# CLASS 11 PHYSICS: KINEMATICS

## Premium CBSE Board Study Material with Complete Derivations

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## MODULE 1: INTRODUCTION & BASIC CONCEPTS

### What is Kinematics?

**Definition:** The branch of mechanics that describes the motion of objects without considering the forces causing the motion.

**Key Point:** Kinematics tells us "**HOW**" objects move, but NOT "**WHY**" they move. The "WHY" part belongs to dynamics (Newton's laws).

### Frame of Reference

- **Definition:** A coordinate system with respect to which position, displacement, velocity, and acceleration are measured.
- **Inertial Frame:** A frame of reference where Newton's laws are valid (non-accelerating frame)

- **Point Mass:** An object whose dimensions are negligible compared to the distances involved in the problem

**BOARD EXAM TIP:** Always establish your frame of reference FIRST. Questions often test this concept through relative motion problems.

**Sign Convention (Very Important!)**

- **Positive Direction:** Right, Up, or Forward (choose one consistently)
- **Negative Direction:** Left, Down, or Backward
- Always maintain consistency throughout a single problem

**For Vertical Motion (Standard Convention):**

- Upward direction: Positive
- Downward direction: Negative
- Acceleration due to gravity: $g = -10\ m/s^2$ (when up is positive)

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## MODULE 2: DISPLACEMENT, DISTANCE, AND VELOCITY

### 2.1 Distance vs. Displacement

| Aspect | Distance | Displacement |
|---|---|---|
| **Definition** | Total length of actual path traveled | Straight-line distance between initial and final positions |
| **Physical Quantity** | Scalar (magnitude only) | Vector (magnitude + direction) |
| **Symbol** | S (without arrow) | $\vec{s}$ or $\Delta x$ |
| **Value** | Always positive or zero | Can be positive, negative, or zero |
| **Depends on** | Actual path taken | Only initial and final positions |
| **Example** | Person walks 3m East, then 4m West. Distance = 7m | Displacement = 1m West (or -1m East) |

**Mathematical Relation:**

$$\text{Distance} \geq |\text{Displacement}|$$

They are equal ONLY when motion is in one direction without reversal.

### 2.2 Speed and Velocity

**Speed (Scalar Quantity)**

- **Average Speed:**

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

- **Instantaneous Speed:** Speed at a particular instant (magnitude of instantaneous velocity)

$$v_{inst} = \left|\frac{ds}{dt}\right|$$

- **Always positive or zero**

**Velocity (Vector Quantity)**

- **Average Velocity:**

$$\vec{v}_{avg} = \frac{\vec{s}}{t} = \frac{\text{Displacement}}{\text{Time}}$$

- **Instantaneous Velocity:**

$$\vec{v} = \lim_{\Delta t \to 0} \frac{\Delta \vec{s}}{\Delta t} = \frac{d\vec{s}}{dt}$$

- Can be positive, negative, or zero

**CRITICAL INSIGHT FOR CBSE:**For uniform acceleration:

$$\text{Average Velocity} = \frac{u+v}{2}$$

where u = initial velocity and v = final velocity.

This relationship is POWERFUL and frequently used in board exams!

### 2.3 Special Cases - Average Speed Formulas

**Case 1: Equal Distances at Different Speeds**

If a body travels equal distances $d$ at speeds $v_1$ and $v_2$:

**Derivation:**

- Time for first half: $t_1 = \frac{d}{v_1}$

- Time for second half: $t_2 = \frac{d}{v_2}$
- Total distance = $2d$
- Total time = $t_1 + t_2 = \frac{d}{v_1} + \frac{d}{v_2} = d\left(\frac{v_1+v_2}{v_1 v_2}\right)$

$$v_{avg} = \frac{\text{Total Distance}}{\text{Total Time}} = \frac{2d}{d\left(\frac{v_1+v_2}{v_1 v_2}\right)} = \frac{2v_1 v_2}{v_1 + v_2}$$

**This is the Harmonic Mean!**

**Case 2: Equal Time at Different Speeds**

If a body travels for equal time intervals $t$ at speeds $v_1$ and $v_2$:

