PHYSICS – CLASS XI

Chapter 2 : Motion in a Straight Line

SOLUTIONS AND MARKING SCHEME (Step-by-Step)

Marks for each step are shown in brackets. Alternative correct methods carry full marks.

Quick answer key – Section A

Q	1	2	3	4	5	6	7	8
Ans	(b)	(c)	(b)	(a)	(b)	40 m	-2 m s^{-2}	(c)

SECTION A

1. **Ans: (b) 13 m s^{-1}.** **(1)**

$v = dx/dt = 8t - 3$. At $t = 2$ s: $v = 8(2) - 3 =$ **13 m s^{-1}**.

2. **Ans: (c) 3 m s^{-1}.** **(1)**

The velocity is the slope of the x–t graph: $(14 - 2)$ m / $(4 - 0)$ s = **3 m s^{-1}**.

3. **Ans: (b) 80 m.** **(1)**

Displacement = area under the v–t graph = triangle (0–4 s) + rectangle (4–10 s) = ½ × 4 × 10 + 6 × 10 = 20 + 60 = **80 m**.

4. **Ans: (a).** **(1)**

Both statements are true. At the highest point of a vertical throw the velocity is zero but $a = g \neq 0$. This is because acceleration depends on how v is changing, not on its value at that instant, so R explains A.

5. **Ans: (b) zero and 9.8 m s^{-2} downwards.** **(1)**

At the top the velocity is momentarily zero, but the only force is gravity, so the acceleration is still $g = 9.8$ m s^{-2} downwards.

6. **Ans: 40 m.** **(1)**

$v^2 = u^2 + 2as$ with $v = 0$, $u = 20$ m s^{-1}, $a = -5$ m s^{-2}: $0 = 400 - 10s \rightarrow s =$ **40 m**.

7. **Ans: -2 m s^{-2}.** **(1)**

Acceleration = slope of the v–t graph = $(0 - 10)$ m s^{-1} / $(5 - 0)$ s = **-2 m s^{-2}** (a retardation of 2 m s^{-2}).

8. **Ans: (c) 1 : 3 : 5.** **(1)**

From rest, distance in the nth second = ½$g(2n - 1)$. For $n = 1, 2, 3$ this gives ½g × (1, 3, 5), i.e. 1 : 3 : 5.

SECTION B

9. **(2)**

(i) OA: $v = (6 - 0)/(2 - 0) =$ **+3 m s^{-1}**. AB: the graph is horizontal, so $v =$ **0**. BC: $v = (-2 - 6)/(8 - 4) =$ **-2 m s^{-1}**. (1)

(ii) Total path length = 6 + 0 + 8 = 14 m, so average speed = 14/8 = **1.75 m s^{-1}**. Displacement = $-2 - 0 = -2$ m, so average velocity = $-2/8 =$ **-0.25 m s^{-1}** (towards the negative direction). (1)

10. **(2)**

$v = dx/dt = 3t^2 - 12t + 9$. At $t = 2$ s: $v = 12 - 24 + 9 =$ **-3 m s^{-1}**. (1)

$a = dv/dt = 6t - 12$. At $t = 2$ s: $a =$ **0**. (1)

11. Area under the v–t graph gives the displacement s. Area = rectangle OADC + triangle ABC. (½) **(2)**
Rectangle OADC = $u \times t = ut$. (½)
Triangle ABC = ½ × t × ($v - u$) = ½ × t × at (since $v - u = at$) = ½at^2. (½)
Hence $\boldsymbol{s = ut + \frac{1}{2}at^2}$. (½)

OR

For free fall from rest, the distance in time $n\tau$ is $s_n = \frac{1}{2}g(n\tau)^2$. (½)
Distance in the nth interval = $s_n - s_{n-1} = \frac{1}{2}g\tau^2[n^2 - (n-1)^2] = \frac{1}{2}g\tau^2(2n-1)$. (1)
For n = 1, 2, 3, 4 … the distances are in the ratio 1 : 3 : 5 : 7 … (odd numbers). (½)

12. **(i)** At the top $v = 0$: $v^2 = u^2 - 2gH \rightarrow H = u^2/2g = (19.6)^2 / (2 \times 9.8) =$ **19.6 m**. (1) **(2)**
(ii) Time to return to the ground: $t = 2u/g = 2 \times 19.6 / 9.8 =$ **4 s** (2 s up and 2 s down). (1)

SECTION C

13. **(i)** Stage 1 (0–4 s): $a = (8 - 0)/4 =$ **+2 m s⁻²**. Stage 2 (4–10 s): $a =$ **0**. Stage 3 (10–14 s): $a = (0 - 8)/4 =$ **−2 m s⁻²**. (½ + ½ + ½) **(3)**
(ii) Distance = area of trapezium = ½ × 4 × 8 + 6 × 8 + ½ × 4 × 8 = 16 + 48 + 16 = **80 m**. (1½)

14. u = 72 km h⁻¹ = 72 × 5/18 = 20 m s⁻¹. (½) **(3)**
Distance in the reaction time (no braking) = 20 × 0.5 = 10 m. (1)
Braking distance: $v^2 = u^2 + 2as \rightarrow 0 = 400 - 10s \rightarrow s = 40$ m. (1)
Total distance = 10 + 40 = 50 m, which is less than 60 m. Hence the car **stops before the obstacle**, 10 m short of it. (½)

