object float is called buoyancy.

Remember these points :

(i) An object whose weight (i.e., downward gravitational force) is greater than the upthrust of the liquid (say water) on the object, sinks in the liquid. This is possible if density of object is more than the density of liquid.

(ii) An object whose weight (i.e. downward gravitational force) is less than the upthurst of the liquid on the object, floats on the liquid. This is possible if density of object is less than the density of liquid.

EXERCISE

OBJECTIVE DPP - 12.1

1. Pressure varies with force as :

(A) F (B) $\frac{1}{F}$ (C) F^2 (D) $\frac{1}{F^2}$

2. Pressure exerted by a sharp needle on a surface is :

(A) more than the pressure exerted by blunt needle

(B) less than the pressure exerted by a blunt needle

(C) equal to the pressure exerted by a blunt needle

(D) none of these

3. If a force of 10N acts on two surfaces (area in the ratio 1 : 2), then the ratio of thrusts will be :

(A) 1 : 2 (B) 2 : 1 (C) 3 : 1 (D) 1 : 1

4. The height of mercury which exerts the same pressure as 20 cm of water column, is equal to :

(A) 1.48 cm (B) 14.8 cm (C) 148 cm (D) None of these

5. Pressure varies with area (A) as :

(A) A (B) $\frac{1}{A}$ (C) A^2 (D) $\frac{1}{A^2}$

6. A force of 50 N is applied on a nail of area 0.001 sq. cm. Then the thrust is :

(A) 50 N (B) 100 N (C) 0.05 N (D) 10 N

7. The S.I. unit of pressure is :

(A) atmosphere (B) dyne/cm^2 (C) Pascal (D) mm of Hg

8. The pressure exerted by a liquid at depth h is given by :

(A) $\frac{h}{dg}$ (B) hdg (C) $\frac{h}{d}$ (D) hg

9. The S.I. unit of thrust :

(A) N (B) dyne (C) Nm^2 (D) Nm^{-2}

10. Pressure cannot be measured in :

(A) Nm^{-2} (B) bar (C) Pa (D) kg. wt.

11. The total force exerted by the body perpendicular to the surface is called :

(A) pressure (B) thrust (C) impulse (D) none of these

12. Pressure is a :

(A) scalar quantity (B) normal force (C) vector quantity (D) all the above are wrong

13. 1 N/m^2 equals :

(A) 1 Pa (B) 0.1 Pa (C) 0.01 Pa (D) 10 Pa

14. The atmosphere exerts a pressure of P on the surface of earth, then P equal :

(A) 1.01×10^5 Nm^{-2} (B) 1.01×10^{-5} Nm^{-2} (C) 1.01×10^7 Nm^{-2} (D) 1.01×10^{-7} Nm^{-2}

SUBJECTIVE DPP - 12.2

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1. Write mathematical relation between pressure and thrust ?

2. Give S.I. unit of pressure.

3. Is pressure scalar or vector ?

4. Define pressure of fluid.

5. Define 'thrust'. What is the S.I. unit of thrust ?

6. What is difference between thrust and pressure ?

7. A camel can walk easily in Sandy desert than a man although the weight of the camel is mush more than that of the man. Comment.

8. A person weight 60 kg. The area under his feel of the person is 180 cm^2. Find the pressure exerted on the ground by the person.

9. What is meant by pressure ? Give some applications of pressure.

GRAVITATION AND FLUID

PL - 13

ARCHEMED PRINCIPLE

A Greek scientist Archimedes conducted many experiments and concluded that when a body or an object is immersed partially or completely in a liquid or gas (i.e. fluid), it experiences an upthrust or buoyant force. The upthrust or buoyant force is equal to the weight of the fluid displaced by the body. It is known as Archimedes principle.

Statement of Archimedes principle :

When a body is immersed partially or completely in a fluid (liquid or gas), it experiences an upthrust or buoyant force which is equal to the weight of the fluid displaced by the body.

(a) Proof of Archimedes Principe :

Consider a cylindrical body of cross-sectional area 'a' submerged in a liquid of density ρ . Let the upper face of the body is at a depth h_1 below the surface of the liquid and the lower face is at a depth h_2 below the surface of the liquid. The pressure exerted by the liquid on the upper surface of the body is given by $p_1 = h_1 \rho g$.

Downward thrust on the upper surface of the body is ,

$F_1 = p_1 \times a = h_1 \rho g \times a$

Pressure exerted by the liquid at the lower surface of the body,

$P_2 = h_2 \rho g$

Upward thrust on the lower surface of the body is,

$F_2 = P_2 \times a = h_2 \rho g \times a$

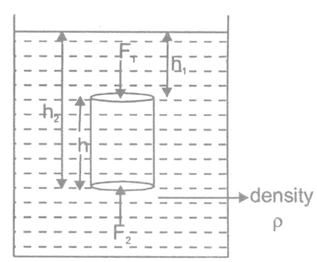
The horizontal thrusts acting on the vertical sides of the body being equal and opposite from all the sides cancels out.

$\therefore$ Resultant upthrust or buoyant force acting on the body is,

$F = F_2 - F_1 = h_2 \rho g\ a - h_1 \rho g\ a = (h_2 - h_1) \rho g\ a$

Since volume of the body, $V = (h_2 - h_1)a$

$\therefore F = V \rho g$

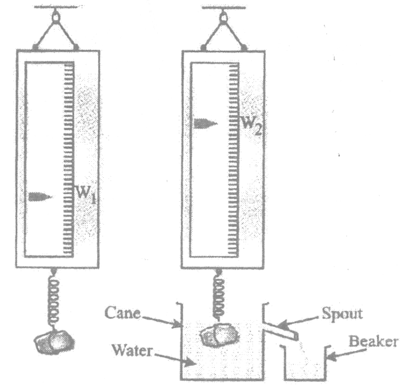


Which implies that products of the volume of the body, the density of the liquid and the acceleration due to gravity gives the weight of the liquid displaced.

Thus, when a body is submerged in a liquid, it experiences an upward thrust equal to the weight of the liquid displaced by the body.

(b) Verification of Archimedes Principle :

To verify the Archimedes Principles we take following steps :



(i) Take a small piece of stone and suspend it with a spring balance. Let the weight of the stone indicated by the spring balance be W_1.

(ii) Now take an empty beaker and measure its weight by suspending it with the spring balance with the help of a thread of negligible mass. Let the weight of the empty beaker be W_2.

(iii) Take a Cane having a side tube known as spout. Fill Cane with water upto the level of spout.

(vi) Lower the stone suspended with a spring balance inside the water. The stone displaces the water which comes out of the Cane through the spout. The water coming out of the Cane is collected in the beaker. When the water stops coming out of the spout, note the reading of the spring balance. This reading shows the weight of the stone inside the water. Let the weight of the stone inside the water be W_3. It is seen that W_3 is less than W_1.

(v) Now measure the weight of the beaker along with the water collected in it. Let this weight be W_4.

(vi) Now find $(W_1 - W_3)$. This difference in weight is equal to the loss of weight of the stone immersed in water (i.e. upthrust or buoyant force).

(vii) Also find $(W_4 - W_2)$. This difference in weight is equal to the weight of the water displaced by the stone.

(viii) It is found that $(W_1 - W_3) = (W_4 - W_2)$. That is upthrust or buoyant force is equal to the weight of the water displaced. Thus, Archimedes principle is verified.

DENSITY

The ratio of mass and volume of the body is known as the density of the material of the body.

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

$$\rho = \frac{M}{V}$$

IF $V = 1\ m^3$, then, $\rho = M$

or the mass per unit volume is known as the density of the material of the object.

Unit of density :

$\therefore \quad \rho = \frac{M}{V} \to g/cm^3$ (in C.G.S.)

$\rho \to kg/m^3$ (in S.I. system)

RELATIVE DENSITY OR SPECIFIC GRAVITY)

The ratio of density of the substance to the density of water at 4^0C is known as the relative density of the substance.

Relative density of substance $= \frac{\text{density of subs tan ce}}{\text{density of water at } 4^0 C}$

It is pure number having no unit.

ILLUSTRATION

1. The relative density of silver is 10.5. The density of water is 10^3 kg/m^3. What is the density of silver in S.I. unit ?

Sol. Density of water $d_w = 10^3$ kg/m^3

Relative density (R.D.) of silver = 10.5

Density of silver d_{Ag} = ?

$\therefore \quad R.D. = \frac{\text{density of silver}}{\text{density of water}}$

$10.5 = \frac{d_{Ag}}{10^3}$

$d_{Ag} = 10.5 \times 10^3$ kg/ m^3.

USES OF ARCHIMEDES PRINCIPLE

Relative density for solids and liquids can also be determined with the help of Archimedes principle.

(i) For solids :

By definition, we have

Relative density $= \frac{\text{Density of substnce}}{\text{Density of water}} = \frac{\text{Weight of certain volume of subs tan ce}}{\text{Weight of sme volume of water}}$

Relative density $= \frac{\text{Weight of a body}}{\text{loss in weight when fully immersed in water}}$

Relative density of a solid can be measured by weighing it first in air and then when fully immersed in water.

Let weight of the body in air = W_1

Weight of solid body in water = W_2

$\therefore$ Loss in weight = $W_1 - W_2$

$\therefore \quad R.D. = \frac{\text{Weight of solid body in air}}{\text{Loss in weight in water}} = \frac{W_1}{W_1 - W_2}$

(ii) For liquids :

To measure relative density of a liquid, choose a body which can be fully immersed in water as well as in the given liquid. The body is weighed first in air, then fully immersed in water and then fully immersed in that particular liquid.

$$\text{R.D.} = \frac{\text{Density of liquid}}{\text{Density of water}} = \frac{\text{Weight of certain volume of liquid}}{\text{Weight of water displaced by the same body}}$$

$$\text{R.D.} = \frac{\text{weight of liquid displace by a body}}{\text{weight of water displaced by the same body}}$$

$$\text{R.D.} = \frac{\text{loss of weight inliquid}}{\text{loss of weight in water}}$$

Let the weight of a body in air = W

Weight of the body fully immersed in water = W′

Weight of the body fully immersed in liquid = W′′

Then loss of weight in liquid = W - W′′

and loss of weight in water = W - W′

$\therefore$ Relative density of the liquid = $\frac{W - W''}{W - W'}$

(iii) Archimedes principle is used to design :

(A) the ships and submarines.

(B) the hydrometers to find the densities of liquids.

(C) the lactometers to test the purity of milk.

Tale of densities and relative densities of some substances :

S.No.	Name of Substance	Density at S.T.P. in (kg m^{-3})	Relative Density
1	Air	1.29	1.29×10^{-3}
2	Wood	800	0.80
3	Ice	920	0.917
4	Water	1000	1.00
5	Glycerin	1260	1.26
6	Glass	2500	2.50
7	Aluminium	2700	2.70
8	Iron	7900	7.90
9	Silver	10500	10.50
10	Mercury	13600	13.60
11	Gold	19320	19.32

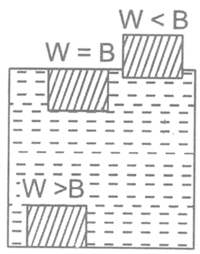
PHYSICAL MEANING OF RELATIVE DENSITY

Relative density of a substance is a number of times the given substance is heavier than the equal volume of water. When we say that the relative density of silver = 10.5, it means, silver is 10.5 times heavier than equal volume of water.

LAW OF FLOATATION

Law of floatation is an extension of Archimedes principles.

When a body is immersed partially or wholly in a fluid, then the various forces acting on the body are (i) upward thrust (B) acting at the centre of buoyancy and whose magnitude is equal to the weight of the liquid displaced and (ii) the weight of the body (W) which acts vertically downwards through its centre of gravity.



Floatation

(i) When W > B, the body will sink in the liquid.

(ii) When W = B, then the body will remain in equilibrium inside the liquid.

(iii) When W < B, then the body will come upto the surface of the liquid in such a way that the weight of the liquid displaced due to it balance the weight of body immersed inside the liquid.

Thus law of floatation is defined as follows :

Definition :

A body floats is a liquid if weight of the liquid displaced by the immersed portion of the body is equal to the weight of the body.

