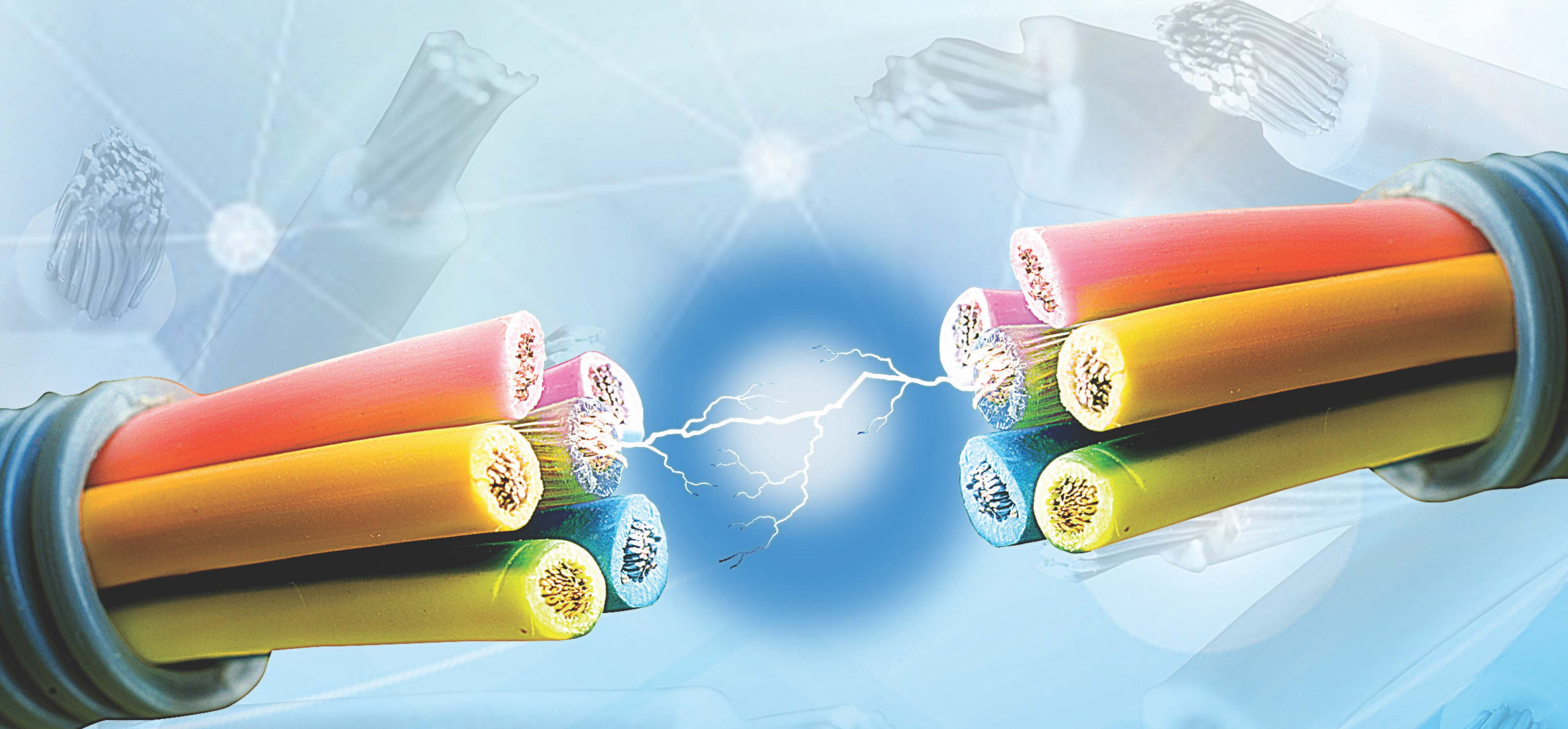
Based on the latest CBSE syllabus

9

LIVING SCIENCE
PHYSICS

Dhiren M Doshi



Ratna Sagar

Based on the latest syllabus and guidelines issued
by the Central Board of Secondary Education (CBSE)

LIVING SCIENCE
PHYSICS

9

Dhiren M Doshi

Ratna Sagar

ABOUT THE AUTHOR

Dhiren M Doshi is a well-known author of a number of Physics textbooks for schools. He has classroom teaching experience of more than 25 years. As a Physics resource person and a part of the In-service Teachers' Training Programme, he has conducted hundreds of 'Effective Science Teaching' workshops for teachers all over India.

His interactive, interesting and innovative style of writing books as if the 'Teacher-is-in-the-Book' helps students understand the fundamental concepts of Physics clearly and logically, for lifelong learning.

