AL AMAL LEARNING CENTER

PHYSICS KEY BOOK

Class 9 | Unit 2

KINEMATICS

What is inside

Part	Contents
A	Chapter notes in simple words, with headings, original graphs and **difference tables** (sections 2.1 to 2.6)
B	Quick revision: key formulas, unit conversions and the differences to learn
C	Solved exercise: MCQs, short questions, long questions and numericals

Student Learning Outcomes covered
Types of motion; distance and displacement; speed and velocity; average and instantaneous speed; uniform and non-uniform velocity; acceleration (uniform and non-uniform); free fall with $g = 9.8\ m/s^2$; distance-time and speed-time graphs (gradient and area under the graph); and the universal speed limit of 3×10^8 m/s.

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Notes written from Class 9 Physics, Unit 2 (Kinematics). Wording, tables, graphs and layout are our own, for classroom revision.

PART A CHAPTER NOTES

Introduction

Mechanics is the study of motion. Everything around us is moving: people and vehicles on roads, the Earth, the planets and stars, and even the atoms and molecules inside objects that look still. Our formal study of physics begins with **kinematics**, which is the study of motion **without considering its causes**. The word comes from a Greek word meaning “motion”. In this unit we only *describe* motion and do not ask which forces cause or change it.

2.1 Rest and Motion

If an object does not change its position with time with respect to an observer, it is **at rest**. If its position changes with time, it is **in motion**. A bench fixed in a park is at rest for a person standing next to it; a car moving along the road changes its position every second and so it is in motion.

Difference: rest vs motion

Point	Rest	Motion
Position	Does not change with time	Changes with time
Example	A bench in a park	A car on a road
Depends on observer?	Yes	Yes

Point to ponder: rest and motion are relative
The same object can be at rest and in motion at the same time. A car is moving with respect to its surroundings, but the car and its road are also carried around by the spinning Earth. The Earth moves around the Sun, the Sun moves with the solar system through the Milky Way galaxy, and the galaxy travels through space. So, when we say an object is at rest or in motion, we must say **with respect to which observer**.

2.1.1 Types of motion

Objects move in different ways. The three basic types are **translatory**, **rotatory** and **vibratory** motion.

- **Translatory motion:** all points of the object move in the same direction by the same amount, so the orientation of the object does not change. Examples: a ball moving through the air, a car, a flying bird, an aeroplane. (Also called translational motion.)
- **Rotatory motion:** the object turns about its own axis, a line passing through the object. Every point of the object moves in a circle around that axis. Examples: blades of a fan, helicopter rotors, a spinning ball. (Also called rotational motion.)
- **Vibratory motion:** the object moves to and fro about a fixed middle position, called the **mean position**, and repeats this again and again. Examples: a swing, the strings of a sitar or guitar. (Also called vibrational motion.)

Point	Translatory	Rotatory	Vibratory
What happens	The whole body changes its place	The body turns about an axis	The body moves back and forth about a mean position
Path	Straight, curved or random	Points move in circles	Repeats the same to-and-fro path
Examples	Ball, car, flying bird, airplane	Fan blades, helicopter rotor	Swing, guitar and sitar strings

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Kinds of translatory motion

Kind	Meaning	Examples
Rectilinear	Translatory motion along a straight line	Train on a straight track, bullet fired from a gun, falling apple
Curvilinear	Translatory motion along a curved path. **Circular motion** is a special case where the radius stays constant	A kicked football, a roller coaster, a vehicle taking a turn
Random	Translatory motion with no fixed or regular path	Kites flying in the sky, clouds, a butterfly

An object may show a combination of these types of motion at the same time, for example a football that is rolling forward and spinning.

2.2 Distance and Displacement

Position is the distance and direction of a body from a fixed reference point.

Suppose you search on a map for a route between two places. The app may show a twisty road, but the straight line between the same two places is shorter.

- **Distance** is the length of the path travelled between two positions. It has no direction, so it is a **scalar**. It is usually written Δx, Δr, Δs, Δd or Δl and its SI unit is the **metre (m)**.
- **Displacement** is the shortest (straight, directed) distance from the initial position to the final position. It has direction, so it is a **vector**. Its SI unit is also the metre (m).

Formula for displacement
If an object moves from initial position $\mathbf{d_i}$ to final position $\mathbf{d_f}$, then $\mathbf{\Delta d = d_f - d_i}$.
The symbol **Δ** (Greek letter delta) means "change in". For time, $\Delta t = t_f - t_i$ is the elapsed time.

Difference: distance vs displacement

Point	Distance	Displacement
Meaning	Total length of the path travelled	Shortest straight line from start to end, with direction
Direction	None	Has direction
Type	Scalar	Vector
Depends on path?	Yes	No, only on the start and end points
Can it be zero?	Not while the object is moving	Yes, when the object comes back to its start
SI unit	metre (m)	metre (m)

Can you tell? On a 400 m running track, if your start and end points are the same, the distance is **400 m** and the displacement is **zero**. Displacement can **never be greater** than distance. They are **equal** only for motion along a straight line in one direction.

2.3 Speed and Velocity

Speed tells how fast an object is moving. **Velocity** gives the speed *and* the direction of motion.

2.3.1 Speed

To describe speed we need two measurements: the **distance travelled** and the **time elapsed**.

Speed
speed = distance ÷ elapsed time or $\mathbf{v = \Delta d \div \Delta t = (s_f - s_i) \div (t_f - t_i)}$
Speed is a scalar. SI unit: **metre per second (m/s)**. One m/s means one metre is covered in one second.
Conversion: **km/h ÷ 3.6 = m/s** and **m/s × 3.6 = km/h**.