(a) Relation between Density of Solid and Liquid :

Let ρ_1 be the density of the solid whose volume if V_1. Let ρ_2 be the density of the liquid and the volume of the portion of the solid immersed in the liquid be V_2.

Now, weight of the floating solid = weight of the liquid displaced.

i.e. $V_1\rho_1 g = V_2\rho_2 g \quad \therefore \quad \frac{\rho_1}{\rho_2} = \frac{V_2}{V_1}$

or $\frac{\text{Density of solid}}{\text{Density of liquid}} = \frac{\text{Volume of the immersed portion of the solid}}{\text{Total volume of the solid}}$

= Fraction of volume of body immersed in liquid

(b) Equilibrium of Floating Bodies

From law of floatation, we know that a body will float in a liquid when its weight W is equal to the weight w of the liquid displaced by the immersed part of the body. But this does to necessarily indicate that the body will be in equilibrium. A body will be in equilibrium only if the resultant of all the forces and couples acting on the body is zero. Thus, a floating body can be in equilibrium if no couple acts on it. It will be so if the line of action of W and w is along the same vertical straight line. Thus, there will be equilibrium of floating bodies if the following conditions are fulfilled:

(i) A body can float if the weight of the liquid displaced by the immersed part of body must be equal to the weight of the body.

(ii) A body can be in equilibrium in the centre of gravity of the body and centre of buoyancy must be along the same vertical line.

(iii) The body will be in stable equilibrium if centre of gravity lies vertically above the centre of buoyancy.

❖ **NOTE :**

When an ice block is floating in water in a vessel, then the level of water in the vessel will not change when the whole ice melts into water.

When an ice block is floating in a liquid in a vessel and ice completely melts, then the following cases may arise for the level of liquid in the vessel.

(i) If density of liquid is grater than that of water i.e., $\rho_L > \rho_w$ the level of liquid plus water will rise.

(ii) If density of liquid is less than the density of water i.e., $\rho_L < \rho_w$ the level of liquid plus water will decrease

(iii) If density of liquid is equal to the density of water i.e., $\rho_L = \rho_w$, the level of liquid plus water will remain unchanged.

EXERCISE

OBJECTIVE DPP - 13.1

1. A piece of wood is held under water. The upthrust on it is :

(A) equal to the weight of the wood (B) less than the weight of the wood

(C) more than the weight of wood (D) zero

2. Archimedes principle states that when a body is totally or partially immersed in a fluid the upthrust is equal to :

(A) the weight of the fluid displaced. (B) the weight of the body.

(C) volume of the fluid displaced (D) volume of the body.

3. S.I. unit of density is :

(A) kgm^{-2} (B) kgm^{-3} (C) $m^2\ kg^{-1}$ (D) $N\ kg^{-1}$

4. Unit of relative density is :

(A) kgm^{-3} (B) gcm^{-3} (C) g $litre^{-1}$ (D) It does not have a unit

5. Relative density of a solid is 0.6. It floats in water with :

(A) whole of its volume inside water (B) 60% volume inside water

(C) 60% volume outside water (D) 40% volume inside water.

6. Buoyant force acting on a body due to different fluids is :

(A) same (B) different (C) zero (D) none of these

7. The relative density of silver is 10.5, if the density of water is 1000 kgm^{-3}, then density of silver will be :

(A) 10.5 kgm^{-3} (B) 1050 kgm^{-3} (C) 10.5 kgm^{-3} (D) 10.500 kgm^{-3}

8. A body floats with $\frac{1}{3}$rd of its volume outside water and $\frac{3}{4}$th of its volume outside liquid, then the density of liquid is :

(A) $\frac{3}{8} g/cm^3$ (B) $\frac{8}{3} g/cm^3$ (C) $\frac{9}{4} g/cm^3$ (D) $\frac{4}{9} g/cm^3$

9. A boat full of iron nail is floating on water in a take. When the iron nails are removed, the water level :

(A) rises (B) remains same

(C) fails (D) nothing can be said

10. A cylinder of wood floats vertically in water with one-fourth of its length out of water. The density of wood is :

(A) 0.5 g/cm^3 (B) 0.5 g/cm^3 (C) 0.75 g/cm^3 (D) 1 g/cm^3

11. Relative density of a solid is :

(A) $R.D. = \frac{\text{Density of substance}}{\text{Density of water}}$ (B) $R.D. = \frac{\text{Weight of certain volume of substance}}{\text{Weight of same volume of water}}$

(C) $R.D. = \frac{\text{Weight of substance}}{\text{Density of water}}$ (D) All of the above

12. Archimedes principle is used to :

(A) design ships (B) design Submarines

(C) design Lactometers (D) all of them

13. Two solids X and Y float on water, X floats with half of its volume submerged while Y float s with one - third of its volume out of water. The densities of X and Y are in the ratio of

(A) 4 : 3 (B) 3 : 4 (C) 2 : 3 (D) 1 : 3

14. The balloon stops rising up beyond a particular height when the density of gas inside the balloon :

(A) exceeds the density of air outside (B) equal the density of air

(C) becomes less than the density of air (D) none of these above

SUBJECTIVE DPP - 13.2

1. Give S.I. unit of relative density.
2. When a stone in immersed in water it displaces water of weight 5N, Calculate the upthrust acting on the stone.
3. If a solid of the same density as that of a liquid is placed in it, what will happen to the solid ?
4. Explain, why a ship sinks to a great depth in river water than in sea water ?

5. You are provided with a hollow iron ball of volume 20 cm^3 and of mass 15g and a solid iron ball of mass 20g. both are placed on the surface of water containing in a large tube. Which will float ? Give reasons for your answer ?

6. A solid weights 200 g in air, 160 g in water and 170g in a liquid. Calculate the relative density of the solid and that of the liquid.

7. Explain briefly why a balloon filled with helium gas rises in air ?

8. What are the laws of floatation in a liquid ? Give some illustrations.

ANSWER KEY

(Objective DPP # 9.1)

Qus.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Ans.	C	A	D	A	B	C	B	D	C	C	C	D	B	D

(Subjective DPP # 9.2)

6. 3.33×10^{-9} N

(Objective DPP # 10.1)

Qus.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	C	C	D	A	D	A	C	A	C	C	C	A	B	A	D

(Subjective Dpp # 10.2)

5. 5 ms^{-2} 7. 6.785 ms^{-2}

(Objective DPP # 11.1)

Qus.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	B	A	B	A	D	C	A	C	D	C	A	A	D	C	B

(Subjective DPP # 11.2)

10. (i) 60 ms^{-1} (ii) 180 m (iii) 160 m above the thrower

(Objective DPP # 12.1)

Qus.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Ans.	A	A	D	A	B	A	C	B	A	D	B	A	A	A

(Subjective DPP # 12.2)

8. $\frac{10^5}{3} \text{Nm}^{-2}$

(Objective DPP # 13.1)

Qus.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Ans.	C	A	B	D	B	B	D	B	C	C	D	D	B	B

(Subjective DPP # 13.2)

2. 5 N **6.** 0.5, 0.75

WORK, ENERGY AND POWER

PL - 14

INTRODUCTION

In everyday language, the word **work** is used to describe any activity in which muscular or mental effort is exerted. In physical, the word work has a special meaning. Work in one done when the force acting on body produced motion in it in the direction of force (or in the direction of component of force). Thus a boy pushing the wall is doing no work from physics' point of view. If is because the force exerted by the body is not producing motion of the wall. The speed at which work can be done is an indication of the power of the body doing work. For example, a boy may carry a suitcase upstairs in 3 minutes while a man may do it in 1 minute. Obviously, the power of the man is more than the power of the boy. Thus, time factor is important for power. A body which has the capacity to do work is said to posses energy. The greater the capacity of a body to do work, the greater the energy it has. Thus work, energy and the power are related to each other. In this topic we shall deal with these three important concepts of physics.

WORK

In our day to day life, the word work means any kind of mental and physical activity. For example, we say that we are doing work while,

(i) reading a book,
(ii) cooking the food,
(iii) walking on a level road with a box on our head,
(iv) pushing a wall of a house but fails to do so.

In all these cases, either mental or physical activity is involved.

But is physics, the term work has entirely a different meaning. In physics work is done if a force applied on a body displaced the body in its own direction. In other words, the condition which must be satisfied for the work done are : (i) a force must act on the body and (ii) the body must be displaced from one position to another position. Thus, no work is done in all cases mentioned above.

Definition :

Work is said to be done by a force on a body o an object if the force applied causes a displacement in the body or object.

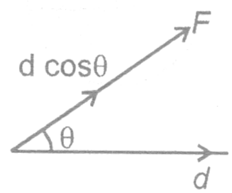
Eg. : Work is done, when a box is dragged on the floor from one position to another. In this case, force is on box to drag it one the floor and the box moves through a certain distance between one position to another position.

(a) Measurement of Work :

Work is measured by the product of force and the displacement in the direction of force. Work is a scalar quantity.

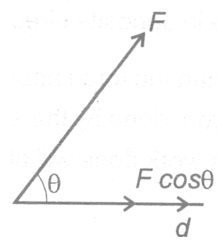
Work = Force × displacement in the direction of force

W = F(d cos θ) ...... (i)



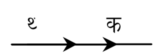
or work done = displacement × force in the direction of displacement.

W = d(F cos θ) ......(ii)



Special cases :

Case -I : If θ = 0^0, then -



From equation (i)

W = Fd cos θ = Fd $\cos 0^0$

So, W = Fd (maximum)

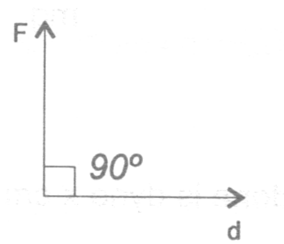
When force and displacement are in same direction then work done will be maximum.

Case - II : When θ = 90^0, then -

From equation (i) $\therefore \cos 0^0 = 1$

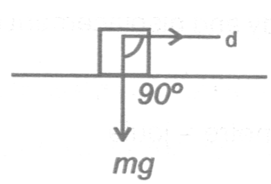
W = Fd $\cos 90^0$

So, W = 0

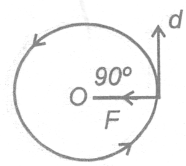


When force and displacement are perpendicular to each other then work done will be zero.

Eg. : If a body is moving in horizontal direction then work done by the force of gravity will be zero.



Eg. : if a body is moving on a circular path then work done by the centripetal force will be zero, because the direction of centripetal force is towards the center of the circle and displacement will be along the tangent.



Case III :

If $\theta = 180^0$

then from equation (i)

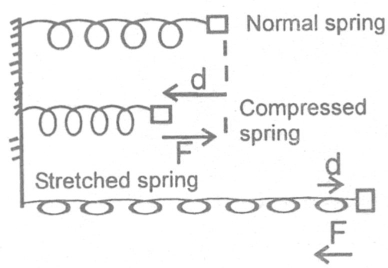
W = Fd $\cos 180^0$ $\quad\therefore \cos 180^0 = -1$

then W = - Fd

When the force and displacement are in opposite direction then work done will be negative.

Eg.: When a spring is compressed then the force applied by the spring and the displacement will be in opposite direction to each other, so work done by the spring will be negative.

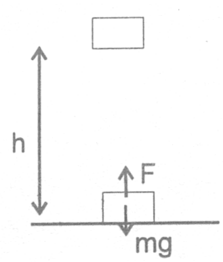
When the spring is stretched then the work done will also be negative.



Eg.: When a body of mass m in lifted upward a fore F = mg has to be applied upward

Work done by the force of gravity will be negative

Work done, W = - mgh



(b) Units of Work done :

Work done, W = Fd

In C.G.S. system the unit of work done is dyne x cm = erg.

Definition of 1 etg :

If F = 1 dyne and d = 1 cm.

then W = 1 × 1 = 1 erg.

If one dyne force is applied on a body and displacement in the body in 1 cm in the direction of force, then work done will be one erg.

S.I. unit of work done is Newton × metre = joule.

