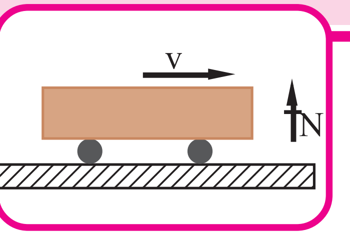
Chapter 2

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 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 undertook his study of 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 motion.

What is relative ?

We use many statements in our daily life to express our views. The meaning of a statement depends on the context in which it is made.

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.

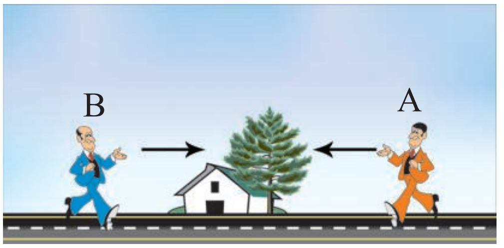


Fig-1

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 of 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 his left and right sides.

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 place on the globe where the question is being asked.

Up and down

Can 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.Observe the fig-2 by inverting the book

- Why do we observe these changes?

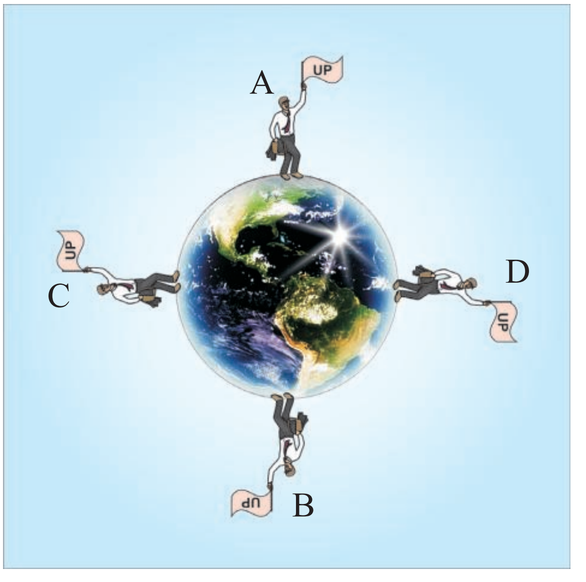


Fig-2

We know that earth is a sphere, the upward direction of the vertical position on its surface depends upon 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.

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.

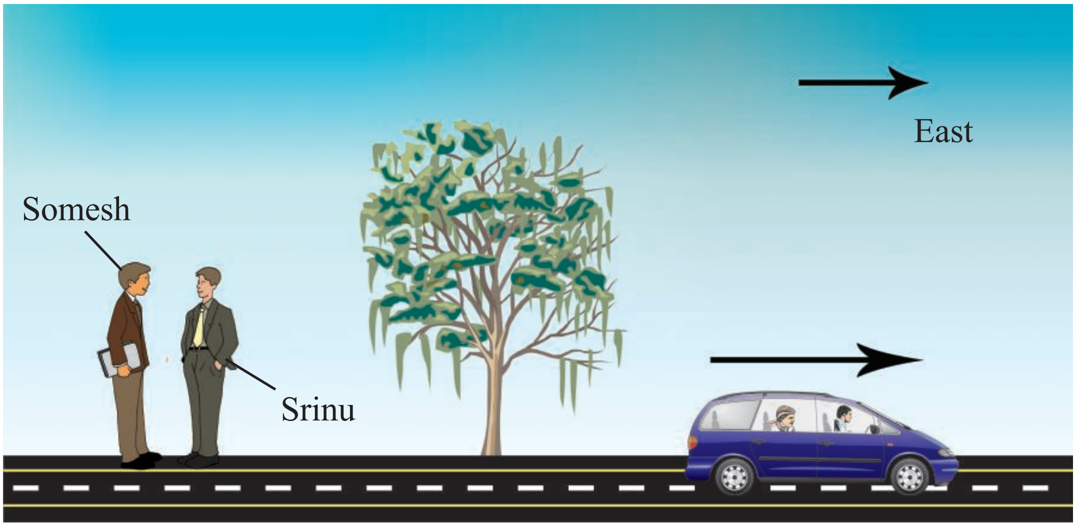


Fig-3: Motion in view of Srinu and Somesh

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.

