Class 11 Physics · Chapter 2: Motion in a Straight Line

Answer key and marking scheme · 20 marks · about 40 minutes · based on NCERT

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1. The velocity of a cyclist on a straight road rises uniformly from 4 m s^{-1} to 12 m s^{-1} in 5 s. The displacement of the cyclist in these 5 s is [1]

(a) 60 m (b) 20 m
(c) 40 m (d) 80 m

Answer: (c) Displacement is the area under the v-t line, a trapezium: ½ (4 + 12) × 5 = 40 m. Using only the final velocity (12 × 5) gives 60 m and only the initial velocity gives 20 m.

2. A hockey ball moving at 6 m s^{-1} towards the east is struck and moves at 4 m s^{-1} towards the west 2 s later. Taking east as positive, the average acceleration of the ball in this interval is [1]

(a) 5 m s^{-2} (b) −1 m s^{-2}
(c) 1 m s^{-2} (d) −5 m s^{-2}

Answer: (d) $\bar{a} = (v_2 - v_1)/(t_2 - t_1) = (-4 - 6)/2 = -5$ m s^{-2}, that is, 5 m s^{-2} towards the west. Taking −1 m s^{-2} ignores the reversal of direction.

3. A jogger runs 300 m due east along a straight track and then turns and runs some distance due west along the same track. Over the whole run her average speed is twice the magnitude of her average velocity. How far did she run westward? [1]

(a) 100 m (b) 150 m
(c) 200 m (d) 50 m

Answer: (a) Let the westward run be w. Path length = 300 + w; magnitude of displacement = 300 − w. Both are divided by the same time, so 300 + w = 2(300 − w), 3w = 300 and w = 100 m.

4. A physics student treats a bus travelling 60 km between two towns as a point object. This is a fair approximation because [1]

(a) the bus moves with a uniform speed (b) the size of the bus is much smaller than the distance it moves
(c) the mass of the bus can be neglected (d) the road between the towns is straight

Answer: (b) A body may be treated as a point object when its size is much smaller than the distance it moves in the time considered; a bus about 10 m long covering 60 km qualifies. Speed, mass and the shape of the road do not decide this.

5. A portion of the position-time graph of a car is a curve that bends downward (its slope keeps decreasing). In that portion the acceleration of the car is [1]

(a) positive (b) negative
(c) zero (d) increasing with time

Answer: (b) The slope of the x-t graph is the velocity. A curve bending downward has a decreasing slope, so the velocity decreases and the acceleration is negative; a straight line would mean zero acceleration.

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6. A stone is released near the earth's surface. State two conditions under which its fall can be treated as motion with uniform acceleration g. [2]

(i) Air resistance is negligible, so the only acceleration is that due to gravity (free fall). (ii) The height of fall is small compared with the earth's radius, so g can be taken as constant, 9.8 m s^{-2}.

- air resistance negligible (1)
- height small compared with the earth's radius, so g constant (1)

7. A car moving with uniform acceleration along a straight road covers 60 m in 4 s, at the end of which its speed is 20 m s^{-1}. Find its speed at the start of the 4 s and its acceleration. [2]

For constant acceleration, $x = \tfrac{1}{2}(v_0 + v)t$: $60 = \tfrac{1}{2}(v_0 + 20) \times 4$, so $v_0 + 20 = 30$ and $v_0 = 10$ m s^{-1}. From $v = v_0 + at$, $a = (20 - 10)/4 = 2.5$ m s^{-2}.

- $v_0 = 10$ m s^{-1} from the average-velocity relation (1)
- $a = 2.5$ m s^{-2} (1)

8. A particle starts from rest at the origin and moves along the x-axis with acceleration $a = 6t$ (a in m s^{-2}, t in s). Find its velocity and position at t = 2 s. [2]

$a = dv/dt = 6t$, so $v = \int_0^t 6t\,dt = 3t^2$; at t = 2 s, v = 12 m s^{-1}. $v = dx/dt = 3t^2$, so $x = \int_0^t 3t^2\,dt = t^3$; at t = 2 s, x = 8 m. The equations for constant acceleration cannot be used, since a changes with time.

- $v = 3t^2$, 12 m s^{-1} (1)
- $x = t^3$, 8 m (1)

9. Ball A is dropped from rest from the top of a 40 m high tower. At the same instant ball B is thrown vertically upward from the foot of the tower at 20 m s^{-1} along the same vertical line ($g = 10$ m s^{-2}, air resistance neglected). Find (a) when the balls meet, (b) the height at which they meet, (c) the velocity of B at that instant. [3]

(a) Both balls have the same acceleration g, so the velocity of B relative to A stays 20 m s^{-1} upward. The 40 m gap closes in $t = 40/20 = 2$ s. (b) A has fallen $\tfrac{1}{2}gt^2 = 5 \times 4 = 20$ m, so they meet 40 − 20 = 20 m above the ground. (c) $v_B = 20 - 10 \times 2 = 0$: B is at its highest point when they meet.

- relative velocity constant, t = 2 s (1)
- meeting height 20 m (1)
- $v_B = 0$, B at its highest point (1)

10. A body moves along a straight line with uniform acceleration a, its velocity changing from v_0 at t = 0 to v at time t. Using its velocity-time graph, derive (a) $x = v_0t + \tfrac{1}{2}at^2$ and (b) $v^2 = v_0^2 + 2ax$, where x is its displacement in time t. [3]

The v-t graph is a straight line from $(0, v_0)$ to (t, v). (a) The area under it is a rectangle of height v_0 and base t plus a triangle of base t and height $(v - v_0)$: $x = v_0t + \tfrac{1}{2}(v - v_0)t$. Since $v - v_0 = at$, $x = v_0t + \tfrac{1}{2}at^2$. (b) The area is also a trapezium: $x = \tfrac{1}{2}(v + v_0)t$. With $t = (v - v_0)/a$, $x = (v + v_0)(v - v_0)/2a = (v^2 - v_0^2)/2a$, so $v^2 = v_0^2 + 2ax$.

- area under the v-t graph equals displacement; area split into rectangle and triangle (1)
- substituting $v - v_0 = at$ to get $x = v_0t + \tfrac{1}{2}at^2$ (1)
- trapezium area with $t = (v - v_0)/a$ gives $v^2 = v_0^2 + 2ax$ (1)

11. A trolley released from rest rolls down a uniform inclined track with constant acceleration and covers 4 cm in the first second. Find (a) its acceleration, (b) the distance it covers in the fourth second, (c) the second during which it covers 44 cm. [3]

(a) From rest, $x = \tfrac{1}{2}at^2$: $4 = \tfrac{1}{2}a(1)^2$, $a = 8$ cm s^{-2}. (b) $s_n = (a/2)(2n - 1) = 4(2n - 1)$; for n = 4, $s_4 = 4 \times 7 = 28$ cm (the distances in successive seconds go as 1 : 3 : 5 : 7). (c) $4(2n - 1) = 44$ gives $2n - 1 = 11$, n = 6: the sixth second.

- $a = 8$ cm s^{-2} (1)
- 28 cm in the fourth second (1)
- sixth second (1)

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