Definition of 1 joule :

if F = 1N and d = 1m.

then, W = 1 × 1 = 1 joule (J)

If a force of 1 Newton is applied on a body and displacement in the body is 1m in the direction of force then work done will be 1 joule.

Relation between joule and erg :

1 joule = 10^7 erg

❖ **NOTE :**

(i) If F = 0 then work done, W = 0

Eg. A student revising his notes by memory without moving his limbs is doing no physical work.

A meditating saint is doing no physical work though he keeps sitting for hours.

(ii) If displacement, d = 0 then work done, W = 0.

Eg. A foolish labour trying to displace a building has done no work though he may spend the whole day.

Erg and joule are the absolute units of work done.

Gravitational unit of work :

Work is said to have gravitational unit of work if unit gravitational force displaces the body through unit distance in the direction of force.

(i) In C.G.S. system, gravitational unit of work is gram-weight-centimeter (g wt cm).

Since W = FS

$\therefore$ 1g wt cm = 1 g wt × 1 cm = 981 dyne × 1 cm

1g wt cm = 981 erg.

Thus 1g-wt-cm of work is done when a force of 1g-wt displaces a body through 1 cm in its own direction.

(ii) **In S.I. system,** gravitational unit of work is kilogram weight meter (kg wt m)

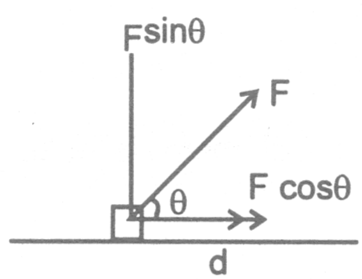
1kg wt m = 1kg wt × 1m = 9.81 N × 1 m

1 kg wt m = 9.81 J

Thus, 1 kg wt m of work is done when a force of 1 kg-wt displaces a body through 1 m in its own direction.

(c) Positive Work done :

When the angle between force and the displacement is acute ($\theta < 90^0$), then work done will be positive because one component of force (F $\cos\theta$) is in the direction of displacement so work done by this component will be positive (Fd $\cos\theta$). Work done by the vertical component (i.e. F $\sin\theta$) will be zero ($\because$ the angle between F $\sin\theta$ and displacement is 90^0) so net work done will be positive.

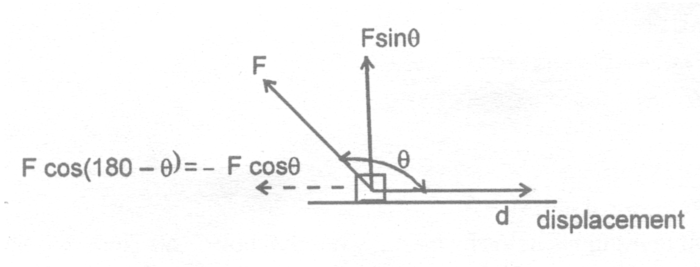


(i) In lifting a weight upward by applying an upward force, the work done by the applied force will be positive.

(ii) In stretching a spring, the work done by the eternal force will be positive.

(d) Negative Work done :

When the angle between the force and the displacement is obtuse, $(\theta > 90^0)$, then work done will be negative because work done by the horizontal component of force (i.e. F $\cos\theta$) is negative (-Fd $\cos\theta$) and the work done by the vertical component (F $\sin\theta$) will be zero, so net work done will be negative.



ILLUSTRATIONS

1. A porter lifts a luggage of 15 kg from the ground and put it on his head, 1.5 m above the ground. Calculate the work done by him on the luggage. (take g = 10 m/s^2.)

Sol. Mass of luggage, m = 15 kg

displacement, d = 1.5 m

acceleration due to gravity, g = 10 m/s^2

work done, W = Fd = mgd

W = 15 × 10 × 1.5 = 225 J

2. A force of 10 N displaces a body by 5m, the angle between force and displacement i 60^0, then find the work done.

Sol. Force, F = 10 N,

displacement, d = 5m,

angle between force and displacement, $\theta = 60^0$,

work done, W = Fd $\cos\theta$ = 10 × 5 × $\cos 60^0$, $\quad \therefore \cos 60^0 = \frac{1}{2}$

then, $W = 10 \times 5 \times \frac{1}{2} \Rightarrow W = 25$ J

ENERGY

When a man does a work, he feels tired. he feels that he has lost something which he must regain to work more. A weak man gets exhausted after doing only a small amount of work. A strong man can continue to work for longer duration.

Something that a working man loses is called energy.

Definition :

Capacity of doing work or total work done by a man or by an agent, is called the energy of the man or the agent.

(a) Units of energy :

C.G.S. unit of energy is erg and S.I. unit of energy is joule.

❖ NOTE :

(i) kilo Watt × hour (kWh) is commercial unit of energy.

1 kWh = 1000 watt × 60 × 60 s.

= 3.6 × 10^6 watt × s

1 kWh = 3.6 × 10^6 J.

(ii) Electron volt (eV) is also the unit of energy. The energy of an electron, when it is accelerated by a potential difference of 1 volt, is known as one eV

$$1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}.$$

DIFFERENCE FORMS OF ENERGY

(i) Heat energy :

When we burn coal, wood or gas, heat energy is released. Steam possess heat energy that is why is a steam engine, the heat energy of steam is used to get the work done. Sun also radiates hat energy.

(ii) Light energy :

It is a form of energy which gives us the sensation of vision. Natural source of light is the sun. An electric bulb also emits light energy.

(iii) Sound energy :

The energy emitted by a vibrating wire, tuning fork, vibrating membrane etc., that can be sensed by human ears is called sound energy.

Eg. whistle, flute, sitar, all emits sound energy when they are made to vibrate.

(iv) Magnetic energy :

A magnet also possess energy known as magnetic energy. When a current is passed through a coil, it stores magnetic energy.

(v) Electrical energy :

An electric cell stores electrical energy. Two changes placed at some distance experience a force. They also possess electrical energy.

Eg. A charged body possess electrical energy.

(vi) Solar energy :

The energy radiated by the sun is solar energy. Sun is the natural source of energy.

(viii) Nuclear energy :

Sometimes, a heavy nucleus breaks into two or more lighter nuclei with the release of some energy. This energy is called nuclear energy and the process is called nuclear fission. On the other hand, when two lighter nuclei combine to form a heavy nucleus, the process is called nuclear fusion.

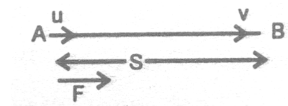
KINETIC ENERGY

Energy of a body due to its motion is known as the kinetic energy of the body. If a body of mass m is moving with velocity v, then its kinetic energy = $\frac{1}{2}$ mv^2.

(a) Dedication of Formula for K.E. :

The kinetic energy of a moving body can be find by calculating the work done in bringing the body in motion from rest.

A body of mass m is moving with initial velocity u. A force F is applied in the direction of motion then after some distance s, its final velocity becomes v.



Work done $W = Fs$ .....(i)

By Newton's second law of motion

$F = ma$

So, $W = mas$ ....(ii)

On applying third equation of motion between points A and B

$v^2 = u^2 + 2as$

$2as = v^2 - u^2$ or $as = \frac{v^2 - u^2}{2}$

On putting the value of as in equation (ii)

$$W = m\left(\frac{v^2 - u^2}{2}\right) = \frac{m}{2}(v^2 - u^2)$$

$$W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2 \quad .....(iii)$$

By the definition, if u = 0, then work done W = Kinetic energy

So from equation (iii)

$$\text{Kinetic energy} = \frac{1}{2}mv^2 - \frac{1}{2}m(o)^2$$

$$\text{or, Kinetic energy} = \frac{1}{2}mv^2$$

3. What is the work to be done to increase the velocity of a car from 30 km/h to 60 km/h. If mass of the car is 1500 kg.

Sol. Mass of car, m = 1500 kg.

Initial velocity, u = 30 km/h = 8.33 m/s.

Final velocity, v = 60 km/h = 16.67 m/s.

Work done, $W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

$W = \frac{1}{2} \times 1500[(16.67)^2 - (8.33)^2]$

$= 750(277.9 - 69.4)$

$W = 750 \times 208.5 = 156375$ J.

$W = 1.56 \times 10^5$ J.

EXERCISE

OBJECTIVE DPP - 14.1

1. Work done upon a body is :

(A) a vector quantity
(B) a scalar quantity
(C) (A) and (B) both are correct
(D) none of these

2. Work done :

(A) is always positive
(B) is always negative
(C) can be positive, negative or zero
(D) none of these

3. No work is done when :

(A) a nail is plugged in a wooden board
(B) a box is pushed along a horizontal floor
(C) there is no component of force parallel to the direction of motion
(D) there is no component of force perpendicular to the direction of motion

4. A body at rest can have :

(A) speed
(B) velocity
(C) momentum
(D) energy

5. Types of mechanical energy are :

(A) kinetic energy only
(B) potential energy only
(C) kinetic energy and potential energy both
(D) neither kinetic energy nor potential energy

6. Work means :

(A) effort
(B) interview
(C) achievement
(D) get-together

7. Work is done on a body when :

(A) force acts on the body but the body is not displaced
(B) force does not act on the body but it is displaced
(C) force acts on the body in a direction perpendicular to the direction of the displacement of the body
(D) force acts on the body and they body is either displaced in the direction of force or opposite to the direction of force.

8. Force F acts on a body such that force F makes an angle θ with the horizontal direction and the body is also displaced through a distance S in the horizontal direction, then the work done by the force is :

(A) FS (B) FS $\cos\theta$ (C) FS $\sin\theta$ (D) Zero

9. In tug of war work done by winning team is :

(A) zero (B) positive (C) negative (D) none of these

10. In tug of war work done by loosing team is :

(A) zero (B) positive (C) negative (D) none of these

11. Work done by the force of gravity, when a body is lifted to height h above the ground is :

(A) zero (B) positive (C) negative (D) none of these

12. When work is done on a body :

(A) it gains energy (B) it looses energy

(C) its energy remains constant (D) none of these

13. Choose correct relation :

(A) 1 J = 10^5 erg (B) 1 J = 10^7 erg (C) 1 J = 10^3 erg (D) none of these

14. The kinetic energy of an object is K. If its velocity is doubled than its kinetic energy will be :

(A) K (B) 2K (C) $\frac{K}{2}$ (D) 4K

15. Two bodies of mass 1 kg and 4 kg possess equal momentum. The ratio of their K.E. :

(A) 4 : 1 (B) 1 : 4 (C) 2 : 1 (D) 1 : 2

16. Which of is not the unit of energy ?

(A) kilocalorie (B) kWh (C) erg (D) watt

17. 1 kg mass has K.E. of 1 J when its speed is :

(A) 0.45 ms^{-1} (B) 1 ms^{-1} (C) 1.4 ms^{-1} (D) 4.4 ms^{-1}

18. When you compress a spring you do work on it. The elastic potential energy of the spring :

(A) increases (B) decreases (C) disappears (D) remains constant

SUBJECTIVE DPP - 14.2

1. Is work a scalar or a vector quantity?
2. What work is done when a mass m is raised vertically against gravity by a vertical upward distance h ?
3. What is work done by a body moving along a circular path ? Explain.
4. A work of 4900 J is done on a load of mass 50 kg to lift it to a certain height. Calculate the height through which the load is lifted ?
5. How many ergs are equivalent to 1 J ?
6. Is potential energy scalar or vector quantity ?
7. What happens to the kinetic energy of an object if its velocity is bobbled ? Explain.
8. Give three examples when work done is zero.
9. Answer the following :

   (i) What are different types of energy ?

   (ii) Give the type of mechanical energy.

   (iii) Give some examples of kinetic energy.
10. Define joule. Is it unit of work or energy ? Justify your answer. A freely falling body stops on reaching the ground. What happened to its kinetic energy ?

WORK, ENERGY AND POWER

PL - 15

POTENTIAL ENERGY

When a child lifts a football from the ground and place it on the top of a table, some work is done on the ball. Now, if this football falls down from the top of the table and hits another football lying on the ground, then the football lying on the ground in displaced from its position. This simple activity shows that a falling football is able to do work.