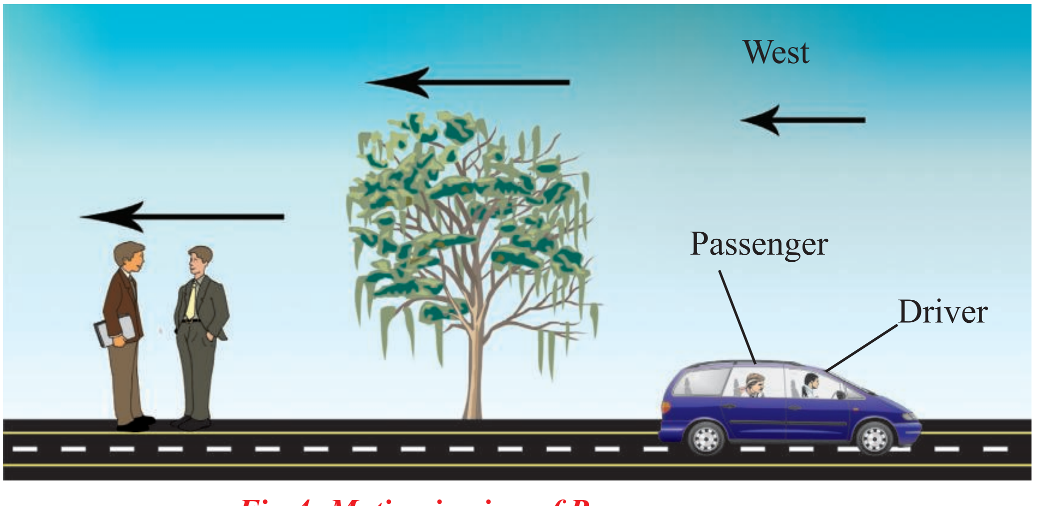


Fig-4: Motion in view of Passenger

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 answer may 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' or 'rest' 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.

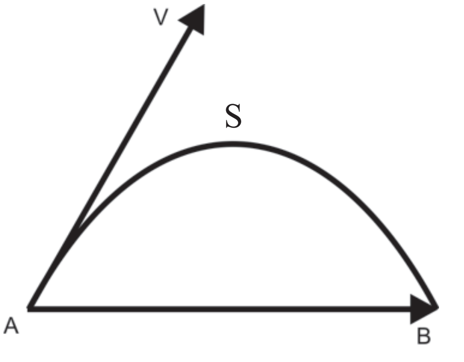
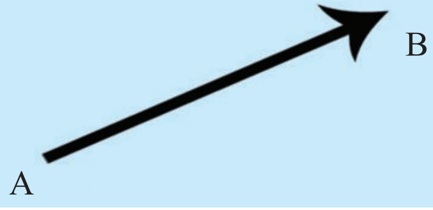


Fig-5:Distance - displacement

Observe the difference between distance(S) and displacement(AB)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 does not require any direction for its specification 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 object.AB is called displacement vector.

- The SI unit of distance or displacement is metre denoted by 'm'.
- Other units like kilometre, centimetre 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 given below.

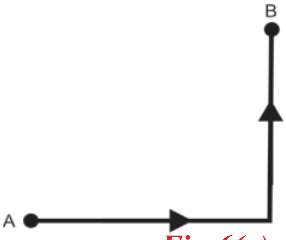


Fig-6(a)

Fig-6(b)

Generally, the distance covered and displacement are time dependent quantities.

Think and discuss

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

Average speed and average velocity

A train named Telangana express starts at 2.00 pm from Sirpur Kaghaz Nagar and reaches Hyderabad at 8.00 pm the same day as shown in figure 7.

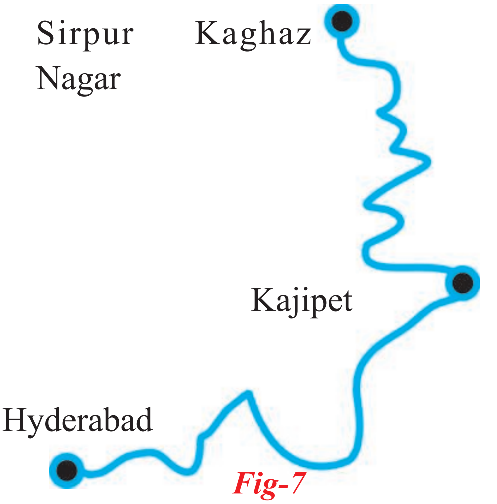


Fig-7

Draw displacement vectors from Sirpur Kaghaz Nagar to Kajipet, Kajipet to Hyderabad and from Sirpur Kaghaz Nagar to Hyderabad.