**Derivation:**

- Distance in first interval: $s_1 = v_1 t$
- Distance in second interval: $s_2 = v_2 t$
- Total distance = $s_1 + s_2 = (v_1 + v_2)t$
- Total time = $2t$

$$v_{avg} = \frac{(v_1 + v_2)t}{2t} = \frac{v_1 + v_2}{2}$$

**This is the Arithmetic Mean!**

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# MODULE 3: ACCELERATION

### 3.1 Definition and Mathematical Expression

**Definition:** Rate of change of velocity with respect to time.

$$\vec{a} = \frac{d\vec{v}}{dt}$$

**Average Acceleration:**

$$\vec{a}_{avg} = \frac{\Delta\vec{v}}{\Delta t} = \frac{v_f - v_i}{t_f - t_i}$$

**Instantaneous Acceleration:**

$$\vec{a}_{inst} = \lim_{\Delta t \to 0} \frac{\Delta \vec{v}}{\Delta t} = \frac{d\vec{v}}{dt}$$

Since $\vec{v} = \frac{d\vec{s}}{dt}$, we can also write:

$$\vec{a} = \frac{d^2\vec{s}}{dt^2}$$

### 3.2 Types of Motion Based on Acceleration

| Type | Acceleration | Velocity | Example |
|---|---|---|---|
| **Uniform Motion** | a = 0 | Constant | Car on highway at steady speed |
| **Uniformly Accelerated** | a = constant ≠ 0 | Changes uniformly | Free fall under gravity |
| **Non-uniformly Accelerated** | a ≠ constant | Changes non-uniformly | Vehicle in traffic |

### 3.3 Important Concepts About Acceleration

**Vector Nature:**

- When $\vec{v}$ and $\vec{a}$ are in **same direction:** Speed INCREASES
- When $\vec{v}$ and $\vec{a}$ are in **opposite directions:** Speed DECREASES

**Board Exam Insight:** At the highest point of a vertically thrown ball:

- Velocity = 0
- Acceleration = g (downward) ≠ 0
- This is why the ball doesn't remain suspended!

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## MODULE 4: EQUATIONS OF MOTION (COMPLETE DERIVATIONS)

**Conditions for Applicability:**

1. Acceleration must be constant
2. Motion must be in a straight line

### 4.1 FIRST EQUATION: v = u + at

**Derivation Method 1: Using Definition of Acceleration**

By definition:

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

Rearranging:

$$at = v - u$$

$$v = u + at \quad \boxed{\text{First Equation}}$$

**Derivation Method 2: Using Calculus**

$$a = \frac{dv}{dt}$$

$$dv = a\,dt$$

Integrating both sides:

$$\int_u^v dv = \int_0^t a\,dt$$

$$[v]_u^v = a[t]_0^t$$

$$v - u = at$$

$$v = u + at$$

**Physical Meaning:** Final velocity = Initial velocity + Change in velocity due to acceleration

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### 4.2 SECOND EQUATION: $s = ut + \frac{1}{2}at^2$

**Derivation Method 1: Using Average Velocity**

For uniformly accelerated motion:

$$\text{Average velocity} = \frac{u + v}{2}$$

Also:

$$\text{Average velocity} = \frac{s}{t}$$

Therefore:

$$\frac{s}{t} = \frac{u + v}{2}$$

$$s = \frac{(u + v)t}{2}$$

From first equation: $v = u + at$

Substituting:

$$s = \frac{u + (u + at)}{2} \times t$$

$$s = \frac{2u + at}{2} \times t$$

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

$$s = ut + \frac{1}{2}at^2 \quad \boxed{\text{Second Equation}}$$

**Derivation Method 2: Using Velocity-Time Graph**

Consider a v-t graph for uniformly accelerated motion:

- The graph is a straight line
- Displacement = Area under v-t graph

Area = Area of rectangle OABC + Area of triangle ABD

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

Since $v - u = at$:

