PHYSICS

REFERENCE STUDY MATERIAL

for

CLASS – IX

2017 – 18

CHAPTER WISE CONCEPTS, FORMULAS AND NUMERICALS INLCUDING HOTS PROBLEMS

Prepared by

M. S. KUMARSWAMY, TGT(MATHS)
M. Sc. Gold Medallist (Elect.), B. Ed.

Kendriya Vidyalaya GaCHIBOWLI

PREFACE

It gives me great pleasure in presenting the Reference Study Material in Class IX Physics for Annual Examination 2018. It is in accordance with the syllabus of the session 2017–18 as per new CBSE guidelines.

Each chapter has a large number of Numerical Problems along with all concepts and descriptions of topics in such a simple style that even the weak students will be able to understand the topic very easily. The most important feature of this material is that **NCERT book questions(intext questions) and exercises** included along with answers. All concepts and formulas based on Numerical and HOTS Numerical are also included in the material. It is also helpful to all the students for competitive examinations.

Keeping the mind the mental level of a child, every effort has been made to introduce simple Numerical Problems in starting before HOTS Numerical so that the child solve them easily and gets confidence.

I avail this opportunity to convey my sincere thanks to respected sir, Shri U. N. Khaware, Additional Commissioner(Acad), KVS Headquarter, New Delhi, respected sir, Shri S. Vijay Kumar, Joint Commissioner(Admn), KVS Headquarter, New Delhi, respected sir Shri P. V. Sairanga Rao, Deputy Commissioner(Acad), KVS Headquarter, New Delhi, respected sir Shri. D. Manivannan, Deputy Commissioner, KVS RO Hyderabad, respected sir Shri Isampal, Deputy Commissioner, KVS RO Bhopal, respected sir Shri Jagdish Mohan Rawat, Director, KVS ZIET Chandigarh, respected sir Shri P. Deva Kumar, Deputy Commissioner, KVS RO Bangalore, respected sir Shri Nagendra Goyal, Deputy Commissioner, KVS RO Ranchi, respected sir Shri Y. Arun Kumar, Deputy Commissioner, KVS RO Agra,, respected sir Shri Sirimala Sambanna, Assistant Commissioner, KVS RO Jammu, respected sir Shri. K. L. Nagaraju, Retd-AC, KVS RO Bangalore and respected sir Shri M.K. Kulshreshtha, Retd-AC, KVS RO Chandigarh for their blessings, motivation and encouragement in bringing out this project in such an excellent form.

I also extend my special thanks to respected sir Shri. P. S. Raju, Principal, KV Gachibowli, respected madam Smt. Nirmala Kumari M., Principal, KV Mysore & respected sir Shri. M. Vishwanatham, Principal, KV Raichur for their kind suggestions and motivation while preparing this Question Bank. I would like to place on record my thanks to respected sir Shri. P. K. Chandran, Principal, presently working in KV Bambolim. I have started my career in KVS under his guidance, suggestions and motivation.

Inspite of my best efforts to make this notes error free, some errors might have gone unnoticed. I shall be grateful to the students and teacher if the same are brought to my notice. You may send your valuable suggestions, feedback or queries through email to kumarsir34@gmail.com that would be verified by me and the corrections would be incorporated in the next year Question Bank.

M. S. KUMARSWAMY

ISAMPAL
DEPUTY COMMISSIONER

केन्द्रीय विद्यालय संगठन, क्षेत्रीय कार्यालय,
के. कामराज मार्ग, बेंगलूर–560 042
KENDRIYA VIDYALAYA SANGATHAN
REGIONAL OFFICE
K. KAMARAJA ROAD, BANGALORE- 560042

F. DO-DC./2013-KVS(BGR) **Dated:05.09.2013**

Dear Shri M.S.Kumarswamy,

It has been brought to my notice the good work done by you with regard to making question bank and worksheets for classes VI to X in Mathematics. I am pleased to look at your good work. Mathematics is one discipline which unfortunately and wrongly perceived as a phobia. May be lack of motivation from teachers and inadequate study habits of students is responsible for this state of affairs. Your work in this regard assumes a great significance. I hope your own students as well as students of other Vidyalayas will benefit by your venture. You may mail the material to all the Kendriya Vidyalayas of the region for their benefit. Keep up the good work.

May God bless!,

Yours sincerely,

(Isampal)

Shri M.S.Kumarswamy
TGT (Maths)
Kendriya Vidyalaya
Donimalai

Copy to: the principals, Kendriya Vidyalayas, Bangalore Region with instructions to make use of the materials prepared by Mr. M.S.Kumarswamy being forwarded separately.

DEDICATED

TO

MY FATHER

LATE SHRI. M. S. MALLAYYA

CHAPTER – 8

MOTION

MOTION

Motion means movement. The motion of an object is perceived when its position changes continuously with respect to some stationary object.

DISTANCE

The **distance** travelled by an object is the length of actual path travelled by the object during the motion.

DISPLACEMENT

The **displacement** of an object is the shortest distance travelled between the initial and final position of the object.

- When final position coincides with the initial position, displacement is 0 but distance is not equal to 0.
- Both, the distance and displacement are measure in meter or cm or km.
- Distance is a scalar quantity having only. Displacement is a vector quantity having both magnitude and direction.
- The distance travelled by an object in motion can never be zero or negative. The displacement can be positive, zero or negative.

INTEXT QUESTIONS PAGE NO. 100

1. A farmer moves along the boundary of a square field of side 10 m in 40 s. What will be the magnitude of displacement of the farmer at the end of 2 minutes 20 seconds?

Ans. The farmer takes 40 s to cover 4 × 10 = 40 m.

In 2 min and 20 s (140 s), he will cover a distance = $\frac{40}{40} \times 140 = 140m$

Therefore, the farmer completes $\frac{140}{40} = 3.5$ rounds (3 complete rounds and a half round) of the field in 2 min and 20 s.

That means, after 2 min 20 s, the farmer will be at the opposite end of the starting point.

Now, there can be two extreme cases.

Case I: Starting point is a corner point of the field.

In this case, the farmer will be at the diagonally opposite corner of the field after 2 min 20 s.

Therefore, the displacement will be equal to the diagonal of the field.

Hence, the displacement will be $\sqrt{10^2 + 10^2} = 14.1m$

Case II: Starting point is the middle point of any side of the field.

In this case the farmer will be at the middle point of the opposite side of the field after 2 min 20 s.

Therefore, the displacement will be equal to the side of the field, i.e., 10 m.

For any other starting point, the displacement will be between 14.1 m and 10 m.

2. Which of the following is true for displacement?

(a) It cannot be zero.

(b) Its magnitude is greater than the distance travelled by the object.

Ans. (a) Not true. Displacement can become zero when the initial and final position of the object is the same.

(b) Not true. Displacement is the shortest measurable distance between the initial and final positions of an object. It cannot be greater than the magnitude of the distance travelled by an object. However, sometimes, it may be equal to the distance travelled by the object.

UNIFORM MOTION

A body is said to have a uniform motion if it travels equal distances in equal intervals of time, no matter how small these intervals may be.

Eg. A vehicle running at a constant speed of 10m/sec ,will cover equal distances of 10metres every second, so its motion will be uniform.

NON-UNIFORM MOTION

A body is said to have a non- uniform motion if it travels unequal distances in equal intervals of time, no matter how small these intervals may be.

Eg. A freely ball from a certain height covers unequal distances in equal intervals of time, so its motion is non uniform.

Non uniform motion is also called accelerated motion.

SPEED

Speed of a body is defined as the distance travelled by the body in unit time.

$$Speed\,(v) = \frac{\text{distance travelled}(s)}{\text{time taken}(t)}$$

Speed is a scalar quantity.

Uniform Speed: When a body travels equal distances in equal intervals of time, the speed of the body is said to be uniform.

Non-uniform Speed: When a body travels unequal distances in equal intervals of time, the speed of the body is said to be non-uniform.

VELOCITY

Velocity of a body is the distance travelled by the body in unit time in a given direction.

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

Velocity is a vector quantity.

Uniform Velocity: When a body travels equal distances in equal intervals of time in a particular direction, the velocity of the body is said to be uniform.

Non-uniform Velocity: When a body travels unequal distances in equal intervals of time in a particular direction, the velocity of the body is said to be non-uniform.

Both speed and velocity are measured in m/s or cm/s or km/hr

AVERAGE VELOCITY

Average Velocity: When velocity of a body is changing at a uniform rate, average velocity is given by $v_{av} = \frac{\text{Initial velocity}(u) + \text{final velocity}(v)}{2}$

INTEXT QUESTIONS PAGE NO. 102

1. Distinguish between speed and velocity.

Ans.

Speed	Velocity
Speed is the distance travelled by an object in a given interval of time. It does not have any direction.	Velocity is the displacement of an object in a given interval of time. It has a unique direction.
The speed of an object can never be negative. At the most, it can become zero. This is because distance travelled can never be negative.	The velocity of an object can be negative, positive, or equal to zero. This is because displacement can take any of these three values.

2. Under what condition(s) is the magnitude of average velocity of an object equal to its average speed?

Ans. $Average \;\; speed = \dfrac{\text{Total distance covered}}{\text{Total time taken}}$ and

$$Average \;\; velocity = \frac{\text{Displacement}}{\text{Total time taken}}$$

If the total distance covered by an object is the same as its displacement, then its average speed would be equal to its average velocity.

3. What does the odometer of an automobile measure?

Ans. The odometer of an automobile measures the distance covered by an automobile.

4. What does the path of an object look like when it is in uniform motion?

Ans. An object having uniform motion has a straight line path.

5. During an experiment, a signal from a spaceship reached the ground station in five minutes. What was the distance of the spaceship from the ground station? The signal travels at the speed of light, that is, 3×10^8 m s^{-1}.

Ans. Time taken by the signal to reach the ground station from the spaceship

= 5 min = 5 × 60 = 300 s

Speed of the signal = 3×10^8 m/s

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

$\therefore$Distance travelled = Speed × Time taken = $3 \times 10^8 \times 300 = 9 \times 10^{10}$ m

Hence, the distance of the spaceship from the ground station is 9×10^{10} m.

ACCELERATION

Acceleration of a body is defined as the rate of change of velocity of the body with time. It is given by formula: $a = \dfrac{v-u}{t}$

It is measured in m/s^2 or cm/s^2 or km/hr^2. Acceleration is a vector quantity.

If the velocity of the body increases with time, the acceleration is positive, and the kind of motion is called accelerated motion. If the velocity of the body decreases with time, the acceleration is negative (retardation), and the motion is called decelerated motion.

Uniform Acceleration: When velocity of the body changes by equal amounts in equal intervals of time in a particular direction, the acceleration of the body is said to be uniform.

Non-uniform Acceleration: When velocity of the body changes by unequal amounts in equal intervals of time in a particular direction, the acceleration of the body is said to be non-uniform.

INTEXT QUESTIONS PAGE NO. 103

1. When will you say a body is in (i) uniform acceleration? (ii) non-uniform acceleration?
Ans. (i) A body is said to have uniform acceleration if it travels in a straight path in such a way that its velocity changes at a uniform rate, i.e., the velocity of a body increases or decreases by equal amounts in an equal interval of time.
(ii) A body is said to have non-uniform acceleration if it travels in a straight path in such a way that its velocity changes at a non-uniform rate, i.e., the velocity of a body increases or decreases in unequal amounts in an equal interval of time.

2. A bus decreases its speed from 80 km h^{-1} to 60 km h^{-1} in 5 s. Find the acceleration of the bus.

Ans. Initial speed of the bus, u = 80 km/h = $80 \times \frac{5}{18} = 22.22 m/s$

Final speed of the bus, v = 60 km/h = $60 \times \frac{5}{18} = 16.66 m/s$

Time take to decrease the speed, t = 5 s

$$Acceleration, a = \frac{v-u}{t} = \frac{16.66-22.22}{5} = -1.12 m/s^2$$

Here, the negative sign of acceleration indicates that the velocity of the car is decreasing.

3. A train starting from a railway station and moving with uniform acceleration attains a speed 40 km h^{-1} in 10 minutes. Find its acceleration.
Ans. Initial velocity of the train, u = 0 (since the train is initially at rest)

Final velocity of the train, v = 40 km/h = $40 \times \frac{5}{18} = 11.11 m/s$

$$Acceleration, a = \frac{v-u}{t} = \frac{11.11-0}{5} = 0.0185 m/s^2$$

Time taken, t = 10 min = 10 × 60 = 600 s
Hence, the acceleration of the train is 0.0185 m/s^2.

NUMERICALS

1. A particle is moving in a circle of diameter 5m. Calculate the distance covered and the displacement when it competes 3 revolutions.

2. A body thrown vertically upwards reaches a maximum height 'h'. It then returns to ground. Calculate the distance travelled and the displacement.

3. A body travels a distance of 15m from A to B and then moves a distance of 20m at right angles to AB. Calculate the total distance travelled and the displacement.

4. An object is moving in a circle of radius 'r'. Calculate the distance and displacement
(i) when it completes half the circle
(ii) when it completes one full circle.

5. An object travels 16m in 4s and then another 16m in 2s. What is the average speed of the object?

6. Vishnu swims in a 90m long pool. He covers 180m in one minute by swimming from one end to the other and back along the same straight path. Find the average speed and average velocity of Vishnu.

7. In along distance race, the athletics were expected to take four rounds of the track such that the line of finish was same as the line of start. Suppose the length of the track was 200m.

(a) What is the total distance to be covered by the athletics?

(b) What is the displacement of the athletics when they touch the finish line?

(c) Is the motion of the athletics uniform or non-uniform?

(d) Is the displacement of an athletic and the distance covered by him at the end of the race equal?

8. Starting from a stationary position, Bhuvan paddles his bicycle to attain a velocity of 6m/s in 30s. Then he applies brakes such that the velocity of bicycle comes down to 4m/s in the next 5s. Calculate the acceleration of the bicycle in both the cases.

9. Amit is moving in his car with a velocity of 45km/hr. How much distance will he cover
(a) in one minute and
(b) in one second.

10. The odometer of a car reads 2000 km at the start of a trip and 2400km at the end of the trip. If the trip took 8 hr, calculate the average speed of the car in km/hr and m/s.

11. An electric train is moving with a velocity of 120km/hr. How much distance will it move in 30s?

12. A body is moving with a velocity of 15m/s. If the motion is uniform, what will be the velocity after 10s?

13. A train travels some distance with a speed of 30km/hr and returns with a speed of 45km/hr. Calculate the average speed of the train.

14. A train 100m long moving on a straight level track passes a pole in 5s. Find
(a) the speed of the train

(b) the time it will take to cross a bridge 500m long.

15. A car travels along a straight line for first half time with speed 40km/hr and the second half time with speed 60km/hr. Find the average speed of the car.

16. A body starts rolling over a horizontal surface with an initial velocity of 0.5m/s. Due to friction, its velocity decreases at the rate of $0.05 m/s^2$. How much time will it take for the body to stop?

17. A car traveling at 36km/hr speeds upto 70km/hr in 5 seconds. What is its acceleration? If the same car stops in 20s, what is the retardation?

18. A scooter acquires a velocity of 36km/hr in 10seconds just after the start. It takes 20 seconds to stop. Calculate the acceleration in the two cases.

19. On a 120km track, a train travels the first 30 km at a uniform speed of 30 km/hr. How fast must the train travel the next 90 km so as to average 60 km/hr for the entire trip?

20. A train travels at 60 km/hr for 0.52 hr; at 30 km/hr for the next 0.24 hr and at 70 km/hr for the next 0.71 hr. What is the average speed of the train?

GRAPHICAL REPRESENTATION OF MOTION

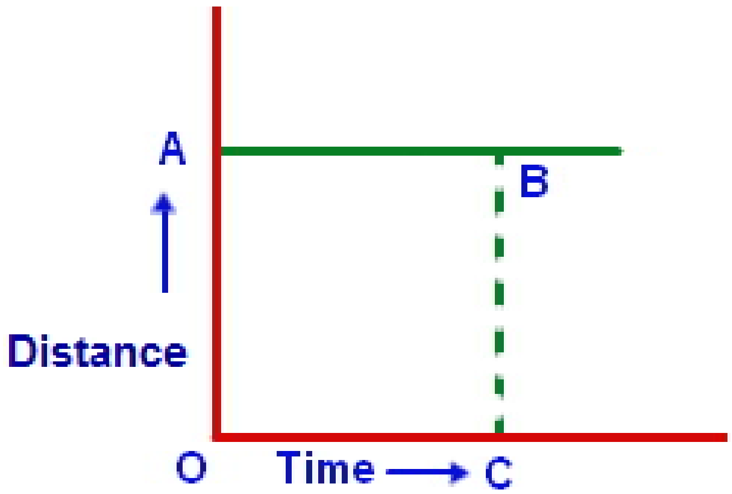
A graph represents the relation between two variable quantities in pictorial form. It is plotted between two variable quantities. The quantity that is varied our choice is called independent variable. The other quantity, which varies as a result of this change, is called dependent variable. For example, in distance-time graph, time is independent variable and distance is dependent variable. Similarly, in velocity-time graph, time is independent variable and velocity is dependent variable.

DISTANCE-TIME GRAPH

The distance-time graph represents the change in the position of a body with time. In this graph, we take time along the x-axis and the distance along the y-axis. The distance-time graph under different conditions are shown below.

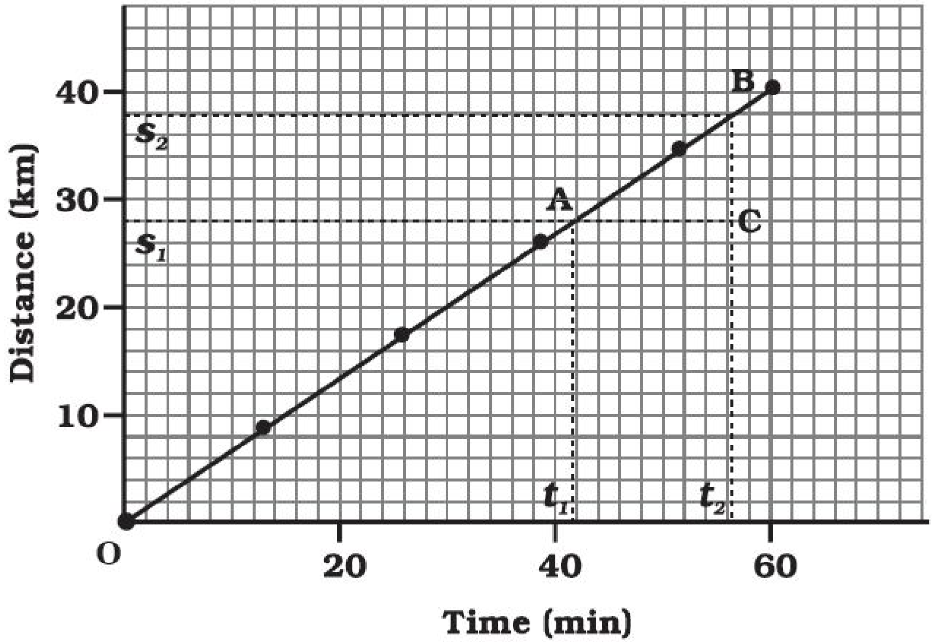
1. **<u>When the body is at rest</u>**

The position of the body does not change with time. Its distance from the origin continues to be same at all instants of time. Therefore, we obtain a straight line parallel to x-axis(time axis) (see the below figure)



2. **<u>When the body is in uniform motion</u>**

When an object travels equal distances in equal intervals of time, it moves with uniform speed. This shows that the distance travelled by the object is directly proportional to time taken. Thus, for uniform speed, a graph of distance travelled against time is a straight line, as shown in below figure. The portion OB of the graph shows that the distance is increasing at a uniform rate.



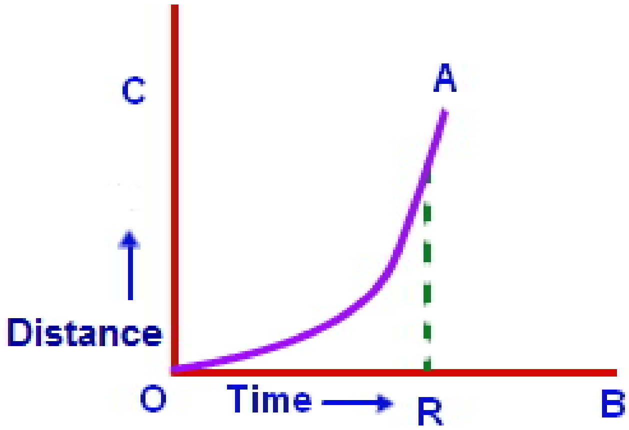
On the graph, AC denotes the time interval $(t_2 - t_1)$ while BC corresponds to the distance $(s_2 - s_1)$. We can see from the graph that as the object moves from the point A to B, it covers a distance $(s_2 - s_1)$ in time $(t_2 - t_1)$. The speed, v of the object, therefore can be represented as

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

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

3. **<u>When the body is in non-uniform motion</u>**

When a body moves with non-uniform speed it covers unequal distance in equal intervals of time. The distance-time graph for a body which is moving with non-uniform speed is not a straight line. It is a curve. The speed of the object will change with respect to time.



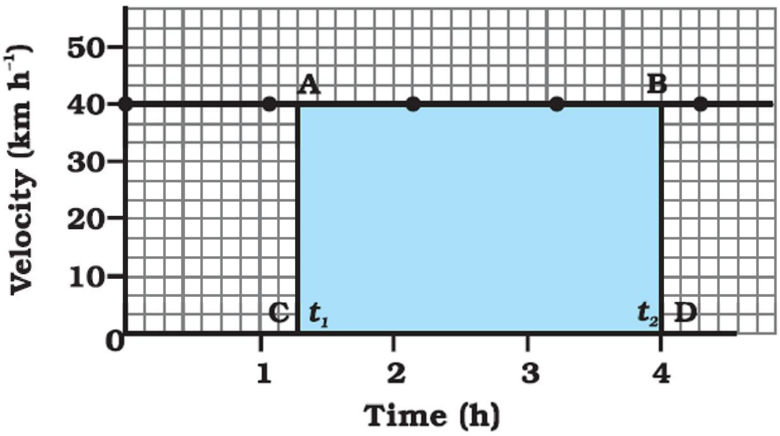
VELOCITY-TIME GRAPH

The geometrical relationship between the velocity of an object and the time taken by the object is called the velocity-time graph.

The velocity-time graph of an object can be drown by taking the time taken along the X-axis and the velocity along the Y-axis. The ratio of the velocity and the time taken will give the acceleration of the object. Therefore, the slope of the velocity-time graph gives the acceleration of the given object. That is, by using this graph one can find the acceleration of an object. The velocity-time graph under different conditions are shown below.

1. **When the body is moving with uniform velocity**

If the object moves at uniform velocity, the height of its velocity-time graph will not change with time. It will be a straight line parallel to the *x*-axis. We know that the product of velocity and time give displacement of an object moving with uniform velocity. The area enclosed by velocity-time graph and the time axis will be equal to the magnitude of the displacement.

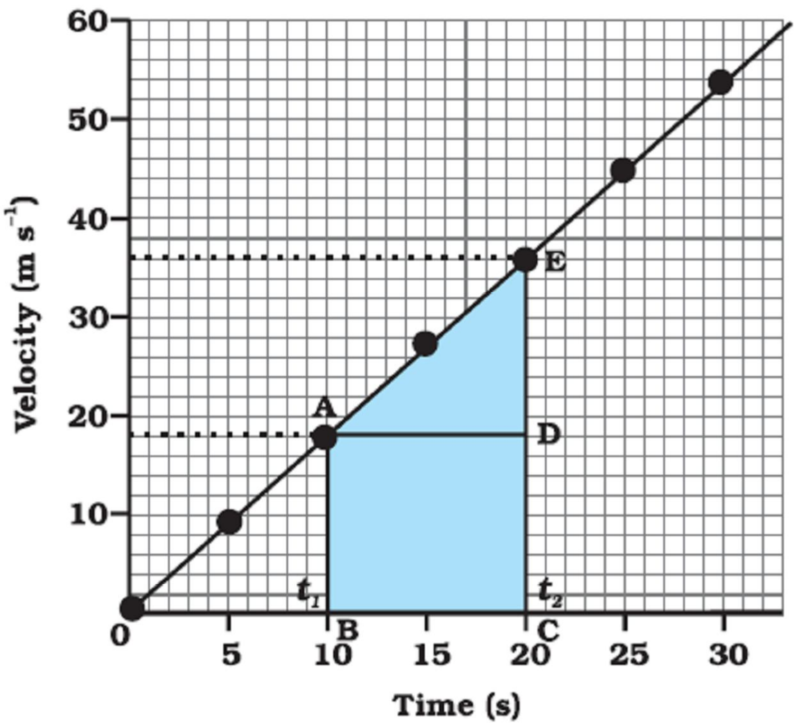


To know the distance moved by the car between time t_1 and t_2 using the above figure, draw perpendiculars from the points corresponding to the time t_1 and t_2 on the graph. The velocity of v km/h is represented by the height AC or BD and the time $(t_2 - t_1)$ is represented by the length AB. So, the distance s moved by the car in time $(t_2 - t_1)$ can be expressed as

s = AC × CD = $v(t_2 - t_1)$ = Area of the rectangle ABDC (shaded portion)

2. **When the body is moving with uniform acceleration**

In this case, the velocity-time graph for the motion of the car is shown in below figure. The nature of the graph shows that velocity changes by equal amounts in equal intervals of time. Thus, for all uniformly accelerated motion, the velocity-time graph is a straight line.



The area under the velocity-time graph gives the distance (magnitude of displacement) moved by the car in a given interval of time. If the car would have been moving with uniform velocity, the distance travelled by it would be represented by the area ABCD under the graph. Since the magnitude of the velocity of the car is changing due to acceleration, the distance *s* travelled by the car will be given by the area ABCDE under the velocity-time graph.

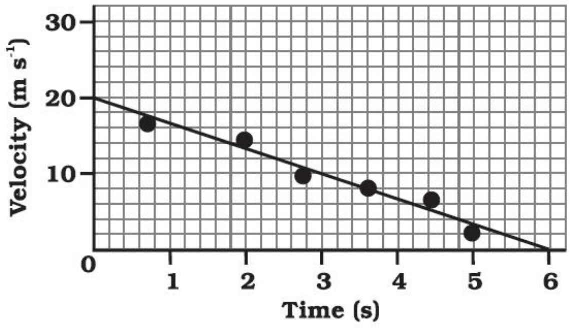
That is,

s = area ABCDE = area of the rectangle ABCD + area of the triangle ADE

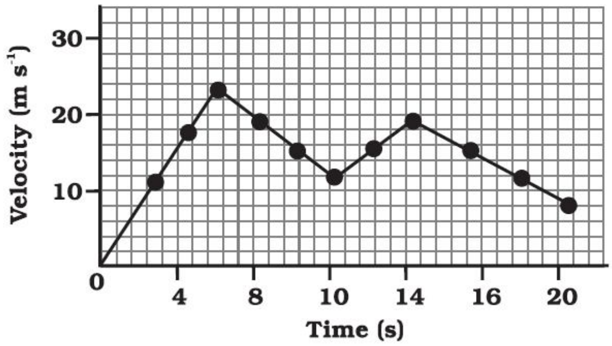
$$= AB \times BC + \frac{1}{2}(AD \times DE)$$

3. <u>When the body is moving with a variable acceleration</u>

In the case of non-uniformly accelerated motion, velocity-time graphs can have any shape. In below Fig. (a) shows a velocity-time graph that represents the motion of an object whose velocity is decreasing with time while Figure (b) shows the velocity-time graph representing the non-uniform variation of velocity of the object with time.



(a)

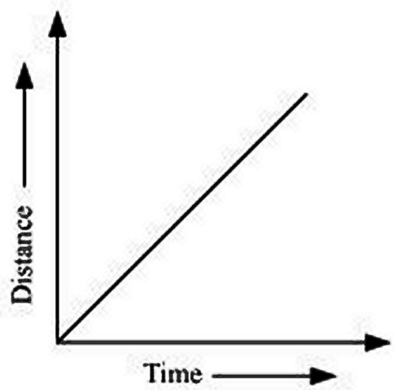


(b)

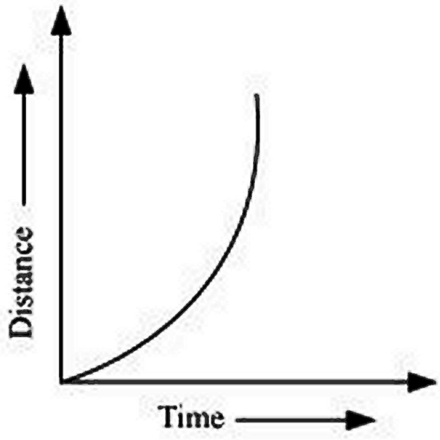
INTEXT QUESTIONS PAGE NO. 107

1. What is the nature of the distance−time graphs for uniform and non-uniform motion of an object?

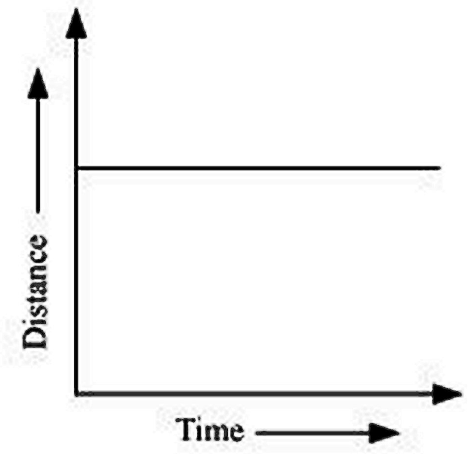
Ans. The distance−time graph for uniform motion of an object is a straight line (as shown in the following figure).



The distance−time graph for non-uniform motion of an object is a curved line (as shown in the given figure).

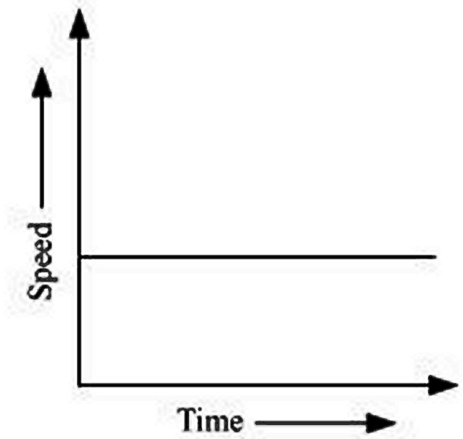


2. What can you say about the motion of an object whose distance–time graph is a straight line parallel to the time axis?
Ans. When an object is at rest, its distance–time graph is a straight line parallel to the time axis.



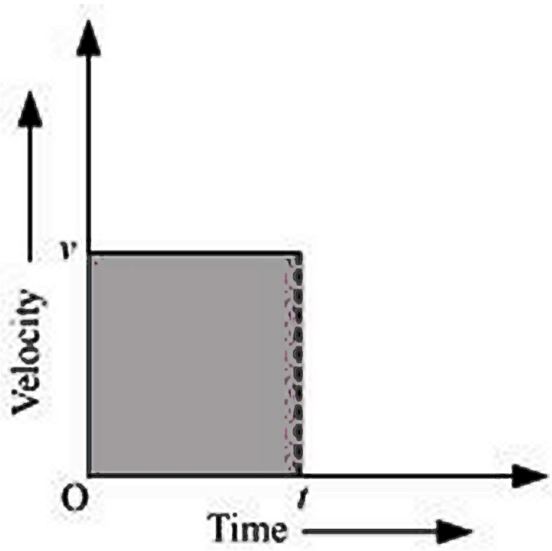
A straight line parallel to the *x*-axis in a distance–-time graph indicates that with a change in time, there is no change in the position of the object. Thus, the object is at rest.

3. What can you say about the motion of an object if its speed–time graph is a straight line parallel to the time axis?
Ans. Object is moving uniformly.



A straight line parallel to the time axis in a speed–time graph indicates that with a change in time, there is no change in the speed of the object. This indicates the uniform motion of the object.

4. What is the quantity which is measured by the area occupied below the velocity–time graph?
Ans. Distance



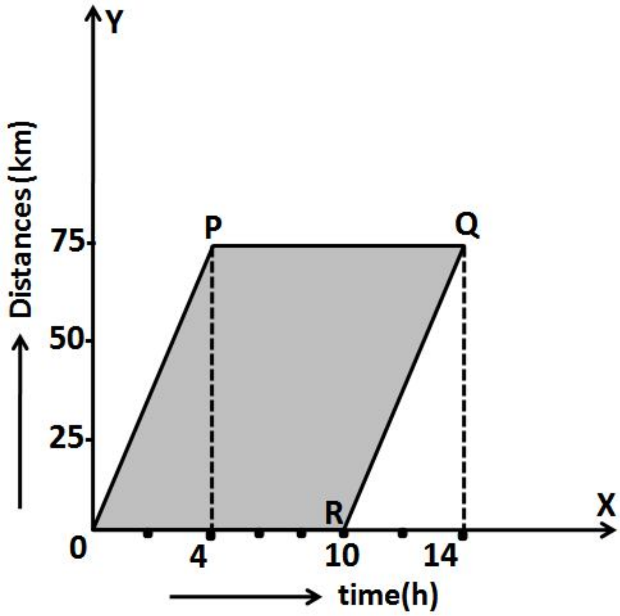
The graph shows the velocity–time graph of a uniformly moving body.
Let the velocity of the body at time (t) be v.
Area of the shaded region = length × breath
Where, Length = t, Breath = v
Area = vt = velocity × time …(i)

We know, $Velocity = \frac{\text{Distance}}{Time}$

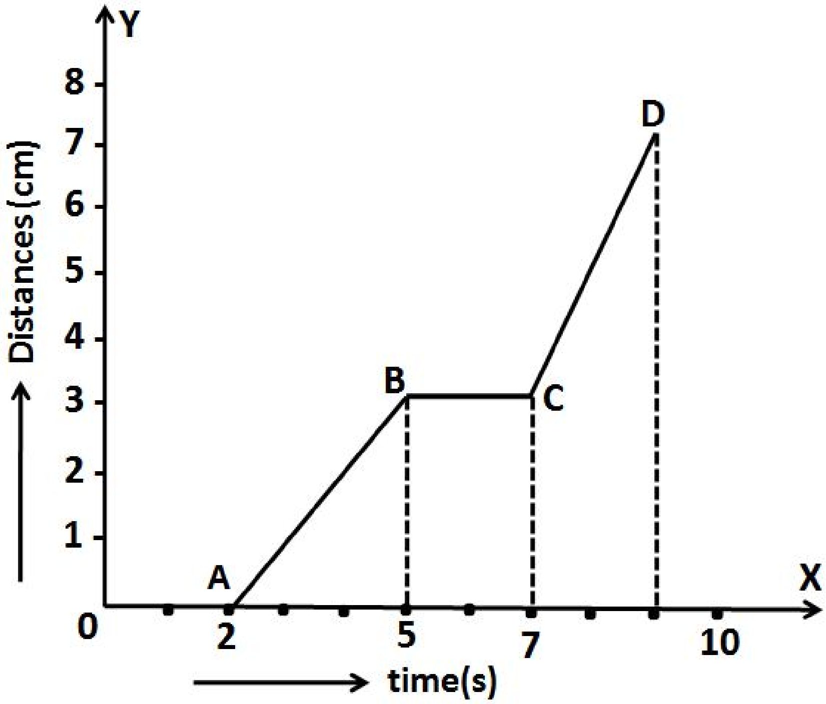
∴ Distance = Velocity × Time…(ii)
From equations (i) and (ii), Area = Distance
Hence, the area occupied below the velocity–time graph measures the distance covered by the body.

