🚗 MOTION IN A STRAIGHT LINE

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Class 11 CBSE Physics - Chapter 2

Complete Study Material for Home Exam Preparation

Session: 2025-26

📚 CHAPTER OVERVIEW

🎯 What You'll Master in This Chapter:

- **Motion Fundamentals:** Position, Displacement, Distance
- **Velocity Concepts:** Average & Instantaneous Velocity
- **Acceleration:** Rate of change of velocity
- **Kinematic Equations:** Three golden equations of motion
- **Graphical Analysis:** x-t, v-t, and a-t graphs
- **Real Applications:** Free fall, stopping distance, reaction time

⏱ **Chapter Weightage:** 5-7 marks in Board Exam

⭐ **Difficulty Level:** EASY to MODERATE - Formula-based Chapter!

🔑 KEY DEFINITIONS (MUST MEMORIZE!)

1️⃣ MOTION:

An object is said to be in motion if its position changes with time.

2️⃣ RECTILINEAR MOTION:

Motion along a straight line is called rectilinear motion or one-dimensional motion.

3️⃣ KINEMATICS:

The branch of physics that deals with the description of motion without going into its causes.

4️⃣ POSITION:

The location of an object with respect to a chosen reference point (origin) .

5️⃣ DISPLACEMENT:

The change in position of an object. It is a vector quantity.

$$\Delta x = x_2 - x_1$$

🎯 VELOCITY - THE COMPLETE PICTURE

📊 Average Velocity:

Average Velocity ($\bar{v}$):

$$\bar{v} = \Delta x / \Delta t = (x_2 - x_1) / (t_2 - t_1)$$

It is the displacement per unit time.

Unit: m/s (meter per second)

It's a VECTOR - has both magnitude and direction

⚡ Instantaneous Velocity:

Instantaneous Velocity (v):

$v = \lim_{\Delta t \to 0} \Delta x/\Delta t = dx/dt$

Velocity at a particular instant of time.

Graphically: Slope of tangent to position-time graph at that instant.

🎯 Understanding Velocity with Example:

Given: Position $x = a + bt^2$

where a = 8.5 m, b = 2.5 m/s²

Find velocity:

$v = dx/dt = d(a + bt^2)/dt$

$v = 0 + 2bt$

$v = 2bt = 2(2.5)t = 5.0t$ m/s

At t = 0 s: v = 0 m/s

At t = 2 s: v = 10 m/s

🏃 Speed vs Velocity:

Speed	Velocity
Scalar quantity	Vector quantity
Always positive	Can be positive or negative
Distance / Time	Displacement / Time
Average speed ≥ |Average velocity|	Can be zero even when speed is not
Instantaneous speed = |v|	Magnitude of velocity vector

💡 Key Point:

Instantaneous speed is ALWAYS equal to the **magnitude of instantaneous velocity**.

However, **average speed** is generally GREATER than or equal to the **magnitude of average velocity**.

🚀 ACCELERATION - RATE OF CHANGE OF VELOCITY

📊 Average Acceleration:

Average Acceleration ($\bar{a}$):

$$\bar{a} = \Delta v / \Delta t = (v_2 - v_1) / (t_2 - t_1)$$

Change in velocity per unit time.

Unit: m/s^2 (meter per second squared)

It's a VECTOR - has both magnitude and direction

⚡ Instantaneous Acceleration:

Instantaneous Acceleration (a):

$$a = \lim_{\Delta t \to 0} \Delta v/\Delta t = dv/dt$$

Acceleration at a particular instant of time.

Graphically: **Slope of tangent** to velocity-time graph at that instant.

🎯 Understanding Acceleration:

- **Positive acceleration:** Velocity increasing in positive direction OR velocity decreasing in negative direction (speeding up or slowing down less)
- **Negative acceleration:** Velocity decreasing in positive direction OR velocity increasing in negative direction (slowing down or speeding up in reverse)
- **Zero acceleration:** Velocity is constant (uniform motion)

⚠️ COMMON MISCONCEPTION:

Wrong Thinking: Negative acceleration always means slowing down.

Right Thinking: The sign of acceleration depends on the chosen positive direction!

Example:

- If upward is positive: gravity gives **$a = -9.8\ m/s^2$**
- A ball falling down is **speeding up** with **negative acceleration**
- A ball thrown up is **slowing down** with same **negative acceleration**

📈 GRAPHICAL REPRESENTATION OF MOTION

1️⃣ Position-Time (x-t) Graph:

Key Points:

- **Slope of x-t graph = Velocity**
- Steeper slope → Higher velocity
- Horizontal line → Object at rest (v = 0)
- Straight line → Uniform velocity
- Curved line → Non-uniform velocity (acceleration present)

Types of x-t Graphs:

Graph Shape	Motion Type	Acceleration
Straight line (slope > 0)	Uniform motion in +ve direction	a = 0
Curve opening upward	Accelerated motion	a > 0 (positive)
Curve opening downward	Decelerated motion	a < 0 (negative)
Horizontal line	Object at rest	a = 0, v = 0