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

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

**Derivation Method 3: Using Calculus**

$$v = \frac{ds}{dt}$$

From first equation: $v = u + at$

Therefore:

$$\frac{ds}{dt} = u + at$$

$$ds = (u + at)dt$$

Integrating:

$$\int_0^s ds = \int_0^t (u + at)dt$$

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

### 4.3 THIRD EQUATION: $v^2 = u^2 + 2as$

**Derivation Method 1: Eliminating Time**

From first equation:

$$v = u + at$$

$$t = \frac{v-u}{a} \quad \text{...(i)}$$

From second equation:

$$s = ut + \frac{1}{2}at^2 \quad \text{...(ii)}$$

Substituting (i) into (ii):

$$s = u\left(\frac{v-u}{a}\right) + \frac{1}{2}a\left(\frac{v-u}{a}\right)^2$$

$$s = \frac{u(v-u)}{a} + \frac{1}{2a} \times (v-u)^2$$

$$s = \frac{u(v-u)}{a} + \frac{(v-u)^2}{2a}$$

$$s = \frac{2u(v-u) + (v-u)^2}{2a}$$

$$s = \frac{(v-u)[2u + (v-u)]}{2a}$$

$$s = \frac{(v-u)(2u + v - u)}{2a}$$

$$s = \frac{(v-u)(u+v)}{2a}$$

$$2as = (v-u)(v+u) = v^2 - u^2$$

$$v^2 = u^2 + 2as \quad \boxed{\text{Third Equation}}$$

**Derivation Method 2: Using Calculus**

$$a = \frac{dv}{dt} = \frac{dv}{ds} \times \frac{ds}{dt} = \frac{dv}{ds} \times v$$

$$a = v\frac{dv}{ds}$$

$$a\,ds = v\,dv$$

Integrating:

$$\int_0^s a\,ds = \int_u^v v\,dv$$

$$as = \frac{v^2}{2} - \frac{u^2}{2}$$

$$2as = v^2 - u^2$$

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

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**4.4 FOURTH EQUATION: Distance in nth Second**

**Formula:**

$$S_n = u + \frac{a}{2}(2n - 1)$$

**Derivation:**

Distance covered in $n$ seconds:

$$S_n = un + \frac{1}{2}an^2 \quad \text{...(i)}$$

Distance covered in $(n - 1)$ seconds:

$$S_{n-1} = u(n - 1) + \frac{1}{2}a(n - 1)^2 \quad \text{...(ii)}$$

Distance in $n^{th}$ second = $S_n - S_{n-1}$

$$S_n = \left[un + \frac{1}{2}an^2\right] - \left[u(n - 1) + \frac{1}{2}a(n - 1)^2\right]$$

$$S_n = un + \frac{1}{2}an^2 - un + u - \frac{1}{2}a(n^2 - 2n + 1)$$

$$S_n = u + \frac{1}{2}an^2 - \frac{1}{2}a(n^2 - 2n + 1)$$

$$S_n = u + \frac{1}{2}a[n^2 - n^2 + 2n - 1]$$

$$S_n = u + \frac{a}{2}(2n - 1)$$

**Special Case:** When $u = 0$ (starting from rest):

$$S_n = \frac{a}{2}(2n - 1)$$

This gives the ratio: $S_1 : S_2 : S_3 : ... = 1 : 3 : 5 : 7 : ...$

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### 4.5 Summary of Equations with When to Use

| Equation | Use When | Best For |
|---|---|---|
| $v = u + at$ | Time is given or required | Finding final velocity with time |
| $s = ut + \frac{1}{2}at^2$ | Time is known | Finding displacement with time |
| $v^2 = u^2 + 2as$ | Time is NOT involved | Finding velocity without time |
| $S_n = u + \frac{a}{2}(2n - 1)$ | Distance in specific second needed | nth second problems |

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## MODULE 5: GRAPHICAL ANALYSIS OF MOTION

