SCIENCE

Textbook for class IX

As per the latest syllabus issued by CBSE

- Dr. JOSHI
- Dr. SAINI
- Dr. TAMBER
- GUPTA

9 CBSE

Best Seller
India's No. 1 Textbook

REVISED EDITION
2020-2021

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PHYSICS

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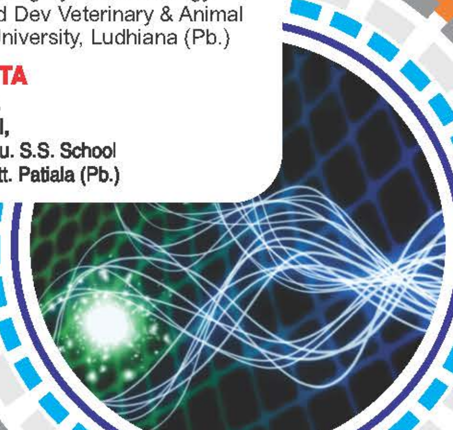

PHYSICS

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A FEW INTRODUCTORY WORDS

Science Textbook(Physics) has been written for the students of **Class IX** as per the latest syllabus and new instructions issued by CBSE. By making use of the long experience in the field of science education, every possible effort has been made, while writing the present book, to make it most useful to the students in their pursuit of knowledge. ***The following main features are making their appropriate contributions towards usefulness of this book :***

(i) The subject matter has been dealt with giving necessary and requisite details.

(ii) Scientific principles and facts have been written in an interesting and easy style using very simple language.

(iii) A number of neat and labelled diagrams have also been incorporated for the clarity of the subject matter wherever necessary.

(iv) The treatment of the subject matter is neither too brief to be difficult to find out the scientific facts nor it is so wide and spread out that the students may get lost while searching out the desired facts from it.

(v) The essential facts and principles as well as various topics and sub-topics have been given in bold prints so that the students may be able to locate and learn the required and needed information quite easily in the shortest possible time.

(vi) A large number of very short, short, long answer questions including numericals have been incorporated in the form of various exercises after covering the concerned topics or sub-topics so that the students by attempting these may prepare well with ease and self-confidence for the short term and long term examinations.

(vii) One of the unique feature of this book is that "Hints and Answers to Some Questions" have been given for all the questions appearing in the "Exercises" for encouraging and developing the process of self-study among the students.

(viii) A special care has been taken while writing the subject matter of this book that the acquired knowledge should provide a solid base for science subjects to be studied in the higher classes.

(ix) In this book, the subject matter has been given under unitwise heads in the form of concerned chapters as Quick Revision, Very Short Answer Questions (1 mark each), Short Answer Questions–I (2 marks each), Short Answer Questions–II (3 marks each), Long Answer Questions (5 marks each), Numerical Problems (if any), Higher Order Thinking Skills (HOTS) Questions, Value Based Questions along with required model answers to the questions.

(x) Special effort has been made to add a number of Multiple Choice Questions (MCQ) related to the Theory Topics dealt with and as well as the concerned practicals for the benefit of the students.

(xi) All questions appearing in the Science Textbook for IX class by NCERT have been dealt with in each chapter under sub-head, **"NCERT Textbook Questions"**. **NCERT Science Examplar Questions** (with answers) are also added for follow up by the learners.

I am highly thankful to all persons who have extended their willing help and co-operation in their own way in the preparation of this book. Every effort has been made while writing this book to cater to the needs of the students, therefore, this book will certainly be helpful and useful to the students.

In spite of my sincere efforts, there might have crept in some deficiencies in the preparation of this book. Constructive suggestions for removing the deficiencies and improving the book by the students, teachers and educationists will be gratefully appreciated. Any point concerning improvement of the book may please be shared with the author without any hesitation.

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SCIENCE (PHYSICS) IX

CONTENTS

CBSE SYLLABUS
Class–IX

Theme : Materials

Unit I : Matter-Nature and Behaviour **(50 Periods)**

Definition of matter; solid, liquid and gas; characteristics - shape, volume, density; change of state-melting (absorption of heat), freezing, evaporation (cooling by evaporation), condensation, sublimation.

Nature of matter : Elements, compounds and mixtures. Heterogeneous and homogenous mixtures, colloids and suspensions.

Particle nature, basic units : Atoms and molecules, Law of constant proportions, Atomic and molecular masses. Mole concept : Relationship of mole to mass of the particles and numbers.

Structure of atoms : Electrons, protons and neutrons, valency, chemical formula of common compounds. Isotopes and Isobars.

Theme : The World of the Living

Unit II : Organization in the Living World **(45 Periods)**

Call - Basic Unit of life : Cell as a basic unit of life; prokaryotic and eukaryotic cells, multicellular organisms; cell membrane and cell wall, cell organelles and cell inclusions; chloroplast, mitochondria, vacuoles, endoplasmic reticulum, Golgi apparatus; nucleus, chromosomes - basic structure, number.

Tissues, Organs, Organ System, Organism : Structure and functions of animal and plant tissues (only four types of tissues in animals; Meristematic and Permanent tissues in plants).

Biological Diversity : Diversity of plants and animals - basic issues in scientific naming, basis of classification. Hierarchy of categories / groups, Major groups of plants (salient features) (Bacteria, Thallophyta, Bryophyta, Pteridophyta, Gymnosperms and Angiosperms). Major groups of animals (salient features) (Non-chordates upto phyla and chordates upto classes).

Health and Diseases : Health and its failure. Infectious and Non-infectious diseases, their causes and manifestation. Diseases caused by microbes (Virus, Bacteria and Protozoans) and their prevention; Principles of treatment and prevention. Pulse Polio programmes.

Theme : Moving Things, People and Ideas

Unit III : Motion, Force and Work (60 Periods)

Motion : Distance and displacement, velocity; uniform and non-uniform motion along a staight line; acceleration, distance-time and velocity-time graphs for uniform motion and uniformly accelerated motion, derivation of equations of motion by graphical method; elementary idea of uniform circular motion.

Force and Newton's laws : Force and Motion, Newton's Laws of Motion, Action and reaction forces, Inertia of a body, Inertia and mass, Momentum, Force and Acceleration. Elementary idea of conservation of Momentum.

Gravitation : Gravitation; Universal Law of Gravitation, Force of Gravitation of the earth (gravity), Acceleration due to Gravity; Mass and Weight; Free fall.

Floatation : Thrust and Pressure. Archimedes' Principle; Buoyancy; Elementary Idea of Relative Density.

Work, energy and power : Work done by a Force, Energy, Power; Kinetic and Potential energy; Law of conservation of energy.

Sound : Nature of sound and its propagation in various media, speed of sound, range of hearing in humans; ultrasound; reflection of sound; echo and SONAR. Structure of the Human Ear (Auditory aspect only).