Let the distance of the entire trip from Sirpur Kaghaz Nagar to Hyderabad be 300 km.

The journey time is 6 h. What is the distance covered by the train in each hour?

It is equal to 300km/6h = 50km/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 the train each hour. So we take the 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 the above example be 120 km due South–West. What is the displacement in each hour?

The displacement per hour

= 120 km/ 6h South - west

= 20km / h South - 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.

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

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 25h. What is his average speed during the journey?

♦ Can you measure the average speed and average velocity?

♦ How can you differentiate speed and average velocity?

Let us do some activities to undersand about speed and velocity.

Activity-3

Measuring the average speed

Choose two points (say A & B) 50 meters apart in the school play ground. Ask some students to stand at point A. Ask another group of students with stop watches to stand at B.

When you clap your hand, the students at A start running towards the point B in any path. At the same time the students at B start their stop watches.

See that for each runner there is a student at B to measure the time taken for completing the race. Note the time taken by each student to cover the distance between the points A and B in table.

Table -1

Student	Time taken to reach B (sec)	average speed (50/t) m/s
A_1	t_1	-
A_2	t_2	-
A_3	t_3	-

The student who took the least time to reach B (from A) is said to be the fastest runner, i.e., he/she has the greatest average speed.

Measuring the average velocity

Repeat the whole activity after drawing a set of parallel straight lines from A to B and ask each student to run along a line (This ensures that each student is covering the same distance along a straight line specified for him/her from A to B)

Measure the time taken by each student and note it in a table as shown above and calculate the average velocity of each student. The student who took the least time to reach B from A along the line is said to have run with the greatest average velocity.

- What difference did you notice between the two activities?
- Why are we calling the ratio of distance and time as average speed in first activity and as average velocity in second activity? Discuss with your teacher.

Speed and velocity

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

- Can you find the speed of the 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.**

We can describe the motion of a car moving along a straight road with varying speed using a 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 8.

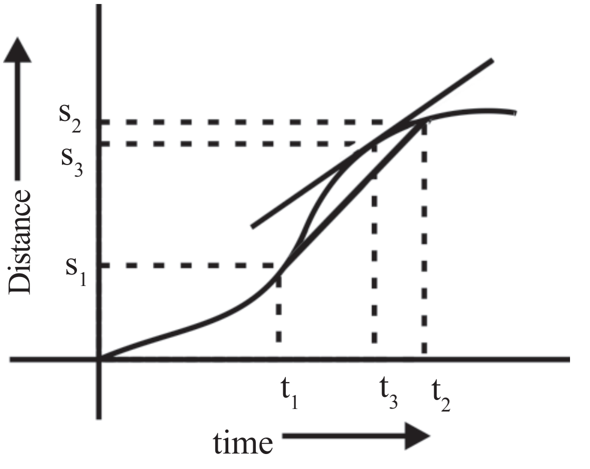


Fig-8:Distance vs time graph

- 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 the 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 the 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.

For Example :

A car moves with 15 m/s due east. Here 15 m/s is speed and 15 m/s due east is velocity

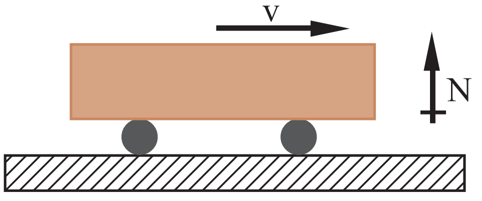


Fig-9

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?

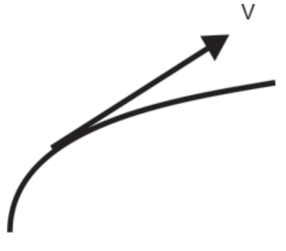


Fig-10:Direction of velocity at a point of path

Think and discuss

- Very often you must have seen traffic police stopping motorists or 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.