### 5.1 Position-Time (x-t) Graph

**Key Points:**

- **Slope = Velocity**
- **Positive slope:** Motion in positive direction
- **Negative slope:** Motion in negative direction
- **Zero slope (horizontal):** Object at rest
- **Curved graph:** Non-uniform velocity (acceleration present)

| Graph Shape | Motion | Velocity | Acceleration |
|---|---|---|---|
| Straight line (+ve slope) | Uniform, forward | Constant, positive | Zero |
| Straight line (-ve slope) | Uniform, backward | Constant, negative | Zero |
| Horizontal line | Stationary | Zero | Zero |
| Parabola (opening up) | Accelerated forward | Increasing | Positive |
| Parabola (opening down) | Decelerated | Decreasing | Negative |

**Mathematical Relation:**

$$v = \frac{dx}{dt} = \text{slope of x-t graph}$$

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### 5.2 Velocity-Time (v-t) Graph

**Key Points:**

- **Slope = Acceleration**
- **Area under curve = Displacement**
- **Area above time axis:** Positive displacement
- **Area below time axis:** Negative displacement

| Graph Feature | Physical Meaning |
|---|---|
| Horizontal line | Uniform motion (a = 0) |
| Straight line (+ve slope) | Uniform acceleration |
| Straight line (-ve slope) | Uniform deceleration |
| Curve | Non-uniform acceleration |
| Graph crosses time axis | Object changes direction (v = 0) |

**Mathematical Relations:**

$$a = \frac{dv}{dt} = \text{slope of v-t graph}$$

$$s = \int v\,dt = \text{area under v-t graph}$$

**Board Exam Example:** For uniformly accelerated motion from rest:

- Graph is a straight line from origin
- Slope = a
- Area of triangle = $\frac{1}{2} \times t \times v = \frac{1}{2}vt$ = displacement

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### 5.3 Acceleration-Time (a-t) Graph

**Key Points:**

- **Height = Acceleration value**
- **Area under curve = Change in velocity**

- Rarely appears in basic problems but important for variable acceleration

**Mathematical Relation:**

$$\Delta v = \int a\, dt = \text{area under a-t graph}$$

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## MODULE 6: RELATIVE MOTION

### 6.1 Fundamental Concept

**Definition:** Motion of one object as observed from another object.

All motion is relative! There is no absolute motion in nature.

### 6.2 Relative Velocity in One Dimension

**For two objects A and B:**

$$\vec{v}_{AB} = \vec{v}_A - \vec{v}_B$$

Where:

- $\vec{v}_{AB}$ = velocity of A relative to B
- $\vec{v}_A$ = velocity of A w.r.t. ground
- $\vec{v}_B$ = velocity of B w.r.t. ground

**Important Property:**

$$\vec{v}_{AB} = -\vec{v}_{BA}$$

### 6.3 Relative Motion in Two Dimensions

When objects move at angle $\theta$ to each other:

**Using Vector Subtraction:**

$$\vec{v}_{AB} = \vec{v}_A - \vec{v}_B$$

**Magnitude:**

$$|\vec{v}_{AB}| = \sqrt{v_A^2 + v_B^2 - 2v_A v_B \cos\theta}$$

**SPECIAL CASES (MUST REMEMBER):**

1. **Same direction** (θ = 0°): $$v_{AB} = |v_A - v_B|
2. **Opposite directions** (θ = 180°): $$v_{AB} = v_A + v_B
3. **Perpendicular** (θ = 90°): $$v_{AB} = \sqrt{v_A^2 + v_B^2}

### 6.4 Rain and River Problems

**Rain Problem:**If rain falls vertically with velocity $v_r$ and person moves horizontally with $v_p$:

- Relative velocity: $v_{rel} = \sqrt{v_r^2 + v_p^2}$
- Angle with vertical: $\tan\alpha = \frac{v_p}{v_r}$

**River Crossing (CBSE Favorite):**

**For shortest time:** Boat should head perpendicular to river current

$$T_{min} = \frac{d}{v_b}$$

where $d$ = width of river, $v_b$ = boat speed

**For shortest path (straight line):** Boat velocity component perpendicular to drift should equal current velocity

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## MODULE 7: PROJECTILE MOTION (WITH DERIVATIONS)