NUMERICALS

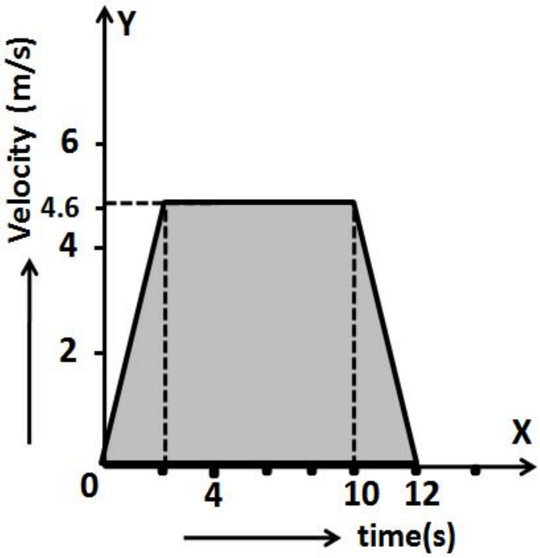
1. The right-sided figure is the distance-time graph of an object. Do you think it represents a real situation? If so, why? If not, why not?



2. The graph in below figure shows the positions of a body at different times. Calculate the speed of the body as it moves from (i) A to B (ii) B to C and (iii) C to D.



3. The velocity time graph of an ascending passenger lift is given below. What is the acceleration of the lift: (i) during the first two seconds (ii) between 2nd and 10th second (iii) during the last two seconds.



4. A body is moving uniformly with a velocity of 5m/s. Find graphically the distance travelled by it in 5 seconds.
5. Study the speed-time graph of a body shown in below figure and answer the following questions:

   (a) What type of motion is represented by OA?

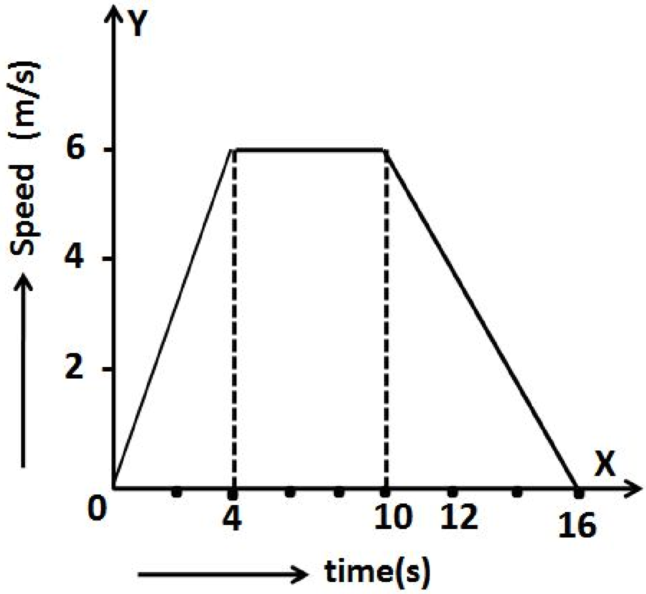
   (b) What type of motion is represented by AB?

   (c) What type of motion is represented by BC?

   (d) Calculate the acceleration of the body.

   (e) Calculate the retardation of the body.

   (f) Calculate the distance travelled by the body from A to B.



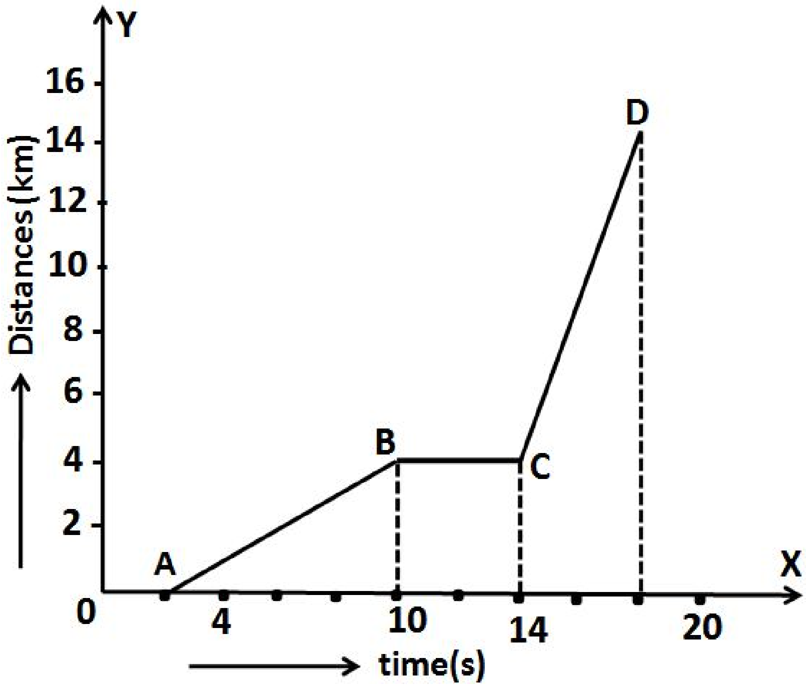
6. In the above question, calculate (i) distance travelled from O to A (ii) distance travelled from B to C. (iii) total distance travelled by the body in 16 sec.

7. A car is moving on a straight road with uniform acceleration. The following table gives the speed of the car at various instants of time:

Time(t)	0	10	20	30	40	50
Speed(m/s)	5	10	15	20	25	30

Draw the speed time graph choosing a convenient scale. Determine from it (i) the acceleration of the car (ii) the distance travelled by the car in 50 sec.

8. The graph in below figure shows the positions of a body at different times. Calculate the speed of the body as it moves from (i) A to B (ii) B to C and (iii) C to D.

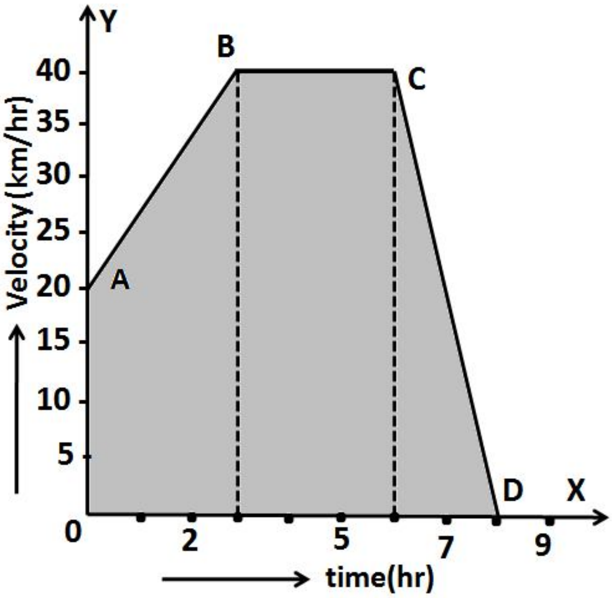


9. A car is moving on a straight road with uniform acceleration. The speed of the car varies with time as follows:

Time(t)	0	2	4	6	8	10
Speed(m/s)	4	8	12	16	20	24

Draw the speed time graph choosing a convenient scale. Determine from it (i) the acceleration of the car (ii) the distance travelled by the car in 10 sec.

10. The graph given below is the velocity-time graph for a moving body. Find (i) velocity of the body at point C (ii) acceleration acting on the body between A and B (iii) acceleration acting on the body between B and C.



EQUATIONS OF MOTION BY GRAPHICAL METHOD

When an object moves along a straight line with uniform acceleration, it is possible to relate its velocity, acceleration during motion and the distance covered by it in a certain time interval by a set of equations known as the equations of motion. There are three such equations. These are:

$$v = u + at \text{ --------------- } (1)$$

$$s = ut + \frac{1}{2}at^2 \text{ ------------- } (2)$$

$$2a\,s = v^2 - u^2 \text{ ----------- } (3)$$

where u is the initial velocity of the object which moves with uniform acceleration a for time t, v is the final velocity, and s is the distance travelled by the object in time t. Eq. (1) describes the velocity-time relation and Eq. (2) represents the position-time relation. Eq. (3), which represents the relation between the position and the velocity, can be obtained from Eqs. (1) and (2) by eliminating t. These three equations can be derived by graphical method.

EQUATION FOR VELOCITY-TIME RELATION

In the graph, AC gives the initial velocity (u). BE gives the final velocity (v). CE represents the time taken t. DF gives the change in velocity.

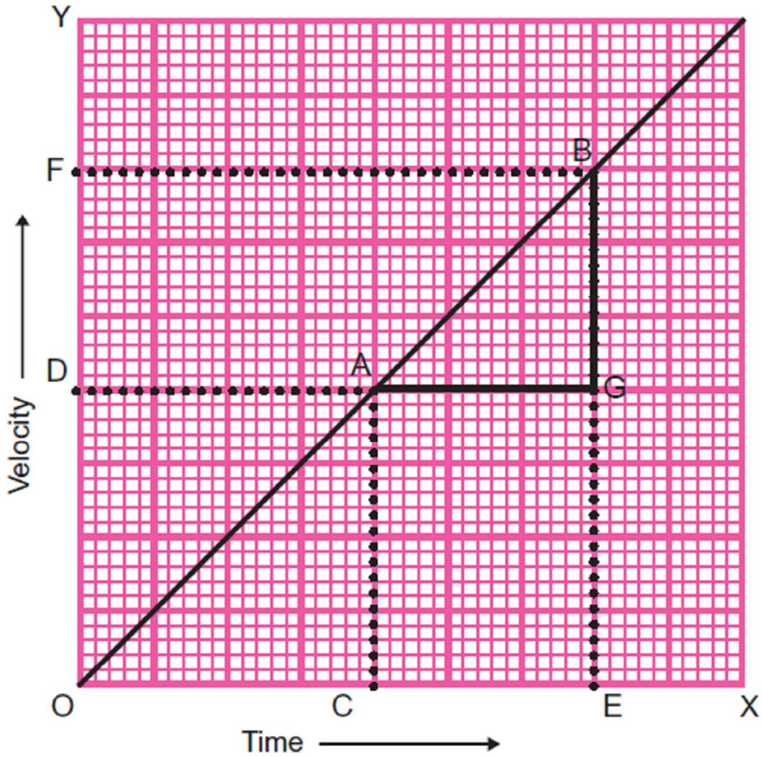
$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{Time}}$$

$$\Rightarrow a = \frac{DF}{CE} = \frac{OF - OD}{OE - OC}$$

But OE – OC = t

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

$\Rightarrow v - u = at$ …… (i)
$\Rightarrow v = u + at$ ……(I)



EQUATION FOR POSITION-VELOCITY RELATION

Let 's' be the displacement of the body in a time t.
In the graph, Displacement = Area CABE
s = Area of the rectangle CAGE + Area of the triangle ABG.

$s = AC \times CE + \frac{1}{2} (AG \times GB)$

Here AC = u
CE = t
AG = t
GB = v – u = at [from(i)]

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

$s = ut + \frac{1}{2} at^2$ …………… (II)

EQUATION FOR POSITION-TIME RELATION

In the graph, Displacement = Area of the trapezium CABE

$s = \frac{1}{2} (AC+EB) \times CE$

Here AC = u, EB = v, CE = t

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

From (i), we have $t = \frac{v-u}{a}$

Substituting the value of t,

$$s=\frac{u+v}{2}\times\frac{v-u}{a}$$
$$\Rightarrow s=\frac{v^2-u^2}{2a}$$
$$\Rightarrow v^2-u^2=2as$$
$v^2 = u^2 + 2as$ …………….(III)
(I), (II) and (III) are the equations of motion.

Acceleration due to gravity

The velocity of the body gradually decreases and becomes zero at a maximum height.The body is decelarated or retarded. When the body is allowed to fall down, the velocity gradually increases. Now the body is accelerated.

The decelaration or acceleration due to the gravitational force of earth is known as accelaration due to gravity, denoted as 'g'. The average value of 'g' is 9.8 m/s2. The velocity of the body thrown vertically upwards will decrease by 9.8m for every second and the velocity of a body falling down increases by 9.8m for every second.

The equations of motion for this body can be obtained from the equations of motion.

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

For the body thrown upwards, equations can be obtained by substituting
a = –g and s = h we get,

$$v = u - gt$$
$$h = ut - \frac{1}{2}gt^2$$
$$v^2 = u^2 - 2gh$$

When a body allowed to fall freely, u = 0. a = g and s = h.
Now, the equations will be

$$v = gt$$
$$h = \frac{1}{2}gt^2$$
$$v^2 = 2gh$$

INTEXT QUESTIONS PAGE NO. 109

1. A bus starting from rest moves with a uniform acceleration of 0.1 m s^{-2} for 2 minutes. Find (a) the speed acquired, (b) the distance travelled.

Ans.
(a) Initial speed of the bus, $u = 0$ (since the bus is initially at rest)
Acceleration, $a = 0.1$ m/s^2
Time taken, $t = 2$ minutes = 120 s
Let v be the final speed acquired by the bus.
$$\therefore a=\frac{v-u}{t}\Rightarrow 0.1=\frac{v-0}{120}$$
$\therefore v = 12$ m/s

(b) According to the third equation of motion:
$v^2 - u^2 = 2as$
Where, s is the distance covered by the bus
$(12)^2 - (0)^2 = 2(0.1)\, s$
$s = 720$ m
Speed acquired by the bus is 12 m/s.
Distance travelled by the bus is 720 m.

2. A train is travelling at a speed of 90 km h^{-1}. Brakes are applied so as to produce a uniform acceleration of -0.5 m s^{-2}. Find how far the train will go before it is brought to rest.
Ans. Initial speed of the train, u = 90 km/h = 25 m/s
Final speed of the train, v = 0 (finally the train comes to rest)
Acceleration = -0.5 m s^{-2}
According to third equation of motion:
$v^2 = u^2 + 2\, as$
$(0)^2 = (25)^2 + 2\,(-0.5)\,s$
Where, s is the distance covered by the train
$$s = \frac{25^2}{2 \times 0.5} = 625m$$
The train will cover a distance of 625 m before it comes to rest.

3. A trolley, while going down an inclined plane, has an acceleration of 2 cm s^{-2}. What will be its velocity 3 s after the start?
Ans. Initial velocity of the trolley, u = 0 (since the trolley was initially at rest)
Acceleration, a = 2 cm s^{-2} = 0.02 m/s^2
Time, t = 3 s
According to the first equation of motion:
$v = u + at$
Where, v is the velocity of the trolley after 3 s from start
$v = 0 + 0.02 \times 3 = 0.06$ m/s
Hence, the velocity of the trolley after 3 s from start is 0.06 m/s.

4. A racing car has a uniform acceleration of 4 m s^{-2}. What distance will it cover in 10 s after start?
Ans. Initial velocity of the racing car, u = 0 (since the racing car is initially at rest)
Acceleration, a = 4 m/s^2
Time taken, t = 10 s
According to the second equation of motion: $s = ut + \frac{1}{2}at^2$
Where, s is the distance covered by the racing car
$$s = 0 + \frac{1}{2} \times 4 \times 10^2 = \frac{400}{2} = 200m$$
Hence, the distance covered by the racing car after 10 s from start is 200 m.

5. A stone is thrown in a vertically upward direction with a velocity of 5 m s^{-1}. If the acceleration of the stone during its motion is 10 m s^{-2} in the downward direction, what will be the height attained by the stone and how much time will it take to reach there?
Ans. Initially, velocity of the stone,u = 5 m/s
Final velocity, v = 0 (since the stone comes to rest when it reaches its maximum height)
Acceleration of the stone, a = acceleration due to gravity, g = 10 m/s^2
(in downward direction)
There will be a change in the sign of acceleration because the stone is being thrown upwards.

Acceleration, $a = -10$ m/s^2
Let s be the maximum height attained by the stone in time t.
According to the first equation of motion:
$v = u + at$
$0 = 5 + (-10)\,t$
$\therefore t = \frac{-5}{-10} = 0.5s$
According to the third equation of motion:
$v^2 = u^2 + 2\,as$
$(0)^2 = (5)^2 + 2(-10)$ s
$s = \frac{5^2}{20} = 1.25m$
Hence, the stone attains a height of 1.25 m in 0.5 s.

UNIFORM CIRCULAR MOTION

An athlete runs along the circumference of a circular path. This type of motion is known as circular motion. The movement of an object in a circular path is called circular motion.

When an object moves in a circular path with a constant velocity, its motion is called uniform circular motion. In uniform circular motion, the magnitude of the velocity is constant at all points and the direction of the velocity changes continuously.

We know that the circumference of a circle of radius r is given by $2\pi r$. If the athlete takes t seconds to go once around the circular path of radius r, the velocity v is given by

$$v = \frac{2\pi r}{t}$$

NUMERICALS

1. A car increases its speed from 20 km/h to 50 km/h in 10 seconds. What is its acceleration?

2. A ship is moving at a speed of 56km/h. One second later, it is moving at 58km/h. What is its acceleration?

3. A scooter acquires a velocity of 36km/h in 10 seconds just after the start. Calculate the acceleration of the scoter.

4. A racing car has uniform acceleration of 4m/s^2. What distance will it cover in 10 seconds after start?

5. A car acquires a velocity of 72km/h in 10 seconds starting from rest. Find (a) the acceleration (b) the average velocity (c) the distance travelled in this time.

6. A body is accelerating at a constant rate of 10m/s^2. If the body starts from rest, how much distance will it cover in 2 seconds?

7. An object undergoes an acceleration of 8m/s^2 starting from rest. Find the distance travelled in 1 second.

8. A moving train is brought to rest within 20 seconds by applying brakes. Find the initial velocity, if the retardation due to brakes is $2m/s^2$.

9. A car accelerates uniformly from 18km/h to 36 km/h in 5 seconds. Calculate (i) acceleration and (ii) the distance covered by the car in that time.

10. A body starts to slide over a horizontal surface with an initial velocity of 0.5 m/s. Due to friction, its velocity decreases at the rate of $0.05\ m/s^2$. How much time will it take for the body to stop?

11. A train starting from the rest moves with a uniform acceleration of $0.2\ m/s^2$ for 5 minutes. Calculate the speed acquired and the distance travelled in this time.

12. A bus was moving with a speed of 54 km/h. On applying brakes, it stopped in 8 seconds. Calculate the acceleration and the distance travelled before stopping.

13. A motor cycle moving with a speed of 5 m/s is subjected to an acceleration of 0.2 m/s^2. Calculate the speed of the motor cycle after 10 seconds and the distance travelled in this time.

14. The brakes applied to a car produce an acceleration of $6\ m/s^2$ in the opposite direction to the motion. If the car takes 2 seconds to stop after the application of brakes, calculate the distance it travels during this time.

15. A train starting from rest attains a velocity of 72 km/h in 5 minutes. Assuming that the acceleration is uniform, find (i) the acceleration and (ii) the distance travelled by the train for attaining this velocity.

16. Calculate the speed of the tip of second's hand of a watch of length 1.5 cm.

17. A cyclist goes once round a circular track of diameter 105m in 5 minutes. Calculate his speed.

18. A cyclist moving on a circular track of radius 50m complete revolution in 4 minutes. What is his (i) average speed (ii) average velocity in one full revolution?

19. The length of minutes hand of a clock in 5 cm. Calculate its speed.

20. A car starts from rest and moves along the x-axis with constant acceleration 5m/s2 for 8 seconds. If it then continues with constant velocity, what distance will the car cover in 12 seconds since it started from the rest?

21. An object is dropped from rest at a height of 150m and simultaneously another object is dropped from rest at a height 100m. What is the difference in their heights after 2 seconds if both the objects drop with same acceleration? How does the difference in heights vary with time?

22. Obtain a relation for the distance travelled by an object moving with a uniform acceleration in the interval between 4^{th} and 5^{th} seconds.

23. Two stones are thrown vertically upwards simultaneously with their initial velocities u_1 and u_2 respectively. Prove that the heights reached by them would be in the ratio of $u_1^2:u_2^2$ (Assume upward acceleration is – g and downward acceleration to be +g).

24. An object starting from rest travels 20m in first 2 seconds and 160m in next 4 seconds. What will be the velocity after 7 seconds from the start?

25. An electron moving with a velocity of 5×10^4 m/s enters into a uniform electric field and acquires a uniform acceleration of $10^4 m/s^2$ in the direction of its initial motion. (i) Calculate the time in which the electron would acquire a velocity double of its initial velocity. (ii) How much distance the electron would cover in this time?

EXERCISE QUESTIONS PAGE NO. 112

1. An athlete completes one round of a circular track of diameter 200 m in 40 s. What will be the distance covered and the displacement at the end of 2 minutes 20 s?
Ans. Diameter of a circular track, d = 200 m

Radius of the track, $r = \frac{d}{2} = 100m$

Circumference = $2\pi r$ = 2π (100) = 200π m
In 40 s, the given athlete covers a distance of 200π m.

In 1 s, the given athlete covers a distance = $\frac{200\pi}{40} m$

The athlete runs for 2 minutes 20 s = 140 s

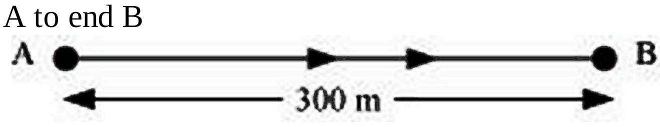
$\therefore$Total distance covered in $140s = \frac{200 \times 22}{40 \times 7} \times 140 = 2200m$

The athlete covers one round of the circular track in 40 s. This means that after every 40 s, the athlete comes back to his original position. Hence, in 140 s he had completed 3 rounds of the circular track and is taking the fourth round.
He takes 3 rounds in 40 × 3 = 120 s. Thus, after 120 s his displacement is zero.
Then, the net displacement of the athlete is in 20 s only. In this interval of time, he moves at the opposite end of the initial position. Since displacement is equal to the shortest distance between the initial and final position of the athlete, displacement of the athlete will be equal to the diameter of the circular track.

$\therefore$ Displacement of the athlete = 200 m

Distance covered by the athlete in 2 min 20 s is 2200 m and his displacement is 200 m.

2. Joseph jogs from one end A to the other end B of a straight 300 m road in 2 minutes 50 seconds and then turns around and jogs 100 m back to point C in another 1 minute. What are Joseph's average speeds and velocities in jogging (a) from A to B and (b) from A to C?
Ans. (a) From end A to end B



Distance covered by Joseph while jogging from A to B = 300 m
Time taken to cover that distance = 2 min 50 seconds = 170 s

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

Total distance covered = 300 m
Total time taken = 170 s
Displacement = shortest distance between A and B = 300 m
Time interval = 170 s

$$Average\ \ speed = \frac{300}{170} = 1.765m/s$$

$$Average\ \ velocity = \frac{\text{Displacement}}{\text{Total time taken}}$$

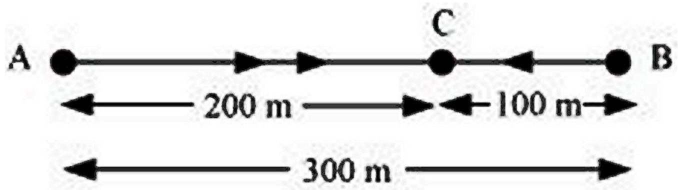
Displacement = shortest distance between A and B = 300 m

Time interval = 170 s

$$Average\ \ velocity = \frac{300}{170} = 1.765 m/s$$

The average speed and average velocity of Joseph from A to B are the same and equal to 1.765 m/s.

(b) From end A to end C



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

Total distance covered = Distance from A to B + Distance from B to C

= 300 + 100 = 400 m

Total time taken = Time taken to travel from A to B + Time taken to travel from B to C = 170 + 60 = 230 s

$$Average\ \ speed = \frac{400}{230} = 1.739 m/s$$

$$Average\ \ velocity = \frac{\text{Displacement}}{\text{Total time taken}}$$

Displacement from A to C = AC = AB − BC = 300 − 100 = 200 m

Time interval = time taken to travel from A to B + time taken to travel from B to C

= 170 + 60 = 230 s

$$Average\ \ velocity = \frac{200}{230} = 0.87 m/s$$

The average speed of Joseph from A to C is 1.739 m/s and his average velocity is 0.87 m/s.

3. Abdul, while driving to school, computes the average speed for his trip to be 20 km/h. On his return trip along the same route, there is less traffic and the average speed is 40 km/h. What is the average speed for Abdul's trip?

Ans. Case I: While driving to school

Average speed of Abdul's trip = 20 km/h

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

Total distance = Distance travelled to reach school = *d*

Let total time taken = t_1

$$\therefore 20 = \frac{d}{t_1} \Rightarrow t_1 = \frac{d}{20} ....(i)$$

Case II: While returning from school

Total distance = Distance travelled while returning from school = *d*

Now,total time taken = t_2

$$\therefore 40 = \frac{d}{t_2} \Rightarrow t_1 = \frac{d}{40} ....(ii)$$

$$\text{Average Speed for Abdul's trip} = \frac{\text{Total distance covered in the trip}}{\text{Total time taken}}$$

Where,
Total distance covered in the trip = $d + d = 2d$
Total time taken, t = Time taken to go to school + Time taken to return to school
= $t_1 + t_2$

$$\therefore \text{Average speed} = \frac{2d}{t_1+t_2}$$

From equations (i) and (ii),

$$\text{Average speed} = \frac{2d}{\frac{d}{20}+\frac{d}{40}} = \frac{2}{\frac{2+1}{40}} = \frac{80}{3} = 26.67 m/s$$

Hence, the average speed for Abdul's trip is 26.67 m/s.

4. A motorboat starting from rest on a lake accelerates in a straight line at a constant rate of 3.0 m/s^2 for 8.0 s. How far does the boat travel during this time?
Ans. Initial velocity, $u = 0$ (since the motor boat is initially at rest)
Acceleration of the motorboat, $a = 3$ m/s^2
Time taken, $t = 8$ s
According to the second equation of motion:

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

Distance covered by the motorboat, s

$$s = 0 + \frac{1}{2}\times 3\times 8^2 = 96m$$

Hence, the boat travels a distance of 96 m.

5. A driver of a car travelling at 52 km/h applies the brakes and accelerates uniformly in the opposite direction. The car stops in 5 s. Another driver going at 3 km/h in another car applies his brakes slowly and stops in 10 s. On the same graph paper, plot the speed versus time graphs for the two cars. Which of the two cars travelled farther after the brakes were applied?
Ans. Case A:
Initial speed of the car, u_1 = 52 km/h = 14.4 m/s
Time taken to stop the car, t_1 = 5 s
Final speed of the car becomes zero after 5 s of application of brakes.
Case B:
Initial speed of the car, u_2 = 3 km/h = 0.833 m/s □ 0.83 m/s
Time taken to stop the car, t_2 = 10 s
Final speed of the car becomes zero after 10 s of application of brakes.
Plot of the two cars on a speed–time graph is shown in the following figure:

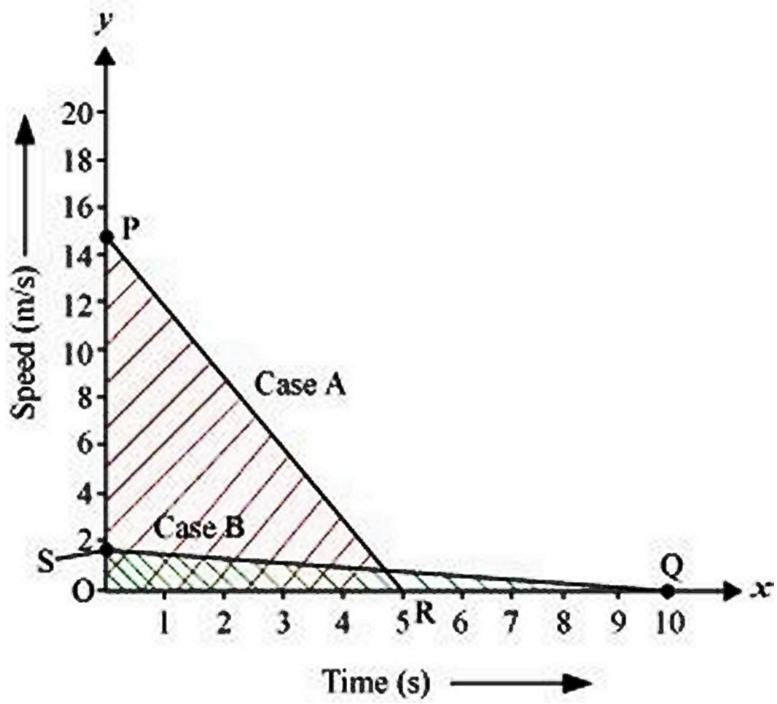
Distance covered by each car is equal to the area under the speed–time graph.
Distance covered in case A,

$$S_1 = \frac{1}{2}\times OP\times OR = \frac{1}{2}\times 14.4\times 5 = 36m$$

Distance covered in case B,

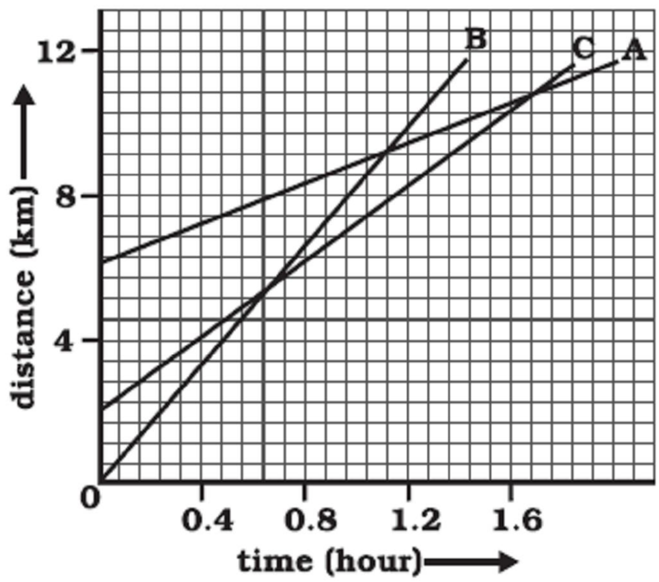
$$S_2 = \frac{1}{2}\times OS\times OQ = \frac{1}{2}\times 0.83\times 10 = 4.15m$$

Area of ΔOPR > Area of ΔOSQ



Thus, the distance covered in case A is greater than the distance covered in case B.
Hence, the car travelling with a speed of 52 km/h travels farther after brakes were applied.

6. Fig 8.11 shows the distance-time graph of three objects A,B and C. Study the graph and answer the following questions:



(a) Which of the three is travelling the fastest?
(b) Are all three ever at the same point on the road?
(c) How far has C travelled when B passes A?
(d) How far has B travelled by the time it passes C?

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

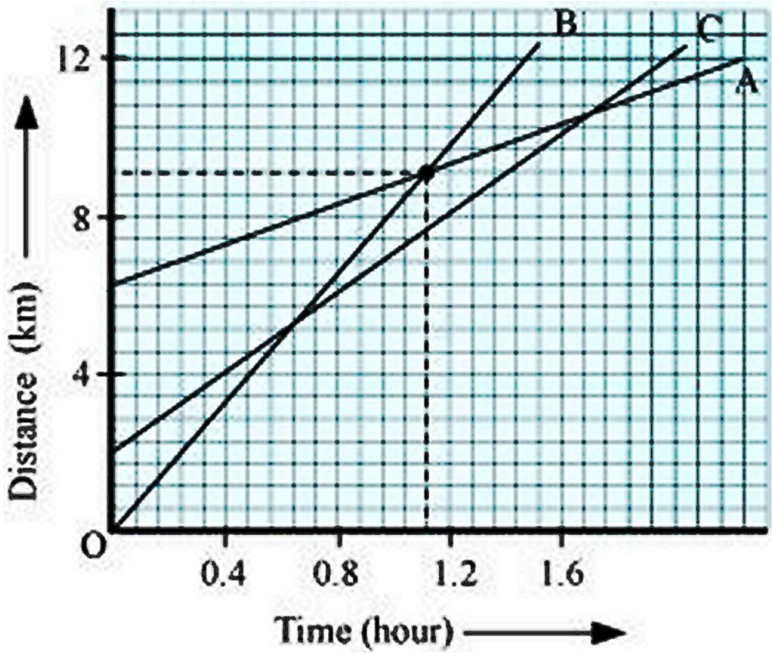
Slope of the graph= $\frac{\text{y-axis}}{\text{x-axis}} = \frac{\text{Distance}}{\text{Time}}$

$\therefore$Speed = slope of the graph

Since slope of object B is greater than objects A and C, it is travelling the fastest.

(b) All three objects A, B and C never meet at a single point. Thus, they were never at the same point on road.

(c) On the distance axis:



7 small boxes = 4 km

$\therefore$1 small box $= \frac{4}{7} km$

Initially, object C is 4 blocks away from the origin.