Cover Image: TRIFF, D_ARTS/shutterstock.com

First Published 2007

First revised edition 2011

Second revised edition 2017

10 9 8 7 6 5 4 3 2 1

ISBN 978-93-85976-87-2

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an ISO 9001:2015 and 14001:2015 company

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Preface

It has been a real pleasure to note the response with which the first revised edition has been received. It gives me immense pleasure in presenting the revised edition of Living Science Physics for Class IX written strictly in accordance with the latest NCERT syllabus woven with the latest CBSE guidelines aimed at the holistic assessment of the learners. While presenting the revised edition, the basic user-friendly structure of the previous edition has been retained.

Salient Features of the Book

- This book contains Check Your Progress, activities, chapter-end exercises, etc. in each chapter to develop cognitive, psychomotor and affective domains of learning and lays emphasis on scientific thought process.
- **Exercises:** Each chapter has exercises at the end. It measures or 'sums-up' how much a student has learnt from the chapter. It is a graded assignment consisting of the questions based on knowledge, understanding, application, analysis, synthesis and evaluation type of questions.

  The following types of questions have been included in exercises:
  - Very Short Answer Type (VSA) questions (one-mark each)
  - Short Answer Type-I (SA-I) questions (two-marks each)
  - Short Answer Type-II (SA-II) questions (three-marks each)
  - Long Answer Type (LA) questions (five-marks each)

  Due weightage has been given to
  - Higher Order Thinking Skills (HOTS) questions
  - Value-Based Questions
  - Questions Based on Practical Skills in Science

I sincerely hope that this book will serve its intended purpose and be received enthusiastically by both, the students and the teachers. Constructive criticisms and valuable suggestions from both teachers and learners are welcome for the improvement of the book.

With warm regards

Delhi **Dhiren M Doshi**

Remodeled Assessment Structure

(Based on CBSE Circular No.: Acad-05/2017 dated 31/01/2017)

1. SCHOLASTIC AREA

<table>
<tr><td></td><td colspan="4">Total 100 marks
(Syllabus for assessment will be only Class-X)</td></tr>
<tr><td rowspan="3">Subjects</td><td rowspan="3">80 Marks
(Board Examination)
Student has to secure 33% marks out of 80 marks in each subject</td><td colspan="3">20 Marks
(Internal Assessment)
Students has to secure 33% marks out of overall 20 marks earmarked in each subject</td></tr>
<tr><td>Periodic Test
(10 Marks)</td><td>Notebook Submission
(5 Marks)</td><td>Subject Enrichment Activity
(5 Marks)</td></tr>
<tr><td>(i)</td><td>(ii)</td><td>(iii)</td></tr>
<tr><td>Language 1</td><td rowspan="5">Board will conduct Class-X Examination for 80 marks in each subject covering 100% syllabus of the subject of Class-X only.
Marks and Grades both will be awarded for individual subjects.
9-point grading will be same as followed by the Board in Class XII.</td><td rowspan="5">Periodic written Test, restricted to three in each subject in an Academic Year.
Average of the best two tests to be taken for final marks submission.</td><td rowspan="5">This will cover:
❖ Regularity
❖ Assignment Completion
❖ Neatness & upkeep of notebook</td><td>Speaking and listening skills</td></tr>
<tr><td>Language 2</td><td>Speaking and listening skills</td></tr>
<tr><td>Science</td><td>Practical Lab work</td></tr>
<tr><td>Mathematics</td><td>Maths Lab Practical</td></tr>
<tr><td>Social Science</td><td>Map Work and Project Work</td></tr>
</table>

(i) Periodic Test (10 marks)

The school should conduct three periodic written tests in the entire academic year and the average of the best two will be taken. The schools have the autonomy to make its own schedule. However, for the purpose of gradient learning, three tests may be held as one being the mid-term test and other the two being pre-mid and post mid-term with portion of syllabus cumulatively covered. The gradually increasing portion of contents would prepare students acquire confidence for appearing in the Board examination with 100% syllabus. The school will take the average of the best two tests for final marks submission.

(ii) Notebook Submission (5 marks)

Notebook submission as a part of internal assessment is aimed at enhancing seriousness of students towards preparing notes for the topics being taught in the classroom as well as assignments. This also addresses the critical aspect of regularity, punctuality, neatness and notebook upkeep.

(iii) Subject Enrichment Activities (5 marks)

These are subject specific application activities aimed at enrichment of the understanding and skill development. These activities are to be recorded internally by respective subject teachers.

For Languages: Activities conducted for subject enrichment in languages should aim at equipping the learner to develop effective speaking and listening skills.

For Mathematics: The listed laboratory activities and projects as given in the prescribed publication of CBSE/NCERT may be followed.

For Science: The listed practical works/activities may be carried out as prescribed by the CBSE in the curriculum.

For Social Science: Map and project work may be undertaken as prescribed by the CBSE in the curriculum.