OR

(i) $d = \frac{1}{2}gt^2 \rightarrow t = \sqrt{(2d/g)} = \sqrt{(2 \times 0.196 / 9.8)} = \sqrt{0.04} =$ **0.2 s**. (2)
(ii) $d = \frac{1}{2} \times 9.8 \times (0.3)^2 = 0.441$ m = **44.1 cm**. (1)

15. **P:** the graph curves upwards (slope increasing), so a is **positive**. Starting from rest the velocity increases continuously in the positive direction. (1) **(3)**
Q: the graph is a straight line (constant slope), so $a =$ **0**. The velocity is constant. (1)
R: the graph curves downwards (slope decreasing), so a is **negative**. The slope is positive at first, becomes zero at the peak and then negative, so the velocity changes from positive to negative (the particle reverses direction at the peak). (1)

SECTION D

16. **(5)**

(a) Instantaneous velocity is the limit of the average velocity as the time interval tends to zero: $v = \lim_{\Delta t \to 0} \Delta x/\Delta t = \mathrm{d}x/\mathrm{d}t$; it is the slope of the tangent to the x–t graph at that instant. (1)

(b) $v = \mathrm{d}x/\mathrm{d}t = \mathbf{12 - 6t}$; $a = \mathrm{d}v/\mathrm{d}t = \mathbf{-6\ m\ s^{-2}}$ (constant). (1)

(c) $v = 0 \rightarrow 12 - 6t = 0 \rightarrow \boldsymbol{t = 2\ s}$. Position $x = 2 + 24 - 12 = \mathbf{14\ m}$. (1)

(d) $x(0) = 2$ m, $x(4) = 2 + 48 - 48 = 2$ m, so displacement = **0**. The particle goes from 2 m to 14 m (12 m) and returns to 2 m (12 m), so distance = **24 m**. (1)

(e) Average velocity = 0/4 = **0**. Average speed = 24/4 = **6 m s⁻¹**. (1)

OR

Take upward as positive: $u = +15$ m s^{-1}, $a = -10$ m s^{-2}.

(a) At the top $v = 0$: $0 = 15^2 - 2(10)h \rightarrow h = 225/20 = \mathbf{11.25\ m}$ above the tower. (1)

(b) Ground is at $y = -20$ m: $-20 = 15t - \tfrac{1}{2}(10)t^2 \rightarrow 5t^2 - 15t - 20 = 0 \rightarrow t^2 - 3t - 4 = 0 \rightarrow (t - 4)(t + 1) = 0$. (1½) Taking the positive root, $\boldsymbol{t = 4\ s}$. (½)

(c) $v = u + at = 15 - 10 \times 4 = \mathbf{-25\ m\ s^{-1}}$ (25 m s^{-1} downwards). (1)

(d) Distance = 11.25 m (up) + (11.25 + 20) m (down) = **42.5 m**. (1)

17. **(5)**

(a) 0–5 s: $a = (-4 - 6)/5 = \mathbf{-2\ m\ s^{-2}}$. 5–7 s: v is constant, so $a = \mathbf{0}$. (1)

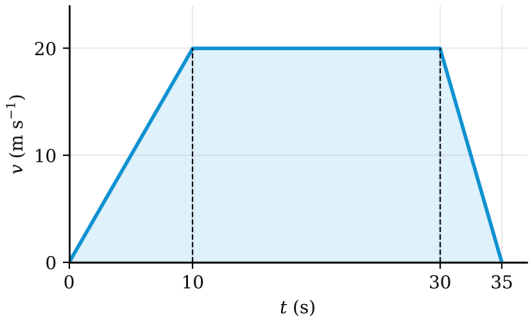
(b) The velocity changes sign from positive to negative at $v = 0$, i.e. at $\boldsymbol{t = 3\ s}$ ($6 - 2t = 0$). (1)

(c) Displacement = signed area under the graph. 0–3 s: $+\tfrac{1}{2} \times 3 \times 6 = +9$ m. 3–5 s: $-\tfrac{1}{2} \times 2 \times 4 = -4$ m. 5–7 s: $-4 \times 2 = -8$ m. (1) Net displacement = $9 - 4 - 8 = \mathbf{-3\ m}$. (1)

(d) Distance = sum of magnitudes = 9 + 4 + 8 = **21 m**. (1)

OR

(a) The graph is shown below: a straight line from (0, 0) to (10 s, 20 m s^{-1}), horizontal up to 30 s, then a straight line down to (35 s, 0). (1)



(b) Maximum speed = $2 \times 10 = 20$ m s^{-1}. Retardation = 20/5 = **4 m s⁻²**. (1)

(c) Stage 1: $\tfrac{1}{2} \times 2 \times 10^2 = 100$ m. Stage 2: $20 \times 20 = 400$ m. Stage 3: $\tfrac{1}{2} \times 20 \times 5 = 50$ m. Total = 100 + 400 + 50 = **550 m**. (2)

(d) Total time = 10 + 20 + 5 = 35 s. Average speed = 550/35 ≈ **15.7 m s⁻¹**. (1)

— END OF SOLUTIONS —