$\therefore$Initial distance of object C from origin $= \frac{16}{7} km$

Distance of object C from origin when B passes A = 8 km

Distance covered by C $= 8 - \frac{16}{7} = \frac{56-16}{7} = \frac{40}{7} = 5.714 km$

Hence, C has travelled a distance of 5.714 km when B passes A.

(d)

Distance covered by B at the time it passes C for 9 boxes $= \frac{4}{7} \times 9 = \frac{36}{7} = 5.143 km$

Hence, B has travelled a distance of 5.143 km when B passes A.

7. A ball is gently dropped from a height of 20 m. If its velocity increases uniformly at the rate of 10 m/s^2, with what velocity will it strike the ground? After what time will it strike the ground?

Ans. Distance covered by the ball, s = 20 m

Acceleration, a = 10 m/s^2

Initially, velocity, u = 0 (since the ball was initially at rest)

Final velocity of the ball with which it strikes the ground, v

According to the third equation of motion:

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

$v^2 = 0 + 2\,(10)\,(20)$

v = 20 m/s

According to the first equation of motion:

$v = u + at$

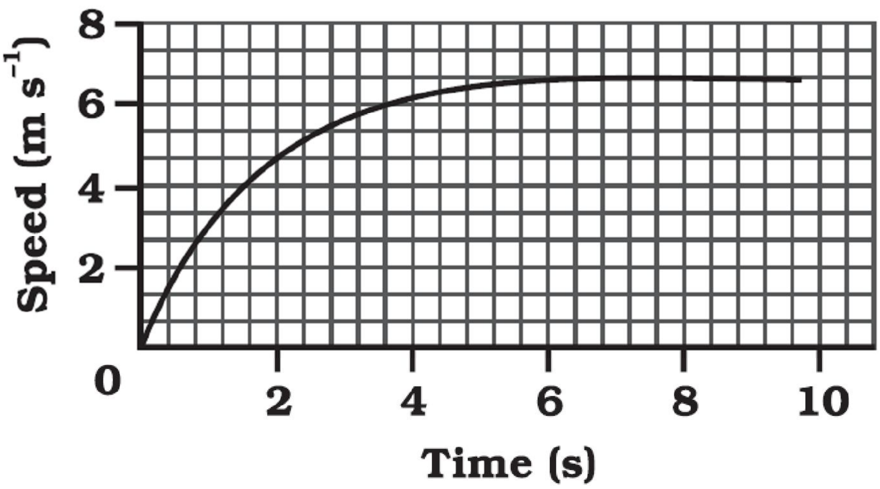
Where,

Time, t taken by the ball to strike the ground is,

20 = 0 + 10 (t)

$t = 2$ s
Hence, the ball strikes the ground after 2 s with a velocity of 20 m/s.

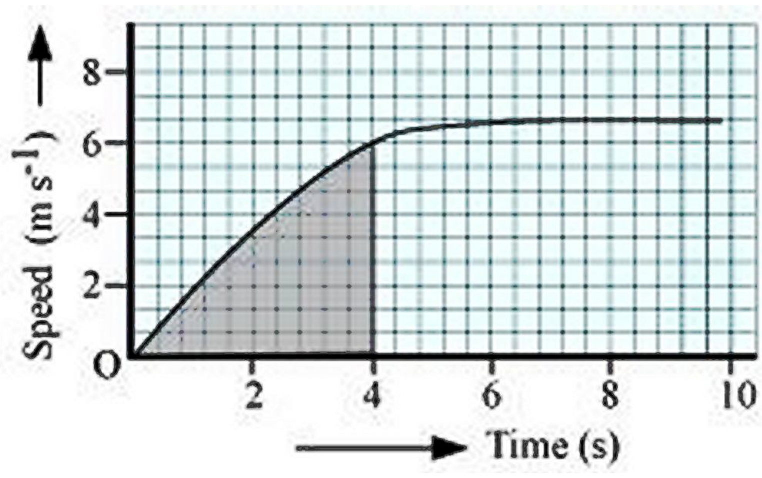
8. The speed-time graph for a car is shown is Fig. 8.12.



(a) Find how far does the car travel in the first 4 seconds. Shade the area on the graph that represents the distance travelled by the car during the period.
(b) Which part of the graph represents uniform motion of the car?

(a)

The shaded area which is equal to $\frac{1}{2} \times 4 \times 6 = 12m$ represents the distance travelled by the car in the first 4 s.



(b) The part of the graph in red colour between time 6 s to 10 s represents uniform motion of the car.

9. State which of the following situations are possible and give an example for each of these: (a) an object with a constant acceleration but with zero velocity (b) an object moving in a certain direction with an acceleration in the perpendicular direction.
Ans. (a) Possible
When a ball is thrown up at maximum height, it has zero velocity, although it will have constant acceleration due to gravity, which is equal to 9.8 m/s^2.
(b) Possible
When a car is moving in a circular track, its acceleration is perpendicular to its direction.

10. An artificial satellite is moving in a circular orbit of radius 42250 km. Calculate its speed if it takes 24 hours to revolve around the earth?

Ans. Radius of the circular orbit, r = 42250 km

Time taken to revolve around the earth, t = 24 h

Speed of a circular moving object,

$$v = \frac{2\pi r}{t}$$

$$\Rightarrow v = \frac{2 \times 3.14 \times 42250}{24}$$

$$\Rightarrow v = 1.105 \times 10^4 km/h = 3.069 km/s$$

Hence, the speed of the artificial satellite is 3.069 km/s.

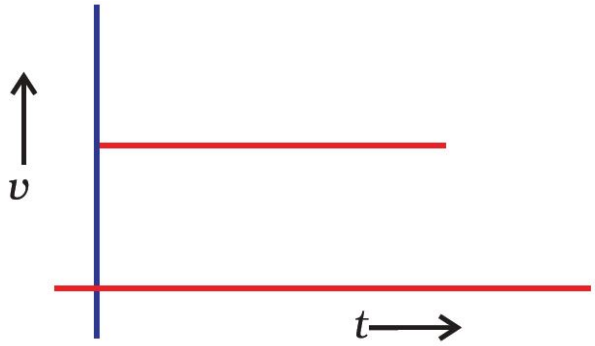
ASSIGNMENT QUESTIONS
MOTION

Multiple Choice Questions

1. If the displacement of an object is proportional to square of time, then the object moves with
(a) uniform velocity
(b) uniform acceleration
(c) increasing acceleration
(d) decreasing acceleration

2. The distance time graph of a body coincides with its time axis. The body must be
(a) in uniform motion
(b) at rest
(c) in uniformly accelerated motion
(d) in zig-zag motion

3. From the given *v* – *t* graph (see below Fig.), it can be inferred that the object is
(a) in uniform motion
(b) at rest
(c) in non-uniform motion
(d) moving with uniform acceleration



4. The velocity time graph of a body is parallel to the time axis. The body is
(a) at rest
(b) having uniform acceleration
(c) having zero acceleration
(d) having non-uniform acceleration

5. A particle is moving in a circular path of radius *r*. The displacement after half a circle would be:
(a) Zero
(b) πr
(c) $2r$
(d) $2\pi r$

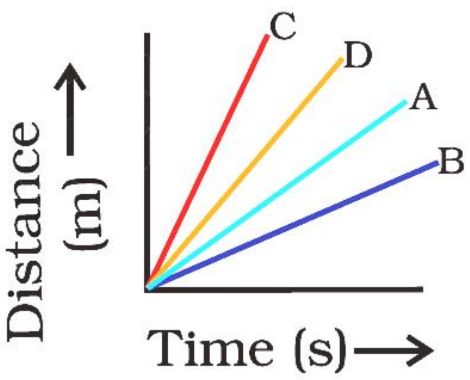
6. A body is thrown vertically upward with velocity *u*, the greatest height *h* to which it will rise is,
(a) u/g (b) $u^2/2g$ (c) u^2/g (d) $u/2g$

7. The numerical ratio of displacement to distance for a moving object is
(a) always less than 1
(b) always equal to 1
(c) always more than 1
(d) equal or less than 1

8. Suppose a boy is enjoying a ride on a *merry-go-round* which is moving with a constant speed of 10 m/s. It implies that the boy is
(a) at rest
(b) moving with no acceleration
(c) in accelerated motion
(d) moving with uniform velocity

9. Area under *a v – t* graph represents a physical quantity which has the unit
(a) m^2
(b) m
(c) m^3
(d) m/s

10. Four cars A, B, C and D are moving on a levelled road. Their distance versus time graphs are shown in below Fig.. Choose the correct statement
(a) Car A is faster than car D.
(b) Car B is the slowest.
(c) Car D is faster than car C.
(d) Car C is the slowest.



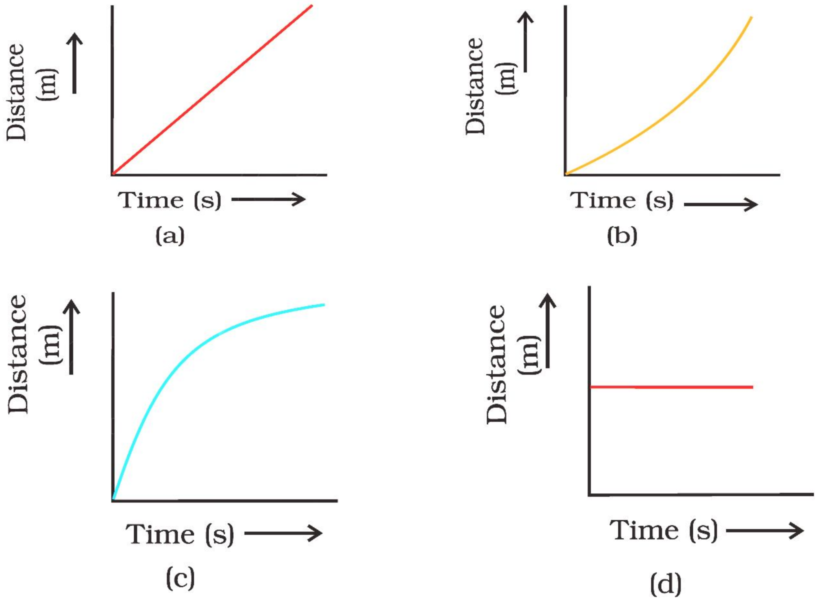
11. Slope of a velocity – time graph gives

(a) the distance
(b) the displacement
(c) the acceleration
(d) the speed

12. In which of the following cases of motions, the distance moved and the magnitude of displacement are equal?

(a) If the car is moving on straight road
(b) If the car is moving in circular path
(c) The pendulum is moving to and fro
(d) The earth is revolving around the Sun

13. Which of the following figures (see below Figure) represents uniform motion of a moving object correctly?



SHORT ANSWER QUESTIONS

14. The displacement of a moving object in a given interval of time is zero. Would the distance travelled by the object also be zero? Justify you answer.

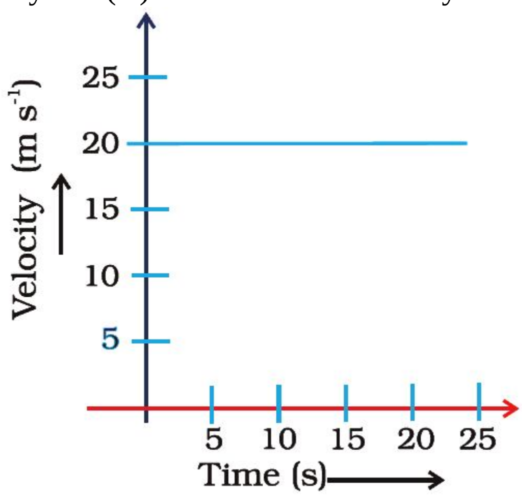
15. How will the equations of motion for an object moving with a uniform velocity change?

16. A car starts from rest and moves along *the x*-axis with constant acceleration 5 m/s^2 for 8 seconds. If it then continues with constant velocity, what distance will the car cover in 12 seconds since it started from the rest?

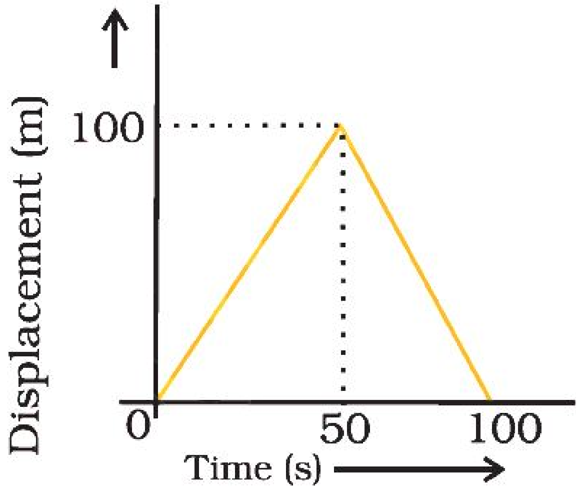
17. A motorcyclist drives from A to B with a uniform speed of 30 km/h and returns back with a speed of 20 km/h. Find its average speed.

18. Draw a velocity versus time graph of a stone thrown vertically upwards and then coming downwards after attaining the maximum height.

19. The velocity-time graph (see below Figure) shows the motion of a cyclist. Find (i) its acceleration (ii) its velocity and (iii) the distance covered by the cyclist in 15 seconds.



20. A girl walks along a straight path to drop a letter in the letterbox and comes back to her initial position. Her displacement–time graph is shown in below figure. Plot a velocity–time graph for the same.



LONG ANSWER QUESTIONS

21. An object starting from rest travels 20 m in first 2 s and 160 m in next 4 s. What will be the velocity after 7 s from the start.

22. An electron moving with a velocity of 5 × 104 m/s enters into a uniform electric field and acquires a uniform acceleration of 104 m/s^2 in the direction of its initial motion.
(i) Calculate the time in which the electron would acquire a velocity double of its initial velocity.
(ii) How much distance the electron would cover in this time?

23. Obtain a relation for the distance travelled by an object moving with a uniform acceleration in the interval between 4th and 5th seconds.

24. Two stones are thrown vertically upwards simultaneously with their initial velocities u_1 and u_2 respectively. Prove that the heights reached by them would be in the ratio of $u_1^2 : u_2^2$ (Assume upward acceleration is $-g$ and downward acceleration to be $+g$).

25. An object is dropped from rest at a height of 150 m and simultaneously another object is dropped from rest at a height 100 m. What is the difference in their heights after 2 s if both the objects drop with same accelerations? How does the difference in heights vary with time?

CHAPTER – 9

FORCE AND LAWS OF MOTION

FORCE

A force is anything that can cause a change to objects. Forces can:

- change the shape of an object
- move or stop an object
- change the direction of a moving object.

A force can be classified as either a contact force or a non-contact force.

A contact force must touch or be in contact with an object to cause a change. Examples of contact forces are:

- the force that is used to push or pull things, like on a door to open or close it
- the force that a sculptor uses to turn clay into a pot
- the force of the wind to turn a windmill

A non-contact force does not have to touch an object to cause a change. Examples of non-contact forces are:

- the force due to gravity, like the Earth pulling the Moon towards itself
- the force due to electricity, like a proton and an electron attracting each other
- the force due to magnetism, like a magnet pulling a paper clip towards itself

The unit of force is the newton (symbol N). This unit is named after Sir Isaac Newton who first defined force. Force is a vector quantity and has a magnitude and a direction.

EFFECT OF FORCE:

1. Force can make a stationary body in motion. For example a football can be set to move by kicking it, i.e. by applying a force.
2. Force can stop a moving body – For example by applying brakes, a running cycle or a running vehicle can be stopped.
3. 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.
4. 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.
5. 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 can also divided into two types:

1. Balanced Forces
2. Unbalanced Forces

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 teams 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.

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:

NEWTON'S LAWS OF MOTION:

- Newton's First Law of Motion - 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.
- Newton's Second Law of Motion - The rate of change of momentum is directly proportional to the force applied in the direction of force.
- Newton's Third Law of Motion - There is an equal and opposite reaction for evrey action

NEWTON'S FIRST LAW OF MOTION:

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 untill a exernal force is applied to change its state. Similarly an object will remain in motion untill 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 is start 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 tendency to remain in rest. Because of this 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 the contact with bus come in rest while the rest parts of his body have tendency to remain in motion. Because of this person falls forward if he is not alert.

MASS AND INERTIA:

The property of an object because of which it resists to get disturbed 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 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 pul a heavy box over the ground than lighter one.

INTEXT QUESTIONS PAGE NO. 118

1. Which of the following has more inertia: (a) a rubber ball and a stone of the same size? (b) a bicycle and a train? (c) a five-rupees coin and a one-rupee coin?
Ans. Inertia is the measure of the mass of the body. The greater is the mass of the body; the greater is its inertia and vice-versa.
(a) Mass of a stone is more than the mass of a rubber ball for the same size. Hence, inertia of the stone is greater than that of a rubber ball.
(b) Mass of a train is more than the mass of a bicycle. Hence, inertia of the train is greater than that of the bicycle.
(c) Mass of a five rupee coin is more than that of a one-rupee coin. Hence, inertia of the five rupee coin is greater than that of the one-rupee coin.

2. In the following example, try to identify the number of times the velocity of the ball changes:
"A football player kicks a football to another player of his team who kicks the football towards the goal. The goalkeeper of the opposite team collects the football and kicks it towards a player of his own team". Also identify the agent supplying the force in each case.
Ans. The velocity of the ball changes four times. As a football player kicks the football, its speed changes from zero to a certain value. As a result, the velocity of the ball gets changed. In this case, the player applied a force to change the velocity of the ball. Another player kicks the ball towards the goal post. As a result, the direction of the ball gets changed. Therefore, its velocity also changes. In this case, the player applied a force to change the velocity of the ball. The goalkeeper collects the ball. In other words, the ball comes to rest. Thus, its speed reduces to zero from a certain value. The velocity of the ball has changed. In this case, the goalkeeper applied an opposite force to stop/change the velocity of the ball. The goalkeeper kicks the ball towards his team players. Hence, the speed of the ball increases from zero to a certain value. Hence, its velocity changes once again. In this case, the goalkeeper applied a force to change the velocity of the ball.

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

4. Why do you fall in the forward direction when a moving bus brakes to a stop and fall backwards when it accelerates from rest?
Ans. Due to the inertia of the passenger. Every body tries to maintain its state of motion or state of rest. If a body is at rest, then it tries to remain at rest. If a body is moving, then it

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

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 x Velocity.

Or, p = m x v

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

NEWTON'S SECOND LAW OF MOTION

Newton's second Law of Motion states that The rate of change of momentum is directly proportional to the force applied in the direction of force.
For example; when acceleration is applied on a moving vehicle, the momentum of the vehicle increases and the increase is in the direction of motion because the force is being applied in the direction of motion. On the other hand, when brake is applied on the moving vehicle, the momentum of the vehicle decreases and the decrease is in the opposite direction of motion because the force is being applied in the opposite direction of motion.

Mathematical formulation of Newton's Second Law of Motion:

Let mass of an moving object = m.
Let the velocity of the object changes from 'u' to 'v' in the interval of time 't'.
This means,
Initial velocity of the object = u.
Final velocity of the object = v.
We know that momentum (p) = Mass x velocity
Therefore,
Momentum (p) of the object at its initial velocity u = m x u = mu
Momentum (p) of the object at its final velocity v = m x v = mv
The change in momentum = mv – mu

Rate of change of momentum $= \frac{mv - mu}{t}$ ………………… (i)

According to the Newton's Second Law of motion force is directly proportional to the rate of change of momentum.

This means, Force ∝ Rate of change of moentum

After substituting the value of rate of change of momentum from equation (i) we get.

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

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

$$\Rightarrow F \propto ma \left(\because a = \frac{v-u}{t} \right)$$

$$\Rightarrow F = k.ma$$ ……………. **(ii)**

where, k is proportionality constant.
Since, 1 unit force is defined as the mass of 1kg object produces the acceleration of $1m/s^2$
Therefore, 1 unit of Force = k x 1 kg x $1m/s^2$
Thus k = 1.

By substituting the value of 'k = 1' in equation (ii) we get

F = m.a ……………… (iii)

⇒ Force = mass × acceleration

Thus Newton's Second Law of Motion gives the relation between force, mass and acceleration of an object.

According to the relation obtained above, Newton's Second Law can be modified as follows: The product of mass and acceleration is the force acting on the object.

The SI unit of Force: Newton (N)

Since Force = Mass x Acceleration

The unit of mass = kg and The unit of acceleration = m/s^2

If force, mass and acceleration is taken as 1 unit.

Therefore,

1 Newton (N) = 1kg x $1m/s^2$

Thus, Newton (N) = kg m/s^2

Equation (iii) can be also written as

$$a = \frac{F}{m} \quad \text{…………………} \quad \text{(iv)}$$

This equation is the form of Newton's Second Law of Motion.

According to this equation, Newton's Second Law of Motion can also be stated as follow: The acceleration produced by a moving body is directly proportional to the force applied over it and inversely proportional to the mass of the object.

From the above relation it is clear that

Acceleration increases with increase in force and vice versa.

Acceleration decreases with increase in mass and vice versa.

That's why a small vehicle requires less force to attain more acceleration while a heavy vehicle requires more force to get the same acceleration.

<u>NEWTON'S SECOND LAW OF MOTION IN EVERYDAY LIFE:</u>

a. A fielder pulls his hand backward; while catching a cricket ball coming with a great speed, to reduce the momentum of the ball with a little delay. According to Newton's Second Law of Motion; rate of change of momentum is directly proportional to the force applied in the direction.

b. While catching a cricket ball the momentum of ball is reduced to zero when it is stopped after coming in the hands of fielder. If the ball is stopped suddenly, its momentum will be reduced to zero instantly. The rate of change in momentum is very quick and as a result, the player's hand may get injured. Therefore, by pulling the hand backward a fielder gives more time to the change of momentum to become zero. This prevents the hands of fielder from getting hurt.

NUMERICAL

1. What is acceleration produced by a force of 12 Newton exerted on an object of mass 3 kg?

2. What force would be needed to produce an acceleration of $4m/s^2$ on a ball of mass 6 kg?

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

4. Calculate the force required to impart a car a velocity of 30m/s in 10 seconds. The mass of the car is 1500 kg.

5. A motorcycle is moving with a velocity of 90km/h and it takes 5 seconds to stop after the brakes are applied. Calculate the force exerted by the brakes on the motorcycle if its mass along with the rider is 200kg.

6. What is the momentum of a man of mass 75kg when he walks with a velocity of 2m/s?

7. What would be the force required to produce an acceleration of $2m/s^2$ in a body of mass 12 kg? What would be the acceleration it the force were doubled?

8. A man pushes a box of mass 50 kg with a force of 80N.What will be the acceleration of the box? What would be the acceleration if the mass were doubled?

9. A certain force exerted for 1.2 second raises the speed of an object from 1.8m/s to 4.2 m/s. Later, the same force is applied for 2 second. How much does the speed change in 2 second?

10. A constant force acts on an object of mass 5 kg for duration of 2 second. It increases the object's velocity from 3cm/s to 7m/s. Find the magnitude of the applied force. Now if the force were applied for a duration of 5 seconds, what would be the final velocity of the object?

11. A motorcar is moving with a velocity of 108km/h and it takes 4 seconds to stop after the brakes are applied. Calculate the force exerted by the brakes on the motorcar it its mass along with the passengers is 1000 kg.

12. A force of 5 N gives a mass m_1, an acceleration of 10 m/s^2, and a mass m_2, an acceleration of 20 m/s^2. What acceleration would it give if both the masses were tied together?

13. For how long should a force of 100 N act on a body of mass 20 kg so that it acquires a velocity of 100 m/s?

14. A 150 g ball traveling at 30m/s strikes the palm of a players hand and is stopped in 0.06 sec. Calculate the force exerted by the ball on the hand.

15. A body of mass 1 kg is kept at rest. A constant force of 6.0 N starts acting on it . Find the time taken by the body to move through a distance of 12m.

16. A force of 4 N acts on a body of mass 2 kg for 4 s. Assuming that the body to be initially at rest, find (i) its velocity when the force stops acting (ii) the distance covered in 10 s after the force starts acting.

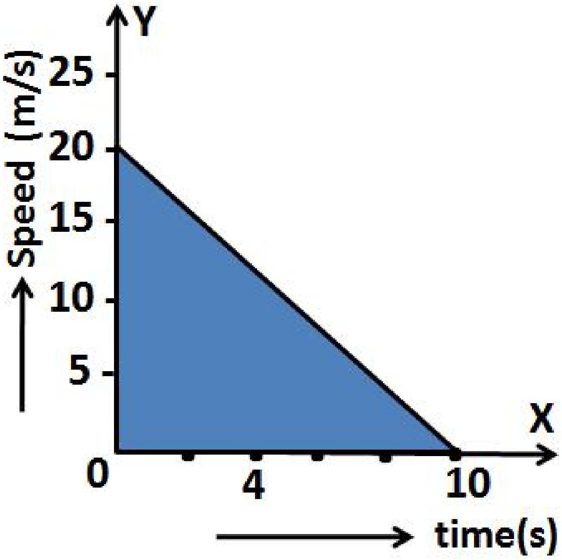
17. A feather of mass 10 g is dropped from a height. It is found to fall down with a constant velocity. What is the net force acting on it?

18. A hockey ball of mass 200g traveling from west to east at 10m/s is struck by a hockey stick. As a result, then ball gets turned back and now has a speed of 5m/s. If the ball and hockey stick were in contact for 0.2 s, calculate (i) initial and final momentum of the ball (ii) rate of change of momentum of the ball (iii) the force exerted by hockey stick on the ball.

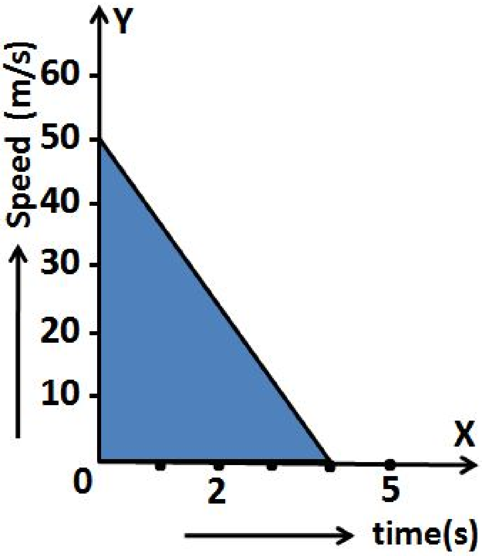
19. A stone of mass 500 g is thrown with a velocity of 20m/s across the frozen surface of a lake. It comes to rest after traveling a distance of 0.1 km. Calculate force of friction between the stone and frozen surface of lake.

20. A body starts from rest and rolls down a hill with a constant acceleration. If its travels 400 m in 20 seconds, calculate the force acting on the body if its mass is 10kg.

21. The velocity time graph of a ball of mass 20g moving along a straight line on a long table is given in below figure. How much force does the table exert on the ball to bring it to rest?



22. The speed time graph of a ball of mass 30g moving along a straight line is shown in below figure. Calculate the opposing force that brings the ball to rest.



What will be the percentage change in momentum of a body when both its mass and velocity are doubled?

23. A force of 2 N gives a mass m1 an acceleration of 5m/s2 and a mass m2, an accelerated of 7m/s2. What acceleration would be produced if both the masses are tied together?

24. A body of mass 2 kg moving with a velocity of 10m/s is brought to rest in 5 sec. Calculate the stopping force applied.

NEWTON'S THIRD LAW OF MOTION

Newton's Third Law of Motion states that there is always reaction for every action in opposite direction and of equal magnitude.

Explanation: Whenever a force is applied over a body, that body also applies same force of equal magnitude and in opposite direction.

Example –

(a) Walking of a person - A person is able to walk because of the Newton's Third Law of Motion. During walking, a person pushes the ground in backward direction and in the reaction the ground also pushes the person with equal magnitude of force but in opposite direction. This enables him to move in forward direction against the push.

(b) Recoil of gun - When bullet is fired from a gun, the bullet also pushes the gun in opposite direction, with equal magnitude of force. This results in gunman feeling a backward push from the butt of gun.

(c) Propulsion of a boat in forward direction – Sailor pushes water with oar in backward direction; resulting water pushing the oar in forward direction. Consequently, the boat is pushed in forward direction. Force applied by oar and water are of equal magnitude but in opposite directions.

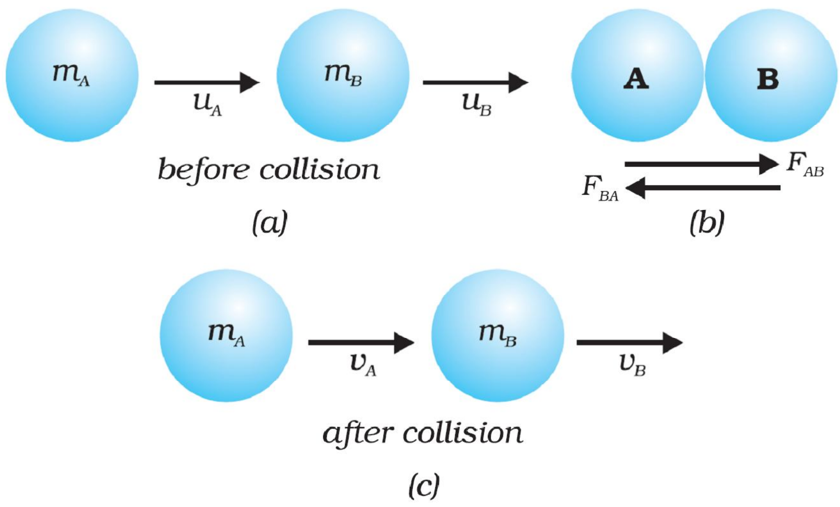
CONSERVATION OF MOMENTUM –

Law of Conservation of Momentum – The sum of momenta of two objects remains same even after collision.

In other words, the sum of momenta of two objects before collision and sum of momenta of two objects after collision are equal.

Mathematical Formulation of Conservation of Momentum:

Suppose that, two objects A and B are moving along a straight line in same direction and the velocity of A is greater than the velocity of B.



Let the initial velocity of A=u_A

Let the initial velocity of B= u_B

Let the mass of A= m_A

Let the mass of B=m_B

Let both the objects collide after some time and collision lasts for ' t' second.

Let the velocity of A after collision= v_A

Let the velocity of B after collision= v_B

We know that, Momentum = Mass x Velocity
Therefore,
Momentum of A (F_A) before collision = m_A x u_A
Momentum of B (F_B) before collision = m_B x u_B
Momentum of A after collision = m_A x v_A
Momentum of B after collision = m_B x v_B

Now, we know that Rate of change of momentum = mass x rate of change in velocity

$\Rightarrow$ Rate of change of momentum $= \text{mass} \times \dfrac{\text{Change in velocity}}{time}$

Therefore, rate of change of momentum of A during collision, $F_{AB} = m_A\left(\dfrac{v_A - u_A}{t}\right)$

Similarly, the rate of change of momentum of B during collision, $F_{BA} = m_B\left(\dfrac{v_B - u_B}{t}\right)$

Since, according to the Newton's Third Law of Motion, action of the object A (force exerted by A) will be equal to reaction of the object B (force exerted by B). But the force exerted in the course of action and reaction is in opposite direction.
Therefore,

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

$$or, m_A\left(\frac{v_A - u_A}{t}\right) = -m_B\left(\frac{v_B - u_B}{t}\right)$$

$$\Rightarrow m_A(v_A - u_A) = -m_B(v_B - u_B)$$

$$\Rightarrow m_A v_A - m_A u_A = -m_B v_B + m_B u_B$$

$$\Rightarrow m_A v_A + m_B v_B = m_A u_A + m_B u_B \quad \ldots\ldots\ldots\ldots\ldots\ (i)$$

Above equation says that total momentum of object A and B before collision is equal to the total momentum of object A and B after collision. We observe that the total momentum of the two balls remains unchanged or conserved provided no other external force acts. As a result of this ideal collision experiment, we say that the sum of momenta of the two objects before collision is equal to the sum of momenta after the collision provided there is no external unbalanced force acting on them. This is known as the law of conservation of momentum. This statement can alternatively be given as the total momentum of the two objects is unchanged or conserved by the collision.

CONSERVATION OF MOMENTUM – PRACTICAL APPLICATION

- Bullet and Gun – When bullet is fired from a gun, gun recoils in the opposite direction of bullet. The momentum of bullet is equal to momentum of gun. Since, the bullet is has very small mass compared to the gun, hence velocity of bullet is very high compared to the recoil of gun. In the case of firing of bullet, law of conservation of momentum is applied as usual.
- When a cricket ball is hit by bat, the Law of Conservation of Momentum is applied.

NUMERICAL

1. The velocity of a body of mass 10kg increases from 4m/s to 8m/s when a force acts on it for 2s. (a) What is the momentum before and after the force acts? (b) What is the gain in momentum per second? (c) What is the value of the force?

2. A boy pushes a wall with a force of 20N. What is the magnitude and direction of the force experienced by the body?

3. A 20 g bullet is shot from a 5 kg gun with a velocity of 500m/s. What is the speed of the recoil of the gun?

4. A 10 g bullet is shot from a 5 kg gun with a velocity of 400m/s. What is the speed of the recoil of the gun?

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

6. A man weighting 60kg runs along the rails with a velocity of 18km/h and jumps into a car of mass 1 quintal standing on the rails. Calculate the velocity with which car will start traveling along the rails.

7. The car A of mass 1500kg, traveling at 25m/s collides with another car B of amss 1000kg traveling at 15m/s in the same direction. After collision, the velocity of car A becomes 20m/s. Calculate the velocity of car B after collision.

8. A bullet of mass 10g is fired from a gun of mass 6 kg with a velocity of 300m.s. Calculate the recoil velocity of the gun.

9. A bullet of mass 50g is fired from a gun of mass 6 kg with a velocity of 400m.s. Calculate the recoil velocity of the gun.

10. A bullet of mass 10g is moving with a velocity of 400m/s gets embedded in a freely suspended wooden block of mass 900g. What is the velocity acquired by the block?

11. A gun of mass 3 kg fires a bullet of mass 30g. The bullet takes 0.003s to move through the barrel of the gun and acquires a velocity of 100m/s. Calculate (i) the velocity with which the gun recoils (ii) the force exerted on gunman due to recoil of the gun.

12. A heavy car of mass 200kg traveling at 10m/s has a head on collision with a sports car B of mass 500kg. If both cars stop dead on colliding, what was the velocity of car B?