2. CO-SCHOLASTIC ACTIVITIES

Schools should promote co-curricular activities for the holistic development of the student. These activities will be graded on a 5-point grading scale (A to E) and will have no descriptive indicators. No upscaling of grades will be done.

Activity	To be graded on a 5-point scale (A–E) in school	Areas and Objectives (as prescribed in the Scheme of Studies for Subjects of Internal Assessment)
Work Education or Pre-Vocational Education	By the concerned Teacher	Work education is a distinct curricular area for students for participation in social, economic and welfare activities. Student gets a sense of community service and develops self-reliance. (for Pre-Vocational Education as per Scheme of Studies)
Art Education	By the VA/PA or the concerned teacher	Art Education constitutes an important area of curricular activity for development of wholesome personality of the students. Students will select one or more forms of creative arts.
Health & Physical Education (Sports/ Martial Arts/Yoga/ NCC, etc.)	By the PE Teacher	Health & Physical Activity preferably sports must be given a regular period. Students should be provided opportunities to get professionally trained in the area of their interest. Indigenous sports, yoga and NCC must be encouraged in the schools creating a sense of physical fitness, discipline, sportsmanship, patriotism, self-sacrifice and health care.

3. DISCIPLINE (Attendance, Sincerity, Behaviour, Values)

Discipline significantly impacts career shaping and it helps build character. Sincerity, good behaviour and values develop strength and foster unity and cooperation. Therefore, the element of discipline has been introduced. Class teacher will be responsible for grading the students on a Five-point scale (A to E).

The internal assessment comprising 20 marks (10 + 5 + 5) entails objectivity and a structured approach. For a holistic assessment, the teachers are expected to make it an effective tool.

B. DOCUMENTATION

Records pertaining to the internal assessment of the students done by the schools will be maintained for a period of three months from the date of declaration of result for verification at the discretion of the Board. Subjudiced cases, if any or those involving RTI/Grievances may however be reatined beyond three months.

C. ASSESSMENT SCHEME FOR CLASS VI TO IX IN THE CBSE AFFILIATED SCHOOLS

The CBSE affiliated schools, for the purpose of uniformity in classes VI to IX may, replicate the same assessment model as described above for Class X.

The above scheme must be implemented in letter and spirit.

Contents

"Nothing in life is to be feared. It is only to be understood."

— MARIE CURIE

CHAPTER 1

Motion

Learning Objectives

- Motion: displacement, velocity
- Uniform and non-uniform motion along a straight line
- Acceleration, distance–time and velocity–time graphs for uniform and uniformly accelerated motion
- Equations of motion by graphical method
- Elementary idea of uniform circular motion

We observe that bodies are either in motion or at rest in our surroundings. Examples of bodies at rest are benches, stones, walls, etc. whereas people and vehicles moving on roads, trains, aeroplanes, etc. are examples of objects in motion. Sometimes we are unable to observe motion directly. In such cases, we feel the presence of motion by indirect means or evidences. For example, we feel the motion of air by observing the movement of dust and the movement of leaves and branches of trees.

CONCEPT OF REST AND MOTION

When we are sitting inside a moving car or bus, we constantly keep on changing our position with respect to the trees, poles, shops and other surrounding objects. In physics, to describe the location of an object, we specify its position with respect to a fixed point taken as the reference point called the origin. For example, if we say our school is 2 km north of a particular building (X), we are describing the position of our school with respect to a fixed point, i.e. the building X. The place from which a location is observed and measured is called the **reference point** or the **origin.**

In physics, **a body is said to be at rest if it does not change its position with respect to a fixed point, taken as a reference point in its surroundings, with the passage of time.** A book lying on a table, if not moved by anybody, does not change its position with respect to the table (taken as a reference point) with the passage of time. So, the book is said to be in a state of rest with respect to the table.

Now, a man walking on a road, a girl playing in a playground, a bus moving on a road, are all in motion. One thing is common in every moving object, i.e. it keeps on changing its position continuously with respect to a reference point. In physics, **a body is said to be in motion if it changes its position continuously with respect to a fixed point, taken as a reference point in its surroundings, with the passage of time.** A man walking on a road is said to be in motion because as time passes, the man changes his position with respect to the trees or buildings (taken as reference point) in the surroundings.

Rest and motion are relative terms

Suppose we are sitting in a moving train. Then, we are in motion with respect to a farmer working in a field outside or with respect to the trees outside or the railway platform itself because our positions are changing with respect to all of them with the passage of time. However, if we compare our positions with respect to the objects inside the train, i.e. other passengers, the seats and ceiling of the compartment, the fan, etc., our positions are not changing. Therefore, in relation to these objects, we are at rest. Thus, we see that **an object can be in motion in relation to one object while it can be at rest in relation to another object at the same instant of time**. We can therefore say that **rest and motion are relative terms.** There is nothing called absolute rest or absolute motion.