Theme : Natural Resources : Balance in Nature

Unit IV : Our Environment (15 Periods)

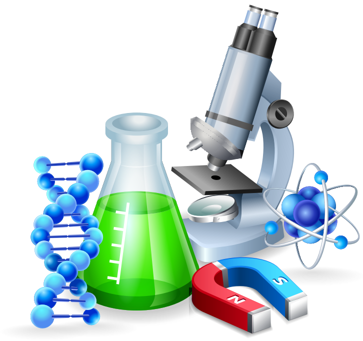
Physical resources : Air, Water, Soil. Air for respiration, for combustion, for moderating temperatures; movements of air and its role in bringing rains across India. Air, Water and Soil pollution (brief introduction). Holes in ozone layer and the probable damages.

Bio-geo chemical cycles in nature : Water, Oxygen, Carbon and Nitrogen.

Theme : Food

Unit V : Food Production (10 Periods)

Plant and animal breeding and selection for quality improvement and management; Use of fertilizers and manures; Protection from pests and diseases; Organic farming.



1 Motion

In our daily life, we notice many changes around us. The persons and animals move from one place to another, buses and cars run on roads, sun rises and sets daily, air blows, birds fly, water flows in rivers, blood flows through veins and arteries, atoms, molecules, planets, stars and galaxies all are in motion. During all these motions, the bodies change their positions. In case of some of them, the change is quite evident but in many cases, motion can only be inferred through indirect evidences. For example, the motion of air is felt by observing the movement of leaves and branches of trees.

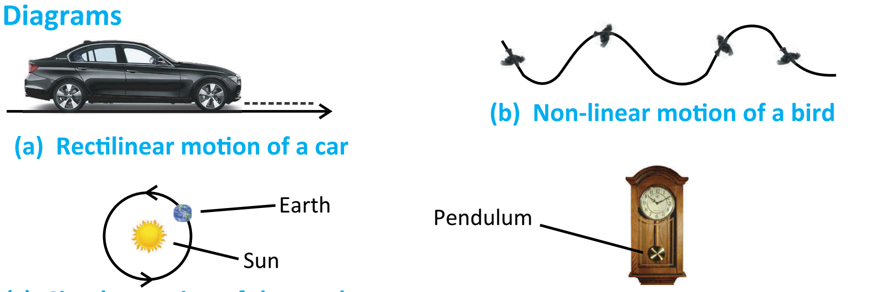
NATURE OF MOTION

1.1 (A) Types of Motion

Depending upon the shape of path traced by a body, motion can be divided into four types :

1. **Rectilinear Motion,** such as the motion of a car on a straight road [Fig. 1.1(a)]
2. **Non-linear (zigzag) Motion,** such as the motion of a flying bird [Fig. 1.1(b)].
3. **Circular Motion,** such as the motion of the earth around the sun [Fig. 1.1(c)]
4. **Vibratory (to and fro) Motion,** such as the motion of a pendulum [Fig. 1.1(d)]

Diagrams



(a) Rectilinear motion of a car

(b) Non-linear motion of a bird

(c) Circular motion of the earth

(d) Vibratory motion of pendulum of clock

Fig. 1.1: Different types of motion

Most of the motions are complex which involve a combination of many kinds of motions.

Chapter Overview

- Nature of Motion
- Describing Motion
- Uniform Motion and Non-Uniform Motion
- Measuring the Rate of Motion
- Speed
- Velocity
- Rate of Change of Velocity
- Acceleration
- Graphical Representation of Motion
- Distance-Time or Displacement-Time Graphs
- Equations of Motion and their Derivation by Graphical Method
- Uniform Circular Motion

Quick Revision

- Exercises with Hints and Answers to Some Questions
  - Very Short Answer Questions
  - Short Answer Questions–I
  - Short Answer Questions–II
  - Long Answer Questions
  - Numerical Problems
  - Higher Order Thinking Skills(HOTS) Questions
  - Value Based Questions (VBQ)
  - NCERT Science Exemplar Questions (With Answers)
    - ❑ Short Answer Questions (With Answers)
    - ❑❑ Long Answer Questions (With Answers)
  - MULTIPLE CHOICE QUESTIONS (MCQ) (Theory)

(B) Motion is Relative

An object may appear to be moving for one person and stationary for another, depending upon the position (condition) of the observer (person). *For example :*

1. A person sitting in a moving bus is in motion for the observers standing along the road whereas he is stationary for the co-passengers sitting in the same bus. For the passengers sitting in a bus, the roadside trees appear to be moving backward though they are stationary.
2. The phenomenon of sunrise and sunset are caused by the motion (rotation) of the earth around its own axis. Also the change of seasons is the result of motion (rotation) of the earth around its axis and the motion of the earth around the sun. But we do not directly perceive the motion of the earth because all the surrounding bodies such as mountains, trees, buildings and other persons are situated on the earth itself. However, the motion of the earth can be observed by a person while sitting in a satellite revolving in space.

(C) Rest and Motion

1. ***A body is said to be* at rest *if it does not change its position with respect to stationary objects around it, taken as reference. For example***, electric poles and trees are at rest.
2. ***A body is said to be* in motion *if it changes its position continuously with reference to stationary objects, taken as reference.*** For example, the cars and buses running on roads are in motion because they change their position with respect to the buildings, trees and poles.

(D) Activities

(i) Discuss whether the walls of your classroom **are at rest** or **in motion**.

Answer : Walls of our classroom are at rest for us while sitting in the classroom but they may appear to be in motion for persons moving fast outside the room. This happens because motion is relative.

(ii) Have you ever experienced that the stationary train in which you are sitting appears to move while it is at rest? Discuss and share your experience.

Answer : Yes, on a platform, the stationary train in which we are sitting appears to be moving for us, if another moving train passes nearby our train when we look at it. This is due to the relative nature of motion.

(E) Think and Act

Sometimes, we are endangered by the motion of objects around us, especially if that motion is erratic and uncontrolled such as observed in a flooded river, a hurricane or a tsunami. On the other hand, controlled motion can be a service to human beings such as for the generation of hydro-electric power.

Do you feel the necessity to study the erratic motion of some objects and learn to control them?

DESCRIBING MOTION

1.2 (A) Determination of Position of a Body

Whenever an object is in motion, it changes its position continuously. It means that the body covers some distance and may change the direction also. The measurement of covered distance and the change in direction is not possible without fixing a Reference Point (origin) and the Reference Axis. Let us understand this by an example. Suppose in a village, school is situated 2.5 km south of the bus stop. Thus, we have specified the position of the school with respect to the bus stop. In this example, bus stop is the Reference Point and the straight line perpendicular to the line joining the school and the bus stop is the Reference Axis. In the diagram (Fig.1.2), O is the Reference Point and OX is the Reference Axis.