2️⃣ Velocity-Time (v-t) Graph:

Key Points:

- **Slope of v-t graph = Acceleration**
- **Area under v-t graph = Displacement**
- Horizontal line → Uniform velocity (a = 0)
- Straight line with slope → Uniform acceleration
- Curved line → Non-uniform acceleration

Important Cases:

- **Line above time axis:** Motion in positive direction
- **Line below time axis:** Motion in negative direction
- **Line crosses time axis:** Object reverses direction
- **Positive slope:** Positive acceleration
- **Negative slope:** Negative acceleration

💡 Area Under v-t Graph:

Displacement = Area under v-t curve

For Uniform Velocity:

Area = Rectangle = $v \times t$

For Uniform Acceleration:

Area = Rectangle + Triangle

$= v_0t + \frac{1}{2}(v - v_0)t$

$= \frac{1}{2}(v + v_0)t$

3️⃣ Acceleration-Time (a-t) Graph:

Key Points:

- **Area under a-t graph = Change in velocity**
- Horizontal line → Uniform acceleration
- Line above time axis → Positive acceleration
- Line below time axis → Negative acceleration

🎓 THE THREE KINEMATIC EQUATIONS

⭐ GOLDEN EQUATIONS OF MOTION ⭐

(Valid ONLY for uniform acceleration)

Equation 1:

$$v = v_0 + at$$

Relates: velocity, initial velocity, acceleration, time

Equation 2:

$$x = v_0 t + \frac{1}{2}at^2$$

Relates: displacement, initial velocity, acceleration, time

Equation 3:

$$v^2 = v_0^2 + 2ax$$

Relates: velocities, acceleration, displacement (no time!)

🎯 Variables in Equations:

- **v_0** = Initial velocity (at t = 0)
- **v** = Final velocity (at time t)
- **a** = Acceleration (constant)
- **t** = Time taken
- **x** = Displacement

If object starts from $x = x_0$:

Replace x by $(x - x_0)$ in all equations

📝 IMPORTANT DERIVATIONS FROM SYLLABUS:

📐 Derivation Using Calculus Method (NCERT Example 2.2)

Objective: Obtain equations of motion for constant acceleration using method of calculus.

Derivation 1: $v = v_0 + at$

Step 1: By definition of acceleration

$a = dv/dt$

Step 2: Separate variables

$dv = a\,dt$

Step 3: Integrate both sides

$\int_{v_0}^{v} dv = \int_{0}^{t} a\,dt$

Step 4: Since a is constant

$[v]_{v_0}^{v} = a\,[t]_{0}^{t}$

Step 5: Simplify

$v - v_0 = at$

∴ $v = v_0 + at$

Derivation 2: $x = x_0 + v_0t + \frac{1}{2}at^2$

Step 1: By definition of velocity

$v = dx/dt$

Step 2: We know $v = v_0 + at$, so

$dx/dt = v_0 + at$

Step 3: Separate variables

$dx = (v_0 + at)\, dt$

Step 4: Integrate both sides

$\int_{x_0}^{x} dx = \int_0^t (v_0 + at)\, dt$

Step 5: Simplify

$[x]_{x_0}^{x} = v_0[t]_0^t + \frac{1}{2}a[t^2]_0^t$

$x - x_0 = v_0 t + \frac{1}{2}at^2$

$\therefore x = x_0 + v_0 t + \frac{1}{2}at^2$

Derivation 3: $v^2 = v_0^2 + 2a(x - x_0)$

Step 1: We can write

$a = dv/dt = (dv/dx)(dx/dt) = v(dv/dx)$

Step 2: Separate variables

$v\, dv = a\, dx$

Step 3: Integrate both sides

$\int_{v_0}^{v} v\, dv = \int_{x_0}^{x} a\, dx$

Step 4: Since a is constant

$[v^2/2]_{v_0}^{v} = a[x]_{x_0}^{x}$

Step 5: Simplify

$(v^2 - v_0^2)/2 = a(x - x_0)$

$$\therefore v^2 = v_0^2 + 2a(x - x_0)$$

🎯 Advantages of Calculus Method:

- ✓ Can be used for non-uniform acceleration also
- ✓ More rigorous and general approach
- ✓ Provides deeper understanding of motion
- ✓ Important for JEE/NEET preparation

🔢 GALILEO'S LAW OF ODD NUMBERS (NCERT Example 2.5)

Statement: "The distances traversed, during equal intervals of time, by a body falling from rest, stand to one another in the same ratio as the odd numbers beginning with unity [namely, 1 : 3 : 5 : 7 : 9 ...]."

Proof:

Step 1: For an object falling from rest ($v_0 = 0$)

Position at time t: $y = -\frac{1}{2}gt^2$

Step 2: Divide time into equal intervals τ

Let's find positions at times: 0, τ, 2τ, 3τ, 4τ, 5τ...

