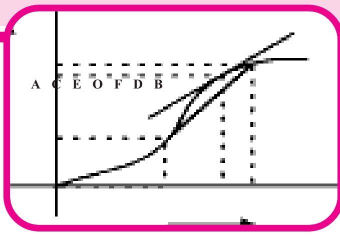
Chapter 2

MOTION



We are familiar with the idea of motion. We see several examples of motion around us like motion of people, vehicles, trains, aeroplanes, birds, rain drops, objects thrown into air, etc. We know that it is due to the motion of the earth that the phenomena like sunrise, sunset, changes in the seasons etc occur.

- If earth is in motion why don't we directly perceive the motion of the earth?
- Are the walls of your class room at rest or in motion? Why?
- Have you ever experienced that the train in which you sit appears to move when it is at rest? Why?

To give answers to these questions we need to understand the terms 'relative' and 'motion'.

Great progress in understanding motion occurred when Galileo under took his study about rolling balls on inclined planes. To understand motion, we need to understand the meaning of the word 'relative', which plays an important role in explaining various ways of motion.

What is relative ?

We use many statements in our daily life to express our views. The meaning of a statement depends on the relation between the words used in it.

Does every statement have a meaning?

Evidently the answer is 'no'. Even if you choose perfectly sensible words and put them together according to all the rules of grammar, you may still get complete non- sense. For instance the statement "This water is triangular "can hardly be given any meaning.

A statement has a meaning only when there is a relation between words.

Similarly there may exist other situations in our daily life where we use statements having meaning depending upon the situation. Let us observe the following example.

Right and Left

As shown in the figure 1, two persons say A and B are moving opposite to each other on a road.

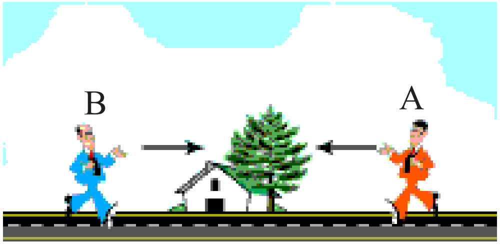


Fig-1

Examine the meaning of the following sentence.

Question: On which side of the road is the house? Is it on the right side or on the left side to the road?

There are two answers for the above question. For person A, the house is on the right and for the person B, the house is on the left. Thus the position of the house is relative to the observer i.e., clearly when speaking of left and right by a person, he has to assume a direction based on which he can decide the left and right sides of himself.

Is day or night just now ?

The answer depends on where the question is being asked. When it is daytime in Hyderabad, it is night in New- York. The simple fact is that day and night are relative notions and our question cannot be answered without indicating the point on the globe where the question is being asked.

Up and down

Can the orientations like up and down be the same for all persons at all places? Observe the following figure 2.

For the person standing at A on the globe, his position appears up and the orientation of person standing at B appears down but for the person standing at B it appears exactly opposite. Similarly for the persons standing at the points C and D the directions of up and down are not same. They change with the point of observation on the globe.

- Why do we observe these changes?

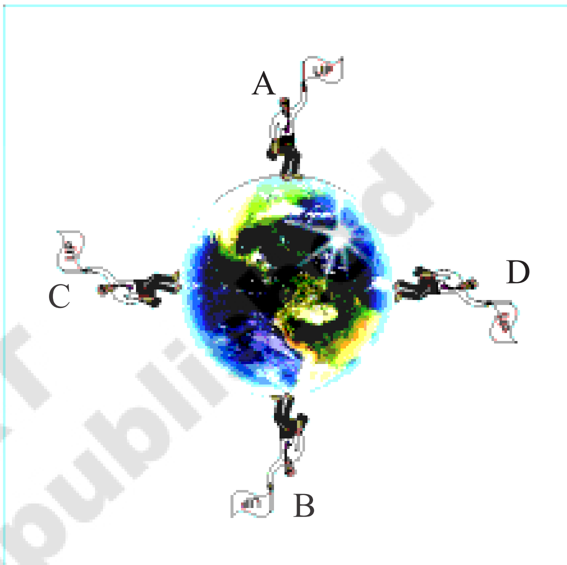


Fig-2

We know that earth is a sphere, the upward direction of the vertical position on its surface decisively depends up on the place on the earth's surface, where the vertical is drawn.

Hence the notions "up and down" have no meaning unless the point on the Earth's surface, to which they refer, is defined.

Discuss the meaning of the terms "longer and shorter" with few examples.

- Are these terms relative or not?

Motion is relative

Like the terms right and left, up and down, larger and shorter etc., 'motion' is also relative to the observer. Let us examine this.

To understand the idea of motion, let us take the following hypothetical activity.

Observe the figure 3 and follow the conversation between Srinu and Somesh who stand beside a road as shown in the figure3.

