4.2 Kinematics: constant acceleration

Name: _____ Class: _____ Date: _____ **Total: 25 marks**

KEY WORDS velocity • acceleration

Kinematics: constant acceleration

Objective

Solve single- and multi-phase suvat problems with signs chosen per phase, and read and sketch displacement-time, velocity-time and speed-time graphs (objectives 3.1).

1 Key knowledge and worked examples

Method. List s, u, v, a, t per phase with signs (up positive or down positive – then stay consistent). Choose the formula that omits the unknown you do not need. Graphs: velocity-time gradient = acceleration, area = displacement (negative below the axis); speed-time graphs never go negative, so up-then-down motion is a V with its vertex on the time axis.

Worked example – up then down (WME01 June 2025 Q3). Projected up from A, 12 m above the ground at B, reaching B after 4 s (up positive, origin A): $-12 = 4U - 4.9(16)$ gives $U = 16.6\ \mathrm{m\,s^{-1}}$; then $v^2 = 16.6^2 + 2(9.8)(12)$ gives $v = 22.6\ \mathrm{m\,s^{-1}}$. The speed-time graph falls from 16.6 to 0 at $t = 16.6/9.8 = 1.7$ s, then rises to 22.6 at $t = 4$ – a V, downward leg longer.

2 Practice

2.1 A car decelerates uniformly from $12\ \mathrm{m\,s^{-1}}$ to rest with acceleration $-2\ \mathrm{m\,s^{-2}}$. Find the time taken and the distance travelled. [3]

2.2 A train brakes from $20\ \mathrm{m\,s^{-1}}$ to rest with uniform deceleration $5\ \mathrm{m\,s^{-2}}$. Find the braking distance. [3]

2.3 A ball is projected vertically upwards at $15\ \mathrm{m\,s^{-1}}$ from a point on level ground. Find its maximum height and the time until it returns to the point of projection. [4]

2.4 On a velocity-time graph, a particle accelerates uniformly from $8\ \mathrm{m\,s^{-1}}$ to $20\ \mathrm{m\,s^{-1}}$ in 15 s. Find its acceleration and the distance travelled. [4]

3 Exam-style questions

3.1 *(Edexcel IAL WME01 June 2025 Q3.)* A particle is projected vertically upwards from A with speed $U\ \mathrm{m\,s^{-1}}$. A is 12 m vertically above the point B on horizontal ground. The particle moves freely under gravity until it hits the ground at B, 4 seconds after leaving A. (a) Find U. (b) Find the speed with which the particle hits the ground. (c) Sketch a speed-time graph for the motion from A to B, marking the values of the speed at A, at B and at the instant the speed is zero. [8]

3.2 *(Original.)* A stone is dropped from rest and falls 45 m to the ground. Find its speed on impact. [3]

Solutions

2.1 $0 = 12 - 2t$ gives $t = 6$ s; $s = 12(6) - \frac{1}{2}(2)(36) = 72 - 36 = 36$ m.

2.2 $0 = 20^2 - 2(5)s$ gives $s = \frac{400}{10} = 40$ m.

2.3 Max height $= \frac{15^2}{2(9.8)} = \frac{225}{19.6} = 11.5$ m (2 s.f. 11); time up $= \frac{15}{9.8} = 1.53$ s, so total time back $= 3.1$ s.

2.4 $a = \dfrac{20-8}{15} = 0.8\ \mathrm{m\,s^{-2}}$; distance = trapezium area $= \frac{1}{2}(8+20)(15) = 210$ m.

3.1 (a) Up positive, origin A, $s = -12$ when $t = 4$: $-12 = 4U - 4.9(16)$, so $4U = 66.4$ and $U = 16.6\ \mathrm{m\,s^{-1}}$ (17 to 2 s.f.). (b) $v^2 = 16.6^2 + 2(9.8)(12) = 510.8$, so $v = 22.6\ \mathrm{m\,s^{-1}}$ (23). (c) V-shaped graph: starts at 16.6, falls to zero at $t = 1.7$ s, rises to 22.6 at $t = 4$; the falling leg is shorter than the rising leg, and both meet ON the time axis (no vertical jump).

3.2 $v^2 = 2(9.8)(45) = 882$, so $v = 29.7\ \mathrm{m\,s^{-1}}$ (30).

Local review guidance: one suvat relation per phase with signed quantities; 2–3 s.f. final answers with units; graph shapes honouring non-negativity of speed and continuity at the vertex. This is authored classroom guidance.