पु॰ना International School

Shree Swaminarayan Gurukul, Zundal

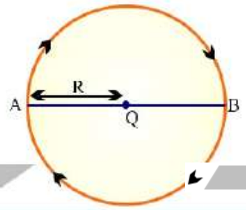
Class – IX

Physics

Year-

2021-22

Index



Chapter 8

Motion

CHAPTER AT A GLANCE

Physical-State
- Rest
- Motion

Motion
- Uniform motion
- Non-uniform motion

Non-uniform Motion
- Accelerated motion
  - Uniformly accelerated motion
  - Non-uniformly accelerated motion
- Decelerated motion
  - Uniformly decelerated motion
  - Non-uniformly decelerated motion

Equations of Motion
- $v = u + at$ → First equation
- $s = ut + \frac{1}{2}at^2$ → Second equation
- $v^2 = u^2 + 2as$ → Third equation

Circular Motion
↓
An-accelerated motion

Contents :

Rest : A body is said to be in a state of rest when its position does not change with respect to a reference point.

Motion : A body is said to be in a state of motion when its position change continuously with reference to a point.

Motion can be of different types depending upon the type of path by which the object is going through.

(i) Circulatory motion/Circular motion – In a circular path.

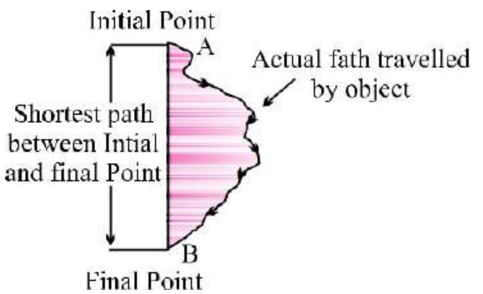
(ii) Linear motion – In a straight line path.

(iii) Oscillatory/Vibratory motion – To and fro path with respect to origin.

Scalar quantity : It is the physical quantity having own magnitude but no direction *e.g.,* distance, speed.

Vector quantity : It is the physical quantity that requires both magnitude and direction *e.g.,* displacement, velocity.

Distance and Displacement :



- The actual path or length travelled by a object during its journey from its initial position to its final position is called the distance.
- Distance is a scalar quantity which requires only magnitude but no

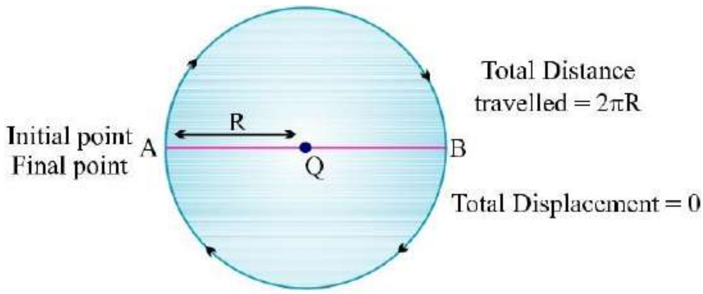
direction to explain it.

Example, Ramesh travelled 65 km. (Distance is measured by odometer in vehicles.)

- Displacement is a vector quantity requiring both magnitude and direction for its explanation.

  Example, Ramesh travelled 65 km south-west from Clock Tower.

- Displacement can be zero (when initial point and final point of motion are same) *Example,* circular motion.



Difference between Distance and Displacement

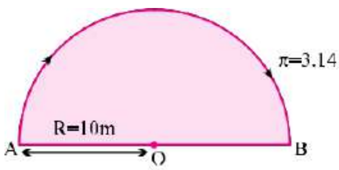
Distance	Displacement
1. Length of actual path travelled by an object.	1. Shortest length between initial point and far point of an object.
2. It is scalar quantity.	2. It is vector quantity.
3. It remains positive, can't be '0' or negative.	3. It can be positive (+ve), negative (-ve) or zero.
4. Distance can be equal to displacement (in linear path).	4. Displacement can be equal to distance or its lesser than distance.

Example 1. *A body travels in a semicircular path of radius 10 m starting its motion from point 'A' to point 'B'. Calculate the distance and displacement.*

Solution : Total distance travelled by body, S = ?

Given, $\pi = 3.14$, $R = 10$ m

$S = \pi R$



$= 3.14 \times 10$ m

$= 31.4$ m **Ans.** Total displacement of

body, D = ?

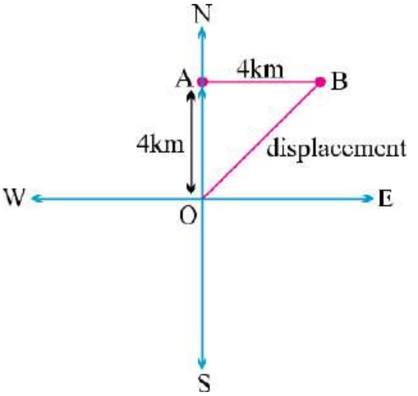
Given, R = 10 m

$D = 2 \times R$

$= 2 \times 10 \text{ m} = 20 \text{ m}$ **Ans.**

Example 2. *A body travels 4 km towards North then he turn to his right and travels another 4 km before coming to rest. Calculate (i) total distance travelled, (ii) total displacement.*

Solution :



Total distance travelled = OA + AB

= 4 km + 4 km

= 8 km **Ans.**

Total displacement = OB

$$OB = \sqrt{OA^2 + OB^2}$$

$$= \sqrt{(4)^2 + (4)^2}$$

$$= \sqrt{16 + 16}$$

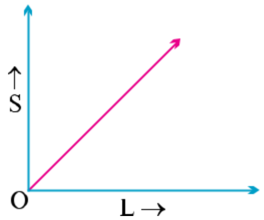
$$= \sqrt{32}$$

= 5.65 km **Ans.**

Uniform and Non-uniform Motions

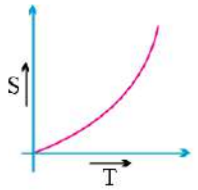
- ***Uniform Motion :***

  When a body travels equal distance in equal interval of time, then the motion is said to be uniform motion.

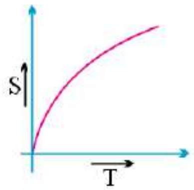


- **Non-uniform Motion :**

  In this type of motion, the body will travel unequal distances in equal intervals of time.



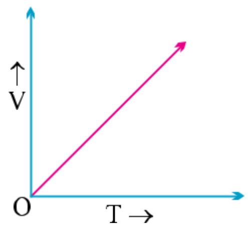
Continuous increase in slope of curve indicates accelerated non-uniform motion.



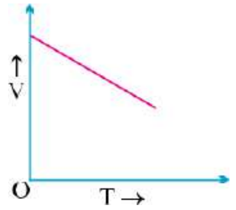
Continuous decrease in slope of curve indicates decelerate non-uniform motion.

Non-uniform motion is of two types :

(i) ***Accelerated Motion :*** When motion of a body increases with time.



(ii) ***De-accelerated Motion :*** When motion of a body decreases with time.



Speed : The measurement of distance travelled by a body per unit time is called speed.

$$\text{Speed} = \frac{\text{Distance travelled}}{\text{Time taken}}$$

$$v = \frac{s}{t}$$

- SI unit = m/s (meter/second)
- If a body is executing uniform motion, then there will be a constant speed or uniform motion.
- If a body is travelling with non-uniform motion, then the speed will not remain uniform but have different values throughout the motion of such body.
- For non-uniform motion, average speed will describe one single value of speed throughout the motion of the body.

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

Example : *What will be the speed of body in m/s and km/hr if it travels 40 kms in 5 hrs ?*

Solution : Distance (s) = 40 km

Time (t) = 5 hrs.

$$\text{Speed (in km / hr)} = \frac{\text{Total distance}}{\text{Total time}}$$

$$= \frac{40 \text{ km}}{5 \text{ hrs}}$$

$$= 8 \text{ km/hr}$$ **Ans.**

Speed (in m/s) = ?

40 km = 40 × 1000 m = 40,000 m

5 hrs = 5 × 60 × 60 sec.

$$= \frac{40 \times 1000 \text{ m}}{5 \times 60 \times 60 \text{ s}}$$

$$= \frac{80 \text{ m}}{36 \text{ s}}$$

$$= 2.22 \text{ m/s}$$ **Ans.**

Conversion Factor

Change from km/hr to m/s $= \frac{1000 \text{ m}}{60 \times 60 \text{ s}}$

$= \frac{5}{18} \text{ m / s}$

Velocity : It is the speed of a body in given direction.

$$\text{Velocity} = \frac{\text{Displacement}}{\text{Time}}$$

- Velocity is a vector quantity. Its value changes when either its magnitude or direction changes.
- For non-uniform motion in a given line, average velocity will be calculated in the same way as done in average speed.

$$\text{Average velocity} = \frac{\text{Total displacement}}{\text{Total time}}$$

- For uniformly changing velocity, the average velocity can be calculated as follows :

$$\text{Avg velocity} = \frac{\text{Initial velocity + Final velocity}}{2}$$

$$V_{(avg)} = \frac{u + v}{2}$$

where, u = initial velocity, v = final velocity SI

unit of velocity = ms^{-1}

$$\text{Velocity} = \frac{\text{Displacement}}{\text{Time}}$$

∴

- It can be positive (+ve), negative (-ve) or zero.

Example 1 : *During first half of a journey by a body it travel with a speed of 40 km/hr and in the next half it travels with a speed of 20 km/hr. Calculate the average speed of the whole journey.*

Solution : Speed during first half (v_1) = 40 km/hr

Speed during second half (v_2) = 20 km/hr

$$\text{Average speed} = \frac{v_1 + v_2}{2}$$

$$= \frac{40+20}{2} = \frac{60}{2}$$

= 30 km/hr

Average speed by an object (body) = 30 km/hr. **Ans.**

Example 2 : *A car travels 20 km in first hour, 40 km in second hour and 30 km in third hour. Calculate the average speed of the train.*

Solution : Speed in Ist hour = 20 km/hr, *Distance travelled during 1st hr = 1×20= 20 km*

Speed in IInd hour = 40 km/hr, *Distance travelled during 2nd hr = 1×40= 40 km*

Speed in IIIrd hour = 30 km/hr, *Distance travelled during 3rd hr = 1×30= 30 km*

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

$$= \frac{20+40+30}{3} = \frac{90}{3} = \frac{20+40+30}{1+1+1}$$

= 30 km/hr **Ans.**

Acceleration : Acceleration is seen in non-uniform motion and it can be defined as the rate of change of velocity with time.

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{Time}}$$

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

where, v = final velocity, u = initial velocity

If $v > u$, then 'a' will be positive (+ve).

Retardation/Deaceleration : Deaceleration is seen in non-uniform motion during decrease in velocity with time. It has same definition as acceleration.

$$\text{Deaceleration} = \frac{\text{Change in velocity}}{\text{Change in time}}$$

$$a' = \frac{v - u}{t}$$

Here $v < u$, 'a' = negative (-ve).

Example 1 : *A car speed increases from 40 km/hr to 60 km/hr in 5 sec. Calculate the acceleration of car.*

Solution : $u = \frac{40\text{ km}}{\text{hr}} = \frac{40\times5}{18} = \frac{100}{9} = 11.11\text{ ms}^{-1}$

$v = \frac{60\text{ km}}{\text{hr}} = \frac{60\times5}{18} = \frac{150}{9} = 16.66\text{ ms}^{-1}$

$a = ?$ $t = 5$ sec.

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

$$= \frac{16.66 - 11.11}{5}$$

$$= \frac{5.55}{5}$$

$= 1.11\text{ ms}^{-2}$ **Ans.**

Example 2. *A car travelling with a speed of 20 km/hr comes into rest in 0.5 hrs. What will be the value of its retardation ?*

Solution : $v = 0$ km/hr

u = 20 km/hr

$t = 0.5$ hrs

Retardation, $a' = ?$

$$a' = \frac{v - u}{t}$$

$$= \frac{0-20}{0.5}$$

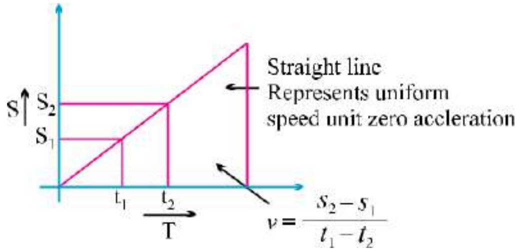
$$= -\frac{200}{5}$$

$= -40\text{ km/hr}^2$ **Ans.**

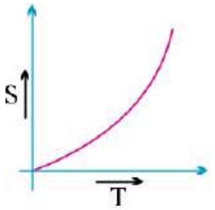
Graphical Representation of Equation

(i) Distance-Time Graph : *s/t* graph :

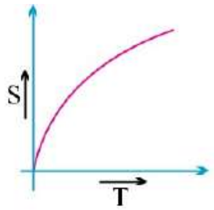
(a) *s/t* graph for uniform motion :



(b) *s/t* graph for non-uniform motion :

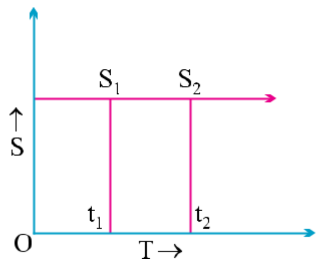


Continuous increase in slope of curve indicates accelerated non-uniform motion.



Continuous decrease in slope of curve indicates decelerate non-uniform motion.

(c) *s/t* graph for a body at rest :



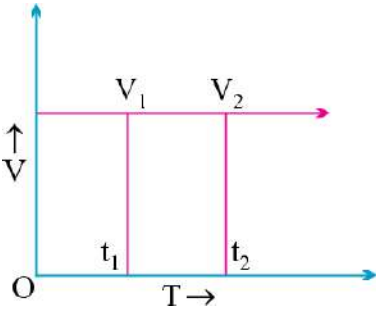
$$v = \frac{s_2 - s_1}{t_2 - t_1}$$

But, $s_2 = s_1$

\ $v = \frac{0}{t_2 - t_1}$ Or $v = 0$

(ii) **Velocity-Time Graph :** *v/t* graph :

(a) ***v/t* graph for uniform motion :**



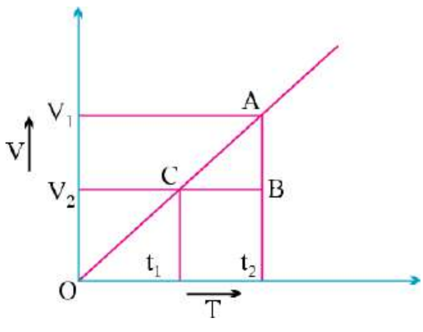
$$a = \frac{v_2 - v_1}{t_2 - t_1}$$

But, $v_2 = v_1$

$$\therefore \quad a = \frac{0}{t_2 - t_1} \quad \text{Or} \quad a = 0$$

(b) ***v/t* graph for non-uniform motion :**

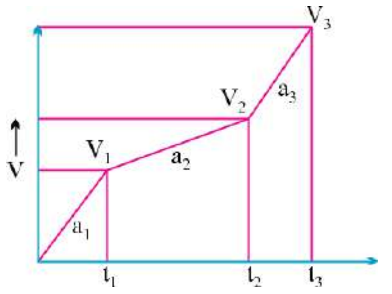
(A) ***v/t* graph for accelerated (uniform) motion :**



$$a = \frac{v_2 - v_1}{t_2 - t_1}$$

In uniformly accelerated motion, there will be equal increase in velocity in equal interval of time throughout the motion of body.

