7

Motion and Its Description

In this world, we see many objects moving around us, for example, cars, buses, trucks, and bicycles moving on the road, aeroplanes flying in air and ships sailing on the sea, leaves falling from the trees and water flowing in the river. All these objects are changing their position with time. When an object changes its position with time, it is said to be in **motion.** In these examples, motion is easily visible to us. But in some cases, motion is not easily visible to us. For example, air moves in and out of our lungs and blood flows in our body. The moon moves around the earth, while the two together go around the sun. The sun itself with its planets travels through our own galaxy.

An object that does not change its position with time is said to be at rest, for example a book lying on a table.

In this lesson, you will learn how to describe motion. For this, we will develop the concepts of **displacement, velocity** and **acceleration**. You will also learn how these quantities are related to each other. For an object moving along a straight line with uniform acceleration, we will obtain simple equations (known as equations of motion) connecting these quantities with time.

OBJECTIVES

After completing this lesson, you will be able to:

- define the terms motion, scalar and vector quantities, displacement, speed, velocity and acceleration,
- distinguish between

  (a) rest and motion

  (b) scalar and vector quantities

  (c) speed and velocity;
- differentiate between uniform and non-uniform motion;
- plot and interpret the following graphs

  (a) displacement – time graph for uniform motion,

  (b) velocity – time graph for uniformly accelerated motion;
- establish three equations of motion;
- solve problems based on equations of motion.

7.1 SOME BASIC ASPECTS OF MOTION

7.1.1 Types of motion

In our daily life we see many objects moving. Some objects move in a straight line. For example, a ball rolling on a horizontal surface, a stone falling from a building and a runner on a 100m race track. In all these examples, objects change their positions with time along a straight line. This type of motion is called **rectilinear motion**.

Observe the motion of a second's hand of a clock, or motion of a child sitting on a marry-go round, or the motion of the blades of an electric fan. In such a motion, an object follows a circular path during motion. This type of motion is called **circular motion**. If you take a stone, tie a thread to it and whirl it with your hand, you will find that the stone moves on a circular path. In all such cases, though an object changes its position with time, it remains at a fixed distance from a point.

Some objects move to and fro, such as a swing, a pendulum, the branches of a tree in the wind and the needle of a sewing machine. Such type of motion is called **oscillatory motion**. In such a motion, an object oscillates about a point, often called **equilibrium position.**

7.1.2 Scalar and vector quantities

Each of the physical quantities you encounter in this book can be categorized as either a **scalar** or a **vector quantity**. A scalar is a quantity that can be completely specified by its magnitude with appropriate units; i.e. a **scalar** has only magnitude and no direction. A vector is a physical quantity that requires the specification of both magnitude and direction.

Mass is an example of a scalar quantity. If someone tells you that mass of an object is 2 kg, that information completely specifies the mass of the object; no direction is required. Other examples of scalar quantities are, temperature, time interval, the number of students in a class, the volume of water in a bucket and the number of pages in this book.

An example of a vector quantity is **force**. If your friend tells you that he is going to exert a force of 5N on an object, this is not enough information to let you know what will happen to the object. The effect of a force of 5N *exerted horizontally* is different from the effect of a force of 5N *exerted vertically upward* or *downward*. In other words, you need to know the direction of the force as well as its magnitude. Velocity is a vector quantity. If you wish to describe the velocity of a moving vehicle, you must specify both its magnitude (say, 30 m/s) and the direction in which the vehicle is moving (say, northeast). Other examples of vector quantities include displacement and acceleration, which are defined in this lesson.

We use different symbols to represent scalar and vector quantities. A scalar quantity is represented by an ordinary letter (such as a) or number (such as 5) with appropriate unit. 3 cm, 6 L, and 12 kg represent scalar quantities.

A vector quantity is represented by a symbol printed in boldface, such as **a** or **A**. Since in handwriting, this representation is not practical, a common notation is to indicate a vector quantity by an arrow over its symbol, $\vec{a}$ or $\vec{A}$. When we are interested only in the magnitude of a vector quantity, such as **a**, we write it as a scalar (that is, a) indicating that its direction is not being considered. Graphically, a vector is represented by an arrow. The length of the arrow is proportional to the magnitude of the vector and the arrow points in the direction of the vector. Fig. 7.1 a shows vector **A** and vector **–A**, both has the same magnitude but are in opposite directions.

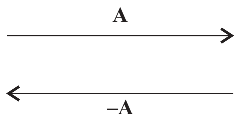

Fig. 7.1 (a) Vectors in same direction

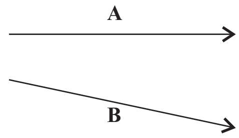

Fig. 7.1 (b) Vectors in different directions

Figure 7.1 (b) shows vector **A** and another vector **B** whose magnitude is same as that of **A** but direction is different.

