

CLASS 9 SCIENCE — CHAPTER 4

DESCRIBING MOTION AROUND US

 **New *Exploration* Science Textbook | 2026–27**

Note: All formulas below are written in simple **text format** for easy copying into your website, WordPress, Canva, notes, and PDFs.

1. What Is Motion?

Look around you. 👁️

You can see many objects moving:

-  A car moving on a road
-  A bicycle moving along a street
-  A person running
-  A ball rolling
-  Earth moving around the Sun

An object is said to be in **motion** when its position changes with time relative to a reference point.

An object is said to be **at rest** when its position does not change with time relative to a reference point.

Example

Suppose you are sitting inside a moving car.

 Relative to the car → You are **at rest**.

 Relative to the road → You are **in motion**.

Therefore:

★ Motion and rest are relative.

2. Reference Point

To determine whether an object is moving or at rest, we need a:

Reference point

A reference point is a fixed object or location relative to which the position of another object is described.

Example

A boy is walking along a road.

If a nearby tree  is taken as the reference point, the boy's position changes with time.

Therefore, the boy is in motion relative to the tree.

3. Position

The **position** of an object tells us where it is located relative to a chosen reference point.

To describe position, we need:

-  A reference point
-  A chosen positive direction
-  A unit of distance

The reference point is generally called the:

Origin

and is represented by:

$$x = 0$$



4. Motion Along a Straight Line

The simplest type of motion is motion along a straight line.

Examples:



Car moving on a straight road



Train moving along a straight railway track



Athlete running on a straight track

In such motion, the position of an object can be represented using a single coordinate.



5. Distance



Definition

Distance is the total length of the actual path travelled by an object.

Distance is a:

Scalar quantity

because it has magnitude but no direction.

Example

A person walks:



5 m forward

and then:



3 m backward.

Total distance:

Distance = 5 m + 3 m

Distance = 8 m



6. Displacement



Definition

Displacement is the change in position of an object from its initial position to its final position, along with direction.

Displacement is a:

Vector quantity

because it has both magnitude and direction.

Example

A person walks:

➡ 5 m east

and then:

← 3 m west.

Final position is 2 m east of the starting point.

Therefore:

Displacement = 2 m east



7. Distance vs Displacement

Distance 

Displacement 

Total length of actual path Change in position

Scalar quantity Vector quantity

No direction Has direction

Always non-negative

Can be positive, negative or zero

Depends on actual path

Depends on initial and final positions

★ Important

Distance $\geq$ Magnitude of displacement

8. Example of Distance and Displacement

A runner completes one complete lap of a 400 m circular track and returns to the starting point.

Distance:

Distance = 400 m

Displacement:

Initial position = Final position

Therefore:

Displacement = 0 m

★ Remember

An object can travel a large distance but have **zero displacement**.

9. Speed

Speed tells us:

How fast an object is moving.

Formula:

Speed = Distance / Time

SI Unit:

metre per second (m/s)

Another commonly used unit is:

kilometre per hour (km/h)



10. Example of Speed

A car travels 150 m in 10 seconds.

Speed = Distance / Time

Speed = 150 / 10

Speed = 15 m/s

Therefore:



Speed = 15 m/s



11. Conversion of Speed

km/h to m/s

Speed in m/s = Speed in km/h $\times$ 5/18

Example

72 km/h:

72 $\times$ 5/18 = 20 m/s

Therefore:

72 km/h = 20 m/s

m/s to km/h

Speed in km/h = Speed in m/s $\times$ 18/5

Example

10 m/s:

$$10 \times 18/5 = 36 \text{ km/h}$$

Therefore:

$$10 \text{ m/s} = 36 \text{ km/h}$$



12. Average Speed

When an object travels different distances in different time intervals, we use:

Average Speed

Formula:

$$\text{Average Speed} = \text{Total Distance} / \text{Total Time}$$



13. Example of Average Speed

A car travels:

100 km in 2 hours

and then:

50 km in 1 hour.