Types of motion

Objects move in various ways. A car moving on a straight road is said to have **rectilinear motion.** A javelin or shot-put thrown by an athlete moves along a curved path and is said to have **curvilinear motion.** The blades of a fan rotate around a fixed point and therefore have **rotatory motion.** The pendulum of a clock moves to and fro about its mean position and is said to have **oscillatory motion.** The motion of a sitar string when plucked exhibits **vibratory motion.** Sometimes an object possesses two or more types of motions at the same time. Such motion is called **multiple motion.** For example, when a car moves on a straight road its wheels exhibit two types of motion, i.e. rotatory motion as well as rectilinear motion. **The branch of physics which deals with the study of motion of objects and their response to force is called mechanics.**

SCALAR AND VECTOR QUANTITIES

Physics is an experimental science. We deal with a large number of physical quantities in physics. All physical quantities can be classified into two groups:

1. Scalar quantities
2. Vector quantities

Scalar quantity

A physical quantity which is described completely by its magnitude (or size) is called a scalar quantity. A scalar quantity has magnitude only and no direction. Let the mass of a body be 40 kg. We see here that mass is represented by the number 40 along with unit kilogram. This number represents the magnitude, or the size of the quantity. So, mass is completely described by magnitude only and is therefore a scalar quantity. Length, time, volume, density, distance, area, speed, temperature, energy and power are all scalar quantities.

Vector quantity

Some physical quantities cannot be described completely by their magnitude. **A physical quantity which is described completely by its magnitude (or size) as well as its direction is called a vector quantity.** A vector quantity has both magnitude and direction. If a car is moving with a speed of 40 km/h in a particular direction, say north, we say that the velocity of the car is 40 km/h due north. So, velocity has both magnitude and direction and is therefore a vector quantity. Displacement, acceleration, force, torque, weight and momentum are all vector quantities.

CONCEPT OF DISTANCE AND DISPLACEMENT

Generally, distance and displacement are used in the same sense. But these quantities are quite different in physics. Let us go through the following example to understand it further.

Suppose a person lives at place A and moves 4 km towards B (to reach his office) located in the east (along AB) and then after reaching B, he starts moving along BC a distance equal to 3 km due north to reach the market (Fig. 1.1). The actual length of the path travelled by the person to reach C, starting from A is AB + BC = 4 km + 3 km = 7 km, irrespective of the direction in which he travels. So, 7 km is the distance travelled by him.

The actual length of the path travelled by a moving body in a given interval of time is called the distance travelled by that body. It is a scalar quantity and its value can never be zero or negative during the motion of the body. In the SI system, the unit of distance is metre (m). It is denoted by *S* or *s*.

In the above example, to know the shortest distance from A to C, join AC. The length of straight line AC, which is 5 km, is the displacement from A to C. The displacement represents the shortest straight line path between the initial and final positions.

The displacement of the person is AC which can be calculated by Pythagoras' theorem, i.e.

$$\begin{aligned} AC &= \sqrt{AB^2 + BC^2} \\ &= \sqrt{4^2 + 3^2} \\ &= \sqrt{16+9} \\ &= \sqrt{25} \\ &= 5 \text{ km} \end{aligned}$$

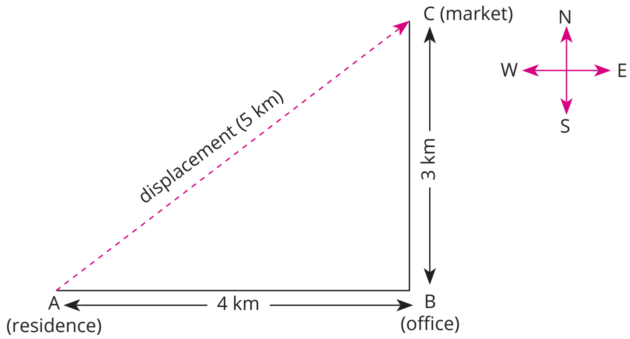
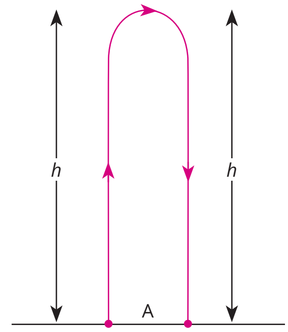


Fig. 1.1 Representation of displacement



Distance travelled is $2h$ but displacement is zero.

When a body moves from one position to another, the shortest distance (straight distance) measured between the initial and the final positions of the body in a particular direction is called its displacement. It is a vector quantity. Displacement can be positive, negative or zero. When a body (say a ball) is thrown vertically upwards it comes back to the same point after some time. During the upward journey, the displacement is negative. On reaching the same point, the displacement becomes zero.

The differences between distance and displacement are given in Table 1.1.