### 7.1 Fundamental Principles

**Definition:** Motion of an object under gravity alone (neglecting air resistance).

**Key Observations:**

1. Horizontal motion: Uniform (no acceleration)
2. Vertical motion: Uniformly accelerated (acceleration = -g)
3. Both motions are independent

### 7.2 Analysis of General Projectile

**Initial Conditions:**

- Velocity: $u$ at angle $\theta$ with horizontal
- Position: Origin (0, 0)

**Resolving initial velocity:**

- Horizontal component: $u_x = u\cos\theta$
- Vertical component: $u_y = u\sin\theta$

**Equations of Motion:**

**Horizontal:**

$$x = u\cos\theta \cdot t$$

**Vertical:**

$$y = u\sin\theta \cdot t - \frac{1}{2}gt^2$$

$$v_y = u\sin\theta - gt$$

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**7.3 TIME OF FLIGHT (Derivation)**

**Definition:** Total time the projectile remains in air.

**Derivation:**

At maximum height, vertical velocity = 0.

Time to reach maximum height:

$$v_y = u_y - gt$$

$$0 = u\sin\theta - gt_{max}$$

$$t_{max} = \frac{u\sin\theta}{g}$$

By symmetry, time to fall back = time to rise

$$T = 2t_{max} = \frac{2u\sin\theta}{g}$$

**Board Exam Formula:**

$$\boxed{T = \frac{2u\sin\theta}{g}}$$

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### 7.4 MAXIMUM HEIGHT (Derivation)

**Definition:** Maximum vertical distance reached by projectile.

**Derivation Method 1: Using Third Equation**

At maximum height, $v_y = 0$

Using: $v_y^2 = u_y^2 - 2gH$

$$0 = (u\sin\theta)^2 - 2gH$$

$$2gH = u^2\sin^2\theta$$

$$H = \frac{u^2\sin^2\theta}{2g}$$

**Derivation Method 2: Using Second Equation**

$$H = u_y t - \frac{1}{2}gt^2$$

At time $t = \frac{u\sin\theta}{g}$ (time to reach max height):

$$H = u\sin\theta \times \frac{u\sin\theta}{g} - \frac{1}{2}g\left(\frac{u\sin\theta}{g}\right)^2$$

$$H = \frac{u^2 \sin^2 \theta}{g} - \frac{1}{2} \times \frac{u^2 \sin^2 \theta}{g}$$

$$H = \frac{u^2 \sin^2 \theta}{2g}$$

**Board Exam Formula:**

$$\boxed{H = \frac{u^2 \sin^2 \theta}{2g}}$$

**For maximum H:** $\theta = 90^\circ$ (vertical projection)

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**7.5 HORIZONTAL RANGE (Derivation)**

**Definition:** Horizontal distance covered during time of flight.

**Derivation:**

Horizontal distance = Horizontal velocity × Time of flight

$$R = u_x \times T$$

$$R = u \cos \theta \times \frac{2u \sin \theta}{g}$$

$$R = \frac{2u^2 \sin \theta \cos \theta}{g}$$

Using identity: $\sin 2\theta = 2 \sin \theta \cos \theta$

$$R = \frac{u^2 \sin 2\theta}{g}$$

**Board Exam Formula:**

$$\boxed{R = \frac{u^2 \sin 2\theta}{g}}$$

**For maximum Range:**

$$\sin 2\theta = 1$$

$$2\theta = 90^\circ$$

$$\theta = 45^\circ$$

$$R_{max} = \frac{u^2}{g}$$

**Important:** Two angles give same range: $\theta$ and $(90^\circ - \theta)$Because $\sin 2\theta = \sin(180^\circ - 2\theta)$

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**7.6 EQUATION OF TRAJECTORY (Derivation)**