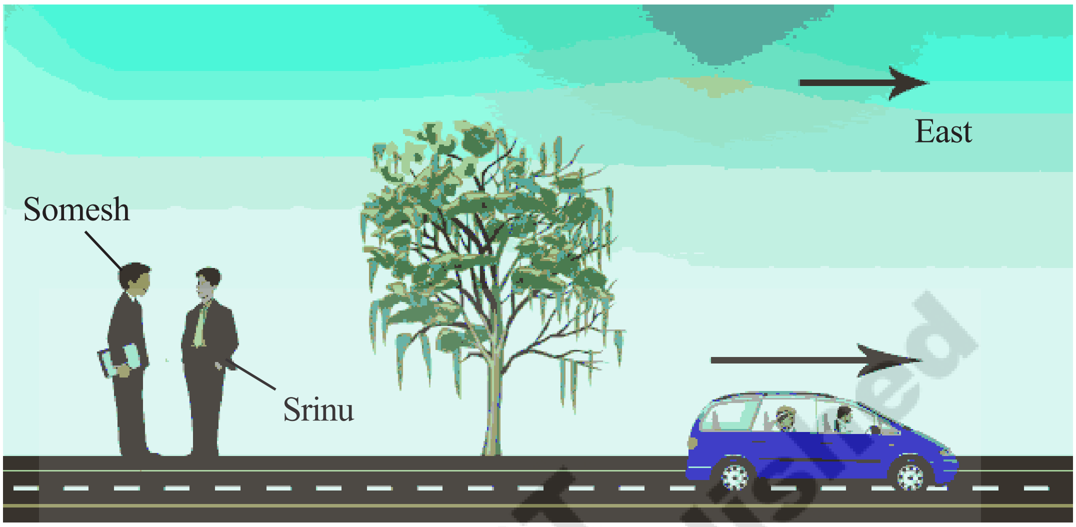


Fig-3: Somesh's point of view

Srinu	:	What is the state of motion of the tree?
Somesh	:	It is at rest.
Srinu	:	What is the state of motion of the car?
Somesh	:	It is moving due east.
Srinu	:	What is the state of motion of the driver and the passenger in the car?
Somesh	:	They are also moving like the car.
Srinu	:	How do you decide that the car, the passenger and the driver are moving?
Somesh	:	With respect to us, the position of the car,the passenger and the driver are changing with time. So, they are in motion.

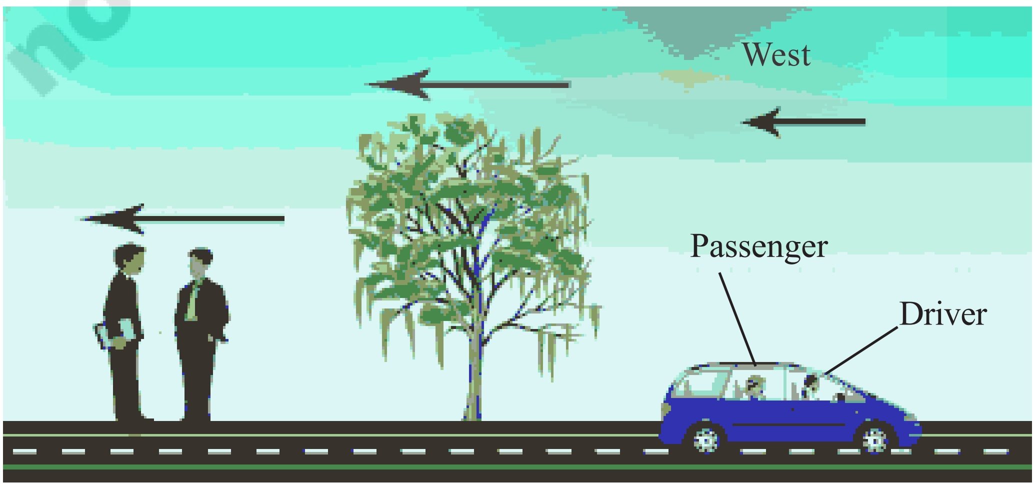


Fig-4: Passenger's point of view

Now follow the conversation of the driver and the passenger in moving car.

Driver : What is the state of motion of the tree?

Passenger : It is moving due west

Driver : What is the state of motions of both the persons beside the road?

Passenger : They are also moving due west.

Driver : What is my state of motion?

Passenger : You are at rest.

Driver : What is the state of motion of the car?

- What answers should the passenger give to the driver? Discuss with your friends.

From the above discussion, it is clear that the tree is at rest with respect to Somesh and it is moving due west with respect to passenger.

The motion of an object depends on the observer. So motion is a combined property of the observer and the body which is being observed.

Now we are able to define motion of an object.

A body is said to be in motion when its position is changing continuously with time relative to an observer.

Note: Any object can be taken as a point of observation.

- How do we understand motion?

Distance and displacement

Activity-1

Drawing path and distinguishing between distance and displacement

Take a ball and throw it into the air with some angle to the horizontal. Observe its path and draw it on paper.

Figure 5 shows the path taken by the ball when it was thrown into air. “Distance” is the length of the path traversed by an object in a given time interval and displacement is the shortest distance covered by the object in a specified direction.

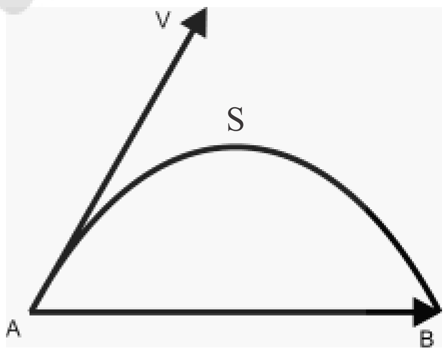
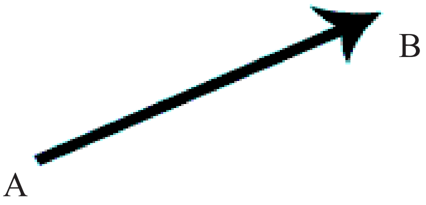


Fig-5:Distance - displacement

Observe the difference between distance and displacement from figure 5.

So, Displacement is a vector. To describe a physical situation, some quantities are specified with magnitude as well as direction. Such a physical quantity is called a vector. The physical quantity which do not require any direction for its explanation is called scalar. So distance is a scalar.

A vector can be represented as a directed line segment. It's length indicates magnitude and arrow indicates it's direction. Point 'A' is called tail and point 'B' is called head



In the above example (Fig-5) ASB shows the actual distance covered by an object and AB is a displacement which is a straight line drawn from initial position to final position of the motion.

