Exercise walk-through

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

International Baccalaureate · IB Diploma · Physics · HL

Motion · 3.1

Reasoning

The gradient of a displacement-time graph is velocity. The area under a velocity-time graph gives displacement. A constant-acceleration formula is valid only when its assumption is justified. Choose a positive direction and state it. Use a light gate or video with a known scale and frame interval for repeatable motion measurements. Avoid assuming hand timing is exact over very short intervals.

A ball reaches its highest point

1. **Set the model** Launch upward at $15\,\mathrm{m/s}$; take upward positive and $a = -9.8\,\mathrm{m/s^2}$. Ignore air resistance.
2. **Calculate** At the top $v = 0$: $t = (0 - 15)/(-9.8) = 1.53\,\mathrm{s}$; $s = (0 - 225)/(2(-9.8)) = 11.5\,\mathrm{m}$.

Decision

Zero velocity at the top does not mean zero acceleration. These equations require constant acceleration.

One time links two motions

1. **Set the model** A ball leaves level ground at $12\,\mathrm{m/s}$ and 35°. Ignore resistance and use $g = 9.8\,\mathrm{m/s^2}$.
2. **Calculate** $u_x = 12\cos 35^\circ = 9.83$; $u_y = 12\sin 35^\circ = 6.88\,\mathrm{m/s}$. Flight time $2u_y/g = 1.40\,\mathrm{s}$; range $u_x t = 13.8\,\mathrm{m}$.

Decision

The horizontal velocity is constant; the vertical velocity changes. Use the same time in both components.

Exercises 2.1·2.3

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]

Exercises 2.1·2.3

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

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

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

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

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

Exercises 2.4·3.1

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]

3.1 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]

Exercises 2.4·3.1

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]

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

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

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

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]

3.1 $u_x = 18\cos 35° = 14.7$ 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.

Exercises 3.2·3.3

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]

Exercises 3.2·3.3

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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 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]

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.