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A fast object covers a large distance in a short time. A car that leaves Tarnol at 2:00 pm and reaches Sawabi (70 km away) at 3:00 pm has a speed of 70 km ÷ 1 h = 70 km/h.

A. Average speed

Over a whole trip, speed goes up and down. The **average speed** is the total distance covered in the total time: $\mathbf{v_{ave} = s \div t}$, or equivalently $\mathbf{s = v_{ave} \times t}$.

B. Instantaneous speed

The speed at one particular instant is the **instantaneous speed**. A speed-limit board such as "70 km/h" refers to this, and a car's speedometer shows it.

C. Uniform and variable speed

If an object covers **equal distances in equal intervals of time**, it moves with **uniform speed**. If the speed changes, it is **variable speed**.

Difference: average speed vs instantaneous speed

Point	Average speed	Instantaneous speed
Meaning	Total distance ÷ total time of the whole trip	Speed at one particular instant
Measured by	Calculation over the trip	Speedometer reading
Value	One value for the whole trip	Can be different at every instant

Difference: uniform speed vs variable speed

Point	Uniform speed	Variable speed
Distances	Equal in equal intervals of time	Unequal in equal intervals of time
Speed	Does not change	Changes (speeding up or slowing down)
Example	A car moving steadily at 60 km/h	A car in busy traffic

Activity: measure your bowling speed
Measure the length of the cricket pitch in metres. A friend starts a stopwatch when you release the ball and stops it when the ball reaches the batter. Speed = pitch length ÷ time (m/s). Multiply by 3.6 to get km/h so you can compare with international bowlers.

Solved examples (speed)

Example 2.1 – Reaction time of a batsman

Shoaib Akhtar bowled at 161.3 km/h in the 2003 World Cup. If the batsman is 17.5 m from the bowler, what is the reaction time for the delivery?

- Speed v = 161.3 km/h = 161.3 × 1000 ÷ 3600 = **44.8 m/s**; distance s = 17.5 m.
- From v_{ave} = s ÷ t: t = s ÷ v = 17.5 ÷ 44.8 = **0.39 s**.

Example 2.2 – Fastest train in the world

Shanghai's Maglev train travels 30 km in 7 minutes 30 seconds. Find its speed in m/s and km/h.

- Distance = 30 km = 30 000 m. Time = 7 × 60 + 30 = 450 s.
- v = 30 000 ÷ 450 = **66.67 m/s**. In km/h: 66.67 × 3600 ÷ 1000 = **240 km/h** (more than a motorway limit of 120 km/h).

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Interesting speed facts

Who or what	Speed
Usain Bolt (100 m in 9.58 s, 2009)	10.44 m/s = 37.58 km/h
Cheetah (fastest land animal)	33.33 m/s = 120 km/h
Peregrine falcon (fastest animal)	up to 108.33 m/s = 390 km/h
Three-toed sloth (slowest animal)	about 0.00134 m/s = 0.0048 km/h
Sound in air	about 343 m/s (1235 km/h)
Light in a vacuum	about 3×10^8 m/s (299 792 458 m/s)

Universal speed limit
Nothing can go faster than light. Einstein showed that light always moves at the same speed whatever the motion of the observer. Anything made of matter can come close to the speed of light but can never reach it. At this speed you could go around the Earth about 7.5 times in one second.

2.3.2 Velocity

Velocity
velocity = displacement ÷ elapsed time or $\mathbf{v = \Delta d \div \Delta t = (d_f - d_i) \div (t_f - t_i)}$
Velocity is a **vector** with the same direction as the displacement. SI unit: **m/s**.
For straight-line motion in one direction, speed and the size of velocity are equal. The difference is that for velocity, a direction must be stated.

- **Average velocity** = total displacement ÷ total time, $\mathbf{v_{ave} = d \div t}$.
- **Instantaneous velocity** = velocity measured over a very small time interval; both the speed and the direction at that moment must be given.
- **Uniform velocity:** equal displacements in equal intervals of time, so both speed and direction stay constant. Otherwise it is **variable velocity**. To change velocity, the speed, the direction or both must change.

A satellite moving at a constant speed in a circular orbit around the Earth does **not** have constant velocity, because its direction keeps changing.

Difference: speed vs velocity

Point	Speed	Velocity
Definition	Distance ÷ time	Displacement ÷ time
Direction	Not needed	Needed
Type	Scalar	Vector
For one full lap of a track	Not zero (the object moved)	Average velocity is zero (displacement is zero)
SI unit	m/s	m/s

Difference: uniform velocity vs variable velocity

Point	Uniform velocity	Variable velocity
Displacements	Equal in equal intervals of time	Unequal in equal intervals of time
Speed and direction	Both stay constant	Speed, direction or both change
Example	A car on a long straight road at steady speed	A satellite in orbit, a car going round a bend

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Example 2.3 – Velocity of a car

A car travels a curvy track of length 800 m in 40 s. The straight path between the start and end is 600 m. Find (a) average speed and (b) average velocity.

- (a) Average speed = distance ÷ time = 800 ÷ 40 = **20 m/s**.
- (b) Average velocity = displacement ÷ time = 600 ÷ 40 = **15 m/s**, directed from the start to the end of the track.

Note: the textbook divides 600 m by 36 s (a different trip) and gets 16.67 m/s. For the same 40 s journey, the answer is 15 m/s.

2.4 Acceleration

Velocity changes when the speed changes, the direction changes, or both. To measure *how quickly* velocity changes we need one more quantity: **acceleration**, the time rate of change of velocity.