(B) *v/t* graph for accelerated (non-uniform) motion :



Here if, $t_2 - t_1 = t_2 - t_3$

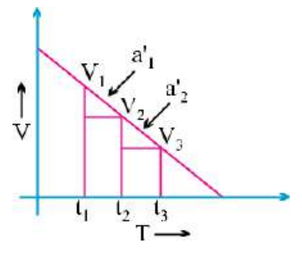
Then, $v_2 - v_1 \neq v_3 - v_2$

$$\frac{v_2 - v_1}{t_2 - t_1} \neq \frac{v_3 - v_2}{t_3 - t_2}$$

Or

Or $a_2 \neq a_1$

(C) *v/t* graph for decelerated (uniform) motion :



Here, $v_2 - v_1 = v_3 - v_2$

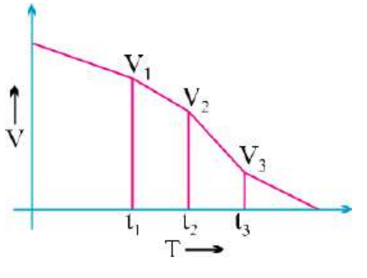
If $t_2 - t_1 = t_3 - t_2$

$$\frac{v_2 - v_1}{t_2 - t_1} = \frac{v_3 - v_2}{t_3 - t_2}$$

Then,

Or $a'_1 = a'_2$

(D) *v/t* graph for decelerated (non-uniform) motion :



Here, $v_2 - v_1 \neq v_3 - v_2$

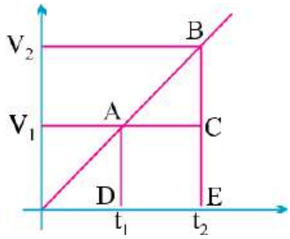
If $t_2 - t_1 = t_3 - t_2$

$$\frac{v_2 - v_1}{t_2 - t_1} \neq \frac{v_3 - v_2}{t_3 - t_2}$$

Then,

Or $a'_1 \neq a'_2$

Note : The area enclosed between any two time intervals is '$t_2 - t_1$' in v/t graph will represent the total displacement by that body.

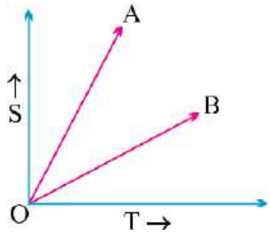


Total distance travelled by body between t_2 and t_1, time intervals

= Area of ΔABC + Area of rectangle ACDB

$= \frac{1}{2} \times (v_2 - v_1) \times (t_2 - t_1) + v_1 \times (t_2 - t_1)$

Example : *From the information given in s/t graph, which of the following body 'A' or 'B' will be more faster ?*



Solution : $V_A > V_B$

Equation of Motion (For Uniformly Accelerated Motion)

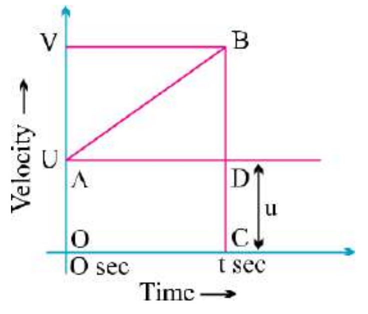
(i) First Equation

$$v = u + at$$

Or Final velocity = Initial velocity + Acceleration × Time

Graphical Derivation :

Suppose a body has initial velocity 'u' (*i.e.,* velocity at time $t = 0$ sec.) at point 'A' and this velocity changes to 'v' at point 'B' in 't' secs. *i.e.,* final velocity will be 'v'.



For such a body there will be an acceleration.

$$a = \frac{\text{Change in velocity}}{\text{Change in time}}$$

$$a = \frac{OB - OA}{OC - 0} = \frac{v - u}{t - 0}$$

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

Or

Or $v = u + at$

(ii) Second Equation

$s = ut + ½at^2$

Distance travelled by object = Area of OABC (trapezium)

= Area of OADC (rectangle) + Area of ΔABD

$= OA \times AD + ½ \times AD \times BD$

$= u \times t + ½ \times t \times (v - u)$

$= ut + ½ \times t \times at$

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

$s = ut + ½at^2$

(iii) Third Equation

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

s = Area of trapezium OABC

$$s = \frac{(OA + BC) \times OC}{2}$$

$$s = \frac{(u+v) \times t}{2}$$

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

$$s = \frac{u+v}{2} \times \frac{v-u}{a}$$

$$s = \frac{v^2 - u^2}{2a}$$

\

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

Example 1. *A car starting from rest moves with uniform acceleration of 0.1 ms^{-2} for 4 mins. Find the speed and distance travelled.*

Solution : $u = 0$ ms^{-1} ∵ car is at rest.

$a = 0.1$ ms^{-2}

$t = 4 \times 60 = 240$ sec.

$v = ?$

From, $v = u + at$

$v = 0 + 0.1 \times 240$

Or $v = 24$ ms^{-1} **Ans.**

Example 2. *The brakes applied to a car produces deceleration of 6 ms^{-2} in opposite direction to the motion. If car requires 2 sec. to stop after application of brakes, calculate distance travelled by the car during this time.*

Solution : Deceleration, $a = -6$ ms^{-2}

Time, $t = 2$ sec.

Distance, $s = ?$

Final velocity, $v = 0$ ms^{-1} ∵ car comes to rest.

Now, $v = u + at$

Or $u = v - at$

Or $u = 0 - (-6) \times 2 = 12$ ms^{-1}

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

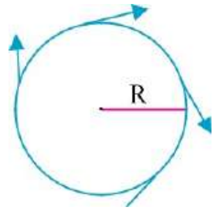
$= 12 \times 2 + \frac{1}{2} \times (-6) \times (2)^2$

$= 24 - 12 = 12$ m **Ans.**

Uniform Circular Motion

If a body is moving in a circular path with uniform speed, then it is said to be executing uniform circular motion.

In such a motion the speed may be same throughout the motion but its velocity (which is tangential) is different at eact and every point of its motion. Thus, uniform circular motion is an accelerated motion.



(Tangential)

QUESTIONS

VERY SHORT ANSWER TYPE QUESTIONS (1 Mark)

1. Change the speed 6 m/s into km/hr.
2. What do speedometer and odometer used for ?
3. What is the other name of negative acceleration ?
4. What does the slope of distance-time graph indicate ?
5. What can you say about the motion of a body if its speed-time graph is a straight line parallel to the time axis ?
6. What does the slope of speed-time graph indicate ?
7. Name the physical quantity which gives an idea of how slow or fast a body is moving ?

SHORT ANSWER TYPE QUESTIONS (2 Marks)

1. A tortoise moves a distance of 100 m in 15 minutes. What is its average speed in km/hr ?
2. If a bus travelling at 20 m/s is subjected to a steady deceleration of 5 m/s^2, how long will it take to come to rest ?
3. What is the difference between uniform linear motion and uniform circular motion ?
4. Explain why the motion of a body which is moving with constant speed in a circular path is said to be accelerated.

LONG ANSWER TYPE QUESTIONS (5 Marks)

1. Derive the equations $v = u + at$, $s = ut + ½at^2$ and $v^2 = u^2 + 2as$ graphically.
2. What is uniform circular motion ? Give two examples which force is responsible for that.

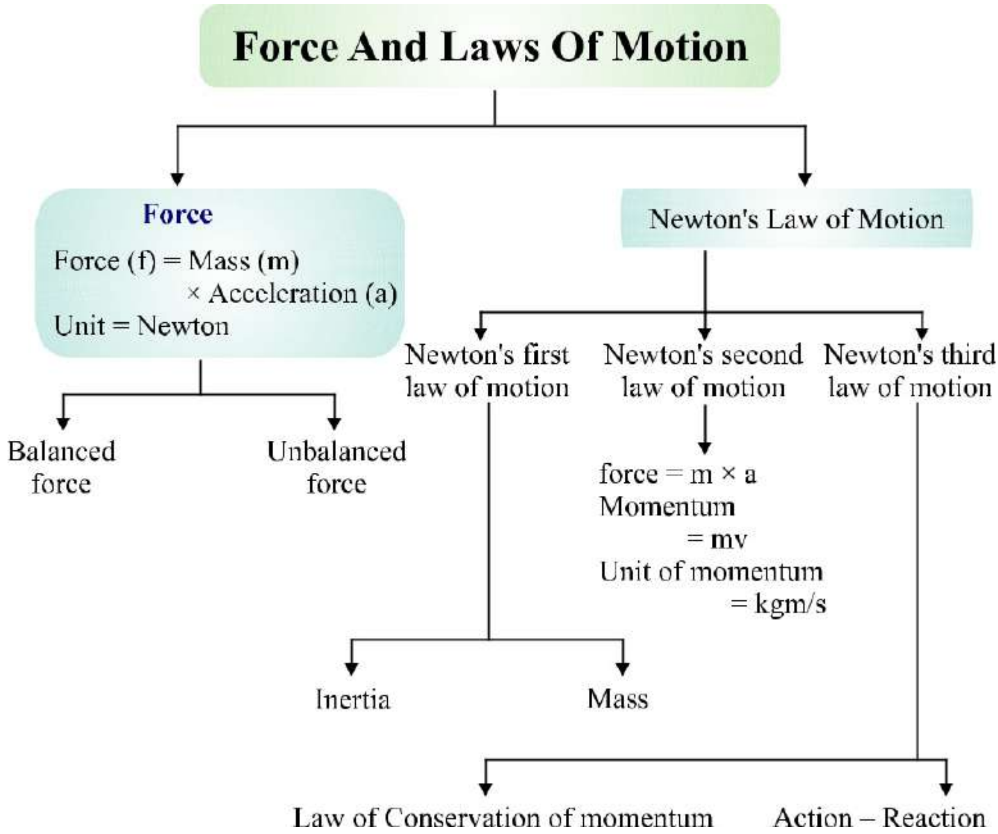
HOTS

1. What can you say about the motion of a body if its displacement-time graph and velocity-time graph both are straight line ?

Chapter 9

Force And Laws Of Motion

CHAPTER AT A GLANCE



Forces and Laws of Motion :

Force : It is the force that enables us to do any work. To do anything, either we pull or push the object. Therefore, pull or push is called force.

Example, to open a door, either we push or pull it. A drawer is pulled to open and pushed to close.

Effect of Force

(i) Force can make a stationary body in object. For example, a football can be set to move by kicking it, *i.e.,* by applying a force.

(ii) Force can stop a moving body. For example, by applying brakes, a running cycle or a running vehicle can be stopped.

(iii) Force can change the direction of a moving object. For example, by applying force, *i.e.,* by moving handle, the direction of a running bicycle can be changed. Similarly by moving steering, the direction of a running vehicle is changed.

(iv) Force can change the speed of a moving body. By accelerating, the speed of a running vehicle can be increased or by applying brakes the speed of a running vehicle can be decreased.

(v) Force can change the shape and size of an object. For example, by hammering, a block of metal can be turned into a thin sheet. By hammering, a stone can be broken into pieces.

Forces are mainly of two types :

(A) Balanced forces

(B) Unbalanced forces

(A) Balanced Forces

- If the resultant of applied forces is equal to zero, it is called balanced forces.

  Example, in the tug of war if both the team apply similar magnitude of forces in opposite directions, rope does not move in either side. This happens because of balanced forces in which resultant of applied forces become zero.

- Balanced forces do not cause any change of state of an object. Balanced forces are equal in magnitude and opposite in direction.

- Balanced forces can change the shape and size of an object. For example, when forces are applied from both sides over a balloon, the size and shape of balloon is changed.

(B) Unbalanced Forces

- If the resultant of applied forces are greater than zero, the forces are called unbalanced forces. An object in rest can be moved because of applying balanced forces.
- Unbalanced forces can do the following :
  - * Move a stationary object
  - * Increase the speed of a moving object
  - * Decrease the speed of a moving object
  - * Stop a moving object
  - * Change the shape and size of an object

Laws of Motion :

Galileo Galilei : Galileo first of all said that object move with a constant speed when no foces act on them. This means if an object is moving on a frictionless path and no other force is acting upon it, the object would be moving forever. That is, there is no unbalanced force working on the object.

- But practically it is not possible for any object. Because to attain the condition of zero, unbalanced force is impossible. Force of friction, force of air and many other forces are always acting upon an object.

Newton's Laws of Motion :

Newton studied the ideas of Galileo and gave the three laws of motion. These laws are known as Newton's laws of motion.

Newton's First Law of Motion (Law of Inertia) :

Any object remains in the state of rest or in uniform motion along a straight line, until it is compelled to change the state by applying external force.

Explanation : If any object is in the state of rest, then it will remain in rest until a external force is applied to change its state. Similarly, an object will remain in motion until any external force is applied over it to change its state. This means all objects resist to in changing their state. The state of any object can be changed by applying external forces only.

Newton's First Law of Motion in Everyday Life :

(a) A person standing in a bus falls backward when bus starts moving suddenly. This happens because the person and bus both are in rest while bus is not moving, but as the bus starts moving, the legs of the person start moving along with bus but rest portion of his body has the tendency to remain in rest. Because of this, the person falls backward; if he is not alert.

(b) A person standing in a moving bus falls forward if driver applies brakes suddenly. This happens because when bus is moving, the person standing in it is also in motion along with bus. But when driver applies brakes the speed of bus decreases suddenly or bus comes in the state of rest suddenly, in this condition the legs of the person which are in contact with the bus come in rest while the rest part of his body have the tendency to remain in motion. Because of this person falls forward if he is not alert.

(c) Before hanging the wet clothes over laundry line, usually many jerks are given to the clothes to get them dried quickly. Because of jerks, droplets of water from the pores of the cloth falls on the ground and reduced amount of water in clothes dries them quickly. This happens because when suddenly clothes are made in motion by giving jerks, the water droplets in it have the tendency to remain in rest and they are separated from clothes and fall on the ground.

(d) When the pile of coin on the carom-board is hit by a striker, coin only at the bottom moves away leaving rest of the pile of coin at same place. This happens because when the pile is struck with a striker, the coin at the bottom comes in motion while rest of the coin in the pile has the tendency to remain in the rest and they vertically falls the carom-board and remain at same place.