"We know, anything capable of doing work possess energy." Therefore a football placed on the table also possess energy. This energy of the football lying on the top of the table is known as potential energy. Now the question arises from where this potential energy came in the football lying on the top of the table. Infect, the work done by the child to rises it to the top of table from the ground the stored as energy. This stored energy is known as potential energy.

(a) Definition of Potential Energy :

The energy possessed by a body virtue of its positions or shape or configuration is known as potential energy.

(b) Examples :

(i) Water stored in dam has potential energy due to its position.

(ii) A stone lying on the top of all hill or a mountain has potential energy due to its position.

(iii) A stretched or compressed spring has potential energy due to this shape. When spring is stretched or compressed, work is done on it. This work done is stored as potential energy of the stretched or compressed spring.

(iv) A wound spring of a watch has potential energy due to its shape.

(v) A stretched bow and arrow has potential energy due to its shape.

(c) Gravitational and Elastic Potential Energy :

(i) Gravitational potential energy :

The energy possessed by a body by virtue of its position (i.e., height above the surface of the earth) is known as gravitational potential energy.

(ii) Elastic potential energy :

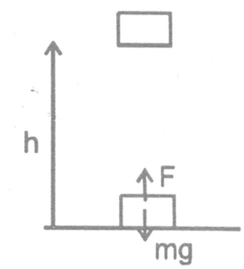
The energy possessed by a body by virtue of its deformed shape (i.e. either stretched or compressed) is known as elastic potential energy.

(d) Expression for Potential Energy of A body at a Certain Height :

The energy possessed by a body due to its position in the gravitational field of the earth is called gravitational potential energy.

Consider a block of mass m which is to be raised to a height 'h'. The force required to lift the block must be equal to the gravitational force (i.e. weight of the block). Thus, F_g = mg. Let the applied force on the block be F = mg and the block is raised to the height h as shown in the figure.

Work done by the applied force F is given by



$$W = \vec{F}.\vec{h} = Fh\cos 0^0 \quad [\therefore \cos 0^0 = 1]$$

or $$W = Fh = mgh$$

Now, work done by the gravitational force on the block,

$$W = \vec{F}_g.\vec{h} = F_g h \cos 180^0 \qquad [\therefore \theta = 180^0 \text{ between } \vec{F}_g \text{ and } \vec{h}]$$

or $$W_g = -F_g h = -mgh \qquad [\therefore F_g = mg]$$

Work done against the gravitational force on the block is known as gravitational potential energy.

U_g= -(mgh) = mgh

❖ **IMPORTANT INFORMATION :**

(i) Gravitational potential energy of a body on the surface of the earth (i.e. h = 0) is zero.

(ii) Gravitational potential energy of a body increases if the body moves upward (i.e. h increases).

(iii) Gravitational potential energy of a body deceases if the body moves downward (i.e. decreases).

(iv) Gravitational potential energy depends only on the initial and final position of the body and not on the path followed by the body to go form initial position to final position. It means, the gravitational potential energy of body at height h will be same if it is either taken straight upward to height h or it is taken along a curved path to height h.

INTERCOVERSION OF POTENTIAL AND KINEIC ENERGY

(i) **For a freely falling body, potential energy changes into kinetic energy.**

Let a body of mass m be at rest at a point at height h from the ground.

At highest point :

Potential energy of the body U_1 = mgh

Kinetic energy of the body K_1 = 0 [$\therefore$ u = 0]

As the body falls freely, it gains velocity and reduces height. Let the body have velocity v when it reaches the ground.

At lowest point :

Potential energy of the body, U_2 0 $[\therefore h = 0]$

Kinetic energy of the body, $K_2 = \frac{1}{2}mv^2$

From third equation of motion, $v^2 = u^2 + 2gh$

We have, $v^2 = 2gh$ $[\because u = 0]$

Hence, final kinetic energy $= \frac{1}{2}mv^2 = \frac{1}{2}m(2gh)$

= mgh = Initial potential energy

(ii) **For an upward projected body, kinetic energy changes into potential energy.**

Let a body of mass m be projected upwards with a velocity u from a point on the ground.

At lowest point :

Kinetic energy of the body, $K_1 = \frac{1}{2}mu^2$

Potential energy of the body, $U_2 = 0$

As the body rises upward, it gains height and loses velocity.

Let the body reach highest point height h where velocity becomes zero.

At highest point :

Kinetic energy of the body, $K_2 = 0$

Potential energy of the body $U_2 = mgh$

From third equation of motion, $v^2 = u^2 + 2gh$

We have $0 = u^2 - 2gh$

($\therefore$ v = 0 and g is negative for upward motion)

or $u^2 = 2gh$

Hence, final P.E. $= mgh = m\frac{u^2}{2}$

$\text{P.E.} = \frac{1}{2}mu^2 = \text{Initial K.E.}$

LOAW OF CONSERVATION OF ENERGY

According to this principle, the total sum of energy of all kinds in an isolated system remains constant at all times. This means that energy can neither be created nor be destroyed. Energy can only be changed from one form to another form of energy. The amount of energy appearing in one form is always equal to the amount of energy disappearing in some other form. The total energy thus remains constant, always provided, at all point, we measure the amount of energy present in each from (including mass which too is a form of energy).

(a) Law of Conservation of Mechanical Energy :

If conservation forces are acting on a body or on a system, then the sum of kinetic energy and potential energy (mechanical energy) of the body or of the system will be conserved. If the presence of conservative forces, if the kinetic energy is increased by an amount of ΔK, then the potential energy of the body will decrease by the same amount i.e. ΔU.

So, $\Delta K = -\Delta U$ $\therefore$ $\Delta K = K_2 - K_1$ and $\Delta U = U_2 - U_1$

So, $K_2 - K_1 = -(U_2 - U_1)$

$K_2 - K_1 = -U_2 + U_1$

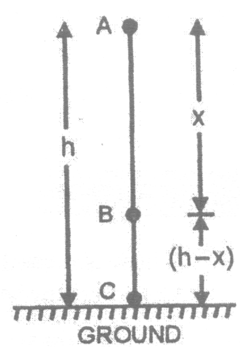
$K_2 + U_2 = K_1 + U_1$

Final mechanical energy = Initial mechanical energy.

So in the presence of conservative forces the sum of Kinetic energy and the potential energy of a body will be conserved.

(b) Mechanical Energy of a Freely Falling Body:

Let a body of mass m is at rest at a height h from the earth's surface, when it starts falling, after a distance x (point B) its velocity becomes v and at earth's surface its velocity is v'/



At point A :

E_A= Kinetic energy + Potential energy

$E_A = m(o)^2 + mgh$

$E_A = mgh$ .... (i)

At point B :

$E_B = \frac{1}{2}mv^2 + mg(h-x)$ ....(ii)

From third equation of motion at points A and B

$v^2 = u^2 + 2gx$ $\therefore$ u = 0

$v^2 = 2gx$

On putting the value of v^2 in equation (ii)

E_B m(2gx) + mgh - mgx

E_B = mgx + mgh - mgx

E_B mgh ..... (iii)

At point C :

$$E_C = \frac{1}{2} m (v')^2 + mg \times o.$$

$$E_C = \frac{1}{2} m(v')^2 \qquad ......(iv)$$

From third equation of motion at points A and C.

$(v')^2 = u^2 + 2gh \qquad \therefore u = 0$

So, $(v')^2 = 2gh$

On putting the value of $(v')^2$ in equation (iv)

$$E_C = \frac{1}{2} m(2gh)$$

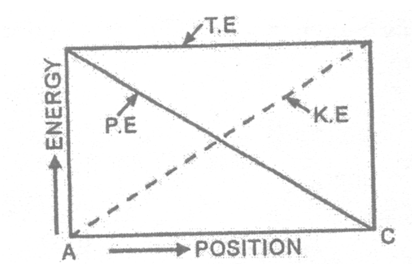
or $E_C = mgh$ ....(v)

From equation (i), (ii) and (v)

$E_A = E_B = E_C$

Hence, the mechanical energy of a freely falling body will be constant.

i.e. Total energy of the body during free fall, remains constant at all positions. The form of energy, however keeps on changing. AT point A, energy is entirely potential energy and at point C, it is entirely kinetic energy In between A and C, energy is partially potential and practically kinetic. This variation of energy is shown in figure. Total mechanical energy stays constant (mgh) throughout. Thus is an isolated system, where only conservation forces cause energy changes, the kinetic energy and potential energy can change, but the mechanical energy of the system (which is sum of kinetic energy and potential energy) cannot change. We can, therefore, equate the sum of kinetic energy and potential energy at one instant to the sum of kinetic energy and potential energy at another instant without considering intermediate state. This law has been found to be valid in every situation. No violation, whatsoever, of this law has ever been observed.



ILLUSTRATION

1. A body of mass 10 kg is kept at a height 10 m from the ground, when it is released after sometime its kinetic energy becomes 450 J. What will be the potential energy of the body at the instant ?

Sol. At a height of 10 m. The mechanical energy of the body,

E = Kinetic energy + potential energy

$E = m(o)^2 + mgh \qquad (\because$ initial velocity of the body is zero)

$E = 10 \times 10 \times 10 = 1000$ J.

After sometime the kinetic energy is 450 J. Suppose at that instant potential energy is U, then by the law of conservation of mechanical energy.

E = 450 + U

1000 = 450 + U

or U = 1000 - 450 $\Rightarrow$ U = 550 J.

EXERCISE

OBJECTIVE DPP - 15.1

1. When a ball is thrown upward, its total energy :

(A) increases (B) decreases (C) remains same (D) none of these

2. If a stone of mass 'm' falls a vertical distance 'd' the decrease in gravitational potential energy is :

(A) $\frac{Mg}{d}$ (B) $\frac{Mg^2}{2}$ (C) mgd (D) $\frac{Mg}{d^2}$

3. An object of mass 10 kg falls from height 10 m. Kinetic energy gained by the body will be approximately equal to :

(A) 1000 J (B) 500 J (C) 100 J (D) None of these

4. A spring is stretched. The potential energy in stretching the spring :

(A) remains the same (B) increases (C) decreases (D) becomes zero

5. The potential energy of a boy is maximum when he is :

(A) standing (B) sleeping on the ground

(C) sitting on the ground (D) sitting on chair

6. The potential energy of a freely falling object decreases continuously. What happens to the loss of potential energy ?

(A) it is continuously converted into sound energy (B) it is continuously converted into kinetic energy

(C) It is continuously destroyed (D) None of these

7. A device which converts mechanical energy into electrical energy is known as :

(A) electric motor (B) lever (C) generator (D) microphone

8. The value of g on moon 1/6th of the value of g on the earth. A man can jump 1.5 m high on the earth. On moon he can jump up to a height of :

(A) 9 m (B) 7.5 m (C) 6 m (D) 4.5 m

9. A raised hummer possess :

(A) kinetic energy only (B) gravitational potential energy

(C) electrical energy (D) sound energy

10. An object of mass 1 kg has a P.E. of 1 J relative to the ground when it is at a height of : (g = 9.8 m/s^2)

(A) 0.10 m (B) 10 m (C) 9.8 m (D) 32 m

11. To lift a 5 kg mass to a certain height, amount of energy spent is 245 J. The mass was raised to a height of :

(A) 15 m (B) 10 m (C) 7.5 m (D) 5 m

SUBJECTIVE DPP - 15.2

1. Is potential energy a vector quantity ?

2. Define potential energy.

3. What type of energy change taken place when a ball is thrown up ?

4. What is the unit of potential energy ?

5. What is the difference between "Gravitational potential energy" and "Elastic potential energy" ?

6. Define potential energy and show that potential energy of mass m at height is mgh.

7. Show that the mechanical energy of a freely falling body is conserved.

WORK, ENERGY AND POWER

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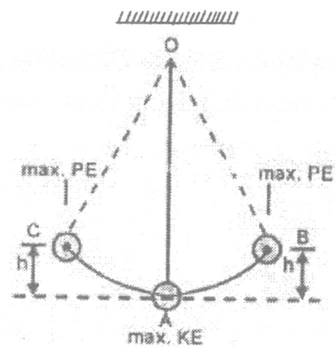
SOME OTHER EXAMPLES OF CONSERVATION OF ENERGY

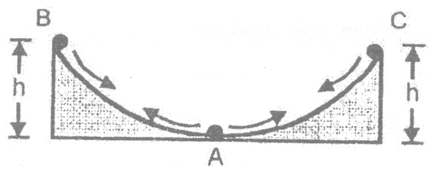
(i) Vibrations of a simple pendulum :

In the figure OA is normal position of rest of a simple pendulum. When the bob of the pendulum is displaced to B, through a height h, it is given potential energy (mgh), where m is the mass of the bob. On releasing the bob at B, it moves towards A. Potential energy has been converted into kinetic energy. The bob, therefore, cannot stop at A. On account of inertia, it overshoots the position A and reaches C at the same height h above A. The entire kinetic energy of the bob at A is converted into potential energy at C. The whole process is repeated and the pendulum vibrates about the equilibrium position A. At extreme positions B and C, the bob is momentarily at rest. Therefore its kinetic energy is zero. The entire energy at B and C is potential energy. At A, there is no height and hence no potential energy. The entire energy at A is kinetic energy.