Acceleration
acceleration = change in velocity ÷ elapsed time or **$a = \Delta v \div \Delta t = (v_f - v_i) \div (t_f - t_i)$**
Acceleration is a **vector** with the same direction as the *change* in velocity. SI unit: **metre per second squared (m/s^2)**.
Positive acceleration: velocity increases with time. **Negative** acceleration (**deceleration**): velocity decreases with time.
Because velocity includes direction, a change in direction alone also produces acceleration (for example, a drone turning in the air).

Uniform and non-uniform acceleration

A body has **uniform acceleration** if its velocity changes by equal amounts in equal intervals of time. In **non-uniform acceleration** the velocity changes, but not at a steady rate, so the acceleration itself changes. Many real-life situations are of this kind, because forces vary with time.

Difference: uniform vs non-uniform acceleration

Point	Uniform acceleration	Non-uniform acceleration
Change in velocity	Equal in equal intervals of time	Unequal in equal intervals of time
Acceleration	Constant	Changes with time
Example	A ball falling freely (no air resistance)	A car in city traffic

Difference: acceleration vs deceleration

Point	Acceleration (positive)	Deceleration (negative acceleration)
Velocity	Increases	Decreases
Direction of a	Same as the motion	Opposite to the motion
Example	A car pulling away from a signal	A car braking at a red light

Can you tell? How to read motion from pictures
For a car photographed at equal time intervals: cars at the **same place** = at rest; **equal gaps** = constant speed; **gaps getting bigger** = speeding up; **gaps getting smaller** = slowing down.
For a ball with initial and final velocity: if the velocity is the same, there is **no acceleration**. If the speed increases or decreases, or the direction reverses, there **is** acceleration, and it points in the direction of ($v_f - v_i$).

Example 2.4 – Acceleration of a cheetah

A cheetah increases its speed from zero to 26.8 m/s east in 3 s. Find its acceleration.

- $a = (v_f - v_i) \div \Delta t = (26.8 - 0) \div 3 =$ **8.93 m/s^2** towards the east.
- This is large: typical cars have an acceleration of only 3 to 4 m/s^2.

Note: the textbook prints 9.93 m/s^2, but 26.8 ÷ 3 = 8.93.

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2.5 Motion due to Gravity

Galileo was the first scientist to measure speed as distance over time. His experiments showed that falling objects of different masses reach the ground together. Objects that fall only under the pull of gravity are called **freely falling bodies**, and their acceleration is the **acceleration due to gravity**, written **g**.

Acceleration due to gravity
g = 9.8 m/s^2 (32.2 ft/s^2) near the Earth's surface, directed **downward** towards the centre of the Earth.
All freely falling objects have the same g, **independent of their mass**.

Time after release from rest	1 s	2 s	3 s	4 s	5 s
Speed (m/s)	9.8	19.6	29.4	39.2	49.0

Air resistance. A coin falls faster than a sheet of paper because of air resistance. If the air is pumped out of a jar (a vacuum), the coin and paper fall **at the same rate** and reach the bottom together.

Sign convention for g
Moving **with** gravity (downward): acceleration = **+g**. Moving **against** gravity (upward, like a ball thrown up): acceleration = **−g**.
From the definition of acceleration, $\mathbf{v_f = v_i + g\,t}$, so $\mathbf{t = (v_f - v_i) \div g}$.

Example 2.5 – Acceleration due to gravity

A 2 kg block is left at the top of a building and hits the ground at 78.5 m/s (ignore air resistance). How long does it take to reach the ground?

- $v_i = 0$, $v_f = 78.5$ m/s, $g = 9.8$ m/s^2. The mass (2 kg) is not needed.
- $\Delta t = (v_f - v_i) \div g = (78.5 - 0) \div 9.8 = 8.01$, so **$\Delta t \approx 8$ s**.

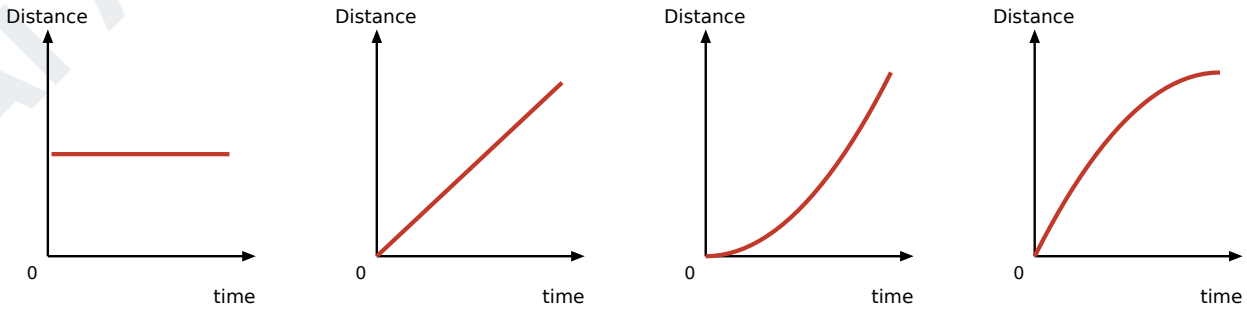
2.6 Graphical Analysis of Motion

A **graph** shows how one physical quantity depends on another. It uses a coordinate system with a horizontal axis (x) and a vertical axis (y). For motion, **time is always on the horizontal axis**.

2.6.1 Distance-time graph

Time is plotted on the x-axis and distance on the y-axis. Distance never becomes negative, so a distance-time graph is always drawn in the positive x-y plane, whatever the direction of motion.

