ANSWER KEY & MARKING SCHEME · CBSE CLASS 11

# Motion in a Plane

Physics · Chapter 3 · Use this with the Board Paper · Companion to Quick Drill

**HOW TO USE**

Attempt the Board Paper first (closed-book, full time). Then come here. For 2-mark+ questions, compare your answer to the model. For 3-4 mark questions, also consult the **Topper Templates** below — these show the exact step-by-step structure that scores full marks per CBSE marking-scheme conventions.

## MODEL ANSWERS · BOARD PAPER

### Section A — 1 mark each

**Q1. Define a unit vector. State whether it carries any physical units.** **[1 mark]**

**Ans:** A unit vector is a vector of magnitude exactly 1 used to indicate direction. It is dimensionless — it carries no physical units (e.g. metre, second).

**Q2. At what angle is the horizontal range of a projectile launched from the ground maximum?** **[1 mark]**

**Ans:** At theta = 45 degrees, giving R_max = u^2 / g.

**Q3. What is the direction of centripetal acceleration?** **[1 mark]**

**Ans:** Centripetal acceleration is directed radially inward, i.e. from the moving body toward the centre of the circular path.

**Q4. Write the cross product i-hat x j-hat.** **[1 mark]**

**Ans:** i-hat x j-hat = k-hat (by right-hand rule and cyclic order).

**Q5. State the dot product of two perpendicular vectors A and B.** **[1 mark]**

**Ans:** A . B = AB cos 90 = 0. Dot product of perpendicular vectors is always zero.

### Section B — 2 marks each

**Q6. Resolve a force F = 100 N acting at 60 degrees above the horizontal into its horizontal and vertical components.** **[2 marks]**

**Ans:** F_x = F cos 60 = 100 * 0.5 = 50 N (horizontal). F_y = F sin 60 = 100 * 0.866 = 86.6 N (vertical, upward).

**Q7. Two vectors of magnitudes 6 and 8 are perpendicular. Find the magnitude of their resultant.** **[2 marks]**

**Ans:** R = sqrt(6^2 + 8^2) = sqrt(36 + 64) = sqrt(100) = 10. (Pythagoras applies for perpendicular vectors.)

**Q8. If A = 2 i-hat + 3 j-hat and B = i-hat - j-hat, find A + B and its magnitude.** **[2 marks]**

**Ans:** A + B = (2+1) i-hat + (3-1) j-hat = 3 i-hat + 2 j-hat. |A + B| = sqrt(9 + 4) = sqrt(13) = 3.606.

**Q9. A stone is whirled in a circle of radius 1 m at constant speed 5 m/s. Find its centripetal acceleration.** **[2 marks]**

**Ans:** a_c = v^2 / r = 25 / 1 = 25 m/s^2, directed toward the centre of the circle.

**Q10. Why does horizontal velocity of a projectile remain constant throughout its flight?** **[2 marks]**

**Ans:** In projectile motion, the only force acting (ignoring air resistance) is gravity, which is purely vertical. Hence the horizontal component of acceleration is zero, and by v = u + at the horizontal velocity remains equal to its initial value u cos theta throughout the flight.

### Section C — 3 marks each

**Q11. Two forces of magnitudes 6 N and 8 N act at a point at an angle of 60 degrees. Find the magnitude and direction of the resultant.** **[3 marks]**

**Ans:** R = sqrt(6^2 + 8^2 + 2*6*8*cos 60) = sqrt(36 + 64 + 48) = sqrt(148) = 12.17 N. Direction: tan alpha = (8 sin 60) / (6 + 8 cos 60) = (8 * 0.866) / (6 + 4) = 6.928 / 10 = 0.6928 => alpha = 34.7 degrees from the 6 N force. Answer: R = 12.17 N at 34.7 degrees from the 6 N force.

**Q12.** **A particle moves in a circle of radius 2 m at constant speed and completes one revolution in 4 seconds. Find its (a) angular velocity, (b) linear speed, (c) centripetal acceleration.** **[3 marks]**

> **Ans:** (a) omega = 2 pi / T = 2 pi / 4 = pi/2 rad/s = 1.571 rad/s. (b) v = omega * r = 1.571 * 2 = 3.142 m/s. (c) a_c = v^2 / r = (3.142)^2 / 2 = 9.87 / 2 = 4.93 m/s^2, directed toward centre.