(ii) **Motion of a small spherical ball over a watch glass :**

Figure shows a watch glass of a large concave mirror embedded in clay. Consider a tiny spherical ball placed at the edge B at a height h above the centre A. if m is mass of the ball, potential energy of the ball held at B is mgh.



When the ball is released from point B, it starts rolling down the mirror. Potential energy of the ball is being converted into kinetic energy. At the bottom A, velocity of the ball is maximum as the entire potential energy has been converted into kinetic energy. The ball cannot stop at A on account of inertia. It goes over to the other edge C. The velocity of the ball goes on decreasing and so does its kinetic energy. AT point C kinetic energy is zero and potential energy is maximum. The entire process is repeated at thus the ball keeps on rolling over the mirror about A.

❖ **NOTE :**

In all the above examples, we have neglected the loss of energy due to air resistance/friction etc. If we were to take into account these opposing forces, kinetic energy would go on decreasing as it appears in the form of heat energy. But total energy (including the heat energy) would remain constant.

POWER

Introduction:

We have learnt that when a force causes displacement, work is done. Work done is measured as the product of the magnitude of the force and the displacement in its direction.

A certain amount of work done appears to be tiring if done quickly and in a very short time. Same amount of work is done slowly in a larger interval of time gives no feeling of tiredness.

This fact has given rise to a new concept i.e. the rate at which work is done ant it defines power.

Definition :

Rate of doing work i.e. work done per unit time (second) by a man or machine, is called power of the man or the machine. it is represented by the symbol P. It is a scalar quantity.

(a) Expression for Power :

Let a force F displaces a body by distance S in its own direction in time t, to give it a velocity, $v = \frac{S}{t}$

Then, by definition -

$$\text{Power} = \frac{\text{Work}}{\text{Time}}$$

Hence, $P = \frac{W}{t} = \frac{F \times S}{t}$ or $P = F \times v$

i.e. **Power = Force × Velocity**

Unit

S.I. unit of power is watt (W).

One watt is the power of a man or a machine capable of doing work at the rate of one joule per second

i.e. $1\,\text{Watt} = \frac{1\,\text{Joule}}{1\,\text{sec ond}}$ or $W = J\,s^{-1}$

Since watt is a smaller unit, higher units used are

1 Kilowatt (kW) = 10^0 watt

1 Megawatt (MW) = 10^6 watt

1 Gigawatt (GW) = 10^9 W

commercial unit of power is horse power

1 horse power (1 H.P) = 746 watt (W)

(b) Distinction with Energy :

Energy measures total work done.

Power measures work done per unit time (second).

Eg : An old man works slowly for eight hours and manufactures 24 items in a day. His younger son works quickly for two hours and manufactures 16 items in a day.

The old man has more energy but less power.

The young mas has less energy but more power.

ILLUSTRAION

1. A boy of mass 50 kg runs up a staircase of 45 steps in 9 s. If the height of each step is 15 cm. Find his power. ($g = 10\ m/s^2$)

Sol. Mass of man, m = 50 kg.

Height covered, h = 45 × 15 = 675 cm = 6.75 m

Power $P = \frac{W}{t} = \frac{mgh}{t} = \frac{50 \times 10 \times 6.75}{9}$

P = 375 watt.

ENERGY FROM THE SUN

The sun is the ultimate source of all forms of energy available on the earth. This can illustrated as follows :

(a) Wind Energy :

Solar energy heats up the surface of the earth and the air near it. The hot air rises up and the cool air from above rushes to occupy its space. This makes the air to move. Moving air is known as wind and possesses kinetic energy. Thus, solar energy + air $\rightarrow$ wind energy. Wind energy is converted into electrical energy in a wind farm using wind mills.

(b) Green Plants make their food :

Green leaves of plants make their food using sunlight (i.e. sun energy) by the process of photosynthesis. The cells of green leaves of plants contain chloroplasts. Each chloroplast contains chlorophyll (a green pigment) which converts carbon dioxide into sugar in the presence of sunlight by the process of photosynthesis. Process of photosynthesis is represented as follows :

$$\text{Carbon dioxide + water} \xrightarrow[\text{sunlight}]{\text{chlorophyll}} \text{Sugar} + \text{Oxygen}$$

The energy stored in the food is known as chemical energy. The food eaten by a man or an animal provides him the muscular energy, is used to do work. In other words, muscular energy is converted into mechanical energy. Thus,

Solarenergy + Green leaves $\rightarrow$ Food (chemical energy) $\rightarrow$ Muscular energy $\rightarrow$ Mechanical energy (work)

EXERCISE

OBJECTIVE DPP - 16.1

1. Chlorophyll in the plants convert the light energy into :

(A) heart energy (B) chemical energy

(C) mechanical energy (D) electrical energy

2. Kilowatt is the unit of :

(A) energy (B) power (C) force (D) momentum

3. Work is product of time and :

(A) energy (B) power (C) force (D) distance

4. A young son work quickly for two hours and prepares 16 items in a day. His old father works slowly for either hours and prepare 24 items a day :

(A) son has more power (B) son has more energy

(C) both have equal power (D) both have equal energy

5. One horse power is :

(A) 746 W (B) 550 W (C) 980 W (D) 32 W

6. Power of a moving body is stored in the form of :

(A) work and distance (B) force and distance (C) force and velocity (D) force and time

7. A weight lifter lifts 240 kg from the ground to a height of 2.5 m in 3 second his average power is :

(A) 1960 W (B) 19.6 W (C) 1.96 W (D) 196 W

8. Which of the following is not the unit of power ?

(A) J/s (B) Watt (C) kJ/h (D) kWh

SUBJECTIVE DPP - 16.2

1. What is S.I. unit of power ?

2. When an arrow is shot from its bow, it has potential energy only, then from where does it get the kinetic energy ?

3. A man whose mass is 50 kg climbs up 30 steps of the stair in 30s. If each step is 20 cm high, calculate the power used in climbing the stairs. (Take $g = 10\ ms^{-2}$)

4. Define power. Give it units.

5. A world record holder lifted 261 kg to a height of 2.3 m in 4 sec. Assuming $g = 10\ ms^{-2}$, find :

(i) weight lifted (ii) work done by the lifter (iii) power developed by the lifter

ANSWER KEY

(Objective DPP # 14.1)

Qus.	1	2	3	4	5	6	7	8	9	10
Ans.	B	C	C	D	C	C	D	B	B	C
Qus.	11	12	13	14	15	16	17	18		
Ans.	C	A	B	D	A	D	C	A		

(Subjective DPP # 14.2)

4. 10 m

(Objective DPP # 15.1)

Qus.	1	2	3	4	5	6	7	8	9	10	11
Ans.	C	C	A	B	A	B	C	A	B	A	D

(Objective DPP # 16.1)

Qus.	1	2	3	4	5	6	7	8
Ans.	B	B	B	A	A	C	A	D

(Subjective DPP # 16.2)

3. 100 W

5. (i) 2610 N (ii) 6003 J (iii) 1501 W

WAVE MOTION AND SOUND

PL - 17

NATUR OF SOUND

Sound is a form of energy which effects our sensation of hearing through the ear. The sensation is produced by longitudinal waves in an elastic medium, where the vibrations (oscillations) of the particles are in the same direction in which the wave propagates.

PRODUCTION OF SOUND WAVES

In laboratory sound is produced by a tuning fork by striking its one prong on a soft rubber pad. Sound can also be produced by plucking a stretched string (violin), by blowing flute, by striking tabla and many other ways.

PROPAGATION OF SOUND

Take a tuning for (a source of standard frequency). It is set into vibrations and its prongs A and B are kept vertical. The prongs move in and out from their means position and have a transverse vibratory motion. When the prongs are in means position, the air in their surrounding has normal density. (It is shown in figure (a) with equidistant lines).

As the right prong moves out onwards right, it pushes the air layers to the right. This produces a compression (It is shown in figure (b) with closer lines).

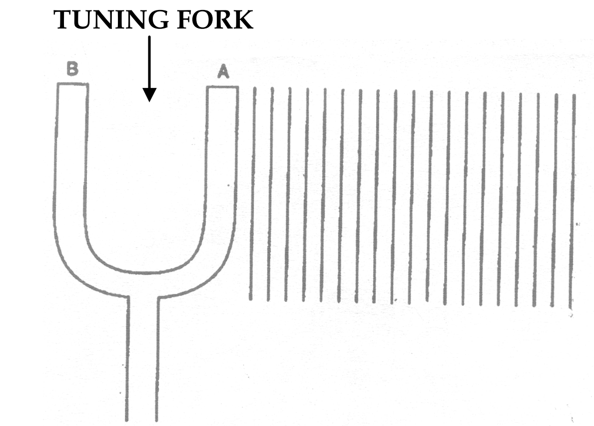
The prong returns inwardly to mean position. The compression moves to the right. The air near the prong again has normal density as shown in figure (c).

As the prong continues moving toward s extreme left, vacating the space, density of air falls in the region and a rarefaction is produced (It is shown in figure (d) with spread lines).

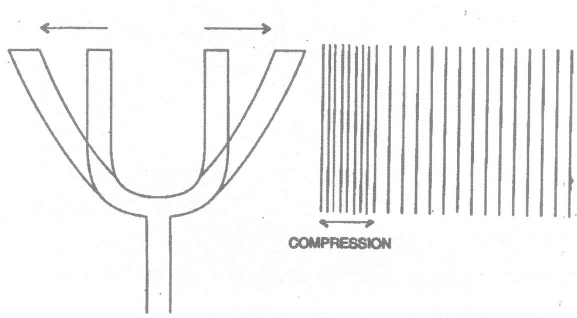
As the prong moves back to right extreme, it competes one vibration. Also the motion of the prong produces a new compression. This completes one wave.

Since on vibration of the prong has generated one wave in the medium (air), in one second and many waves will be generated as the number of vibrations that the tuning fork will make in one second. This number is called frequency of the tuning fork (This number is engraved on the tuning fork near the bend). Hence we conclude that the wave frequency (the number of waves being generated per second) is equal to the frequency of the tuning fork.