The gradient (slope) of a distance-time graph gives the speed
1. Choose two points P_i (t_i, s_i) and P_f (t_f, s_f) on the graph.
2. Find $\Delta t = t_f - t_i$ (horizontal difference) and $\Delta s = s_f - s_i$ (vertical difference).
3. **gradient = $\Delta s \div \Delta t = (s_f - s_i) \div (t_f - t_i) = v$** (the speed).



(a) At rest **(b) Constant speed** **(c) Speeding up** **(d) Slowing down**

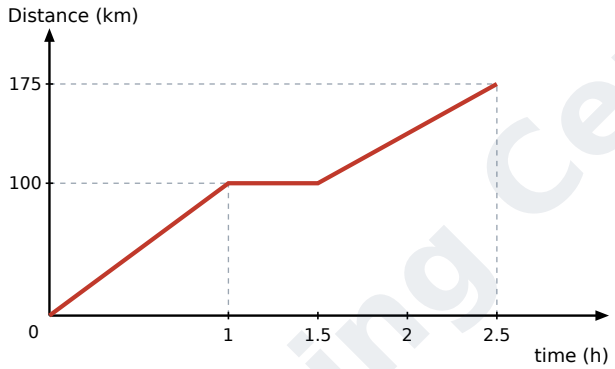
Graph	Shape	Meaning
(a) Body at rest	Horizontal line	Distance does not change, so the slope and speed are zero
(b) Constant speed	Straight sloping line	Distance increases uniformly; the slope is constant, so the speed is uniform

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Graph	Shape	Meaning
(c) Variable speed: increasing	Curve bending upward	The slope keeps increasing, so the body is speeding up (accelerating)
(d) Variable speed: decreasing	Curve flattening out	The slope keeps decreasing, so the body is slowing down (decelerating)

Example 2.5 – Peshawar to Islamabad through M1

A car travels from Peshawar to Islamabad on the motorway and stops for 30 minutes at a rest area. Find its speed (a) from Peshawar to the rest area, (b) from the rest area to Islamabad, and (c) for the whole journey. From the graph: the rest area is at 100 km (after 1 h); the car leaves at 1.5 h and reaches Islamabad at 175 km after 2.5 h.



Distance-time graph

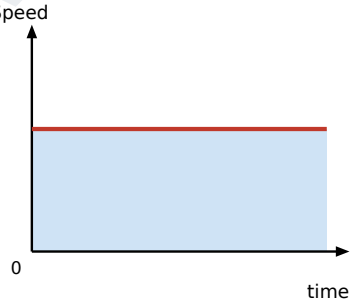
Part	Working	Speed
(a) Peshawar to rest area	$\Delta s = 100 - 0 = 100$ km; $\Delta t = 1$ h → 100 ÷ 1	**100 km/h** = 100 000 ÷ 3600 = **27.78 m/s**
(b) Rest area to Islamabad	$\Delta s = 175 - 100 = 75$ km; $\Delta t = 2.5 - 1.5 = 1$ h → 75 ÷ 1	**75 km/h** = 75 000 ÷ 3600 = **20.83 m/s**
(c) Whole journey	$\Delta s = 175$ km; $\Delta t = 2.5$ h → 175 ÷ 2.5	**70 km/h** = 175 000 ÷ 9000 = **19.44 m/s**

Note: the textbook prints 100 km/h for part (b), but 75 km in 1 hour is 75 km/h (its m/s answer, 20.83, is correct).

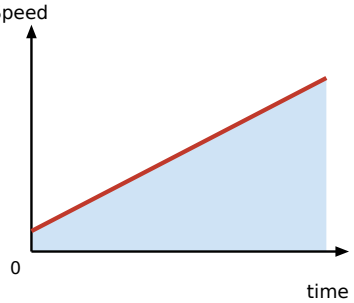
2.6.2 Speed-time graph

Speed is plotted on the y-axis and time on the x-axis. A speed-time graph serves two purposes: its **slope gives the magnitude of acceleration** and the **area under it gives the distance travelled**.

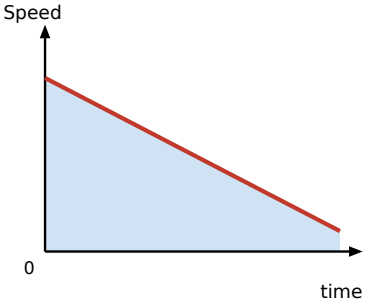
A. The gradient of a speed-time graph gives the acceleration
gradient = $\Delta v \div \Delta t = (v_f - v_i) \div (t_f - t_i) = |a|$



(a) Zero acceleration



(b) Uniform acceleration



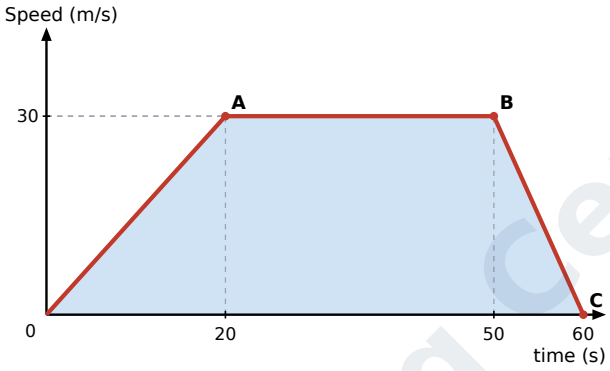
(c) Uniform deceleration

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B. The area under a speed-time graph gives the distance travelled
Rectangle (constant speed v for time t): Area = v × t, and distance s = v × t.
Triangle (speed rising uniformly from zero, or falling to zero): Area = ½ × v × t, and distance s = ½ v t.
For a graph made of several shapes, find the area of each rectangle and triangle and add them.