**Goal:** Find relation between x and y (eliminate time)

From horizontal motion:

$$x = u \cos\theta \cdot t$$

$$t = \frac{x}{u \cos\theta} \quad \text{...(i)}$$

From vertical motion:

$$y = u \sin\theta \cdot t - \frac{1}{2}gt^2 \quad \text{...(ii)}$$

Substituting (i) into (ii):

$$y = u\sin\theta \times \frac{x}{u\cos\theta} - \frac{1}{2}g\left(\frac{x}{u\cos\theta}\right)^2$$

$$y = x\tan\theta - \frac{gx^2}{2u^2\cos^2\theta}$$

Using $\sec^2\theta = 1 + \tan^2\theta$:

$$y = x\tan\theta - \frac{gx^2}{2u^2}(1 + \tan^2\theta)$$

**Board Exam Formula:**

$$\boxed{y = x\tan\theta - \frac{gx^2}{2u^2\cos^2\theta}}$$

This is an **equation of a parabola**, proving projectile motion is parabolic!

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**7.7 Special Cases**

**Case 1: Horizontal Projection** (θ = 0°)

From height $h$:

- Time of flight: $T = \sqrt{\frac{2h}{g}}$
- Range: $R = u\sqrt{\frac{2h}{g}}$
- Final velocity: $v = \sqrt{u^2 + 2gh}$

**Case 2: Projection from Height**

If projected from height $h$ above ground:

- Modify y-equation: Add $h$ to initial height
- Time of flight increases
- Range increases

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## MODULE 8: IMPORTANT FORMULAS SUMMARY

### Equations of Motion (Constant Acceleration)

1. $v = u + at$
2. $s = ut + \frac{1}{2}at^2$
3. $v^2 = u^2 + 2as$
4. $S_n = u + \frac{a}{2}(2n - 1)$

### Average Velocity

- General: $v_{avg} = \frac{s}{t}$
- Uniform acceleration: $v_{avg} = \frac{u+v}{2}$
- Equal distances: $v_{avg} = \frac{2v_1v_2}{v_1+v_2}$
- Equal times: $v_{avg} = \frac{v_1+v_2}{2}$

### Projectile Motion

- Time of Flight: $T = \frac{2u\sin\theta}{g}$
- Maximum Height: $H = \frac{u^2\sin^2\theta}{2g}$
- Range: $R = \frac{u^2\sin 2\theta}{g}$
- Trajectory: $y = x\tan\theta - \frac{gx^2}{2u^2\cos^2\theta}$

### Relative Motion

- $\vec{v}_{AB} = \vec{v}_A - \vec{v}_B$
- Same direction: $v_{rel} = |v_A - v_B|$
- Opposite: $v_{rel} = v_A + v_B$
- Perpendicular: $v_{rel} = \sqrt{v_A^2 + v_B^2}$

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## MODULE 9: COMMON MISTAKES & BOARD EXAM TIPS

### Critical Mistakes to Avoid

1. **Using distance instead of displacement** in velocity calculations
2. **Forgetting sign conventions** in vertical motion

3. **Assuming acceleration = 0 when velocity = 0** (wrong at highest point!)

4. **Using equations when acceleration is not constant**

5. **Confusing time of flight with time to maximum height** ($T \neq t\_max$!)

6. **Thinking horizontal velocity changes in projectile** (it remains constant!)

**Board Exam Success Strategy**

✓ Always draw diagrams
✓ Write given data clearly
✓ Show all steps (even simple ones)
✓ Box final answers with units
✓ Check dimensional consistency
✓ Verify if answer makes physical sense

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## MODULE 10: 30 CBSE PATTERN PRACTICE QUESTIONS

**SECTION A: Multiple Choice Questions (1 Mark Each)**

**Q1.** A particle is moving in a straight line with constant acceleration. Which of the following graphs represents this motion correctly? (a) x-t graph is a straight line (b) v-t graph is a parabola (c) v-t graph is a straight line (d) a-t graph is a parabola

**Q2.** The displacement of a particle starting from rest is proportional to the square of time. The acceleration: (a) increases with time (b) decreases with time (c) remains constant (d) becomes zero