Mass and Inertia

- The property of an object because of which it resists to get disturb its state is called inertia. Inertia of an object is measured by its mass. Inertia is directly proportional to the mass. This means inertia increases with increase in mass and decreases with decrease in mass. A heavy object will have more inertia than the lighter one.
- In other words, the natural tendency of an object that resists the change in state of motion or rest of the object is called inertia.

- Since a heavy object has more inertia, thus it is difficult to push or pull a heavy box over the ground than the lighter one.

Momentum

- Momentum is the power of motion of an object.
- The product of velocity and mass is called the momentum. Momentum is denoted by ‘p’.

  Therefore, Momentum of the object = Mass × Velocity

  Or, $p = m \times v$

Where, p = momentum, m = mass of the object and v = velocity of the object.

Consider the following explanations to understand the momentum :

- A person get injured in the case of hitting by a moving object, such as stone, pebbles or anything because of momentum of the object.
- Even a small bullet is able to kill a person when it is fired from a gun because of its momentum due to great velocity.
- A person get injured severely when hit by a moving vehicle because of momentum of vehicle due to mass and velocity.

Momentum and Mass and Velocity

- Since momentum is the product of mass and velocity ($p = m \times v$) of an object. This means momentum is directly proportional to mass and velocity. Momentum increases with increase of either mass or velocity of an object.
- This means if a lighter and a heavier object is moving with same velocity, then heavier object will have more momentum than the lighter one.
- If a small object is moving with great velocity, it has tremendous momentum. And because of momentum, it can harm an object more severely. For example, a small bullet having a little mass even kills a person when it is fired from a gun.
- Usually, road accidents prove more fatal because of high speed than in slower speed. This happens because vehicles running with high speed have greater momentum compared to a vehicle running with slower speed.

Momentum of an object which is in the state of rest :

Let an object with mass ‘m’ is in the rest.

Since, object is in rest, therefore, its velocity, $v = 0$

Now, we know that

$$\text{Momentum} = \text{mass} \times \text{velocity}$$

Or $p = m \times 0 = 0$

Thus, the momentum of an object in the rest *i.e.,* non-moving, is equal to zero.

Unit of momentum :

SI unit of mass = kg

SI unit of velocity = meter per second *i.e.,* m/s

We know that Momentum (p) = $m \times v$

Therefore, p = kg × m/s

Or p = kg m/s

Therefore, SI unit of momentum = kg m/s

Numerical Problems Based on Momentum

Type I. Calculation of Momentum

Example 1. *What will be the momentum of a stone having mass of 10 kg when it is thrown with a velocity of 2 m/s ?*

Solution : Mass (m) = 10 kg

Velocity (v) = 2 m/s

Momentum (p) = ?

We know that, Momentum (p) = Mass (m) × Velocity (v)

Therefore, p = 10 kg × 2 m/s = 20 kg m/s

Thus, the momentum of the stone = 20 kg m/s. **Ans.**

Example 2. *Calculate the momentum of a bullet of 25 g when it is fired from a gun with a velocity of 100 m/s.*

Solution : Given, Velocity of the bullet (v) = 100 m/s

Mass of the bullet (m) = 25 g = 25/1000 kg = 0.025 kg

Momentum (p) = ?

Since, $p = m \times v$

So, $p = 0.025 \times 100 = 2.5$ kg m/s

Thus, momentum of the bullet = 2.5 kg m/s. **Ans.**

Example 3. *Calculate the momentum of a bullet having mass of 25 g is thrown using hand with a velocity of 0.1 m/s.*

Solution : Given, Velocity of the bullet (v) = 0.1 m/s

Mass of the bullet (m) = 25 g = 25/1000 kg = 0.025 kg

Momentum (p) = ?

We know that, Momentum (p) = Mass (m) × Velocity (v)

Therefore, $p = 0.025$ kg × 0.1 m/s

Or $p = 0.0025$ kg m/s

Thus, the momentum of the bullet = 0.0025 kg m/s. **Ans.**

Example 4. *The mass of a goods lorry is 4000 kg and the mass of goods loaded on it is 20000 kg. If the lorry is moving with a velocity of 2 m/s, what will be its momentum ?*

Solution : Given, Velocity (v) = 2 m/s

Mass of lorry = 4000 kg, Mass of goods on the lorry = 20000 kg

Therefore, Total mass (m) on the lorry = 4000 kg + 20000 kg = 24000 kg

Momentum (p) = ?

We know that, Momentum (p) = Mass (m) × Velocity (v)

Therefore, $p = 24000$ kg × 2 m/s

Or $p = 48000$ kg m/s

Thus, the momentum of the lorry = 48000 kg m/s. **Ans.**

Example 5. *A car having mass of 1000 kg is moving with a velocity of 0.5 m/s. What will be its momentum ?*

Solution : Given, Velocity of the car (v) = 0.5 m/s

Mass of the car (m) = 1000 kg

Momentum (p) = ?

We know that, Momentum (p) = Mass (m) × Velocity (v)

Therefore, p = 1000 kg × 0.5 m/s = 500 kg m/s

Thus, momentum of the car = 500 kg m/s. **Ans.**

Statement of Second Law

Rate of change of momentum of an object is proportional to applied unbalanced force in the direction of force.

Mathematical expression

Suppose, Mass of an object = m kg

Initial velocity of an object = u m/s

Final velocity of an object = v m/s

So, Initial momentum, $p_1 = mu$, Final momentum, $p_2 = mv$

∴ Change in momentum = Final momentum – Initial momentum

$= mv - mu$

$= m(v - u)$

∴ Rate of change of momentum $= \frac{\text{Change in momentum}}{\text{Time taken}}$

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

- According to IInd law, this rate of change is momentum is directly proportional to force.

¥ $F \propto \frac{m(v-u)}{t}$

We know that, $\frac{v-u}{t} = a$ (From Ist equation of motion)

So, $F = kma$

Where k is a constant. Its value = 1.

\ $F = 1 \times m \times a = ma$

SI unit = kg m/s^2 or Newton

Q. Define 1 Newton.

Ans. When an acceleration of 1 m/s^2 is seen in a body of mass 1 kg, then the force applied on the body is said to be 1 Newton.

Proof of Newton's First Law of Motion from Second Law

First law states that if external force F = 0, then a moving body keeps moving with the same velocity, or a body at rest continues to be at rest.

So, $F = 0$

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

(a) A body is moving with initial velocity u, then

$$0 = \frac{m(v-u)}{t} \qquad \Rightarrow v - u = 0$$

So, $v = u$

Thus, final velocity is also same.

(b) A body is at rest *i.e.,* $u = 0$.

Therefore, from above $u = v = 0$

So, the body will continue to be at rest.

Third Law of Motion

To every action there is an equal an opposite reaction.

Applications :

(i) Walking is enabled by IIIrd law.

(ii) A boat moves back when we deboard it.

(iii) A gun recoils.

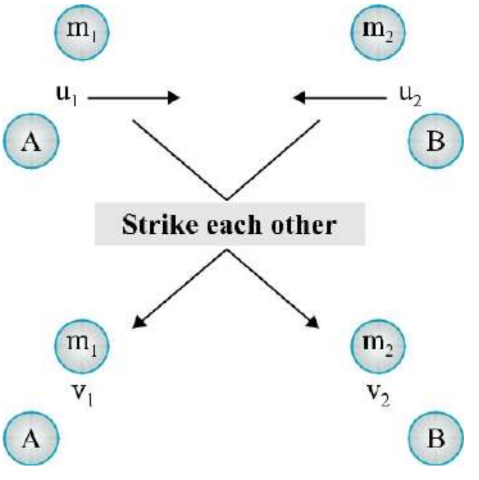
(iv) Rowing of a boat.

Law of Conservation of Momentum

When two (or more) bodies act upon one another, their total momentum remains constant (or conserved) provided no external forces are acting.

Initial momentum = Final momentum

Suppose, two objects A and B each of mass m_1 and mass m_2 are moving initially with velocities u_1 and u_2, strike each other after time t and start moving with velocities v_1 and v_2 respectively.



Now, Initial momentum of object A = m_1u_1

Initial momentum of object B = m_2u_2

Final momentum of object A = m_1v_1

Final momentum of object B = m_2v_2

So, Rate of change of momentum in A, $F_1 = \frac{m_1v_1 - m_1u_1}{t}$

$$= \frac{m_1(v_1 - u_1)}{t} \quad ...(i)$$

And Rate of change of momentum in B, $F_2 = \frac{m_2 v_2 - m_2 u_2}{t}$

$$= \frac{m_2(v_2 - u_2)}{t} \quad ...(ii)$$

We know from IIIrd law of motion,

$$F_1 = -F_2$$

So, $\frac{m_1(v_1 - u_1)}{t} = -\frac{m_2(v_2 - u_2)}{t}$ [From equations (i) & (ii)]

Or $m_1v_1 - m_2v_2 = - m_2v_2 + m_2u_2$

So $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

Thus, Initial momentum = Final momentum

Example 1. *A bullet of mass 20 g is fired horizontally with a velocity of 150 m/s from a pistol of mass 2 kg. Find the recoil velocity of the pistol.*

Solution : Given, Mass (m_1) of bullet = 20 g = 0.02

kg Mass (m_2) of pistol = 2 kg

Initially bullet is inside the gun and it is not moving.

So, Mass $= m_1 + m_2 = (0.02 + 2)$ kg = 2.02 kg

And $u_1 = 0$

So, Initial momentum = 2.02 × 0 = 0 ...(i)

Finally let the velocity of pistol be v_2 and v_1 for bullet = 150

So, Final momentum $= m_1v_1 + m_2v_2$

$= 0.02 \times 150 + 2v_2$ ...(ii)

We know that Initial momentum = Final momentum

So, $0 = \frac{0.02 \times 150}{100} + 2v_2$ [From equations (i) and (ii)]

$\Rightarrow$ $3 + 2v_2 = 0$

Or $2v_2 = -3$

Or $v_2 = -1.5$ m/s **Ans.**

(−)ve sign indicates that gun recoils in direction opposite to that of the bullet.

Example 2. *Two hockey players viz A of mass 50 kg is moving with a velocity of 4 m/s and another one B belonging to opposite team with mass 60 kg is moving with 3 m/s, get entangled while chasing and fall down. Find the velocity with which they fall down and in which direction ?*

Solution : Given, $m_A = 50$ kg, $u_A = 4$ m/s

$m_B = 60$ kg, $u_B = 3$ m/s

Initial momentum$_A$ $= m_A u_A$

$= 50 \times 4 = 200$ kg m/s

Initial momentum$_B$ $= m_B u_B$

$= 60 \times 3 = 180$ kg m/s

So, Total initial momentum $= 200 + 180 = 380$ kg m/s ...(i)

Final momentum $= (m_A + m_B)v = (50 + 60)v$

$= 110v$ ...(ii)

According to the law of conservation of momentum,

$380 = 110v$

Or $v = \frac{380}{110} = 3.454$ m/s **Ans.**

QUESTIONS

VERY SHORT ANSWER TYPE QUESTIONS (1 Mark)

1. Can force be (−)ve ? When ?
2. What is the tendency of a body to resist its change of state called ?
3. Inertia is also measured by................ of an object.
4. Higher the mass of an object, higher is its................ .
5. $\frac{\text{Force}}{\text{Acceleration}}$ is determined by................ which is also mass of the object.
6. Why does the load from the cage above the seats in a bus falls down when suddenly brakes are applied ?

SHORT ANSWER TYPE QUESTIONS (2 Marks)

1. Quantity of motion contained in a body is................ .
2. Unit of momentum is................ .
3. Define 1 Newton.
4. Although we know that a moving body keeps moving indefinitely until an external force is applied on it, then why does a ball stops when we slide it on ground (without stopping it) ?
5. Why is it difficult to stop a truck suddenly than a motorbike ?
6. Why do we jerk forward when a moving bus suddenly stops ?
7. Why do we jerk backwards when a bus suddenly starts moving ?
8. I noticed that when my car takes a right or left turn on a road my body moves in opposite direction. Can you find out why ?

SHORT ANSWER TYPE QUESTIONS (3 Marks)

1. When a metro suddenly stops all the passengers fell forward on its floor. Why do this happen ?
2. We have a huge atmosphere above us that exerts a huge pressure on our shoulders, head and whole body. Why don’t we get crushed under it ?
3. A coin of mass 1 kg and a stone of mass 5 kg are thrown down the Eiffel

Tower with an acceleration of 10 m/s^2. Which one would reach the ground early and why ?

4. Give applications of Ist law of motion i.e., inertia.

5. (a)Friction is measured in.................. .

   (b) Distinguish between balanced and unbalance forces.

LONG ANSWER TYPE QUESTIONS (5 Marks)

1. Cite 5 examples of Newton's third law of motion from our surroundings.

2. Prove the law of conservation of momentum.

3. (a)Derive first law of Newton from second law.

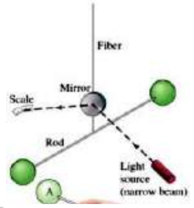
   (b) Find the force required to stop a car of mass 100 kg with two passengers each of 50 kg sitting inside, if it is moving at 60 km/hr speed and takes 5 s to stop.

4. Two balls A and B of masses 40 g and 50 g are moving at speeds of 40 m/s and 30 m/s respectively. If after colliding, B stars moving with a velocity of 25 m/s, what is the velocity of A ?

5. A girl of mass 30 kg jumps on a cart of mass 5 kg with a velocity of 10 m/s. Find the velocity with which she and cart start moving after she jumps on it.

Answers to Long answer type questions

3. (b) - 2000/3 N   4. 46.25 m/s   5. 8.57 m/s



Chapter-10

Gravitation

CHAPTER AT A GLANCE

Gravitation

reaction

Newton's Universal law of gravitation

Force (f) = $\frac{GM_1M_2}{R^2}$

G = Gravitational Constant

M_1 = Mass of object 1

M_2 = Mass of object 2

R = distance between object

W = m × g

Weight = Mass × Gravity

Buoyant force 'f'

Trust → Pressure

P = F/A

P = Pressure

F = Force

A = Area

Acceleration due to gravity (g) = 9.8 m/s^2

$g = \frac{GM}{R^2}$

R = Radius of Earth

M = Mass of Earth

G = Gravitational constant

Value of G = 6.67×10^{-11} Nm^2/kg^2

Gravitational Force of Earth

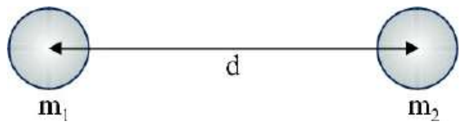
If we release a small stone without pushing it from a height, it accelerates towards earth. The stone is when accelerated towards earth, means some force is acting on it.