Example 2.6 – Speed of a car from a graph

A car increases its speed from zero to 30 m/s in 20 s, moves with uniform speed for the next 30 s, and then brakes and stops in 10 s. Find (a) the magnitude of acceleration in each part, (b) the total distance, and (c) the average speed.



Speed-time graph

Part	Working	Answer
(a) First 20 s (OA)	a = (30 − 0) ÷ (20 − 0) = 30 ÷ 20	**1.5 m/s^2**
20 s to 50 s (AB)	a = (30 − 30) ÷ (50 − 20) = 0 ÷ 30	**0 m/s^2**
Last 10 s (BC)	a = (0 − 30) ÷ (60 − 50) = −30 ÷ 10	**−3 m/s^2** (the negative sign shows slowing down)
(b) Total distance	Area = ½(30)(20) + (30)(30) + ½(30)(10) = 300 + 900 + 150	**1350 m**
(c) Average speed	total distance ÷ total time = 1350 ÷ 60	**22.5 m/s**

Difference: distance-time graph vs speed-time graph

Point	Distance-time graph	Speed-time graph
Vertical axis	Distance	Speed
Gradient (slope) gives	Speed	Acceleration
Area under graph gives	Not used in this unit	Distance travelled
Horizontal line means	Body at rest	Constant speed (zero acceleration)
Straight sloping line means	Constant speed	Constant (uniform) acceleration

Chapter summary

- **Position** is the distance and direction of a body from a fixed reference point; **distance** is the length of the path; **displacement** is the shortest directed distance from start to end.
- **Speed** is the time rate of change of distance (scalar). **Velocity** is the time rate of change of displacement (vector). **Acceleration** is the time rate of change of velocity (vector).
- The **gradient of a distance-time graph** gives speed, the **gradient of a speed-time graph** gives acceleration, and the **area under a speed-time graph** gives the distance travelled.

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PART B QUICK REVISION

Key formulas and facts

Topic	Formula / fact
Displacement	$\Delta d = d_f - d_i$ (vector, metre)
Speed	$v = \Delta d \div \Delta t$ (scalar, m/s)
Average speed	v_{ave} = total distance ÷ total time = $s \div t$; $s = v_{ave} \times t$
Average velocity	v_{ave} = total displacement ÷ total time = $d \div t$ (vector)
Acceleration	$a = (v_f - v_i) \div (t_f - t_i)$ (vector, m/s^2)
Free fall	$g = 9.8\ m/s^2$ downward; $v_f = v_i + g\,t$
Gradient of distance-time graph	= speed
Gradient of speed-time graph	= acceleration (magnitude)
Area under speed-time graph	= distance (rectangle $v \times t$; triangle ½ v t)
Speed of light	3×10^8 m/s (universal speed limit)

Unit conversions

To change	Do this	Example
km/h to m/s	÷ 3.6	72 km/h = 20 m/s
m/s to km/h	× 3.6	10 m/s = 36 km/h
km/h^2 to m/s^2	× 1000 ÷ 3600^2 (÷ 12 960 000 × 1000)	1 km/h^2 = 7.7×10^{-5} m/s^2
m/s^2 to km/h^2	× 3600^2 ÷ 1000 (= × 12 960)	1 m/s^2 = 12 960 km/h^2

Differences to revise before the test

- Rest vs motion
- Translatory vs rotatory vs vibratory motion; rectilinear vs curvilinear vs random motion
- Distance vs displacement
- Speed vs velocity
- Average vs instantaneous speed; uniform vs variable speed and velocity
- Uniform vs non-uniform acceleration; acceleration vs deceleration
- Distance-time graph vs speed-time graph

Exam tips
Always change units first (km/h to m/s) and write the unit with every answer. Use the **displacement** for velocity and the **distance** for speed. For a graph question: read the **slope** for speed or acceleration and the **area** for distance. A negative acceleration means slowing down.

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PART C SOLVED EXERCISE

Q1. Multiple Choice Questions – answers with reasons

#	Question	Answer	Reason
1	Change in position of a body from initial to final point is called	**B. Displacement**	Displacement = final position − initial position.
2	Motion of the screw of a rotating fan is	**D. Rotatory motion**	Every point turns in a circle about the fan's axis.
3	A cyclist travelling west decelerates at 8 m/s^2 to stop. Direction of acceleration?	**B. East**	Deceleration acts opposite to the motion, so it points east.
4	A girl walks 3 km west and 4 km south. Distance and displacement?	**D. 7 km, 5 km**	Distance = 3 + 4 = 7 km; displacement = $\sqrt{(3^2 + 4^2)}$ = 5 km.
5	A horse moves 60 m right in 3 s, then 30 m back in 2 s. Average velocity?	**A. 6 m/s**	Displacement = 60 − 30 = 30 m; time = 5 s; 30 ÷ 5 = 6 m/s.
6	Acceleration 2 m/s^2 for 5 s: change in velocity?	**B. 10 m/s**	$\Delta v = a\,t = 2 \times 5 = 10$ m/s.
7	v_i = 10 m/s, a = 2 m/s^2 for 10 s. Final velocity?	**A. 30 m/s**	$v_f = 10 + 2 \times 10 = 30$ m/s.
8	When the slope of a displacement-time graph increases, the body moves with	**A. increasing velocity**	Slope = velocity, so a larger slope means a larger velocity.
9	A ball thrown straight up: magnitude of acceleration at the top?	**B. 9.8 m/s^2**	Gravity still acts, so a = g = 9.8 m/s^2 downward even at the top.
10	Slope of a distance-time graph is	**C. speed**	$\Delta s \div \Delta t$ is the definition of speed.
11	Area under a speed-time graph equals ____ of the moving body	**A. distance**	Area ($v \times t$ or ½ $v\,t$) = distance travelled.
12	In 5 s a car's velocity increases by 20 m/s. Acceleration?	**B. 4 m/s^2**	a = 20 ÷ 5 = 4 m/s^2.
13	A ball dropped from a tower reaches the ground in 4 s. Speed of impact?	**D. 39.2 m/s**	$v = g\,t = 9.8 \times 4 = 39.2$ m/s.
14	Which distance-time graph shows increasing speed?	**C**	Graph C is a curve bending upward, so the slope (speed) keeps increasing. A = rest, B = constant speed, D = decreasing speed.