**Q3.** A body is thrown vertically upward. Which of the following statements is true? (a) At highest point, both velocity and acceleration are zero (b) At highest point, velocity is zero but acceleration is g downward (c) Throughout motion, acceleration keeps changing (d) At highest point, velocity is maximum

**Q4.** Two cars are moving in the same direction with velocities 30 km/h and 50 km/h. The relative velocity of second car w.r.t. first is: (a) 20 km/h (b) 80 km/h (c) -20 km/h (d) 40 km/h

**Q5.** The area under velocity-time graph represents: (a) acceleration (b) velocity (c) displacement (d) distance

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**SECTION B: Very Short Answer Questions (2 Marks Each)**

**Q6.** Distinguish between distance and displacement with a suitable example.

**Q7.** A particle starts from rest and moves with constant acceleration. If it covers 100 m in 10 seconds, find the acceleration.

**Q8.** Can a body have zero velocity and non-zero acceleration simultaneously? Explain with an example.

**Q9.** The position-time graph of a particle is a straight line making an angle of 30° with time axis. Find the velocity of the particle.

**Q10.** A stone is dropped from a tower. What is its velocity after 3 seconds? (Take $g = 10\ m/s^2$)

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**SECTION C: Short Answer Questions (3 Marks Each)**

**Q11.** Derive the relation: $v = u + at$ using graphical method.

**Q12.** A car accelerates uniformly from 18 km/h to 36 km/h in 5 seconds. Calculate: (a) Acceleration (b) Distance covered during this time

**Q13.** Prove that for a freely falling body starting from rest, the distances traveled in successive seconds are in the ratio 1:3:5:7:...

**Q14.** Two trains are moving in opposite directions with speeds 60 km/h and 40 km/h. Find their relative velocity.

**Q15.** A ball is thrown vertically upward with a velocity of 20 m/s. Find: (a) Maximum height reached (b) Time taken to reach maximum height (Take $g = 10\ m/s^2$)

**Q16.** The velocity-time graph of a particle is shown below:

```
v(m/s)
20 |    /---\
   |   /     \
10 |  /       \
   | /         \
 0 |_/__________\_____
   0  2  4  6  8  t(s)
```

Calculate the total displacement of the particle.

**Q17.** A car travels half the distance with speed 40 km/h and the remaining half with speed 60 km/h. Find the average speed.

**Q18.** Explain why the path of a projectile is a parabola.

**Q19.** Rain is falling vertically with a speed of 30 m/s. A person is moving horizontally with speed 40 m/s. Find the velocity of rain relative to the person.

**Q20.** A particle moves with uniform acceleration. Its velocity after 5 seconds is 25 m/s and after 8 seconds is 34 m/s. Find: (a) Initial velocity (b) Acceleration

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**SECTION D: Long Answer Questions (5 Marks Each)**

**Q21.** Derive the equation: $s = ut + \frac{1}{2}at^2$ using: (a) Graphical method (b) Calculus method

**Q22.** A stone is thrown vertically upward with an initial velocity of 40 m/s from the top of a building 50 m high. Find: (a) Maximum height from the ground (b) Time to reach maximum height (c) Velocity with which it hits the ground (d) Total time of flight (Take g = 10 m/s²)

**Q23.** Derive an expression for: (a) Time of flight (b) Maximum height (c) Horizontal range for a projectile thrown at an angle θ with horizontal with initial velocity u.

**Q24.** Draw velocity-time graph for a body moving with: (a) Uniform velocity (b) Uniform acceleration (c) Uniform deceleration From the graphs, show how displacement and acceleration can be obtained.

**Q25.** A particle moves along a straight line such that its displacement at any time t is given by: $s = t^3 - 6t^2 + 3t + 4$ meters. Calculate: (a) Velocity at t = 0 (b) Velocity at t = 2s (c) Acceleration at t = 2s (d) When is the velocity zero?