The SI unit of distance or displacement is metre denoted by 'm'. Other units like kilometre, centimtre etc. are also used to express this quantity.

1 km = 1000 m

1 m = 100 cm

Activity-2

Drawing displacement vectors

A car moves along different paths as shown in figures 6(a) and 6(b). The points A and B are the initial and final positions of the car.

Draw displacement vectors for two situations.

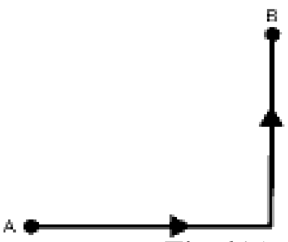
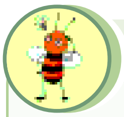


Fig-6(a)

Fig-6(b)

Generally the distance covered and displacement are time dependent quantities.



Think and discuss

- What is the displacement of the body if returns to same point where it is started? Give one example in daily life.
- When do the distance and magnitude of displacement become equal?

Average speed and average velocity

A train named Godavari express starts at 5.00 pm from Visakhapatnam and reaches Hyderabad at 5.00 am the next day as shown in figure 7.

Fig-7

Draw displacement vectors from Visakhapatnam to Vijayawada, Vijayawada to Hyderabad and from Visakhapatnam to Hyderabad.

Let the distance of the entire trip from Visakhapatnam to Hyderabad be 720 km.

The journey time is 12 h. What is the distance covered by the train in each hour?

It is equal to 720km/12h = 60km/h

Can you say that the train has covered exactly 60 km in each hour?

Obviously the answer is "No", because there may be some variations in distance covered by train for each hour. So we take average of distances covered by the train for each hour to decide its average speed. The distance covered by an object in unit time is called average speed.

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

Let the displacement of the trip in above example be 360 km due North–West. What is the displacement in each hour?

The displacement per hour

= 360 km/ 12h north - west

= 30km / h north - west

The displacement of an object per unit time is called average velocity. Average Velocity is a vector and is along the direction of displacement.

$$\text{Average velocity} = \frac{\text{Displacement}}{\text{Time taken}}$$

The quantities average speed and average velocity explain the motion of a body in a given time interval. They do not give any information about the motion of the body at a particular instant of time.

Think and discuss

- What is the average speed of the car if it covers 200 km in 5 h?
- When does the average velocity become zero?
- A man used his car. The initial and final odometer readings are 4849 and 5549 respectively. The journey time is 70h. What his average speed during the journey?

Speed and velocity

Things in motion often have variations in their speeds. For example a car may travel along a street at 50 km/h get slow down to 0km/h at red light and then attain a speed of 30 km/h due to traffic on the road.

- Are you able to find the pead of a car at a particular instant of time?

You can tell the speed of the car at any instant by looking at its speedometer. The speed at any instant is called instantaneous speed.

Let us suppose that a body is moving rectilinearly (along a straight line) but with varying speed.

How can we calculate the instantaneous speed of the body at a certain point "O" of its path?

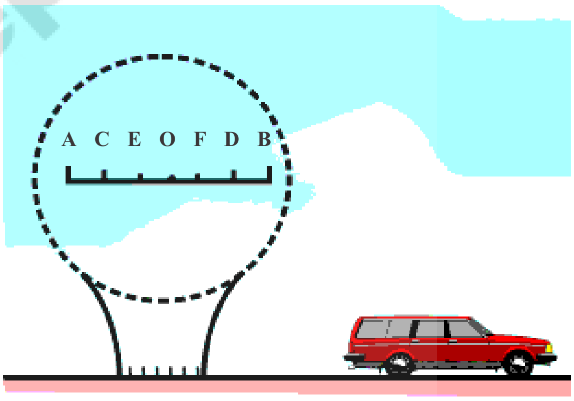


Fig-8

We take a small segment AB on this path, which contains the point O as shown figure 8. We denote this small distance covered by the body as S_1, and the small time interval over which it covers that distance is taken as t_1. We obtain the average speed over this segment by dividing S_1 to t_1. The speed varies continuously and hence it is different at different points of segment AB.

Let us now reduce the length of segment AB. We choose a segment CD which also includes point O, the ratio S_2/t_2 gives us average speed for this smaller segment CD. If we take a segment EF which also includes point O and is smaller than segments AB and CD, the change in speed over this segment will be still smaller. Dividing the distance S_3 by the time interval t_3, we again obtain the average speed on this small part of the path.

If we reduce the time interval gradually over which the distance travelled by the body is being considered, then the distance covered decreases continuously and ultimately the segment of path having this point O contracts closer and closer to reach the reference point O. Thus average speed approaches a certain value. This value is called the **instantaneous speed** at point O.

"The instantaneous speed at a given point is equal to the ratio between sufficiently small distances over a part of the path which contains the reference point and the corresponding small time interval."

Let us understand this in a graphical way.

Consider a car moving along a straight road with varying speed.

A more useful way of describing motion of any body along a straight line is distance – vs – time graph.

Along the horizontal axis we plot the time elapsed in seconds, and along the vertical axis the distance covered in metres.

A general case of motion with varying speed is shown in figure 9.