Step 3: Calculate positions and distances

Time	Position y	Distance in interval	Ratio
0	0	-	-
τ	$-\frac{1}{2}g\tau^2$	$\frac{1}{2}g\tau^2 = y_0$	1
2τ	$-\frac{1}{2}g(2\tau)^2 = -2g\tau^2$	$3(\frac{1}{2}g\tau^2) = 3y_0$	3
3τ	$-\frac{1}{2}g(3\tau)^2 = -9/2\ g\tau^2$	$5(\frac{1}{2}g\tau^2) = 5y_0$	5
4τ	$-\frac{1}{2}g(4\tau)^2 = -8g\tau^2$	$7(\frac{1}{2}g\tau^2) = 7y_0$	7
5τ	$-\frac{1}{2}g(5\tau)^2 = -25/2\ g\tau^2$	$9(\frac{1}{2}g\tau^2) = 9y_0$	9

Step 4: General formula

Distance in nth interval = $(2n - 1) \times y_0$

where $y_0 = \frac{1}{2}g\tau^2$ (distance in first interval)

Ratio = 1 : 3 : 5 : 7 : 9 : 11 : ...

📚 Historical Importance:

This law was established by Galileo Galilei (1564-1642), who was the first to make quantitative studies of free fall. This was a revolutionary discovery as it contradicted Aristotle's belief that heavier objects fall faster than lighter ones.

💡 Which Equation to Use?

Given/Unknown	Use Equation
Time not given/needed	$v^2 = v_0^2 + 2ax$
Final velocity not needed	$x = v_0t + \frac{1}{2}at^2$
Displacement not needed	$v = v_0 + at$
Find time when v is known	$v = v_0 + at$
Find v when x is known	$v^2 = v_0^2 + 2ax$

SOLVED EXAMPLES - STEP BY STEP

Example 1: Basic Application

Problem: A car accelerates uniformly from 18 km/h to 36 km/h in 5 seconds. Find (a) acceleration, (b) distance covered.

Solution:

Step 1: Convert to SI units

$v_0 = 18$ km/h $= 18 \times (5/18) = 5$ m/s

$v = 36$ km/h $= 36 \times (5/18) = 10$ m/s

$t = 5$ s

Step 2: Find acceleration

Using: $v = v_0 + at$

$10 = 5 + a(5)$

$5 = 5a$

$a = 1$ m/s²

Step 3: Find distance

Using: $x = v_0 t + \frac{1}{2}at^2$

$x = 5(5) + \frac{1}{2}(1)(5)^2$

$x = 25 + 12.5$

$x = 37.5$ m

Example 2: Ball Thrown Upward

Problem: A ball is thrown vertically upward with velocity 20 m/s from top of a building 25 m high. Find: (a) maximum height reached, (b) time to hit ground. (g = 10 m/s²)

Solution:

Taking upward as positive direction:

$v_0 = +20$ m/s, $a = -g = -10$ m/s²

(a) Maximum height from launch point:

At maximum height: $v = 0$

Using: $v^2 = v_0^2 + 2ax$

$0 = (20)^2 + 2(-10)x$

$0 = 400 - 20x$

$x = 20$ m

Maximum height from ground = 25 + 20 = **45 m**

(b) Time to hit ground:

Total displacement from launch = -25 m (downward)

Using: $x = v_0t + \frac{1}{2}at^2$

$-25 = 20t + \frac{1}{2}(-10)t^2$

$-25 = 20t - 5t^2$

$5t^2 - 20t - 25 = 0$

$t^2 - 4t - 5 = 0$

$(t - 5)(t + 1) = 0$

$t = 5$ s (taking positive value)

Example 3: Two-Part Motion

Problem: A car moving at 10 m/s accelerates at 2 m/s² for 4 seconds, then decelerates at 3 m/s² till it stops. Find total distance.

Solution:

Part 1: Acceleration phase

$v_0 = 10$ m/s, $a = 2$ m/s², $t = 4$ s

$v = v_0 + at = 10 + 2(4) = 18$ m/s

$x_1 = v_0t + \frac{1}{2}at^2 = 10(4) + \frac{1}{2}(2)(4)^2$

$x_1 = 40 + 16 =$ **56 m**

Part 2: Deceleration phase

$v_0 = 18$ m/s, $v = 0$, $a = -3$ m/s²

Using: $v^2 = v_0^2 + 2ax$

$0 = (18)^2 + 2(-3)x_2$

$0 = 324 - 6x_2$

$x_2 =$ **54 m**

Total distance = 56 + 54 = 110 m

🌍 FREE FALL - MOTION UNDER GRAVITY

🎯 What is Free Fall?

When an object falls under the influence of gravity alone (neglecting air resistance), it is said to be in **free fall**.