Total distance:

$$100 + 50 = 150 \text{ km}$$

Total time:

$$2 + 1 = 3 \text{ hours}$$

Therefore:

$$\text{Average Speed} = 150 / 3$$

$$\text{Average Speed} = 50 \text{ km/h}$$



14. Velocity

Velocity tells us how quickly the **position of an object changes**.

Formula:

$$\text{Velocity} = \text{Displacement} / \text{Time}$$

Velocity is a:

Vector quantity

because it has magnitude and direction.

SI Unit:

m/s



15. Speed vs Velocity

Speed 🚗

Distance / Time

Scalar

Velocity 🧭

Displacement / Time

Vector

No direction

Has direction

Always non-negative

Can be positive, negative or zero

Tells how fast

Tells how fast and in which direction



16. Average Velocity

Formula:

Average Velocity = Total Displacement / Total Time

Example

A person travels:

100 m east

and then:

40 m west.

Displacement:

100 – 40 = 60 m east

If total time is 20 seconds:

Average Velocity = 60 / 20

Average Velocity = 3 m/s east



17. Uniform Motion

An object is said to be in **uniform motion** if it covers:

Equal distances in equal intervals of time.

Example

A car travels:

10 m every second.

1 second → 10 m

2 seconds → 20 m

3 seconds → 30 m

4 seconds → 40 m

The speed remains constant.



18. Non-Uniform Motion

An object is in **non-uniform motion** when it covers unequal distances in equal intervals of time.

It can also cover equal distances in unequal intervals of time.

Examples:



Car moving through traffic



A runner speeding up



Train starting from a station



19. Acceleration

Acceleration tells us how quickly velocity changes with time.

Formula:

Acceleration = Change in Velocity / Time

or

$$a = (v - u) / t$$

Where:

a = Acceleration

u = Initial velocity

v = Final velocity

t = Time

SI Unit:

m/s²



20. Example of Acceleration

A car's velocity increases from 10 m/s to 30 m/s in 5 seconds.

Given:

u = 10 m/s

v = 30 m/s

t = 5 s

a = (v - u) / t

a = (30 - 10) / 5

a = 20 / 5

a = 4 m/s²



21. Positive Acceleration

When the velocity of an object increases in the chosen positive direction, the acceleration is positive.

Example:

10 m/s → 15 m/s → 20 m/s

The object is speeding up in the positive direction.

22. Negative Acceleration

When acceleration is opposite to the chosen positive direction, it is negative.

It is commonly associated with slowing down when the object is moving in the positive direction.

It is also called:

Deceleration or retardation

Important

Negative acceleration does **not always mean slowing down**.

We must consider both velocity and acceleration.

23. Uniform Acceleration

An object has uniform acceleration when its velocity changes by equal amounts in equal intervals of time.

Example

Velocity changes by 5 m/s every second:

1 s → 5 m/s

2 s → 10 m/s

3 s → 15 m/s

4 s → 20 m/s

24. Position-Time Graph

A **position-time graph** shows how the position of an object changes with time.

Usually:

Time → X-axis

Position → Y-axis

25. Position-Time Graph for an Object at Rest

If an object remains at the same position:

Position remains constant.

Therefore, the position-time graph is:

A horizontal straight line



26. Position-Time Graph for Uniform Motion

During uniform motion, position changes uniformly with time.

Therefore, the position-time graph is:

A straight line

The slope of the position-time graph gives:

Velocity

Formula:

Velocity = Change in Position / Change in Time



27. Slope of Position-Time Graph

If two points are:

(t_1, x_1)

and

(t_2, x_2)

then:

$$\text{Slope} = (x_2 - x_1) / (t_2 - t_1)$$

This represents velocity.



Remember

Position-Time Graph $\rightarrow$ Slope = Velocity



28. Different Position-Time Graphs



Positive slope

Object moves in the positive direction.



Negative slope

Object moves in the negative direction.



Zero slope

Object is at rest.



Steeper slope

Greater magnitude of velocity.