Activity-4

Observing the direction of motion of a body

Carefully whirl a small object tied at 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 an 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-5

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 table2.

Table -2

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-11.

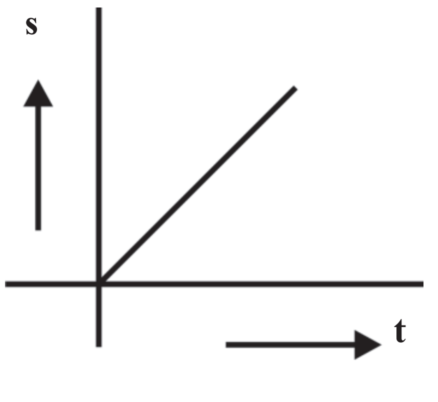

Fig-11

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 uniform when its velocity is constant.

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 values given in table 3.

Table-3

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-6

Observing the motion of a ball on an inclined plane

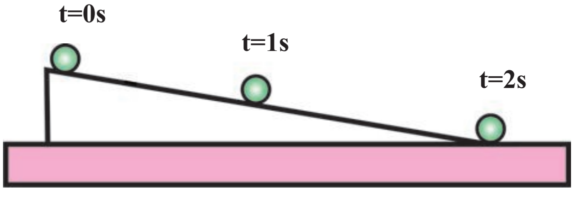


Fig-12:Ball moving down the inclined plane

Set up an inclined plane as shown in figure 12. Take a ball and release it from the top of the inclined plane. The positions of the ball at various times are shown in figure13.

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

Draw velocity vectors in figure 12 at times t=0s, 1s and 2s

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

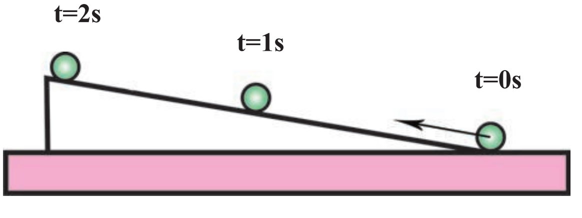


Fig-13:Ball moving up the inclined plane

Set up an inclined plane as shown in figure 13. Take a ball and push it with a speed from the bottom of the inclined plane so that it moves up.

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

Draw velocity vectors at times t = 0s, 1s, 2s in figure-13.

In above two situations of activity-6, we observe that the speed changes but the direction of motion remains constant.

Activity-7

Observing uniform circular motion

Whirl a stone which is tied to the end of a string continuously. Draw its path of motion and velocity vectors at different positions as shown in the figure 14. Assume that the speed of the stone is constant.

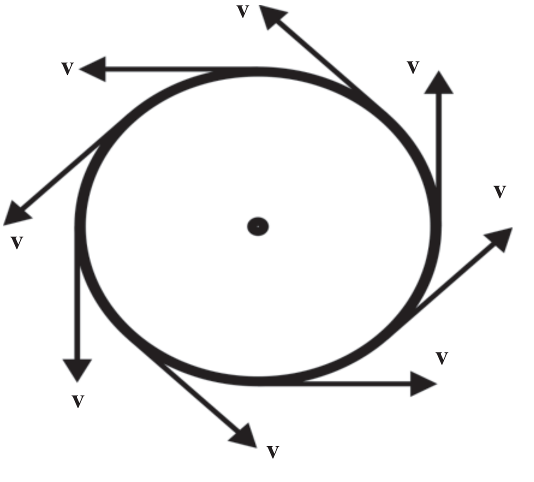


Fig-14

- 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 examples for motion of an object where its speed remains constant but velocity changes?

Activity-8

Observing the motion of an object thrown into air

Throw a stone into the air while 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 the velocity of a body is changing.

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

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 seat 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 the car is increasing 5 km/hr per second.

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

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

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 the air and similarly we can experience deceleration when a moving 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 fig-15. 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.

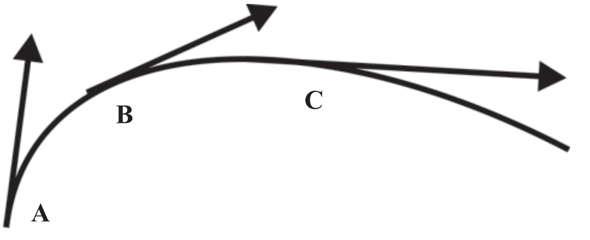


Fig-15: Motion diagram

- 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 a 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 "Acceleration gives an idea of how fast the position changes."