Key Points:

- Acceleration due to gravity: **$g = 9.8\ m/s^2 \approx 10\ m/s^2$**
- Direction: Always **downward** (towards Earth's center)
- It's a case of **uniformly accelerated motion**
- All objects fall with same acceleration (in vacuum)

📝 Equations for Free Fall:

Taking downward as POSITIVE:

$$v = v_0 + gt$$

$$y = v_0 t + \frac{1}{2}gt^2$$

$$v^2 = v_0^2 + 2gy$$

Taking upward as POSITIVE:

$$v = v_0 - gt$$

$$y = v_0 t - \frac{1}{2}gt^2$$

$$v^2 = v_0^2 - 2gy$$

Example: Object Dropped from Rest

Problem: A stone is dropped from 80 m height. Find: (a) time to reach ground, (b) velocity on hitting ground. ($g = 10\ m/s^2$)

Solution:

Taking downward as positive:

$v_0 = 0$, $a = g = 10\ m/s^2$, $y = 80\ m$

(a) Time to reach ground:

$y = v_0 t + \frac{1}{2}gt^2$

$80 = 0 + \frac{1}{2}(10)t^2$

$80 = 5t^2$

$t^2 = 16$

$t = 4\ s$

(b) Final velocity:

$v = v_0 + gt = 0 + 10(4)$

$v = 40\ m/s$

Or using: $v^2 = v_0^2 + 2gy$

$v^2 = 0 + 2(10)(80) = 1600$

$v = 40\ m/s$

🎓 GALILEO'S LAW OF ODD NUMBERS

📜 Historical Discovery:

Statement: "The distances traversed during equal intervals of time by a body falling from rest stand to one another in the same ratio as the odd numbers beginning with unity [1 : 3 : 5 : 7 : 9 ...]"

Proof:

Let object fall for equal time intervals τ each.

Position after time $n\tau$: $y = \frac{1}{2}g(n\tau)^2$

Time	Position	Distance in interval	Ratio
0	0	-	-
τ	$\frac{1}{2}g\tau^2$	$\frac{1}{2}g\tau^2$	1
2τ	$4(\frac{1}{2}g\tau^2) = 2g\tau^2$	$3(\frac{1}{2}g\tau^2)$	3
3τ	$9(\frac{1}{2}g\tau^2) = 4.5g\tau^2$	$5(\frac{1}{2}g\tau^2)$	5
4τ	$16(\frac{1}{2}g\tau^2) = 8g\tau^2$	$7(\frac{1}{2}g\tau^2)$	7

Distances in successive equal time intervals = 1 : 3 : 5 : 7 : ...

🚗 PRACTICAL APPLICATIONS

1️⃣ Stopping Distance:

🛑 What is Stopping Distance?

The distance a vehicle travels before coming to complete stop after brakes are applied.

Formula:

Using $v^2 = v_0^2 + 2ax$ where $v = 0$ (stops)

$0 = v_0^2 + 2(-a)ds$

$ds = v_0^2 / (2a)$

Key Insight: Stopping distance ∝ (Initial velocity)²

If you double the speed, stopping distance becomes **4 times**!

Example: Car Braking

A car moving at 126 km/h is brought to stop in 200 m. Find: (a) deceleration, (b) time to stop.

Solution:

$v_0 = 126$ km/h $= 126 \times (5/18) = 35$ m/s

$v = 0$, $x = 200$ m

(a) Deceleration:

$v^2 = v_0^2 + 2ax$

$0 = (35)^2 + 2a(200)$

$0 = 1225 + 400a$

$a = -1225/400 =$ **-3.06 m/s²**

(b) Time to stop:

$v = v_0 + at$

$0 = 35 + (-3.06)t$

$t = 11.4$ s

2️⃣ Reaction Time:

⏱️ What is Reaction Time?

The time taken by a person to observe, think, and act in response to a situation.

Typical values:

- Simple reaction: 0.15 - 0.3 s
- Complex reaction: 0.5 - 1.0 s

Measurement: Ruler drop experiment

If ruler falls distance d before catching:

$d = \frac{1}{2}gt^2$ (starting from rest)

Reaction time $t = \sqrt{2d/g}$

Example: Ruler Drop

A ruler drops 21 cm before being caught. Find reaction time. ($g = 9.8\ m/s^2$)

Solution:

$d = 21\ cm = 0.21\ m$

$t = \sqrt{2d/g} = \sqrt{2 \times 0.21 / 9.8}$

$t = \sqrt{0.42 / 9.8} = \sqrt{0.0429}$

$t \approx 0.21\ s$

⚠️ COMMON MISTAKES TO AVOID

❌ MISTAKE 1: Sign Convention Errors

Wrong: Always taking $g = +9.8\ m/s^2$

Right: Sign depends on chosen positive direction!

- If upward is +ve: $g = -9.8\ m/s^2$
- If downward is +ve: $g = +9.8\ m/s^2$

❌ MISTAKE 2: Using Equations When Acceleration is Not Constant

Wrong: Using $v = v_0 + at$ when acceleration varies

Right: These equations work ONLY for constant acceleration!