Diagram

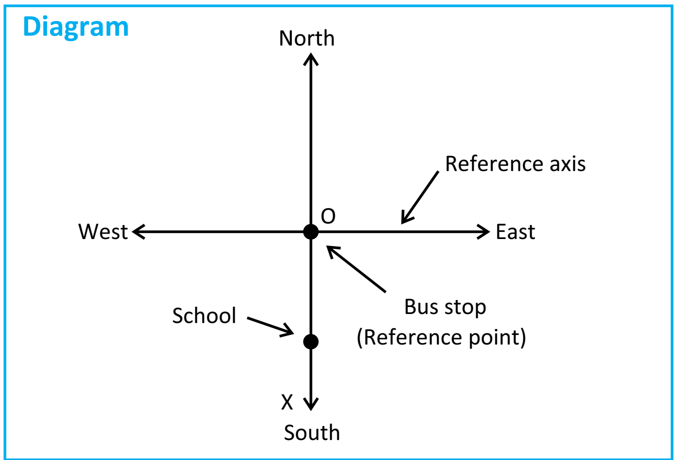


Fig. 1.2 : Reference Point and Reference Axis

Any Reference Point can be chosen according to the convenience. Therefore, to describe the position of an object, it is necessary to specify a Reference Point and a Reference Axis.

Thus, to describe the position of a body at any time during its motion, two things are essential:

(i) ***Its distance from the reference point.***

(ii) ***Direction or the angle which the line joining the position of the body and the reference point makes with the reference axis.***

(B) Scalar and Vector Quantities

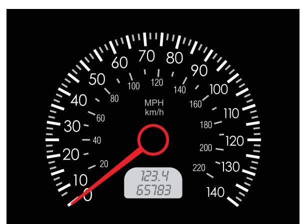
Physical quantities can be classified into two categories : *Scalar quantities* and *Vector quantities*.

(i) **Scalar quantities :** *Those quantities which can be described completely by their numerical value known as magnitude are called* **scalar quantities**. For example, *distance, time* and *length* are scalar quantities.

(ii) **Vector quantities :** *Those physical quantities which require the mention of magnitude and the direction both to describe them completely are known as* **vector quantities**.

For example, *displacement, velocity* and *force* are vector quantities. A vector quantity is denoted by an arrow head over the symbol. *A scalar quantity cannot be added to a vector quantity and vice versa.*

(C) Distance



Odometer

The total length of the path followed by a moving body from its initial position to the final position is called the **distance** *travelled by the body.* In short, it is written as 'S'. Distance is a scalar quantity and its S.I. Unit is **metre** written as m. A bigger unit of distance is kilometre (km) and smaller is centimetre (cm).

The **odometer** *of an automobile measures the total distance travelled by the automobile upto a particular place.*

Speedometer *shows the speed of an automobile at a particular time.*

(D) Displacement

The shortest (straight line) distance between the initial position and the final position of the moving body alongwith the direction with respect to the reference axis is called the **displacement of the body.**

Displacement is a vector quantity. It is written as $\vec{S}$. Its S.I. unit is also metre (m) but with a definite direction. For example it may be written as 'm east' (say).

(E) Illustrations of Distance and Displacement

(i) *The magnitude of displacement is equal to the distance travelled by an object only if the body moves along a straightline path without any change in its direction*. Suppose, an object starts its journey from point O which is referred as reference point. Let points A, B and C represent positions of the object at different times as shown in the diagram (Fig. 1.3).

Diagram

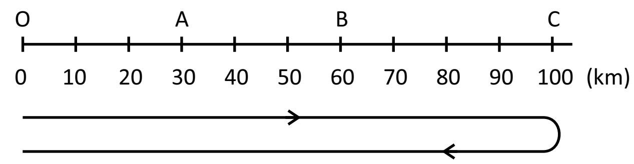


Fig. 1.3 : Positions of an object on a straight line path

Let the object moves from O to C through A and B but then returns back to its original point, O. The value of distance and the magnitude of displacement upto point C is equal, i.e. 100 km. In its backward journey, while at point B, the distance travelled is equal to OC + CB = 100 + 40 = 140 km, whereas the magnitude of displacement is equal to OB = 60 km.

(ii) *An object may cover certain distance but it can have zero displacement, if it returns back to the starting point*. For example :

(a) Suppose an object starts travelling from point O and returns back to this point after going through points A, B and C as shown in diagram (Fig. 1.3). Then at the end of journey ,

Distance travelled = OC + CO = 100 km + 100 km = 200 km

Displacement = Distance between the finishing point 'O' and the starting point 'O' = Zero

(b) When an object revolves in a circle, then the distance travelled by it in every complete revolution is equal to the circumference of the circular path whereas the displacement is equal to zero.

Thus, when a body moves, the distance covered by it can never be zero whereas the magnitude of displacement may be equal to zero.

(iii) *The Magnitude of displacement can never be more than the distance.*

(F) Activities

(i) Take a metre scale and a long rope.

Walk from one corner of a basketball court to its opposite corner along its sides.

Measure the distance covered by you and magnitude of displacement.

What difference would you notice between the two quantities in this case?

Diagram

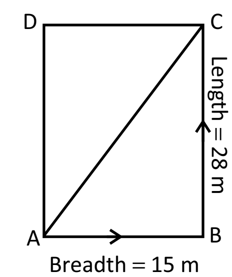


Fig. 1.4 : A basketball court

Answer: A basketball court has length 28 metres and breadth 15 metres as shown in the diagram (Fig. 1.4) Suppose, we walk from its corner A to opposite corner C along its sides and measure the actual distance.

This distance = AB + BC = 15 m + 28 m = 43 m

Magnitude of displacement from corner A to corner 'C' is equal to $AC = \sqrt{AB^2 + BC^2} = \sqrt{15^2 + 28^2} = 31.76$ m

The magnitude of displacement is less than the distance covered.

(ii) Automobiles are fitted with a device that shows the distance travelled. Such a device is known as an **odometer**. Suppose a car is driven from Chandigarh to New Delhi. Let the difference between the final reading and initial reading of the odometer is 245 km. Also find the magnitude of the displacement between Chandigarh and New Delhi by using the Road Map of India.

Answer: On the Road Map of India, length of the straightline journey between Chandigarh and New Delhi is equal to 2.1 cm.

The scale of map is 1 cm = 100 km

Magnitude of displacement between Chandigarh and New Delhi = $2.1 \times 100 = 210$ km

The distance between Chandigarh and New Delhi = 245 km

Thus, magnitude of displacement is less than the distance between Chandigarh and New Delhi.

(G) Difference between distance and displacement

Distance	Displacement
(i) *Distance is the total length of the path followed by the moving object from its point of start to the finishing point.*	*Displacement is the straight line distance between the initial and final position of the moving body.*
(ii) *Distance is a scalar quantity.*	*Displacement is a vector quantity.*
(iii) *When a body moves, the distance travelled by it cannot be equal to zero or negative. It is always a positive number.*	*Displacement can be positive, zero or negative.*
(iv) *Distance is never less than the magnitude of the displacement.*	*Magnitude of displacement can be zero, equal to or less than the distance travelled.*

(H) *In short, to describe the overall motion of an object and to locate its final position with reference to its initial position at a given time*, two different physical quantities, i.e., the distance and the displacement are used.