Scalars can be added and subtracted like ordinary numbers. Vectors follow different laws. However, vectors having same direction can be added easily. For example, sum of vector **A** and a vector **C** (Fig. 7.1c) is a vector **D** whose magnitude is the sum of the magnitudes of vector **A** and **C** and direction is the same as that of **A**.

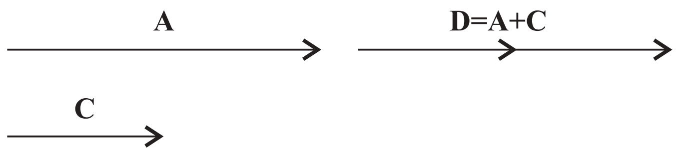

Fig. 7.1 c Addition of vector

Subtraction of vector **C** from vector **A** can be seen as addition of vector **– C** to vector A as shown in Fig. 7.1d. The resultant has a magnitude equal to the difference of the magnitude of **A** and the magnitude of **B**. It points in the direction of **A** (the bigger of the two vectors).

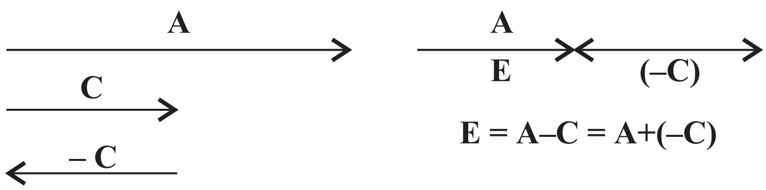

Fig. 7.1 (d) Subtraction of vectors

7.1.3 Distance and displacement

Motion occurs when an object changes position. Therefore, in order to describe the motion of an object, one must be able to specify its position at all times. In this course, we shall consider motion of objects in which position changes along a straight line, known as rectilinear motion. Let us say that the object moves along x-axis as shown in Fig. 7.2

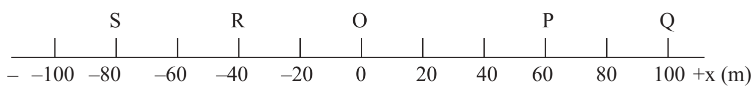

Fig. 7.2 Movement of an object along x-axis

Then position of the object is specified with reference to a point, say O. This point is called *origin* of the axis. The position is taken to be positive if it is to the right of the origin and negative, if it is to the left. So, if a car is at P, its position is + 60m. If it is at R, its position is –40m.

Suppose a car starts from O, moves to Q and then comes back to P. During this motion, the actual path length covered by the car = OQ + QP = +100m + (40m) = 140m. This is known as **distance**. *The total path length covered by an object irrespective of its direction of travel is called distance. It is a scalar quantity*. In SI unit, it is measured in metres (m).

In the above example, at the end of journey, the car is at P. So, its final position is P while its initial position was O. Therefore, change in position is OP +60m only. This is known as **displacement.**

The displacement of an object is defined as the change in its position and is given by the difference between its final and initial position.

Displacement of an object = final position – initial position.

Displacement is a vector quantity. In SI units, it is measured in metres (m).

In the above example, the displacement of the car is + 60m. The plus sign means that it is along + x-axis. The magnitude of this displacement is 60m and its direction is towards right or + x-axis.

Consider another case. Suppose a truck moves from O to R and returns to O. What is the distance covered by the truck? What is its displacement? Though the truck is moving along – x-direction, the length of path covered is positive. (The minus or plus sign, as explained earlier, indicates the direction of travel).

Distance covered by the truck = Path length of OR + Path length of RO

= 40 m + 40 m = 80 m

Displacement of the truck = Final position – initial position

= O (since it returns to origin O, its initial position)

Example7.1: What is the distance covered and displacement of a car,

a) If the car moves from O to P

b) If the car moves from O to P and then back to R (see Fig. 7.2).

Solution :

a) Distance covered in moving from O to P = Length of path OP = 60 m

Displacement = Final position – Initial position

= + 60 m – (0 m)

= + 60 m

60 m is the magnitude of the displacement and + sign indicates that it is directed towards right or towards P.

Note that in this case magnitude of displacement is equal to the distance. This is so because the object does not change its direction during the course of motion.

b) Distance covered in this case = Length of path OP + Length of path PR

$$= 60\text{ m} + (60\text{ m} + 40\text{ m})$$
$$= 160\text{ m}$$
$$\text{Displacement} = \text{Final position} - \text{Initial position}$$
$$= (-40\text{ m}) - (0\text{ m})$$
$$= -40\text{ m}$$

The minus sign shows that the direction of displacement is towards left or towards – x direction.