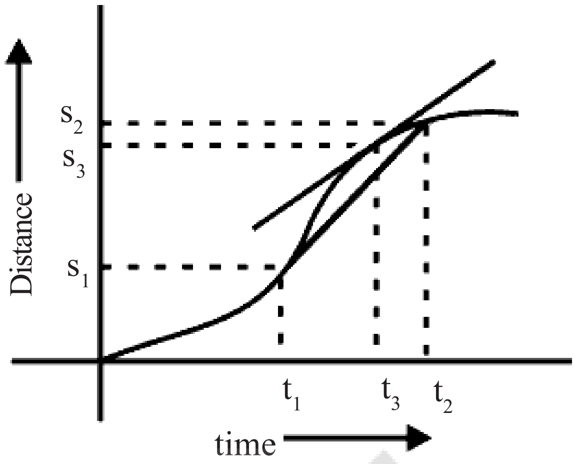


Fig-9:Distance vs time graph

- What is the speed of the car at the instant of time 't_3' for given motion?

We know how to find average speed during the time interval from t_1 to t_2, which includes the instant t_3 is

$$\text{Average speed} = \frac{S_2 - S_1}{t_2 - t_1}$$

Then we calculate average speed for a very short time interval encompassing the time at an instant t_3– which is so short interval, that value of average speed would not change materially if it was made even shorter. The instantaneous speed is represented by the slope of the curve at a given instant of time. We can find slope of the curve at any point on it by drawing a tangent to the curve at that point. The slope of the curve gives speed of the car at that instant. If the slope is large, speed is high and if the slope is small, speed is low.

Speed gives the idea of how fast the body moves. In general, bodies move in a particular direction at an instant of interest and this direction may not be constant throughout the journey. So we need to define another quantity called "Velocity".

Velocity is the speed of an object in a specified direction.

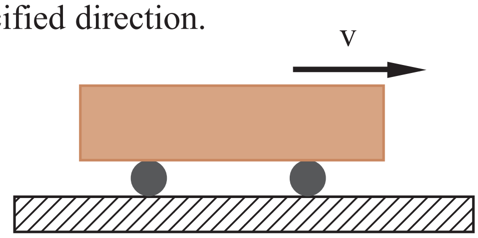


Fig-10

Velocity gives the idea of how fast the body moves in specified direction. Velocity is a vector. It can be represented by a directed line segment. Its length indicates speed and arrow gives the direction of motion.

If a body moves in a curved path, the tangent drawn at a point on the curve gives direction of velocity at that instant. Observe that following diagram and try to draw tangents to the curve at different points. Does the direction of velocity of body remain constant or not?

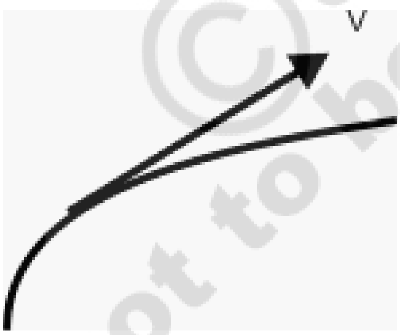


Fig-11:Direction of velocity at a point of path

Activity-3

Observing the direction of motion of a body

Carefully whirl a small object on the end of the string in the horizontal plane. Release the object while it is whirling on the string.

- In what direction does it move?

Try to release the object at different points on the circle and observe the direction of motion of object after it has been released from the string.

You will notice that the object moves on a straight-line along the tangent to the circle at the point where you released it. The direction of velocity is tangent to the path at a point of interest.

The SI unit of velocity is metre/sec.

In our daily life we must have observed many motions where, in some cases the velocity of object which is in motion is constant but in other cases it continuously changes.

- Which motion is called uniform? Why?

Let us find out.

Uniform motion

Activity-4

Understanding uniform motion

Consider a cyclist moving on a straight road. The distance covered by him with respect to time is given in the following table. Draw distance vs time graph for the given values in the table1.

Table -1

Time (t in seconds)	Distance (s in metres)
0	0
1	4
2	8
3	12
4	16
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- What is the shape of the graph?

You will get a graph which resembles the graph shown in fig-12.

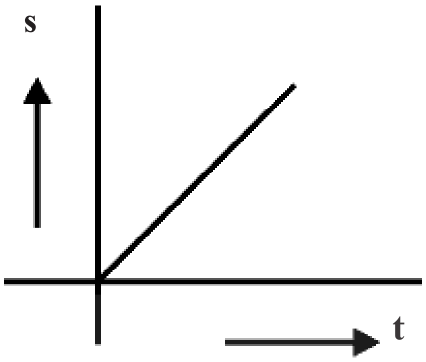

Fig-12

The straight line graph shows that the cyclist covers equal distances in equal intervals of time. From the graph you can understand that the instantaneous speed is equal to average speed. If the direction of motion of the cyclist is assumed as constant then we conclude that velocity is constant.

The motion of the body is said to be in uniform when its velocity is constant.

Think and discuss

- Very often you must have seen traffic police stopping motorists and scooter drivers who drive fast and fine them. Does fine for speeding depend on average speed or instantaneous speed? Explain.
- One airplane travels due north at 300 km/h and another airplane travels due south at 300 km/h Are their speeds the same? Are their velocities the same? Explain.
- The speedometer of the car indicates a constant reading. Is the car in uniform motion? Explain.

Example-1

A man standing under a street lamp of height 'H' above the ground starts running with a constant speed 'v' in a constant direction. The light from the lamp falling on the man form a shadow of him. Find the velocity with which the edge of the shadow of the man's head moves over the ground if his height is "h".

Solution

Here we need to compare the motions of the man and the edge of the shadow of the man's head. To solve this problem, a common starting point is necessary. Let this point be 'O' which is taken exactly under the lamp as shown in the fig-13.

Let 's' and 'S' be the distances covered in a time interval 't' from the point 'O' by the man and the edge of the shadow of the man's head respectively.