❌ MISTAKE 3: Confusing Distance and Displacement

Wrong: Using distance in equations

Right: Kinematic equations use **displacement**, not distance!

Example: If you go 10 m forward and 5 m back:

- Distance = 15 m
- Displacement = 5 m (use this in equations!)

❌ MISTAKE 4: Zero Velocity Means Zero Acceleration

Wrong: At highest point of projectile, $v = 0$ so $a = 0$

Right: Velocity can be zero while acceleration is non-zero!

Example: Ball at highest point has $v = 0$ but $a = -g \neq 0$

❌ MISTAKE 5: Not Converting Units

Wrong: Using km/h directly in equations

Right: Always convert to SI units (m/s)!

Conversion: km/h to m/s → multiply by 5/18

Example: 36 km/h = 36 × (5/18) = 10 m/s

📚 CASE STUDY BASED QUESTIONS

Case Study 1: Metro Train Motion Analysis

Background: The Delhi Metro operates on a computerized system that controls acceleration and braking to ensure passenger safety and comfort. A particular metro line between two stations follows a specific motion pattern for efficient operation.

Given Information:

- Distance between stations: 2.4 km
- Maximum speed: 80 km/h
- Acceleration phase: Train accelerates uniformly from rest to maximum speed
- Constant speed phase: Train maintains maximum speed
- Deceleration phase: Train decelerates uniformly to rest
- Acceleration rate: 1.25 m/s^2
- Deceleration rate: 1.0 m/s^2

Questions:

Q1. What is the maximum speed of the metro in SI units?

(a) 20 m/s
(b) 22.22 m/s ✓
(c) 25 m/s
(d) 80 m/s

Answer: (b) 22.22 m/s

Explanation: v = 80 km/h = 80 × (5/18) = 400/18 = 22.22 m/s

Q2. How much time does the train take to reach maximum speed from rest?

(a) 16.67 s
(b) 17.78 s ✓
(c) 20 s
(d) 22.22 s

Answer: (b) 17.78 s

Explanation: Using $v = v_0 + at$
$22.22 = 0 + 1.25 \times t$
$t = 22.22 / 1.25 = 17.78$ s

Q3. What distance does the train cover during acceleration?

(a) 197.5 m ✓
(b) 200 m
(c) 222 m
(d) 246.9 m

Answer: (a) 197.5 m

Explanation: Using $v^2 = v_0^2 + 2ax$:
$(22.22)^2 = 0 + 2 \times 1.25 \times x$
$x = 493.73 / 2.5 = 197.5$ m

Q4. If the train needs to stop with deceleration 1.0 m/s^2, what distance will it cover during braking?

(a) 222 m
(b) 246.9 m ✓
(c) 197.5 m
(d) 200 m

Answer: (b) 246.9 m

Explanation: Using $v^2 = v_0^2 + 2ax$
$0 = (22.22)^2 + 2 \times (-1.0) \times x$
$2x = 493.73$
$x = 246.9$ m

Case Study 2: Traffic Safety - Reaction Time and Stopping Distance

Background: Road safety depends on understanding stopping distance, which consists of two parts: (1) reaction distance (distance traveled during driver's reaction time before applying brakes) and (2) braking distance (distance traveled while braking).

Given Information:

- A car is traveling at 60 km/h on a city road
- Average human reaction time: 0.75 seconds
- Maximum deceleration on dry road: 7.5 m/s^2
- Maximum deceleration on wet road: 3.75 m/s^2
- A child suddenly appears 30 m ahead

Questions:

Q1. What is the reaction distance (distance covered during reaction time)?

(a) 10 m
(b) 12.5 m ✓
(c) 15 m
(d) 16.67 m

Answer: (b) 12.5 m

Explanation: v = 60 km/h = 16.67 m/s
Reaction distance = v × t = 16.67 × 0.75 = 12.5 m

Q2. What is the braking distance on a dry road?

(a) 16.67 m
(b) 18.52 m ✓
(c) 20 m
(d) 25 m

Answer: (b) 18.52 m

Explanation: Using $v^2 = v_0^2 + 2ax$

$0 = (16.67)^2 + 2 \times (-7.5) \times x$

$15x = 277.89$

$x = 18.52$ m

Q3. What is the total stopping distance on a dry road?

(a) 29.17 m
(b) 31.02 m ✓
(c) 33 m
(d) 35 m

Answer: (b) 31.02 m

Explanation: Total = Reaction distance + Braking distance = 12.5 + 18.52 = 31.02 m

Q4. Will the car be able to stop before hitting the child on a dry road?

(a) No, as stopping distance is more than 30 m ✓
(b) Yes, as stopping distance is less than 30 m
(c) Exactly stops at 30 m
(d) Cannot be determined

Answer: (a) No

Explanation: Total stopping distance = 31.02 m > 30 m. This demonstrates why speed limits are crucial in residential areas!

Case Study 3: Rocket Launch - Vertical Motion

Background: ISRO's PSLV follows a carefully planned trajectory during launch. The initial phase involves vertical motion with varying acceleration. For simplification, we'll analyze the first phase assuming constant acceleration.

