1.2 Equations of motion and projectiles (full A.1)

Name: _____ Class: _____ Date: _____ **Total: 28 marks**

KEY WORDS uniformly accelerated motion • terminal speed

Objective

Practise the full guide A.1 toolkit beyond the focus lesson: the four equations of uniformly accelerated motion, choosing the right equation, and projectile motion resolved into components, with the qualitative effects of fluid resistance. Original practice; not an official IB paper.

1 Key knowledge and worked examples

■ **Choose the equation by what you know**

$$s = \frac{u+v}{2}t \qquad v = u + at \qquad s = ut + \tfrac{1}{2}at^2 \qquad v^2 = u^2 + 2as$$

No time in the problem? Use $v^2 = u^2 + 2as$. No final velocity? Use $s = ut + \frac{1}{2}at^2$. Always state the positive direction first.

■ **Projectiles: two independent motions**

Horizontal: constant velocity, $x = u_x t$. Vertical: free fall, u_y, $a = -g$. Connect the two motions only through t. Fluid resistance (qualitative): shorter range, steeper descent, terminal speed.

Worked check. A ball rolls off a 0.80 m table at 3.0 m/s: $t = \sqrt{2 \times 0.80/9.8} = 0.404$ s; lands $3.0 \times 0.404 = 1.21$ m away.

2 Practice

2.1 A car accelerates uniformly from 5.0 m/s to 25 m/s over 120 m. Calculate the acceleration. [3]

2.2 A stone is thrown up at 12 m/s. Calculate its maximum height ($g = 9.8\ m/s^2$). [2]

2.3 State the four equations of uniformly accelerated motion. [4]

2.4 A projectile is launched at 20 m/s, 40° above the horizontal. Calculate the horizontal and vertical components of the launch velocity. [2]

2.5 State two qualitative effects of fluid resistance on a projectile's flight. [2]

3 Exam-style questions

3.1 A ball is kicked from level ground at 18 m/s, 35° above the horizontal ($g = 9.8\ m/s^2$). Calculate the time of flight, the maximum height and the range, stating the independence assumption you used. [6]

3.2 A stone is thrown horizontally at 6.0 m/s from a cliff and lands in the sea 4.5 s later. Calculate the cliff height and the stone's speed on impact. [5]

3.3 The same kick as 3.1 is now performed into a strong headwind. Without calculation, describe how the time of flight, trajectory shape and range change, and explain what a falling skydiver's terminal speed tells you about the forces on them. [4]

Solutions

Original-task marking: M1 method, A1 accuracy, B1 reasoning.

2.1 $v^2 = u^2 + 2as$: $625 = 25 + 240a$; $a = 600/240 = 2.5$ m/s^2; equation chosen because s is given and t is not.

2.2 At the top $v = 0$: $0 = 144 - 2(9.8)s$; $s = 144/19.6 = 7.3$ m.

2.3 $s = (u + v)t/2$; $v = u + at$; $s = ut + \frac{1}{2}at^2$; $v^2 = u^2 + 2as$.

2.4 $u_x = 20\cos 40° = 15.3$ m/s; $u_y = 20\sin 40° = 12.9$ m/s.

2.5 Any two: range reduced; time of flight reduced; trajectory steeper (non-parabolic); falling object reaches terminal speed.

3.1 $u_x = 18\cos 35° = 14.7$ m/s, $u_y = 18\sin 35° = 10.3$ m/s; time of flight $t = 2u_y/g = 20.6/9.8 = 2.11$ s; max height $= u_y^2/2g = 106.6/19.6 = 5.44$ m; range $= u_x t = 14.7 \times 2.11 = 31.0$ m; assumption: no fluid resistance, so the two motions are independent.

3.2 Height: $s = \frac{1}{2}gt^2 = 4.9 \times 20.25 = 99$ m; vertical impact component $= 9.8 \times 4.5 = 44.1$ m/s; speed $= \sqrt{6^2 + 44.1^2} = 44.5$ m/s.

3.3 Headwind reduces the horizontal velocity throughout: shorter range, steeper final descent, and (since the vertical motion is unchanged by a horizontal wind with no vertical drag) the same time of flight. A skydiver at terminal speed has drag equal and opposite to weight, so the resultant force – and the acceleration – is zero.