## Section D — 5 marks (long numerical)

**Q13.** **A projectile is launched from the ground with initial speed u = 50 m/s at an angle of 53 degrees above the horizontal. Take g = 10 m/s^2, sin 53 = 0.8, cos 53 = 0.6. Find (a) time of flight T, (b) maximum height H, (c) horizontal range R, (d) speed of the projectile at the highest point.** **[5 marks]**

> **Ans:** Resolve u: u_x = u cos 53 = 50 * 0.6 = 30 m/s. u_y = u sin 53 = 50 * 0.8 = 40 m/s. (a) T = 2 u sin theta / g = 2 * 50 * 0.8 / 10 = 80 / 10 = 8 s. (b) H = u^2 sin^2 theta / (2g) = 2500 * 0.64 / 20 = 1600/20 = 80 m. (c) R = u^2 sin(2 theta)/g = 2500 * sin 106 / 10. sin 106 = sin 74 = 2 sin 53 cos 53 = 2 * 0.8 * 0.6 = 0.96. R = 2500 * 0.96 / 10 = 240 m. (d) At highest point, v_y = 0 and v_x = u cos 53 = 30 m/s. So speed = 30 m/s (horizontal).

**Q14.** **A stone is thrown horizontally with initial velocity 15 m/s from a cliff of height 45 m. Take g = 10 m/s^2. Find (a) time taken to reach the ground, (b) horizontal distance covered, (c) velocity (both components) and speed when it hits the ground, (d) angle the velocity makes with the horizontal on landing.** **[4 marks]**

> **Ans:** Take downward +ve. (a) H = (1/2) g t^2 => 45 = (1/2)(10) t^2 => t^2 = 9 => t = 3 s. (b) R = u_x * t = 15 * 3 = 45 m. (c) v_x = 15 m/s (unchanged); v_y = g * t = 10 * 3 = 30 m/s downward. Speed = sqrt(15^2 + 30^2) = sqrt(225 + 900) = sqrt(1125) = 33.54 m/s. (d) tan(phi) = v_y / v_x = 30/15 = 2 => phi = arctan 2 = 63.43 degrees below the horizontal.

## ★ TOPPER ANSWER TEMPLATES

5 TEMPLATES · MEMORISE THE FORMAT

### ★ TOPPER TEMPLATE — Projectile launched from ground at angle theta with initial speed u — find range, max height, time of flight.

Annual

| | | |
|---|---|---|
| **Step 1** [1 mark] | **Resolve u into components + list u_x, u_y, a_x, a_y** | Taking horizontal +x and vertical +y upward. Given u = 20 m/s, theta = 30 degrees, g = 10 m/s^2. u_x = u cos theta = 20 cos 30 = 17.32 m/s. u_y = u sin theta = 20 sin 30 = 10 m/s. a_x = 0, a_y = -g = -10 m/s^2. |
| **Step 2** [2 marks] | **Apply T = 2u sin theta / g and H = u^2 sin^2 theta / (2g)** | Time of flight T = 2(20)(sin 30)/10 = 2(20)(0.5)/10 = 2 s. Max height H = (20)^2 (sin 30)^2 / (2*10) = 400 * 0.25 / 20 = 5 m. |
| **Step 3** [2 marks] | **Apply R = u^2 sin(2 theta) / g + state results with units** | Range R = (20)^2 sin(60) / 10 = 400 * 0.866 / 10 = 34.64 m. Answer: T = 2 s, H = 5 m, R = 34.64 m. |

**COMMON LOSS OF MARKS:**

- Forgetting to resolve u into u_x and u_y up front — examiner cannot verify your setup. -1 mark.
- Using sin where cos is needed in the components (or vice versa). Loss: 1-2 marks.
- Writing answer without units (m, s, m/s). -0.5 mark per missing unit.

### ★ TOPPER TEMPLATE — Find resultant of two vectors A and B inclined at angle theta — magnitude and direction.

Annual

| | | |
|---|---|---|
| **Step 1** **[1 mark]** | **Draw the parallelogram / triangle + label A, B, theta** | Vectors A = 5 N and B = 12 N at angle theta = 60 degrees. Place them tail-to-tail; complete the parallelogram. The diagonal is R. |
| **Step 2** **[1 mark]** | **Apply R = sqrt(A^2 + B^2 + 2AB cos theta)** | R = sqrt(25 + 144 + 2(5)(12)(0.5)) = sqrt(25 + 144 + 60) = sqrt(229) = 15.13 N. |
| **Step 3** **[1 mark]** | **Find direction angle alpha from A using tan alpha = B sin theta / (A + B cos theta)** | tan alpha = (12 * sin 60) / (5 + 12 cos 60) = (12 * 0.866) / (5 + 6) = 10.39 / 11 = 0.9447 => alpha = 43.4 degrees. Answer: R = 15.13 N at 43.4 degrees from A. |

**COMMON LOSS OF MARKS:**

- Adding magnitudes directly (5 + 12 = 17) — only valid for parallel vectors. Loses entire numerical step.
- Using sin instead of cos inside the square root, or forgetting the +2AB cos theta term.
- Reporting only magnitude without the angle — vector answers need both.