UNIFORM MOTION AND NON-UNIFORM MOTION

1.3 When a body moves, its position keeps on changing continuously. To describe its position at a certain time, we must know how fast the change in position is taking place. We should also be able to know its past position as well as to predict the future position at a certain time. So, we have to adopt the means to find out the location of the body at different instants of time. The means depend on the manner the body moves, i.e., whether its motion is uniform or non-uniform.

(A) Uniform Motion

A body is said to be in uniform motion, if it travels equal distances in equal intervals of time howsoever small these may be.

Suppose, an object is moving along a straight path. Let it travels 30 km in the first hour, 30 km more in the second hour, 30 km in the third hour and 30 km in the fourth hour. Thus, the object covers 30 km in each hour. As it covers equal distances in equal intervals of time, it is said to be moving with uniform motion.

When an object is in uniform motion the shape of its path is a straight line.

(B) Non-uniform Motion

A body is said to be in non-uniform motion if it covers unequal distances in equal intervals of time.

For example, when a car is moving on a crowded road or a person is jogging in a park, unequal distances are covered in equal intervals of time. The motion of the car and the person is non-uniform. The motion of an object falling freely from a certain height is also an example of non-uniform motion. Non-uniform motion is also called the **accelerated motion.**

(C) Activity

The data regarding the motion of two different objects A and B is given here in table 1.1. Examine it carefully and state whether the motion of the objects is uniform or non-uniform.

Table: 1.1

Time	Distance travelled by object A, in metres	Distance travelled by object B, in metres
9.30 a.m.	10	12
9.45 a.m.	20	19
10.00 a.m.	30	23
10.15 a.m.	40	35
10.30 a.m.	50	37
10.45 a.m.	60	41
11.00 a.m.	70	44

Solution –The distance travelled by object A and object B in equal time interval is as given in table 1.2

The object A travels 10 metres in every equal interval of 15 minutes. So, its motion is uniform.

The object B travels varying distance in equal intervals of 15 minutes. So motion of object B is non-uniform.

Table : 1.2

Time Interval	Distance travelled by object A in metres	Distance travelled by object B in metres
9.45 – 9.30 = 15 minute	10	7
10.00 – 9.45 = 15 "	10	4
10.15 – 10.00 = 15 "	10	8
10.30 – 10.15 = 15 "	10	12
10.45 – 10.30 = 15 "	10	4
11.00 – 10.45 = 15 "	10	3

MEASURING THE RATE OF MOTION

1.4 (A) Different objects may take different amount of time to travel a certain given distance. Some of them may move faster than others. But there may be some objects which move with the same rate. So measurement of rate of motion is very important. *For example :*

(i) As shown in the diagram (Fig. 1.5(a) the bowling speed of a player in cricket match is 143 km h^{-1} (say). It means that the ball travels 143 kilometres in one hour.

Diagrams

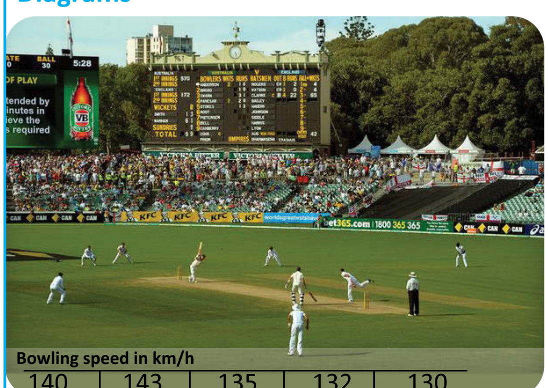


Fig. 1.5(a) : Scoreboard by a cricket match.

Fig. 1.5 (b) : Signboard on the road.

(ii) The signboard erected on the roadside reads as “speed limit 50 km/h for a car and 40 km/h for other light vehicles as shown in the diagram (Fig 1.5(b). It means that a car should not cover more than 50 km in one hour and other light vehicle should not travel more than 40 km in one hour.

SPEED

(B) (i) Definition and Units

Speed is defined as the distance travelled by an object in unit interval of time. It is written as ‘v’

$$\therefore \quad \text{Speed} = \frac{\text{Total distance travelled}}{\text{Total time taken}}$$

If an object covers distance S, in time t, then, its speed, $\boxed{v = \frac{S}{t}}$

Speed is a scalar quantity.

In S.I. units, distance is measured in metres (m) and time in seconds (s)

Note : ‘S’ is the symbol of distance whereas ‘s’ is the symbol of second.

$\therefore$ S.I. unit of speed is metre/second **or** m/s **or** ms^{-1}

In many situations, the unit of speed is also taken as kilometer per hour written as km/h **or** km h^{-1}

$$1\text{kmh}^{-1} = \frac{1\text{km}}{1\text{h}} = \frac{1 \times 1000\text{m}}{1 \times 60 \times 60\text{s}}$$

$$= \frac{5}{18}\ \text{ms}^{-1} = 0.28\ \text{ms}^{-1}$$

$$\boxed{\therefore\ 1\text{km h}^{-1} = \frac{5}{18}\text{ms}^{-1} = 0.28\ \text{ms}^{-1}}$$

$$\text{Also,}\ 1\ \text{ms}^{-1} = \frac{1\ \text{m}}{1s} = \frac{1 \times 10^{-3}\text{km}}{\frac{1}{3600}\text{h}} = 3.6\ \text{km h}^{-1}\ \textbf{or}\ \frac{36}{10} = \frac{18}{5}\text{km h}^{-1}$$

$$\therefore \boxed{1\ \text{ms}^{-1} = \frac{18}{5}\text{km h}^{-1} = 3.6\ \text{km h}^{-1}}$$

(ii) Illustration :

If the speed of a car is 18 ms^{-1}, then its speed in km h^{-1} will be equal to, $18 \times \frac{18}{5} = 64.8\text{kmh}^{-1}$

If the speed of this car is 18 km h^{-1}, then its speed in ms^{-1} will be equal to $18 \times \frac{5}{18} = 5\ \text{ms}^{-1}$

The speed of an object is also measured in centimetres per second (cm s^{-1})

$$1\text{cms}^{-1} = \frac{1\text{cm}}{1\text{s}} = \frac{1/100\text{m}}{1\text{s}} = \mathbf{10^{-2}\,ms^{-1}}$$

and

$$1\text{ms}^{-1} = \frac{1\text{m}}{1\text{s}} = \frac{100\text{cm}}{1\text{s}} = \mathbf{10^{2}\,cms^{-1}}$$

(C) Average Speed

The speed of an object may not be constant throughout its journey. It may increase or decrease. Therefore, the rate of motion of such object is described in terms of its average speed.