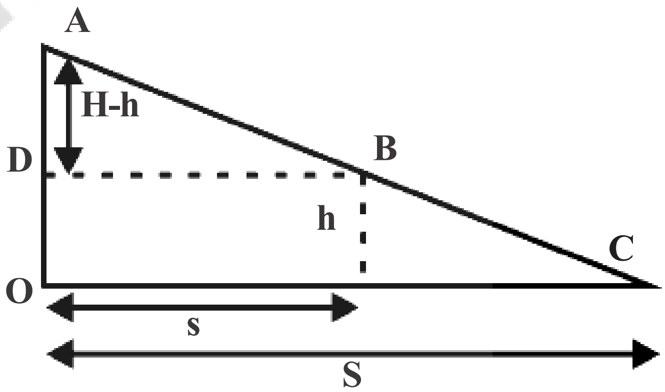

Fig-13

As shown in figure 13 we get two similar triangles namely ΔABD and ΔACO

From these two similar triangles

$$\frac{DB}{AD} = \frac{OC}{AO}$$

$$\frac{s}{H-h} = \frac{S}{H}$$

But we know, $s = vt$

$$\frac{vt}{H-h} = \frac{S}{H}$$

We know that S/t is the speed of the shadow of the man's head,

Then,

$$V = \frac{Hv}{H-h}$$

Non uniform motion

In our daily life in many situations when a body is in motion, its velocity changes with time. Let us observe the following example.

Consider a cyclist moving on a straight road. The distance covered by him with respect to time is given in the following table. Draw distance vs time graph for the given values in the table2.

Table-2

Time (t in seconds)	Distance (s in metres)
0	0
1	1
2	4
3	9
4	16
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- What is the shape of the graph?
- Is it a straight line or not? Why?

Activity-5

Observing the motion of a ball on a inclined plane

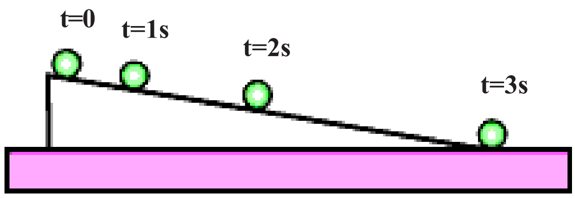

Fig-14:Ball moving down the inclined plane

Set up an inclined plane as shown in figure 14. Take a ball and release it from the top of the inclined plane. The positions of the ball at various times are shown in figure14.

- What is the path of the ball on the inclined plane?
- How does the velocity of the ball change?

On close observation we find that when the ball moves down on the inclined plane its speed increases gradually. And the direction of motion remains constant on inclined plane.

Set up an inclined plane as shown in figure 15. Take a ball and push it with a speed from the bottom of the inclined plane so that it moves up.

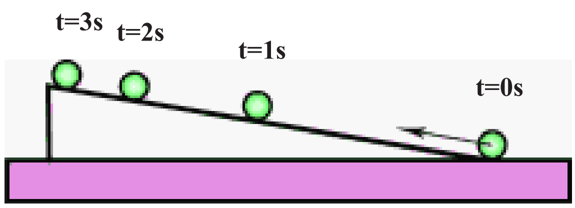

Fig-15:Ball moving up the inclined plane

- What is the path of the ball?
- What happens to its speed?

In above two situations of activity-5, we observe that the speed changes but the direction of motion remains constant.

Activity-6

Observing uniform circular motion

Whirl a stone which is tied to the end of the string continuously. Draw its path of motion and velocity vectors at different positions as shown in the figure 16. Assume that the speed of the stone is constant.

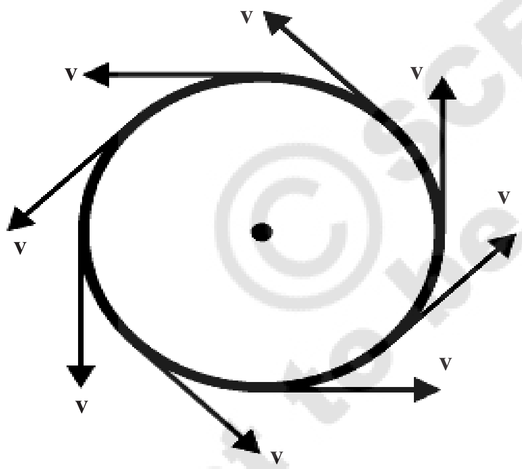

Fig-16

- What is the path of the stone?

It is clear that the path is a circle and the direction of velocity changes at every instant of time but the speed is constant.

Hence in this activity we observe that though speed remains constant, its velocity changes.

- Can you give few example for motion of an object where its speed remains constant but velocity changes?

Activity-7

Observing the motion of an object thrown into air

Throw a stone into the air by making some angle with the horizontal. Observe the path taken by it. Draw a diagram to show its path and velocity vectors.

- Is the speed of the stone uniform? Why?
- Is the direction of motion constant? How?

In the above activity you might have noticed that the speed and direction of motion both change continuously.

- Can you give some more examples where speed and direction simultaneously change?

From the above three activities you can conclude that the change in velocity takes place in three ways.

1. Speed changes with direction remaining constant.
2. Direction of motion changes with speed remaining constant.
3. Both direction and speed change simultaneously.

Motion of an object is said to be non-uniform when its velocity is changing.

Think and discuss

- An ant is moving on the surface of a ball. Does it's velocity change or not? Explain.
- Give an example of motion where there is a change only in speed but no change in direction of motion.

Acceleration

We can change the velocity of an object by changing its speed or its direction of motion or both. In either case the body is said to be accelerated. Acceleration gives an idea how quickly velocity of a body is changing.

- What is acceleration? How can we know that a body is in acceleration?