Q2. Short Response Questions

1. What kind of motion does the big wheel (Ferris wheel) have, and what motion do the riders have?

The big wheel turns about its central axis, so it has **rotatory motion**. The riders sit in cabins that stay upright and travel along a circle, so they have **curvilinear (circular) translatory motion**.

2. A boy moves for some time. Give two situations in which his displacement is zero but the distance covered is not zero.

(i) He runs one full lap around a circular or oval track and stops at his starting point. (ii) He walks from his house to a shop 200 m away and returns to the house. In both cases the start and end points are the same, so displacement = 0, but the distance covered is not zero (400 m in example ii).

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3. A stone tied to a string is whirled in a circle. What is the direction of its velocity at any instant?

The velocity at any instant is along the **tangent** to the circle at that point, in the direction the stone is moving at that instant. Its direction changes continuously, so the velocity is not constant. If the string breaks, the stone flies off along the tangent.

4. Is it possible to accelerate an object without speeding it up or slowing it down?

Yes. Acceleration is a change in **velocity**, and velocity changes if the **direction** changes even when the speed stays the same. Examples: a car going round a bend at constant speed, a satellite in a circular orbit.

5. Can a car moving towards the right have its acceleration towards the left?

Yes. When the car slows down (brakes), its velocity decreases, so the acceleration (deceleration) points **opposite** to the motion, that is, towards the left.

6. With daily-life examples, describe the situations in which (a) acceleration is in the direction of motion, (b) acceleration is against the direction of motion, (c) acceleration is zero and the body is in motion.

(a) A car speeding up after a traffic signal; a stone falling freely. (b) A car braking to stop; a ball thrown upward (gravity acts against its motion). (c) A car moving at constant velocity on a straight highway; a train running steadily on a straight track.

7. Examine the distance-time graph of a motorcyclist. What does it tell about the speed? Also plot its velocity-time graph.

The graph is a **straight line through the origin**, so the distance increases by equal amounts in equal times: the motorcyclist moves with **uniform (constant) speed**. Speed = gradient = $\Delta s \div \Delta t$ = 30 m ÷ 4 s = **7.5 m/s** (also 45 m in 6 s). Because the speed is constant, the velocity-time (speed-time) graph is a **horizontal straight line at 7.5 m/s**, with zero acceleration.

8. Which controls in a car can produce acceleration or deceleration?

The **accelerator pedal** increases the speed (acceleration). The **brake pedal** (and handbrake) decreases the speed (deceleration). The **steering wheel** changes the direction of motion, which also produces acceleration because velocity changes.

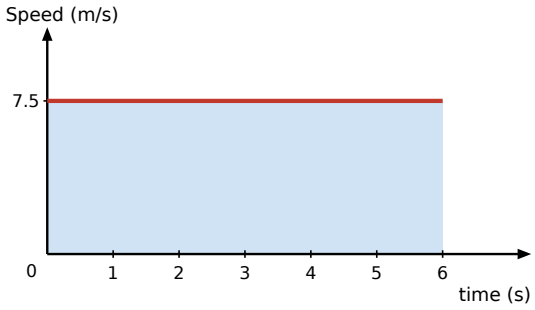
9. Two stones of 10 kg and 1 kg are dropped from a 1 km high tower. Which hits the ground with greater velocity? Which hits first? (Neglect air resistance)

Neither. All freely falling bodies have the same acceleration g = 9.8 m/s^2, independent of mass. So **both stones hit the ground at the same time and with the same velocity** (about 14.3 s and 140 m/s for a 1 km tower).

10. A 100 g ball is just released from rest and another is thrown downward at 10 m/s. Which will have the greater acceleration? (Neglect air resistance)

Both have the **same acceleration**, g = 9.8 m/s^2. Throwing the second ball downward only gives it a bigger initial velocity (10 m/s), so its velocity is greater at every instant, but the acceleration of both is the same.

Graph for Q7: velocity-time (speed-time) graph of the motorcyclist



Speed-time graph

Q3. Long Response Questions

1. Differentiate between rest and motion. With the help of an example, show that rest and motion are relative to the observer.

Point	Rest	Motion
Position	Does not change with time	Changes with time
Example	A bench in a park	A car moving on a road

Relative to the observer: a passenger sitting in a moving bus is **at rest** with respect to the bus (or another passenger), because the distance between them does not change. But the same passenger is **in motion** with respect to a person standing on the road, because the passenger's position changes with time. Even a bench that seems at rest is moving with the spinning Earth, so rest and motion always depend on the chosen observer.

2. What are the different types of motion? Define each type with examples from daily life.

Type	Definition	Daily-life examples
Translatory	The whole body changes its position; all points move the same way, with no change in orientation	Car, flying bird, aeroplane, a ball thrown
Rectilinear	Translatory motion in a straight line	Train on a straight track, falling apple, bullet
Curvilinear	Translatory motion along a curved path (circular is a special case with a constant radius)	Kicked football, roller coaster, car taking a turn
Random	Translatory motion with no specific path	Butterfly, kite, clouds
Rotatory	The body turns about its own axis; its points move in circles	Fan blades, helicopter rotor
Vibratory	To-and-fro motion about a mean position, repeated again and again	Swing, sitar string, guitar string

3. What are scalars and vectors? Give examples. How are vectors represented symbolically and graphically?

Scalars are physical quantities that have only magnitude (a number with a unit) and no direction, e.g. distance, speed, time, mass, energy, temperature. **Vectors** have both magnitude and direction, e.g. displacement, velocity, acceleration, force, weight, momentum.