Note that in this case, the magnitude of displacement (i.e. 40 m) is not equal to the distance (160 m).

7.1.4 Speed and velocity

An object in motion travels a given distance in a certain time interval. How fast is the object moving? This is indicated by a quantity called **speed.**

The speed of an object is defined as the length of the path travelled per unit time.

$$\text{Speed} = \frac{\text{Path length or distance covered}}{\text{Time taken}} \qquad \ldots(7.1)$$

Its unit is m/s. It is also expressed in kmh^{-1}. For example, if a car covers a distance of 61 km in 2h, its speed is 61km / 2h = 30.5 kmh^{-1}.

The **velocity** of an object is defined as *the displacement divided by the time interval during which the displacement occurred*:

$$\text{Velocity} = \frac{\text{Displacement}}{\text{Time taken}} \qquad \ldots(7.2)$$

Since displacement is a vector quantity, velocity is also a vector quantity. Its unit is the same as that of speed, i.e. ms^{-1} or kmh^{-1}.

ACTIVITY 7.1

Aim : To calculate your average speed of walking.

What is required ?

A metre stick or a measuring tape; stop watch or a wrist watch with second's hand.

What to do?

i) Take a stopwatch to a field.

ii) Using the measuring tape mark two positions (in a straight line) on the field that are 50m apart.

iii) Start the clock as you walk down the marked line and stop it as you reach the 50m mark. Find the time taken by you to cover this distance.

iv) Calculate your average speed of walking.

v) Measure the time it takes you to run the same distance. What is your average speed?

To represent displacement and velocity, we must use vector notations. But in this class, we shall be considering motion along a straight line. As mentioned earlier, in such cases, direction can be represented by + or – signs. Therefore, we **need not** use vector notations.

For example, consider a car moving towards + x axis (Fig. 10.1). It moves from O to A position + 900 m in 1 minute.

Then its displacement = + 900 m – (0 m) = + 900 m.

Therefore, velocity = $\frac{+900\text{ m}}{60\text{ s}}$ = +15 ms^{-1}

The magnitude of velocity is 15 m/s and it's direction (as indicated by + sign) is towards right or towards + x axis.

Suppose the car travels back to origin O in 90 s.

Then, speed for this motion = Distance covered/ time taken

= (900 m + 900 m)/ (60 s + 90 s)

= $\frac{1800\text{ m}}{150\text{ s}}$ = 12 ms^{-1}

Velocity for this motion = $\frac{\text{Displacement}}{\text{Time taken}} = \frac{0\text{ m}}{150\text{ s}}$ = 0 ms^{-1}

(Displacement is zero because final position coincides with the initial position).

CHECK YOUR PROGRESS 7.1

1. If the average velocity of an object is zero in some time-interval, what can you say about the displacement of the object for that time interval?
2. If B is added to **A**, under what conditions does the resultant vector have a magnitude equal to A+B? Under what conditions is the resultant vector equal to zero?
3. Car A travelling from Delhi to Ghaziabad, has a speed of 25 ms^{-1}. Car B, travelling from Delhi to Gurgaon, also has a speed of 25 ms^{-1}. Are their velocities equal? Explain.
4. Give one example of circular motion and one example of motion in a straight line.
5. A body moves in a straight line from O to P and then to Q. What is the value of (i) distance travelled by the body, and (ii) displacement of the body.

7.2 GRAPHICAL REPRESENTATION OF MOTION

7.2.1 Position time graph

It is easy to analyze and understand motion of an object if it is represented graphically. To draw graph of the motion of an object, its positions at different times are shown on y – axis and time on x – axis. For example, positions of an object at different times are given in Table 7.1.

Table 7.1 Position of different objects at different times

Time (s)	0	1	2	3	4	5	6	7	8	9	10
Position (m)	0	10	20	30	40	50	60	70	80	90	100

In order to plot position – time graph for data given in Table 7.1, we represent time on horizontal axis and position on vertical axis drawn on a graph paper. Next, we choose a suitable scale for this. For example, in Fig. 7.3, 1 cm on horizontal axis represent 2 s of time interval and 1 cm on vertical axis represent 20 m, respectively. If we connect different points representing corresponding position time data, we get a straight line as shown in

Fig. 7.3. This line represents the position-time graph of the motion corresponding to data given in Table 7.1.