### ★ TOPPER TEMPLATE — Horizontal projectile from height H with horizontal speed u — find time of flight and range.

Common

| | | |
|---|---|---|
| **Step 1** **[1 mark]** | **Decouple into vertical and horizontal motions + list knowns** | Take downward +ve. Vertical: u_y = 0, a_y = g = 10 m/s^2, s_y = H = 80 m. Horizontal: u_x = u = 20 m/s, a_x = 0. |
| **Step 2** **[1 mark]** | **Find time of flight from vertical motion** | H = (1/2) g t^2 => 80 = (1/2)(10) t^2 => t^2 = 16 => t = 4 s. |
| **Step 3** **[1 mark]** | **Find horizontal range and state with units** | Range R = u_x * t = 20 * 4 = 80 m. Answer: t = 4 s, R = 80 m. |

**COMMON LOSS OF MARKS:**

- Using R = u^2 sin(2 theta)/g — that formula is for ground-to-ground projection, not horizontal launch from a height.
- Treating motion as 1D — leaves out either vertical (no time) or horizontal (no range) component.
- Forgetting that horizontal velocity u_x stays constant — students sometimes apply g horizontally too.

### ★ TOPPER TEMPLATE — Uniform circular motion — find centripetal acceleration of a body moving in a circle of radius r with speed v.

Common

| | | |
|---|---|---|
| **Step 1** **[1 mark]** | **Identify v, r + state formula** | Given v = 20 m/s, r = 10 m. Centripetal acceleration a_c = v^2 / r, directed toward the centre of the circle. |
| **Step 2** **[1 mark]** | **Substitute and compute** | a_c = (20)^2 / 10 = 400 / 10 = 40 m/s^2. |
| **Step 3** **[1 mark]** | **State magnitude + direction + note** | a_c = 40 m/s^2 directed radially inward (toward centre). Note: although a_c is non-zero, speed is constant — only direction of velocity changes. |

**COMMON LOSS OF MARKS:**

- Writing a_c = v/r instead of v^2/r (dimensional error). Full step loss.
- Forgetting to state direction — 'toward centre' is the key vector information.
- Saying speed changes — common misconception, -0.5 marks.

**★ TOPPER TEMPLATE — Resolve a vector A of magnitude A at angle theta to the x-axis into rectangular components.**

Common

| | | |
|---|---|---|
| **Step 1** **[1 mark]** | **Draw axes + project A onto them** | Draw +x and +y axes from origin. Vector A makes angle theta with +x axis. Drop perpendiculars from tip of A to both axes. |
| **Step 2** **[1 mark]** | **Write components using sin and cos** | A_x = A cos theta (along +x). A_y = A sin theta (along +y). In unit-vector form: A = A cos theta i-hat + A sin theta j-hat. |
| **Step 3** **[1 mark]** | **Substitute numbers + verify magnitude** | For A = 10, theta = 60: A_x = 10 cos 60 = 5, A_y = 10 sin 60 = 8.66. Verify: sqrt(5^2 + 8.66^2) = sqrt(25 + 75) = sqrt(100) = 10. Matches original A. |

**COMMON LOSS OF MARKS:**

- Swapping sin and cos (cos for y instead of x). -1 mark.
- Not measuring theta from the +x axis but from +y axis — flips the components.
- Skipping the magnitude-verification check, which catches sin/cos swaps.

**MARKING SCHEME — GENERAL NOTES**

- 1 mark for resolving the initial velocity into horizontal and vertical components in any projectile problem.
- 1 mark for stating the correct kinematic equation and substituting given values.
- 1 mark per final numerical answer with correct units AND direction (for vector quantities).
- Half-mark deduction for missing units in any final answer.
- Half-mark deduction for missing direction on a vector quantity (velocity, acceleration, force).
- Full credit if an alternative valid method (e.g. component-wise instead of formula) is used and yields the same final answer.
- No credit for a final number alone without working — every step must be shown.