We experience acceleration many times in our day to day activities. For example, if we are travelling in a bus or a car, when the driver presses the accelerator, the passengers sitting in the bus experience acceleration. Our bodies press against the seats due to the acceleration.

Suppose we are driving a car. Let us steadily increase the velocity from 30 km/h to 35 km/h in 1sec and then 35km/h to 40km/h in the next second and so on.

In the above case the velocity of car is incresing 5 km/hr per second.

This type of rate of change of velocity of an object is called **acceleration.**

Acceleration is uniform when in equal intervals of time, equal changes of velocity occur.

Uniform acceleration is the ratio of change in velocity to time taken.

The term acceleration not only applies to increasing velocity but also to decreasing velocity. For example when we apply brakes to a car in motion, its velocity decreases continuously. We call this as deceleration. We can observe the deceleration of a stone thrown up vertically into air and similarly we can experience deceleration when a train comes to rest.

Let us suppose that we are moving in a curved path in a bus. We experience acceleration that pushes us towards the outer part of the curve.

Observe the following fig-17. The motion of an object in a curved path at different instants is shown as a motion diagram. The length of the vector at a particular point corresponds to the magnitude of velocity (speed) at that point and arrow indicates direction of motion at every instant.

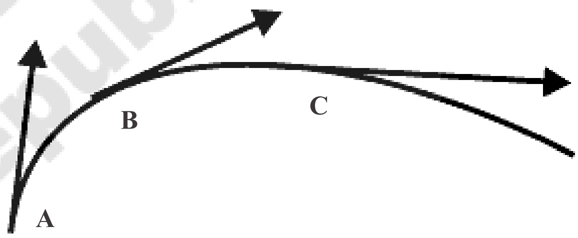

Fig-17: Motion diagram

- At which point is the speed maximum?
- Does the object in motion possess acceleration or not?

We distinguish speed and velocity for this reason and define "acceleration" as the rate at which velocity changes, there by encompassing changes both in speed and direction.

Acceleration is also a vector and is directed along the direction of change in velocity.

The SI unit of acceleration is m/s^2

Think and discuss

- What is the acceleration of the race car that moves at constant velocity of 300 km/h ?
- Which has the greater acceleration, an airplane, that goes from 1000 km/h to 1005 km/h in 10s or a skateboard that goes from zero to 5km/h in 1 second?
- What is the deceleration of a vehicle moving in a straight line that changes its velocity from 100 km/h to a dead stop in 10s?
- Correct your friend who says "The acceleration gives the idea of how fast the position changes."

Equations of uniform accelerated motion

Consider the motion of object along straight line with constant acceleration.

Then,

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

$$a = \frac{\Delta v}{\Delta t} = \text{constant}$$

Let u be the velocity at the time t = 0 and v be the velocity at the time t and let s be the displacement covered by the body during time " t" shown in figure 18.

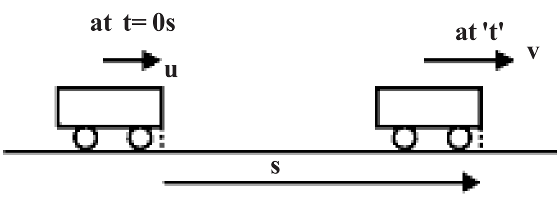

Fig-18

From the definition of uniform acceleration,

$$\text{Acceleration,} \quad a = \frac{v-u}{t}$$

$$at = v - u$$

$$u + at = v \quad .... (1)$$

Since the acceleration of the body is constant.

$$\text{Average velocity} = \frac{v+u}{2}$$

But we know

$$\text{Average velocity} = \frac{\text{Displacement}}{\text{Time taken}}$$

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

From here onwards we are manipulating the equations (1) and (2).

Put $v = u + at$ in equation (2), we have

$$\frac{u + at + u}{2} = \frac{s}{t}$$

$$\frac{2u + at}{2} = \frac{s}{t}$$

$$ut + \tfrac{1}{2} a t^2 = s \quad .... (3)$$

From equation $v = u + at$, we get

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

Substitute the value of t in equation (2), we have

$$\left(\frac{v+u}{2}\right)\left(\frac{v-u}{a}\right) = s$$

$$v^2 - u^2 = 2as \text{.................} \quad (4)$$

The equations of motion are,

$$v = u + at$$
$$s = ut + \tfrac{1}{2} a t^2$$
$$v^2 - u^2 = 2as$$

NOTE:

1. If the speed of an object increases, the direction of velocity and acceleration are one and the same.
2. If the speed of the object decreases, the direction of velocity and acceleration are in opposite directions. In such a case, at a certain instant speed becomes zero.
3. If there exists an acceleration of a body at a point where its speed becomes zero for an instant; then the body 'returns' in the direction of acceleration and moves continuously. (like in the case of stone thrown vertically up into air.)

NOTE: Care must be taken to remember the following points while we are using equations of motion.

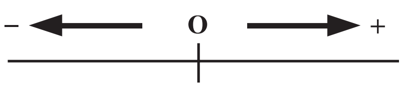

Fig-19

- Choose origin on a straight line. The quantities directed due right are taken as positive and due left are taken as negative.
- Expressing the displacement with proper sign, is important. Displacement is positive while measured along the positive direction and is negative while measured along negative direction.

Lab Activity

Aim

- To find the acceleration and velocity of an object moving on an inclined track.
- To draw the graph between distance and time.

Materials required

Glass marbles, identical books, digital clock, long plastic tubes and steel plate.

Procedure

Take a long plastic tube of length nearly 200cm and cut it in half along the length of the tube. Use these tube parts as tracks. Mark the readings in cm along the track. Place the one end of the tube on the book or books and the other end on the floor.