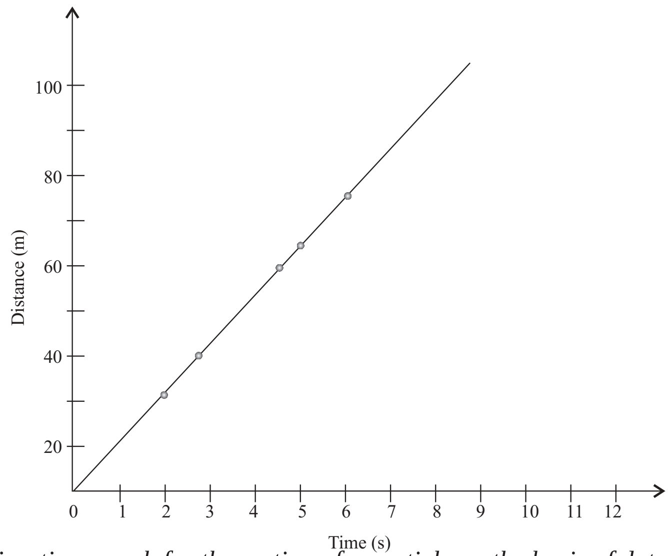

Fig. 7.3 Position-time graph for the motion of a particle on the basis of data given in table 7.1

We note from the data that displacement of the object in 1st second, 2nd second,………, 10th second is the same i.e. 10 m. In 10 second, the displacement is 100 m. Therefore, velocity is 100 m/10 s = 10 m/s for the whole course of motion.

Velocity during 1st second = 10 m/ 1s = 10 ms^{-1}

Velocity during 2nd second = 10 m/1s = 10 ms^{-1} and so on.

Thus, velocity is constant i.e., equal to 10 m/s throughout the motion. The motion of an object in which its velocity is constant, is called **uniform motion**. As you see in Fig. 7.3, for uniform motion, position-time graph is a straight line.

ACTIVITY 7.2

Aim : To plot and interpret the graph of the motion (walking) of your friend.

What is required ?

A metre stick, stop watch, and a marker (chalk, etc.)

What to do?

(i) Go out to your college field with your friend.

(ii) Using a meter stick, mark positions, 0, 5m, 10m, 15m, 20m, 25m, 30m, 35m, 40m, 45m, and 50m.

(iii) Ask your friend to walk down the line starting from position marked 0m.

(iv) As your friend starts walking, start the stop watch and record the reading of the stopwatch as he touches the marks 5m, ..., 50m.

What do you observe?

(i) Record your data in the following table:

Displacement (m)	Time (s)	Displacement (m)	Time (s)
0	0	30m	
5m		35m	
10m		40m	
15m		45m	
20m		50m	
25m			

(ii) Plot a graph of distance (vertical axis) and time (horizontal axis).

What do you infer?

(i) Is the graph a straight line? If yes, what does it mean? If no, what does it mean?

(ii) Did your friend travel this distance with uniform velocity?

(iii) Calculate the average velocity of your friend for a dsiplacement of 20m, 40m and 50m. Are they same? Explain your result.

Like position-time graph, one can also plot displacement-time graph. Displacement is represented on the vertical axis and time interval on the horizontal axis. Since displacement in each second is 10 m for data in Table 7.1, the same graph (Fig. 7.3) also represents the displacement-time graph if the vertical axis is labelled as displacement.

How will the position-time graph look like for a stationary object or object at rest. Suppose an object is at rest at position x = 40 m. Then, its position-time graph will be a straight line parallel to the time axis as shown in Fig. 7.4 because at all times, it is at 40 m.

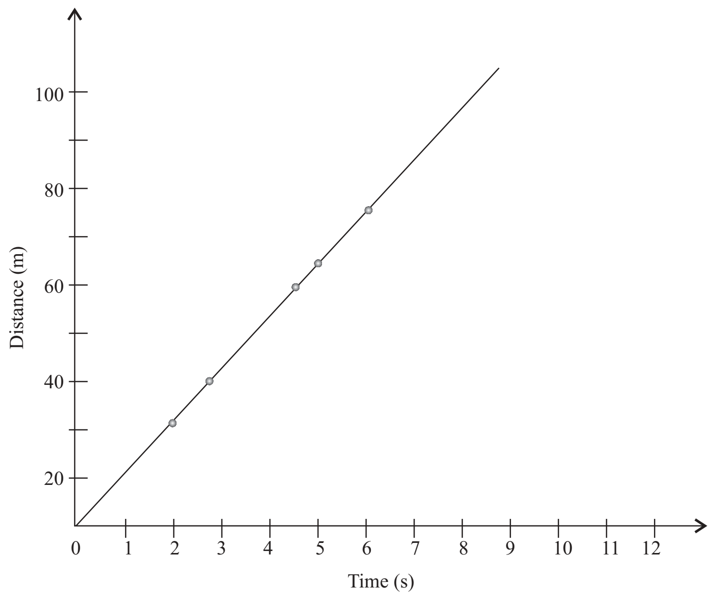

Fig. 7.4 Position time graph of a particle at rest

7.2.2 Velocity – time graph

Take time on the horizontal axis and velocity on the vertical axis on a graph paper. Let 1 cm on horizontal axis represent 2 s and 1 cm on vertical axis represent 10 ms^{-1}. Plotting the data in Table 7.2 gives us the graph as shown in Fig. 7.5.