13. A machine gun fires 25h bullet at the rate of 600 bullets per minute with a speed of 200m/s. Calculate the force required to keep the gun in position.

14. A bullet of mass 20g is moving with a velocity of 300m/s gets embedded in a freely suspended wooden block of mass 880g. What is the velocity acquired by the block?

15. A girl of mass 50kg jumps out of a rowing boat of mass 300kg on to the bank with a horizontally velocity of 3m/s. With what velocity does the boat begin to move backwards?

16. A truck of mass 2500kg moving at 15m/s collides with a car of mass 1000kg moving with at 5m/s in the opposite direction. What is their common velocity?

17. A bullet of mass 20 g is fired horizontally with a velocity of 150m/s from a pistol of mass 2kg. What is the recoil velocity of the pistol?

18. A body of mass 60kg running at 3m/s jumps on to a trolley of mass 140kg moving with a velocity of 1.5m/s in the same direction. What is their common velocity?

19. A girl of mass 40kg jumps with a horizontal velocity of 5m/s onto a stationary cart with frictionless wheels. The mass of the cart is 3kg. What is her velocity as the cart starts moving? Assume that there is no external unbalanced force working in the horizontal direction?

20. Two hockey players of opposite teams, while trying to hit a hockey ball on the ground collide and immediately become entangled. One has a mass of 60kg, and was moving with a velocity 5m/s, while the other has a mass 55kg and was moving faster with a velocity of 6m/s towards the first player. In which direction and with what velocity will they move after they become entangled? Assume that the frictional force acting between the feet of the two players and ground is negligible.

INTEXT QUESTIONS PAGE NO. 126

1. If action is always equal to the reaction, explain how a horse can pull a cart.
Ans. A horse pushes the ground in the backward direction. According to Newton's third law of motion, a reaction force is exerted by the Earth on the horse in the forward direction. As a result, the cart moves forward.

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

3. From a rifle of mass 4 kg, a bullet of mass 50 g is fired with an initial velocity of 35 m s^{-1}. Calculate the initial recoil velocity of the rifle.
Ans. Mass of the rifle, m_1 = 4kg
Mass of the bullet, m_2 = 50g = 0.05 kg
Recoil velocity of the rifle = v_1
Bullet is fired with an initial velocity, v_2 = 35m/s
Initially, the rifle is at rest.
Thus, its initial velocity, $v = 0$
Total initial momentum of the rifle and bullet system $=(m_1 + m_2)v = 0$
Total momentum of the rifle and bullet system after firing
$= m_1v_1 + m_2v_2 = 4(v_1) + 0.05 \times 35 \quad = 4v_1 + 1.75$
According to the law of conservation of momentum:
Total momentum after the firing = Total momentum before the firing

$$4v_1 + 1.75 = 0 \Rightarrow v_1 = -\frac{1.75}{4} = -0.4375 m/s$$

The negative sign indicates that the rifle recoils backwards with a velocity of 0.4375 m/s.

4. Two objects of masses 100 g and 200 g are moving along the same line and direction with velocities of 2 m s^{-1} and 1 m s^{-1}, respectively. They collide and after the collision, the first object moves at a velocity of 1.67 m s^{-1}. Determine the velocity of the second object.

Ans.

Mass of one of the objects, m_1 = 100 g = 0.1 kg

Mass of the other object, m_2 = 200 g = 0.2 kg

Velocity of m_1 before collision, v_1 = 2 m/s

Velocity of m_2 before collision, v_2 = 1 m/s

Velocity of m_1 after collision, v_3 = 1.67 m/s

Velocity of m_2 after collision = v_4

According to the law of conservation of momentum:

Total momentum before collision = Total momentum after collision

$\therefore m_1v_1 + m_2v_2 = m_3v_3 + m_4v_4$

$\Rightarrow$ (0.1) x 2 + (0.2) x 1 = (0.1) x 1.67 + (0.2) x v_4

$\Rightarrow$ 0.4 = 0.167 + $0.2v_4$

$\therefore v_4$ = 1.165 m/s

Hence, the velocity of the second object becomes 1.165 m/s after the collision.

EXERCISE QUESTIONS PAGE NO. 128

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

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

2. When a carpet is beaten with a stick, dust comes out of it. Explain.

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

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

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

4. A batsman hits a cricket ball which then rolls on a level ground. After covering a short distance, the ball comes to rest. The ball slows to a stop because

(a) the batsman did not hit the ball hard enough.

(b) velocity is proportional to the force exerted on the ball.

(c) there is a force on the ball opposing the motion.

(d) there is no unbalanced force on the ball, so the ball would want to come to rest.

Ans. (c) A batsman hits a cricket ball, which then rolls on a level ground. After covering a short distance, the ball comes to rest because there is frictional force on the ball opposing its motion. Frictional force always acts in the direction opposite to the direction of motion. Hence, this force is responsible for stopping the cricket ball.

5. A truck starts from rest and rolls down a hill with a constant acceleration. It travels a distance of 400 m in 20 s. Find its acceleration. Find the force acting on it if its mass is 7 metric tonnes (*Hint*: 1 metric tonne = 1000 kg.)
Ans. Initial velocity, u = 0 (since the truck is initially at rest)
Distance travelled, s = 400 m
Time taken, t = 20 s
According to the second equation of motion: $s = ut + \frac{1}{2}at^2$
Where, Acceleration = a
$400 = 0 + \frac{1}{2}a(20)^2 \quad \Rightarrow 400 = \frac{1}{2}a(400)$
$\Rightarrow$ a = 2m/s^2
1 metric tonne = 1000 kg (Given)
$\therefore$ 7 metric tonnes = 7000 kg
Mass of truck, m = 7000 kg
From Newton's second law of motion:
Force, F = Mass × Acceleration
$F = ma$ = 7000 × 2 = 14000 N
Hence, the acceleration of the truck is 2 m/s^2 and the force acting on the truck is 14000 N.

6. A stone of 1 kg is thrown with a velocity of 20 m/s across the frozen surface of a lake and comes to rest after travelling a distance of 50 m. What is the force of friction between the stone and the ice?
Ans. Initial velocity of the stone, u = 20 m/s
Final velocity of the stone, v = 0 (finally the stone comes to rest)
Distance covered by the stone, s = 50 m
According to the third equation of motion:
$v^2 = u^2 + 2as$
Where,
Acceleration, a
$(0)^2 = (20)^2 + 2 \times a \times 50$
$a = -4$ m/s^2
The negative sign indicates that acceleration is acting against the motion of the stone.
Mass of the stone, m = 1 kg
From Newton's second law of motion:
Force, F = Mass × Acceleration
$F = ma$
$F = 1 \times (-4) = -4$ N
Hence, the force of friction between the stone and the ice is −4 N.

7. A 8000 kg engine pulls a train of 5 wagons, each of 2000 kg, along a horizontal track. If the engine exerts a force of 40000 N and the track offers a friction force of 5000 N, then calculate:
(a) the net accelerating force;
(b) the acceleration of the train; and
(c) the force of wagon 1 on wagon 2.

Ans.
(a)Force exerted by the engine, F = 40000 N
Frictional force offered by the track, F_f = 5000 N
Net accelerating force, $F_a = F - F_f = 40000 - 5000 = 35000$ N
Hence, the net accelerating force is 35000 N.
(b)Acceleration of the train = a
The engine exerts a force of 40000 N on all the five wagons.
Net accelerating force on the wagons, F_a = 35000 N
Mass of the wagons, m = Mass of a wagon × Number of wagons
Mass of a wagon = 2000 kg
Number of wagons = 5
$\therefore m = 2000 \times 5 = 10000$ kg
Mass of the engine, m' = 8000 kg
Total mass, M = $m + m'$ = 18000 kg
From Newton's second law of motion:
$F_a = Ma$
$$\Rightarrow a = \frac{F_a}{M} = \frac{35000}{18000} = 1.944 m/s^2$$
Hence, the acceleration of the wagons and the train is 1.944 m/s^2.
(c)Mass of all the wagons except wagon 1 is 4 × 2000 = 8000 kg
Acceleration of the wagons = 3.5 m/s^2
Thus, force exerted on all the wagons except wagon 1
= 8000 × 3.5 = 28000 N
Therefore, the force exerted by wagon 1 on the remaining four wagons is 28000 N.
Hence, the force exerted by wagon 1 on wagon 2 is 28000 N.

8. An automobile vehicle has a mass of 1500 kg. What must be the force between the vehicle and road if the vehicle is to be stopped with a negative acceleration of 1.7 m/s^2?
Ans. Mass of the automobile vehicle, m = 1500 kg
Final velocity, v = 0 (finally the automobile stops)
Acceleration of the automobile, $a = -1.7$ ms^{-2}
From Newton's second law of motion:
Force = Mass × Acceleration = 1500 × (−1.7) = −2550 N
Hence, the force between the automobile and the road is −2550 N, in the direction opposite to the motion of the automobile.

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

10. Using a horizontal force of 200 N, we intend to move a wooden cabinet across a floor at a constant velocity. What is the friction force that will be exerted on the cabinet?
Ans. A force of 200 N is applied in the forward direction. Thus, from Newton's third law of motion, an equal amount of force will act in the opposite direction. This opposite force is the fictional force exerted on the cabinet. Hence, a frictional force of 200 N is exerted on the cabinet.

11. Two objects, each of mass 1.5 kg, are moving in the same straight line but in opposite directions. The velocity of each object is 2.5 m s-1 before the collision during which they stick together. What will be the velocity of the combined object after collision?

Ans. Mass of one of the objects, $m_1 = 1.5$ kg
Mass of the other object, $m_2 = 1.5$ kg
Velocity of m_1 before collision, $v_1 = 2.5$ m/s
Velocity of m_2, moving in opposite direction before collision, $v_2 = -2.5$ m/s
(Negative sign arises because mass m_2 is moving in an opposite direction)
After collision, the two objects stick together.
Total mass of the combined object = $m_1 + m_2$
Velocity of the combined object = v
According to the law of conservation of momentum:
Total momentum before collision = Total momentum after collision
$m_1v_1 + m_2\, v_1 = (m_1 + m_2)\, v$
$1.5(2.5) + 1.5\,(-2.5) = (1.5 + 1.5)\, v$
$3.75 - 3.75 = 3\, v$
$v = 0$
Hence, the velocity of the combined object after collision is 0 m/s.

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

Ans. The truck has a large mass. Therefore, the static friction between the truck and the road is also very high. To move the car, one has to apply a force more than the static friction. Therefore, when someone pushes the truck and the truck does not move, then it can be said that the applied force in one direction is cancelled out by the frictioal force of equal amount acting in the opposite direction. Therefore, the student is right in justifying that the two opposite and equal cancel each other.

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

Ans. Mass of the hockey ball, m = 200 g = 0.2 kg
Hockey ball travels with velocity, $v_1 = 10$ m/s
Initial momentum = mv_1
Hockey ball travels in the opposite direction with velocity, $v_2 = -5$ m/s
Final momentum = mv_2
Change in momentum = $mv_1 - mv_2 = 0.2\,[10 - (-5)] = 0.2\,(15) = 3$ kg m s^{-1}
Hence, the change in momentum of the hockey ball is 3 kg m s^{-1}.

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

Ans. Now, it is given that the bullet is travelling with a velocity of 150 m/s.
Thus, when the bullet enters the block, its velocity = Initial velocity, u = 150 m/s
Final velocity, v = 0 (since the bullet finally comes to rest)
Time taken to come to rest, t = 0.03 s
According to the first equation of motion, $v = u + at$
Acceleration of the bullet, a
$0 = 150 + (a \times 0.03 \text{ s})$

$a = \frac{-150}{0.03} = -5000 m/s^2$

(Negative sign indicates that the velocity of the bullet is decreasing.)

According to the third equation of motion:

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

$0 = (150)^2 + 2(-5000)s$

$s = \frac{-(150)^2}{-2(5000)} = \frac{22500}{10000} = 2.25m$

Hence, the distance of penetration of the bullet into the block is 2.25 m.

From Newton's second law of motion:

Force, F = Mass × Acceleration

Mass of the bullet, m = 10 g = 0.01 kg

Acceleration of the bullet, $a = 5000$ m/s^2

$F = ma = 0.01 \times 5000 = 50$ N

Hence, the magnitude of force exerted by the wooden block on the bullet is 50 N.

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

Ans.

Mass of the object, $m_1 = 1$ kg

Velocity of the object before collision, $v_1 = 10$ m/s

Mass of the stationary wooden block, $m_2 = 5$ kg

Velocity of the wooden block before collision, $v_2 = 0$ m/s

∴ Total momentum before collision = $m_1 v_1 + m_2 v_2$

$= 1(10) + 5(0) = 10$ kg m s^{-1}

It is given that after collision, the object and the wooden block stick together.

Total mass of the combined system = $m_1 + m_2$

Velocity of the combined object = v

According to the law of conservation of momentum:

Total momentum before collision = Total momentum after collision

$m_1 v_1 + m_2 v_2 = (m_1 + m_2) v$

$1(10) + 5(0) = (1 + 5) v$

$v = \frac{10}{6} = \frac{5}{3} m/s$

The total momentum after collision is also 10 kg m/s.

Total momentum just before the impact = 10 kg m s^{-1}

Total momentum just after the impact = $(m_1 + m_2) v$ = $6 \times \frac{5}{3} = 10 kgm/s$

Hence, velocity of the combined object after collision = $\frac{5}{3} m/s$.

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

Ans.

Initial velocity of the object, $u = 5$ m/s

Final velocity of the object, $v = 8$ m/s

Mass of the object, $m = 100$ kg

Time take by the object to accelerate, $t = 6$ s

Initial momentum = mu = 100 × 5 = 500 kg m s^{-1}
Final momentum = mv = 100 × 8 = 800 kg m s^{-1}

Force exerted on the object, $F = \frac{mv - mu}{t}$

$\Rightarrow F = \frac{m(v-u)}{t} = \frac{800-500}{6} = \frac{300}{6} = 50N$

Initial momentum of the object is 500 kg m s^{-1}.
Final momentum of the object is 800 kg m s^{-1}.
Force exerted on the object is 50 N.

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

Ans.

According to the law of conservation of momentum:

Momentum of the car and insect system before collision = Momentum of the car and insect system after collision

Hence, the change in momentum of the car and insect system is zero.

The insect gets stuck on the windscreen. This means that the direction of the insect is reversed. As a result, the velocity of the insect changes to a great amount. On the other hand, the car continues moving with a constant velocity. Hence, Kiran's suggestion that the insect suffers a greater change in momentum as compared to the car is correct. The momentum of the insect after collision becomes very high because the car is moving at a high speed. Therefore, the momentum gained by the insect is equal to the momentum lost by the car.

Akhtar made a correct conclusion because the mass of the car is very large as compared to the mass of the insect.

Rahul gave a correct explanation as both the car and the insect experienced equal forces caused by the Newton's action-reaction law. But, he made an incorrect statement as the system suffers a change in momentum because the momentum before the collision is equal to the momentum after the collision.

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

Ans. Mass of the dumbbell, m = 10 kg
Distance covered by the dumbbell, s = 80 cm = 0.8 m
Acceleration in the downward direction, a = 10 m/s^2
Initial velocity of the dumbbell, u = 0
Final velocity of the dumbbell (when it was about to hit the floor) = v
According to the third equation of motion:
$v^2 = u^2 + 2as$
$v^2 = 0 + 2\,(10)\,0.8$
v = 4 m/s
Hence, the momentum with which the dumbbell hits the floor is = mv = 10 × 4 = 40 kg m s^{-1}

ADDITIONAL EXERCISE QUESTIONS PAGE NO. 128

1. The following is the distance-time table of an object in motion:

Time in seconds	**Distance in metres**
0	0
1	1
2	8
3	27
4	64
5	125
6	216
7	343

(a) What conclusion can you draw about the acceleration? Is it constant, increasing, decreasing, or zero?
(b)What do you infer about the forces acting on the object?

Ans.
(a) There is an unequal change of distance in an equal interval of time. Thus, the given object is having a non − uniform motion. Since the velocity of the object increases with time, the acceleration is increasing.
(b)According to Newton's second law of motion, the force acting on an object is directly proportional to the acceleration produced in the object. In the given case, the increasing acceleration of the given object indicates that the force acting on the object is also increasing.

2. Two persons manage to push a motorcar of mass 1200 kg at a uniform velocity along a level road. The same motorcar can be pushed by three persons to produce an acceleration of 0.2 m s-2. With what force does each person push the motorcar? (Assume that all persons push the motorcar with the same muscular effort.)

Ans.
Mass of the motor car = 1200 kg
Only two persons manage to push the car. Hence, the acceleration acquired by the car is given by the third person alone.
Acceleration produced by the car, when it is pushed by the third person,
$a = 0.2\ m/s^2$
Let the force applied by the third person be *F*.
From Newton's second law of motion:
Force = Mass × Acceleration
$F = 1200 \times 0.2 = 240$ N
Thus, the third person applies a force of magnitude 240 N.
Hence, each person applies a force of 240 N to push the motor car.

3. A hammer of mass 500 g, moving at 50 m s-1, strikes a nail. The nail stops the hammer in a very short time of 0.01 s. What is the force of the nail on the hammer?

Ans.
Mass of the hammer, $m = 500$ g = 0.5 kg
Initial velocity of the hammer, $u = 50$ m/s

Time taken by the nail to the stop the hammer, $t = 0.01$ s
Velocity of the hammer, $v = 0$ (since the hammer finally comes to rest)
From Newton's second law of motion:

$$Force, F = \frac{m(v-u)}{t} = \frac{0.5(0-50)}{0.01} = -2500N$$

The hammer strikes the nail with a force of −2500 N. Hence, from Newton's third law of motion, the force of the nail on the hammer is equal and opposite, i.e., +2500 N.

4. A motorcar of mass 1200 kg is moving along a straight line with a uniform velocity of 90 km/h. Its velocity is slowed down to 18 km/h in 4 s by an unbalanced external force. Calculate the acceleration and change in momentum. Also calculate the magnitude of the force required.

Ans.

Mass of the motor car, $m = 1200$ kg
Initial velocity of the motor car, u = 90 km/h = 25 m/s
Final velocity of the motor car, $v = 18$ km/h = 5 m/s
Time taken, $t = 4$ s
According to the first equation of motion:
$v = u + at$
5 = 25 + a (4)
$a = -5$ m/s^2
Negative sign indicates that its a retarding motion i.e. velocity is decreasing.
Change in momentum = $mv - mu = m(v-u)$
= 1200 (5 − 25) = − 24000 kg m s^{-1}
Force = Mass × Acceleration
= 1200 × − 5 = − 6000 N
Acceleration of the motor car = − 5 m/s^2
Change in momentum of the motor car = − 24000 kg m s^{-1}
Hence, the force required to decrease the velocity is 6000 N. (Negative sign indicates retardation, decrease in momentum and retarding force)

5. A large truck and a car, both moving with a velocity of magnitude v, have a head-on collision and both of them come to a halt after that. If the collision lasts for 1 s:
(a) Which vehicle experiences the greater force of impact?
(b) Which vehicle experiences the greater change in momentum?
(c) Which vehicle experiences the greater acceleration?
(d) Why is the car likely to suffer more damage than the truck?

Ans.

Let the mass of the truck be M and that of the car be m.
Thus, $M > m$
Initial velocity of both vehicles, v
Final velocity of both vehicles, $v' = 0$ (since the vehicles come to rest after collision)
Time of impact, $t = 1$ s
(a) From Newton's second law of motion, the net force experienced by each vehicle is given by the relation:

$$F_{car} = \frac{m(v'-v)}{t} = -mv$$

$$F_{truck} = \frac{M(v'-v)}{t} = -Mv$$

Since the mass of the truck is greater than that of the car, it will experience a greater force of impact.

(b) Initial momentum of the car = mv
Final momentum of the car = 0
Change in momentum = mv
Initial momentum of the truck = Mv
Final momentum of the truck = 0
Change in momentum = Mv
Since the mass of the truck is greater than that of the car, it will experience a greater change in momentum.

(c) From the first equation of motion, acceleration produced in a system is independent of the mass of the system. The initial velocity, the final velocity, and the time of impact remain the same in both cases. Hence, both the car and the truck experience the same amount of acceleration.

(d)According to Newton's third law of motion, for every action there is an equal and opposite reaction that acts on different bodies. Since the truck experiences a greater force of impact (action), this larger impact force is also experienced by the car (reaction). Thus, the car is likely to suffer more damage than the truck.

ASSIGNMENT QUESTIONS
FORCE AND LAWS OF MOTION

Multiple Choice Questions

1. Which of the following statement is ***not*** correct for an object moving along a straight path in an accelerated motion?
(a) Its speed keeps changing
(b) Its velocity always changes
(c) It always goes away from the earth
(d) A force is always acting on it

2. The forces of action and reaction are
(a) always equal only
(b) always equal and opposite
(c) always equal but in same direction
(d) always unequal and opposite.

3. According to the third law of motion, action and reaction
(a) always act on the same body
(b) always act on different bodies in opposite directions
(c) have same magnitude and directions
(d) act on either body at normal to each other

4. The action and reaction forces at
(a) on different bodies always
(b) on some body always
(c) on same body, sometimes
(d) on different bodies, sometimes

5. A goalkeeper in a game of football pulls his hands backwards after holding the ball shot at the goal. This enables the goal keeper to
(a) exert larger force on the ball
(b) reduce the force exerted by the ball on hands
(c) increase the rate of change of momentum
(d) decrease the rate of change of momentum

6. The inertia of an object tends to cause the object
(a) to increase its speed
(b) to decrease its speed
(c) to resist any change in its state of motion
(d) to decelerate due to friction

7. Principle of conservation of linear momentum is deduced from
(a) Newton's first law
(b) Newton's second law
(c) Newton's third law
(d) none of the above

8. The function of mud guards is based on
(a) inertia of rest
(b) inertia of direction

(c) inertia of motion
(d) none of the above

9. The force of action and reaction
(a) always cancel each other
(b) never cancel
(c) cancel sometimes
(d) cannot say

10. A passenger in a moving train tosses a coin which falls behind him. It means that motion of the train is
(a) accelerated
(b) uniform
(c) retarded
(d) along circular tracks

11. An object of mass 2 kg is sliding with a constant velocity of 4 m s–1 on a frictionless horizontal table. The force required to keep the object moving with the same velocity is
(a) 32 N
(b) 0 N
(c) 2 N
(d) 8 N

12. Rocket works on the principle of conservation of
(a) mass
(b) energy
(c) momentum
(d) velocity

13. A water tanker filled up to $\frac{2}{3}$ of its height is moving with a uniform speed. On sudden application of the brake, the water in the tank would
(a) move backward
(b) move forward
(c) be unaffected
(d) rise upwards

14. Inertia of a body in linear motion is measured by its
(a) mass
(b) momentum
(c) velocity
(d) none of the above

15. What mass of a body can attain an acceleration of $5 m/s^2$ under a force of 250 N?
(a) 5 kg
(b) 250 kg
(c) 50 kg
(d) 10 kg

SHORT ANSWER QUESTIONS

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

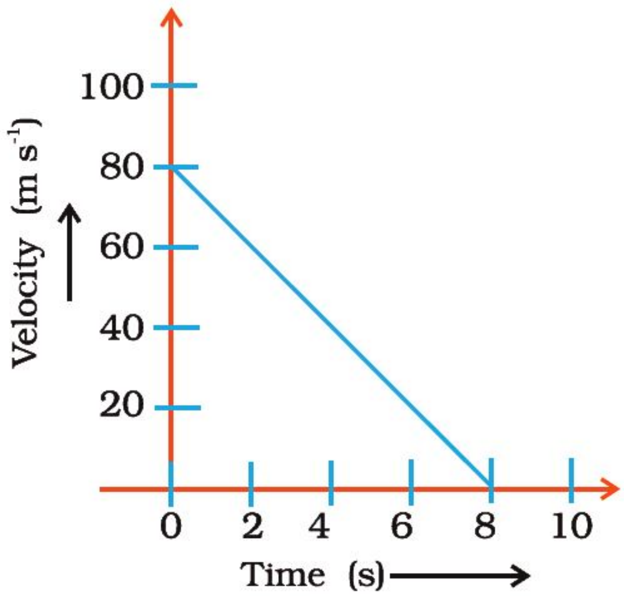
17. Two balls of the same size but of different materials, rubber and iron are kept on the smooth floor of a moving train. The brakes are applied suddenly to stop the train. Will the balls start rolling? If so, in which direction? Will they move with the same speed? Give reasons for your answer.

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

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

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

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



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

23. Why does a gun recoil on firing? Obtain an expression for recoil velocity of gun.

24. A rocket can move in air free space, but a jet plane cannot. Why?

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

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

LONG ANSWER QUESTIONS

27. Using second law of motion, derive the relation between force and acceleration. A bullet of 10 g strikes a sand-bag at a speed of 103 m/s and gets embedded after travelling 5 cm. Calculate

(i) the resistive force exerted by the sand on the bullet

(ii) the time taken by the bullet to come to rest.

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

29. State and explain Newton's third law of motion. How will you prove it experimentally?

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

(a) momentum versus velocity when mass is fixed.

(b) momentum versus mass when velocity is constant.

CHAPTER – 10

GRAVITATION

NEWTON'S UNIVERSAL LAW OF GRAVITATION

Every object in the Universe attracts every other object with a force which is

(i) directly proportional to the product of their masses, and

(ii) inversely proportional to the square of the distance between their centres. The direction of the force is along the line joining the centres of two objects.

$F \propto m_1 m_2$ and $F \propto \frac{1}{r^2}$ $\Rightarrow F \propto \frac{m_1 m_2}{r^2}$

$F = \frac{G.m_1 m_2}{r^2}$ where G is a constant proportionality and is called universal gravitational constant.

UNITS AND VALUE OF GRAVITATIONAL CONSTANT

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

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

Unit of G is Nm^2/kg^2.

If $m_1 = m_2 = 1$ kg, r = 1 then we have G = F

Hence, Universal gravitational constant G is numerically equal to the gravitational force of attraction between two bodies, each of unit mass kept at unit distance from each other.

Value of G = 6.67×10^{-11} Nm^2/kg^2.

KEPLER'S LAWS OF PLANETARY MOTION

KEPLER'S FIRST LAW

Every planet revolves around the Sun in an elliptical orbit, with the sun situated at any one of the foci of the ellipse.

KEPLER'S SECOND LAW

In the elliptical orbit of the planet, the line joining the centre of the planet to the centre of the Sun sweeps equal intervals of time.

KEPLER'S THIRD LAW

The square of time period of revolution of a planet around the Sun is directly proportional to the cube of the semi-major axis of the elliptical orbit.

$$r^3 \propto T^2 \Rightarrow \frac{r^3}{T^2} = constant$$

where r = radius of orbit = mean distance of planet from the Sun (inm), T = the time period of revolution of planet around the Sun (in second)

IMPORTANCE OF THE UNIVERSAL LAW OF GRAVITATION

The universal law of gravitation successfully explained several phenomena which were believed to be unconnected:

(i) the force that binds us to the earth;

(ii) the motion of the moon around the earth;

(iii) the motion of planets around the Sun; and

(iv) the tides due to the moon and the Sun.

INTEXT QUESTIONS PAGE NO. 134

1. State the universal law of gravitation
Ans. The universal law of gravitation states that every object in the universe attracts every other object with a force called the gravitational force. The force acting between two objects is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centers. For two objects of masses m_1 and m_2 and the distance between them r, the force (F) of attraction acting between them is given by the universal law of gravitation as:

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

Where, G is the universal gravitation constant given by: $G = 6.67 \times 10^{-11} Nm^2 / kg^2$

2. Write the formula to find the magnitude of the gravitational force between the earth and an object on the surface of the earth.
Ans. Let M_E be the mass of the Earth and m be the mass of an object on its surface. If R is the radius of the Earth, then according to the universal law of gravitation, the gravitational force (F) acting between the Earth and the object is given by the relation:

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

FREE FALL

When an object falls from any height under the influence of gravitational force only, it is known as free fall. In the case of free fall no change of direction takes place but the magnitude of velocity changes because of acceleration.
This acceleration acts because of the force of gravitation and is denoted by 'g'. This is called acceleration due to gravity.

EXPRESSION FOR ACCELERATION DUE TO GRAVITATION 'G'.

Let mass of the object put under free fall = m.
And acceleration due to gravity = g.
Therefore, according to Newton's Second Law of Motion which states that Force is the product of mass and acceleration,
F = m x g -----------------(i)
Now, according to Universal Law of gravitation,

$$F = G.\frac{M.m}{d^2} \text{ ……………. (ii)}$$

Thus, from above two expressions, we get
Where, g is acceleration due to gravity,
G is the Universal Gravitational Constant.
M is the mass of earth.
And d is the distance between object and centre of earth.

WHEN OBJECT IS NEAR THE SURFACE OF EARTH

When an object is near the surface of earth, the distance between object and centre of the earth will be equal to the radius of earth because the distance of object is negligible in comparison of the radius of earth.
Let the radius of earth is equal to R.
Therefore, after substituting 'R' at the place of 'd' we get,

$$g = \frac{GM}{R^2} ....(iv)$$

Since, earth is not a perfect sphere rather it has oblique shape. Therefore, radius at the equator is greater than at the poles.

Since, value of 'g' is reciprocal of the square of radius of earth, thus, the value of 'g' will be greater at the poles and less at the equator.

And the value of 'g' will decrease with increase of distance of object from earth.

Calculation of value of 'g'

We know that

The accepted value of G is 6.673 x 10^{-11} Nm^2/kg^2.

The mass of earth, M = 6 x 10^{24} kg

The radius of earth, R = 6.4 x 10^6 m

Therefore, by using expression, $g = \frac{GM}{R^2}$, the value of 'g' can be calculated.

Therefore, after substituting the value of G, M and R in the expression for 'g' we get.

$$g = \frac{6.673 \times 10^{-11} \times 6 \times 10^{24}}{(6.4 \times 10^6)^2}$$

$$\Rightarrow g = 9.8 m/s^2$$

Motion of an object under the influence of gravitational force of earth

The expression for 'g' is written as

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

Since, the value of 'g' does not depend upon the mass or distance of an object, therefore, all objects fall over the earth with the same rate.

The equations for motion are as follows:

v = u + at ……….. (i)

s = ut + $\frac{1}{2}$ at^2 ………. (ii)

$v^2 = u^2 + 2as$ ……… (iii)

Therefore, the equations of motion are also applied to calculate the velocity, distance, etc by replacing 'a' by 'g'. After substituting 'g' at the place of 'a' we get above equations as follows:

v = u + gt ……….. (iv)

s = ut + $\frac{1}{2}$ gt^2 ………. (v)

$v^2 = u^2 + 2gs$ ……… (vi)

In the calculation; initial velocity (u), final velocity (v), time taken (t), or distance covered (s), the value of 'g' is taken as positive in the case of object moving towards earth and taken as negative in the case of object is thrown in opposite direction of earth.

MASS

Mass is the measurement of inertia and inertia is the property of any object which opposes the change in state of the object. It is inertia because of which an object in rest has tendency to remain in rest and an object in motion has tendency to remain in motion.

Inertia depends upon the mass of an object. Object having greater mass has greater inertia and vice versa. Mass of an object remains constant everywhere, i.e. mass will remain same whether that object is at the moon, at the earth or anywhere in the universe.

WEIGHT:

Earth attracts every object towards it. We know that force is the product of mass and acceleration due to gravity.

This means, F = m x g -----------------------(i)

The force by which earth attracts an object towards it is called the weight of the object, which is the product of mass (m) of the object and acceleration due to gravity (g).

Weight is denoted by 'W'.

Therefore, by substituting in the expression 'F = mg' we get,

W = m x g ------------------------------(ii)

Since weight is the force which is acting vertically downwards, therefore, weight has both magnitude and direction and hence it is a vector quantity.

Since the value of 'g' is always constant at a given place,

Therefore, expression 'W = m x g' can be written as follows:

W α m --------------------(iii)

This means weight of any object is directly proportional to its mass, i.e. weight will increase with the increase of mass and decrease with decrease in mass.

This is the cause that weight of any object is the measure of its mass.

The unit of weight

Since, weight of an object is equal to the force by which an object is attracted towards earth, therefore, unit of weight is same as the unit of force.

Therefore, Unit of weight is 'newton (N)'.

WEIGHT OF AN OBJECT ON THE SURFACE OF MOON

Let M_E be the mass of the Earth and m be an object on the surface of the Earth. Let R_E be the radius of the Earth. According to the universal law of gravitation, weight W_E of the object on the surface of the Earth is given by,

$$W_E = \frac{GM_E m}{R_E{}^2}$$

Let M_M and R_M be the mass and radius of the moon. Then, according to the universal law of gravitation, weight W_M of the object on the surface of the moon is given by:

$$W_M = \frac{GM_M m}{R_M{}^2} \qquad \Rightarrow \frac{W_M}{W_E} = \frac{\frac{GM_M m}{R_M{}^2}}{\frac{GM_E m}{R_E{}^2}} = \frac{M_M R_E{}^2}{M_E R_M{}^2}$$

$$where, M_E = 5.98 \times 10^{24} kg, M_M = 7.36 \times 10^{22} kg$$

$$R_E = 6.4 \times 10^6 m, R_M = 1.74 \times 10^6 m$$

$$\frac{W_M}{W_E} = \frac{7.36 \times 10^{22} \times (6.4 \times 10^6)^2}{5.98 \times 10^{24} \times (1.74 \times 10^6)^2} = 0.165 \approx \frac{1}{6}$$

Therefore, the weight of an object on the moon $\frac{1}{6}^{th}$ its weight on the earth

NUMERICAL

1. The gravitational force between two objects is F. How will this force change when (i) distance between them is reduced to half (ii) the mass of each object is quadrupled?

2. A sphere of mass 40kg is attracted by a second sphere of mass 15kg when their centres are 20 cm apart, with a force of 0.1 milligram weight. Calculate the value of gravitational constant.

3. A body of mass 1 kg is placed at a distance of 2m from another body of mass 10kg. At what distance from the body of 1 kg, another body of mass 5 kg be placed so that the net force of gravitation acting on the body of mass 1 kg is zero?

4. A geostationary satellite is orbiting the earth at a height 5 R above the surface of earth, where R is the radius of earth. Find the time period of another satellite at a height of 2 R from the surface of earth.