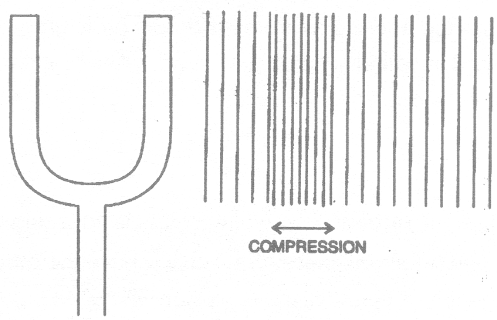
(a)


TUNING FORK
B
A

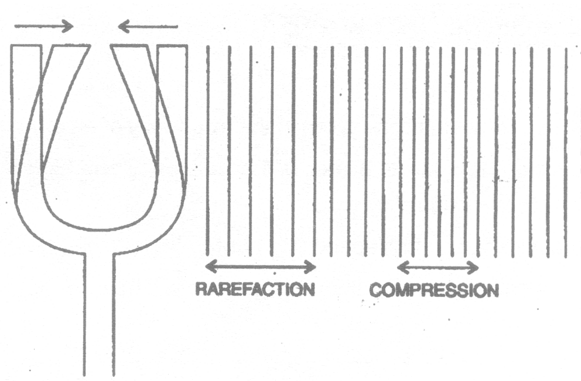
(b)


COMPRESSION

(c)

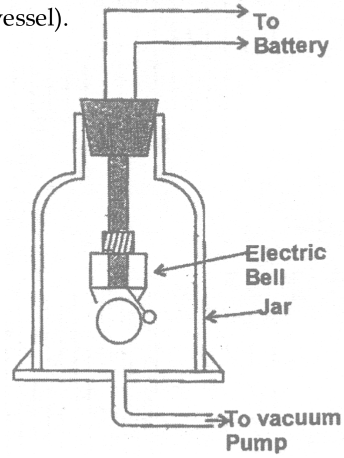

COMPRESSION

(d)


RAREFACTION
COMPRESSION

SOUND NEEDS A MATERIAL MEDIUM FOR ITS PROPAGATION

An electric ell is enclosed inside an inverted bell jar by hanging from the rubber cork. The jar is closed at the bottom by an airtight place with a hole in the centre. A pipe through the hole leads out to a vacuum pump (pump which draw the air out a vessel).



The bell is connected to a battery through a key.

The bell is started by closing the key. Initially when jar has normal air inside it, sound waves produced by the ringing bell heard outside the jar.

The vacuum pump is started and the air form inside the jar is gradually drawn out. With decreases air inside the jar, sound heard becomes weaker and weaker. After sometime no sound is heard, though the bell hammer is seen in vibration.

Conclusion :

In the absence of medium (air) around the source, sound is not being propagated.

A natural fact : Moon has no atmosphere. The space above the atmosphere is also vacuum. If some explosion takes place on moon, sound of the explosion will not be propagated to the earth. So the sound waves never reach the earth.

CHARACTERISTICS OF SOUND WAVE

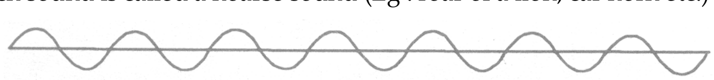
(i) Pitch :

Pitch is the sensation (brain interpretation) of the frequency of an emitted sound.

Faster the vibration of the source, higher is the frequency and higher is the pitch. Similarly low pitch sound corresponds to low frequency.

A high pitch sound is called a shrill sound (Eg : humming of a bee, sound of guitar etc.)

A low pitch sound is called a hoarse sound (Eg : roar of a lion, car horn etc.)

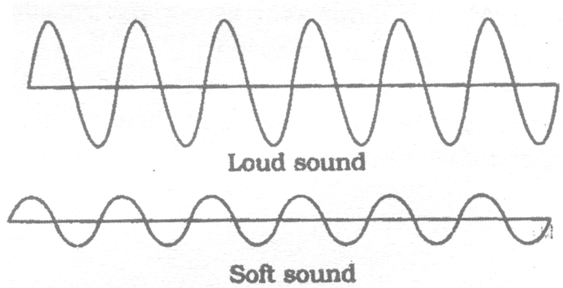


ैतपसस ैवनदक ;ीपही तिमुनमदबल द्ध

भ्वंतेम ैवनदक ;स्वू तिमुनमदबल द्ध

(ii) Loudness or softness :

Loudness or softness of sound wave is the sensations that depends upon is amplitude. When we strike a table to with more force, it vibrates and produces loud sound waves which have more amplitude. When struck with smaller force, vibrating table top produces soft sound waves which have less amplitude. A loud sound wave carries more energy and can be heard at large distance. Reduction in amplitude at large distance, makes the sound soft.



(iii) Timbre or quality :

Quality or timbre is characteristic of a sound which enables us to distinguish between the sound of same loudness and pitch. This characteristic of sound helps up to recognise our friend from his voice without seeing him. The quality of two sounds of same loudness and pitch produced by two different sources are distinguishable because of different wave form produced by them.

Eg. : The violin and flute (Bansuri)

(iv) Intensity :

Intensity of a sound is defined at the sound energy transferred per unit area placed perpendicular to the direction of the propagation of sound.

That is, intensity of sound = $\frac{\text{Sound energy}}{\text{Time}\times\text{Area}}$

Intensity of a sound is an objective physical quantity. It does not depend on the response of our ears.

The S.I. unit of intensity of sound is joule s^{-1} m^{-2} watt m^{-2} $(\therefore\ Js^{-1} = 1W)$

Difference between loudness and intensity of sound :

S.No.	Loudness	Intensity of Sound
1	Loudness is a subjective quantity. If depends upon the sensitivity of the human ear. A sound may be loud for a person but the same sound may be feeble for another who is hard of hearing.	Intensity of sound is an objective physical quantity. It does not depend on the sensitivity of a human ear.
2	Loudness cannot be measured as a physical quantity because it is just sensation which can be felt only.	Intensity of a sound can be measured as a physical quantity.

RANGE OF HEARING

The human ear is able to h ear sound in a frequency range of about 20Hz to 20kHz. We can not hear sounds of frequencies less than 20Hz of more than 20kHz, these limits vary from persons to person and with age. Children can her sounds of somewhat higher frequencies, say upto 30 kHz. With age, our ability to hear high frequency sound diminishes. For the elder, the upper limit often falls to 10-12 kHz. We take 20Hz-20 kHz as the audible range for a average person.

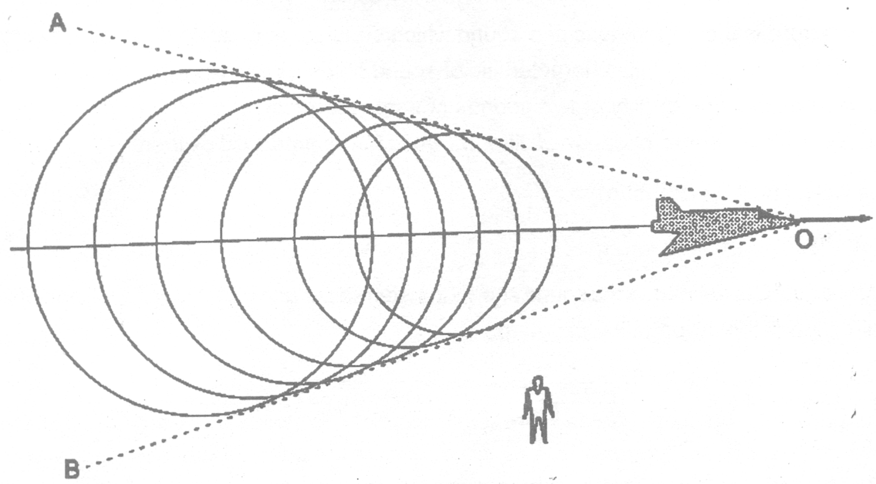
Even in the audible range the human ear is not equally sensitive for all frequency. it is mot sensitive to frequencies around 2000-3000 Hz.

Sound of frequencies less than 20 Hz is known as infrasonic sound or infrasound. Sound of frequency greater than 20 kHz is known as ultrasonic or ultrasound.

Different animals have different ranges of audible frequencies. A dog can hear sound of frequencies upto about 50 kHz and a bat upto about 100 kHz. Dolphins can hear sounds of even higher frequencies. Animals such as elephants and whales can hear sounds of frequencies less than 20 Hz. Some fishes can hear sounds of frequencies as low as 1-25 Hz.

SONIC BOOM

When a body moves with a speed which is greater than the speed of sound in air, it is said to be traveling at supersonic speed. Jet fighters, bullets, etc, often travel at supersonic speed. And when they so son, they produce a sharp, loud sound called a sonic boom.



The source moves at a speed greater then that of sound waves traveling at the speed of sound, are left behind. The high-pressure layers due to sound waves originating at different points bunch together as shown in figure. Actually, these layers fall on the surface of an imaginary cone of which OA, OB is a part. The total pressure on the surface of this cone is very high.

The source is at the apex of this cone. As the source moves ahead, It drags the cone together with it. When the surface of the cone reaches a person, the ears experience a sudden increase in pressure. After the surface crosses him, the pressure is suddenly reduced. This causes the person to hear a sharp, loud sound-the sonic boom.

A region consisting of a very-high-pressure layer followed by a lower-pressure layer travels through the space together with the cone. This is called a shock wave. This shock wave give rise to the sonic boom when it reaches a person.

The shock waves produced by supersonic aircraft have enough energy to shatter glass and even damage weak buildings.

EXERCISE

OBJECTIVE DPP - 17.1

1. A sound wave travels from east to west, in which direction do the particles of air move ?

(A) East - west (B) North - south (C) Up and down (D) None of these

2. In which medium sound travels faster ?

(A) Solid (B) Liquid (C) Gas (D) None of these

3. What is the name of short duration wave ?

(A) Pulse (B) Frequency (C) Time period (D) Velocity

4. What is the velocity of sound in water at room temperature ?

(A) 1500 m/s (B) 330 m/s (C) 1500 km/s (D) 330 km/s

5. The unit of quantity on which pitch of the sound depends is :

(A) Hertz (B) metre (C) metre/second (D) second

6. The unit of quantity on which loudness of found depends is :

(A) metre (B) Hertz (C) metre/second (D) second

7. Nature of sound wave is :

(A) transverse (B) longitudinal (C) electromagnetic (D) seismve

8. Pitch of high frequency sound is :

(A) high (B) low (C) zero (D) infinite

9. Voice of a friend is recognised by its :

(A) pitch (B) quality (C) intensity (D) velocity

10. Sound waves in air are :

(A) Longitudinal waves (B) Radio waves

(C) Transverse waves (D) Electromagnetic waves

11. Sound waves can not pass through :

(A) A solid liquid mixture (B) A liquid gas mixture

(C) An ideal gas (D) A perfect vacuum

12. A periodic wave is characterized by :

(A) Phase only (B) Wavelength only

(C) Frequency only (D) All the above

13. The spend of sound is maximum in :

(A) Air (B) Hydrogen (C) Water (D) Iron

14. When wound waves traveling in air enter into the medium of water, the quantity which remains unchanged is :

(A) Wavelength (B) Velocity (C) Frequency (D) None

SUBJECTIVE DPP - 17.2

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1. In what form of waves, sound travel in air ?

2. Can sound waves travel in vacuum ?

3. Have you every wondered why we hear sound of a hom of an approaching can before the car reaches us ?

4. Distinguish between loudness and intensity of sound ?

5. Which characteristic of sound helps us to identify our friend by his voice while sitting in a dark - room ?

6. What is the loudness of sound ? What factors does it depend upon ?

7. Define the following related to sound waves :

(i) Pitch

(ii) Loudness and softness

(iii) Intensity

(iv) Quality

8. A person has a hearing range from 20 Hz to 20 kHz What are the typical wavelengths of sound waves in air corresponding to these two frequencies ? Take the speed of sound in air as 340 ms^{-1}.

9. The wavelength and frequency of a sound wave in a certain medium are 20 cm and 1650 Hz respectively. Keeping the medium same, if the wavelength is changed to 16 cm, calculate :

(i) the velocity of sound (ii) the new frequency of the sound wave.

WAVE MOTION AND SOUND

PL - 18

REFLECTION FO SOUND

When sound waves strike a surface, hey return back into the same medium. This phenomenon is called reflection.

The reflection of sound waves is similar to that of light rays. The only difference is that sound waves being larger in length. require bigger surfaces for reflection

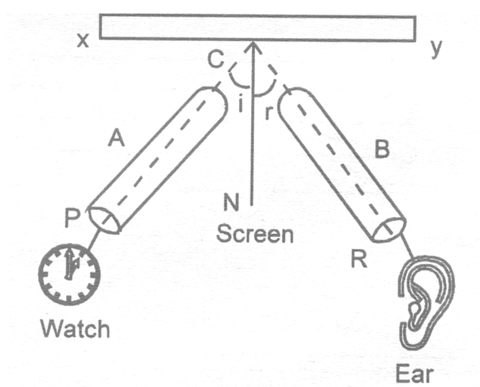
(a) Laws of Reflection :

(i) Angle of incidence is equal to the angle of reflection.