Equations of uniform accelerated motion

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

Then,

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

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

'Δ' - denotes changes

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" as shown in figure 16.

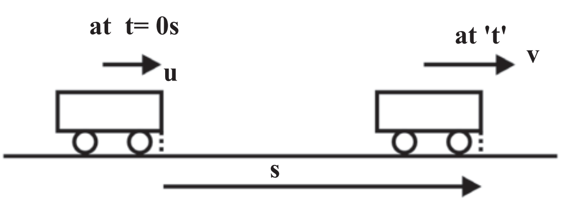


Fig-16

From the definition of uniform acceleration,

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

$$at = v - u$$

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

Since the acceleration of the body is constant.

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

But we know

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

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

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

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

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

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

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

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 uniform accelerated 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 an object decreases, the direction of velocity and acceleration are in opposite directions. In such a case, at a certain instant the 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 the air.)

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

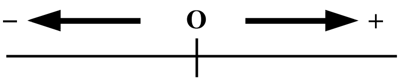


Fig-17

- Choose the origin on a straight line. The quantities measured to the right are taken as positive and these measured to the 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 the 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, book, 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 a book and the other end on the floor, as shown in figure-18.

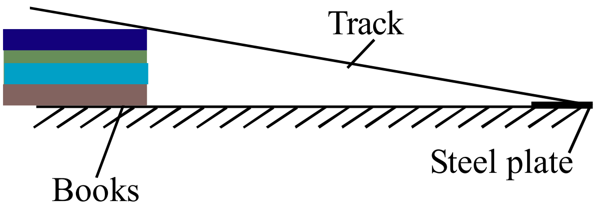


Fig-18

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

Take a marble having adequate size to travel in the track freely. Now release the 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 a sound is produced. Repeat the same experiment for the same distance 2 to 3 times and note the values of times in table-4.

Table-4

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.

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 the 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 the acceleration and draw the S-t graph.

Give your explanation for various accelerations related to slopes.

The values found in this experiment are approximate.

Example 1

A car is moving with the accelaration 2 m/s^2 from rest. Find the distance traveled by the car in 10^{th} second.

Solution

$n = 10$ s

$a = 2\ m/s^2$

$u = 0$ m/s

Substituting the values in the following equation

$$s_n = u + a\left[n - \frac{1}{2}\right]$$
$$= 0 + 2\left[10 - \frac{1}{2}\right]$$
$$= 2 \times \frac{21}{2}$$
$$= 21\text{m}$$

Distance traveled by the car in

10^{th}s =21m.

Example 2

A car is moving with the initial velocity 15 m/s. Car stoped after 5s by application of breaks. Find the retardation (Decelaration).

Solution

$t = 5$ s

$v = 0$ m/s

$u = 15$ m/s

$a = ?$

Substituting the values in the following equation.

$$v = u + at$$
$$0 = 15 + (a \times 5)$$
$$a = \frac{-15}{5}$$
$$a = -3\ m/s^2$$

Example 3

A bus is moving with the initial velocity of 'u' m/s. After applying the breaks, its retardation is 0.5 m/s^2 and it stoped after 12s. Find the initial velocity (u) and distance travel by the bus after applying the breaks.

Solution

$a = 0.5\ m/s^2$

$v = 0\ m/s$

$t = 12\ s$

$u = ?$

$$v = u + at$$
$$0 = u + (-0.5\times12)$$
$$0 = u - 6$$
$$u = 6\ m/s$$

Initial velocity of the bus 6 m/s.

$$s = ut + \frac{1}{2}at^2$$
$$= (12\times6) + \frac{1}{2}(-0.5\times12^2)$$
$$= 72 - \frac{1}{2}(72)$$
$$= 36\ m$$

Bus has stoped 36 m distance after applying the break.