The force which pulls the objects towards the centre of the earth is known as gravitational force of the earth.

Here, stone also attracts earth. It means every object in universe attracts every other object.

Newton's Universal Law of Gravitation

Sir Isaac Newton in 1687 proposed a law about the force of attraction between the two objects in the universe which is known as Newton's law of gravitation.



According to this law :

Every mass in this universe attracts every other mass with a force which is directly proportional to the product of two masses and inversely proportional to the square of the distance between them.

Let masses (m_1) and (m_2) of two objects are distance (d) apart, then force of attraction (F) between them

$$F \propto m_1 \times m_2$$

$$F \propto \frac{1}{d^2}$$

$$F \propto \frac{m_1 \times m_2}{d^2}$$

$$F = \frac{G m_1 \times m_2}{d^2}$$

where G is a constant and is known as Gravitational constant.

> Value of G = 6.67×10^{-11} Nm^2/kg^2
> G is called universal gravitational constant.

If unit of F is in Newton, m is in kg, d is in metre, then unit of G can be calculated as :

$$G = \frac{F \times d^2}{m_1 \times m_2}$$ so unit be $\frac{Nm^2}{kg^2}$ or Nm^2/kg^2

Relation between Newton's third law of motion and Newton's law of gravitation

According to Newton's third law of motion, "Every object exerts equal and opposite force on other object but in opposite direction."

According to Newton's law of gravitation, "Every mass in the universe attracts the every other mass."

In case of freely falling stone and earth, stone is attracted towards earth means earth attracts the stone but according to Newton's third law of motion, the stone should also attract the earth and really it is true that stone also attracts the earth with the same force $F = m \times a$ but due to very less mass of the stone, the acceleration (a) in its velocity is 9.8 m/s^2 and acceleration (a) of earth towards stone is 1.65×10^{-24} m/s^2 which is negligible and we cannot feel it.

Importance of universal law of gravitation

(i) The force that binds us to the earth.

(ii) The motion of moon around the earth.

(iii) The motion of earth around the sun.

(iv) The tides due to moon and the sun.

Free fall of an object and acceleration during free fall

When an object is thrown upward, it reaches certain height, then it starts falling down towards earth. It is because the earth's gravitational force exerts on it. This fall under the influence of earth is called 'free fall of an object'.

During this free fall direction do not change but velocity continuously changes which is called acceleration due to gravity.

It is denoted by 'g'.

Its unit is same as acceleration m/s^2.

Gravitational Acceleration and its value at the surface of earth

The uniform acceleration produced in a freely falling object due to the gravitational force of earth, is called acceleration due to gravity. It is represented by 'g' and it always acts towards the centre of the earth.

Value of 'g' on the surface of earth

The force acting on an object is

$$F = \frac{GM_e m}{R^2} \qquad ...(i)$$

Where M_e = Mass of earth

m = Mass of an object

R = Radius of earth

and if acceleration due to gravity is 'g' due to force F then,

$$F = m \times g \qquad \text{...(ii)}$$

Equating (i) and (ii), we get $m \times g = \frac{GM_e m}{R^2}$

Or $g = \frac{GM_e}{R^2}$

If $G = 6.673 \times 10^{-11}$ Nm^2/kg^2, $M_e = 6 \times 10^{24}$ kg, $R^2 = (6.37 \times 10^6)^2$

Then, $g = \frac{6.6734 \times 10^{-11} \times 6 \times 10^{24}}{(6.37 \times 10^6)^2}$

$g = 9.8$ m/s^2

Relationship and difference between 'G' and 'g'

G = Gravitational constant

g = Acceleration due to gravity

$$g = \frac{GM}{R^2}$$

Difference between G (Gravitational constant) and *g* (Acceleration due to gravity)

Gravitation Constant (G)	Gravitational acceleration (*g*)
1. Its value is 6.6734×10^{-11} Nm^2/kg^2.	1. Its value is 9.8 m/s^2.
2. Its value remains constant always and everywhere.	2. Its value varies at various places.
3. Its unit is Nm^2/kg^2.	3. Its unit is m/s^2.
4. It is a scalar quantity.	4. It is a vector quantity.

Example. *If two stones of 150 gm and 500 gm are dropped from a height, which stone will reach the surface of earth first and why ? Explain your answer.*

Ans. It was Galileo, who first time demonstrated and depicted that the acceleration of an object falling freely towards earth does not depend on the mass of the object.

It can be verified by universal law of gravitation. Let an object of mass m, is allowed to fall from a distance of R, from the centre of the earth.

Then, the gravitational force, $F = \frac{GM_e m}{R^2}$ (M_e = Mass of the earth)

The force acting on the stone is $F = m \times a$

So, $m \times a = \frac{GM_e m}{R^2}$

Or $a = \frac{GM_e}{R^2}$

So, acceleration in an object falling freely towards earth depends on the mass of earth and height of the object from the centre of the earth. So stones of mass 150 gm and 500 gm will reach the earth surface together.

Equation of motion when an object is falling freely towards earth or thrown vertically upwards :

Case 1. When an object is falling towards earth with initial velocity (u), then

Velocity (v) after t seconds, $v = u + ght$

Height covered in t seconds, $h = ut + ½gt^2$

Relation between v and u when t is not mentioned :

$$v^2 = u^2 + 2gh$$

Case 2. When object is falling from rest position means initial velocity $u = 0$ (zero), then

Velocity (v) after t seconds, $v = gt$

Height covered in t seconds, $h = ½gt^2$

Relation between v and u when t is not mentioned :

$$v^2 = 2gh$$

Case 3. When an object is thrown vertically upwards with initial velocity u, the gravitational acceleration will be negative ($- g$), then

Velocity (v) after t seconds, $v = u - gt$

Height covered in t seconds, $h = ut - ½gt^2$

Relation between v and u when t is not mentioned :

$$v^2 = u^2 - 2gh$$

Mass

The mass of a body is the quantity of matter contained in it. Mass is a scalar quantity which has only magnitude but no direction.

SI unit of mass is kilogram which is written in short form as kg.

- Mass of a body is constant and does not change from place to place.
- Mass of a body is usually denoted by the small 'm'.
- Mass of a body cannot be zero.

Weight

The force with which an object is attracted towards the centre of the earth, is called the weight of the object.

$$\text{Force} = m \times a$$

In case of earth, $a = g$

So, $F = m \times g$

But the force of attraction of earth on an object is called its weight (W). So,

$$W = m \times g$$

So, weight is the force and its SI unit is Newton (N). It depends on 'g' and is a vector quantity.

Relation between 1 kg wt and express it into Newton :

We know that $W = m \times g$ If mass (m) = 1 kg, g = 9.8 m/s^2, then

$$W = 1 \text{ kg} \times 9.8 \text{ m/s}^2$$

Or 1 kg wt = 9.8N

So, the gravitational force of earth that acts on an object of mass 1 kg is called as 1 kg wt.

Distinguish between Mass and Weight

Mass	Weight
1. We can measure mass of an object by its inertia.	1. Weight = mass × acceleration or $m \times g$.
2. The total quantity of matter contained in an object is called mass of an object.	2. The gravitational force by which earth attracts an object is called weight of the object.
3. Mass of the object remains constant at all the places.	3. Weight of the object is different at different places.
4. Measurement of mass is done by using a pan or beam balance.	4. Measurement of weight is done by using a spring balance.

5. Mass does not change even value of g is zero at any place.	5. Weight of the object becomes zero if g is zero.

Factors affecting value of g

Earth is not a perfect sphere. The radius of earth increases when we go from pole to equator. Therefore, in most of the calculation, we can take g as constant at the surface of earth or closer to it. But, as we move away from earth, we can use equation $g = \frac{GM}{d^2}$ for solving problems.

Example. *Calculate the value of 'g' at a height of 12800 km from the centre of the earth (radius of earth is 6400 km). Draw its interpretation.*

Solution : We know that $g_1 = \frac{GM_e}{(2R_e)^2}$, $R_e = 6400$ km

Weight of the object from the centre of earth = 12800 km = $2R_e$

$$\therefore \quad g_2 = \frac{GM_e}{(2R_e)^2}$$

Or

$$\frac{g_1}{g_2} = \frac{G \cdot M_e}{(R_e)^2} \times \frac{(2R_e)^2}{G \cdot M_e}$$

$$\frac{g_1}{g_2} = \frac{4}{1} \qquad \text{Or } 4g_2 = g_1$$

So, the value of gravitational acceleration 'g' at a distance of 12800 km from the centre of the earth is ¼.

The value of gravitational acceleration 'g' decreases with increasing height.

The weight of an object on moon is one-sixth of the weight on earth.

Let mass of an object be m, its weight on earth means the force by which earth attracts it towards the centre.

$$\frac{GM_e m}{R_e^2}$$

where G = Gravitational constant, M_e = Mass of the earth, m = Mass of object, R_e = Radius of the earth

Weight of an object on moon,

$$F_m = \frac{GM_m m}{R_m^2} \qquad \text{...(ii)}$$

where M_m = Mass of the moon, R_m = Radius of the moon Dividing equation (i) by equation (ii), we get

$$\frac{F_e}{F_m} = \frac{GM_e \cdot m}{R_e^2} \times \frac{R_m^2}{GM_m \cdot m}$$

$$\frac{F_e}{F_m} = \frac{M_e}{M_m} \times \left(\frac{R_m}{R_e}\right)^2$$

We know that mass of earth is 100 times the mass of the moon.

So, $M_e = 100M_m$

And radius of earth is 4 times the radius of moon.

So, $R_e = 4R_m$

Then,

$$\frac{F_e}{F_m} = \frac{100M_m}{M_m} \times \left(\frac{R_m}{4R_m}\right)^2$$

$$\frac{F_e}{F_m} = \frac{100}{1} \times \frac{1}{16}$$

$$\frac{F_e}{F_m} = 6 \text{ times (approx.)}$$

Hence, $F_e = 6F_m$

Thrust and Pressure

Thrust : The force acting on an object perpendicular to the surface is called thrust.

Pressure : The effect of thrust per unit area is called pressure.

$$\text{Pressure (P)} = \frac{\text{Force (F)}}{\text{Area (A)}}$$

SI unit is N/m^2 or Nm^{-2}.

SI unit of pressure is Pascal denoted by 'Pa'.

Factors on which pressure depends

Pressure depends on two factors :

(i) Force applied

(ii) Area of surface over which force acts

Examples :

- The base of high buildings is made wider so that weight of walls act over a large surface area and pressure is less.
- School bags are having broad strap so that the weight of school bags fall over a larger area of the shoulder and produce less pressure and becomes less painful.
- The blades of knives are made sharp so very small surface area and on applying force, it produces large pressure and cuts the object easily.
- All liquids and gases are fluids and they exert pressure in all directions.

Buoyancy

The upward force experienced by an object when it is immersed into a fluid is called force of buoyancy. It acts in upward direction and it depends on the density of the fluid.

- Force of gravitational attraction of the earth on the surface of the object $\leq$ buoyant force exerted by fluid on the surface of the object.

Result : The object floats.

- Force of gravitational attraction of the earth on the surface of the object $>$ buoyant force exerted by fluid on the surface of the object.

Result : The object sinks.

That is why, allpin sinks and boat/ship floats on the surface of water. (Archimedes' principle)

Density

The mass per unit volume is called density of an object. If M is the mass and V is the volume, then density (d) is

$$\text{Density } (d) = \frac{\text{Mass } (M)}{\text{Volume } (V)}$$

SI unit = kg/m^3

Archimedes' Principle

It states, when a body is immersed fully or partially in a fluid, it experiences a upward force that is equal to the weight of the fluid displaced by it.

Applications of Archimedes' Principle :

(i) It is used in determining relative density of substances.

(ii) It is used in designing ships and submarines.

(iii) Hydrometers and lactometers are made on this principle.

It is because of this ship made of iron and steel floats in water whereas a small piece of iron sinks in it.

Relative density

The ratio of the density of a substance to that of the density of water is called relative density.

$$\text{Relative density} = \frac{\text{Density of a substance}}{\text{Density of water}}$$

It has no unit.

Solved Numericals

Example 1. *Relative density of gold is 19.3. The density of water is 10^3 kg/m^3. What is the density of gold in kg/m^3 ?*

Solution : Given, Relative density of gold = 19.3

Density of water = 10^3 kg/m^3

So, Density of gold = Relative density of gold × Density of water

= 19.3×10^3

Hence, density of gold = 19.3×10^3 kg/m^3. **Ans.**

Example 2. *Mass of 0.025 m^3 of aluminium is 67 kg. Calculate the density of aluminium.*

Solution : Given, Mass of aluminium = 67 kg

Volume of aluminium = 0.025 m^3

So, Density $= \frac{M}{V} = \frac{67}{0.025}$

= 2680 kg/m^3 **Ans.**

Example 3. *The mass of brick is 2.5 kg and its dimensions are 20 cm × 10 cm × 5 cm. Find the pressure exerted on the ground when it is placed on the ground with different faces.*

Solution : Given, Mass of the brick = 2.5 kg

Dimensions of the brick = 20 cm × 10 cm × 5 cm

So, Weight of the brick (Thrust/Force)

$= F = mg = 2.5 \times 9.8 = 24.5$ N

(i) When the surface area 10 cm × 5 cm is in contact with the ground,

then Area = 10 × 5 = 50 cm^2

$$= \frac{50}{10000} = 0.005\ m^2$$

So, $P = \frac{F}{A} = \frac{24.5}{0.0050}$

$= 4900\ N/m^2$ **Ans.**

(ii) When the surface area 20 cm × 5 cm is in contact with the ground,

then Area = 20 × 5 = 100 cm^2

$$= \frac{100}{10000} = 0.01\ m^2$$

So, $P = \frac{F}{A} = \frac{24.5}{0.01}$

$= 2450\ N/m^2$ **Ans.**

(iii) When the surface area 20 cm × 10 cm is in contact with the ground,

then Area = 20 × 10 = 200 cm^2

$$= \frac{200}{10000} = 0.02\ m^2$$

So, $P = \frac{F}{A} = \frac{24.5}{0.02}$

$= 1225\ N/m^2$ **Ans.**

Example 4. *A force of 20N acts upon a body whose weight is 9.8N. What is the mass of the body and how much is its acceleration ?*

Solution : Given, Force = 20N, Weight W = 9.8N

We know, W $= mg$

So, 9.8 $= m \times 9.8$

Or $m = 1$ kg **Ans.**

And, $F = ma$

So, $20 = 1 \times a$

Or $a = 20\ m/s^2$ **Ans.**

Example 5. *A man weighs 1200N on the earth. What is his mass (take g = 10 m/s^2) ? If he was taken to the moon, his weight would be 200N. What is his mass on* *moon ? What is his acceleration due to gravity on moon ?*

Solution : Given, Weight of man on earth $W_1 = 1200$ N

Weight of man on moon $W_2 = 200$ N

Gravitational acceleration of earth = 10 m/s^2

Now, $W = mg$

Or $m = W/g$

$= 120$ kg

So, mass on moon will be 120 kg as it is constant everywhere so mass of man on moon =120 kg. **Ans.**

Now, $W_2 = mg_2$

Or $200 = 120 \times g$

Or $g = \frac{200}{120} = \frac{10}{6} = \frac{5}{3}$

$= 1.66$ m/s^2 **Ans.**

Example 6. *An object is thrown vertically upwards and reaches a height of 78.4 m. Calculate the velocity at which the object was thrown ? ($g = 9.8$ m/s^2)*

Solution : Given, $h = 78.4$ m, $v = 0$, $g = 9.8$ m/s^2, $u = ?$

$v^2 = u^2 - 2gh$

Or $0 = u^2 - 2 \times 9.8 \times 78.4$

Or $u^2 = \frac{2 \times 98 \times 784}{10 \times 10}$

Or $u = \sqrt{\frac{2 \times 2 \times 49 \times 784}{10 \times 10}}$

$u = \frac{2 \times 7}{10}\sqrt{784}$

Or $u = 39.2$ m/s^2 **Ans.**

Example 7. *What is the mass of an object whose weight is 49 Newton ?*

Solution : Given, Weight of object W = 49N

$g = 9.8$ m/s^2

Now, $W = mg$

Or $m = \frac{W}{g} = \frac{49}{9.8}$

$= 5$ kg **Ans.**

QUESTIONS

VERY SHORT ANSWER TYPE QUESTIONS (1 Mark)

1. State the universal law of gravitation.
2. Write the formula to find the magnitude of the gravitational force between the earth and an object on the surface of the earth.
3. Is value of G constant at all the places ?
4. What is the weight of an object of mass 1 kg ? **Ans :** 9.8N
5. A body has weight of 10 kg on the surface of earth. What will be its weight when taken to the centre of the earth ? **Ans :** 0
6. What is the value of gravitational acceleration acting on a free falling object ?
7. What is the value of universal constant G and its unit ?
8. Why do pin sinks in water ?
9. Name a factor on which *g* depends.
10. Name the balance used to measure weight of an object.