The total distance travelled by the body divided by the total time taken to cover this distance is called the average speed of the body.

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

It is denoted by symbol v_{av}

If an object covers distances S_1, S_2, S_3 and S_4 in time intervals of t_1, t_2, t_3 and t_4 respectively,

then total distance travelled, $S = S_1 + S_2 + S_3 + S_4$

Total time taken, $t = t_1 + t_2 + t_3 + t_4$

$$\therefore \quad \text{Average speed, } v_{av} = \frac{S_1 + S_2 + S_3 + S_4}{t_1 + t_2 + t_3 + t_4} = \frac{S}{t}$$

For example, let a car travel a distance of 120 km in 2 hours. Its average speed is equal to $\frac{120 \text{ km}}{2 \text{ h}} = 60 \text{ km h}^{-1}$

The car might not have travelled at this speed throughout its journey.

(D) Uniform Speed

The speed of an object is said to be uniform, if it covers equal distances in equal intervals of time however small these intervals may be.

For example, if a car moves 60 km in an hour, 30 km in half an hour (30 minutes), 15 km in 1/4 hr (15 minutes), 1 km in 1 minute and so on, then its speed is said to be uniform (60 km h^{-1} **or** 16.67 ms^{-1}).

(E) Non-Uniform Speed

If an object covers unequal distances in equal intervals of time, its speed is said to be non-uniform. In this case, the speed of the body changes continuously and the average speed is calculated as usual.

(F) Speed With Direction

The speed of a body gives us an idea that how much fast it is moving. But actual position (location) of the body at a certain time cannot be judged. Thus, rate of motion of an object can be more comprehensive if the direction of motion is also specified alongwith the magnitude of speed.

VELOCITY

(G) Definition and Units of Velocity

The quantity that specifies both magnitude and direction of speed is termed as velocity.

Velocity is the distance travelled by an object in a unit interval of time in a given direction.

If an object travels distance (displacement), S in time, t in a specific direction, then

$$\text{velocity, } \vec{v} = \frac{\vec{S}}{t} \quad \textbf{or} \quad \vec{S} = \vec{v} \times t = \vec{v}.t$$

The units of speed and velocity are the same. In S.I. system, unit of velocity is metre per second written as m/s **or** *ms^{-1}*. It is also expressed in kilometre per hour (km/h or km h^{-1}). Velocity is a vector quantity which is written as $\vec{\mathbf{v}}$

i.e., $\vec{v} = \frac{\vec{S}}{t}$ where $\vec{S}$ is the displacement.

or $\boxed{\mathbf{v} = \frac{\mathbf{S}}{\mathbf{t}}}$

***The velocity of a body at its* initial position *is called* initial velocity *which is generally written as* $\vec{u}$ *or* μ *and its velocity after a certain interval of time is called* final velocity.** It is generally written as $\vec{v}$ or v. If a body starts from rest, its initial velocity is zero and if it stops after travelling for some time, its final velocity is zero.

(H) Average Velocity

(a) When an object is moving along a straight line at a variable speed then the magnitude of its rate can be expressed in terms of average velocity. ***The ratio of the total distance travelled by an object in a certain direction (displacement) and the total time taken to cover this distance is the average velocity.*** It is written as $\vec{v}_{av}$ or v_{av}.

Let an object travels distances S_1, S_2 and S_3 in a certain direction (displacements) during the time intervals of t_1, t_2 and t_3 respectively.

Let $S_1 + S_2 + S_3 = S$ and $t_1 + t_2 + t_3 = t$

The magnitude of average velocity, $v_{av} = \dfrac{S_1 + S_2 + S_3}{t_1 + t_2 + t_3} = \dfrac{S}{t}$

Thus, distance travelled $=$ *Average velocity* $\times$ *time*

or $S = \vec{v}_{av} \cdot t$

In vector form, $\vec{v}_{av} = \dfrac{\vec{S}_1 + \vec{S}_2 + \vec{S}_3}{t_1 + t_2 + t_3} = \dfrac{\vec{S}}{t}$

or $\vec{S} = \vec{v}_{av} . t$

(b) ***In case the velocity of the object is changing at a uniform rate, then average velocity is calculated by taking the arithmetic mean of initial velocity and final velocity for a given duration of time,***

i.e., Average velocity $= \dfrac{\text{Initial velocity} + \text{Final velocity}}{2}$

or $\boxed{v_{av} = \dfrac{u+v}{2}}$

The magnitude of average velocity of an object is equal to its average speed if the direction of motion remains the same. $\therefore$ $v_{av} = \dfrac{u+v}{2}$

(I) Uniform or Constant Velocity

If a body travels equal distances in equal intervals of time in the same direction, its velocity is said to be uniform.

(J) Non-uniform or Variable Velocity

The velocity of a body cannot be uniform if :

(i) *its speed remains constant but direction changes.* For example, velocity of a body moving in a circle with uniform speed is not uniform.

(ii) *its speed changes but direction remains the same* as in the case of a car moving on a straight road with variable speed.

(iii) *its speed as well as direction changes.* For example, the velocity of a swinging body is not uniform.

A body is said to be moving with non-uniform velocity, if it travels unequal distances in equal intervals of time in the same direction or it travels equal distances in unequal intervals of time in the same direction or it travels equal distances in equal intervals of time but in varying directions.

Thus, even if the speed of the body remains uniform, its velocity will be non-uniform if the direction of motion of the body varies.

(K) Difference Between Speed and Velocity

Speed	Velocity
(i) *Speed is the rate at which the distance is covered with time.*	*Velocity is the rate of change of displacement with time.*
(ii) *Speed is a scalar quantity.*	*Velocity is a vector quantity.*
(iii) *Speed is equal to the magnitude of velocity when the motion is in a straight line.*	*Magnitude of velocity can be equal to or less than that of the speed.*

(L) Activities

(i) Measure the time it takes you to walk from your house to your bus stop or the school. If you consider that your average walking speed is 4 km h^{-1}, estimate the distance of the bus stop or school from your house.

Solution : Suppose the time it takes you to walk from your house to your bus stop or the school is half an hour.

Then the distance of the bus stop or school from your house = average speed × time **i.e.,** $S = 4 \text{ km h}^{-1} \times \frac{1}{2} \text{ h} = 2 \text{ km}$

(ii) At a time when it is cloudy, there may be frequent thunder and lightning. The sound of thunder takes some time to reach you after you see the lightning.

(a) Can you answer why this happens?

(b) Measure this time interval using a digital wrist watch or a stop watch.

(c) Calculate the distance of the nearest point of lightning (speed of sound in air = 346 ms^{-1} at 25°C).

Solution: (a) Sound of thunder takes some time to reach you after you see lightning because speed of sound is very small (346 ms^{-1}) as compared to that of light (3×10^8 ms^{-1})

(b) Suppose the time interval noted between the sound of thunder and sight of lightning is 5.50 s.