Table 7.2 Velocity-time data of an object

Time (s)	0	1	2	3	4	5	6	7	8	9	10
Position (m)	0	10	10	10	10	10	10	10	10	10	10

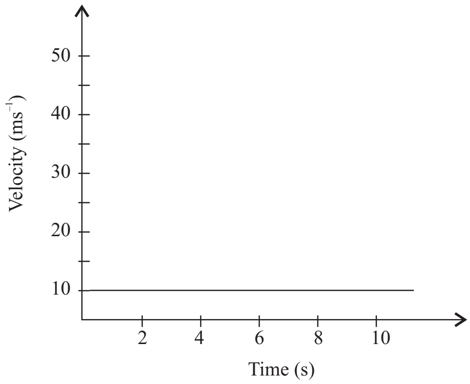

Fig. 7.5 Velocity-time graph for the motion of a particle on the basis of data given in table 7.2

Thus, we see that the velocity-time graph of motion represented in Table 7.1 and Table 7.2 is a straight line parallel to time axis. This is so because the velocity is constant throughout the motion. The motion is uniform.

Consider the area under the graph in Fig. 7.5.

Area = (10 ms^{-1}) x 10 s = 100 m. This is equal to the displacement of the object in 10s.

Area under velocity-time graph = Displacement of the object during that time interval.

Though, we obtained this result for a simple case of uniform motion, it is a general result.

Let x be displacement of an object in time t, moving with uniform velocity v, then

$$x = v\,t \quad \text{(Uniform motion)} \qquad \ldots(10.3)$$

In real life, objects usually do not move with constant velocity. We see that usually an object starts from rest, picks up motion, moves some distance, slows down and finally comes to rest. This means that the velocity during different time intervals of motion is different. In other words, velocity is not constant. Such a motion is called **non-uniform motion**. This change in velocity with time is a physical quantity called **acceleration** which we shall define next.

7.2.3 Acceleration

The acceleration of an object is defined as the change in velocity divided by the time interval during which this change occurs.

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{Time interval}} \qquad \ldots(10.4)$$

Its unit is m/s^2. It is a vector quantity.

Suppose the velocity of a car changes from + 10 m/s to + 30 m/s in a time interval of 2.0 s. Note that both velocities are towards the right, as indicated by + signs. Therefore,

$$\text{Acceleration} = \frac{30\ m/s - 10\ m/s}{2.0\ s} = +10\ ms^{-2}$$

The acceleration in the present case is +10 ms^{-2}. This means that the car accelerates in the + x direction and its velocity increases at a rate of 10 ms^{-1} every second.

If the acceleration of an object during its motion is constant, we say that the object is moving with uniform acceleration. The velocity-time graph of such a motion is a straight line inclined to the time axis as shown in Fig. 7.6.

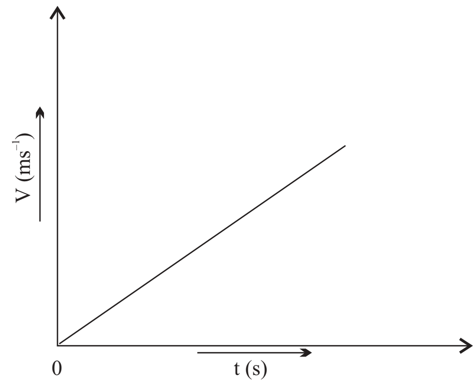

Fig. 7.6 Velocity-time graph of a particle moving with uniform acceleration

For a given time interval, if the final velocity is more than the initial velocity, then according to Fig. 7.6, the acceleration will be positive. However, if the final velocity is less than the initial velocity, the acceleration will be negative.

What is the acceleration corresponding to motion represented in Fig. 7.6? It is zero since there is no change in velocity with time. Thus, for uniform motion, the acceleration is zero and for non-uniform motion, the acceleration is non-zero.

Note: Please note that speed and velocity that we defined in the earlier section are, in fact, **average speed** and **average velocity** for the time-interval under consideration. Unless otherwise specified, terms 'speed' and 'velocity' wherever used refer to the 'average speed' and 'average velocity'.

CHECK YOUR PROGRESS 7.2

1. Look at fig. 7.7.
   (i) What kind of motion does the graph represent?
   (ii) What does the slope of the graph represent?