29. Velocity-Time Graph

A velocity-time graph shows how velocity changes with time.

Usually:

Time → X-axis

Velocity → Y-axis



30. Constant Velocity

If velocity remains constant:

The velocity-time graph is a horizontal line.



31. Uniform Acceleration on a Velocity-Time Graph

If velocity increases uniformly with time:

The graph is a straight line with positive slope.

The slope gives:

Acceleration

Formula:

Acceleration = Change in Velocity / Change in Time



32. Uniform Deceleration

If velocity decreases uniformly with time:

The graph is a straight line with negative slope.



33. Area Under Velocity-Time Graph

The area under a velocity-time graph gives:

Displacement

For constant velocity:

$$\text{Displacement} = \text{Velocity} \times \text{Time}$$

This is equal to the area of the rectangle under the graph.



34. Example

Velocity = 10 m/s

Time = 5 s

$$\text{Displacement} = \text{Velocity} \times \text{Time}$$

$$\text{Displacement} = 10 \times 5$$

$$\text{Displacement} = 50 \text{ m}$$



35. Equations of Motion

For an object moving with:

Uniform acceleration

we use three important equations.

1 First Equation of Motion

$$\mathbf{v = u + at}$$

Where:

u = Initial velocity

v = Final velocity

a = Acceleration

t = Time

2 Second Equation of Motion

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

Where:

s = Displacement

u = Initial velocity

a = Acceleration

t = Time

3 Third Equation of Motion

$$\mathbf{v^2 = u^2 + 2as}$$

Where:

v = Final velocity

u = Initial velocity

a = Acceleration

s = Displacement

36. Equations of Motion — Quick Memory

Remember these three together:

$$v = u + at$$

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

$$v^2 = u^2 + 2as$$

37. Example — First Equation

A car starts with a velocity of 5 m/s and accelerates at 2 m/s² for 4 seconds.

Given:

$$u = 5 \text{ m/s}$$

$$a = 2 \text{ m/s}^2$$

$$t = 4 \text{ s}$$

Using:

$$v = u + at$$

$$v = 5 + (2 \times 4)$$

$$v = 5 + 8$$

$$v = 13 \text{ m/s}$$



38. Example — Second Equation

A body starts from rest and accelerates at 2 m/s^2 for 5 seconds.

Given:

$$u = 0$$

$$a = 2 \text{ m/s}^2$$

$$t = 5 \text{ s}$$

Using:

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

$$s = 0 + \frac{1}{2} \times 2 \times 5^2$$

$$s = 25 \text{ m}$$

Displacement = 25 m



39. Example — Third Equation

A car has:

$$u = 10 \text{ m/s}$$

$$a = 3 \text{ m/s}^2$$

$$s = 20 \text{ m}$$

Using:

$$v^2 = u^2 + 2as$$

$$v^2 = 10^2 + 2 \times 3 \times 20$$

$$v^2 = 100 + 120$$

$$v^2 = 220$$

$$v = \sqrt{220}$$

$$v \approx 14.83 \text{ m/s}$$

40. Object Starting From Rest

If an object starts from rest:

$$u = 0$$

Therefore:

$$v = at$$

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

$$v^2 = 2as$$

★ These forms are frequently useful in numerical problems.

41. Object Coming to Rest

If an object finally stops:

$$v = 0$$

Always identify the values of:

- u
- v
- a
- t
- s

before choosing an equation.

42. Motion in a Plane

Objects do not always move in a straight line.

Some objects move in:

Two dimensions

Examples:

 Basketball thrown towards a basket

 A football kicked into the air

 Car moving around a curved road

 A satellite moving around Earth

To describe position in a plane, we use:

x-coordinate

and

y-coordinate

A position can be represented as:

(x, y)

43. Projectile Motion

When an object is thrown at an angle to the horizontal, it follows a curved path.