**Q26.** A ball is projected at an angle of 30° with the horizontal with a velocity of 20 m/s. Calculate: (a) Time of flight (b) Maximum height (c) Horizontal range (d) Velocity at the highest point (Take g = 10 m/s²)

**Q27.** Two cars A and B are moving on a straight road. Car A is moving with velocity 20 m/s and car B is 50 m ahead moving with velocity 15 m/s in the same direction. (a) Find the relative velocity of A w.r.t. B (b) When will A catch up with B? (c) What distance will A travel before catching B?

**Q28.** A body starting from rest moves with constant acceleration. It travels 100 m in the first 5 seconds. Find: (a) Acceleration (b) Distance traveled in next 5 seconds (c) Velocity at the end of 10 seconds (d) Distance traveled in 5th second

**Q29.** Derive the third equation of motion: $v^2 = u^2 + 2as$ by: (a) Algebraic method (b) Graphical method Show that both methods yield the same result.

**Q30.** A projectile is thrown from the top of a building with velocity 20 m/s at an angle of 60° above the horizontal. The building is 30 m high. Find: (a) Horizontal distance from the base where it hits the ground (b) Time of flight (c) The angle at which it strikes the ground (Take g = 10 m/s²)

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## ANSWER KEY & HINTS

**Section A (MCQs)**

1. (c) - Uniform acceleration → v-t graph is straight line
2. (c) - $s \propto t^2$ implies constant acceleration
3. (b) - At highest point: v = 0, a = g (downward)

4. (a) - Same direction: subtract velocities
5. (c) - Area under v-t curve = displacement

**Section B (Hints)**

6. Distance = scalar, displacement = vector; Example: circular motion
7. Use $s = ut + \frac{1}{2}at^2$ with u = 0
8. Yes! At highest point of vertical throw
9. Velocity = slope = tan 30°
10. Use v = u + gt, u = 0

**Section C (Hints)**

11. Draw v-t graph, show slope = a, derive from geometry
12. Convert km/h to m/s first, use both equations
13. Use $S_n = \frac{g}{2}(2n - 1)$, show ratio
14. Opposite directions: add speeds
15. Use H = $u^2$/2g and t = u/g
16. Calculate area of trapezoid
17. Use harmonic mean formula
18. Explain using trajectory equation
19. Use Pythagoras theorem (perpendicular components)
20. Form two equations using v = u + at

**Section D (Hints)**

21. Complete derivations shown in Module 4
22. Multi-step problem, use h_total = h_building + H_max
23. Complete derivations shown in Module 7
24. Draw three separate graphs, mark areas and slopes
25. Velocity = ds/dt, Acceleration = dv/dt
26. Direct application of projectile formulas
27. Relative motion application, use s = vt

28. Use both second and fourth equations
29. Both derivations shown in Module 4
30. Projection from height, modify equations accordingly

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## MARKING SCHEME GUIDANCE

For **derivation questions:**

- Statement/formula: 1 mark
- Diagram (if applicable): 1 mark
- Mathematical steps: 2 marks
- Final result: 1 mark

For **numerical problems:**

- Formula: 1 mark
- Substitution: 1 mark
- Calculation: 1 mark
- Final answer with unit: 1 mark

For **graph-based questions:**

- Correct shape: 1 mark
- Labeling: 1 mark
- Physical interpretation: 1 mark

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## FINAL BOARD EXAM TIPS

**Day Before Exam:**

✓ Revise all derivations
✓ Practice numerical problems
✓ Review common mistakes
✓ Check formula sheet

**During Exam:**

✓ Read question carefully (identify given and to find)
✓ Draw diagram wherever possible
✓ Show all steps clearly
✓ Write formulas before substitution
✓ Box final answers with proper units
✓ Manage time: 15 min/5 marks question

**Most Important Topics for Boards:**

1. Equations of motion (derivations + numericals)
2. Graphical analysis (v-t graphs especially)
3. Projectile motion (all three derivations)
4. Relative motion (conceptual + numerical)
5. Free fall problems

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**Remember:** "In Physics, understanding WHY is more important than memorizing HOW. Master the concepts, and problems will solve themselves!"

**Best wishes for your CBSE Board Examination!** 🌟

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**END OF PREMIUM CBSE STUDY MATERIAL**