Given Information:

- Rocket starts from rest
- Acceleration during first phase: 25 m/s^2 upward
- Duration of first phase: 8 seconds
- After first phase, engines shut down for 2 seconds (free fall)
- Take $g = 10 \text{ m/s}^2$ downward

Questions:

Q1. What velocity does the rocket achieve at the end of the first phase?

(a) 150 m/s
(b) 180 m/s
(c) 200 m/s ✓
(d) 225 m/s

Answer: (c) 200 m/s

Explanation: Using $v = v_0 + at$
$v = 0 + 25 \times 8 = 200$ m/s

Q2. What altitude does the rocket reach at the end of first phase?

(a) 600 m
(b) 800 m ✓
(c) 1000 m
(d) 1200 m

Answer: (b) 800 m

Explanation: Using $x = v_0t + \frac{1}{2}at^2$
$x = 0 + \frac{1}{2} \times 25 \times 64 = 800$ m

Q3. During the 2-second free fall phase (engines off), what is the net acceleration?

(a) 0 m/s^2
(b) -10 m/s^2 ✓
(c) 25 m/s^2
(d) 15 m/s^2

Answer: (b) -10 m/s^2

Explanation: When engines are off, only gravity acts. $a = -g = -10$ m/s^2

Q4. What is the velocity of the rocket at the end of the free fall phase?

(a) 160 m/s
(b) 170 m/s
(c) 180 m/s ✓
(d) 190 m/s

Answer: (c) 180 m/s

Explanation: Using $v = v_0 + at$
$v = 200 + (-10) \times 2 = 180$ m/s

Case Study 4: Sports Physics - Sprinter's Performance

Background: Olympic sprinters are studied using high-speed cameras. A 100m sprint race can be divided into three phases: acceleration phase, maximum velocity phase, and slight deceleration phase.

Given Information:

- An athlete starts from rest
- Acceleration phase: 0-30m with acceleration 3.5 m/s^2
- Constant speed phase: 30m-95m at maximum speed
- Slight deceleration: 95m-100m with deceleration 0.5 m/s^2

Questions:

Q1. What is the maximum speed reached at the end of acceleration phase?

(a) 12.5 m/s
(b) 13.2 m/s
(c) 14.49 m/s ✓
(d) 15 m/s

Answer: (c) 14.49 m/s

Explanation: Using $v^2 = v_0^2 + 2ax$
$v^2 = 0 + 2 \times 3.5 \times 30 = 210$
$v = \sqrt{210} = 14.49$ m/s

Q2. How much time does the athlete take during the acceleration phase?

(a) 3.85 s
(b) 4.14 s ✓
(c) 4.5 s
(d) 5 s

Answer: (b) 4.14 s

Explanation: Using $v = v_0 + at$
$14.49 = 0 + 3.5 \times t$

t = 4.14 s

Q3. What time does the athlete take to cover the constant speed phase (30m to 95m)?

(a) 4.23 s
(b) 4.49 s ✓
(c) 4.75 s
(d) 5 s

Answer: (b) 4.49 s

Explanation: Distance = 65 m
Time = 65 / 14.49 = 4.49 s

Q4. What is the approximate final speed at the finish line?

(a) 14.14 m/s ✓
(b) 14.49 m/s
(c) 14 m/s
(d) 13.5 m/s

Answer: (a) 14.14 m/s

Explanation: Using $v^2 = v_0^2 + 2ax$
$v^2 = (14.49)^2 + 2 \times (-0.5) \times 5$
$v^2 = 209.96 - 5 = 204.96$
$v \approx 14.14$ m/s

🎯 MOST EXPECTED EXAM QUESTIONS

📌 Question Pattern Analysis:

- ✓ MCQs (1 mark): 2-3 questions from this chapter
- ✓ VSAQs (2 marks): 1-2 questions
- ✓ SAQs (3 marks): 1-2 questions
- ✓ Case Studies (4-5 marks): 1 case study with 4 subquestions
- ✓ Numericals (3-5 marks): 2-3 problems
- ✓ Graph-based questions (3-5 marks): 1-2 questions

Section A: Multiple Choice Questions (1 mark each)

Q1. A body moves with uniform velocity. Which statement is true?

(a) Its speed changes with time
(b) Its acceleration is zero ✓
(c) Its velocity changes direction
(d) It has non-uniform acceleration

Answer: (b) Uniform velocity means constant velocity, so $a = 0$

Q2. The area under velocity-time graph represents:

(a) Velocity
(b) Acceleration
(c) Displacement ✓
(d) Speed

Answer: (c) Area under v-t curve = displacement

Q3. A particle is thrown vertically upward. At the highest point:

(a) Both velocity and acceleration are zero
(b) Velocity is zero but acceleration is not zero ✓
(c) Velocity is not zero but acceleration is zero
(d) Both are maximum

Answer: (b) At highest point, $v = 0$ but $a = -g \neq 0$

Q4. Which equation should be used when time is not given?