EXAMPLE 1 An object has moved through a distance. Can it have zero displacement?

SOLUTION Yes, the displacement can be zero even if the distance is not zero. For example, when a body is thrown vertically upwards from level A on the ground and after some time it returns to the same level A, then the displacement of the body is zero but the distance travelled by the body is not zero. It is $2h$, if h is the maximum height attained by the body.

EXAMPLE 2 A body is moving along a circular path of radius r. What is the distance and the displacement of the body when it completes half a revolution?

SOLUTION If the body travels from the starting point A along a circular path of radius r and reaches halfway at point B, then

$$\text{Distance travelled} = 1/2 \times 2\pi r = \pi r$$

$$[\because \text{ Circumference of a circle is } 2\pi r.]$$

$$\text{Displacement, AB} = 2r$$

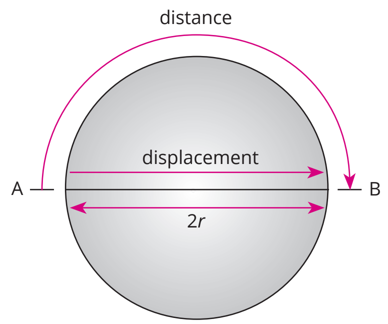


TABLE 1.1 Differences between distance and displacement

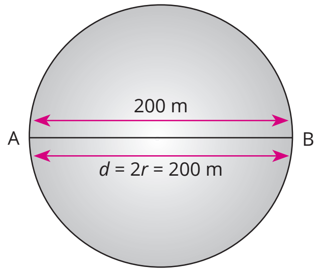
Parameter	Distance	Displacement
1. Concept (Definition)	The actual length of path travelled (or covered) by a moving body irrespective of the direction is called the distance travelled by that body.	The shortest distance (straight distance) measured between the initial and final positions of a moving body in a particular direction is called its displacement.
2. Physical quantity	It is a scalar quantity.	It is a vector quantity.
3. Value	It is always positive (It can never be zero or negative.).	It may be positive, negative or zero.
4. Dependence on path	It depends on the path followed by the moving object.	It does not depend on the path followed by the moving object.
5. Magnitude	Its magnitude is always greater than or equal to the displacement. (In Fig. 1.1, distance travelled by the person is 7 km whereas displacement is 5 km, i.e. distance travelled > displacement)	Its magnitude is always less than or equal to the distance travelled. (In Fig. 1.1, displacement is 5 km whereas the distance travelled is 7 km, i.e. displacement < distance travelled)

EXAMPLE 3 An athlete completes one round of a circular track of diameter 200 m in 40 s. What will be the distance covered and also the displacement at the end of 2 min 20 s? **(Textbook Question)**

SOLUTION Diameter of the circular track $(d) = 200$ m

$\therefore$ Radius of the circular track $(r) = d/2$

$= 200/2 = 100$ m



Time taken to complete one round = 40 s

Total time taken = 2 min 20 s = 140 s

Length of the circular track = $2\pi r$

$$= 2 \times \frac{22}{7} \times 100 \text{ m} = \frac{4400}{7} \text{ m}$$

$$\text{Distance travelled in 40 s} = \frac{4400}{7} \text{ m}$$

$$\therefore \quad \text{Distance travelled in 140 s} = \frac{4400}{7} \times \frac{140}{40} \text{ m}$$

$$= 2200 \text{ m}$$

To find the displacement of the athlete, we have to find his position on the track at the end of 2 min and 20 s. Let us find the number of rounds completed in a distance of 2200 m (calculated above),

$$\text{Number of rounds in 2200 m} = 2200 \times \frac{7}{4400} = 3.5$$

Since in one complete revolution the displacement is zero (as the athlete reaches the same position), the displacement in 3.5 rounds will be equal to the diameter of the track as the athlete will be opposite to the starting point, i.e.

Displacement = Diameter of the track = 200 m

Thus, the distance travelled at the end of 2 min 20 s is 2200 m and displacement will be 200 m.

Motion along a straight line (Linear motion)

We can describe the motion of a body in two ways:

1. with mathematical equations, and
2. with graphs.

Since motion along a straight line (i.e. one-dimensional motion) is the simplest, we shall learn to describe this by an example.

Consider a person moving along a straight road (path) in his car (Fig. 1.2). He starts his journey leaving his home from O, which is treated as its reference point. He crosses city A which is at a distance of 80 km from his home, reaches another city B at a distance of 90 km from A and finally reaches his destination C at a distance of 100 km from B.

a. Calculation of distance travelled and displacement (from O to C): The distance travelled by the person leaving his home from O (treated as the reference point) and reaching his destination C can be known with the help of a device fitted in all automobiles called the odometer, which shows the distance travelled. However, mathematically,

Distance travelled = OA + AB + BC
= 80 km + 90 km + 100 km
= 270 km

Displacement = OA + AB + BC
= 80 km + 90 km + 100 km
= 270 km

Here, the magnitude of distance travelled is equal to displacement.