SHORT ANSWER TYPE QUESTIONS (2 Marks)

1. Mass of an object is 1600 gm on the earth. What is its mass on the moon ? Why ? **Ans :** 1600 gm
2. Two objects placed in a room, are not pulling each other. Why ?
3. Name the force responsible for the motion of moon around the earth. How can some objects move around the earth ?
4. State Archimedes' Principle and explain it with example.
5. State two factors on which buoyant force depends.

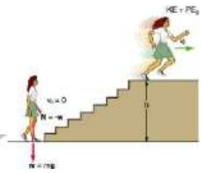
LONG ANSWER TYPE QUESTIONS (5 Marks)

1. Density of aluminium is 2700 kg m^{-3}. What is its relative density ? Denisty of water is 1000 kg m^{-3}. Define relative density. **Ans :** 2.7
2. A ball is released from a height of 1 metre. What time it will take to reach the surface of the earth ? **Ans :** 0.45 s
3. A ball thrown up, vertically returns to the thrower after 6 s. Find :

   (a) the velocity with which it was thrown up. **Ans :** 29.4 m/s

   (b) the maximum height it reaches and **Ans :** 4.9 m

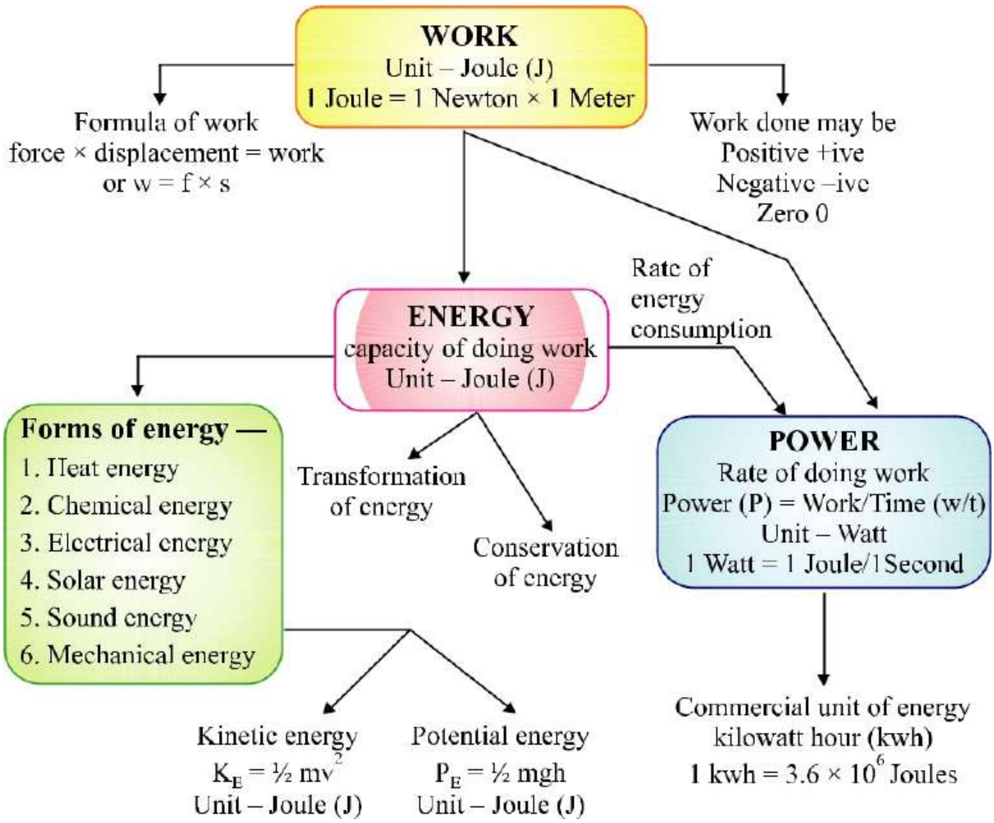
   (c) its position after 4 s. **Ans :** 39.2 m



Chapter 11

Work And Energy

CHAPTER AT A GLANCE



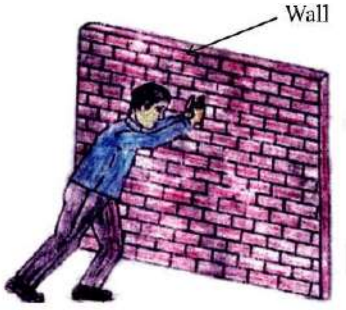
Work

For doing work, energy is required.

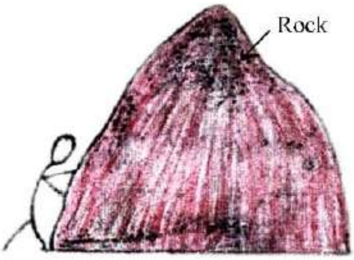
- In animals, energy is supplied by food they eat.
- In machine, energy is supplied by fuel.

Not much work inspite of working hard : Reading, writing, drawing, thinking, analysing are all energy consuming. But in scientific manner, no work is done in above cases.

- *Example :* A man is completely exhausted in trying to push a rock (wall), but work done is zero as wall is stationary.
- A man standing still with heavy suitcase may be tired soon but he does no work in this situation as he is stationary.



When a force is applied on the wall, the wall does not move. So work is not done



When a force is applied on the rock, the rock does not move. So work is not done

Work is said to be done when :

(i) a moving object comes to rest.

(ii) an object at rest starts moving.

(iii) velocity of an object changes.

(iv) shape of an object changes.

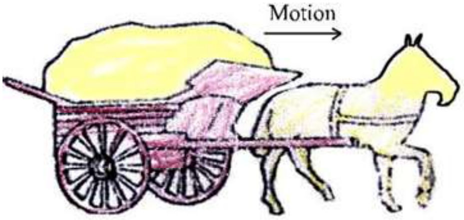
Scientific Conception of Work

- Work is done when a force produces motion in a body.
- Work is said to be done when a force is applied on a body and the body moves under the influence of force.

Condition of Work

(i) Force should be applied on the body.

(ii) Body should be displaced.



Examples : Work is done when :

(i) A cyclist is pedaling the cycle.

(ii) A man is lifting load in upward or downward direction. Work is not done when :

(i) A coolie carrying some load on his head stands stationary.

(ii) A man is applying force on a big rock.

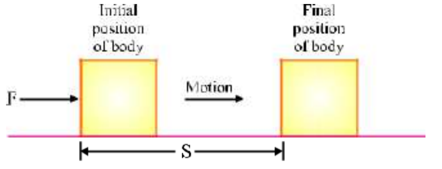
Work Done by a Fixed Force

Work done in moving a body is equal to the product of force and displacement of body in the direction of force.

Work = Force × Displacement

$W = F \times S$

Work is a scalar quantity.



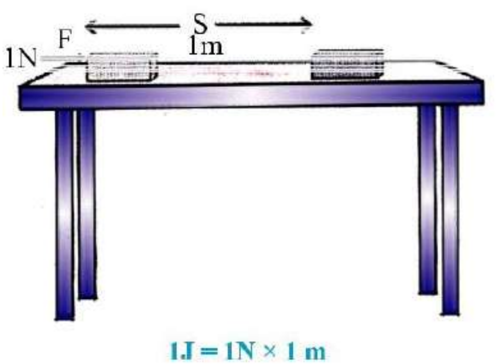
Unit of Work

Unit of work is Newton metre or Joule.

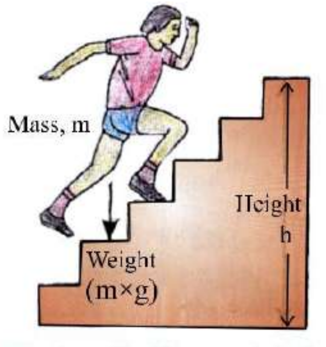
When a force of 1 Newton moves a body through a distance of 1 metre in its own direction, then the work done is 1 Joule.

1 Joule = 1 Newton × 1 metre

1 J = 1 Nm



1J = 1N × 1 m



During climbing work is done against gravity

The amount of work done depends on the following factors :

(i) **Magnitude of force :** Greater the force, greater is the amount of work & vice-versa.

(ii) **Displacement :** Greater the displacement, greater is the amount of work & vice-versa.

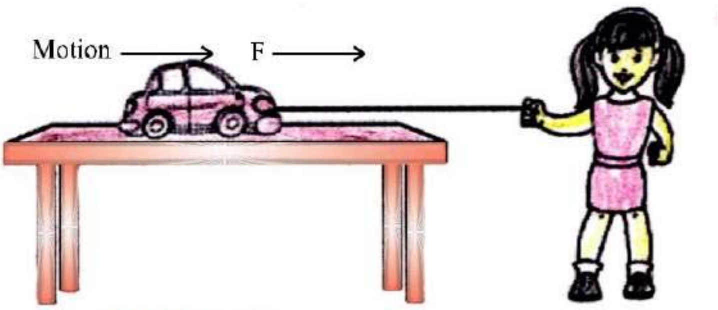
Negative, Positive and Zero Work

Work done by a force can be positive, negative or zero.

(i) Work done is **positive** when a force acts in the direction of motion of the body.[Fig. (a)] ($\theta = 0^o$).

Example : A child pulls a toy car with a string horizontally on the ground. Here work done is positive.

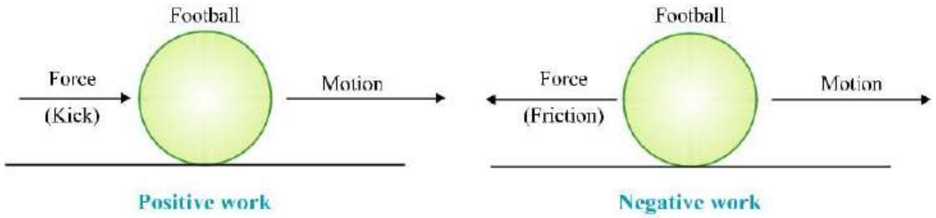
$$W = F \times S$$



Positive work

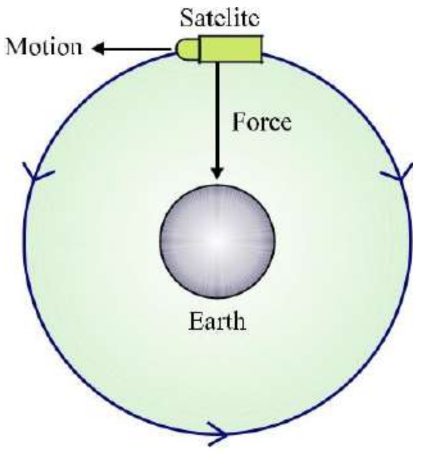
(ii) Work done is **negative** when a force acts opposite to the direction of motion of the body.

Example : When we kick a football lying on the ground, the force of our kick moves the football. Here direction of force applied & motion of football is same so work done is positive. But when football slows due to force of friction acting in a direction opposite to direction of motion of football [Fig. (b)], work done is negative.



(iii) Work done is **zero** when a force acts at right angles to the direction of motion.

Example : The moon moves around the earth in circular path. Here force of gravitation acts on the moon at right angles to the direction of motion of the moon. So work done is zero.



Zero work

- -ve (negative) sign indicates that work is done against gravity.

Note that if work is done against the direction of motion (gravity), then it is taken –ve.

Example. *A coolie 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.*

Solution : Mass of luggage (m) = 15 kg

Displacement (S) = 1.5 m

So, Work done, W = F × S

$= mg \times S$ [$f = mg$]

$= 15 \times 10 \times 1.5$ [$g = 10\ m/s^2$]

[g = force of gravity]

$= 225.0\ kg\ m/s^2$

= 225 Nm = 225 J

Hence, work done = 225 J.

Energy

(i) The sun is the biggest source of energy.

(ii) Most of the energy sources are derived from the sun.

(iii) Some energy is received from nucleus of atoms, interior of the earth and the tides.

Definition : The capacity of doing work is known as energy.

The amount of energy possessed by a body is equal to the amount of work it can do. Working body losses energy, body on which work is done gains energy. Energy is a scalar quantity.

Unit : The SI unit of energy is Joule (J) and its bigger unit is kilo joule

(kJ). 1 kJ = 1000 J

The energy required to do 1 Joule of work is called 1 Joule

energy. **Forms of Energy**

Main forms of energy are :

(i) Kinetic energy
(ii) Potential energy
(iii) Heat energy
(iv) Chemical energy
(v) Electrical energy
(vi) Light energy
(vii) Sound energy
(viii) Nuclear energy

- Sum of kinetic energy & potential energy of a body is called mechanical energy.

Mechanical energy

The energy possessed by a body on account of its motion or position is called mechanical energy.