(a) $v = v_0 + at$
(b) $x = v_0t + \frac{1}{2}at^2$
(c) $v^2 = v_0^2 + 2ax$ ✓
(d) $x = vt$

Answer: (c) $v^2 = v_0^2 + 2ax$ doesn't contain time

Section B: Very Short Answer Questions (2 marks each)

Q5. Can speed ever be negative? Can velocity be negative? Explain.

Answer: Speed cannot be negative as it is the magnitude of velocity. Velocity can be negative depending on the chosen positive direction.

Q6. Under what condition is the magnitude of average velocity equal to average speed?

Answer: When the particle moves in a straight line in one direction only (no change in direction). In this case, total path length = |Displacement|.

Q7. What does a horizontal line parallel to the time axis indicate in an x-t graph?

Answer: It indicates the particle is at rest. Velocity = slope of x-t graph = 0.

Section C: Short Answer Questions (3 marks each)

Q8. Derive $x = v_0t + \frac{1}{2}at^2$ using graphical method.

Answer: Displacement = Area under v-t curve

= Area of rectangle OACD + Area of triangle ABC

$= v_0 \times t + \frac{1}{2} \times t \times (v - v_0)$

$= v_0t + \frac{1}{2} \times t \times at$

$= v_0t + \frac{1}{2}at^2$

Q9. A car accelerates from 5 m/s to 15 m/s in 5 seconds. Find acceleration and distance covered.

Answer:

Given: $v_0 = 5$ m/s, $v = 15$ m/s, $t = 5$ s

Acceleration: $v = v_0 + at$

$15 = 5 + a(5)$

$a = 2$ m/s²

Distance: $x = v_0t + \frac{1}{2}at^2$

$x = 5(5) + \frac{1}{2}(2)(25)$

$x = 25 + 25 = 50$ m

🚀 QUICK REVISION CHECKLIST

✅ Before Exam, Make Sure You Know:

📚 Definitions:

- ☑ Motion, rectilinear motion, kinematics
- ☑ Position, displacement, distance
- ☑ Average velocity vs instantaneous velocity
- ☑ Speed vs velocity
- ☑ Average acceleration vs instantaneous acceleration
- ☑ Free fall motion

📏 Formulas to Memorize:

- ☑ $v = v_0 + at$
- ☑ $x = v_0 t + \frac{1}{2}at^2$
- ☑ $v^2 = v_0^2 + 2ax$
- ☑ Average velocity = $\Delta x / \Delta t$
- ☑ Instantaneous velocity = dx/dt
- ☑ Instantaneous acceleration = dv/dt
- ☑ Stopping distance = $v_0^2 / (2a)$
- ☑ Reaction time from drop = $\sqrt{(2d/g)}$

📊 Graphical Concepts:

- ☑ Slope of x-t graph = velocity
- ☑ Slope of v-t graph = acceleration
- ☑ Area under v-t graph = displacement
- ☑ Area under a-t graph = change in velocity
- ☑ How to identify uniform/non-uniform motion from graphs

🎯 Key Concepts:

- ☑ Sign convention for motion
- ☑ When to use which kinematic equation
- ☑ Difference between instantaneous and average quantities
- ☑ Acceleration due to gravity = 9.8 m/s^2 (or 10 m/s^2)
- ☑ All bodies fall with same acceleration (neglecting air resistance)
- ☑ Galileo's law of odd numbers: 1:3:5:7...

💡 Problem-Solving Skills:

- ☑ Always convert to SI units first
- ☑ Choose proper sign convention and stick to it
- ☑ Identify what's given and what's to be found
- ☑ Select appropriate equation
- ☑ Practice at least 10 numerical problems

💡 EXPERT TIPS FOR SCORING FULL MARKS

🎯 How to Score 100% in Motion in a Straight Line:

1. Master Sign Conventions:

- Choose your positive direction at the start
- Write it clearly in the solution
- Stick to it throughout the problem
- Mark the sign of each quantity correctly

2. Equation Selection Strategy:

- List what's given and what's unknown
- Count: you need equation with those variables
- If time is not involved, use $v^2 = v_0^2 + 2ax$
- If finding time with known velocities, use $v = v_0 + at$

3. Graph Problems:

- Always mark what the slopes and areas represent
- Read values carefully from axes
- For finding velocity: draw tangent and find slope
- For finding displacement: calculate area under curve

4. Free Fall Problems:

- Always take $g = 9.8\ m/s^2$ (or $10\ m/s^2$ if mentioned)
- For upward motion: v decreases
- At highest point: $v = 0$ (but $a \neq 0$!)
- Time up = Time down (for same heights)

5. Unit Conversion Shortcuts:

- km/h to m/s: multiply by 5/18

- m/s to km/h: multiply by 18/5
- Always double-check conversions
- Write final answer with correct units