(c) The distance of the nearest point of lightning = speed of sound × time interval = 346 $ms^{-1} \times 5.50$ s = 1903 m = 1 km and 903 m (The speed of light is so high that time taken by it to travel ordinary distance is negligible).

RATE OF CHANGE OF VELOCITY

1.5 When an object is in uniform motion along a straight line, its velocity remains constant with time. Thus, the change in its velocity is zero. But if the object is in non-uniform motion, its velocity varies with time. It has different values at different instants and at different points of its path. A physical quantity which is a measure of the change in velocity per unit time is termed as *acceleration*.

ACCELERATION

(A) Definition and Units of Acceleration

Acceleration is defined as the rate of change of velocity with time. It is denoted by the symbol, a

i.e., Acceleration $= \dfrac{\text{Change in velocity}}{\text{Time taken}}$

If initial velocity of the body is u and its final velocity after time, t is v,

then, acceleration, $a = \dfrac{\text{Final velocity} - \text{Initial velocity}}{\text{time taken}}$ i.e., $\boxed{a = \dfrac{v-u}{t}}$

In S.I. System, unit of acceleration is metre per second per second or metre per second square written as m/s^2 or ms^{-2}. ***It may be noted that time occurs twice in the unit of acceleration.***

If the velocity is in km h^{-1} and time is in hour then unit of acceleration is km/h^2 or km h^{-2}.

If the velocity increases, then, v is greater than u($v > u$). In this case 'a' is positive. It means that acceleration takes place in the direction of velocity. For example, when an object falls down its acceleration is + 9.8 ms^{-2}

Acceleration is a vector quantity. Therefore, it is written as $\vec{a}$.

In vector form, acceleration, $\vec{a} = \dfrac{\vec{v} - \vec{u}}{t}$

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

(B) Negative Acceleration or Deceleration or Retardation

If the velocity of an object decreases, then final velocity is less than the initial velocity, i.e., $v < u$ and $(v - u)$ is in minus.

Then, acceleration becomes negative $\left(a = \dfrac{v - u}{t}\right)$

The negative acceleration is called **deceleration** or **retardation.** Deceleration is opposite to the direction of velocity.

For example, when an object is thrown up, its velocity decreases continuously and thus it experiences acceleration whose value is -9.8 ms^{-2}. In other words, its retardation is 9.8 ms^{-2}.

(C) Zero Acceleration

When an object moves with uniform velocity then its acceleration is zero.

If velocity is uniform then, $v = u$

$$\therefore \quad a = \frac{v - u}{t} = \frac{0}{t} = 0\ ms^{-2}$$

It must be clear that when acceleration is zero, it does not mean that the body is necessarily at rest. The object may or may not be at rest.

If the body is at rest, then $v = u = 0$

$$\therefore \quad a = \frac{0 - 0}{t} = 0\ ms^{-2}$$

(D) Uniform Acceleration

Acceleration of an object moving in a straight line is said to be **uniform** ***if its velocity increases or decreases (changes) by equal amounts in equal intervals of time.***

In this case average velocity $\vec{v}$ is the mean of initial velocity, $\vec{u}$ and final velocity, $\vec{v}$,

$$\text{i.e., } \vec{v} = \frac{\vec{u} + \vec{v}}{2}$$

We also know that, average velocity, $\vec{v} = \dfrac{\text{Displacement}}{\text{Time}} = \dfrac{\vec{S}}{t}$

$$\therefore \quad \boxed{\frac{\vec{S}}{t} = \frac{\vec{u} + \vec{v}}{2}} \quad \textbf{or} \quad \boxed{\vec{S} = \frac{\vec{u} + \vec{v}}{2} \times t} \quad \textbf{or} \quad \boxed{S = \frac{u + v}{2} \times t}$$

The motion of a freely falling body is an example of uniformly accelerated motion.

(E) Non-uniform Acceleration

If the velocity of the moving object changes at a non-uniform rate, then its acceleration is said to be non-uniform.

For example, if a car moving on the straight road changes its speed by unequal amount in equal intervals of time, then the car is said to be going with non-uniform acceleration.

(F) Illustration of Acceleration

Suppose a car driver starts his journey. He increases the speed of the car for half an hour and then travels with this speed for an hour. After that he stops his car.

In this example, the acceleration of car for first half an hour is positive, it is zero for next one hour and then becomes negative (retardation) till it stops.

An object revolving in a circular path with uniform speed has an acceleration because it changes its direction constantly although speed remains uniform.

(G) Activity

In your everyday life you come across a range of motions in which :

(a) acceleration is in the direction of motion.
(b) acceleration is against the direction of motion.
(c) acceleration is uniform.
(d) acceleration is non-uniform.

Can you identify one example each of the above type of motion. [NCERT Textbook Activity. 8.8.–P103]

Solution

(a) The acceleration of the falling object dropped from a certain height above the surface of the earth is in the direction of its motion. Its value is $+9.8\ ms^{-2}$.
(b) The acceleration of the object thrown up from the surface of the earth is against the direction of motion. Its value is $-9.8\ ms^{-2}$.
(c) The acceleration of the falling or thrown up object is uniform i.e. $+9.8\ ms^{-2}$ **or** $-9.8\ ms^{-2}$.
(d) The acceleration of an object moving in a circle with non-uniform speed is non-uniform.
The acceleration of a racer running in a circular track is non-uniform at most of the time.

1.6 Some Solved Sample Numerical Problems Concerning Distances, Displacement, Speed, Velocity and Acceleration

Numerical Problem–1 : *An object travels 16 m in 4 s and then another 16 m in 2 s. What is the average speed of the object?* **(NCERT Textbook Expl. 1.1.–P101)**

Solution :

Distance travelled by the object in the first 4 seconds = 16 m

Time taken to cover 16 m = 4 s

Distance travelled by the object in next 2 seconds = 16 m

Time taken to cover 16 m = 2 s

Average speed of the object = v_{av} = ? *(To be found out.)*

Total distance travelled by the object, S = 16 m + 16 m = 32 m

Total time taken, t = 4s + 2s = 6 s

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

$$v_{av} = \frac{S}{t} = \frac{32m}{6s} = 5.33\ ms^{-1}$$

$\therefore$ Average speed of the object $= 5.33\ ms^{-1}$ ***(Ans.)***

Numerical Problem–2 : *The odometer of a car reads 2000 km at the start of a trip and 2400 km at the end of the trip. If the trip took 8 h, calculate the average speed of the car in km h^{-1} and ms^{-1}?* **(NCERT Textbook Expl. 1.2–P. 102)**

Solution :