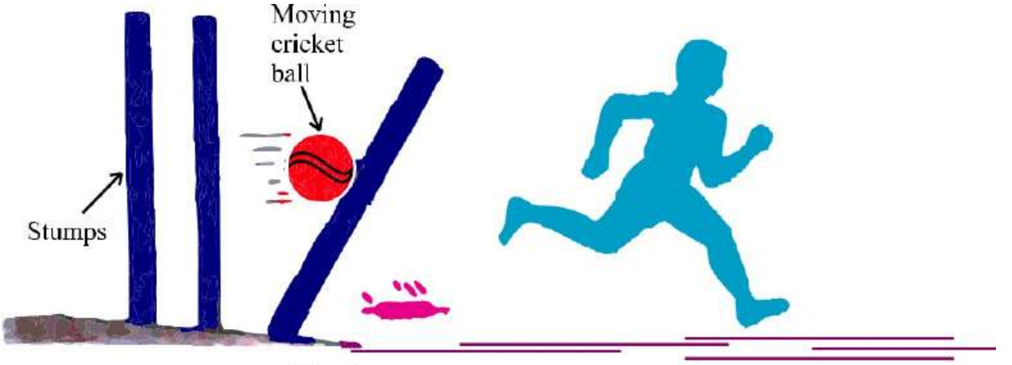
Kinetic Energy

The energy of a body due to its motion is called kinetic energy.

Examples of kinetic energy :

- A moving cricket ball
- Running water
- A moving bullet
- Flowing wind
- A moving car
- A running athelete
- A rolling stone

- Flying aircraft



Kinetic energy

Kinetic energy is directly proportional to mass and the square of velocity. **Formula for Kinetic Energy**

If an object of mass 'm' moving with uniform velocity 'u', it is displaced through a distance 's'. Constant force 'f' acts on it in the direction of displacement. Its velocity changes from 'u' to 'v'. Then acceleration is 'a'.

Work done, $W = f \times s$ ...(i)

and $f = ma$ ...(ii)

According to third equation of motion, relationship between u, v, s and a is as follows :

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

So, $s = \frac{v^2 - u^2}{2a}$ ...(iii)

Now putting the value of f and s from (ii) and (iii) in equation (i),

$$W = ma \times \frac{v^2 - u^2}{2a}$$

$$= \frac{m}{2} \times v^2 - u^2 = \frac{1}{2} m \left(v^2 - u^2\right)$$

If $u = 0$ (when body starts moving from rest)

$$W = ½mv^2$$

Or $E_K = ½mv^2$

Example. *An object of mass 15 kg is moving with uniform velocity of 4 m/sec. What is the kinetic energy possessed by it ?*

Solution : Mass of the object, m = 15 kg

Velocity of the object, v = 4 m/s

$$E_K = \tfrac{1}{2}mv^2$$

$$= \tfrac{1}{2} \times 15\text{ kg} \times 4\text{ ms}^{-1} \times 4\text{ ms}^{-1}$$

$$= 120\text{J}$$

The kinetic energy of the object is 120 J.

Potential Energy

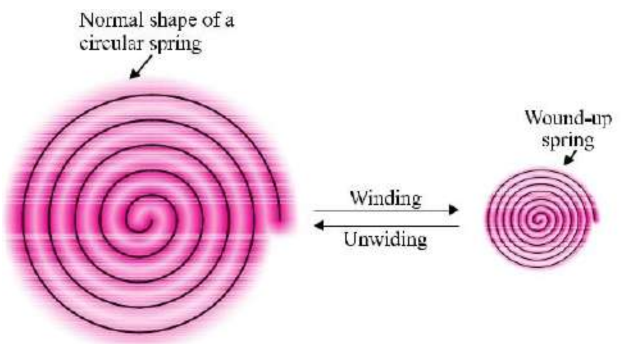
The energy of a body due to its position or change in shape is known as potential energy.

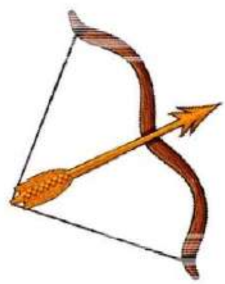
Examples :

(i) Water kept in dam : It can rotate turbine to generate electricity due to its position above the ground.

(ii) Wound up spring of a toy car : It possess potential energy which is released during unwinding of spring. So toy car moves.

(iii) Bent string of bow : Potential energy due to change of its shape (deformation) released in the form of kinetic energy while shooting an arrow.





Factors affecting Potential Energy

(i) **Mass :** P. E. $\propto m$

More the mass of body, greater is the potential energy and vice-versa.

(ii) Height above the ground :

P. E. $\propto h$ (Not depend on the path it follows) Greater the height above the ground, greater is the P.E. and vice-versa.

(iii) Change in shape : Greater the stretching, twisting or bending, more is the potential energy.

Potential Energy of an Object on a Height

If a body of mass '*m*' is raised to a height '*h*' above the surface of the earth, the gravitational pull of the earth ($m \times g$) acts in downward direction. To lift the body, we have to do work against the force of gravity.

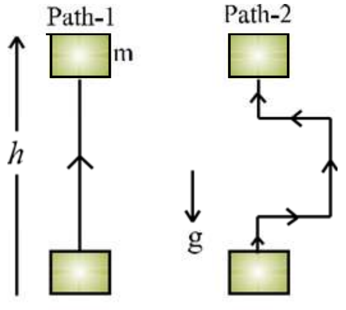
Thus, Work done, W = Force × Displacement

Or W $= m \times g \times h = mgh$

This work is stored in the body as potential energy (gravitational potential energy).

Thus, Potential energy, $E_P = m \times g \times h$

where g = acceleration due to gravity.



Example. *If a body of mass 10 kg is raised to a height of 6 m above the earth, calculate its potential energy.*

Solution : Potential energy of the body = *mgh*

Mass of body = 10 kg

Height above the earth = 6 m

Acceleration due to gravity = 10 m/s^2

So, E_P =10×10×6

=600J

Thus, potential energy of the body is 600 Joules.

Transformation of Energy

The change of one form of energy to another form of energy is known as transformation of energy.

Example :

(i) A stone on a certain height has entire potential energy. But when it starts moving downward, potential energy of stone goes on decreasing as height goes on decreasing but its kinetic energy goes on increasing as velocity of stone goes on increasing. At the time stone reaches the ground, potential energy becomes zero and kinetic energy is maximum.

Thus, its entire potential energy is transformed into kinetic energy.

(ii) At hydroelectric power house, the potential energy of water is transformed into kinetic energy and then into electrical energy.

(iii) At thermal power house, chemical energy of coal is changed into heat energy, which is futher converted into kinetic energy and electrical energy.

(iv) Plants use solar energy to make chemical energy in food by the process of photosynthesis.

Law of Conservation of Energy

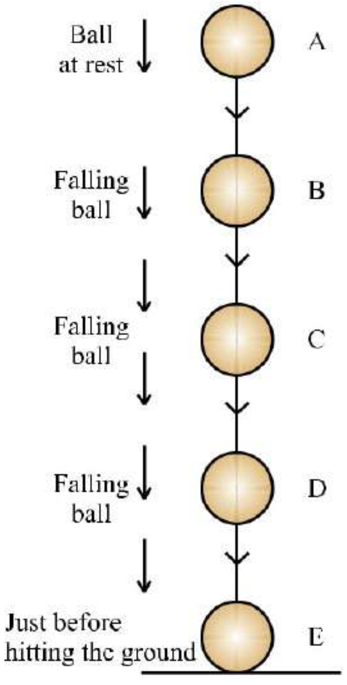
- Whenever energy changes from one form to another form, the total amount of energy remains constant.
- "Energy can neither be created nor be destroyed."
- Although some energy may be wasted during conversion, but the total energy of the system remains the same.

Conservation of Energy during Free Fall of a Body

- A ball of mass 'm' at a height 'h' has potential energy = mgh.
- As ball falls downwards, height 'h' decreases, so the potential energy also decreases.
- Kinetic energy at 'h' is zero but it is increasing during falling of ball.
- The sum of potential energy & kinetic energy of the ball remains the same at every point during its fall.

$$\frac{1}{2}mv^2 + mgh = \text{Constant}$$

Kinetic energy + Potential energy = Constant



Ball	P.E. of Ball	K.E. of Ball	Total Energy of Ball (P.E. + K.E.)
A	20J	0J	20 + 0 = 20J
B	15J	5J	15 + 5 = 20J
C	10J	10J	10 + 10 = 20J
D	5J	15J	5 + 15 = 20J
E	0J	20J	0 + 20 = 20J

Rate of Doing Work – Power

"Power is defined as the rate of energy consumption."

$$\text{Power} = \frac{\text{Work done}}{\text{Time taken}} \quad \text{Or} \quad P = \frac{W}{t}$$

where P = Power

W = Work done

t = Time taken

Unit of Power

SI unit of Power is Watt (W) = 1 Joule/second.

$$1 \text{ Watt} = \frac{1 \text{ Joule}}{1 \text{ second}} \quad \text{Or} \quad 1 \text{ W} = \frac{1 \text{ J}}{1 \text{ s}}$$

Power is one Watt when one Joule work is done in one second.

$$\text{Average Power} = \frac{\text{Total work done or total energy used}}{\text{Total time taken}}$$

Power of Electrical Gadget

The power of an electrical appliance tells us the rate at which electrical energy is consumed by it.

Bigger unit of Power : Bigger unit of power is called Kilowatt or KW. 1 Kilowatt (KW) = 1000 Watt = 1000 W or 1000 J/s

Example. *A body does 20 Joules of work in 5 seconds. What is its power ?*

Solution :
$$\text{Power} = \frac{\text{Work done}}{\text{Time taken}}$$

Work done = 20 Joules

Time taken = 5 sec.

$$P = \frac{20\ J}{5\ s}$$

So, Power = 4 J/s = 4 W

Thus, power of the body is 4 Watts.

Commercial Unit of Energy : Joule is very small unit of energy and it is inconvenient to use it where a large quantity of energy is involved.

For commercial purpose, bigger unit of energy is Kilotwatt hour (KWh).

1 KWh : 1 KWh is the amount of energy consumed when an electric appliance having a power rating of 1 Kilowatt is used for 1 hour.

Relation between Kilowatt hour and Joule

1 Kilowatt hour is the amount of energy consumed at the rate of 1 Kilowatt for 1 hour.

1 Kilowatt hour = 1 Kilowatt for 1 hour

= 1000 Watt for 1 hour

= 1000 Watt × 3600 seconds (60 × 60 seconds = 1 hour)

= 36,00,000 Joules

So, 1 KWh = 3.6×10^6 J = 1 unit

Example. *A bulb of 60 Watt is used for 6 hrs. daily. How many units (KWh) of electrical energy are consumed ?*

Solution : Power of bulb = 60 W = $\frac{60}{1000}$ KW = 0.06 KW

t = 6 hours

Energy = Power × Time taken = 0.06 × 6

h = 0.36 KWh = 0.36 units

QUESTIONS

VERY SHORT ANSWER TYPE QUESTIONS (1 Mark)

1. Define the term 'work'.
2. Define 1 Joule of work.
3. Give an example in which a force does positive work.
4. Give an example in which a force does negative work.
5. Define the term energy of a body.
6. Write the units of : (a) Work, (b) Energy.
7. Define Power.
8. Define 1 Watt energy.
9. Define 1 Kilowatt hour.

SHORT ANSWER TYPE QUESTIONS (2 Marks)

1. What do you undertstand by kinetic energy ? Write its formula.
2. On what factors does the kinetic energy of a body depends ?
3. What happens to potential energy of a body when its height is doubled ?
   (Ans. Doubled)
4. How many joules are there in 1 Kilowatt hour ?
5. What is conservation of energy ? Explain with an example.

SHORT ANSWER TYPE QUESTIONS (3 Marks)

1. What are the quantities on which the amount of work done depend ? How are they related to work ?
2. A load of 100 kg is pulled up to 5 m. Calculate the work done. ($g = 10$ m/s^2) *(Ans. 5000 J)*

3. A body of mass *m* is moving with a velocity 5 ms^{-1}. Its kinetic energy is 25 J. If its velocity is doubled, what is its kinetic energy ?

(Ans. 100 J)

LONG ANSWER TYPE QUESTIONS (3 Marks)

1. A boy weighing 50 kg climbs up a vertical height of 100 m. Calculate the amount of work done by him. How much potential energy he gains ?
(Given $g = 9.8$ m/s^2) *(Ans. 4.9×10^4 J)*

2. Five electric fans of 120 watts each are used for 4 hours. Calculate the electrical energy consumed in kilowatt hours.

(Ans. 2.4 KWh)

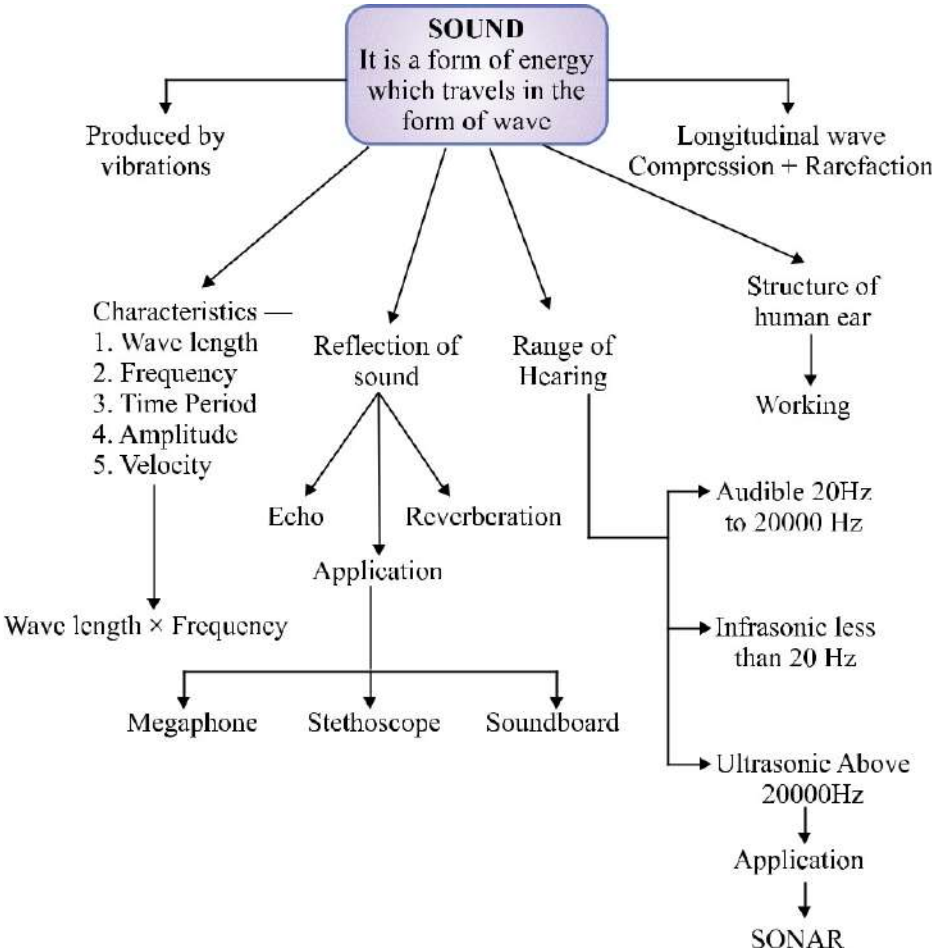
3. The power of an electric heater is 1500 Watt. How much energy it consumes in 10 hours ?