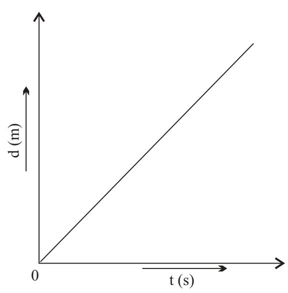

Fig. 7.7

2. Look at fig. 7.8.
   (i) What kind of motion does the graph represent?
   (ii) What does the area under the graph represent?

Fig. 7.8

3. Look at fig. 7.9.
   (i) What kind of motion does the graph represent?
   (ii) What does the slope of the line represent?
   (iii) What does the area under the curve represent?

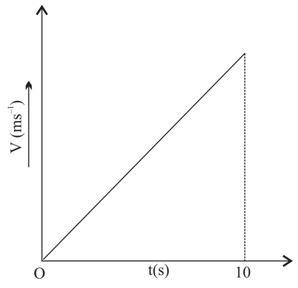

Fig. 7.9

4. A car starts from rest accelerates uniformly and attains a maximum speed of 20 ms^{-1} in 5 seconds. In the next 10 s it slows down uniformly and comes to rest at the end of 10th s. Draw a velocity time graph for the motion. Calculate from the graph (i) acceleration, (ii) retardation, and (iii) distance travelled.
5. A body moving with a constant speed of 10 ms^{-1} suddenly reverses its direction of motion at the 5th second and come to rest in the next 5 seconds. Draw a position - time graph of the motion.

7.3 EQUATIONS OF MOTION

Consider an object moving with uniform acceleration, *a*. Let *u* be its initial velocity (at time *t* = 0), *v*, its velocity after time *t* and *s*, its displacement during this time interval. Let us see how these quantities are related to each other.

7.3.1 Relation between, *v*, *u*, a and *t*

According to the definition of acceleration, we have

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

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

or, $$v = u + a\,t \qquad \ldots(10.5)$$

With the help of this equation, we can find velocity of a uniformly accelerated object after a given time interval. Or, given any three of these quantities, fourth can be found using this equation.

Example 7.2: A car has an initial velocity of 25 ms^{-1}. The brakes are applied and the car stops in 2.0 s. What is the acceleration of the car?

Solution: Using (10.5), $v = 0$, $u = 25$ ms^{-1}, $t = 2.0$ s

$$O = 25\text{ ms}^{-1} + a\,(2.0\text{s}) \quad \text{hence,} \quad a = -\,12.5\text{ ms}^{-2}$$

It is negative. *Negative acceleration is also called deceleration*.

7.3.2 Relation between *s*, *u*, *a* and *t*

From equation (10.3), we have

Displacement = (average velocity) $\times$ (time interval) or, $$s = \left(\frac{v+u}{2}\right)t$$

But, $v = u + at$

Therefore, $$s = \frac{1}{2}(u + u + at)t = ut + \frac{1}{2}at^2$$

$$s = ut + \frac{1}{2}at^2 \qquad \dots (10.6)$$

If an object starts from rest, $u = 0$ and equation (10.6) reduces to

$$s = \frac{1}{2}at^2 \qquad \dots (10.7)$$

Thus, we see that the displacement of an object undergoing a constant acceleration is proportional to t^2, while the displacement of an object with a constant velocity (zero acceleration) is proportional to t (Equation 10.3).

A body in free fall, falls with a uniform acceleration, called acceleration due to gravity (denoted by g) and having an average value 9.8 ms^{-2} near the surface of earth. For this motion the equations of motion become

$$v = u + gt$$

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

Use these concepts to do the following activity:

ACTIVITY 7.3

Aim: To measure your reaction time.

What is required?

To do this activity, you need the help of your friend, a metre scale, and a stop watch.

What to do?

(i) Take a metre scale and ask your friend to hold it vertically between his index finger and thumb.

(ii) Note the position of the metre scale with respect to his index finger.

(iii) Ask your friend to release the ruler and you must catch it (without lowering your hand after catching it).

(iv) Note the position of the metre scale, when you catch it and find the distance through which the ruler falls. Let it be *d*.

(v) Repeat this activity 5 times and note the value of *d* each time.

What do you infer?

(i) The ruler is a freely falling object with $u = 0$, $a = g$ (acceleration due to gravity = 9.8 m/s^2)

Using equation of motion, $s = ut + \frac{1}{2} a t^2$

we have $d = \frac{1}{2} g t_r^2$

or $t_r = \sqrt{\frac{2d}{g}}$

(ii) Using the different experimentally values of d obtained, you can calculate t_r find the mass of all these values. What you get is your reaction time.

(iii)Similarly, you can measure the reaction time of your friend. It is usually about 0.2 s.