He now returns along the same path from C and reaches city A through B.

b. Calculation of distance travelled and displacement (from O to A through C):

Distance travelled = OA + AB + BC + CB + BA
= 80 km + 90 km + 100 km
+ 100 km + 90 km
= 460 km

Displacement from (O to A through C) = 80 km

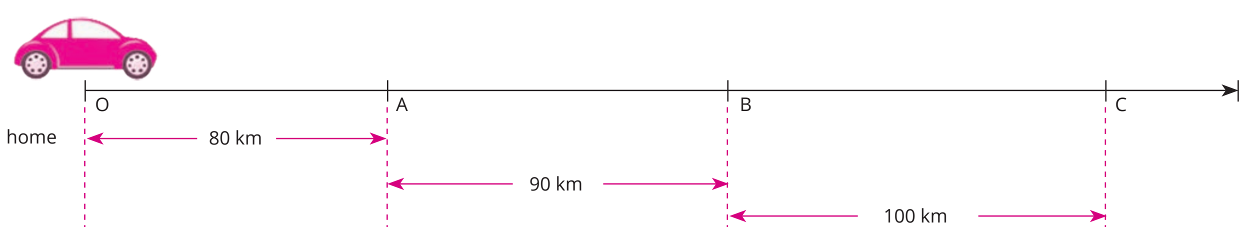


Fig. 1.2 Position of the car on a straight line path

Here, the magnitude of distance is greater than displacement.

c. Calculation of distance travelled and displacement (at O through C):

Distance travelled = OA + AB + BC + CB + BA + AO

= 80 km + 90 km + 100 km + 100 km + 90 km + 80 km

= 540 km

Displacement = zero

($\because$ He returns to the original position)

Here, the displacement is zero.

Check Your Progress

A. Class Response

ORAL QUESTIONING/QUIZ

1. Find the odd-one out. Give reasons for your choice.
   - **a.** Speed, Energy, Force, Mass, Temperature
   - **b.** Weight, Acceleration, Velocity, Distance, Momentum
   - **c.** Rolling stone, Moving ball, Big table, A dancing girl, Vibrating string
2. A book is lying on a table. Examine and define its state.
3. Give two examples where we feel the presence of motion through indirect evidences.
4. Give an example to show that rest and motion are relative terms.
5. Classify the following into scalar and vector quantities:
   - **a.** Velocity **b.** Length
   - **c.** Time **d.** Displacement
   - **e.** Acceleration **f.** Distance
   - **g.** Force **h.** Energy
   - **i.** Momentum **j.** Power
   - **k.** Weight **l.** Mass
6. A bird is flying in the sky. Examine and define its state.
7. Give one example of each of the following types of motion:
   - **a.** Rectilinear motion **b.** Curvilinear motion
   - **c.** Oscillatory motion **d.** Vibratory motion
   - **e.** Multiple motion

WORKSHEET

Tick (✓) the most appropriate answer (Q.1 to Q.5)

1. A ball dropped from a certain height is in a state of
   - **a.** rest. **b.** motion.
   - **c.** both rest and motion. **d.** none of these
2. The SI unit of distance is
   - **a.** centimetre. **b.** metre.
   - **c.** kilometre. **d.** millimetre.
3. A boy starts from his house and travels 5 km to reach the market. After purchasing the books he returns to his house. The displacement of the boy is
   - **a.** 10 km **b.** 5 km **c.** 15 km **d.** zero
4. Distance travelled is always
   - **a.** positive. **b.** negative.
   - **c.** zero. **d.** none of these
5. Which one of the following is a scalar quantity?
   - **a.** Force **b.** Length
   - **c.** Displacement **d.** Velocity
6. Distinguish between rest and motion.
7. A man walking on a road is said to be in the state of motion. Give reasons.
8. Mass is a scalar quantity. Give reasons.
9. What is the displacement of the earth when it completes one revolution around the sun?
10. An athlete completes two rounds of a circular track and returns to the starting point. What is the distance covered by the athlete and his displacement?

[**Ans.** distance covered = $4\pi r$, displacement = zero]

B. Home Assignment

1. Distinguish between the following:
   - **a.** Scalar quantity and vector quantity
   - **b.** Distance travelled and displacement
2. What is the displacement of a fixed point on the

earth when the earth completes one rotation about its axis?

3. On a 100 m straight track, an athlete completes the race from the starting line to the finishing line in a particular time. Calculate
   a. distance travelled and
   b. magnitude of displacement.

[**Ans. a.** distance = 100 m, **b.** displacement = 100 m]

4. A rectangular track is 40 m long and 30 m broad. A man starts walking from one corner of the track and reaches the opposite corner. Find the distance travelled and the magnitude of displacement.