This is called:

Projectile motion

Examples:

 Basketball thrown towards a basket

 Football kicked into the air

 An arrow moving through the air

Projectile motion can be considered as two simultaneous motions:

→ Horizontal motion

↑ Vertical motion



44. Components of Velocity

If an object is projected with initial velocity v at an angle θ to the horizontal:

Horizontal component:

$$v_x = v \cos \theta$$

Vertical component:

$$v_y = v \sin \theta$$



45. Gravity During Projectile Motion

Near Earth's surface, if air resistance is ignored:

Horizontal acceleration ≈ 0

Vertical acceleration = g downward

The value of acceleration due to gravity is approximately:

$$g = 9.8 \text{ m/s}^2$$



46. Circular Motion

When an object moves along a circular path, it is said to be in:

Circular motion

Examples:



Ferris wheel



A stone tied to a string



Car moving around a circular track



Satellite moving around Earth



47. Uniform Circular Motion

When an object moves along a circular path with constant speed, it is called:

Uniform circular motion

Although the speed remains constant, the:

Direction of velocity keeps changing.

Therefore, velocity changes continuously.

Hence:



Uniform circular motion is accelerated motion.



48. Centripetal Acceleration

The acceleration of an object moving in a circular path is directed towards the centre of the circle.

It is called:

Centripetal acceleration

Formula:

$$\text{Centripetal Acceleration} = v^2 / r$$

or

$$a = v^2 / r$$

Where:

v = Speed

r = Radius of circular path

49. Centripetal Force

The force required to keep an object moving in a circular path acts towards the centre.

This is called:

Centripetal force

Examples:



Tension in a string when a stone is whirled.



Friction between tyres and road when a car turns.



Gravitational force keeping a satellite in orbit.



50. Important Physical Quantities

Quantity	Formula	Type	SI Unit
 Distance	Total path travelled	Scalar	m
 Displacement	Final position – Initial position	Vector	m
 Speed	Distance / Time	Scalar	m/s
 Velocity	Displacement / Time	Vector	m/s



Acceleration

Change in velocity / Time

Vector m/s^2



51. Important Unit Conversions

Length

$$1 \text{ km} = 1000 \text{ m}$$

Time

$$1 \text{ hour} = 3600 \text{ s}$$

Speed

$$1 \text{ km/h} = 5/18 \text{ m/s}$$

$$1 \text{ m/s} = 18/5 \text{ km/h}$$



52. Distance and Displacement

Example

A person walks:

10 m east

and then:

10 m west.

Total distance:

$$\text{Distance} = 10 + 10$$

$$\text{Distance} = 20 \text{ m}$$

Displacement:

The person returns to the starting point.

Displacement = 0 m

53. Speed and Velocity Example

A runner completes one complete circular lap.

Suppose:

Distance = 400 m

Time = 20 s

Average speed:

Average Speed = $400 / 20$

Average Speed = 20 m/s

But the runner finishes at the starting point.

Therefore:

Average velocity = 0 m/s

54. Graphs — Must Remember

Position-Time Graph

Slope = Velocity

Velocity-Time Graph

Slope = Acceleration

Velocity-Time Graph

Area under graph = Displacement

★ Easy Memory Trick

Position → Velocity

Velocity → Acceleration

Velocity-Time Area → Displacement



55. Important Exam Questions

Q1. What is motion?

Motion is the change in position of an object with time relative to a reference point.

Q2. What is a reference point?

A reference point is a fixed object or location relative to which the position of another object is described.

Q3. Define distance.

Distance is the total length of the actual path travelled by an object.

Q4. Define displacement.

Displacement is the change in position from the initial position to the final position, along with direction.

Q5. Is distance a scalar or vector quantity?

Distance is a scalar quantity.

Q6. Is displacement a scalar or vector quantity?

Displacement is a vector quantity.

Q7. Define speed.

Speed is the distance travelled per unit time.

Q8. Define velocity.

Velocity is the displacement per unit time.

Q9. Define acceleration.

Acceleration is the rate of change of velocity with time.

Q10. What is uniform motion?

Motion in which an object covers equal distances in equal intervals of time.

Q11. What is non-uniform motion?