Example 7.3: An object with an initial velocity of 4.0 m/s is accelerated at 6.0 m/s^2 for 2.0 s.

(a) How far does the object travel during this period?

(b) How far would the object travel if it were initially at rest?

Solution:

a) Given $u = 4.0$ ms^{-1}, $t = 2.0$ s, $a = 6.0$ ms^{-2}

$s = u\,t + ½\, a\, t^2 = (4.0\ \text{ms}^{-1})\ (2.0\ \text{s}) + (1/2)\ (6.0\ \text{ms}^{-2})\ (2.0\ \text{s})^2$

$= 8.0\ \text{m} + 12.0\ \text{m} = 20\ \text{m}.$

b) For $u = 0$,

$s = 0 + ½\ (6.0\ \text{ms}^{-2})\ (2.0\ \text{s})^2$

$= 12$ m

7.3.3 Relation between *u*, *v*, and *s*

We know that,

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

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

On multiplying these two equations, we have

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

or, $v^2 = u^2 + 2\,a\,s$ …(10.8)

Equations (10.5), (10.6) and (10.8) are the three equations of motion.

Example 7.4: A bus starts from rest and moves with a uniform acceleration of 3ms^{-2}. What will be its velocity after moving a distance of 37.5 m?

Solution :

Given $u = 0$, $a = 3\ ms^{-2}$, $s = 37.5\ m$

$v = u^2 + 2\,a\,s$

$= 0 + 2\ (3\ ms^{-2})\ (37.5\ m)$

$= 225\ m^2/s^2 = (15\ ms^{-1})^2$

$v = 15\ ms^{-1}$

Example 7.5: A body is dropped from the top of a 3 story (h=15m) building. After how much time will it strike the ground? (g=10ms**⁻²**)

Solution: $s = ut + \frac{1}{2}gt^2$

$u = 0$, $g = 10\ ms^{-2}$, $s = 15m$

$$\therefore\ 15 = \frac{1}{2} \times 10t^2$$

$$\Rightarrow\ t = \sqrt{\frac{15}{5}} = \sqrt{3} = 1.732s$$

CHECK YOUR PROGRESS 7.3

1. A ball is thrown straight up with an initial velocity of + 19.6 ms^{-1}. It was caught at the same distance above ground from which it was thrown:
   (i) How high does the ball rise.
   (ii) How long does the ball remain in air? ($g=9.8\ m/s^2$)
2. A ball is thrown vertically upwards.
   (i) What are its velocity and acceleration when it reaches the highest point?
   (ii) What is its acceleration just before it hits the ground?
3. A body accelerates from rest and attains a velocity of 10 ms^{-1} in 5s. What is its acceleration?
4. A body starts its motion with a speed of 10 ms^{-1} and accelerates for 10 s with 10 ms^{-2}. What will be the distance covered by the body in 10s?
5. A body starts from rest and covers a distance of 50m in 10 s. What is the average speed of the body?

LET US REVISE

- If a body stays at the same position with time, it is at rest.
- If the body changes its position with time, it is in motion.
- Motion is said to be rectilinear if the body moves in the same straight line all-the time, e.g, a car moving in a straight line on a level road.
- The motion is said to be circular if the body moves on a circular path: e.g, the motion of the tip of the hand of a watch.
- The total path length covered by a moving body is the distance travelled by it.

- The difference between the final and initial position of a body is called its displacement.
- Physical quanities are of two types (i) scalar: which have magnitude only, no direction (ii) vector: which have magnitude as well as direction.
- Distance, speed, mass, time, temperature etc. are scalar quantities, whereas displacement, velocity, acceleration, momentum, force etc. are vector quantities.
- Distance travelled in unit time is called speed, whereas, displacement per unit time is called velocity.
- Position-time graph of a body moving in a straight line with constant speed is a straight line sloping with time axis. The slope of the line gives the velocity of the motion.
- Velocity-time graph of a body in a straight line with constant speed is a straight line parallel to time axis. Area under the graph gives distance travelled.
- Velocity-time graph of a body in a straight line with constant acceleration is a straight line sloping with the time axis. The slope of the line gives acceleration.
- For uniformly accelerated motion :

  $v = u + at$

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

  where u = initial velocity, v = final velocity, and s = distance travelled in t seconds.

TERMINAL EXERCISES

1. Explain whether or not the following particles have an acceleration:
   (i) a particle moving in a straight line with constant speed, and
   (ii) a particle moving on a curve with constant speed
2. Consider the following combination of signs and values, for velocity and acceleration of an object with respect to a one-dimensional motion along x-axis:

Velocity	Acceleration	Velocity	Acceleration
a. Positive	Positive	e. Negative	Negative
b. Positve	Negative	f. Negative	Zero.
c. Positive	Zero	g. Zero	Positive
d. Negative	Positive	h. Zero	Negative

Describe what an object is doing in each case, and give a real-life example for a car on an east-west one-dimensional axis, with east considered as the positive direction.