[**Ans.** distance travelled = 70 m, displacement = 50 m]

5. A person walks along the side of a square field whose each side is 100 m long. What is the magnitude of displacement if the person moves from one corner of the square to the diagonally opposite corner.

[**Ans.** $100\sqrt{2}$ m]

6. An object moves 60 m due east and then 80 m due north. Find the distance travelled and the magnitude of displacement. [**Ans.** distance travelled = 140 m, displacement = 100 m due north-east]

7. In game of cricket, the length of pitch is 18 m. After completing one run, a batsman turns back but gets run out when he is halfway through his second run. Calculate the distance travelled and also his displacement.

[**Ans.** distance travelled = 27 m, displacement = 9 m]

UNIFORM AND NON-UNIFORM MOTION

We know that a body is said to be in motion if it changes its position with respect to a fixed point taken as a reference point in its surroundings, with the passage of time. If we wish to describe such a motion, we must know how fast or slow is the change of position. For example, an expert controller sitting in a control room monitors how fast various trains are moving and where exactly each one of them is located at a given instant of time so that he can give correct signals and prevent train accidents. To describe motion we need to classify it as uniform motion or non-uniform motion.

Uniform motion

A body is said to be in uniform motion if it covers equal distances in equal intervals of time, no matter how small these time intervals may be. For example, if a car in uniform motion covers 100 m in 50 s, this means it covers equal distances of 100 m in every 50 s (Fig. 1.3). Further it means it should move 20 m in every 10 s or 10 m is every 5 s or 1 m in every 0.5 s and so on.

Examples of uniform motion

1. The movement of hands of watches
2. The movement of the earth about its axis
3. The movement of the earth around the sun
4. A gas molecule is in uniform motion between collisions.

The distance–time graph for a body having uniform motion is a straight line (Fig. 1.4).

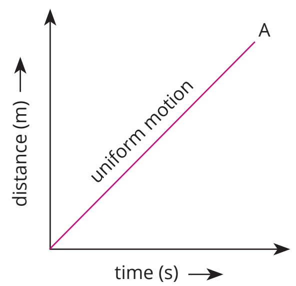


Fig. 1.4 The distance–time graph for a body having uniform motion is a straight line.

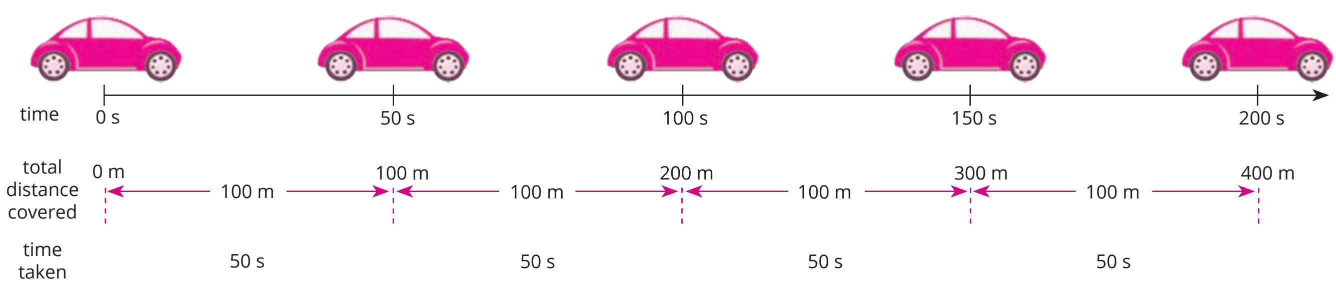


Fig. 1.3 A body having uniform motion

time	0 s	50 s	100 s	150 s
total distance covered	0 m	100 m	250 m	270 m
time interval	0 s	50 s	50 s	50 s
distance covered in each interval	0 m	100 m	150 m	20 m

Fig. 1.5 A body having non-uniform motion

Non-uniform motion

A body is said to be in non-uniform motion if it covers unequal distances in equal intervals of time, however small these time intervals may be. Most of the motions which we observe around us are non-uniform motions. For example, a car which covers 100 m in 50 s may cover 150 m in next 50 s if the road is clear or may cover only 20 m in next 50 s if the road is congested and so on (Fig. 1.5).

Examples of non-uniform motion

1. A train leaving a railway station covers larger distances in equal intervals of time, conversely when it approaches a station, it covers smaller distances in equal intervals of time.
2. A free-falling stone under the action of gravity.
3. When brakes are applied to a speeding car.
4. When an oscillating simple pendulum is left for some time, the amplitude of its oscillation becomes smaller and smaller and finally the oscillation stops (Fig. 1.6).