Motion in which an object covers unequal distances in equal intervals of time.

Q12. What does the slope of a position-time graph represent?

Velocity.

Q13. What does the slope of a velocity-time graph represent?

Acceleration.

Q14. What does the area under a velocity-time graph represent?

Displacement.

Q15. Why is uniform circular motion an accelerated motion?

Because the direction of velocity continuously changes even though the speed remains constant.

56. Competency-Based Question

Situation

A car travels 60 km east and then 20 km west.

Q1. Find the total distance.

Distance = 60 + 20

Distance = 80 km

Q2. Find the displacement.

Displacement = 60 – 20

Displacement = 40 km east

Q3. Which is a scalar quantity?

👉 Distance

Q4. Which is a vector quantity?

👉 Displacement

57. Competency-Based Numerical

A car starts from rest and accelerates uniformly at 4 m/s^2 for 5 seconds.

Find its final velocity.

Given:

$$u = 0$$

$$a = 4 \text{ m/s}^2$$

$$t = 5 \text{ s}$$

Using:

$$v = u + at$$

$$v = 0 + (4 \times 5)$$

$$v = 20 \text{ m/s}$$

✅ **Answer: 20 m/s**



58. Competency-Based Question

A cyclist moves around a circular track at constant speed.

Is the cyclist accelerating?

✓ **Yes.**

Although the speed remains constant, the direction of velocity continuously changes.

Therefore:

Velocity changes → Acceleration exists



59. Common Mistakes to Avoid

✗ **Mistake 1**

Distance and displacement are always equal.

✓ **Correct**

They are equal only when the object moves along a straight line in one direction.

✗ **Mistake 2**

Constant speed always means constant velocity.

✓ **Correct**

In circular motion, speed can remain constant while velocity changes.

✗ **Mistake 3**

Negative acceleration always means slowing down.

✓ **Correct**

The direction of both velocity and acceleration must be considered.

✗ **Mistake 4**

Using average of speeds to calculate average speed.

✓ **Correct**

Average Speed = Total Distance / Total Time

60. QUICK REVISION

- ★ Motion = Change in position with time.
- ★ Rest and motion are relative.
- ★ Reference point is required to describe motion.
- ★ Distance = Total path travelled.
- ★ Displacement = Change in position.
- ★ Distance = Scalar.
- ★ Displacement = Vector.
- ★ Speed = Distance / Time.
- ★ Velocity = Displacement / Time.
- ★ Acceleration = Change in velocity / Time.
- ★ Uniform motion = Equal distances in equal time intervals.
- ★ Position-Time Graph → Slope = Velocity.
- ★ Velocity-Time Graph → Slope = Acceleration.
- ★ Velocity-Time Graph → Area = Displacement.

★ $v = u + at$

★ $s = ut + \frac{1}{2}at^2$

★ $v^2 = u^2 + 2as$

★ Uniform circular motion is accelerated motion.

★ Centripetal acceleration acts towards the centre.

★ Centripetal acceleration = v^2 / r .



61. MEMORY TRICKS



Distance & Displacement

Distance → Actual path

Displacement → Initial to final position



Speed & Velocity

Speed → Distance

Velocity → Displacement + Direction



Graphs

Position-Time → Velocity

Velocity-Time → Acceleration

Velocity-Time Area → Displacement



Equations of Motion

Remember:

$$v = u + at$$

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

$$v^2 = u^2 + 2as$$

62. CHAPTER 4 — FINAL TAKEAWAY

Motion is the change in the position of an object with time. 🚗

To describe motion scientifically, we need to understand:

 **Position**

 **Distance**

 **Displacement**

 **Speed**

 **Velocity**

 **Acceleration**

 **Motion graphs**

 **Equations of motion**

 **Circular motion**

The most important idea is:

 **Motion is described by how position changes with time, while velocity and acceleration tell us how that motion changes.**

 **Remember the complete chain:**

Position → Displacement → Velocity → Acceleration

Graphs → Understand motion visually

Equations → Calculate motion numerically