Reading of odometer at the start of the trip = 2000 km

Reading of odometer at the end of the trip = 2400 km

Time of the trip, t = 8 hr

Average speed of the car, $= v_{av} = ?$ *(To be found out.)*

Distance covered by the car, S = 2400 km –2000 km = 400 km

Average speed of the car in hrs, $v_{av} = \frac{S}{t} = \frac{400\ km}{8\ hr} = 50\ km\ hr^{-1}$ ***(Ans.)***

Average speed of car in m/s $= \frac{50 \times 1000\ m}{60 \times 60 s} = 13.9\ ms^{-1}$ ***(Ans.)***

Numerical Problem–3 : *Usha swims in a 90 m long pool. She covers 180 m in one minute by swimming from one end to the other and back along the same straight path. Find the average speed and average velocity of Usha?* **(NCERT Textbook Expl. 1.3.–102)**

Solution :

Length of swimming pool = 90 m

Total distance covered by Usha, S = 90 + 90 = 180 m *(from start to come to the same point.)*

Time taken to cover 180 m, t = 1 min = 60 s

(a) Average speed of Usha $= \frac{\text{Total distance covered}}{\text{Total time taken}}$

$$v_{av} = \frac{S}{t} = \frac{180\ m}{60\ s} = 3\ ms^{-1}$$ ***(Ans.)***

(b) Displacement of Usha = 0 m

Average velocity of Usha $= \frac{\text{Displacement}}{\text{Time}} = \frac{0m}{60s} = 0\ ms^{-1}$ ***(Ans.)***

Numerical Problem–4 : *Starting from a stationary position, Rahul paddles his bicycle to attain a velocity of 6 ms^{-1} in 30 s. Then he applies brakes such that the velocity of the bicycle comes down to 4 ms^{-1} in the next 5 s. Calculate the acceleration of the bicycle in both the cases.* **(NCERT Textbook Expl. 1.4.–103)**

Solution : First Case

Initial velocity, $u = 0\ ms^{-1}$

Final velocity, $v = 6\ ms^{-1}$

Time taken, t = 30 s

acceleration of bicycle = a = ? *(To be found out.)*

$$\text{Acceleration} = \frac{\text{Final velocity} - \text{Initial velocity}}{\text{Time taken}}$$

$$\therefore \quad a = \frac{v-u}{t} = \frac{6\ ms^{-1} - 0\ ms^{-1}}{30\ s}$$

$$= \frac{1}{5}\ ms^{-2} = 0.2\ ms^{-2}$$

$\therefore$ Acceleration of the bicycle in the first case = **$0.2\ ms^{-2}$** *(Ans.)*

Second Case :

Initial velocity, $u = 6\ ms^{-1}$
Final velocity, $v = 4\ ms^{-1}$
Time taken, $t = 5\ s$

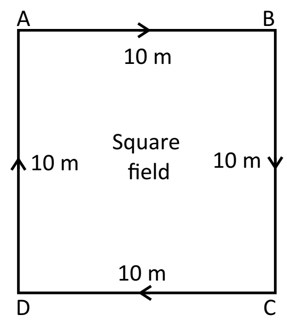
Acceleration of bicycle, $a = \frac{v-u}{t} = \frac{4ms^{-1} - 6ms^{-1}}{5s}$

$$= -\frac{2}{5}ms^{-2} = -0.4\ ms^{-2}$$

Retardation of the bicycle in the second case is equal to **$0.4\ ms^{-2}$** *(Ans.)*

Numerical Problem–5 : *A farmer moves along the boundary of a square field of side 10 m in 40 s. What will be the magnitude of displacement of the farmer at the end of 2 minutes, 20 seconds*? **(NCERT Textbook Q. 2–P. 100)**

Solution :



Let the line diagram of the square field be ABCD as shown in the figure. Let the farmer start moving from corner A and after moving along AB, BC, CD and DA reaches the starting point A.

The distance travelled by the farmer for the completion of one round along the field,

$$S = AB + BC + CD + DA$$

$$= 4 \times 10\ m = 40\ m$$

Time taken to cover this distance $t = 40$ s

Distance travelled by farmer in 1 second $= \frac{40m}{40s} = 1ms^{-1}$

Distance travelled by farmer in 2 minutes and 20 s i.e. $(2 \times 60 + 20s = 140\ s) = 1\ ms^{-1} \times 140 =$ **140 m**

Number of rounds completed by the farmer in 140 s $= \frac{140m}{40m} = 3.5$

$\therefore$ After completing three rounds the farmer will be at a point = 20 m from corner A (starting point) i.e., at corner C.

Magnitude of displacement of the farmer at the end of 140 s = AC

$$= AC = \sqrt{AB^2 + BC^2}\ m$$

$$= \sqrt{10^2 + 10^2}\ m$$

$$= \sqrt{2 \times 100\ m}$$

$$= \sqrt{2} \times 10\ m$$

$$= 1.414 \times 10$$

$\therefore$ Displacement = **14.14 m** *(Ans.)*

Numerical Problem–6 : *During an experiment a signal from a spaceship reached the ground station in five minutes. What was the distance of the spaceship from the ground station? The signal travels at the speed of light, that is,* $3 \times 10^8\ ms^{-1}$. **(NCERT Textbook Q. 5–P. 102)**

Solution :

Time taken by the signal from spaceship to the ground station, t = 5 minutes = 5 × 60 seconds = 300 s

Speed of the signal, $v = 3 \times 10^8\ ms^{-1}$

Distance of spaceship from the ground = S = ? *(To be found out.)*

Distance travelled by the signal from spaceship to the ground station, S = speed × time

$$= v \times t$$

$$= 3 \times 10^8\ ms^{-1} \times 300\,s$$

$$= 9 \times 10^{10}\,m = \frac{9 \times 10^{10}}{10^3}\,km$$

$$= 9 \times 10^7\ km$$

∴ Distance of the spaceship from the ground station = **9×10^7 km** ***(Ans.)***

Numerical Problem–7 : *A bus decreases its speed from 80 km h^{-1} to 60 km h^{-1} in 5 s. Find the acceleration of the bus?* **(NCERT Textbook Q. 2–P. 103)**

Solution :

Initial speed of the bus, $u = 80\ km\ h^{-1} = \frac{80 \times 1000}{60 \times 60}\ ms^{-1} = \frac{200}{9}\ ms^{-1}$

Final speed of the bus, $v = 60\ km\ h^{-1} = \frac{60 \times 1000}{60 \times 60}\ ms^{-1} = \frac{50}{3}\ ms^{-1}$

Time taken to decrease the speed, t = 5 s

Acceleration of the bus, = a = ? *(To be found out.)*

$$\text{Acceleration, } a = \frac{v - u}{t} = \frac{\left(\frac{50}{3} - \frac{200}{9}\right) ms^{-1}}{5s} = \frac{-10}{9}\ ms^{-2} = -1.11\ m/s^{-2}$$

∴ Acceleration of the bus is = **$-1.11\ ms^{-2}$** ***(Ans.)***

Negative sign shows that it is deceleration (retardation).