3. A car travelling initally at + 7.0 m/s accelerates at the rate of + 0.80 m/s^2 for an interval of 2.0s. What is its velocity at the end of the acceleration?
4. A car travelling in a straight line has a velocity of + 5.0 m/s at some instant. After 4.0s, its velocity is + 8.0 m/s. What is its average acceleration in this time interval?
5. The velocity - time graph for an object moving along a straight line as shown in figure. 7.10.

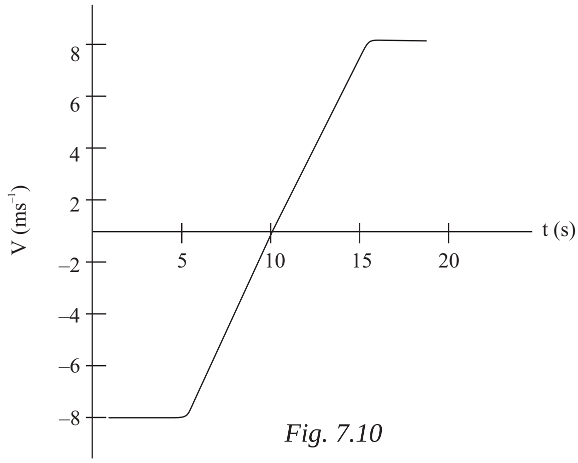

Fig. 7.10

Find the average acceleration of this object during the time intervals 0 to 5.0 s, 5.0s to 15.0s, and 0 to 20.0s.

6. The velocity of an automobile changes over a period of 8 s as shown in the table given below:

Time(s)	**Velocity (m/s)**	**Time (s)**	**Velocity (m/s)**
0.0	0.0	5.0	20.0
1.0	4.0	6.0	20.0
2.0	8.0	7.0	20.0
3.0	12.0	8.0	20.0
4.0	16.0		

(i) Plot the velocity - time graph of motion.
(ii) Determine the distance the car travels during the first 2s.
(iii) What distance does the car travel during the first 4s?
(iv) What distance does the car travel during the entire 8s?
(v) Find the slope of the line between t = 0s and t = 4.0s. What does this slope represent?
(vi) Find the slope of the line between t = 5.0s and t = 7.0s. What does the slope indicate?

7. The position-time data of a car is given in the table given below:

Time(s)	**Position(m)**	**Time(s)**	**Position(m)**
0	0	25	150
5	100	30	112.5
10	200	35	75
15	200	40	37.5
20	200	45	0

(i) Plot the position-time graph of the car.
(ii) Calculate the average velocity of the car during first 10 seonds.
(iii) Calculate the average velocity between t = 10s to t = 20s.

(iv) Calculate the average velocity between t = 20s and t = 25 s. What can you say about the direction of the motion of car?

8. Distance is always (a) less than; (b) greater than; (c) less than or equal to; (d) greater than or equal to, the magnitude of displacement.
9. The graph of x *vs.* t plot for an object with a uniform velocity in the x-direction is (a) a curved line; (b) a straight line; (c) a circle; (d) a point.
10. An object initially at rest moves for t seconds with a constant acceleration a. The average speed of the object during this time interval is (a) at/2; (b) 2 at; (c) 1/2 at^2 (d) 1/2at.
11. A car starts from rest with a uniform acceleration of 4 m/s^2. The distances travelled at the ends of each of the first 4 seconds are, respectively, (a) 4, 8, 16, 32m, (b) 2, 8, 18, 32m, (c) 2, 4, 8, 16m, (d) 4, 16, 32, 64m.

ANSWERS TO CHECK YOUR PROGRESS

7.1

1. Zero
2. Both A and B should be along the same direction. B should be equal in magnitude and opposite in direction to A
3. No. Though the magnitudes of their velocites are the same (25 ms^{-1}), their direction are different. Hence, $V_A \neq V_B$.
4. Motion of a second's hand of a clock is a circular motion. A ball rolling on a horizontal surface executes motion along a straight line.
5. (i) 25m, (ii) –5m

7.2

1. (i) uniform motion (ii) velocity of the object
2. (i) uniform motion (ii) displacement of the object
3. (i) uniformly accelerated motion
   (ii) accleration
   (iii) displacement
4. refer section 7.2.2
5. refer section 7.2.1

7.3

1. (i) 19.6m (ii) 4s
2. (i) v = 0, a = g (ii) g
3. $2ms^{-2}$
4. 600m
5. $5ms^{-1}$