[Ans. 15 KWh (units)]

Chapter- 12

Sound

CHAPTER AT A GLANCE



Sound

(i) The sensation felt by our ears is called sound.

(ii) Sound is a form of energy which makes us hear.

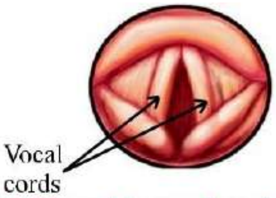
(iii) Law of conservation of energy is also applicable to sound.

(iv) Sound travels in form of wave.

Production of Sound

Sound is produced when object vibrates or sound is produced by vibrating objects.

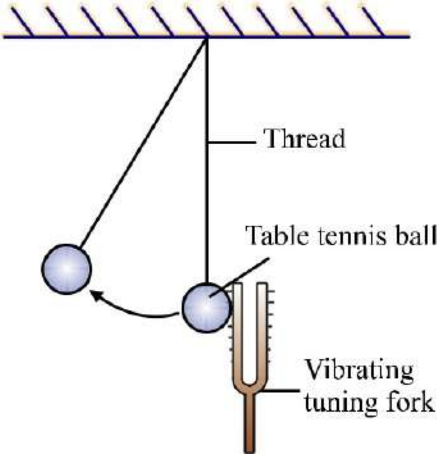
- The energy required to make an object vibrate and produce sound is provided by some outside source (like our hand, wind etc.).
- *Example :* Sound of our voice is produced by vibration of two vocal cords in our throat [Fig. (a)].
- Sound of a drum or tabla is produced by vibration of its membrane when struck [Fig. (b)].



(a) Sound is produced when our vocal cords vibrate


(b) Sound is produced when the skin of a drum vibrates

- In laboratory experiments, sound is produced by vibrating tuning fork. The vibrations of tuning fork can be shown by touching a small suspended pith ball (cork ball) with a prong of the sounding tuning fork. The pith ball is pushed away with a great force.



Sound can be produced by following methods :

(i) By vibrating string (sitar)

(ii) By vibrating air (flute)

(iii) By vibrating membrane (table, drum)

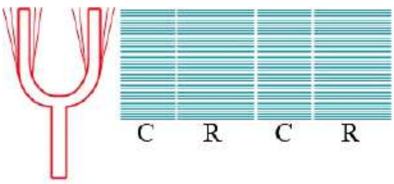
(iv) By vibrating plates (bicycle bell)

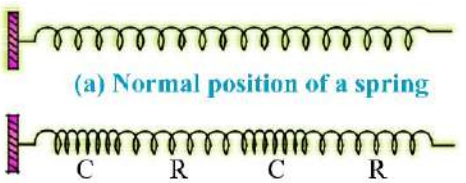
(v) By friction in objects

(vi) By scratching or scrubbing the objects etc.

Propogation of Sound

- The substance through which sound travels is called a medium.
- The medium may be solid, liquid or gas.
- When an object vibrates, then the air particles around it also start vibrating in exactly the same way and displaced from their stable position.
- These vibrating air particles exert a force on nearby air particles so they are also displaced from their rest position and start to vibrate.
- This process is continued in the medium till sound reaches our ears.
- The disturbance produced by sound travels through the medium (not the particles of the medium).
- Wave is a disturbance which travels through a medium and carries energy.
- So sound travels in wave form known as mechanical waves.





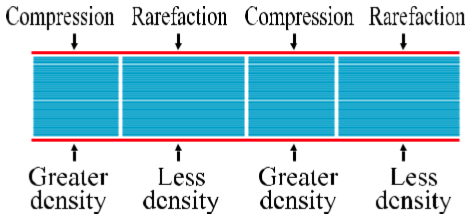
(a) Normal position of a spring

(b) Longitudinal wave in a spring

Sound Waves are Longitudinal Waves

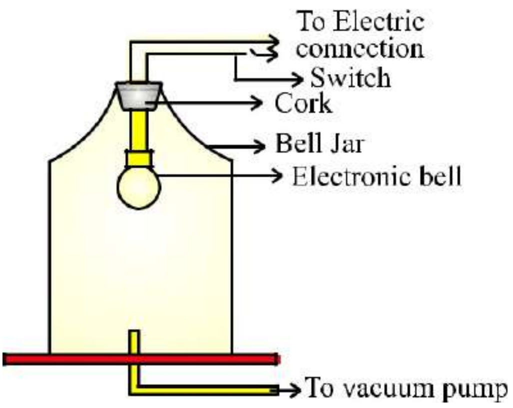
- When a body vibrates then it compresses the air surrounding it and form a area of high density called compression (C).
- Compression is the part of wave in which particles of the medium are closer to one another forming high pressure.
- This compression move away from the vibrating body.
- When vibrating body vibrates back a area of low pressure is formed called rarefaction (R).
- Rarefaction is the area of wave in which particles of the medium are further apart from one another forming a low pressure or low density area.

- When body vibrates back and forth, a series of compression and rarefaction is formed in air resulting in sound wave.
- Propogation of sound wave is propogation of density change.



Sound needs Medium for Propogation

- Sound waves are mechanical waves.
- It needs material medium for propogation like air, water, steel etc.
- It cannot travel in vaccum.
- An electric bell is suspended in airtight bell jar connected with vacuum pump.
- When bell jar is full of air, we hear the sound but when air is pumped out from the bell jar by vacuum pump and we ring the bell, no sound is heard.
- So medium is necessary for propagation of sound.



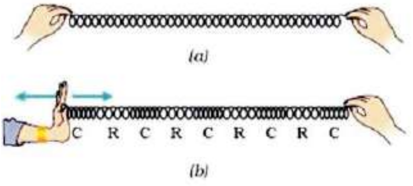
Experiment to show that sound cannot travel through vacuum

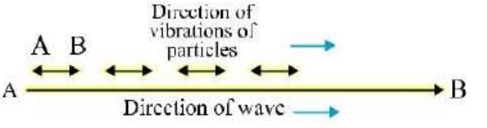
Sound Waves are Longitudinal Waves

(i) A wave in which the particles of the medium vibrate back and forth in the same direction in which the wave is moving, is called a **longitudinal wave**.

- When we push and pull the slinky compression (number of turns are more or closer) and rarefaction (number of turns are less or farther) are formed.

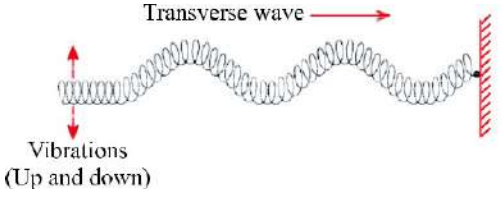
- When a wave travels along with slinky, its each turn moves back and forth by only a small distance in the direction of wave. So the wave is longitudinal.
- The direction of vibrations of the particles is parallel to the direction of wave.

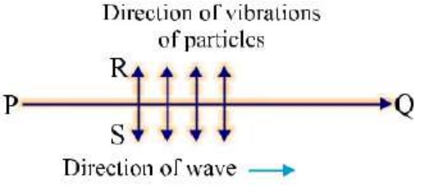




(ii) When one end of a slinky is moved up and down rapidly whose other end is fixed, it produces **transverse wave.**

- This wave possess along the slinky in horizontal direction, while turns of slinky (particles) vibrate up and down at right angle to the direction of wave.
- Thus in transverse wave particles of the medium vibrate up and down at right angles to the direction of wave.
- Light waves are transverse waves but they don't need a material medium for propagation.

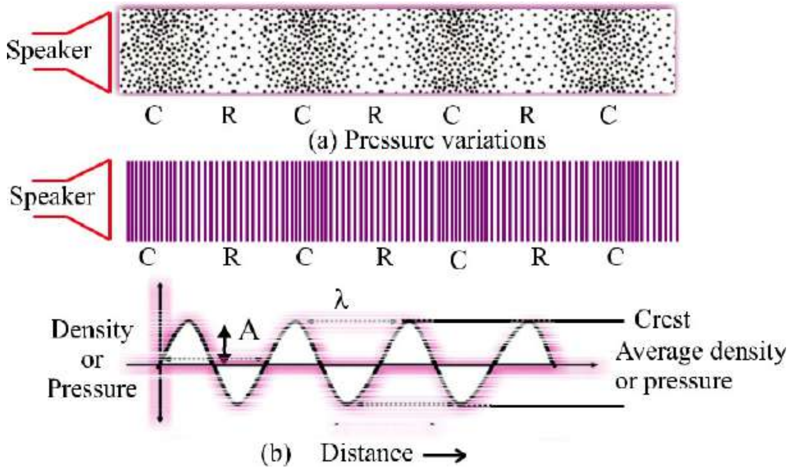




Characteristics of Sound Wave

The characteristics of sound waves are : wavelength, frequency, amplitude, time period and velocity.

- When a wave travel in air the density and pressure of air changes from their mean position.
- Compression is shown by crest while rarefaction is shown by trough.
- Compression is the region of maximum density or pressure.
- Rarefaction is the region of minimum density or pressure.

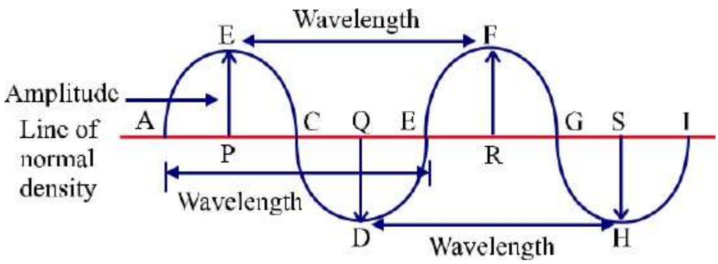


(i) Wavelength :

(a) In sound waves the combined length of a compression and an adjacent rarefaction is called its wavelength.

(b) The distance between the centres of two consecutive compressions or two consecutive rarefactions is also called its wavelength.

(c) It is denoted by the Greek letter lamda λ. Its SI unit is metre.



(ii) Frequency :

(a) No. of complete waves produced in one second or number of vibrations per second is called frequency.

(b) Number of compressions or rarefactions passed in one second is also frequency.

- Frequency of wave is same as the frequency of the vibrating body which produces the wave.
- The SI unit of frequency is hertz (Hz). The symbol of frequency is *v* (nu).
- **1 Hertz :** One Hz is equal to 1 vibration per second.
- Bigger unit of frequency is kilohertz kHz = 1000 Hz.

(iii) Time Period :

(a) Time taken to complete one vibration is called time period.

(b) Time required to pass two consecutive compressions or rarefactions through a point is called time period.

- SI unit of time period is second (s). Time period is denoted by T.
- The frequency of a wave is the reciprocal of the time period.

$$\nu = \frac{1}{T}$$

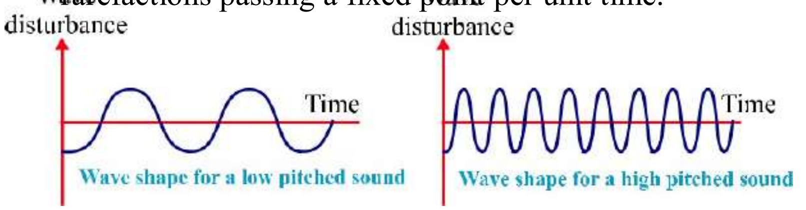
(iv) Amplitude :

The maximum displacement of the particle of the medium from their original undisturbed position is called amplitude of the wave.

- Amplitude is denoted by A and its SI unit is metre (m). Sound have characteristics like pitch and loudness and timbre.

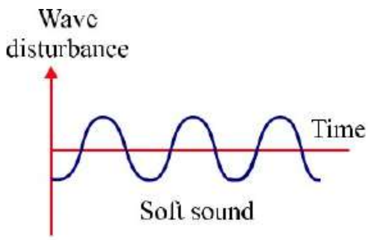
Pitch : The pitch of sound depends on the frequency of sound (vibration). It is directly proportional to its frequency. Greater the frequency, higher is the pitch and lesser the frequency, lower is the pitch.

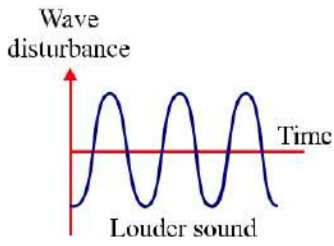
- A woman's voice is shrill having a high pitch while a man's voice is flat having low pitch.
- High pitch sound has large number of compressions and rarefactions passing a fixed point per unit time.



Loudness : The loudness depends on the amplitude of the sound wave.

- Loudness is the measure of the sound energy reaching the ear per sec.
- Greater the amplitude of sound wave, greater is the energy, louder the sound; short is the amplitude, less is the energy, soft is the sound.
- Loudness is measured in decibel 'dB'.





Quality or Timbre : The timbre of a sound depends on the shape of sound wave produced by it. It is the characteristic of musical sound.

- It helps us to distinguish between two sounds of same pitch & loudness.
- Sound of single (same) frequency is called **tone** while a mixture of different frequencies is called **note**. Noise is unpleasant to hear while music is pleasant to hear and it is of good quality.

(v) Velocity :

The distance travelled by a wave in one second is called velocity of the wave. Its SI unit is metre per second (ms^{-1}).

$$\text{Velocity} = \frac{\text{Distance travelled}}{\text{Time taken}}$$

$$V = \frac{\lambda}{T}$$

(λ is the wavelength of the waves travelled in one time timeperiod T)

$$V = \lambda \nu \qquad \frac{1}{T} = \nu$$

So, Velocity = Wavelength × Frequency

This is the wave equation.

Example. *What is the frequency of sound wave whose time period is 0.05 second ?*

Solution : Frequency, $\nu = \frac{1}{T}$

Given $T = 0.05$ s

So, $\nu = \frac{1}{0.05} = \frac{100}{5} = 20$ Hz

Hence frequency = 20 Hz.

Speed of Sound in Various Mediums

(i) Speed of sound depends on the nature of material through which it travels. It is slowest in gases, faster in liquids and fastest in solids.

(ii) Speed of sound increases with the rise in temperature.