Symbolically: a vector is written as a letter with an arrow above it (for example F with an arrow, or d with an arrow), while a scalar is written as a plain letter. **Graphically:** a vector is drawn as an **arrow**. Its **length**, to a chosen scale, shows the magnitude; the **arrowhead** shows the direction; the starting end is the **tail**. Example: with scale 5 km = 1 cm, a displacement of 20 km is an arrow 4 cm long.

4. Define the term position. Differentiate between distance and displacement.

Position is the distance and direction of a body from a fixed reference point.

Point	Distance	Displacement
Meaning	Length of the path travelled	Shortest straight line from start to end
Direction	None	Has direction
Type	Scalar	Vector
Depends on path?	Yes	No
Can it be zero?	Not for a moving object	Yes, if the body returns to its start

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5. Differentiate between speed and velocity. Also define average speed, uniform and variable speeds, average velocity, uniform and variable velocities.

Point	Speed	Velocity
Definition	Distance ÷ time	Displacement ÷ time
Direction	Not needed (scalar)	Needed (vector)
Example	60 km/h	60 km/h towards north

Average speed: total distance covered ÷ total time taken (v_{ave} = s ÷ t). **Uniform speed:** equal distances covered in equal intervals of time. **Variable speed:** the speed changes with time.

Average velocity: total displacement ÷ total time (v_{ave} = d ÷ t). **Uniform velocity:** equal displacements in equal intervals of time (speed and direction both constant). **Variable velocity:** speed, direction or both change, e.g. a satellite in orbit.

6. What are freely falling bodies? What is gravitational acceleration? Write the sign conventions. Write the three equations of motion of a freely falling body.

Freely falling bodies are objects that fall under the action of gravity alone (air resistance neglected). All of them have the same acceleration, called the **acceleration due to gravity (g)**. Near the Earth's surface **g = 9.8 m/s^2**, directed downward towards the centre of the Earth.

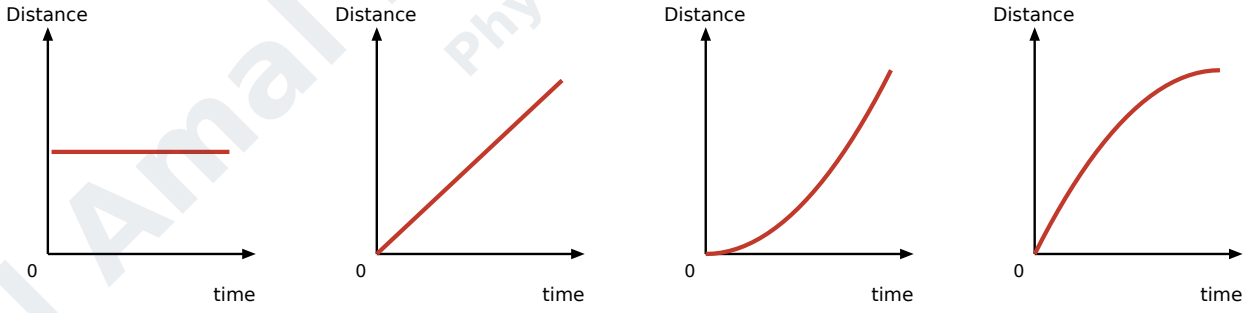
Sign convention: when a body moves **downward** (with gravity), g is taken as **+g**. When it moves **upward** (against gravity), g is taken as **−g**.

Equations of motion for a freely falling body (v_i = initial velocity, v_f = final velocity, t = time, h = height or distance covered):

1st equation	$v_f = v_i + g\,t$
2nd equation	$h = v_i\,t + \frac{1}{2}\,g\,t^2$
3rd equation	$v_f^2 = v_i^2 + 2\,g\,h$

For a body dropped from rest, $v_i = 0$, so $v_f = g\,t$, $h = \frac{1}{2}\,g\,t^2$ and $v_f^2 = 2\,g\,h$.

7. Draw distance-time graphs for rest, uniform speed, increasing speed and decreasing speed.

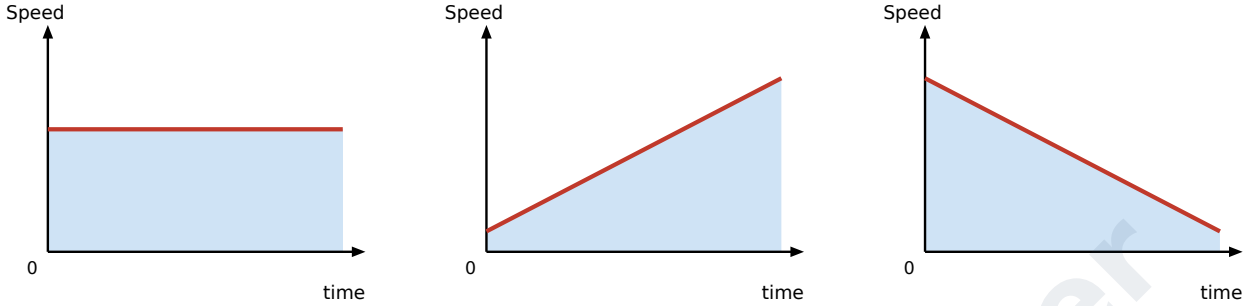


(a) At rest **(b) Constant speed** **(c) Speeding up** **(d) Slowing down**

(a) **Rest:** horizontal line (distance does not change). (b) **Uniform speed:** straight sloping line (constant slope). (c) **Increasing speed:** curve bending upward (slope increases). (d) **Decreasing speed:** curve flattening out (slope decreases).