5. The distance of planet Jupiter from the sun 5.2 times that of Earth. Find the period of revolution of Jupiter around sun.

6. If the distance of Earth from the Sun were half the present value, how many days will make one year?

7. Two satellites of a planet have periods 32 days and 256 days. If the radius of orbit of former is R, find the orbital radius of the latter.

8. The mass of Earth is 6×10^{24} kg and that of moon is 7.4×10^{22} kg. If the distance between the Earth and the Moon is 3.84×10^{5} km, calculate the force exerted by Earth on the Moon. Given $G = 6.7 \times 10^{-11}$ Nm^2/kg^2.

9. If the distance between two masses is increased by a factor of 4, by what factor would the mass of one of them have to be altered to maintain the same gravitational force?

10. Two bodies A and B having masses 2kg and 4kg respectively are separated by 2m. Where should a body of mass 1kg be placed so that the gravitational force on this body due to bodies A and B is zero?

11. The mass of Sun is 2×10^{30} kg and mass of Earth is 6×10^{24} kg. If the distance between the centres of Sun and Earth is 1.5×10^{8} km, calculate the force of gravitation between them.

12. Two electrons each of mass 9.1×10^{-31} kg are at a distance of $10\overset{0}{A}$. Calculate the gravitational force of attraction between them. Given $1\overset{0}{A} = 10^{-10}m$

13. The gravitational force between force two objects is 100 N. How should the distance between these objects be changed so that force between them becomes 50 N?

14. Calculate the force of gravitation between two objects of masses 80kg and 1200 kg kept at a distance of 10 m from each other. Given $G = 6.67 \times 10^{-11}$ Nm^2/kg^2.

15. Calculate the force of attraction between the Earth and the Sun, given that the mass of Earth is 6×10^{24} kg and that of sun is 2×10^{30} kg. The average distance between thte two is 1.5×10^{11}m.

16. A sphere of mass 25kg attracts another sphere of mass 24kg with a force of 0.1milligram weight. If distance between the centres of two spheres is 20cm, what is the value of G?

17. If distance between two masses is quadrupled, what will be the new force of attraction between them? Given the initial gravitational pull is 9.8N.

18. An electron of mass 9.1 x 10–31kg is at a distance of $10\overset{0}{A}$ from a proton of mass 1.67 x 10^{-27}kg. Calculate the gravitational force of attraction between them. Given $1\overset{0}{A} = 10^{-10}m$

19. Two bodies A and B having masses 20kg and 40kg are separted by 10m. At what distance from body A should another body C of mass 15kg be placed so that net gravitational force on C is zero?

20. Calculate the gravitational force on a body of mass 1kg lying on the surface of earth. Given mass of earth is 6 x 10^{24} kg and radius of earth is 6400km.

INTEXT QUESTIONS PAGE NO. 136

1. What do you mean by free fall?
Ans. Gravity of the Earth attracts every object towards its centre. When an object is released from a height, it falls towards the surface of the Earth under the influence of gravitational force. The motion of the object is said to have free fall.

2. What do you mean by acceleration due to gravity?
Ans. When an object falls towards the ground from a height, then its velocity changes during the fall. This changing velocity produces acceleration in the object. This acceleration is known as acceleration due to gravity (*g*). Its value is given by 9.8 m/s^2.

INTEXT QUESTIONS PAGE NO. 138

1. What are the differences between the mass of an object and its weight?
Ans.

Mass	Weight
Mass is the quantity of matter contained in the body.	Weight is the force of gravity acting on the body.
It is the measure of inertia of the body.	It is the measure of gravity.
Mass is a constant quantity.	Weight is not a constant quantity. It is different at different places.
It only has magnitude.	It has magnitude as well as direction.
Its SI unit is kilogram (kg).	Its SI unit is the same as the SI unit of force, i.e., Newton (N).

2. Why is the weight of an object on the moon $\frac{1}{6}^{th}$ its weight on the earth?

Ans. Let M_E be the mass of the Earth and m be an object on the surface of the Earth. Let R_E be the radius of the Earth. According to the universal law of gravitation, weight W_E of the object on the surface of the Earth is given by,

$$W_E = \frac{GM_E m}{R_E^2}$$

Let M_M and R_M be the mass and radius of the moon. Then, according to the universal law of gravitation, weight W_M of the object on the surface of the moon is given by:

$$W_M = \frac{GM_M m}{R_M^2}$$

$$\frac{W_M}{W_E} = \frac{\frac{GM_M m}{R_M^2}}{\frac{GM_E m}{R_E^2}} = \frac{M_M R_E^2}{M_E R_M^2}$$

$$where, M_E = 5.98\times10^{24}kg, M_M = 7.36\times10^{22}kg$$

$$R_E = 6.4\times10^6 m, R_M = 1.74\times10^6 m$$

$$\frac{W_M}{W_E} = \frac{7.36\times10^{22}\times(6.4\times10^6)^2}{5.98\times10^{24}\times(1.74\times10^6)^2} = 0.165 \approx \frac{1}{6}$$

Therefore, the weight of an object on the moon $\frac{1}{6}^{th}$ its weight on the earth

NUMERICAL

1. Calculate the force of gravity acting on your friend of mass 60kg. Given mass of earth = 6×10^{24} kg and radius of Earth = 6.4×10^6m.

2. Mass of an object is 10kg. What is its weight on Earth?

3. What is the mass of an object whose weight is 49N?

4. An object weighs 10N when measured on the surface of the earth. What would be its weight when measured on the surface of the Moon?

5. An object is thrown vertically upwards and rises to a height of 10m. Calculate (i) the velocity with which the object was thrown upwards and (ii) the time taken by the object to reach the highest point.

6. A force of 2 kg wt. acts on a body of mass 4.9kg. Calculate its acceleration.

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

8. A body has a weight of 10 kg on the surface of earth. What will be its mass and weight when taken to the centre of earth?

9. How much would a 70 kg man weigh on moon? What will be his mass on earth and moon? Given g on moon = 1.7 m/s^2.

10. The Earth's gravitational force causes an acceleration of 5 m/s^2 in a 1 kg mass somewhere in space. How much will the acceleration of a 3 kg mass be at the same place?

11. A particle is thrown up vertically with a velocity of 50m/s. What will be its velocity at the highest point of the journey? How high would the particle rise? What time would it take to reach the highest point? Take g = 10 m/s^2.

12. If a planet existed whose mass was twice that of Earth and whose radius 3 times greater, how much will a 1kg mass weigh on the planet?

13. A boy on cliff 49m high drops a stone. One second later, he throws a second stone after the first. They both hit the ground at the same time. With what speed did he throw the second stone?

14. A stone drops from the edge of a roof. It passes a window 2m high in 0.1s. How far is the roof above the top of the window?

15. A stone is dropped from the edge of a roof. (a) How long does it take to fall 4.9m ? (b) How fast does it move at the end of that fall? (c) How fast does it move at the end of 7.9m? (d) What is its acceleration after 1s and after 2s?

EXERCISE QUESTIONS PAGE NO. 143

1. How does the force of gravitation between two objects change when the distance between them is reduced to half?

Ans. According to the universal law of gravitation, gravitational force (*F*) acting between two objects is inversely proportional to the square of the distance (*r*) between them, i.e.,

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

If distance *r* becomes *r*/2, then the gravitational force will be proportional to $\frac{1}{\left(\frac{r}{2}\right)^2} = \frac{4}{r^2}$

Hence, if the distance is reduced to half, then the gravitational force becomes four times larger than the previous value.

2. Gravitational force acts on all objects in proportion to their masses. Why then, a heavy object does not fall faster than a light object?

Ans. All objects fall on ground with constant acceleration, called acceleration due to gravity (in the absence of air resistances). It is constant and does not depend upon the mass of an object. Hence, heavy objects do not fall faster than light objects.

3. What is the magnitude of the gravitational force between the earth and a 1 kg object on its surface? (Mass of the earth is 6×10^{24} kg and radius of the earth is 6.4×10^6 m).

Ans. According to the universal law of gravitation, gravitational force exerted on an object of mass *m* is given by:

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

Where,

Mass of Earth, $M = 6 \times 10^{24}$ kg

Mass of object, $m = 1$ kg

Universal gravitational constant, G = 6.7×10^{-11} Nm^2 kg^{-2}

Since the object is on the surface of the Earth, r = radius of the Earth (R)

$r = R = 6.4 \times 10^6$ m

Gravitational force, $F = \frac{GMm}{R^2} = \frac{6.7 \times 10^{-11} \times 6 \times 10^{24} \times 1}{(6.4 \times 10^6)^2} = 9.8N$

4. The earth and the moon are attracted to each other by gravitational force. Does the earth attract the moon with a force that is greater or smaller or the same as the force with which the moon attracts the earth? Why?

Ans. According to the universal law of gravitation, two objects attract each other with equal force, but in opposite directions. The Earth attracts the moon with an equal force with which the moon attracts the earth.

5. If the moon attracts the earth, why does the earth not move towards the moon?

Ans. The Earth and the moon experience equal gravitational forces from each other. However, the mass of the Earth is much larger than the mass of the moon. Hence, it accelerates at a rate lesser than the acceleration rate of the moon towards the Earth. For this reason, the Earth does not move towards the moon.

6. What happens to the force between two objects, if

(i) the mass of one object is doubled?

(ii) the distance between the objects is doubled and tripled?

(iii) the masses of both objects are doubled?

Ans. According to the universal law of gravitation, the force of gravitation between two objects is given by: $F = \frac{Gm_1m_2}{r^2}$

(i) F is directly proportional to the masses of the objects. If the mass of one object is doubled, then the gravitational force will also get doubled.

(ii) F is inversely proportional to the square of the distances between the objects. If the distance is doubled, then the gravitational force becomes one-fourth of its original value. Similarly, if the distance is tripled, then the gravitational force becomes one-ninth of its original value.

(iii) F is directly proportional to the product of masses of the objects. If the masses of both the objects are doubled, then the gravitational force becomes four times the original value.

7. What is the importance of universal law of gravitation?

Ans. The universal law of gravitation proves that every object in the universe attracts every other object.

8. What is the acceleration of free fall?

Ans. When objects fall towards the Earth under the effect of gravitational force alone, then they are said to be in free fall. Acceleration of free fall is 9.8 m s^{-2}, which is constant for all objects (irrespective of their masses).

9. What do we call the gravitational force between the Earth and an object?

Ans. Gravitational force between the earth and an object is known as the weight of the object.

10. Amit buys few grams of gold at the poles as per the instruction of one of his friends. He hands over the same when he meets him at the equator. Will the friend agree with the weight of gold bought? If not, why? [*Hint*: The value of g is greater at the poles than at the equator].

Ans. Weight of a body on the Earth is given by:

$W = mg$

Where,

m = Mass of the body

g = Acceleration due to gravity

The value of g is greater at poles than at the equator. Therefore, gold at the equator weighs less than at the poles. Hence, Amit's friend will not agree with the weight of the gold bought.

11. Why will a sheet of paper fall slower than one that is crumpled into a ball?

Ans. When a sheet of paper is crumbled into a ball, then its density increases. Hence, resistance to its motion through the air decreases and it falls faster than the sheet of paper.

Gravitational force on the surface of the moon is only $\frac{1}{6}$ as strong as gravitational force on the Earth. What is the weight in newtons of a 10 kg object on the moon and on the Earth?

Ans. Weight of an object on the moon = $\frac{1}{6} \times$ Weight of an object on the Earth

Also,

Weight = Mass × Acceleration

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

Therefore, weight of a 10 kg object on the Earth = 10 × 9.8 = 98 N

And, weight of the same object on the moon = $\frac{1}{6} \times 98 = 16.3N$

12. A ball is thrown vertically upwards with a velocity of 49 m/s. Calculate

(i) the maximum height to which it rises.

(ii)the total time it takes to return to the surface of the earth.

Ans. According to the equation of motion under gravity:

$v^2 - u^2 = 2\,gs$

Where,

u = Initial velocity of the ball

v = Final velocity of the ball

s = Height achieved by the ball

g = Acceleration due to gravity

At maximum height, final velocity of the ball is zero, i.e., $v = 0$

u = 49 m/s

During upward motion, g = − 9.8 $m\,s^{-2}$

Let h be the maximum height attained by the ball.

Hence, $0 - 49^2 = 2 \times (-9.8) \times h$

$$\Rightarrow h = \frac{49 \times 49}{2 \times 9.8} = 122.5m$$

Let t be the time taken by the ball to reach the height 122.5 m, then according to the equation of motion:

$v = u + gt$

We get,

$$0 = 49 + t \times (-9.8) \Rightarrow 9.8t = 49 \Rightarrow t = \frac{49}{9.8} = 5s$$

But,
Time of ascent = Time of descent
Therefore, total time taken by the ball to return = 5 + 5 = 10 s

13. A stone is released from the top of a tower of height 19.6 m. Calculate its final velocity just before touching the ground.
Ans. According to the equation of motion under gravity:
$v^2 - u^2 = 2\ gs$
Where,
u = Initial velocity of the stone = 0
v = Final velocity of the stone
s = Height of the stone = 19.6 m
g = Acceleration due to gravity = 9.8 m s^{-2}
$\therefore v^2 - 0^2 = 2 \times 9.8 \times 19.6$
$v^2 = 2 \times 9.8 \times 19.6 = (19.6)^2$
$v = 19.6$ m s^{-1}
Hence, the velocity of the stone just before touching the ground is 19.6 m s^{-1}.

14. A stone is thrown vertically upward with an initial velocity of 40 m/s. Taking g = 10 m/s^2, find the maximum height reached by the stone. What is the net displacement and the total distance covered by the stone?
Ans. According to the equation of motion under gravity:
$v^2 - u^2 = 2\ gs$
Where,
u = Initial velocity of the stone = 40 m/s
v = Final velocity of the stone = 0
s = Height of the stone
g = Acceleration due to gravity = −10 m s^{-2}
Let h be the maximum height attained by the stone.
Therefore,
$$0 - (40)^2 = 2 \times h \times (-10) \Rightarrow h = \frac{40 \times 40}{20} = 80m$$
Therefore, total distance covered by the stone during its upward and downward journey = 80 + 80 = 160 m
Net displacement of the stone during its upward and downward journey
= 80 + (−80) = 0

15. Calculate the force of gravitation between the earth and the Sun, given that the mass of the earth = 6×10^{24} kg and of the Sun = 2×10^{30} kg. The average distance between the two is 1.5×10^{11} m.
Ans. According to the universal law of gravitation, the force of attraction between the Earth and the Sun is given by: $F = \frac{GM_{Sun}M_{Earth}}{R^2}$
Where,
M_{Sun} = Mass of the Sun = 2×10^{30} kg
M_{Earth} = Mass of the Earth = 6×10^{24} kg
R = Average distance between the Earth and the Sun = 1.5×10^{11} m
G = Universal gravitational constant = 6.7×10^{-11} $Nm^2\ kg^{-2}$
$$F = \frac{6.7 \times 10^{-11} \times 2 \times 10^{30} \times 6 \times 10^{24}}{(1.5 \times 10^{11})^2} = 3.57 \times 10^{22} N$$

16. A stone is allowed to fall from the top of a tower 100 m high and at the same time another stone is projected vertically upwards from the ground with a velocity of 25 m/s. Calculate when and where the two stones will meet.

Ans. Let the two stones meet after a time *t*.

(i) For the stone dropped from the tower:

Initial velocity, $u = 0$

Let the displacement of the stone in time *t* from the top of the tower be *s*.

Acceleration due to gravity, g = 9.8 m s^{-2}

From the equation of motion,

$$s = ut + \frac{1}{2}gt^2 = 0 \times t + \frac{1}{2} \times 9.8 \times t$$

$$\Rightarrow s = 7.9t^2 ------(1)$$

(ii) For the stone thrown upwards:

Initial velocity, u = 25 m s^{-1}

Let the displacement of the stone from the ground in time *t* be *s*'.

Acceleration due to gravity, g = −9.8 m s^{-2}

Equation of motion,

$$s' = ut + \frac{1}{2}gt^2 = 25t - \frac{1}{2} \times 9.8 \times t^2$$

$$\Rightarrow s' = 25t - 4.9t^2 ------(2)$$

The combined displacement of both the stones at the meeting point is equal to the height of the tower 100 m.

$$\therefore s + s' = 100$$

$$\Rightarrow \frac{1}{2}gt^2 + 25t - \frac{1}{2}gt^2 = 100$$

$$\Rightarrow t = \frac{100}{25} = 4s$$

In 4 s, the falling stone has covered a distance given by equation (1) as

$$s = \frac{1}{2} \times 10 \times 4^2 = 80m$$

Therefore, the stones will meet after 4 s at a height (100 − 80) = 20 m from the ground

17. A ball thrown up vertically returns to the thrower after 6 s. Find

(a) the velocity with which it was thrown up,

(b) the maximum height it reaches, and

(c) its position after 4 s.

Ans. (a) Time of ascent is equal to the time of descent. The ball takes a total of 6 s for its upward and downward journey.

Hence, it has taken 3 s to attain the maximum height.

Final velocity of the ball at the maximum height, $v = 0$

Acceleration due to gravity, g = −9.8 m s^{-2}

Equation of motion, $v = u + gt$ will give,

$0 = u + (-9.8 \times 3)$

$u = 9.8 \times 3 = 29.4$ ms^{-1}

Hence, the ball was thrown upwards with a velocity of 29.4 m s^{-1}.

(b) Let the maximum height attained by the ball be *h*.

Initial velocity during the upward journey, u = 29.4 m s^{-1}

Final velocity, $v = 0$

Acceleration due to gravity, g = −9.8 m s^{-2}

From the equation of motion, $s = ut + \frac{1}{2}at^2$

$\Rightarrow h = 29.4 \times 3 + \frac{1}{2} \times (-9.8) \times 3^2 = 44.1m$

(c) Ball attains the maximum height after 3 s. After attaining this height, it will start falling downwards.
In this case,
Initial velocity, u = 0
Position of the ball after 4 s of the throw is given by the distance travelled by it during its downward journey in 4 s − 3 s = 1 s.

Equation of motion, $s = ut + \frac{1}{2}gt^2$ will give

$\Rightarrow s = 0 \times t + \frac{1}{2} \times (9.8) \times 1^2 = 4.9m$

Total height = 44.1 m
This means that the ball is 39.2 m (44.1 m − 4.9 m) above the ground after 4 seconds.

ASSIGNMENT QUESTIONS
GRAVITATION

MULTIPLE CHOICE QUESTIONS

1. Two objects of different masses falling freely near the surface of moon would
(a) have same velocities at any instant
(b) have different accelerations
(c) experience forces of same magnitude
(d) undergo a change in their inertia

2. The value of acceleration due to gravity
(a) is same on equator and poles
(b) is least on poles
(c) is least on equator
(d) increases from pole to equator

3. The gravitational force between two objects is *F*. If masses of both objects are halved without changing distance between them, then the gravitational force would become
(a) $F/4$ (b) $F/2$ (c) F (d) $2F$

4. A boy is whirling a stone tied with a string in an horizontal circular path. If the string breaks, the stone
(a) will continue to move in the circular path
(b) will move along a straight line towards the centre of the circular path
(c) will move along a straight line tangential to the circular path
(d) will move along a straight line perpendicular to the circular path away from the boy

5. An object is put one by one in three liquids having different densities. The object floats with $\frac{1}{9}, \frac{2}{11}$ *and* $\frac{3}{7}$ parts of their volumes outside the liquid surface in liquids of densities d_1, d_2 and d_3 respectively. Which of the following statement is correct?
(a) $d_1 > d_2 > d_3$
(b) $d_1 > d_2 < d_3$
(c) $d_1 < d_2 > d_3$
(d) $d_1 < d_2 < d_3$

6. In the relation $F = G\,M\,m/d^2$, the quantity G
(a) depends on the value of *g* at the place of observation
(b) is used only when the earth is one of the two masses
(c) is greatest at the surface of the earth
(d) is universal constant of nature

7. Law of gravitation gives the gravitational force between
(a) the earth and a point mass only
(b) the earth and Sun only
(c) any two bodies having some mass
(d) two charged bodies only

8. The value of quantity G in the law of gravitation
(a) depends on mass of earth only
(b) depends on radius of earth only
(c) depends on both mass and radius of earth
(d) is independent of mass and radius of the earth

9. Two particles are placed at some distance. If the mass of each of the two particles is doubled, keeping the distance between them unchanged, the value of gravitational force between them will be

(a) $\frac{1}{4}$ (b) 4 times (c) $\frac{1}{2}$ times (d) unchanged

10. The earth attracts a body of mass 2 kg on its surface with a force of
(a) 9.8 N
(b) 19.6 N
(c) 6.67 x 10^{-11} N
(d) 2 x 6.67 x 10^{-11} N

11. A stone dropped from a building takes 4 s to reach the ground. The height of the building is
(a) 19.6 m
(b) 80.4 m
(c) 78.4 m
(d) 156.8 m

12. If g_e is acceleration due to gravity on earth and g_m is acceleration due to gravity on moon, then
(a) $g_e = g_m$
(b) $g_e < g_m$
(c) $g_e = \frac{1}{6} g_m$
(d) $g_m = \frac{1}{6} g_e$

13. The mass of a body on the surface of earth is 12 kg. If acceleration due to gravity on moon is $\frac{1}{6}$ of acceleration due to gravity on earth, then its mass on moon will be
(a) 2 kgf
(b) 72 kg
(c) 12 kg
(d) zero

14. The atmosphere is held to the earth by
(a) gravity
(b) wind
(c) clouds
(d) earth's magnetic field

15. The force of attraction between two unit point masses separated by a unit distance is called
(a) gravitational potential
(b) acceleration due to gravity
(c) gravitational field
(d) universal gravitational constant

16. The weight of an object at the centre of the earth of radius *R* is
(a) zero
(b) infinite
(c) *R* times the weight at the surface of the earth
(d) $1/R^2$ times the weight at surface of the earth

SHORT ANSWER QUESTIONS

17. What is the source of centripetal force that a planet requires to revolve around the Sun? On what factors does that force depend?

18. On the earth, a stone is thrown from a height in a direction parallel to the earth's surface while another stone is simultaneously dropped from the same height. Which stone would reach the ground first and why?

19. Suppose gravity of earth suddenly becomes zero, then in which direction will the moon begin to move if no other celestial body affects it?

20. Identical packets are dropped from two aeroplanes, one above the equator and the other above the north pole, both at height h. Assuming all conditions are identical, will those packets take same time to reach the surface of earth. Justify your answer.

21. The weight of any person on the moon is about 1/6 times that on the earth. He can lift a mass of 15 kg on the earth. What will be the maximum mass, which can be lifted by the same force applied by the person on the moon?

22. Calculate the average density of the earth in terms of g, G and R.

23. The earth is acted upon by gravitation of Sun, even though it does not fall into the Sun. Why?

24. Calculate the density of Earth from Newton's law of gravitation.

25. A body weighs more at poles than at the equator of earth. Why?

26. Two particles of equal mass(m) move in a circle of radius (r) under the action of their mutual gravitational attraction. Find the speed of each particle.

LONG ANSWER QUESTIONS

27. How does the weight of an object vary with respect to mass and radius of the earth. In a hypothetical case, if the diameter of the earth becomes half of its present value and its mass becomes four times of its present value, then how would the weight of any object on the surface of the earth be affected?

28. How does the force of attraction between the two bodies depend upon their masses and distance between them? A student thought that two bricks tied together would fall faster than a single one under the action of gravity. Do you agree with his hypothesis or not? Comment.

29. Two objects of masses m_1 and m_2 having the same size are dropped simultaneously from heights h_1 and h_2 respectively. Find out the ratio of time they would take in reaching the ground. Will this ratio remain the same if (i) one of the objects is hollow and the other one is solid and (ii) both of them are hollow, size remaining the same in each case. Give reason.

30. Distinguish between mass and weight. Show that mass of a body numerically equal to weight of the body except at the centre of earth.

CHAPTER - 10
GRAVITATION (CONTINUED)

THRUST AND PRESSURE

Force acting normally on a surface is called the thrust i.e. the force that acts on an object perpendicular to its surface is the thrust, measured in newton in the SI system.

When you stand on loose sand, the force, that is, the weight of your body is acting on an area equal to area of your feet. When you lie down, the same force acts on an area equal to the contact area of your whole body, which is larger than the area of your feet. Thus, the effects of forces of the same magnitude on different areas are different. In the above cases, thrust is the same. But effects are different. Therefore the effect of thrust depends on the area on which it acts. The effect of thrust on sand is larger while standing than while lying.

The thrust acting on unit area of the surface is called the pressure.
If a thrust F acts on an area A, then

$$\text{Pr}\,essure(P) = \frac{Thrust(F)}{Area(A)}$$

$$\boxed{P = \frac{F}{A}}$$

Thus, the same force acting on a smaller area exerts a larger pressure, and a smaller pressure on a larger area. This is the reason why a nail has a pointed tip, knives have sharp edges and buildings have wide foundations.

The SI unit of pressure is called pascal(Pa).

$$1 \text{ Pa} = 1 \text{ N/m}^2$$

One pascal is defined as the pressure exerted on a surface of area of 1 m^2 by a thrust of 1 N acting normally on it.

Other units of pressure are bar and millibar(m bar)

where 1 bar = 10^5 N/m^2 and 1 millibar = 10^2 N/m^2
or 1 bar = 10^5 Pa and 1 m bar = 10^2 Pa

1 atmospheric pressure (1 atm) = 101.3 k Pa = 1.013 bar = 1013 m bar

NUMERICALS

1. A cube of edge length 10 cm is placed inside a liquid. The pressure at the centre of the face is 15 Pa. Find the force exerted by the liquid on this face.

2. A force of 16 N is distributed uniformly on one surface of a cube of edge 8 cm. Find the pressure on this surface.

3. A force of 100 N is applied on an object of area 2 m^2. Calculate the pressure.

4. The force on a phonogram needle is 1.2 N. The point has a circular cross-section of radius 0.1mm. What pressure does it exert on the record in (i) Pa (ii) atm ?

5. A force of 15 N is uniformly distributed over an area of 150 m^2. Find the pressure in pascals.

6. How much force should be applied on an area of 1 cm^2 to get a pressure of 15 Pa?

7. A block weighing 1.0 kg is in the shape of a cube of length 10 cm. It is kept on a horizontal table. Find the pressure on the portion of the table where the block is kept.

8. The pressure due to atmosphere is 1.013 x 10^5 Pa. Find the force exerted by the atmosphere on the top surface of a table 2.0 m long and 1.0 m wide.

9. Find the thrust acting on the human body due to atmospheric pressure. Take the surface area of a man of middle size to be 1.5 m^2 and atmospheric pressure (1 atm) = 1.013 x 10^5 Pa.

10. A boy weighing 60 kg f is wearing shoes with heel area of cross section 20 cm^2 while a girl weighing 45 kg f is wearing shoes with heel of area of cross section 1.5 cm^2. Compare the pressure exerted on ground by their heels when they stand on the heel of one floor.

11. A nail is driven into a wooden board by using a hammer. The impact of the hammer on the head of nail produces a thrust of 25 N. If the area of the head is 0.5 mm^2 and of the tip 0.1 mm^2, find the pressure on the head and the tip of the nail.

12. A car weighs 1200 kg. This weight is evently distributed on 4 wheels. If the pressure in each tyre is 15 kg wf/cm^2, what is the area of each tyre in contact.

13. Calculate the greatest and the least pressure exerted by a metal block of size 20 cm x 8 cm c 5 cm and having a mass of 5 kg.

14. A hydraulic automobile lift is designed to lift cars with a maximum mass of 3000 kg. The area of the piston carrying the load is 425 cm^2. What maximum pressure would the smaller piston have to bear?

15. A block of wood is kept on a table top. The mass of the wooden block is 5 kg and its dimension are 40 cm x 20 cm x 10 cm. Find the pressure exerted by the wooden block on the table top if it is made to lie on the table with its sides of dimensions
(a) 20 cm x 10 cm (b) 40 cm x 20 cm. Given g = 9.8 m/s^2.

PRESSURE IN FLUIDS

Those substances, which can flow easily, are called fluids. All liquids and gases are fluids. A solid exerts pressure on a surface due to its weight. Similarly, fluids have weight, and they also exert pressure on the base and walls of the container in which they are enclosed. Pressure exerted in any confined mass of fluid is transmitted undiminished in all directions. In other words, a fluid (liquid or gas) exerts pressure in all directions – even upwards.

BUOYANCY

When a body floats or immerses in a liquid, the pressure on the bottom surface is more than that the pressure on the top surface. Due to the difference in pressure, an upward force acts on the body. This upward force is called upthrust or buoyant force. The buoyant force is equal to the weight of the liquid displaced.

The buoyant force (upthrust) acts through the centre of gravity of the displaced liquid which is known as **centre of buoyancy**. Due to the upthrust exerted on the body by the liquid, the weight of the body appears to be less when the body is immersed in the liquid.

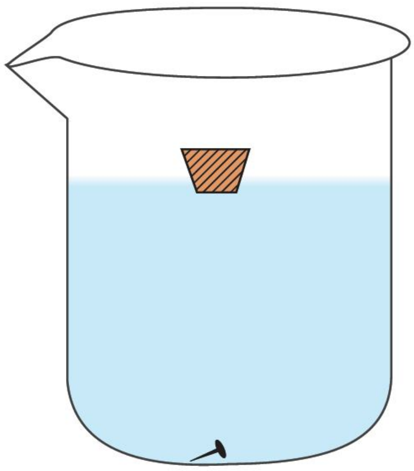
For example, when we immerse a mug into a bucket of water, the mug filled with water appears to be lighter as long as it is under water. But when it is lifted up out of the water we feel that the mug is heavier. This shows that the weight of the body under water is less than its weight when it is above the surface of water.

WHY OBJECTS FLOAT OR SINK WHEN PLACED ON THE SURFACE OF WATER?

If the density of the material of the body is less than that of density of water, it floats and in case if the density of the material of the body is more than that of density of water, it sinks.

The cork floats while the nail sinks. This is because of the difference in their densities. The density of cork is lesser than the density of water. This means that the upthrust of water on the cork is greater than the weight of the cork. So it floats.

The density of the iron nail is more than the density of the water. This means that the upthrust of water on the iron is lesser than the weight of the nail. So it sinks.



Therefore objects of density less than that of a liquid float on the liquid. The objects of density greater than that of a liquid sink in the liquid.

INTEXT QUESTIONS PAGE NO. 141

1. Why is it difficult to hold a school bag having a strap made of a thin and strong string?
Ans.: It is difficult to hold a school bag having a thin strap because the pressure on the shoulders is quite large. This is because the pressure is inversely proportional to the surface area on which the force acts. The smaller is the surface area; the larger will be the pressure on the surface. In the case of a thin strap, the contact surface area is very small. Hence, the pressure exerted on the shoulder is very large.

2. What do you mean by buoyancy?

Ans.: The upward force exerted by a liquid on an object immersed in it is known as buoyancy. When you try to immerse an object in water, then you can feel an upward force exerted on the object, which increases as you push the object deeper into water..

3. Why does an object float or sink when placed on the surface of water?

Ans.: If the density of an object is more than the density of the liquid, then it sinks in the liquid. This is because the buoyant force acting on the object is less than the force of gravity. On the other hand, if the density of the object is less than the density of the liquid, then it floats on the surface of the liquid. This is because the buoyant force acting on the object is greater than the force of gravity.

ARCHIMEDES' PRINCIPLE

When a body is immersed in fluid (liquid or gas) it experiences an apparent loss of weight which is equal to the weight of the fluid displaced. The apparent loss in weight of the body is equal to the upthrust on the body.

Points to be remembered:

- When a body is immersed either partially or fully in a liquid, it experiences and upthrust or buoyant force (F_B). This upthrust (F_B) is equal to the weight (W_l) of the liquid displaced by the body i.e. $F_B = W_l = V.d_l.g$

  where 'd_l' is the density of liquid in which the body is immersed and V is the volume of the liquid displaced.
- Buoyant Force (F_B) depends upon : (a) Volume of the liquid displaced and (b) density of the liquid.
- Apparent weight of a body in a liquid = true weight of the body (W) – weight (W_l)
- Loss in weight when a body is immersed in a liquid = $F_B = W_l$.
- Archimedes' principle has many applications. It is used in designing ships and submarines. Lactometers, which are used to determine the purity of a sample of milk and hydrometers used for determining density of liquids, are based on this principle.

A ship made up of iron floats in water. This is because the ship is hollow and contains air. The large space inside the ship enables it to displace a volume of water much greater than the actual volume of iron that was used in the construction. So the weight of water is placed is greater than the weight of the ship.

A body which floats in a liquid is in equilibrium under the action of the two forces. (a) It's weight acting vertically downwards and (b)the resultant thrust on it due to the liquid acting upwards. These two forces must be equal and opposite. The resultant upthrust may be equal to or greater than the weight of the liquid by the body, and that it acts through the centre of gravity of the displaced liquid.

LAWS OF FLOATATION

1. The weight of the floating body is equal to the weight of the liquid displaced by it.

2. The centre of gravity of the floating body and the centre of gravity of the liquid displaced (centre of buoyancy) are in the same vertical line.

INTEXT QUESTIONS PAGE NO. 142

1. You find your mass to be 42 kg on a weighing machine. Is your mass more or less than 42 kg?
Ans.: When you weigh your body, an upward force acts on it. This upward force is the buoyant force. As a result, the body gets pushed slightly upwards, causing the weighing machine to show a reading less than the actual value.

2. You have a bag of cotton and an iron bar, each indicating a mass of 100 kg when measured on a weighing machine. In reality, one is heavier than other. Can you say which one is heavier and why?
Ans.: The iron bar is heavier than the bag of cotton. This is because the surface area of the cotton bag is larger than the iron bar. Hence, more buoyant force acts on the bag than that on an iron bar. This makes the cotton bag lighter than its actual value. For this reason, the iron bar and the bag of cotton show the same mass on the weighing machine, but actually the mass of the iron bar is more that that of the cotton bag.

DENSITY

Density of a substance is defined as its mass per unit volume.

$$Density(d) = \frac{mass(m)}{volume(V)} \quad or \quad d = \frac{m}{v}$$

The SI unit of density is kg/m^3.