(ii) The incident wave, the reflected wave and the normal, all lie in the same plane.

(b) Verification of Law of Reflection :

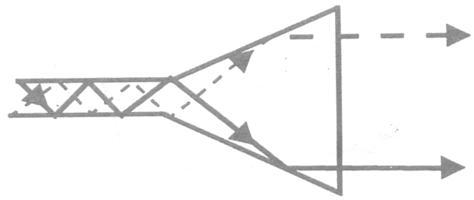
Take a smooth polished large wooden board and mount it vertically on the table. At right angle to the board, fix a wooden screen. One each side of the screen, place a long, narrow and highly polished tube 9inside). Place a clock at the end of he tube A. Move the tube B slightly from left to right, till a distinct tick of clock is heard. Measure the $\angle PCN$ and $\angle RCN$ between tubes and wooden screen. It is found $\angle PCN = \angle RCN$. This experiment illustrates the law of reflection.



(c) Applications of Reflection of Sound :

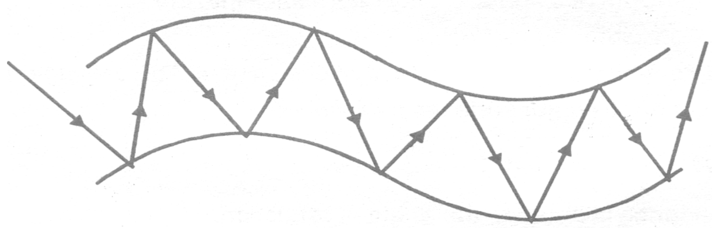
(i) Mega phone or speaking tube :

When we have to call someone at a far off distance (say 100m), we cup our hands and call the persons with maximum sound we can produce. The hands percent the sound energy from spreading in all directions. In the same way, the people use horn shaped metal tubes, commonly called megaphones. The loud speakers have horn shaped openings. In all these devises, the sound energy is prevented from spreading out by successive reflections from the horn shaped tubes.



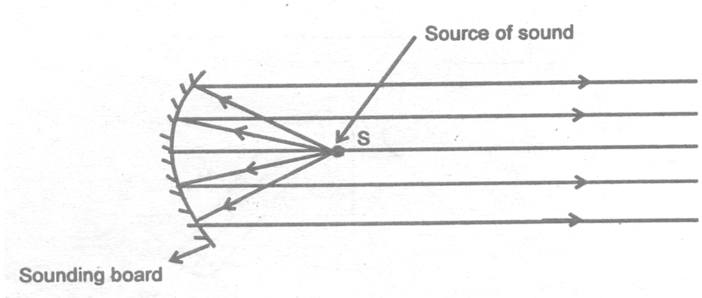
(ii) Stethoscope :

It is an instrument used by the doctors for listening sound produced within the body, empirically in the heart and lungs. In the stethoscope, the sound produced within the body of a patient to picked up by a sensitive diaphragm and then reaches the doctors ears by multiple reflection.



(iii) Sound board :

The sound waves obey the laws of reflection on the place as well as curbed reflecting surfaces. In order to spread sound evenly in big halls or auditoriums, the speaker (S) is fixed at the principle focus of the concave reflector. This concave reflector is commonly called sounding board. The sound waves striking the sound board get reflected parallel to the principal axis.



SPEED OF SOUND IN DIFFERENT MEDIUM

Sound travels with different speed in different media like solid, liquid and gas. This is because, sound travels in a medium due to the transfer of energy from one particle to another particle of the medium.

Solid :

Since the particles of solid are close to each other, so transfer of energy from one particle to another takes place in less time (i.e. faster). Hence speed of sound in solids is large.

Liquid :

Speed of sound in liquids in less than in solids since the particles are away from each other as compared to solids.

Gas :

Speed of sound in gases is less than the speed in liquids and solids as the particles are far always as compare to slides and liquids.

ळें < स्प्नपक < ैवसपक

Speed of sound increases from left to right

EFFECT OF TEMPERATURE ON THE SPEED OF SOUND

Sound travels faster as the temperature of the medium increases and vice-versa. This happens because as temperate increases, the particles of the medium collide more frequently and hence the disturbance spreads faster.

Speed of sound in air increases by 0.61 m/s with every 1^0C increases in temperature. For example if speed of sound in air at 0^0C is 330 m/s, then its speed at 25^0C will be 345 m/s.

Speed of sound does not depend on the pressure of the medium if temperature of the medium remains.

ECHO

The sound heard after reflection from a rigid obstacle is called on echo.

It is of three types :

(a) Instantaneous echo (b) Syllabic echo (c) Successive echo

(a) Instantaneous Echo :

The echo of sound of short duration (like clap, pistol shot) is called instantaneous echo. It is found that sensation of any sound persists for $\frac{1}{10}$ to $\frac{1}{20}$ seconds in our ear, after it, the existing sound dies off. This time is called persistence of sound or persistence of hearing. It varies from persons to person and also with frequency of sound. We will use $\frac{1}{15}$ second as a typical interval needed to distinguish two sounds.

(b) Syllabic Echo :

The echo of syllables of spoken words is called syllabic echo.

This echo is clear when the sound of last syllable of speech is reflected from an obstacle at least 22 m away so that sound takes atleast $\left(\frac{2}{15}\right)$ second during which the last syllable is compactly spoken.

(c) Successive Echo :

This echo is head when sound is produced between two distant parallel rows of tall buildings or hills. A number of echoes are heard successively due to the multiple reflection. This echo is heard only in vast open field.

RELATION BETWEEN SPEED OF SOUND, TIME OF HERING ECHOAND DISTNCE OF REFLECTING BODY

If t is the time at which an echo is heard, d is the distance between the source of sound and the reflecting body and v is the speed of sound. The total distance traveled by the sound is 2d.

Speed of sound, $v = \frac{2d}{t}$

or $d = \frac{vt}{2}$

(a) Calculation of Minimum Distance of Hearing Echo :

d is minimum distance required for hearing an echo when persistence of hearing is $\frac{1}{15}$ second. The velocity of sound (at room temperature) is 340 m/s.

So, $d = \frac{vt}{2} = \frac{340}{2} \times \frac{1}{15} = \frac{22.67}{2}$

11 metre is the minimum distance of hearing echo.

(b) Conditions for Formation of an Echo :

(i) The minimum distance between the source of sound and the reflecting body should be 11 metres.

(ii) The wavelength of the sound should be less than the height of the reflecting body.

(iii) The intensity of sound should e sufficient so that it can be heard after reflection.

REVERBERATION

Persistence of sound after its production is stopped. is called reverberation.

When a sound is produced in a big hall, its wave reflect from the walls and travel back and forth. Due to this, energy does not reduce and the sound persists.

Small amount of reverberation for lesser time helps in adding volume to the programmers. Too much reverberation confuses the programmers and must be reduced.

To reduce reverberation, the rood and walls of the hall are covered with a sound absorbing materials like rough plaster and thick curtains.

AUDIBLE, INFRASONIC AND ULTRSONIC WAVES

(a) Audible Range :

The human ear is sensitive to sound waves of frequency between 20Hz to 20 kHz. This range is known as audible range.

Eg.: By vibrating sitar, guitar, organ pipes, flutes, shehnai etc.

(b) Infrasonic Wave :

A longitudinal elastic wave whose frequency is below the audible range i.e. 20 Hz, is called an infrasonic wave.

it is generally generated by a large source.

Eg. : Earthquake.

(c) Ultrasonic Wave :

A longitudinal wave whose frequency is above the upper limit of audible range i.e. 20 kHz, is called ultrasonic wave. it is generated by very small sources.

Eg. : Quarts crystal.

ULTRASOUND

Sound of very high frequency (greater than 20 kHz) is called ultrasound.

Production :

These are produced by electric oscillator using high frequency vibrations of quarts crystal.

Properties :

Sound wave of all frequencies carry energy with them, with increase in frequency, vibration becomes faster and also energy consents and force increase. When ultrasound travels in solid, liquid and gas it subjects the particles of matter to face large force and energy.

(a) Applications of ultrasound :

(i) Welding metal :

They are used for welding metals like tungsten which cannot be welded by conventional methods. One of the two pieces of the tungsten is held firmly against the other piece and then vibrated with an ultrasonic vibrator. The heat produced due to friction, sat the point of contact, melts the melts. On stopping the vibrator, the melted ends of metals fuse to form a tight weld.

(ii) Medial purposes :

The ultrasonic vibrations can be reflected from the boundaries between the materials of nearly same density. The technique is used in scanning the internal organs of human body. It is superior to the X-ray scanning, as it does not cause any harm to human cells, unlike X-rays.

The instrument which used ultrasonic waves for getting the images of internal organs of human body is called ultrasound scanner. In this technique, the ultrasound waves travel through the tissues of the body and get reflected from the region where there is change in density. These reflected waves are then converted into electrical signals. These signals are then displayed on T.V. monitor or can e printed on a film.

This technique is called ultrasonography and help doctors to deted abnormalities, such as stone in gall bladder and kidney or tumours in different organs.

Ultrasound waves of high intensity are employed to break small stones in the kidney into find grains. The find grains then get flushed out with urine.

(iii) Drilling holes or making cuts of desired shape :

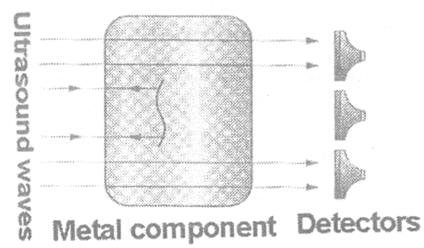
We can use a hammer and a steel punch to make holes in metal plates, plastic sheets or other solid materials. Such holes an also be made using ultrasonic vibrations produced in a metallic rod, called a horn. The horn acts like a hammer, hammering the plate about hundred thousand times per second. The shape of the hole is the same as the of the tip of the hom. The shape of the tip can be designed as per the requirement of the application. ultrasonic cutting and drilling are very effective for fragile material like glass, for which ordinary methods do not give good results.

(iv) Ultrasonic cleaning :

We normally clean dirty clothes, places or other large objects by applying detergent or organic solutions, rubbing and washing. But for small parts such as those used in watches, electronic components, odd-shaped parts such as a spiral tube and parts located in hard-to reach places, this method is inconvenient and sometimes impossible. Such objects are placed in a cleaning solution and ultrasonic waves are sent into the solution. Because of vibrations at high frequencies, all dirt and grease particles get detached from the surface and object gets thoroughly cleaned.

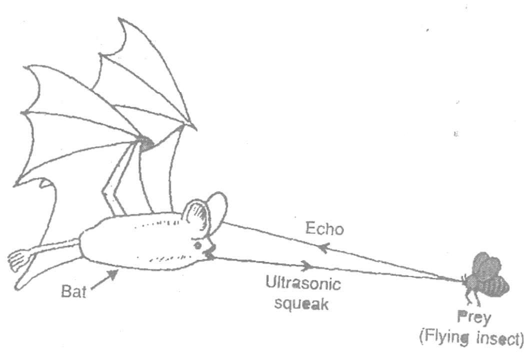
(v) ultrasonic detection of defects in metals :

Metallic components are used in buildings, bridges, machines, scientific equipments and so on. If there are cracks or holes inside the metal used, the strength of the structure or component is reduced and it can fail. Such defects are not visible from the outside. ultrasonic waves can be used to detect such defects.



Ultrasonic waves are sent through the metallic object under study. if there is nor crack or cavity in its path, it goes through the object. A detector placed on the other side detects the transmitted wave. A defect present in the path of the wave reflects the wave. Thus, the intensity of the emerging waves falls in the region that is in line with the defect. When this happens, we know that the object has defect inside. Ordinary sound is not used for this application because ordinary sound will bend considerably round the corners of crakes or cavities and will average of the other side at almost full intensity.

(vi) Bats fly in the darkness of night without colliding with other objects by the method of echolocation. Bats emit high frequency ultrasonic squeaks while flying and listen to he echoes produced by the reflection of their squeaks from the objects in their path. From the time taken by the echo to be heard, bats can judge the distance of the object in their path and hence avoid it by changing the direction. Bats search their prey at night by the method of echolocation.