(iii) Speed of sound increases as humidity of air increases.

(iv) Speed of light is faster than speed of sound.

(v) In air, speed of sound is 344 ms^{-1} at 22ºC.

Sonic Boom

Some aircrafts, bullets, rockets etc. have 'supersonic speed'.

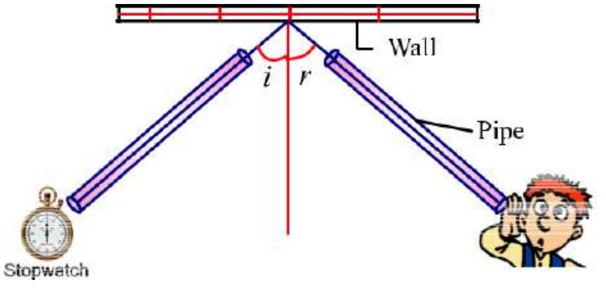
- Supersonic refers to the speed of an object which is greater than the speed of sound and it produces extremely loud sound waves called 'shock waves' in air.
- Sonic boom is an explosive noise caused by shock waves.
- It emits tremendous sound energy which can shatter the glass panes of windows.

Reflection of Sound

Like light, sound also bounce back when it falls on a hard surface. It is called reflection of sound. The laws of reflection of light are obeyed during reflection of sound.

(i) The incident sound wave, the reflected sound wave and normal at the point of incidence lie in the same plane.

(ii) Angle of reflection of sound is always equal to the angle of incidence of sound.



Reflection of Sound

Echo

The repetition of sound caused by the reflection of sound waves is called an echo.

- We can hear echo when there is a time gap of 0.1 second in original sound and echo (reflected sound).
- Echo is produced when sound reflected from a hard surface (*i.e.,* brick wall, mountain etc.) as soft surface tends to absorb sound.

v To calculate the minimum distance to hear an echo :

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

Here Speed of sound in air = 344 ms^{-1} at 22ºC

Time = 0.1 second

So, $$344 = \frac{\text{Distance}}{0.1 \text{ sec}}$$

Or Distance = 344 × 0.1 = 34.4 m

So, distance between reflecting surface and audience = $\frac{34.4}{2}$ = 17.2 m (at 22ºC).

- Rolling of thunder is due to multiple reflection of sound of thunder from a number of reflecting surfaces such as clouds and the earth.

Reverberation

(i) The persistence of sound in a big hall due to repeated reflection of sound from the walls, ceiling and floor of the hall is called reverberation.

(ii) If it is too long, sound becomes blurred, distorted and confusing.

Methods to reduce reverberation in big halls or auditoriums

(i) Panels made of felt or compressed fibre board are put on walls and ceiling to absorb sound.

(ii) Heavy curtains are put on doors and windows.

(iii) Carpets are put on the floor.

(iv) Seats are made of material having sound absorbing properties.

Difference between Echo and Reverberation

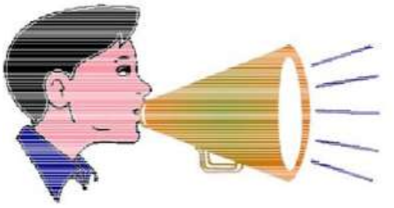
Echo	Reverberation
1. The repetition of sound caused by reflection of sound wave is called echo.	1. The persistence of sound in a big hall due to repeated or multiple reflections of sound from the walls, ceiling and floor of the hall is called reverberation.

2. Echo is produced in a big empty hall. Here is no multiple reflections of sound. Sound is not persistant.	2. If reverberation is too long, sound becomes blurred, distorted and confusing due to overlapping of different sound.

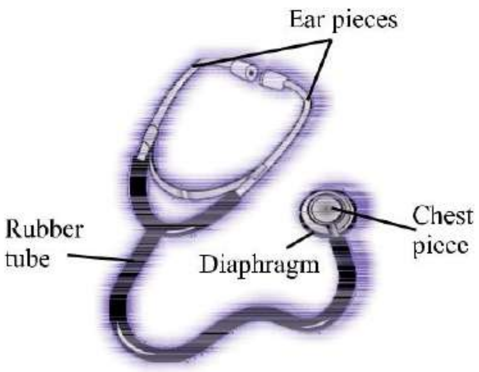
Applications of Reflection of Sound

(i) Megaphone, loudspeakers, bulb horns and trumpets, shehnai etc. are designed to send sound in a particular direction without spreading all around. All these instruments have funnel tube which reflects sound waves repeatedly towards audience. In this amplitude of sound waves adds up to increase loudness of sound.

(ii) **Stethoscope :** It is a medical instrument used for listening the sounds produced in human body mainly in heart and lungs. The sound of the heartbeats reaches the doctor's ears by the multiple reflection of the sound waves in the rubber tube of stethoscope.

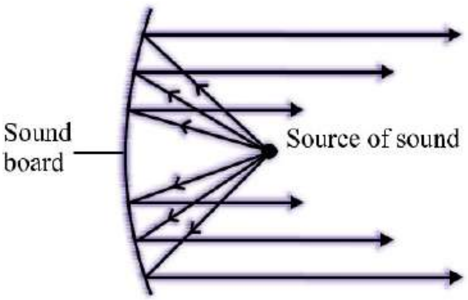


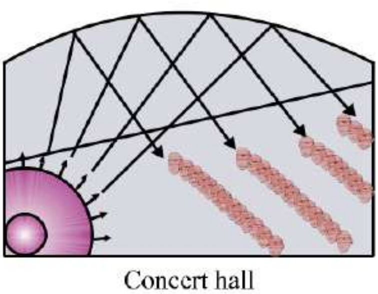
Megaphone



(iii) **Sound Board :** In big halls or auditoriums sound is absorbed by walls, ceiling, seats etc. So a curved board (sound board) is placed behind the speakers so that his speech can be heard easily by audiences. The soundboard works on the multiple reflection of sound.

(iv) The ceiling of concert halls are made curved, so that sound after reflection from ceiling, reaches all the parts of the hall.





Concert hall

Range of Hearing

(i) Range of hearing in human is 20 Hz to 20000 Hz.

- Children younger than 5 years and dogs can hear upto 25 KHz.

(ii) The sounds of frequencies lower than 20 Hz are known as 'infrasonic sounds'.

- A vibrating simple pendulum produces infrasonic sounds.
- Rhinoceroses communicate each other using frequencies as low as 5 Hz.
- Elephants and whales produces infrasonic waves.
- Earthquakes produces infrasonic waves (before shock waves) which some animals can hear and get disturbed.

(iii) The sounds of frequencies higher than 20 KHz are known as 'ultrasonic waves'.

- Dogs, parpoises, dolphins, bats and rats can hear ultrasonic sounds.
- Bats and rats can produce ultrasonic sounds.

Hearing Aid

It is battery operated electronic device used by persons who are hard of hearing. Microphone convert sound into electrical signals, than those are amplified by amplifier. Amplified signals are send to the speaker of hearing aid. The speaker converts the amplified signal to sound and sends to ear for clear hearing.

Applications of Ultrasound

(i) It is used to detect cracks in metal blocks in industries without damaging them.

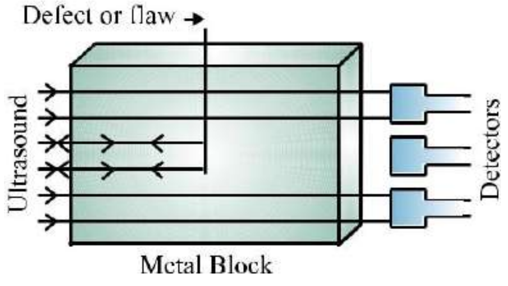
(ii) It is used in industries to clean 'hard to reach' parts of objects such as spiral tubes, odd shaped machines etc.

(iii) It is used to investigate the internal organs of human body such as liver, gall bladder, kidneys, uterus and heart.

(iv) **Ecocardiography :** These waves are used to reflect the action of heart and its images are formed. This technique is called echocardiography.

(v) **Ultrasonography :** The technique of obtaining pictures of internal organs of the body by using echoes of ultrasound waves is called ultrasonography.

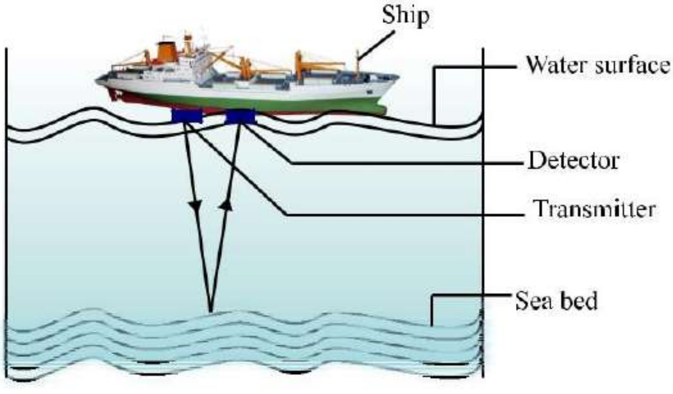
(vi) Ultrasound is used to split tiny stones in kidneys into fine grains.



SONAR

The word 'SONAR' stands for 'Sound Navigation And Ranging'.

- SONAR is a device which is used to find distance, direction and speed of underwater objects.
- SONAR consists of a transmitter and a receptor or detector and installed at the bottom of a ship.
- The transmitter produces and transmits ultrasonic waves.
- These waves travel through water and after striking the objects on the bottom of sea, are reflected back and received by detector.



SONAR

- These reflected waves are converted into electric signals by detector.
- The sonar device measures the time taken by ultrasound waves to travel from ship to bottom of sea and back to ship.

Half of this time gives the time taken by the ultrasound waves from ship to bottom.

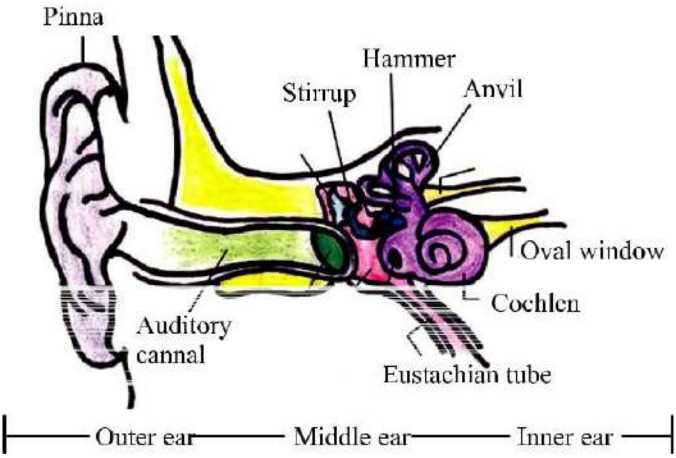
Let the time interval between transmission and reception of ultrasound signal is t. Speed of sound through sea water is v, total distance travelled by waves = $2d$. Then, $2d = v \times t$. This is called echo ranging.

The sonar is used to find the depth of sea, to locate underwater hills, valleys, submarines, icebergs and sunken ships etc.

- Bats fly in the dark night by emitting high pitched ultrasound waves which are reflected from the obstacle or prey and returned to bats ear. The nature of reflection tells the bat where the obstacle or prey is and what it is like.

Structure of Human Ear

- The ear consists of three parts : outer ear, middle ear and inner ear.
- The ears are the sense organs which help us in hearing sound.
- **The outer ear** is called **pinna**. It collects the sound from surroundings.
- This sound passes through the auditory canal.
- At the end of auditory canal, is a thin elastic membrane called ear drum or tympanic membrane.
- **The middle ear** contains of three bones : hammer, anvil and stirrup linked with one another. Free end of hammer touches ear drum and that of stirrup linked with membrane of oval window of inner ear.
- The lower part of middle ear has a narrow ‘Eustachian tube’.
- **The inner ear** has a coiled tube called cochlea, which is connected with oval window. Cochlea is filled with a liquid containing nerve cells. Other side of cochlea is connected to auditory nerve which goes to brain.



Working :

- When compression of sound wave strikes the ear drum, the pressure on the outside of ear drum increases and pushes the ear drum inwards.

While during rarefaction ear drum moves outwards. Thus, ear drum starts vibrating back and forth.

- These vibrations are increased by three bones and middle ear transmits these amplified pressure variations received from sound waves to inner ear.
- In the inner ear the pressure variations are turned into electric signals by the cochlea.
- These electric signals are sent to the brain via auditory nerve and the brain interprets them as sound.

Working of Human ear

Pinna → Ear canal → Ear drum → Hammer → Anvil → Stirrup → Oval window → Cochlea → Auditory nerve → Brain

QUESTIONS

VERY SHORT ANSWER TYPE QUESTIONS (1 Mark)

1. Why sound waves are called mechanical waves ?
2. Which characteristic of sound determine : (a) Pitch, (b) Loudness ?
3. Write wave formula for velocity of sound.
4. Write the hearing range of human being.
5. What is sound ?
6. Name the two types of waves which can be generated in a slinky.
7. What is SI unit of frequency ? Write its bigger unit also.
8. How is sound produced ?
9. In which medium sound travels fastest : air, water or steel ?
10. Name two devices which work on the reflection of sound.

SHORT ANSWER TYPE QUESTIONS (2 Marks)

1. State two laws of reflection of sound.
2. Define the term wavelength & frequency.
3. Define the term time period and amplitude.

4. Explain why, the flash of lighning reaches us first and the sound of thunder is heard a little later ?
5. What is meant by supersonic speed ?
6. Why are the ceiling of concert halls made curved ?

SHORT ANSWER TYPE QUESTIONS (3 Marks)

1. What is reverberation ? How can reverberation in a big hall be reduced ?
2. What is echo ? How is echo formed ? How thunder of clouds is formed ?
3. Write any three applications of ultrasound.
4. Explain how bats use ultrasound to catch the prey.

LONG ANSWER TYPE QUESTIONS (5 Marks)

1. What is SONAR ? Explain its working. Give its uses.
2. A wave is moving in air with a velocity of 340 m/s. Calculate the wavelength if its frequency is :

   (a) 512 vibrations per second (b) 100 Hz.
3. A sonar station picks up a return signal after 3 seconds. How far away is the object ? [Speed of sound in water = 1440 m/s]
4. A stone is dropped from the top of a tower 500 m high into a pond of water at the base of tower. When is the splash heard at the top ? Given $g = 10\ ms^{-2}$ and speed of sound = $340\ ms^{-1}$.

Hints to Long Answer Type Questions

2. (a) 0.66 metre (b) 3.4 m
3. 2160 m
4. 11.47 s

[*Hint :* Time taken by stone to reach at pond, t = ?, Use $s = ut + \frac{1}{2}gt^2$, $500 = 0 + \frac{1}{2} \times 10t^2$; so, $t^2 = 100$ or $t = 10$ sec.]