RELATIVE DENSITY

Relative density of a substance is defined as the ratio of its density to that of water at 4^0C.

$$\text{Relative density} = \frac{\text{Density of substance}}{\text{Density of water at } 4^0\text{C}}$$

Relative density can also be defined as the ratio between the mass of the substance and the mass of an equal volume of water at 4^0C.

Density of water at $4^0C = 1\ g/cm^3 = 1000\ kg/m^3$.

Since the relative density is a ratio of similar quantities, it has no unit

NUMERICALS

1. Calculate the mass of a body whose volume is 2 m^3 and density 0.52 g/cm3.

2. A wooden block of dimensions 10 cm x 20 cm x 50 cm weighs 6.5kg. Calculate the density of the block.

3. A dining hall has dimensions 50m x 15m x 3.5m. Calculate the mass of air in the hall. Given density of air = 1.30 kg/m^3.

4. A thread of mercury of 10.2 g is in a tube of uniform cross-section 0.1cm^2. Calculate the length of the thread. The density of mercury is 13.6 g/cm^3.

5. The mass of a empty bucket of capacity 10 litres is 1 kg. Find its mass when completely filled with a liquid of relative density 0.8.

6. A piece of copper of mass 106g is dipped in a measuring cylinder containing water at 22 ml mark. The water rises to 34 ml mark. Find (a) volume of the copper piece (b) the density of copper.

7. A bottle weighs 30g when empty, 53.4 g when filled with a liquid and 48 g when filled with water. Calculate the density of the liquid. Given, density of water at 4^0C = 1000 kg/m^3.

8. An iron cylinder of radius 1.4 cm and length 8 cm is found to weigh 369.6 g. Calculate the density of iron.

9. Calculate the mass of air enclosed in a room of length, breadth and height equal to 5m, 3m and 4m respectively. Density of air = 1.3 kg/m^3.

10. The mass of a solid rectangle block of iron is 23.6 g and its dimensions are 2.1cm x 1.2cm x 1.1cm. Calculate the density of iron.

11. The mass of an empty 40 litre petrol tank of a vehicle is 8.0 kg. What will be its mass when filled completely with a fuel of density 700 kg/m^3.

12. A weather forecasting plastic balloon of volume 15m^3 contains hydrogen of density 0.09 kg/m^3. The mass of the empty balloon is 7.15kg. Calculate (a) the mass of hydrogen in the balloon (b) the mass of the balloon filled with hydrogen.

13. The mass of a density bottle is 25g when empty, 50g when filled completely with water and 365g when filled completely with mercury. Find the density of mercury.

14. A bottle can hold 100 g of water at 4^0C What mass of sea water (density = 1030 kg/m^3) can hold it hold?

15. Relative density of silver is 10.8. The density of water is 1000 kg/m^3. What is the density of silver in SI?

16. A piece of rock salt weighs 108.2 g in air and 48.2 g in saturated brine of relative density 1.2. What is the relative density of the rock salt?

17. A silver ornament is suspected to be hollow. Its weight is 250g and it displaces 50 cc of water. If the relative density of silver be 10, find the volume of the cavity.

18. If 100 cc iron of relative density 7.8 floats on mercury of relative density 13.6, what volume of iron is immersed?

19. A coil of wire of cross-section 0.75 mm^2 weighs 125g in air and 115 g in water. Find the length of the coil. (Density of water = 1000 kg/m^3?

20. A cubical block of water is dipped completely in water. Each edge of the block is 1cm in length. Find the buoyant force acting on the block.

21. A body of mass 2.0 kg and density 8000 kg/m^3 is completely dipped in a liquid of density 800 kg/m^3. Find the force of buoyancy on it.

22. A piece of iron of density 7.8 x 10^3 kg/m^3 and volume 100 cm^3 is totally immersed in water. Calculate (a) the weight of iron piece in air (b) the upthrust and (c) apparent weight in water.

23. A solid body of mass 150g and volume 250 cm^3 is put in water. Will the body float or sink?

24. A body of 50 cm^3 is completely immersed in water. Find the force of buoyancy on it.

25. A metallic sphere of radius 2.0 cm is completely dipped in water. Find the force of buoyancy on it.

26. A body of 2.0 kg floats in a liquid. What is the buoyant force on the body?

27. A solid of density 5000 kg/m^3 weighs 0.5 kg f in air. It is completely immersed in water of density 1000 kg/m^3. (a) Calculate the apparent weight of the solid in water. (b) What will be its apparent weight if water is replaced by a liquid of density 8000 kg/m^3.

28. The mass of block made of certain material is 13.5 kg and its volume is 15 x 10^{-3} m^3. Will the block float or sink in water? Give a reason for your answer.

29. A solid body of mass 4.0 x 10^3 kg and volume 2m^3 is put in water. Will the body float or sink?

30. A cube 8.5 cm on each side has a mass of 0.65 kg. Will the cube float or sink in water? Give reason for your answer.

<u>EXERCISE QUESTIONS PAGE NO. 145</u>

19. In what direction does the buoyant force on an object immersed in a liquid act?
An object immersed in a liquid experiences buoyant force in the upward direction.

20. Why does a block of plastic released under water come up to the surface of water?
Two forces act on an object immersed in water. One is the gravitational force, which pulls the object downwards, and the other is the buoyant force, which pushes the object upwards. If the upward buoyant force is greater than the downward gravitational force, then the object comes up to the surface of the water as soon as it is released within water. Due to this reason, a block of plastic released under water comes up to the surface of the water.

21. The volume of 50 g of a substance is 20 cm3. If the density of water is 1 gcm^{-3}, will the substance float or sink?

If the density of an object is more than the density of a liquid, then it sinks in the liquid. On the other hand, if the density of an object is less than the density of a liquid, then it floats on the surface of the liquid.

$$\text{Here, density of the substance} = \frac{\text{Mass of the substance}}{\text{Volume of the substance}} = \frac{50}{20} = 2.5 g / cm^3$$

The density of the substance is more than the density of water (1 g cm–3). Hence, the substance will sink in water.

22. The volume of a 500 g sealed packet is 350 cm^3. Will the packet float or sink in water if the density of water is 1 g cm^{-3}? What will be the mass of the water displaced by this packet?

$$\text{Density of the 500 g sealed packet} = \frac{\text{Mass of the packet}}{\text{Volume of the packet}} = \frac{500}{350} = 1.428 g / cm^3$$

The density of the substance is more than the density of water (1 g/cm^3). Hence, it will sink in water.

The mass of water displaced by the packet is equal to the volume of the packet, i.e., 350g.

CHAPTER - 11
WORK AND ENERGY

WORK

Work (W) is said to be done, when a force (F) acts on the body and point of application of the force is displaced (s) in the direction of force.

Work done = force x displacement W = F x s

i). If the body is displaced in the same direction of force, work is done by a force
ii). If the displacement is against a force, the work is done against the force.
iii). If the displacement is perpendicular to the direction of the force, work done is zero.

Unit of work

Unit of work is joule (J).

One joule of work is said to be done when a force of 1 newton acting on a body displacing it by a distance of 1 m.

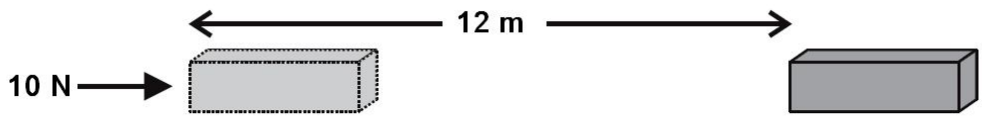
Larger units of work are

i) kilojoule (1000 joule)

ii) megajoule (10 lakh joule)

NUMERICALS

1. A force of 10 N acts on an object. The object is displaced through 12 m, in the direction of the force. If the force acts all through the displacement, find the work done by the force.



2. A porter lifts a luggage of 15 kg from the ground and puts it on his head 1.5 m above the ground. Calculate the work done by him on the luggage.

3. A boy pushes a book by applying a force of 40 N. Find the work done by this force on the book is displaced through 25 cm along the path.

4. A ball of mass 1 kg thrown upwards, reaches a maximum height of 4 m. Calculate the work done by the force of gravity during the vertical displacement. (g = 10m/s^2)

5. Find the amount of work done by a labourers who carrier 'n' bricks of 'm' kg each to the roof of a house 'h' metre high by climbing a ladder.

6. An engine pulls a train 1 km over a level track. Calculate the work done by the train given that the frictional resistance is 5 x 10^5 N.

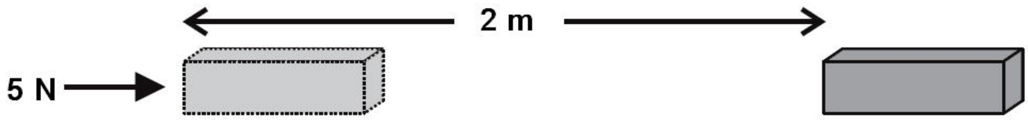
7. A man weighing 70 kg carries a weight of 10 kg on the top of a tower 100 m high. Calculate the work done by the man (g = $10 m/s^2$).

8. A boy of mass 55 kg runs up a flight of 40 stairs, each measuring 0.15m. Calculate the work done by the boy.

9. Calculate the work done in lifting 200 kg of water through a vertical height of 6 metres (g = $10 m/s^2$).

10. A crane pulls up a car of mass 500 kg to a vertical height of 4 m. Calculate the work done by the crane.

11. A force of 5 N acts on an object. The object id displaced through 8 m, in the direction of the force. If the force acts all through the displacement, find the work done by the force.



12. A porter lifts a luggage of 15 kg from the ground and puts it on his head 1.5 m above the ground. Calculate the work done by him on the luggage.

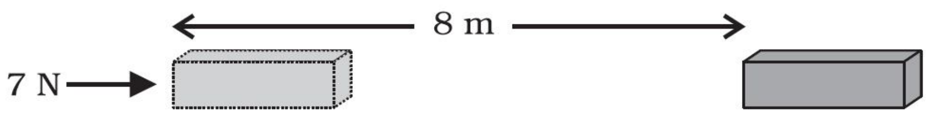
13. Calculate the work done by a student in lifting 0.5 kg book from the ground and keeping it on a shelf 1.5m high.

14. A collie carries a load of 50 kg on his head and walks on a level road upto 100 m. What is the work done by him?

15. A car weighing 1000 kg and traveling at 30m/s stops at a distance of 50m decelerating uniformly. What is the force exerted on it by the brakes? What is the work done by the brakes?

INTEXT QUESTIONS PAGE NO. 148

1. A force of 10 N acts on an object. The displacement is, say 8 m, in the direction of the force. Let us take it that the force acts on the object through the displacement. What is the work done in this case?



Ans: When a force F acts on an object to displace it through a distance S in its direction, then the work done W on the body by the force is given by:

Work done = Force × Displacement
W = F × S
where, F = 7 N , S = 8 m
Therefore, work done, W = 7 × 8 = 56 Nm = 56 J

INTEXT QUESTIONS PAGE NO. 149

1. **When do we say that work is done?**
   Ans: Work is done whenever the given conditions are satisfied:
   (i) A force acts on the body.
   (ii) There is a displacement of the body caused by the applied force along the direction of the applied force.

2. **Write an expression for the work done when a force is acting on an object in the direction of its displacement.**
   Ans: When a force F displaces a body through a distance S in the direction of the applied force, then the work done W on the body is given by the expression:
   Work done = Force × Displacement
   $W = F \times s$

3. **Define 1 J of work.**
   Ans: 1 J is the amount of work done by a force of 1 N on an object that displaces it through a distance of 1 m in the direction of the applied force.

4. **A pair of bullocks exerts a force of 140 N on a plough. The field being ploughed is 15 m long. How much work is done in ploughing the length of the field?**
   Ans: Work done by the bullocks is given by the expression:
   Work done = Force × Displacement
   $W = F \times d$
   Where,
   Applied force, F = 140 N
   Displacement, d = 15 m
   $W = 140 \times 15 = 2100$ J
   Hence, 2100 J of work is done in ploughing the length of the field.

ENERGY

The energy of the body is defined as its capacity to do work.

Unit of energy

Energy is measured in terms of work. Unit of energy is also joule. One joule of energy is required to do one joule of work.

DIFFERENT FORMS OF ENERGY

We live in a world where we have energy in many different forms. Some important forms of energy are mechanical energy, chemical energy, light energy, heat energy, electrical energy, nuclear energy and sound energy.

MECHANICAL ENERGY

The energy used to displace a body or to change the position of the body or to deform the body is known as mechanical energy.

Mechanical energy is of two types
i) Kinetic energy ii) Potential energy

KINETIC ENERGY

Energy possessed by an object due to its motion is called kinetic energy.
Kinetic energy of an object increases with its speed. Kinetic energy of an object moving with a velocity is equal to the work done on it to make it acquire that velocity.

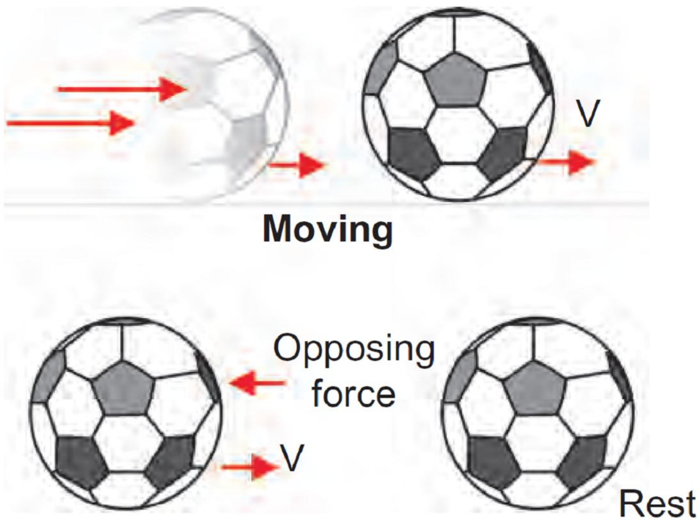
Example-1 Kinetic energy of a hammer is used to drive a nail into the wall.
Example-2 Bullet fi red from a gun can penetrate into a target due to its kinetic energy.

EXPRESSION FOR KINETIC ENERGY

Let a body (ball) of mass m is moving with an initial velocity v. If it is brought to rest by applying a retarding (opposing) force F, then it comes to rest by a displacement S. Let, E_k = work done against the force used to stop it.

$$E_k = F \cdot S \text{ -----> (1)}$$

But retarding force F = ma-----> (2)



Let initial velocity u = v, fi nal velocity v = 0
From III equation of motion, $v^2 = u^2 + 2as$ applying,

$$0 = v^2 - 2as \text{ (a is retardation)}$$

$$2as = v^2$$

$$\text{displacement, } s = \frac{v^2}{2a} \text{ ---------------->(3)}$$

substituting (2) and (3) in (1), we get

$$E_k = ma.\frac{v^2}{2a}$$

$$\Rightarrow E_k = \frac{1}{2}mv^2$$

Kinetic Energy of a moving object is defined as half the product of the mass of the object square of the speed of the object.

Work done (W) = Change in kinetic energy(E_k)

$$W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2 \text{ (when v > u)}$$

$$\text{Or } W = \frac{1}{2}mu^2 - \frac{1}{2}mv^2 \text{ (when u > v)}$$

INTEXT QUESTIONS PAGE NO. 152

1. **What is the kinetic energy of an object?**
   Ans:
   Kinetic energy is the energy possessed by a body by the virtue of its motion. Every moving object possesses kinetic energy. A body uses kinetic energy to do work. Kinetic energy of

hammer is used in driving a nail into a log of wood, kinetic energy of air is used to run wind mills, etc.

2. **Write an expression for the kinetic energy of an object.**
Ans:
If a body of mass m is moving with a velocity v, then its kinetic energy E_k is given by the expression, $E_k = \frac{1}{2}mv^2$. Its SI unit is Joule (J).

3. **The kinetic energy of an object of mass, m moving with a velocity of 5 ms^{-1} is 25 J. What will be its kinetic energy when its velocity is doubled? What will be its kinetic energy when its velocity is increased three times?**
Ans: Expression for kinetic energy is $E_k = \frac{1}{2}mv^2$
m = Mass of the object
v = Velocity of the object = 5 m/s
Given that kinetic energy, E_k = 25 J
(i) If the velocity of an object is doubled, then v = 5 × 2 = 10 m/s.
Therefore, its kinetic energy becomes 4 times its original value, because it is proportional to the square of the velocity. Hence, kinetic energy = 25 × 4 = 100 J.
(ii) If velocity is increased three times, then its kinetic energy becomes 9 times its original value, because it is proportional to the square of the velocity. Hence, kinetic energy = 25 × 9 = 225 J.

NUMERICALS

21. How far should a man of mass 60 kg run so that his kinetic energy is 750 J?

22. Find the mass of the body which has 5 J of kinetic energy while moving at a speed of 2 m/s.

23. A player kicks a ball of mass 250 g at the centre of a field. The ball leaves his foot with a speed of 10m/s. Find the work done by the player on the ball.

24. A body of mass 5 kg, initially at rest, is subjected to a force of 20 N. What is the kinetic energy acquired by the body at the end of 10 s?

25. A bullet of mass 20g moving with a velocity of 500m/s, strikes a tree and goes out from the other side with a velocity of 400m/s. Calculate the work done by the bullet in joule in passing through the tree.

26. An object of mass 15 kg is moving with a uniform velocity of 4m/s. What is the kinetic energy possessed by the object?

27. What is the work done to increase the velocity of a car from 30 km/hr to 60 km/he if the mass of the car is 1500kg?

28. A bullet of mass 0.03kg moving with a velocity of 400m/s, penetrates 12 cm into fixed a constant resistive force of 1000 N to the motion of the bullet, find (a) the initial kinetic energy of the bullet (b) the distance through which the bullet has penetrated.

29. Two bodies of equal masses move with uniform velocities v and 3v respectively. Find the ratio of their kinetic energies.

30. The mass of a ball A is double the mass of another ball B. The ball A moves at half the speed of the ball B. Calculate the ratio of the kinetic energy of A to the kinetic energy of B.

31. A truck weighing 5000 kgf and a cart weighing 500 kgf are moving with the same speed. Compare their kinetic energies.

32. A bullet of mass 20g is found to pass two points 30m apart in 4s? Assuming the speed to be constant find its kinetic energy.

POTENTIAL ENERGY

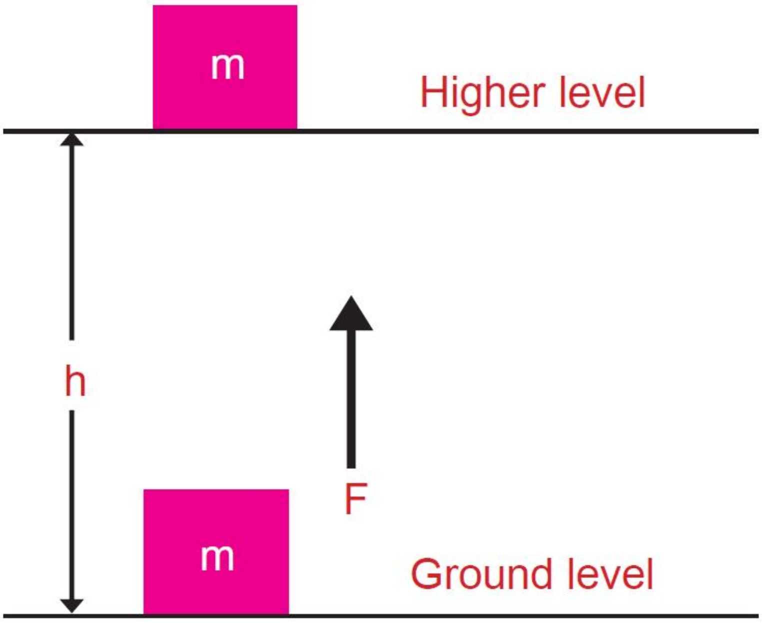
The energy possessed by a body by virtue of its position or due to state of strain, is called *potential energy*. The work done to lift a body above the ground level gives the potential energy of the body. Eg. weight lifting.

Example: Water stored in reservoir has large amount of potential energy due to which it can drive a water turbine when allowed to fall down. This is the principle of production of hydro-electric energy.

EXPRESSION FOR POTENTIAL ENERGY OF A BODY ABOVE THE GROUND LEVEL

Work is done in raising an object from the ground to certain height against the gravity is stored in the body as a potential energy.

Consider an object of mass m. It is raised through a height h from the ground. Force is needed to do this.



The downward force acting on the body due to gravity = mg.

The work has to be done to lift the body through a height h against the force of gravity as shown in above figure.

The object gains energy to do the work done (w) on it.

work done = force x displacement

w = F x h

w = mgh [Since F=ma and a=g, therefore F=mg]

Work done is equal to potential energy of an object.

$$E_p = mgh.$$

NOTE: The potential energy of an object at a height depends on the ground level or the zero level you choose. An object in a given position can have a certain potential energy with respect to one level and a different value of potential energy with respect to another level.

NUMERICALS

1. A body of mass 4 kg is taken from a height of 5m to a height 10m. Find the increase in potential energy.

2. An object of mass 1 kg is raised through a height 'h'. Its potential energy increases by 1 J, find the height 'h'.

3. A 5 kg ball is thrown upwards with a speed of 10m/s. (a) Find the potential energy when it reaches the highest point. (b) Calculate the maximum height attained by it.

4. A 5 kg ball is dropped from a height of 10m. (a) Find the initial potential energy of the ball (b) Find the kinetic energy just before it reaches the ground and (c) Calculate the velocity before it reaches the ground.

5. A body is thrown up with a kinetic energy of 10J. If it attains a maximum height of 5m, find the mass of the body.

6. A rocket of mass 3×10^6 kg takes off from a launching pad and acquires a vertical velocity of 1 km/s and an altitude of 25 km. Calculate its (a) potential energy (b) kinetic energy.

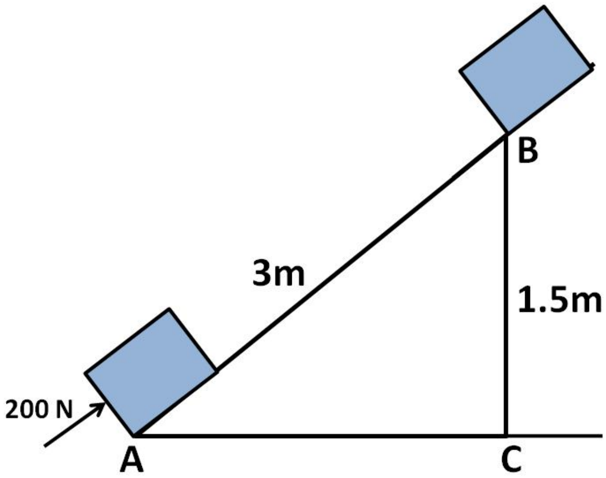
7. Find the energy possessed by an object of mass 10 kg when it is at a height of 6m above the ground. Given, $g = 9.8 \text{ m/s}^2$.

8. An object of mass 12 kg is at a certain height above the ground. If the potential energy of the object is 480 J, find the height at which the object is with respect to the ground. Given, $g = 10 \text{ m/s}^2$.

9. Calculate the increase in potential energy as a block of 2 kg is lifted through 2m.

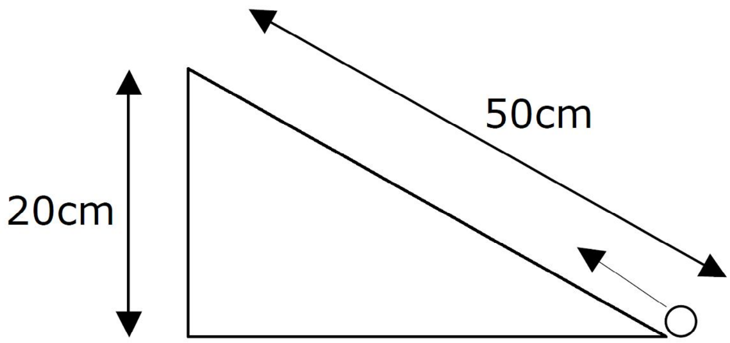
10. A ball of mass 1 kg is dropped from a height of 5m. (a) Find the kinetic energy of the ball just before it reaches the ground (b) What is the speed at this instant?

11. A block of mass 30 kg is pulled up by a rope as shown in below figure with a constant speed by applying of 200 N parallel to the slope. A and B are the initial and final positions of the block. Calculate (a) work done by the force in moving the block from A to B. (b) the potential energy gained by the block (c) account for the difference in work done by the force and the increase in potential energy of the block.



12. A body of mass 5 kg falls from height of 5m. How much energy does it possess at any instant?

13. A 800g ball is pulled up a slope as shown in the diagram. Calculate the potential energy it gains.



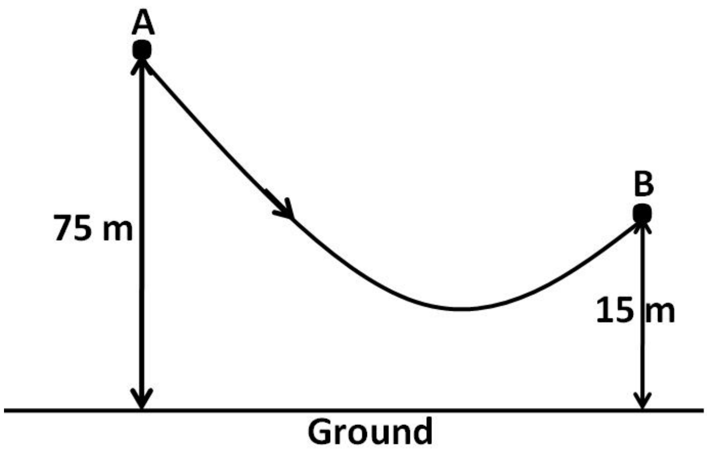
14. A spring is compressed by a toy cart of mass 150g. On releasing the cart, it moves with a speed of 0.2m/s. Calculate the elastic potential energy of the spring.

15. An object of mass 40 kg is raised to a height of 5 m above the ground. What is its potential energy? If the object is allowed to fall, find its kinetic energy when it is half-way down.

16. A box has a mass of 5.8kg. The box is lifted from the garage floor and placed on a shelf. If the box gains 145 J of Potential Energy (Ep), how high is the shelf?

17. A man climbs on to a wall that is 3.6m high and gains 2268J of potential energy. What is the mass of the man?

18. Below figure shows a ski- jump. A skier of mass 60 kg stands at A at the top of the ski-jump. He moves from A to B and takes off his jump at B. (a) Calculate the change in the gravitational potential energy of the skier between A and B (b) If 75% of the energy in part (a) becomes the kinetic energy at B, calculate the speed at which the skier arrives at B.



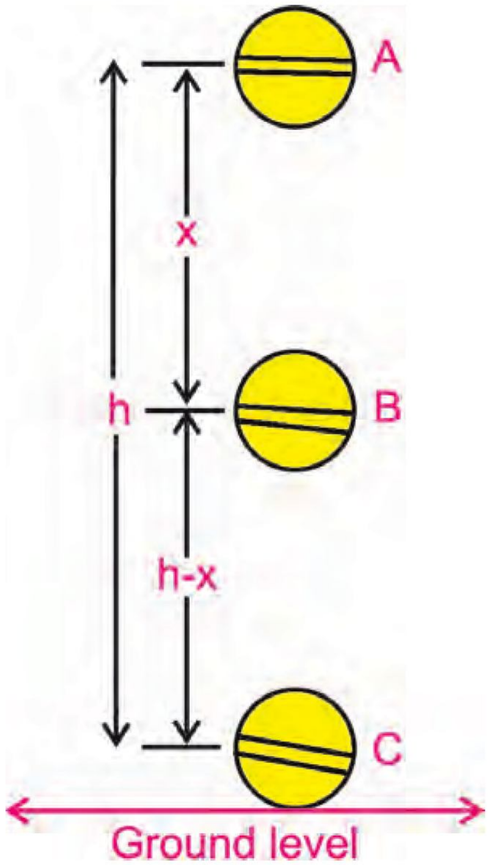
19. Consider the case of freely falling body given in the figure:
At A,
Kinetic energy=0 and
Potential energy=mgh
At B,
Kinetic energy=mgx
At C,
Kinetic energy=mgh and Potential energy=0

a) Find the potential energy of the body at B.

b) Find the total energy at A,B and C.

c) Is there any variation in total energy?

What do you infer from the result?



20. A bag of wheat weighs 200 kg. To what height should it be raised so that its potential energy may be 9800 joules? (9.8 m/s^2)

POWER

Power is defined as the rate of doing work or the rate of transfer of energy. If an agent does a work *W* in time *t*, then power is given by:

$$Power = \frac{Work}{Time} = \frac{Energy}{Time}$$

$$\Rightarrow P = \frac{W}{t}$$

The unit of power is watt having the symbol W. 1 watt is the power of an agent, which does work at the rate of 1 joule per second.
Power is 1 W when the rate of consumption of energy is 1 J/s.
1 watt = 1 joule/second or 1 W = 1 J/s.

Larger Units of Power

1 kilowatt = 1000 watts
1 kW = 1000 W

1 kW = 1000 J/s.

Commercial unit of energy is kilo watt hour.
A unit which is exclusively used in engineering is called a horse power (hp)

1 hp = 746 W

Commercial unit of energy: kilowatt hour (kWh)

$$1 \text{ kWh} = 1 \text{ kW} \times 1 \text{ h} = 1000 \text{ W} \times 3600 \text{ s} = 3600000 \text{ J}$$
$$= 3.6 \times 10^6 \text{ J} = 3.6 \text{ MJ(Mega Joule)}$$

One kilowatt hour is the amount of energy consumed by an agent in one hour working at a constant rate of one kilowatt. It is also called unit of electrical energy

INTEXT QUESTIONS PAGE NO. 156

1. **What is power?**
   Ans:
   Power is the rate of doing work or the rate of transfer of energy. If W is the amount of work done in time t, then power is given by the expression,
   $$Power = \frac{Work}{Time} = \frac{Energy}{Time} \qquad \Rightarrow P = \frac{W}{t}$$
   It is expressed in watt (W).

2. **Define 1 watt of power.**
   Ans:
   1 watt is the power of an agent, which does work at the rate of 1 joule per second.
   Power is 1 W when the rate of consumption of energy is 1 J/s.
   1 watt = 1 joule/second or 1 W = 1 J/s.

3. **A lamp consumes 1000 J of electrical energy in 10 s. What is its power?**
   Ans: Here, electrical energy consumption, W = 1000 J, time, t = 10 s.
   $$Power = \frac{W}{T} = \frac{1000}{10} = 100W$$

4. **Define average power.**
   Ans: A body can do different amount of work in different time intervals. Hence, it is better to define average power. Average power is obtained by dividing the total amount of work done in the total time taken to do this work.
   $$\text{Average power} = \frac{\text{total energy consumed}}{\text{total time taken}}$$

NUMERICALS

1. Two girls each of weight 400N, climb up a rope through a height of 8m. We name one of the girls A and the other B. Girl A takes 20s while B takes 50s to accomplish this task. What is the power expended by each girl?
2. A boy of mass 50kg runs up a staircase of 45 steps in 9s. If the height of each step is 15cm, find his power. Take g = 10 m/s^2.
3. An electric bulb of 60W is used for 6 hr per day. Calculate the ‘units’ of energy consumed in one day by the bulb.
4. A 60 kg person climbs stairs of total height 20 m in 2 min. Calculate the power delivered.

5. The work done by the heart is 1 J per beat. Calculate the power of the heart if it beats 72 times/min.
6. A man exerts a force of 200 N in pulling a cart at a constant speed of 16m/s. Calculate the power spent by the man.
7. Calculate the power of an engine required to lift 10^5 kg of coal per hour from a mine 360m deep.
8. A man does 200 J of work in 10 s and a boy does 100 J of work in 4s. (a) Who is delivering more power? (b) Find the ratio of the power delivered by the man to that delivered by the boy.
9. A boy of mass 40 kg runs up a flight of 50 steps, each of 10cm high in 5s. Find the power developed by the boy.
10. A car of mass 2000 kg is lifted up a distance of 30m by a crane in 1 min. A second crane does the same job in 2 min. What is the power applied by each crane? Do the carne consume the same or different amounts of fuel? Neglect power dissipation against friction.
11. What should be the power of an engine required to lift 90 metric tones of coal per hour from a mine whose depth is 200m?
12. How much time does it take to perform 500 J of work at a rate of 10 W?
13. Calculate the units of energy consumed by 100 W electric bulb in 5 hours.
14. A lift is designed to carry a load of 4000 kg through 10 floors of a building, averaging 6 m per floor, in 10s. Calculate the power of the lift.

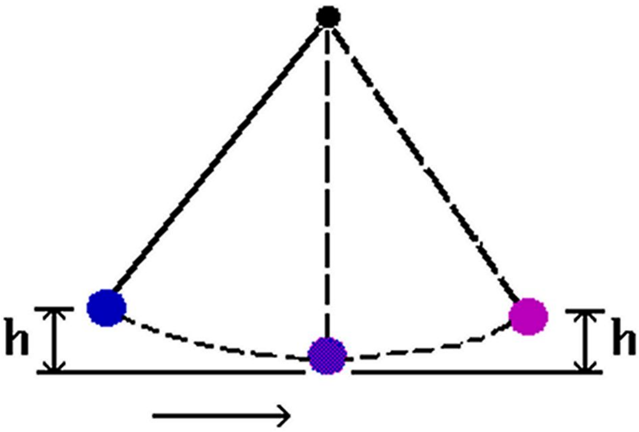
ENERGY TRANSFERMATION

- **Water from dam:** Potential energy into Kinetic energy
- **Microphone :** Sound energy into Electrical energy
- **TV Camera :** Light energy into Electrical energy
- **Solar Cell :** Light energy into Electrical energy
- **Iron Box :** Electrical energy into Heat energy
- **Loud speaker :** Electrical energy into Sound energy
- **Fan :** Electrical energy into Mechanical energy
- **Light :** Electrical energy into Light energy

LAW OF CONSERVATION OF ENERGY

Energy in a system may take on various forms (e.g. kinetic, potential, heat, light). The law of conservation of energy states that energy may neither be created nor destroyed. Therefore the sum of all the energies in the system is a constant.