EXERCISE

OBJECTIVE - DPP - 18.1

1. For the echo of the last syllable of the speech to be heard the least distance of the reflector must be (approximately):

(A) 22 metre (B) 32 metre (C) 110 metre (D) 340 metre

2. During summer, an echo is head :

(A) Sooner than during winter (B) Later than during winter

(C) After same time as in winter (D) Rarely

3. The velocity of sound in air at 30^0C is approximately :

(A) 332 ms^{-1} (B) 350 ms^{-1} (D) 530 ms^{-1} (D) 332 kms^{-1}

4. With the rise of temperature, the velocity of sound :

(A) Decreases (B) Increases

(C) Remains the same (D) Is independent of temperature

5. Infrasonic frequency range is

(A) Below 20 Hz (B) 20 Hz to 20 kHz (C) Above 20 kHz (D) No limit

6. Ultrasonic frequency range is :

(A) Below 20 Hz (B) 20 Hz to 20 kHz (C) Above 20 kHz (D) No limit

7. The speed of sound in air at constant temperature :

(A) Decreases with increases of pressure

(B) Increases with increases of pressure

(C) Remains the same with the increase in pressure

(D) None of these

8. The frequency of sound waves in water is :

(A) Same at that of frequency of source (B) Less than frequency fo source

(C) More than frequency of source (D) None

SUBJECTIVE DPP - 18.2

1. Define reverberation.

2. Define a tone and a note.

3. What is the reflection of sound ? Write the laws of reflection and verify them with the help of experiment.

4. Describe the following with figure :

(i) Sound board (ii) Megaphone (ii) Stethoscope

5. Female voice is more sweet than male voice. Why ?

6. A stone is dropped from the top of a tower 500 m high into a pond of water at the base of the tower. When is the splash heard at the top ? Given, g = 10 m s^{-2} and speed of sound = 340 m s^{-1}.

7. Two children are at opposite ends of an aluminium rod. One strikes the end of the rod with a stone. Find the ratio of times by the sound wave in air and in aluminium to reach the second child.

(Take speed of sound in air at 25^0C = 346 m s^{-1}. Speed of sound in aluminium at 25^0C = 6420 m s^{-1})

WAVE MOTION AND SOUND

PL - 19

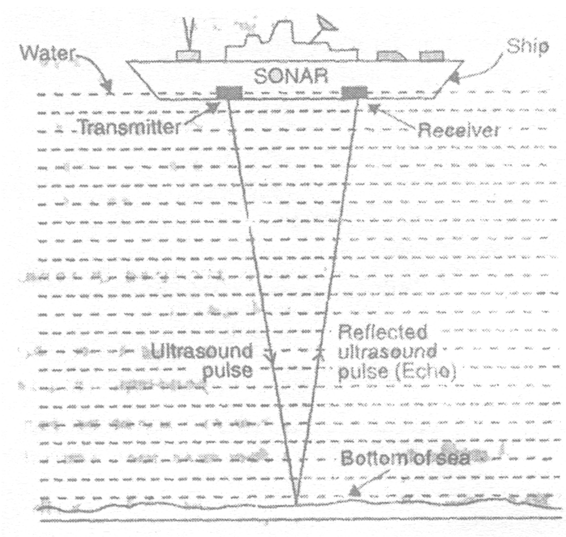
SONAR

The word 'SONAR' stands for 'Sound Navigation and Ranging'/

(a) Principle of Sonar :

Sonar is an apparatus which is used to find the depth of a sea or to locate the under water things like shoals of fish, enemy submarines etc. Sonar works by sending short bursts of ultrasonic sound from a ship down into sea-water and then picking up the echo produced by the reflection of ultrasonic sound from under-water objects like bottom of sea, shoal of fish, a submarine.

(b) Working of Sonar :



A sonar apparatus consists of two parts :

(i) A transmitter (for emitting ultrasonic waves) and (ii) a receiver (for detecting ultrasonic waves). Now suppose a sonar device is attached to the under-side of a ship and we wan to measure the depth of sea (blow the ship). To do this, the transmitter of sonar is made to emit a pulse of ultrasonic sound with a very high frequency of about 50,000 hertz. This pulse of ultrasonic sound travels down in the sea-water towards the bottom of the sea . When the ultrasonic sound pulse strikes the bottom of the sea, it is reflected back to the ship in the from of an echo. This echo produces an electrical signal in the receiver part of the sonar device. The sonar device measures the time taken by the ultrasonic sound pulse to travel from the ship to the bottom of the sea and back to the ship. Half of this time gives the time taken by the ultrasonic sound to travel from the ship to the bottom of the sea.

$$\text{Depth of sea} = \frac{\text{Velocity of cound in sea water} \times \text{time recorded by the recorder}}{2}$$

$$d \frac{v \times t}{2}$$

ILLUSTRATION

1. The ultrasonic waves take 4 seconds to travel from the ship to the bottom of the sea and back to the ship. What is the depth of the sea ? (Speed of sound in water = 1500 m/s.)

Sol. The time taken by the ultrasonic sound waves to travels from the ship to the sea-bed and back to the ship is 4 seconds. So, the time taken by the ultrasonic sound to travel from the ship to sea-bed with be half of this time, which is $\frac{4}{2} = 2$ seconds. This means that the sound takes 2 seconds to travel from the ship to the bottom of the sea.

Now, $\text{Speed} = \frac{\text{Dis tan ce}}{\text{Time}}$

So, $1500 = \frac{\text{Dis tan ce}}{2}$

And, Distance = 1500 × 2 m = 3000 m

REASON FOR USING ULTASONIC WAVES IN SONAR

(i) Ultrasonic waves have a very high frequency due to which they can penetrate deep is sea water without being absorbed.

(ii) Ultrasonic waves cannot be confused with the noises, such as the voice of engines of ship. It is because the ultrasonic waves are not perceived by human ear.

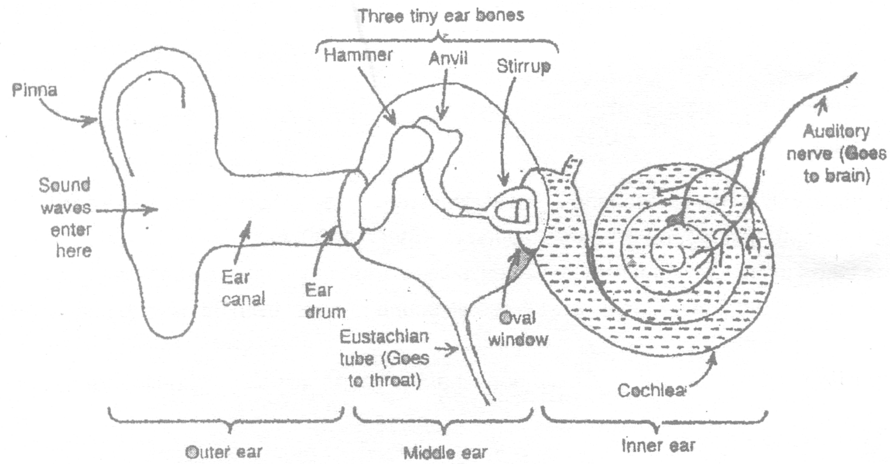
THE HUMAN EAR

The ears the sense organs which help us in hearing sound.

(a) Construction of Human Ear :

The ear consists of three compartments : outer ear, middle ear and inner ear.

The part of ear which we see outside the head is called outer ear. The outer ear consists of broad part called pinna and about 2 to 3 centimeters long passage called ear canal. At the end of ear canal there is a thin, elastic and circular membrane called ear-drum. The ear-drum is also called tympanum. The outer ear contains air. The middle ear contains three small and delicate bones called hammer, anvil and stirrup. These ear-bones are linked to one another. One end of the bone called hammer is touching the ear-drum and its other end is connected to the second bone called anvil. The other end of anvil is connected to the third bone called stirrup and the free and of stirrup is held against the membrane over the oval window of inner ear. The middle ear also contains air. The lower part of middle ear has a narrow tube called 'eustachian tube' going to the throat. Eustachian tube connects the middle ear to throat and ensures that the air pressure inside the middle ear is the same as that on the outside.



The inner ear has a coiled tube cochlea. One side of cochlea is connected to the middle ear through the elastic membrane over the oval window. The cochlea is filled with a liquid. The liquid present in cochlea contains never cells which are sensitive to sound. The other side of cochlea is connected to auditory nerve which goes into the brain.

(b) Working of Human Ear :

The sound waves (coming from a sound producing body) are collected by the pinna of outer ear. These sound waves pass through the ear canal and fall on the ear-drum. Sound waves consist of compressions (high pressure regions) and rarefactions (low pressure regions). When the compression of sound wave strikes the ear-drum, the pressure on the outside of ear-drum increases and pushes the ere-drum inwards and when the rarefaction of sound wave falls on the ear-drum, the pressure on the outside of ear-drum decreases and it moves outward. Thus, when the sound waves fall on the ear-drum, the ear-drum starts vibrating back and forth rapidly.

The vibrating ear-drum causes a small bone hammer to vibrate. From hammer, vibrations are passed on to the second bone anvil and finally to the third bone stirrup. The vibrating stirrup strikes on the membrane of the oval window and passes its vibrations to the liquid in the cochlea. Due to this, the liquid in the cochlea beings to vibrate. The vibrating liquid of cochlea sets up electrical impulses in the nerve cells present in it. These electrical impulses are carried by auditory nerve to the brain. The brain interprets these electrical impulses as sound and w get the sensation of hearing.

EXERCISE

OBJECTIVE DPP - 19.1

1. The equipment (device) used for locating the position and distance of an inside sea, using ultrasound is called :

(A) Pukar (B) Upkar (C) Radar (D) Sonar

2. Human ear can hear :

(A) audible sound (B) infra sound (C) ultra sound (D) all the above

3. A sonar echo takes 4.4s to return from a submarine. If the speed of sound in water is 1500 ms^{-1}, then the distance of submarine from the sonar is - :

(A) 1500 m (B) 3000 m (C) 3300 m (D) 3600 m

4. The eardrum is a :

(A) bone (B) coiled tube (C) stretched membrane (D) fluid

5. The par t of the ear, that is filled with a liquid is the :

(A) cochlea (B) ear canal (C) anril (D) hammer

6. A fishing boat using sonar detects a shoal of fish 190 m below it. How much time elapsed between sending the ultra sonic signal which detected the fish and receiving the signal's echo ? (speed of sound in sea water is 1519 ms^{-1}) :

(A) 0.25 s (B) 0.50 s (C) 0.75 s (D) 1.0 s

SUBJECTIVE DPP - 19.2

1. Guive the reason for using ultra sonic waves in sonar.

2. What is full form of SONAR ?

3. What is the principle of SONAR ?

4. How can you measure the depth of the sea with the help of SONAR ?

5. Draw the well labelled diagram of human ear showing the different parts.

6. Describe the working of human hear.

7. A bat emits ultrasonic sound of frequency 100 kHz in air. If this sound meets a water surface, what is the wavelength of (i) the reflected sound (ii) the transmitted sound ? Speed of sound in air = 340 m s^{-1}, and in water = 1486 m s^{-1}.

8. A sonar device on a submarine sends out a signal and receives an echo 5 s later. Calculate the speed of sound in water if the distance of the object from the submarine is 3625 m.

ANSWER KEY

(Objective DPP # 17.1)

Qus.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Ans.	A	A	A	A	A	A	B	A	B	A	D	D	D	C

(Subjective DPP # 17.2)

8. 17 m, 17 mm. **9.** (a) 330 m/s. **(b)** 2062.5 Hz.

(Objective DPP # 18.1)

Qus.	1	2	3	4	5	6	7	8
Ans.	A	A	B	B	A	C	C	A

(Subjective DPP # 18.2)

6. 11.47 s **7.** 18.55 : 1

(Objective DPP # 19.1)

Qus.	1	2	3	4	5	6
Ans.	D	A	C	C	A	A

(Subjective DPP # 19.2)

7. (i) 3.40×10^{-3} m (ii) 1.349×10^{-2}m **8.** 1450 ms^{-1}.