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8. Draw speed-time graphs for zero acceleration, uniform acceleration and uniform deceleration. Show that the area under a speed-time graph represents distance.



(a) Zero acceleration **(b) Uniform acceleration** **(c) Uniform deceleration**

(a) Zero acceleration: horizontal line. (b) Uniform acceleration: straight line sloping upward. (c) Uniform deceleration: straight line sloping downward.

Area = distance: for uniform speed v for time t, the graph is a rectangle with width t and height v. Area = v × t. But from the definition of speed, distance s = v × t. So the area of the rectangle equals the distance. For speed rising uniformly from zero to v in time t, the graph is a triangle. Area = ½ × base × height = ½ v t, and the distance covered at the average speed (v ÷ 2) is s = (v ÷ 2) × t = ½ v t. Hence the area under a speed-time graph represents the distance travelled.

Q4. Numerical Response Questions

1. Convert the following

	Given	Working	Answer
a	160 km/h into m/s	160 × 1000 ÷ 3600 (or ÷ 3.6)	**44.44 m/s**
b	36 m/s into km/h	36 × 3600 ÷ 1000 (or × 3.6)	**129.6 km/h**
c	15 km/h^2 into m/s^2	15 × 1000 m ÷ (3600 s)^2 = 15 000 ÷ 12 960 000	**0.00116 m/s^2** (≈ 0.001)
d	1 m/s^2 into km/h^2	1 × (3600)^2 ÷ 1000 = 12 960 000 ÷ 1000	**12 960 km/h^2**

2. In 10 s a cyclist increases speed from 5 km/h to 7 km/h, while a car moves from rest to 20 km/h in the same time. Calculate and compare the acceleration in each case.

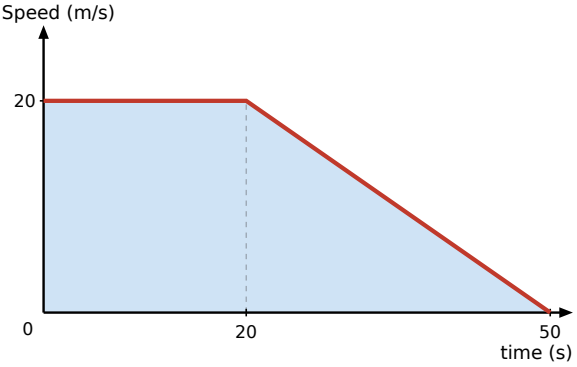
	Working	Acceleration
Cyclist	Δv = 7 − 5 = 2 km/h = 2 ÷ 3.6 = 0.556 m/s; a = 0.556 ÷ 10	**0.056 m/s^2**
Car	Δv = 20 − 0 = 20 km/h = 20 ÷ 3.6 = 5.56 m/s; a = 5.56 ÷ 10	**0.556 m/s^2**

Comparison: the car's acceleration (0.556 m/s^2) is **10 times** the cyclist's (0.056 m/s^2).

3. A ball thrown straight up takes 2 s to reach the top, after which it falls back. What was the speed with which it was thrown up?

At the top $v_f = 0$; moving upward the acceleration is −g. From $v_f = v_i - g\,t$: $0 = v_i - 9.8 \times 2$, so $v_i =$ **19.6 m/s**.

4. A car moves with uniform velocity 20 m/s for 20 s. Then brakes are applied and it comes to rest with uniform deceleration in 30 s. Plot the graph and calculate the distance using the speed-time graph.



Speed-time graph

Distance = area under the graph = rectangle + triangle = (20 × 20) + ½ × 20 × 30 = 400 + 300 = **700 m**.

Note: the textbook's answer key prints 1 km, but with the data given in the question (20 m/s for 20 s, then stopping in 30 s) the distance is 700 m.

5. A girl starts on a racing bicycle at a speed of 50 km/h. Her speed changes at a constant rate. If she stops after 60 s, what is her acceleration?

v_i = 50 km/h = 50 ÷ 3.6 = 13.89 m/s; v_f = 0; t = 60 s. a = (0 − 13.89) ÷ 60 = **−0.23 m/s^2**, that is, a deceleration of **0.23 m/s^2**.

6. From the speed-time graph given in the book (points A at the origin, B (10 s, 50 m/s), C (20 s, 50 m/s), D (30 s, 0)), tell: (a) which part shows acceleration, deceleration and zero acceleration? (b) calculate the distance covered from 10 s to 20 s.

Part	Segment	Working	Answer
(a) Acceleration	AB (0 to 10 s, rising line)	a = (50 − 0) ÷ 10	**+5 m/s^2**
Zero acceleration	BC (10 to 20 s, horizontal line)	a = (50 − 50) ÷ 10	**0 m/s^2**
Deceleration	CD (20 to 30 s, falling line)	a = (0 − 50) ÷ 10	**−5 m/s^2**
(b) Distance 10 s to 20 s	Rectangle under BC	s = v × t = 50 × 10	**500 m**

Note: the textbook's key lists the segments as “OA, BC, AB”; according to the figure the segments are AB (acceleration), BC (zero acceleration) and CD (deceleration). The distance 500 m matches the key.

End of Unit 2
Revise the difference tables (Part A) and the quick revision page (Part B) before attempting a test. Good luck!

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