The most commonly used example is the pendulum:



The formula to calculate the potential energy is: PE = mgh
The mass of the ball = 10kg
The height, h = 0.2m
The acceleration due to gravity, g = 9.8 m/s^2
Substitute the values into the formula and you get:
PE = 19.6J (J = Joules, unit of energy)

- The position of the blue ball is where the Potential Energy (PE) = 19.6J while the Kinetic Energy (KE) = 0.
  As the blue ball is approching the purple ball position the PE is decreasing while the KE is increasing. At exactly halfway between the blue and purple ball position the PE = KE.
- The position of the purple ball is where the Kinetic Energy is at its maximum while the Potential Energy (PE) = 0.
  At this point, theoretically, all the PE has transformed into KE> Therefore now the KE = 19.6J while the PE = 0.
- The position of the pink ball is where the Potential Energy (PE) is once again at its maximum and the Kinetic Energy (KE) = 0.

We can now say and understand that:

$$PE + KE = 0$$

$$PE = -KE$$

The sum of PE and KE is the total mechanical energy:

$$\text{Total Mechanical Energy} = PE + KE$$

COMMERCIAL UNIT OF ENERGY

The unit joule is too small and hence is inconvenient to express large quantities of energy. We use a bigger unit of energy called kilowatt hour (kW h).
The commercial unit of electric energy is kilowatt hour (kW h), commonly known as 'unit'.
1 kWh is the amount of energy consumed by an electrical gadget in one hour at the rate of 1000 J/s or 1kW.

$$\begin{aligned} 1 \text{ kW h} &= 1 \text{ kW} \times 1 \text{ h} \\ &= 1000 \text{ W} \times 3600 \text{ s} \\ &= 3600000 \text{ J} \\ 1 \text{ kW h} &= 3.6 \times 10^6 \text{ J.} \end{aligned}$$

The energy used in households, industries and commercial establishments are usually expressed in kilowatt hour. For example, electrical energy used during a month is expressed in terms of ‘units’. Here, 1 ‘unit’ means 1 kilowatt hour.

EXERCISE QUESTIONS PAGE NO. 158 AND 159

1. **Look at the activities listed below. Reason out whether or not work is done in the light of your understanding of the term ‘work’.**
   a). Suma is swimming in a pond.
   b). A donkey is carrying a load on its back.
   c). A wind-mill is lifting water from a well.
   d). A green plant is carrying out photosynthesis.
   e). An engine is pulling a train.
   f). Food grains are getting dried in the sun.
   g). A sailboat is moving due to wind energy.

Ans:

Work is done whenever the given two conditions are satisfied:
(i) A force acts on the body.
(ii) There is a displacement of the body by the application of force in or opposite to the direction of force.
(a) While swimming, Suma applies a force to push the water backwards. Therefore, Suma swims in the forward direction caused by the forward reaction of water. Here, the force causes a displacement. Hence, work is done by Seema while swimming.
(b) While carrying a load, the donkey has to apply a force in the upward direction. But, displacement of the load is in the forward direction. Since, displacement is perpendicular to force, the work done is zero.
(c) A wind mill works against the gravitational force to lift water. Hence, work is done by the wind mill in lifting water from the well.
(d) In this case, there is no displacement of the leaves of the plant. Therefore, the work done is zero.
(e) An engine applies force to pull the train. This allows the train to move in the direction of force. Therefore, there is a displacement in the train in the same direction. Hence, work is done by the engine on the train.
(f) Food grains do not move in the presence of solar energy. Hence, the work done is zero during the process of food grains getting dried in the Sun.
(g)Wind energy applies a force on the sailboat to push it in the forward direction. Therefore, there is a displacement in the boat in the direction of force. Hence, work is done by wind on the boat.

2. **An object thrown at a certain angle to the ground moves in a curved path and falls back to the ground. The initial and the final points of the path of the object lie on the same horizontal line. What is the work done by the force of gravity on the object?**
   Ans: Work done by the force of gravity on an object depends only on vertical displacement. Vertical displacement is given by the difference in the initial and final positions/heights of the object, which is zero.

   Work done by gravity is given by the expression,
   $W = mgh$, where, h = Vertical displacement = 0
   $W = mg \times 0 = 0$ J
   Therefore, the work done by gravity on the given object is zero joule.

3. **A battery lights a bulb. Describe the energy changes involved in the process.**
Ans: When a bulb is connected to a battery, then the chemical energy of the battery is transferred into electrical energy. When the bulb receives this electrical energy, then it converts it into light and heat energy. Hence, the transformation of energy in the given situation can be shown as:
Chemistry Energy $\rightarrow$ Electrical Energy $\rightarrow$ Light Energy + Heat Energy

4. **Certain force acting on a 20 kg mass changes its velocity from 5 m s^{-1} to 2 m s^{-1}. Calculate the work done by the force.**
Ans: Kinetic energy is given by the expression, $(E_k)_v = \frac{1}{2}mv^2$
where, E_k = Kinetic energy of the object moving with a velocity, v
m= Mass of the object
(i) Kinetic energy when the object was moving with a velocity 5 m s−1
$(E_k)_5 = \frac{1}{2}\times 20\times 5^2 = 250J$
Kinetic energy when the object was moving with a velocity 2 m s−1
$(E_k)_2 = \frac{1}{2}\times 20\times 2^2 = 40J$
Work done by force is equal to the change in kinetic energy.
Therefore, work done by force = $(E_k)_2 - (E_k)_5$ = 40 − 250 = −210 J
The negative sign indicates that the force is acting in the direction opposite to the motion of the object.

5. **A mass of 10 kg is at a point A on a table. It is moved to a point B. If the line joining A and B is horizontal, what is the work done on the object by the gravitational force? Explain your answer.**
Ans: Work done by gravity depends only on the vertical displacement of the body. It does not depend upon the path of the body. Therefore, work done by gravity is given by the expression,
W = mgh
where, Vertical displacement, h = 0
Therefore, W = mg × 0 = 0
Hence, the work done by gravity on the body is zero.

6. **The potential energy of a freely falling object decreases progressively. Does this violate the law of conservation of energy? Why?**
Ans: No. The process does not violate the law of conservation of energy. This is because when the body falls from a height, then its potential energy changes into kinetic energy progressively. A decrease in the potential energy is equal to an increase in the kinetic energy of the body. During the process, total mechanical energy of the body remains conserved. Therefore, the law of conservation of energy is not violated.

7. **What are the various energy transformations that occur when you are riding a bicycle?**
Ans: While riding a bicycle, the muscular energy of the rider gets transferred into heat energy and kinetic energy of the bicycle. Heat energy heats the rider's body. Kinetic energy provides a velocity to the bicycle. The transformation can be shown as:
Mechanical Energy $\rightarrow$ Kinetic Energy + Heat Energy
During the transformation, the total energy remains conserved.

8. **Does the transfer of energy take place when you push a huge rock with all your might and fail to move it? Where is the energy you spend going?**
Ans: When we push a huge rock, there is no transfer of muscular energy to the stationary rock. Also, there is no loss of energy because muscular energy is transferred into heat energy, which causes our body to become hot.

9. **A certain household has consumed 250 units of energy during a month. How much energy is this in joules?**
Ans: 1 unit of energy is equal to 1 kilowatt hour (kWh).
1 unit = 1 kWh
1 kWh = 3.6×10^6 J
Therefore, 250 units of energy = $250 \times 3.6 \times 10^6 = 9 \times 10^8$ J

10. **An object of mass 40 kg is raised to a height of 5 m above the ground. What is its potential energy? If the object is allowed to fall, find its kinetic energy when it is half-way down.**
Ans: Gravitational potential energy is given by the expression,
W = mgh
Where,
h = Vertical displacement = 5 m
m = Mass of the object = 40 kg
g = Acceleration due to gravity = 9.8 m s−2
Therefore, W = 40 × 5 × 9.8 = 1960 J.
At half-way down, the potential energy of the object will be $\frac{1960}{2}$ = 980 J.
At this point, the object has an equal amount of potential and kinetic energy. This is due to the law of conservation of energy. Hence, half-way down, the kinetic energy of the object will be 980 J.

11. **What is the work done by the force of gravity on a satellite moving round the earth? Justify your answer.**
Ans: Work is done whenever the given two conditions are satisfied:
(i) A force acts on the body.
(ii) There is a displacement of the body by the application of force in or opposite to the direction of force.
If the direction of force is perpendicular to displacement, then the work done is zero.
When a satellite moves around the Earth, then the direction of force of gravity on the satellite is perpendicular to its displacement. Hence, the work done on the satellite by the Earth is zero.

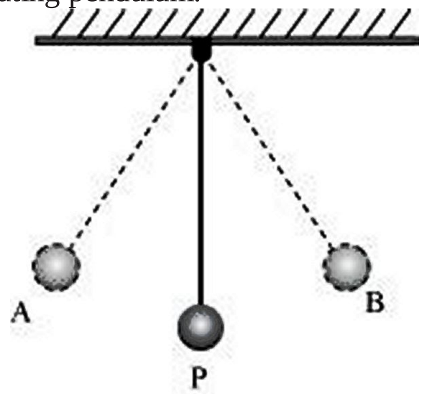
12. **Can there be displacement of an object in the absence of any force acting on it? Think. Discuss this question with your friends and teacher.**
Ans: Yes. For a uniformly moving object
Suppose an object is moving with constant velocity. The net force acting on it is zero. But, there is a displacement along the motion of the object. Hence, there can be a displacement without a force.

13. **A person holds a bundle of hay over his head for 30 minutes and gets tired. Has he done some work or not? Justify your answer.**
Ans: Work is done whenever the given two conditions are satisfied:
(i) A force acts on the body.

(ii) There is a displacement of the body by the application of force in or opposite to the direction of force.
When a person holds a bundle of hay over his head, then there is no displacement in the bundle of hay. Although, force of gravity is acting on the bundle, the person is not applying any force on it. Hence, in the absence of force, work done by the person on the bundle is zero.

14. An electric heater is rated 1500 W. How much energy does it use in 10 hours?
Ans: Energy consumed by an electric heater can be obtained with the help of the expression, $P = \frac{W}{T}$
where, Power rating of the heater, P = 1500 W = 1.5 kW
Time for which the heater has operated, T = 10 h
Work done = Energy consumed by the heater
Therefore, energy consumed = Power × Time = 1.5 × 10 = 15 kWh
Hence, the energy consumed by the heater in 10 h is 15 kWh.

15. Illustrate the law of conservation of energy by discussing the energy changes which occur when we draw a pendulum bob to one side and allow it to oscillate. Why does the bob eventually come to rest? What happens to its energy eventually? Is it a violation of the law of conservation of energy?
Ans: The law of conservation of energy states that energy can be neither created nor destroyed. It can only be converted from one form to another.
Consider the case of an oscillating pendulum.



When a pendulum moves from its mean position P to either of its extreme positions A or B, it rises through a height h above the mean level P. At this point, the kinetic energy of the bob changes completely into potential energy. The kinetic energy becomes zero, and the bob possesses only potential energy. As it moves towards point P, its potential energy decreases progressively. Accordingly, the kinetic energy increases. As the bob reaches point P, its potential energy becomes zero and the bob possesses only kinetic energy. This process is repeated as long as the pendulum oscillates.

The bob does not oscillate forever. It comes to rest because air resistance resists its motion. The pendulum loses its kinetic energy to overcome this friction and stops after some time.

The law of conservation of energy is not violated because the energy lost by the pendulum to overcome friction is gained by its surroundings. Hence, the total energy of the pendulum and the surrounding system remain conserved.

16. An object of mass, *m* is moving with a constant velocity, *v*. How much work should be done on the object in order to bring the object to rest?

Ans: Kinetic energy of an object of mass, m moving with a velocity, v is given by the expression, $E_k = \frac{1}{2}mv^2$

To bring the object to rest, $\frac{1}{2}mv^2$ amount of work is required to be done on the object.

17. Calculate the work required to be done to stop a car of 1500 kg moving at a velocity of 60 km/h?

Ans: Kinetic energy, $E_k = \frac{1}{2}mv^2$

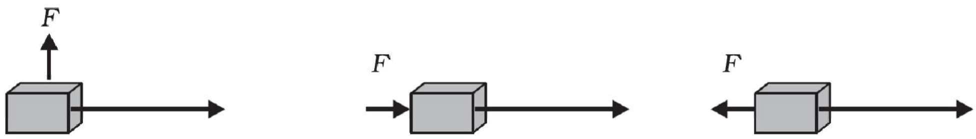
Where, Mass of car, m = 1500 kg

Velocity of car, v = 60 km/h $= 60 \times \frac{5}{18} ms^{-1}$

$\therefore E_k = \frac{1}{2} \times 1500 \times \left(60 \times \frac{5}{18}\right)^2 = 20.8 \times 10^4 J$

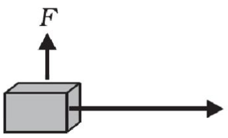
Hence, 20.8 × 104 J of work is required to stop the car.

18. In each of the following a force, *F* is acting on an object of mass, *m*. The direction of displacement is from west to east shown by the longer arrow. Observe the diagrams carefully and state whether the work done by the force is negative, positive or zero.



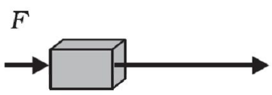
Ans: Work is done whenever the given two conditions are satisfied:
(i) A force acts on the body.
(ii) There is a displacement of the body by the application of force in or opposite to the direction of force.

Case I



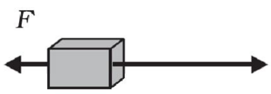
In this case, the direction of force acting on the block is perpendicular to the displacement. Therefore, work done by force on the block will be zero.

Case II



In this case, the direction of force acting on the block is in the direction of displacement. Therefore, work done by force on the block will be positive.

Case III



In this case, the direction of force acting on the block is opposite to the direction of displacement. Therefore, work done by force on the block will be negative.

19. Soni says that the acceleration in an object could be zero even when several forces are acting on it. Do you agree with her? Why?

Ans: Acceleration in an object could be zero even when several forces are acting on it. This happens when all the forces cancel out each other i.e., the net force acting on the object is zero. For a uniformly moving object, the net force acting on the object is zero. Hence, the acceleration of the object is zero. Hence, Soni is right.

20. Find the energy in kW h consumed in 10 hours by four devices of power 500 W each.

Ans: Energy consumed by an electric device can be obtained with the help of the expression for power, $P = \frac{W}{T}$

where, Power rating of the device, P = 500 W = 0.50 kW

Time for which the device runs, T = 10 h

Work done = Energy consumed by the device

Therefore, energy consumed = Power × Time = 0.50 × 10 = 5 kWh

Hence, the energy consumed by four equal rating devices in 10 h will be 4 × 5 kWh = 20 kWh = 20 Units

21. A freely falling object eventually stops on reaching the ground. What happenes to its kinetic energy?

Ans: When an object falls freely towards the ground, its potential energy decreases and kinetic energy increases. As the object touches the ground, all its potential energy gets converted into kinetic energy. As the object hits the hard ground, all its kinetic energy gets converted into heat energy and sound energy. It can also deform the ground depending upon the nature of the ground and the amount of kinetic energy possessed by the object.

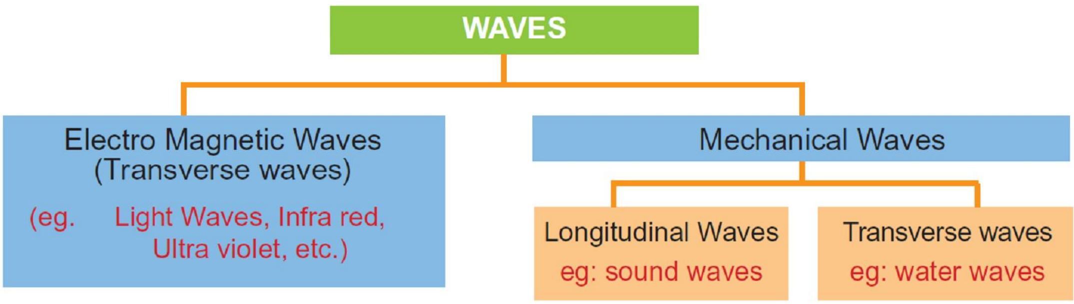
CHAPTER - 12
SOUND

Sound is a mechanical wave and needs a material medium like air, water, steel etc. for its propagation.
A **medium** is the substance or material through which a pulse or a wave moves.

INTEXT QUESTIONS PAGE NO. 162

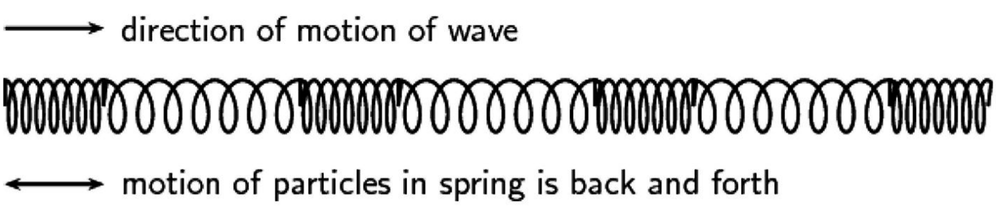
1. How does the sound produced by a vibrating object in a medium reach your ear?
Ans: When an object vibrates, it forces the neighbouring particles of the medium to vibrate. These vibrating particles then force the particles adjacent to them to vibrate. In this way, vibrations produced by an object are transferred from one particle to another till it reaches the ear.

LONGITUDINAL AND TRANSVERSE WAVE

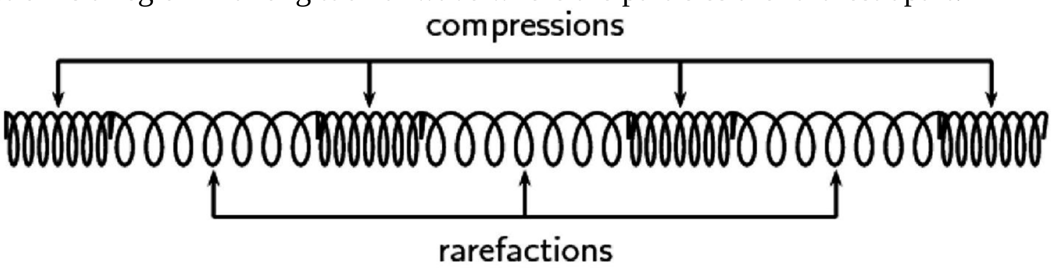


A **longitudinal wave** is a wave where the particles in the medium move **parallel** to the direction of propagation of the wave.
" If the particles of a medium vibrate in a direction, parallel to or along the direction of propagation of wave, it is called longitudinal wave "

Sound waves are pressure waves caused by objects which are vibrating. Sound waves **need a medium through which to travel.**

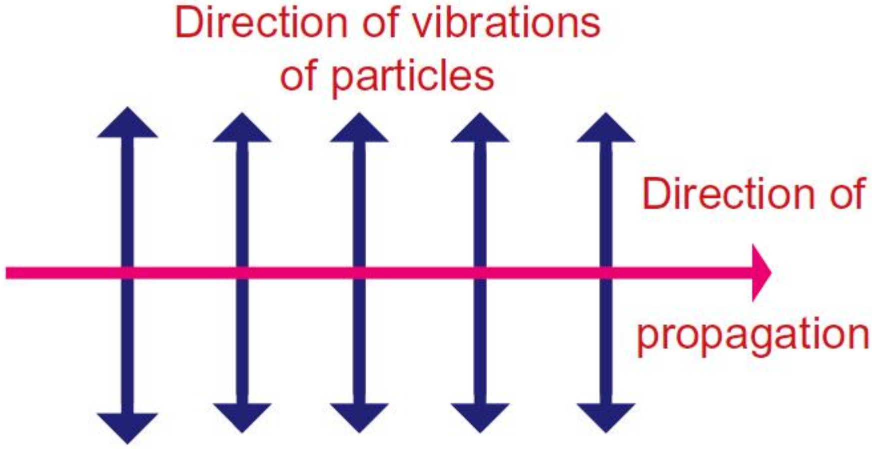


A compression is a region in a longitudinal wave where the particles are closest together. A rarefaction is a region in a longitudinal wave where the particles are furthest apart.

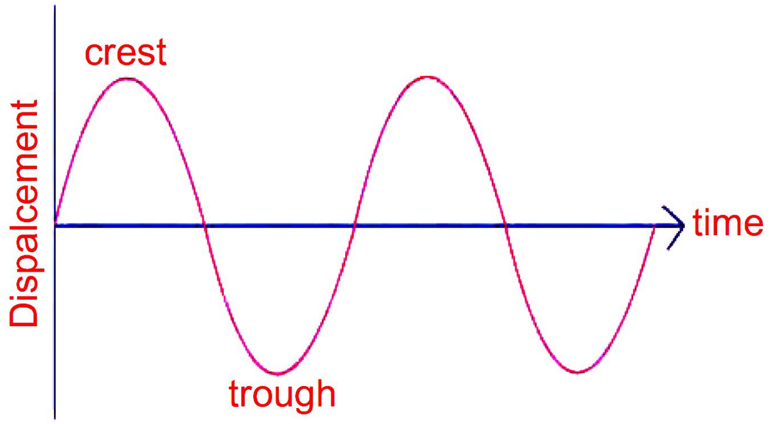


TRANSVERSE WAVE

"If the particles of the medium vibrate in a direction, perpendicular to the direction of propagation, the wave is called transverse wave. "
Example: water waves, vibrations of stretched string.



Transverse waves propagate in a medium in the form of crests and troughs as shown in fig:



Crest : The maximum displacement along the upward direction.
Trough: The maximum displacement along the downward direction.

INTEXT QUESTIONS PAGE NO. 163

1. Explain how sound is produced by your school bell.
   Ans: When the school bell vibrates, it forces the adjacent particles in air to vibrate. This disturbance gives rise to a wave and when the bell moves forward, it pushes the air in front of it. This creates a region of high pressures known as compression. When the bell moves backwards, it creates a region of low pressure know as rarefaction. As the bell continues to move forward and backward, it produces a series of compressions and rarefactions. This makes the sound of a bell propagate through air.

2. Why are sound waves called mechanical waves?
   Ans: Sound waves force the medium particles to vibrate. Hence, these waves are known as mechanical waves. Sound waves propagate through a medium because of the interaction of the particles present in that medium.

3. Suppose you and your friend are on the moon. Will you be able to hear any sound produced by your friend?

Ans: Sound needs a medium to propagate. Since the moon is devoid of any atmosphere, you cannot hear any sound on the moon.

CHARACTERISTICS OF SOUND

Sound can be distinguished from each other by the following three characteristics:

1. Loudness or Intensity
2. Pitch or Frequency
3. Quality or Timbre

1. Loudness

The sensation produced in the ear, which enables us to distinguish between a loud, and a faint sound is called loudness.
The amplitude of the wave determines the loudness or softness of a sound basically.

Intensity

The intensity of sound is defined as the amount of energy passing per unit time per unit area in a direction perpendicular to the area.

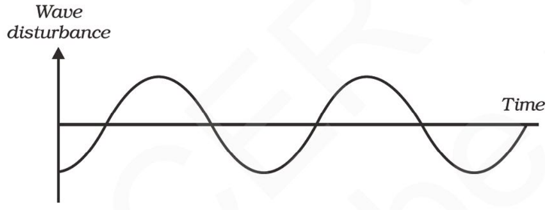
$$Intensity = \frac{energy}{area \times time} = \frac{power}{area}\left(\because power = \frac{energy}{area}\right)$$

The unit of intensity is watt/metre^2(W/m^2) .
Difference between loudness and intensity

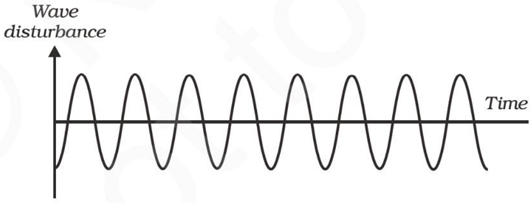
Loudness	Intensity
1. It is not an entirely physical quantity	**1.** It is a physical quantity which can be accurately measured.
2. It depends upon (i) sensitivity of the ear and (ii) intensity of the sound	**2.** It does not depends upon sensitivity of the ear.

Pitch or Frequency

Pitch is that characteristics of sound which helps in differentiating between a shrill sound from a grave (flat or dull) sound.
High and low pitched sounds are called treble and bass respectively.



Wave shape for a low pitched sound

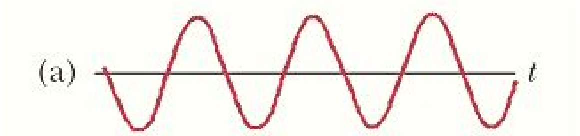


Wave shape for a high pitched sound

Quality or Timbre

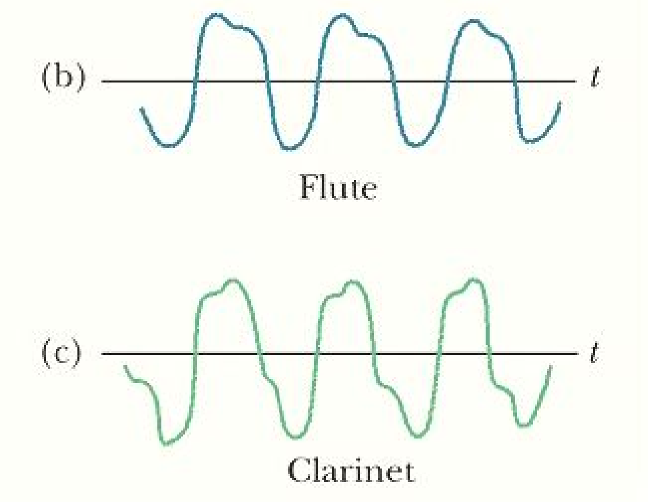
The characteristic of a sound which distinguishes it from another of the same pitch and loudness is called quantity or timbre.

A sound of single frequency is called a tone.



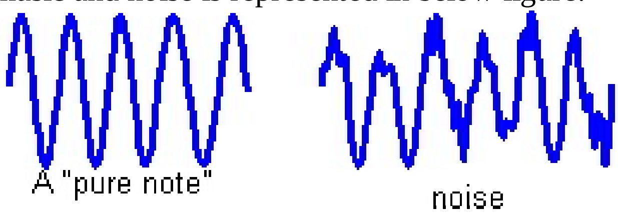
Tuning fork

A sound which is produced due to a mixture of several frequencies is called a note.



Music and Noise

The difference between music and noise is represented in below figure:



First figure is regular and has a definite amplitude. It represents a musical sound.

A musical sound can be defined as a pleasant continuous and uniform sound produced by regular and periodic vibrations. Example: The pleasant sound produced by a guitar, piano, tuning fork etc.

The second curve represents a noise. The curve is irregular and has no definite amplitude.

Musical sound is pleasant to hear and is of rich quality. Noise on the other hand is unpleasant to hear.

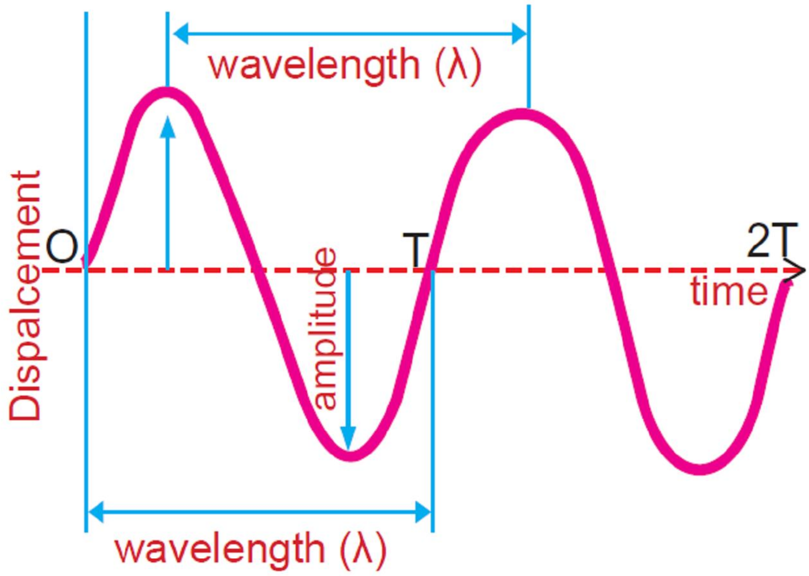
Noise can be defined as an irregular succession of disturbances, which are discordant and unpleasant to the ear.

TERMS RELATED TO SOUND WAVES

The ***amplitude*** A is the maximum excursion of a particle of the medium from the particles undisturbed position.

The ***wavelength*** is the horizontal length of one cycle of the wave.

The ***period*** is the time required for one complete cycle.



The ***frequency*** is related to the period and has units of Hz, or s^{-1}. The number of such oscillations per unit time is the frequency of the sound wave. $\nu = \frac{1}{T}$

The speed of sound is defined as the distance which a point on a wave, such as a compression or a rarefaction, travels per unit time.

We know, speed, $v = \frac{\text{distance}}{\text{time}} = \frac{\lambda}{\text{T}}$

Here λ is the wavelength of the sound wave. It is the distance travelled by the sound wave in one time period (T) of the wave. Thus, $v = \lambda \nu \quad \left(\because \nu = \frac{1}{T}\right)$

That is, speed = wavelength × frequency.

The speed of sound remains almost the same for all frequencies in a given medium

INTEXT QUESTIONS PAGE NO. 166

1. Which wave property determines (a) loudness, (b) pitch?
Ans: (a) Amplitude (b) Frequency
(a) The loudness of a sound depends on its amplitude. If the amplitude of a sound is large, then the sound produced will also be loud.
(b) The pitch of a sound depends on its frequency. A sound will be considered a high pitched sound, if its frequency is high.

2. Guess which sound has a higher pitch: guitar or car horn?
Ans: The frequency of the vibration of a sound produced by a guitar is greater than that produced by a car horn. Since the pitch of a sound is proportional to its frequency, the guitar has a higher pitch than a car horn.

INTEXT QUESTIONS PAGE NO. 166

1. What are wavelength, frequency, time period and amplitude of a sound wave?
Ans: Wavelength: The distance between two consecutive compressions or two consecutive rarefactions is known as the wavelength. Its SI unit is metre (m).
Frequency: The number of complete oscillations per second is known as the frequency of a sound wave. It is measured in hertz (Hz).

Amplitude: The maximum height reached by the crest or trough of a sound wave is called its amplitude.

2. How are the wavelength and frequency of a sound wave related to its speed?
Ans: Speed, wavelength, and frequency of a sound wave are related by the following equation:
Speed (v) = Wavelength (λ) × Frequency (ν)
$v = \lambda \times \nu$

3. Calculate the wavelength of a sound wave whose frequency is 220 Hz and speed is 440 m/s in a given medium.
Ans: Frequency of the sound wave, ν = 220 Hz
Speed of the sound wave, v = 440 m s^{-1}
For a sound wave,
Speed = Wavelength × Frequency
$v = \lambda \times \nu$
$\therefore \lambda = \frac{v}{\nu} = \frac{440}{220} = 2m$
Hence, the wavelength of the sound wave is 2 m.

4. A person is listening to a tone of 500 Hz sitting at a distance of 450 m from the source of the sound. What is the time interval between successive compressions from the source?
Ans: The time interval between two successive compressions is equal to the time period of the wave. This time period is reciprocal of the frequency of the wave and is given by the relation:
$T = \frac{1}{frequency} = \frac{1}{500} = 0.002s$

INTEXT QUESTIONS PAGE NO. 166

1. Distinguish between loudness and intensity of sound.
Ans: Intensity of a sound wave is defined as the amount of sound energy passing through a unit area per second. Loudness is a measure of the response of the ear to the sound. The loudness of a sound is defined by its amplitude. The amplitude of a sound decides its intensity, which in turn is perceived by the ear as loudness.

SONIC BOOM

When the speed of any object exceeds the speed of sound it is said to be travelling at supersonic speed. Bullets, jet aircrafts etc. often travel at supersonic speeds. When a sound, producing source moves with a speed higher than that of sound, it produces shock waves in air. These shock waves carry a large amount of energy. The air pressure variation associated with this type of shock waves produces a very sharp and loud sound called the "sonic boom". The shock waves produced by a supersonic aircraft have enough energy to shatter glass and even damage buildings.

INTEXT QUESTIONS PAGE NO. 167

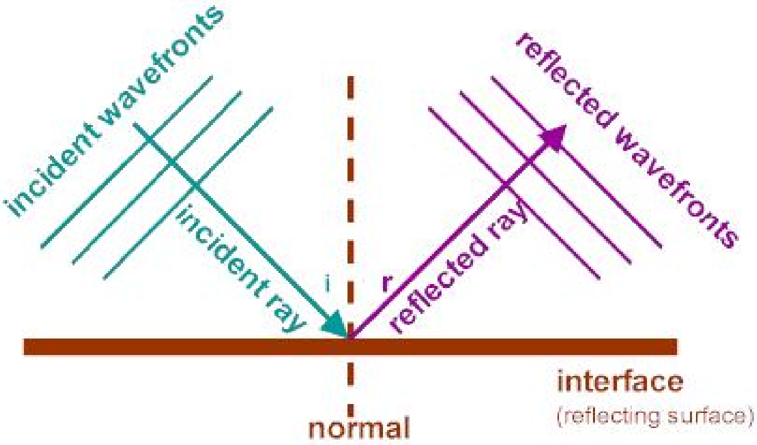
1. In which of the three media, air, water or iron, does sound travel the fastest at a particular temperature?
Ans: The speed of sound depends on the nature of the medium. Sound travels the fastest in solids. Its speed decreases in liquids and it is the slowest in gases.

Therefore, for a given temperature, sound travels fastest in iron.

REFLECTION OF SOUND

The reflection of sound follows the law "angle of incidence equals angle of reflection", sometimes called the law of reflection. The law state that:

1. The incident wave, the reflected wave and the normal(at the pont of incidence), all lie in the same plane.
2. The angle of reflection is always equal to the angle of incidence. i. e. $\angle i = \angle r$



ECHO

An echo is the phenomenon of repetition of sound of a source by reflection from an obstacle. The sensation of sound persists in our brain for about 0.1 s. This property is called persistence of hearing. Therefore, to hear a distinct echo the time interval between the original sound and the reflected one must be at least 0.1s.

Let d = minimum distance of the obstacles from the source

v = speed of sound in air

t = total time taken by the sound to reach the listener after reflection.