Example 4

At a distance L= 400m away from the signal light,brakes are applied to a locomotive moving with a velocity, u = 54 km/h.Determine the position of rest 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

Let v = 0 at time 't' and given

a = -0.3 m/s^2

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

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

During which it will cover a distance

$$s = -\frac{u^2}{2a}$$
$$= -\frac{15^2}{2\times(-0.3)}$$
$$= \frac{225}{0.6}$$
$$= 375\ m$$

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 5

What is the speed of the body moving with uniform acceleration at the midpoint of two points on a 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)

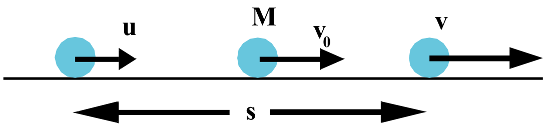


Fig-19

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

Applying the same equation used above, we get

$$v_0^2 - u^2 = 2a\frac{s}{2}$$

From (1), we get

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

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

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

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

Example 6

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

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

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

$$v = \frac{\left(\frac{at^2}{2}\right)}{t}$$

$$= \frac{at}{2}$$

Example 7

A particle moving with constant acceleration of 2m/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

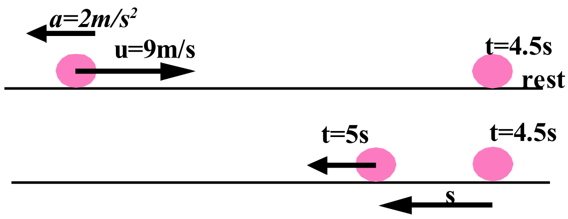


Fig.20 :Motion of the particle

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, $v = u + at$

$$O = 9 - 2t$$

We get, t = 4.5s

Now let us find the distance covered in $\frac{1}{2}$ second i.e. from 4.5 to 5 second

Let u = 0 at t = 4.5 sec.

Then distance covered in $\frac{1}{2}$ s.

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

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

$$= \frac{1}{4}\ \text{m}$$

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

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

Key words

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

$$v = u + at$$

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

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

Let us Improve our learning

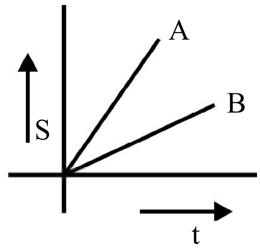
Reflections on concepts

1. Distinguish between speed and velocity. (AS_1)
2. Briefly explain about constant acceleration?
3. How can you say that a body is in motion? Is it a common property? (AS_1)
4. Are average speed and average velocity are same? If not explain why? (AS_1)
5. How do you measure instantaneous speed? (AS_1)
6. Explain acceleration with an example ? (AS_1)
7. What do you mean by acceleration ? (AS_1)

Application of concepts

1. In the above figure distance vs time graphs showing motion of two cars A and B are given. Which car moves fast ? (AS_1)

2. A body leaving a certain point " O" moves with 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)



3. 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)

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

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

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

7. A car travels at a speed 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_7)

8. 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_7)

(7/6 m/s, 1/3 m /s^2, 8.33m)

Higher Order Thinking questions

1. 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)

2. 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 wokeup and ran, but rabbit realized that the tortoise had won the race. Draw distance vs time graph for this story. (AS_5)

3. 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_7)

Multiple choice questions

1. The distance travelled by an object in a specified direction is [ ]

   (a) Speed (b) Displacement

   (c) Velocity (d) Acceleration

2. If an object is moving with constant velocity then the motion is [ ]

   (a) Motion with Non uniform acceleration

   (b) Motion with Uniform Acceleration

   (c) Uniform Motion (d) Non uniform Motion

3. If there is change in the velocity of the object then the state of object with respect to motion is [ ]

   (a) State of Constant Speed (b) State of Constant velocity

   (c) State of Uniform Motion (d) State of Non uniform Motion

4. If the acceleration of a moving object is constant then the motion is said to be [ ]

   (a) Motion with Constant Speed (b) Motion with Uniform Acceleration

   (c) Motion with Uniform Velocity (d) Motion with Non Uniform acceleration

Suggested experiments

1. Conduct an expermiment to find acceleration and velocity of an object moving on an inclined plane and write a report.

Suggested projects

1. Calculate the avarage speeds of students of your class we who have participated in 100 meters and 200 meters running race. Write a report.
2. Suppose that the three balls shown in figure below start simultaneously from the tops of the hills. Which one reaches the bottom first ? Explain. (AS_2)