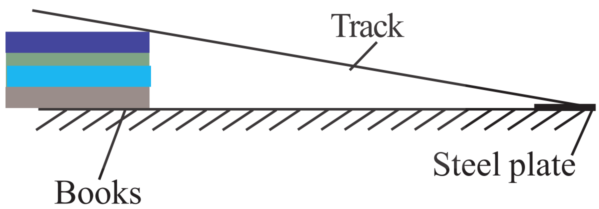

Fig-20

Keep a steel plate on the floor at the bottom of the track. Consider the reading at the bottom of the track as zero.

Take a marble having enough size to travel in the track freely. Now release marble freely from a certain distance say 40cm. Start the digital clock when the marble is released. It moves down on the track and strikes the steel plate. Stop the digital clock when sound is produced. Repeat the same experiment for the same distance 2 to 3 times and note the values of times in the below table-3.

Table-3

Distance, S (cm)	Time t (s)			Average time t	$2S/t^2$
	t_1	t_2	t_3		

Repeat the same experiment for various distances as said above.

Find average time and $2S/t^2$ for every trail. Will it be constant and equal to acceleration? Why?

Draw distance vs time (S-t) graph for above values in the table.

Do the same experiment for various slopes of the track and find accelerations in each case.

- Is there any relation between the slope and acceleration?
- What do you notice from the distance time graphs for various slopes?

Do the same experiment with a small iron block. Find acceleration and draw the S-t graph.

Give your explanation for various accelerations related to slopes.

The values found in this experiment are approximate one.

Example 2

At a distance L= 400m away from the signal light,brakes are applied to a locomotive moving at a velocity u = 54 km/h.Determine the position of the locomotive relative to the signal light after 1 min of the application of the brakes if its acceleration a = - 0.3 m/s^2

Solution

Since the locomotive moves with a constant deceleration after the application of brakes, it will come to rest in "t" sec .

We know ,

$v = u + at$

Here u = 54 km/h = 54 x 5/18 =15 m/s

v = 0 for given situation and given

$a = -0.3\ m/s^2$

From $v = u + at$ we get $t = \dfrac{v-u}{a}$

We get, $t = \dfrac{-15}{-0.3} = 50s$

During which it will cover a distance

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

$$= 375\ m$$

Thus in 1 min after the application of brakes the locomotive will be at a distance $l = L - s = 400 - 375 = 25$ m from the signal light.

Example 3

What is the speed of the body moving with uniform accelerated motion at midpoint of two points on the straight line, where the speeds are u and v respectively?

Solution

Let "a" be the constant acceleration. And s be the distance between the two points,

From equation of motion

$v^2 - u^2 = 2as$................. (1)

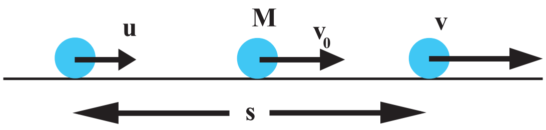

Fig-21

Let v_0 be the speed of the body at midpoint 'M' of the given points.

Applying the same equation used above, we get

$$v_0^2 - u^2 = 2as/2$$

From (1),

$$v_0^2 - u^2 = \frac{v^2 - u^2}{2}$$

After some algebra we get,

$$v_0 = \sqrt{\frac{v^2+u^2}{2}}$$

Example 4

A car travels from rest with a constant acceleration "*a*" for "t" seconds. What is the average speed of the car for its journey if the car moves along a straight road?

Solution

The car starts from rest, so u = 0

The distance covered in time t

$$s = \frac{1}{2} a t^2$$

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

$$V = \frac{(a t^2/2)}{t} = \frac{a t}{2}$$

Example 5

A particle moving with constant acceleration of $2 m/s^2$ due west has an initial velocity of 9 m/s due east. Find the distance covered in the fifth second of its motion.

Solution

Initial velocity u = +9 m/s

Acceleration $a = -2\ m/s^2$

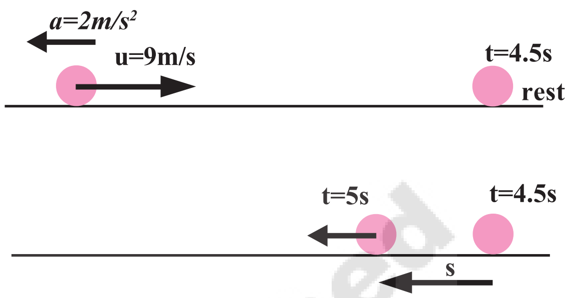

Fig.22 :Motion of the particle

In this problem, acceleration's direction is opposite to the velocity's direction.

Let " t" be the time taken by the particle to, reach a point where it makes a turn along the straight line.

We have, $v = u + at$

$0 = 9 - 2t$

We get, t = 4.5s

Now let us find the distance covered in 1/2 second i.e. from 4.5 to 5 second

Let u = 0 at t = 4.5 sec.