6. Two-Part Motion Problems:

- Divide the motion into parts
- Apply equations separately for each part
- Final velocity of part 1 = Initial velocity of part 2
- Add displacements/times appropriately

7. Common Board Exam Questions:

- Derive kinematic equations (5 marks)
- Graph interpretation (3-4 marks)
- Ball thrown up/down problems (3-5 marks)
- Stopping distance/reaction time (2-3 marks)
- Two vehicles meeting/overtaking (5 marks)

8. Time Management:

- Definitions: 1 minute per mark
- Derivations: 5-7 minutes
- Numericals: 3-5 minutes each
- Graph problems: 4-6 minutes

📝 IMPORTANT FORMULAS AT A GLANCE

🔢 Complete Formula Sheet:

Basic Definitions:

• Average velocity: $\bar{v} = \Delta x / \Delta t$

• Instantaneous velocity: $v = dx/dt$

• Average acceleration: $\bar{a} = \Delta v / \Delta t$

• Instantaneous acceleration: $a = dv/dt$

Kinematic Equations (Constant Acceleration):

• $v = v_0 + at$

• $x = v_0 t + \frac{1}{2}at^2$

• $v^2 = v_0^2 + 2ax$

• $x = \frac{1}{2}(v + v_0)t$ (average velocity form)

Free Fall (Taking downward as positive):

• $v = v_0 + gt$

• $h = v_0 t + \frac{1}{2}gt^2$

• $v^2 = v_0^2 + 2gh$

Special Cases:

• Object dropped from rest: $v_0 = 0$

→ $v = gt$, $h = \frac{1}{2}gt^2$, $v^2 = 2gh$

• Object at highest point: $v = 0$

→ Time to reach = v_0/g

→ Max height = $v_0^2/(2g)$

Practical Formulas:

• Stopping distance: $d_s = v_0^2/(2a)$

• Reaction time: $t = \sqrt{2d/g}$

Conversions:

• km/h to m/s: multiply by 5/18

• m/s to km/h: multiply by 18/5

🎓 SAMPLE EXAM QUESTIONS WITH ANSWERS

Q1. Define: (1 mark each)

1. **Motion:** Change in position of an object with time.
2. **Instantaneous velocity:** Velocity at a particular instant, $v = dx/dt$.
3. **Uniform acceleration:** Motion with constant acceleration.
4. **Free fall:** Motion under gravity alone, neglecting air resistance.

Q2. Derive: $v^2 = v_0^2 + 2ax$ (3 marks)

Answer:

We know: $v = v_0 + at$ ... (1)

And: $x = \frac{1}{2}(v + v_0)t$ ... (2)

From (1): $t = (v - v_0)/a$

Substituting in (2):

$x = \frac{1}{2}(v + v_0) \times (v - v_0)/a$

$x = (v^2 - v_0^2)/(2a)$

$\mathbf{v^2 = v_0^2 + 2ax}$

Q3. A car accelerates from 5 m/s to 15 m/s in 5 seconds. Find acceleration and distance covered. (3 marks)

Answer:

Given: $v_0 = 5$ m/s, $v = 15$ m/s, $t = 5$ s

Acceleration: $v = v_0 + at$

$15 = 5 + a(5)$

$a = 10/5 =$ **$2\ m/s^2$**

Distance: $x = v_0 t + \frac{1}{2}at^2$

$x = 5(5) + \frac{1}{2}(2)(5)^2$

$x = 25 + 25 =$ **50 m**

Q4. Distinguish between average velocity and instantaneous velocity. (3 marks)

Answer:

Average Velocity	Instantaneous Velocity
Over a time interval	At a particular instant
$\bar{v} = \Delta x / \Delta t$	$v = dx/dt$
Slope of chord on x-t graph	Slope of tangent on x-t graph

🏆 FINAL SUCCESS MANTRA

🌟 Remember These Points:

- ✨ This chapter is FORMULA-BASED - memorize all 3 equations!
- ✨ Sign convention is CRITICAL - choose and stick to it
- ✨ Practice graph problems - easy marks if you know slopes/areas
- ✨ Free fall questions are very common - master them
- ✨ Always show proper steps - even if answer is wrong, you get partial marks
- ✨ Unit conversion mistakes cost marks - double check!
- ✨ Solve at least 20 numerical problems before exam

💪 YOU'VE GOT THIS!

"Motion is Fundamental - Master This, Master Physics!"

📚 Study Material Information

This comprehensive study material has been prepared following the latest CBSE curriculum and examination pattern for Class 11 Physics. The content includes detailed explanations, important derivations from NCERT, case study based questions aligned with the current exam format, and practice questions to help students achieve excellence in their board examinations.

Key Features:

- Complete topic coverage with conceptual clarity
- Step-by-step solved derivations using calculus method
- Case study questions with detailed solutions
- Galileo's law of odd numbers with proof
- Practice questions with detailed solutions
- Exam tips and scoring strategies
- Quick revision checklists
- Graphical analysis and interpretations