Then by distance = speed x time formula we have, 2d = v x t

Substituting v = 344m/s (speed of the sound in air at 20^0C) and t = 0.1s, we get

$$2d = 344 \times 0.1 = 34.4 \text{ m}$$

$$\mathbf{d = 17.2 \text{ m}}$$

Hence for hearing a distinct echo, the minimum distance of the obstacle from the source of sound should be 17.2m.

$$\boxed{d = \frac{vt}{2}}$$

where d is the distance between the source of sound and the obstacle, t is the time taken by sound in going to the obstacle and coming back and v is the speed of sound.

d is measured in metre, v in m/s and t in second.

INTEXT QUESTIONS PAGE NO. 168

1. An echo returned in 3 s. What is the distance of the reflecting surface from the source, given that the speed of sound is 342 m s^{-1}?

Ans: Speed of sound, v = 342 m s^{-1}

Echo returns in time, t = 3 s

Distance travelled by sound = v × t = 342 × 3 = 1026 m

In the given time interval, sound has to travel a distance that is twice the distance of the reflecting surface and the source.

Hence, the distance of the reflecting surface from the source $= \frac{1026}{2} = 513m$

MULTIPLE ECHOES

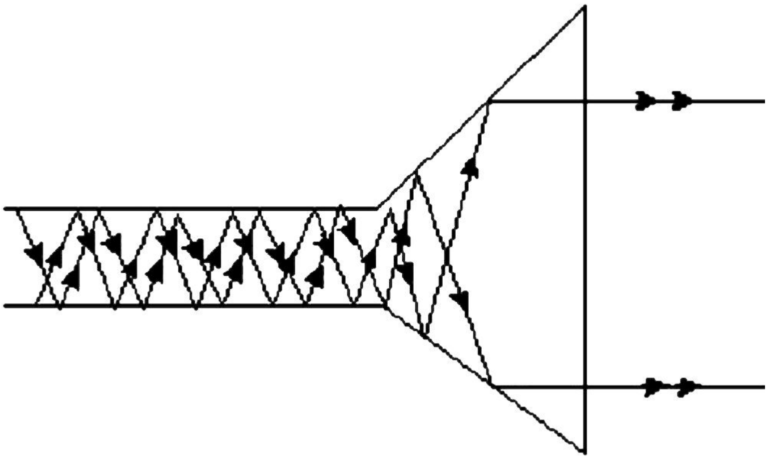
When sound is repeatedly reflected from a number of obstacles at suitable distances, many echoes are heard one after the other. This constitutes multiple echoes.

<u>Uses of Multiple Reflection of sound</u>

The phenomenon of multiple reflection of sound are given below:

1. *Megaphones or Speaking tubes.*

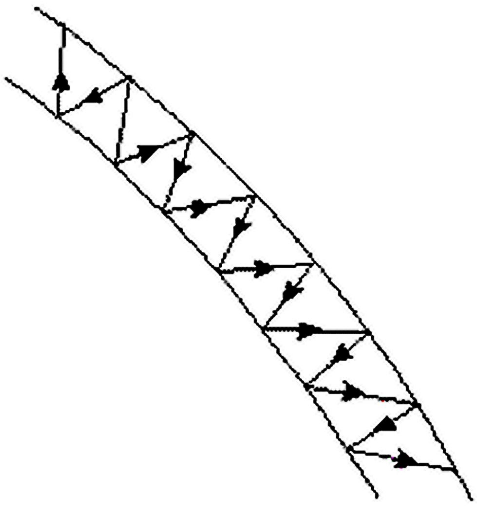
Megaphones or loudhailers, horns, musical instruments are all designed to send sound in a particular direction without spreading it in all directions. In these instruments, a tube followed by a conical opening reflects sounds successively to guide most of the sound waves from the source in the forward direction.



Multiple reflection of sound in a megaphone

2. *Stethoscope*

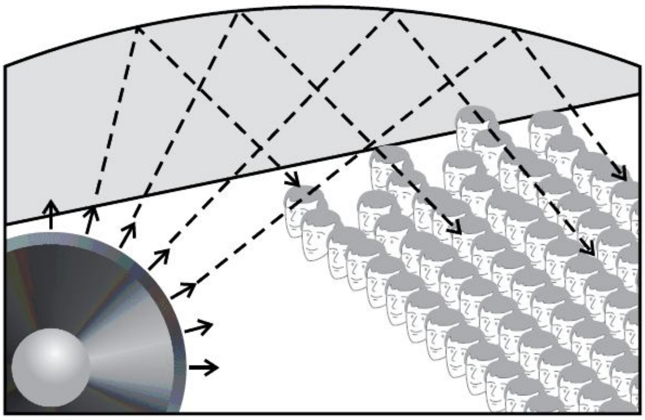
Stethoscope is a medical instrument used for listening to sounds produced within the body, chiefly in the heart or lungs. In stethoscopes the sound of the patient's heartbeat reaches the doctor's ears by multiple reflection of sound, as shown in below figure.

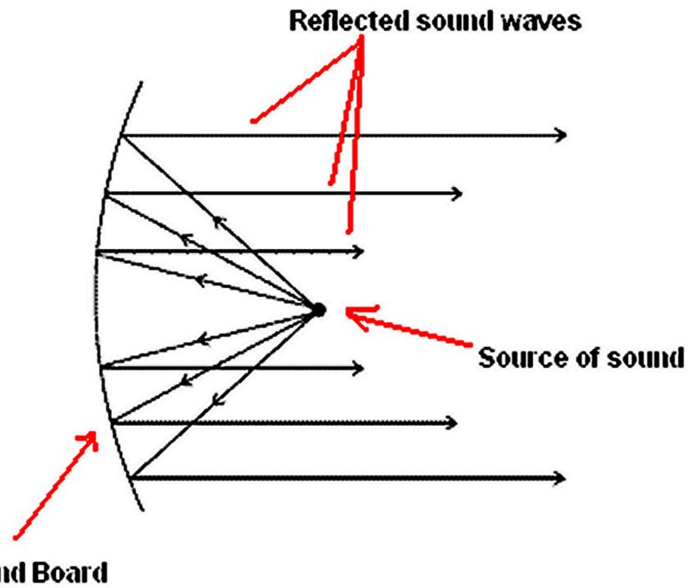


Muliple reflection of sound in the tube of stethoscope

3. *Design of concerts Halls, Cinema Halls and Conference Halls*

The ceilings of these halls are curved. This enables the sound to reach all corners of the hall after reflection from the ceiling as shown in below left figure.





A sound board, which is a curved sound reflecting surface, is placed behind the stage. The source is located at the focus of this reflecting surface. Sound waves coming from the source become parallel after reflection from the sound board and spread evenly throughout the width of the hall as shown in above right sided figure.

REVERBERATION

A sound created in a big hall will persist by repeated reflection from the walls until it is reduced to a value where it is no longer audible. The repeated reflection that results in this persistence of sound is called reverberation.

INTEXT QUESTIONS PAGE NO. 169

1. Why are the ceilings of concert halls curved?
Ans: Ceilings of concert halls are curved so that sound after reflection (from the walls) spreads uniformly in all directions.

RANGE OF FREQUENCIES

There are three categories of longitudinal mechanical waves which cover different range of frequencies:

1. Sound waves or Audible waves
These waves have frequencies which lie between 20 Hz to 20 kHz.

2. Infrasonic waves or Infrasound

Those longitudinal mechanical waves whose frequencies are below 20 Hz are called infrasonic waves.

3. Ultrasonic waves or Ultrasound

Those longitudinal mechanical waves whose frequencies are lie above 20 kHz are called ultrasonic waves.

APPLICATIONS OF ULTRASOUND

INDUSTRIAL USES OF ULTRASOUND

1. Cleaning instruments and electronics components

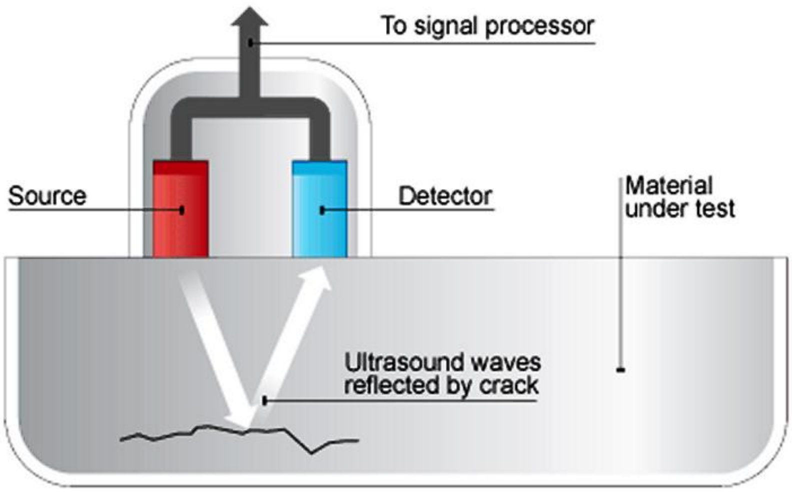
Ultrasound is generally used to clean parts located in hard-to-reach places, for example, spiral tube, odd shaped parts, electronic components etc. Objects to be cleaned are placed in a cleaning solution and ultrasonic waves are sent into the solution. Due to the high frequency, the particles of dust, grease and dirt get detached and drop out. The objects thus get thoroughly cleaned.

2. Plastic welding

Application of small pressure and ultrasonic vibration to two similar surface produce sufficient thermal energy to bond the surfaces together

3. Detecting flaws and cracks in metal blocks.

Ultrasounds can be used to detect cracks and flaws in metal blocks. Metallic components are generally used in construction of big structures like buildings, bridges, machines and also scientific equipment. The cracks or holes inside the metal blocks, which are invisible from outside reduces the strength of the structure. Ultrasonic waves are allowed to pass through the metal block and detectors are used to detect the transmitted waves. If there is even a small defect, the ultrasound gets reflected back indicating the presence of the flaw or defect, as shown in figure.



Medical uses of Ultrasound

1. Echocardiography

Ultrasonic waves are made to reflect from various parts of the heart and form the image of the heart. This technique is called 'echocardiography'.

2. Ultrasonography

Ultrasound scanner is an instrument which uses ultrasonic waves for getting images of internal organs of the human body. A doctor may image the patient's organs such as the liver, gall bladder, uterus, kidney, etc. It helps the doctor to detect abnormalities, such as stones in the gall bladder and kidney or tumours in different organs. In this technique the ultrasonic waves travel through the tissues of the body and get reflected from a region where there is a change of tissue density. These waves are then converted into electrical signals that are used to generate images of the organ. These images are then displayed on a monitor or printed on a film. This technique is called 'ultrasonography'. Ultrasonography is also used for examination of the foetus during pregnancy to detect congenial defects and growth abnormalities.

3. Surgical uses.

Ultrasound is used for bloodless brain surgery as well as painless extraction of teeth etc. Ultrasound may be employed to break small 'stones' formed in the kidneys into fine grains. These grains later get flushed out with urine.

4. Therapeutic uses.

Ultrasound is used for treatment of neuralgic and rheumatic pains.

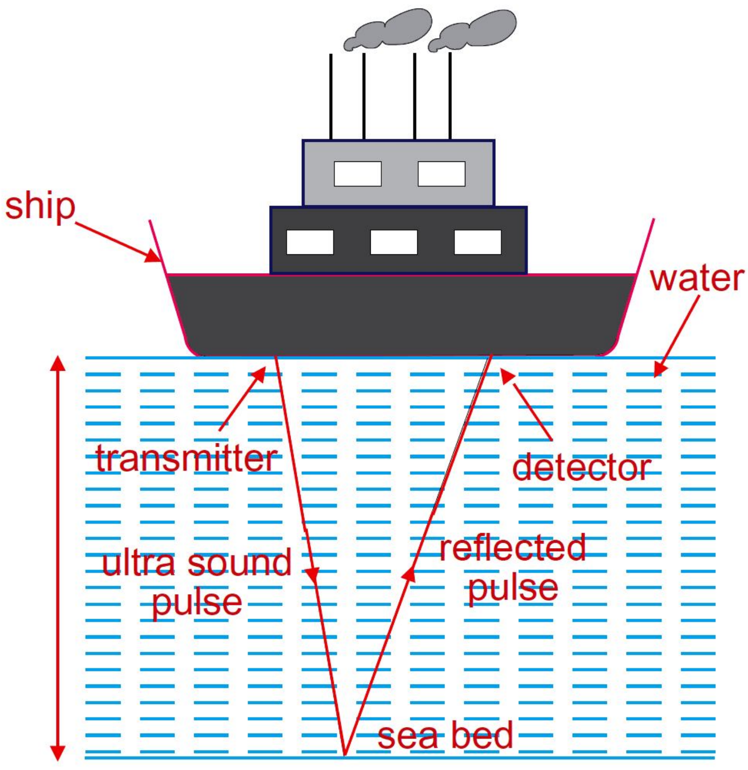
Communication (SONAR)

It is an acronym which means **SO**und **N**avigation **A**nd **R**anging.

A sonar is a device which measure the distance, direction and speed of objects lying under water using ultrasonic waves.

How does the sonar work?

The transmitter produces and transmits ultrasonic waves. These waves travel through water and after striking the object on the seabed, get reflected back and are sensed by the detector. The detector converts the ultrasonic waves into electrical signals which are appropriately interpreted. The distance of the object that reflected the sound wave can be calculated by knowing the speed of sound in water and the time interval between transmission and reception of the ultrasound.



Let the time interval between transmission and reception of ultrasound signal be t and the speed of sound through seawater be v. The total distance, $2d$ travelled by the ultrasound is then, $2d = v \times t$. The above method is called echo-ranging.

The sonar technique is used to determine the depth of the sea and to locate underwater hills, valleys, submarine, icebergs, sunken ship etc.

INTEXT QUESTIONS PAGE NO. 170

1. What is the audible range of the average human ear?
Ans: The audible range of an average human ear lies between 20 Hz to 20,000 Hz. Humans cannot hear sounds having frequency less than 20 Hz and greater than 20,000 Hz.

2. What is the range of frequencies associated with
(a) Infrasound?
(b) Ultrasound?
Ans: (a) Infrasound has frequencies less than 20 Hz.
(b) Ultrasound has frequencies more than 20,000 Hz.

INTEXT QUESTIONS PAGE NO. 172

1. A submarine emits a sonar pulse, which returns from an underwater cliff in 1.02 s. If the speed of sound in salt water is 1531 m/s, how far away is the cliff?
Ans: Time taken by the sonar pulse to return, t = 1.02 s
Speed of sound in salt water, v = 1531 m s^{-1}
Distance of the cliff from the submarine = Speed of sound × Time taken
Distance of the cliff from the submarine $= 1.02 \times 1531 = 1561.62m$
Distance travelled by the sonar pulse during its transmission and reception in water = 2 × Actual distance = 2d

$$\text{Actual distance, } d = \frac{\text{Distance of the cliff from the submarine}}{2}$$

$$= \frac{1561.62}{2} = 780.31m$$

NUMERICALS

1. A boy hears an echo of his own voice from a distant hill after 1 s. the speed of sound is 340m/s. What is the distance of the hill from the boy?

2. A boy is standing in front of wall at a distance of 85m produces 2 claps per second. He notices that the sound of his clapping coincides with the echo. The echo is heard only once when clapping is stopped. Calculate the speed of sound.

3. A man stationed between two parallel cliffs fires a gun. He hears the first echo after 1.5 s and the next after 2.5 s. What is the distance between the cliffs and when does he hear the third echo? Take the speed of sound in air is 340 m/s.

4. A man fires a shot and hears an echo from a cliff after 2s. He walks 85m towards the cliff and the echo of a second shot is now heard after 1.4s What is the velocity of sound and how far was the man from the cliff when he first heard the echo?

5. A boy hears an echo of his own voice from a distant hill after 2.5 s. the speed of sound is 340m/s. Calculate the distance of the hill from the boy.

6. A person clapped his hands near a cliff and heard the echo after 5 s. What is the distance of the cliff from the person if the speed of the sound, v is taken as 346 m/s?

7. A child hears an echo from a cliff after the sound of powerful cracker is produced. How far away is the cliff from the child? (Take speed of the sound in air as 340 m/s).

8. An observer standing between two cliffs fires a gun. He hears one echo after 1.5 s and another after 3.5 s. If the speed of sound is 340 m/s, find (a) the distance of the observer from the first cliff and (b) distance between the cliffs.

9. A boy stands 60m in front of a tall wall and claps. The boy continues to clap every time an echo is heard. Another boy finds that the time between the first (1st) and the fifty first (51st) clap is 18s. Calculate the speed of the sound.

10. A person standing between two vertical cliffs and 680m away from the nearest cliff, shouted. He heard the first echo after 4s and the second echo 3s later. Calculate (a) the speed of sound in air and the distance between the two cliffs.

11. A man standing at 51m from a wall fires a gun. Calculate the time after which an echo is heard. The speed of sound is 340 m/s.

12. A man fires a gun towards a hill and hears its echo after 5s. He then moves 340m towards the hill and fires his gun again. This time he hears the echo after 3s. Calculate the speed of the sound.

13. An engine is approaching a hill at constant speed. When it is at a distance of 0.9km, it blows a whistle, whose echo is heard by the driver after 5s. If the speed of sound is 340m/s, calculate the speed of the engine.

14. It takes 2.4a to record the echo of a sonar. If the speed of sound in water is 1450 m/s, find the depth of the ocean floor.

15. A ship which is stationary, is at a distance of 2900 m from the seabed. The ship sends an ultrasound signal to the seabed and its echo is heard 4s. Find the speed of sound in water.

16. A ship sends out ultrasound that returns from the seabed and is detected after 3.42s. If the speed of the ultrasound through sea water is 1531 m/s, what is the distance of the seabed from the ship?

17. A sonar device on a submarine sends out a signal and receives an echo 5s later. Calculate the speed of sound in water if the distance of the object from the submarine is 3625m.

18. A sonar emits pulses on the surface of water which are detected after reflection from its bottom at a depth of 1531m. If the time interval between the emission and detection of the pulse is 2s, find the speed of sound in water.

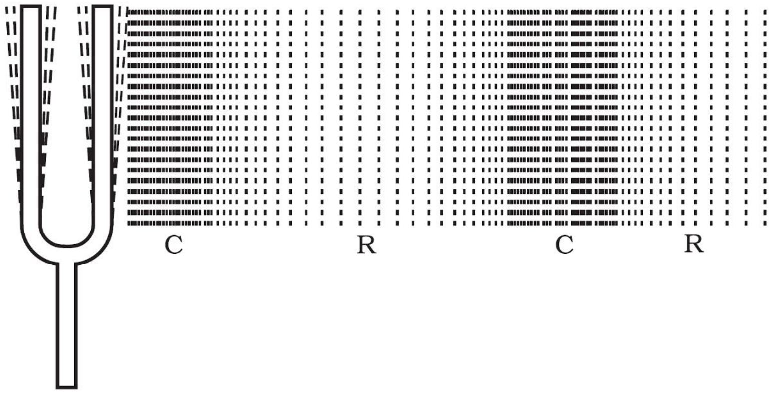
19. A sonar device on a submarine sends out a signal and receives an echo 10 s later. Calculate the speed of sound in water if the distance of the object from the submarine is 7650m.

20. A man standing at 68m from a wall fires a gun. Calculate the time after which an echo is heard. The speed of sound is 340 m/s.

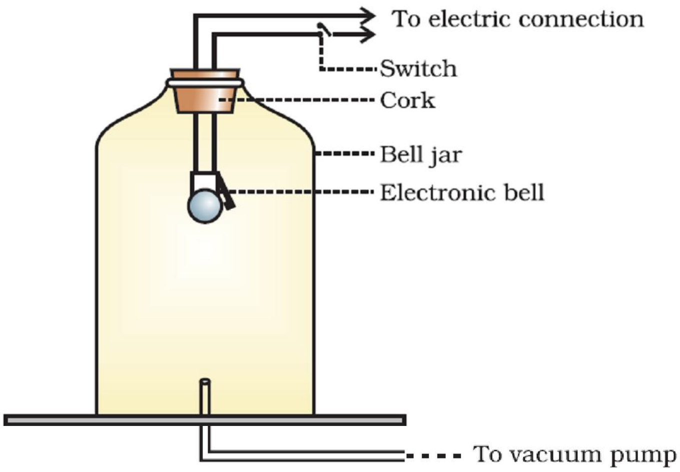
EXERCISE QUESTIONS PAGE NO. 174 AND 175

1. **What is sound and how is it produced?**
   Ans: Sound is produced by vibration. When a body vibrates, it forces the neighbouring particles of the medium to vibrate. This creates a disturbance in the medium, which travels in the form of waves. This disturbance, when reaches the ear, produces sound.

2. **Describe with the help of a diagram, how compressions and rarefactions are produced in air near a source of sound.**
   Ans: When a vibrating body moves forward, it creates a region of high pressure in its vicinity. This region of high pressure is known as compressions. When it moves backward, it creates a region of low pressure in its vicinity. This region is known as a rarefaction. As the body continues to move forward and backwards, it produces a series of compressions and rarefactions (as shown in the following figure).



3. **Cite an experiment to show that sound needs a material medium for its propagation.**
   Ans: Take an electric bell and hang this bell inside an empty bell-jar fitted with a vacuum pump (as shown in the following figure).



   Initially, one can hear the sound of the ringing bell. Now, pump out some air from the bell-jar using the vacuum pump. It will be observed that the sound of the ringing bell decreases. If one keeps on pumping the air out of the bell-jar, then at one point, the glass-jar will be devoid of any air. At this moment, no sound can be heard from the ringing bell although one can see that the prong of the bell is still vibrating. When there is no air present inside, we can say that a vacuum is produced. Sound cannot travel through vacuum. This shows that sound needs a material medium for its propagation.

4. **Why is sound wave called a longitudinal wave?**

Ans: The vibration of the medium that travels along or parallel to the direction of the wave is called a longitudinal wave. In a sound wave, the particles of the medium vibrate in the direction parallel to the direction of the propagation of disturbance. Hence, a sound wave is called a longitudinal wave.

5. **Which characteristic of the sound helps you to identify your friend by his voice while sitting with others in a dark room?**
Ans: Quality of sound is that characteristic which helps us identify a particular person. Sound produced by two persons may have the same pitch and loudness, but the quality of the two sounds will be different.

6. **Flash and thunder are produced simultaneously. But thunder is heard a few seconds after the flash is seen, why?**
Ans: The speed of sound (344 m/s) is less than the speed of light (3×10^8 m/s). Sound of thunder takes more time to reach the Earth as compared to light. Hence, a flash is seen before we hear a thunder.

7. **A person has a hearing range from 20 Hz to 20 kHz. What are the typical wavelengths of sound waves in air corresponding to these two frequencies? Take the speed of sound in air as 344 m s^{-1}.**
Ans: For a sound wave,
Speed = Wavelength × Frequency
$v = \lambda \times \nu$
Given that the speed of sound in air = 344 m/s
(i) For, ν_1 = 20 Hz
$$\lambda_1 = \frac{v}{\nu_1} = \frac{344}{20} = 1.72m$$
(ii) For, ν_2 = 20,000 Hz
$$\lambda_2 = \frac{v}{\nu_2} = \frac{344}{20,000} = 0.0172m$$
Hence, for humans, the wavelength range for hearing is 0.0172 m to 17.2 m.

8. **Two children are at opposite ends of an aluminium rod. One strikes the end of the rod with a stone. Find the ratio of times taken by the sound wave in air and in aluminium to reach the second child.**
Ans: Let the length of the aluminium rod be d.
Speed of sound wave in aluminium at 25°C, $v_{Al} = 6420ms^{-1}$
Therefore, time taken by the sound wave to reach the other end,
$$t_{Al} = \frac{d}{v_{Al}} = \frac{d}{6420}$$
Speed of sound wave in air at 25°C, $v_{Air} = 346ms^{-1}$
Therefore, time taken by sound wave to reach the other end,
$$t_{Air} = \frac{d}{v_{Air}} = \frac{d}{346}$$
The ratio of time taken by the sound wave in air and aluminium:
$$\frac{t_{Air}}{t_{Al}} = \frac{\frac{d}{346}}{\frac{d}{6420}} = \frac{6420}{346} = 18.55:1$$

9. **The frequency of a source of sound is 100 Hz. How many times does it vibrate in a minute?**
Ans: Frequency is defined as the number of oscillations per second. It is given by the relation:

$$\text{Frequency} = \frac{\text{Number of oscillations}}{\text{Total time}}$$

Number of oscillations = Frequency × Total time
Given, Frequency of sound = 100 Hz
Total time = 1 min = 60 s
Number of oscillations/Vibrations = 100 × 60 = 6000
Hence, the source vibrates 6000 times in a minute, producing a frequency of 100 Hz.

10. **Does sound follow the same laws of reflection as light does? Explain.**
Ans: Sound follows the same laws of reflection as light does. The incident sound wave and the reflected sound wave make the same angle with the normal to the surface at the point of incidence. Also, the incident sound wave, the reflected sound wave, and the normal to the point of incidence all lie in the same plane.

11. **When a sound is reflected from a distant object, an echo is produced. Let the distance between the reflecting surface and the source of sound production remains the same. Do you hear echo sound on a hotter day?**
Ans: An echo is heard when the time interval between the original sound and the reflected sound is at least 0.1 s. The speed of sound in a medium increases with an increase in temperature. Hence, on a hotter day, the time interval between the original sound and the reflected sound will decrease. Therefore, an echo can be heard only if the time interval between the original sound and the reflected sound is greater than 0.1 s.

12. **Give two practical applications of reflection of sound waves.**
Ans: (i) Reflection of sound is used to measure the distance and speed of underwater objects. This method is known as SONAR.
(ii) Working of a stethoscope is also based on reflection of sound. In a stethoscope, the sound of the patient's heartbeat reaches the doctor's ear by multiple reflection of sound.

13. **A stone is dropped from the top of a tower 500 m high into a pond of water at the base of the tower. When is the splash heard at the top? Given, g = 10 m s^{-2} and speed of sound = 340 m s^{-1}.**
Ans: Height of the tower, s = 500 m
Velocity of sound, v = 340 m s^{-1}
Acceleration due to gravity, g = 10 m s^{-2}
Initial velocity of the stone, u = 0 (since the stone is initially at rest)

Time taken by the stone to fall to the base of the tower, t_1
According to the second equation of motion:

$$s = ut_1 + \frac{1}{2}gt_1^2$$

$$\Rightarrow 500 = 0 \times t_1 + \frac{1}{2} \times 10 \times t_1^2$$

$$\Rightarrow t_1^2 = 100 \Rightarrow t_1 = 10s$$

Now, time taken by the sound to reach the top from the base of the tower, $t_2 = \frac{500}{340} = 1.47s$

Therefore, the splash is heard at the top after time, t

Where, $t = t_1 + t_2 = 10 + 1.47 = 11.47s$

14. A sound wave travels at a speed of 339 m s–1. If its wavelength is 1.5 cm, what is the frequency of the wave? Will it be audible?

Ans: Speed of sound, v = 339 m s−1

Wavelength of sound, λ = 1.5 cm = 0.015 m

Speed of sound = Wavelength × Frequency

$v = \lambda \times \nu$

$\therefore \nu = \frac{v}{\lambda} = \frac{339}{0.015} = 22600Hz$

The frequency range of audible sound for humans lies between 20 Hz to 20,000 Hz. Since the frequency of the given sound is more than 20,000 Hz, it is not audible.

15. What is reverberation? How can it be reduced?

Ans: Persistence of sound (after the source stops producing sound) due to repeated reflection is known as reverberation. As the source produces sound, it starts travelling in all directions. Once it reaches the wall of a room, it is partly reflected back from the wall. This reflected sound reaches the other wall and again gets reflected partly. Due to this, sound can be heard even after the source has ceased to produce sound.

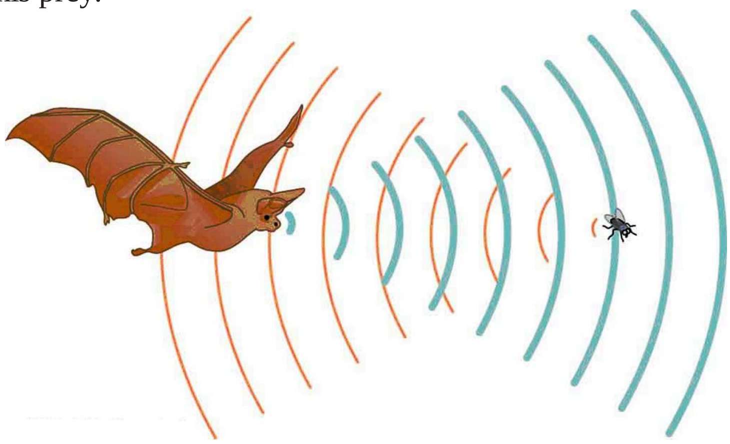
To reduce reverberations, sound must be absorbed as it reaches the walls and the ceiling of a room. Sound absorbing materials like fibreboard, rough plastic, heavy curtains, and cushioned seats can be used to reduce reverberation.

16. What is loudness of sound? What factors does it depend on?

Ans: A loud sound has high energy. Loudness depends on the amplitude of vibrations. In fact, loudness is proportional to the square of the amplitude of vibrations.

17. Explain how bats use ultrasound to catch a prey.

Ans: Bats produce high-pitched ultrasonic squeaks. These high-pitched squeaks are reflected by objects such as preys and returned to the bat's ear. This allows a bat to know the distance of his prey.

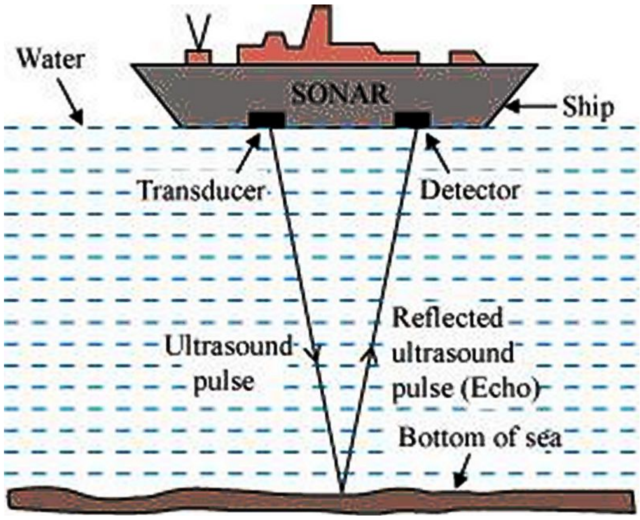


18. How is ultrasound used for cleaning?

Ans: Objects to be cleansed are put in a cleaning solution and ultrasonic sound waves are passed through that solution. The high frequency of these ultrasound waves detaches the dirt from the objects.

19. Explain the working and application of a sonar.

Ans: SONAR is an acronym for Sound Navigation And Ranging. It is an acoustic device used to measure the depth, direction, and speed of under-water objects such as submarines and ship wrecks with the help of ultrasounds. It is also used to measure the depth of seas and oceans.



A beam of ultrasonic sound is produced and transmitted by the transducer (it is a device that produces ultrasonic sound) of the SONAR, which travels through sea water. The echo produced by the reflection of this ultrasonic sound is detected and recorded by the detector, which is converted into electrical signals. The distance (d) of the under-water object is calculated from the time (t) taken by the echo to return with speed (v) is given by $2d = v \times t$. This method of measuring distance is also known as 'echo-ranging'.

20. A sonar device on a submarine sends out a signal and receives an echo 5 s later. Calculate the speed of sound in water if the distance of the object from the submarine is 3625 m.

Ans: Time taken to hear the echo, t = 5 s

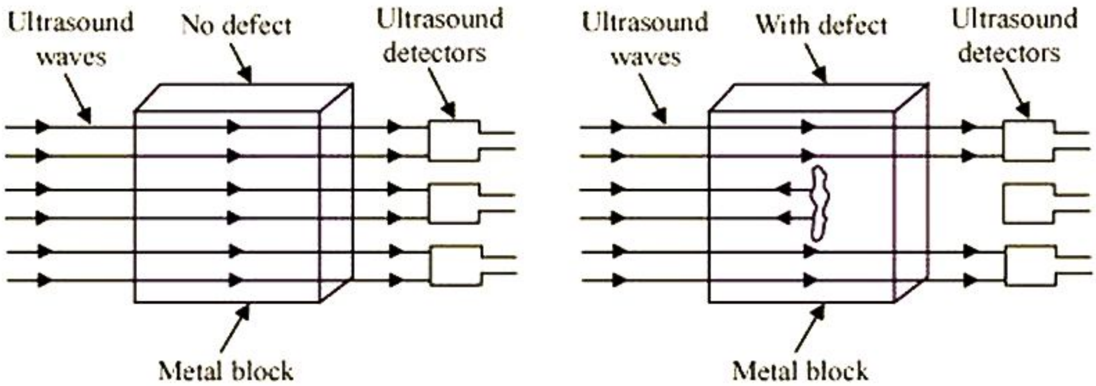
Distance of the object from the submarine, d = 3625 m

Total distance travelled by the sonar waves during the transmission and reception in water = 2d

Velocity of sound in water, $v = \frac{2d}{t} = \frac{2 \times 3625}{5} = 1450 ms^{-1}$

21. Explain how defects in a metal block can be detected using ultrasound.

Ans: Defects in metal blocks do not allow ultrasound to pass through them and they are reflected back. This fact is used to detect defects in metal blocks. Ultrasound is passed through one end of a metal block and detectors are placed on the other end. The defective part of the metal block does not allow ultrasound to pass through it. As a result, it will not be detected by the detector. Hence, defects in metal blocks can be detected using ultrasound.



22. Explain how the human ear works.

Ans: Different sounds produced in our surroundings are collected by pinna that sends these sounds to the ear drum via the ear canal. The ear drum starts vibrating back and forth rapidly when the sound waves fall on it. The vibrating eardrum sets the small bone hammer into vibration. The vibrations are passed from the hammer to the second bone anvil, and finally to the third bone stirrup. The vibrating stirrup strikes on the membrane of the oval window and passes its vibration to the liquid in the cochlea. This produces electrical impulses in nerve cells. The auditory nerve carries these electrical impulses to the brain. These electrical impulses are interpreted by the brain as sound and we get a sensation of hearing.