Numerical Problem–8 : *A train after starting from a railway station and moving with uniform acceleration attains a speed of 40 km h^{-1} in 10 minutes. Find its acceleration ?* **(NCERT Textbook Q. 4–P. 103)**

Solution :

Initial speed of the train, $u = 0\ km\ h^{-1}$ *(starting from rest)*

Final speed of the train, $v = 40\ km\ h^{-1} = \frac{40 \times 1000}{60 \times 60}\ ms^{-1} = \frac{100}{9}\ ms^{-1}$

Time taken to increase the speed, t = 10 minutes = 600 s

Acceleration of the train = a *(To be found out.)*

$$\text{Acceleration, } a = \frac{\text{Final velocity} - \text{Initial velocity}}{\text{Time taken}}$$

$$= \frac{v - u}{t} = \frac{\left(\frac{100}{9} - 0\right) ms^{-1}}{600\,s}$$

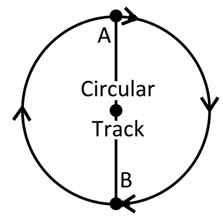
$$= \frac{100}{9 \times 600} ms^{-2} = \frac{1}{54} ms^{-2} = 0.018\ ms^{-2}$$

∴ Acceleration of the train, a = **$0.018\ ms^{-2}$** ***(Ans.)***

Numerical Problem–9 : *An athlete completes one round of a circular track of diameter 200 m in 40 s. What will be the distance covered and the displacement at the end of 2 minutes, 20 s?* **(NCERT Textbook Q.1–P. 112)**

Solution :

Let the circular track is as shown in the diagram. Let the athlete starts from point A and completes half round at point B.



Diameter of the track = 200 m

$$\text{Radius of the track, } r = \frac{200\text{ m}}{2} = 100\text{ m}$$

Time taken to complete a round, t = 40 s

Distance covered at the end of 2 minutes and 20 s = ? *(To be found out.)*

Displacement at the end of 2 minutes and 20 s = ? *(To be found out.)*

(a) The distance covered by the athlete

to complete one round = circumference of circular track

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

$$\text{Speed of the athlete} = \frac{\text{Distance}}{\text{Time}} = \frac{S}{t}$$

$$= \frac{\frac{4400}{7}}{40\text{ s}} = \frac{110}{7}\text{ ms}^{-1}$$

Distance covered by the athlete at the end of 2 minutes 20 s (140 s)

$$= \text{speed} \times \text{time} = v \times t$$

$$= \frac{110}{7}\text{ ms}^{-1} \times 140\text{ s}$$

Distance covered = **2200 m** ***(Ans.)***

(b) Number of rounds completed by the athlete in $140\text{ s} = \frac{2200\text{ m}}{\frac{4400}{7}} = 3.5$

$\therefore$ The athlete has completed three rounds and is in the mid of fourth round.

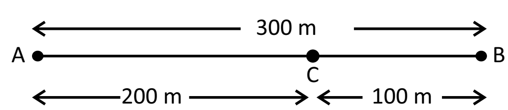
Position of the athlete at the end of 140 s is at point B of the diagram.

Displacement of athlete at the end of 140 s = AB = Diameter of the circular track = **200 m**

$\therefore$ *Displacement* = ***200 m*** ***(Ans.)***

Numerical Problem–10 : *Joseph jogs from one end A to the other end B of a straight 300 m road in 2 minutes, 50 seconds and then turns around and jogs 100 m back to point C in another 1 minute. What are Joseph's average speeds and velocities in jogging: (a) from A to B, (b) from A to C ?* **(NCERT Textbook Q.2–P. 112)**

Solution:



(a) Distance travelled by Joseph from A to B, S = 300 m

Time taken to travel the distance, t = 2 min. 50 s = 170 s

Joseph's average speed and velocity = ? *(To be found out.)*

$$\text{Average speed from A to B} = \frac{\text{Distance}}{\text{time}} = \frac{S_1}{t_1} = \frac{300\text{ m}}{170\text{s}} = \frac{30}{17}\text{ ms}^{-1}$$

Average speed = **1.76 ms^{-1}** ***(Ans.)***

As Joseph has travelled from A to B in a straight path, magnitude of speed and the velocity is the same.

∴ Average velocity of Joseph from A to B = **1.76 ms^{-1}** *(Ans.)*

(b) *Distance travelled by Joseph*

$$\text{from A to C, } S_2 = AB + BC$$
$$= 300\text{ m} + 100\text{ m} = 400\text{ m}$$

Time taken to travel from B to C, $t_2 = 1$ minute

∴ Total time taken to travel from A to B and B to C,

$$t_3 = 2\text{ minute, } 50\text{ sec} + 1\text{ minute}$$
$$= 3\text{ minutes } 50\text{ seconds}$$
$$t_3 = 230\text{ s}$$

Joseph's average speed as he jogged from A to B and then to C

$$= \frac{\text{Total distance travelled}}{\text{Total time taken}} = \frac{S_2}{t_3}$$

$$= \frac{400\text{m}}{230\text{s}} = \frac{40}{23}\text{ ms}^{-1}$$

Average speed = **1.74 ms^{-1}** *(Ans.)*

Displacement from A to C = AB – BC

∴ $S_3 = 300\text{ m} - 100\text{ m} = 200\text{ m}$

Time taken, $t_3 = 230$ s

$$\therefore \text{ Average velocity} = \frac{\text{Displacement}}{\text{Time}} = \frac{S_3}{t_3}$$

$$= \frac{200\text{ m}}{230\text{ s}} = \frac{20}{23}\text{ ms}^{-1}$$

Average Velocity = **0.87 ms^{-1}** *(Ans.)*

Numerical Problem–11 : *Abdul, while driving to school, computes the average speed from his trip to be 20 km h^{-1}. On his return trip along the same route, there is less traffic and the average speed is 40 km h^{-1}. What is the average speed for Abdul's trip?* **(NCERT Textbook Q.3–P. 112)**

Solution :

Average speed of Abdul while going to school $v_1 = 20$ km h^{-1}

Average speed of Abdul while coming back from school $v_2 = 40$ km h^{-1}

Average speed of Abdul's trip = ? *(To be found out.)*

Let the distance travelled by

Abdul in his trip to school = S km

$$\therefore \text{ Time taken by Abdul for his trip to School, } t_1 = \frac{\text{Distance}}{\text{Average speed}} = \frac{S}{20}\text{hour}$$

$$\text{Time taken by Abdul while driving on his return trip, } t_2 = \frac{\text{Distance}}{\text{Average speed}} = \frac{S}{40}$$

$$\text{Total time taken for trip} = t_1 + t_2 = \left(\frac{S}{20} + \frac{S}{40}\right)\text{hour} = \frac{3S}{40}\text{ hour}$$

$$\text{Average speed for Abdul's trip} = \frac{\text{Total distance travelled}}{\text{Total time taken}}$$