Then distance covered in 1/2s.

$$s = \frac{1}{2} a t^2$$

$$s = \frac{1}{2} \times 2 \times \left[\frac{1}{2}\right]^2$$

$$= 1/4 m$$

Total distance covered in fifth second of its motion is given by

$$S_0 = 2s = 2\,(\tfrac{1}{4}) = \tfrac{1}{2}\ m.$$

Key words

Relative, distance, displacement, average speed, average velocity, instantaneous speed (speed), velocity, acceleration, rectilinear motion

What we have learnt

- Motion is relative. Motion of an object depends on the observer.
- Distance is the path length traversed and displacement is the shortest distance in a specified direction.
- Average speed is distance covered per unit time and average velocity is displacement in a specified direction per unit time.
- Speed at an instant is instantaneous speed which gives the idea of how fast the position of the body changes.
- Velocity is speed in specified direction.
- The motion is uniform when the velocity is constant.
- A body has acceleration when the velocity of the body changes.
- Acceleration is the rate of change of velocity.
- The motion is said to be uniform accelerated motion if acceleration is constant.
- The equations of uniform acclerated motion are given by

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

Improve your learning

1. As shown in figure23, a point traverses the curved path. Draw the displacement vector from given points A to B (AS_5)

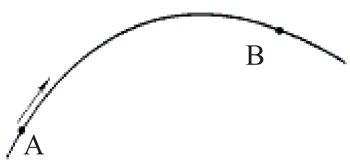

Fig-23

2. "She moves at a constant speed in a constant direction." . Rephrase the same sentence in fewer words using concepts related to motion.(AS_1)

3. What is the average speed of a Cheetah that sprints 100m in 4sec. ? What if it sprints 50m in 2sec? (25 m/s)(AS_1, AS_7)

4. Correct your friend who says, " The car rounded the curve at a constant velocity of 70 km/h".(AS_1)

5. Suppose that the three ball's shown in figure start simultaneously from the tops of the hills. Which one reaches the bottom first ? Explain. See figure 24.(AS_2 ,AS_1)

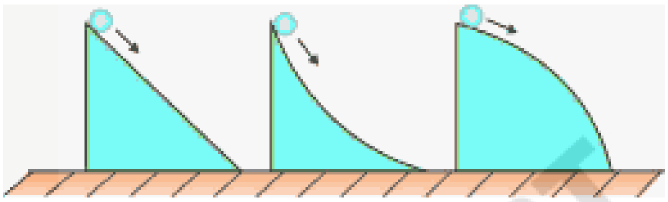

Fig-24

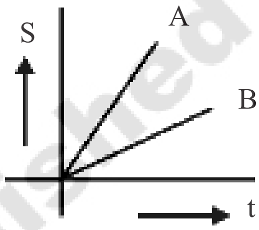

Fig-25

6. Distance vs time graphs showing motion of two cars A and B are given. Which car moves fast ? See figure 25.(AS_1)

7. Draw the distance vs time graph when the speed of a body increases uniformly.(AS_5)

8. Draw the distance – time graph when its speed decreases uniformly.(AS_5)

9. A car travels at a velocity of 80 km/h during the first half of its running time and at 40 km/h during the other half. Find the average speed of the car. (60 km/h) (AS_1 , AS_7)

10. A car covers half the distance at a speed of 50 km/h and the other half at 40km/h.Find the average speed of the car. (44.44 km/h) (AS_1 , AS_7)

11. Derive the equation for uniform accelerated motion for the displacement covered in its nth second of its motion. ($S_n = u + a\,(n - ½)$) (AS_1)

12. A particle covers 10m in first 5s and 10m in next 3s. Assuming constant acceleration. Find initial speed, acceleration and distance covered in next 2s. (AS_1 , AS_7)
(7/6 m/s, 1/3 m /s^2, 8.33m)

13. A car starts from rest and travels with uniform acceleration " α " for some time and then with uniform retardation " β " and comes to rest. The time of motion is " t" . Find the maximum velocity attained by it. ($\alpha \beta t / (\alpha + \beta)$) ($AS_1$, AS_7)

14. A man is 48m behind a bus which is at rest. The bus starts accelerating at the rate of 1 m/s^2, at the same time the man starts running with uniform velocity of 10 m/s. What is the minimum time in which the man catches the bus? (8s) (AS_1 , AS_7)

15. A body leaving a certain point " O" moves with an a constant acceleration. At the end of the 5 th second its velocity is 1.5 m/s. At the end of the sixth second the body stops and then begins to move backwards. Find the distance traversed by the body before it stops. Determine the velocity with which the body returns to point " O " ? (27m, -9 m/s)(AS_1)

16. Distinguish between speed and velocity. (AS_1)

17. What do you mean by constant acceleration?(AS_1)

18. When the velocity is constant, can the average velocity over any time interval differ from instantaneous velocity at any instant? If so, give an example; if not explain why. (AS_2 , AS_1)

19. Can the direction of velocity of an object reverse when it's acceleration is constant? If so give an example; if not, explain why.(AS_2 , AS_1)

20. A point mass starts moving in a straight line with constant acceleration "a". At a time t after the beginning of motion, the acceleration changes sign, without change in magnitude. Determine the time t_0 from the beginning of the motion in which the point mass returns to the initial position. ($(2 + \sqrt{2})$ t) (AS_1)

21. Consider a train which can accelerate with an acceleration of 20cm/s^2 and slow down with deceleration of 100cm/s^2.Find the minimum time for the train to travel between the stations 2.7 km apart. (180 s) (AS_1)

22. You may have heard the story of the race between the rabbit and tortoise. They started from same point simultaneously with constant speeds. During the journey, rabbit took rest somewhere along the way for a while. But the tortoise moved steadily with lesser speed and reached the finishing point before rabbit. Rabbit awoke and ran, but rabbit realized that the tortoise had won the race. Draw distance vs time graph for this story. (AS_5)

23. A train of length 50m is moving with a constant speed of 10m/s. Calculate the time taken by the train to cross an electric pole and a bridge of length 250 m. (5s , 30s) (AS_1)

24. Two trains, each having a speed of 30km/h, are headed at each other on the same track. A bird flies off one train to another with a constant speed of 60km/h when they are 60km apart till before they crash. Find the distance covered by the bird and how many trips the bird can make from one train to other before they crash? (60km infinity,) (AS_1)