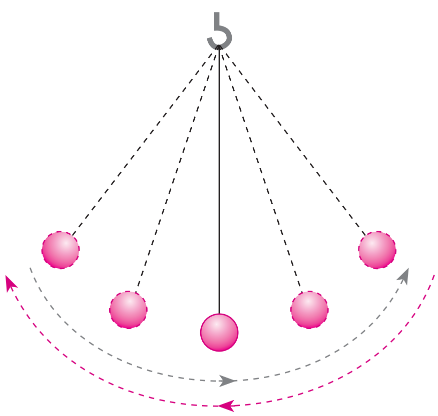


Fig. 1.6 Oscillation of a simple pendulum

The distance–time graph of a body having non-uniform motion is a curved lined (Fig. 1.7).

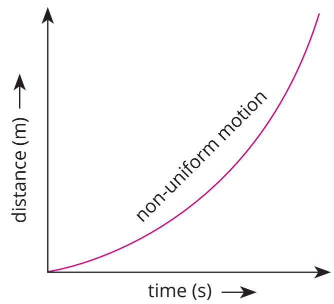


Fig. 1.7 The distance–time graph of a body having non-uniform motion is a curved line.

SPEED AND VELOCITY

These terms give us an idea of how slow or how fast a body is moving. Quite a few times, we need to know which one of the two or more objects is moving faster. For example, one can easily tell which amongst all the vehicles that are moving in the same direction on a road at any given instant of time, is moving faster. But if their direction of motion is opposite to each other, we may not be able to make out which of the two vehicles is moving faster. Therefore, to compare motions of two or more objects moving in any direction one must have an understanding of the concepts of speed and velocity.

Speed

In daily life, if we observe a car running fast, we say that its speed is fast and if we see a bicycle moving slowly, we say that its speed is slow. Thus, we describe the motion of body as fast or slow, in terms of speed. **The speed of a body is the distance travelled by it per unit time.** The speed of a body can be calculated by dividing the distance travelled by the body by the time taken by it to cover that distance. So,

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

If we represent distance by the symbol *s*, time by *t* and speed by *v*, then we can write

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

To specify the speed of a moving object, we require only its magnitude (direction is not required), so, **speed is a scalar quantity.**

Units of speed

The unit of speed depends on the units of distance and time. We know, the SI unit of distance is metre and that of time is second. Thus, the **SI unit of speed is metre per second** written as m s^{-1} or m/s.

The speed of fast moving bodies like cars, trains and planes is expressed in **kilometre per hour** written as km h^{-1} or km/h.

The speed of slow moving objects like snails and insects is expressed in **centimetre per second** written as cm s^{-1} or cm/s.

While comparing the speeds of different bodies, we must convert all speeds into same units. For example, if the speeds of two bodies are expressed in km/h and m/s respectively, then we should either convert km/h to m/s or vice versa.

Average speed

Most of the motions, which we observe around us are of non-uniform type. While travelling in a bus (or a car) we have noticed that the driver changes the speed of the moving bus from time to time depending upon the traffic conditions. The speed is fast when the road is clear but slow when the road is crowded. Therefore, we describe the rate of motion of such objects in terms of their average speed.

The average speed of a body is the total distance travelled by the body divided by the total time taken to cover this distance, i.e.

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

Let us consider another example. A car travels 60 km in first hour and 80 km in second hour. So, it travels a distance of 140 km in 2 hours. Its average speed is 140 km/2 h = 70 km/h. But the car may not have travelled at 70 km/h all the time. Sometimes it might have travelled faster and sometimes slower than

Did you Know?

Hand-held speed checker

A hand-held speed checker transmits radio waves which are bounced back from the moving car. If the car is moving towards the instrument, the wavelength of the returning radio waves is decreased. The faster the car is moving, the greater is the change in wavelength. The speed check instrument gives an instant digital read out. This is used by the traffic police to detect and stop cars crossing the permissible speeding limits.

70 km/h. So, average speed tells nothing about the different speeds that may have been attained by the body in course of the entire journey. A comparison of speeds is given in Table 1.2.

We have learnt that automobiles are fitted with a device called **odometer**, which measures the distance travelled by them. The odometer records the distance in kilometres. The automobiles are also fitted with a device called **speedometer**, which gives the speed of the moving automobile at that instant of time. The speedometer gives the speed in **kilometre per hour.**

TABLE 1.2 Speeds – A comparison

Object	Speed
Average speed of a tortoise	0.5 km/h
Average speed of a human being walking at a steady pace	6 km/h
Maximum speed of a bee	16 km/h
Wind speed during a light breeze	32 km/h
Maximum speed of a cheetah	96 km/h
Maximum speed of a falcon	152 km/h
Wind speed in a hurricane	320 km/h
Speed of light	1080000000 km/h

Velocity

When we say a car is moving with a speed of 60 km/h, it means that the car covers a distance of 60 km in an