Section 1: Introduction

Section test

(Throughout this test, unless instructed otherwise, take g = 9.8 ms^{-2} and round answers, where necessary, to 3 s.f.)

1. Which of the choices below completes this sentence correctly?
   Assuming no air resistance, during the flight of a projectile, the horizontal component of its velocity…

(a) remains constant.
(b) reduces as the projectile is climbing and increases again as it falls.
(c) decreases
(d) increases

2. A particle is projected at 20 ms^{-1} horizontally from a point 80 m above level ground. Taking g = 10 ms^{-2}, find the horizontal distance travelled before the particle hits the ground.

3. A fielder retrieves a cricket ball and throws it horizontally with a speed of 28 ms^{-1} to a wicket keeper standing 12 m way. If the ball is thrown from a height of 2 m, find the height at which it reaches the wicket keeper.

4. The top of a vertical tower is 20 m above ground level. When a ball is thrown horizontally from the top of this tower, it first hits the ground 24 m from the base of the tower. Take g = 10 ms^{-2}. By how much does the ball clears a vertical wall of height 13 m situated 12 m from the tower?

5. A ball is thrown at 12 ms^{-1} at 60º to the horizontal. After 1 second of flight, what is its position in relation to its starting point, rounded to 1 d.p. where necessary?

6. A particle is projected from a point on level ground such that its initial velocity is 56 ms^{-1} at an angle of 30º above the horizontal.
   Find the maximum height of the particle.
   Find the time of flight of the particle.
   Find the horizontal range of the particle.

7. Find the range, to the nearest km, of a shell with a muzzle velocity of 700 ms^{-1} fired at an angle of 15º above the horizontal.

8. A stone is thrown with a speed of 10 ms^{-1} at 30º above the horizontal from the top of a cliff 100 m high. When it lands, find its speed and direction of flight (using g = 10 ms^{-2} and rounding to 2 s.f. where necessary).

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Solutions to section test

1) The only force acting on the projectile is gravity. This acts vertically downwards and so will not affect the horizontal component of the velocity, which will therefore remain constant.

2) Vertically: $u = 0$, $a = -10$, $s = -80$ (at ground), $t = ?$

$s = ut + \frac{1}{2}at^2$

$-80 = 0 + \frac{1}{2} \times -10t^2$

$16 = t^2$

$t = 4$ (t must be > 0)

Horizontally (constant speed): $s = ut = 20 \times 4 = 80$ metres.

3) Horizontally (constant speed): $s = ut$

$12 = 28t$

$t = \frac{3}{7}$

Vertically: $u = 0$, $a = -9.8$, $t = \frac{3}{7}$, $s = ?$

$s = ut + \frac{1}{2}at^2$

$= 0 + \frac{1}{2} \times -9.8 \times \left(\frac{3}{7}\right)^2$

$= -0.9$

The ball is thrown from a height of 2 m, so it reaches the wicket keeper at a height of 2 – 0.9 = 1.1 m.

4) For the complete flight:

Vertically: $u = 0$, $a = -10$, $s = -20$, $t = ?$

$s = ut + \frac{1}{2}at^2$

$-20 = 0 + \frac{1}{2} \times -10t^2$

$4 = t^2$

$t = 2$

Horizontally (constant speed): $s = ut$

$24 = 2u$

$u = 12$

At the wall: horizontally: $s = ut$

$12 = 12t$

$t = 1$

Vertically: $u = 0$, $a = -10$, $t = 1$, $s = ?$

$s = ut + \frac{1}{2}at^2$

$= 0 + \frac{1}{2} \times -10 \times 1^2$

$= -5$

At the wall the ball has dropped by 5 metres, so it is 15 m above the ground, and so it is 2 m above the wall.

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5) Horizontally: $u = 12\cos 60° = 6$

$x = ut = 6 \times 1 = 6$

Vertically: $u = 12\sin 60° = 6\sqrt{3}$

$a = -9.8$

$t = 1$

$s = ?$

$s = ut + \frac{1}{2}at^2$

$= 6\sqrt{3} \times 1 + \frac{1}{2} \times -9.8 \times 1^2$

$= 5.5$ (1 d.p.)

After 1 second the ball is 6 m along and 5.5 m up.

6) At maximum height vertically: $u = 56\sin 30° = 28$

$v = 0$

$a = -9.8$

$s = ?$

$v^2 = u^2 + 2as$

$0 = 28^2 + 2 \times -9.8s$

$19.6s = 784$

$s = 40$

The maximum height of the particle is 40 m.

Vertically: $u = 28$

$a = -9.8$

$s = 0$

$t = ?$

$s = ut + \frac{1}{2}at^2$

$0 = 28t + \frac{1}{2} \times -9.8t^2$

$0 = t(28 - 4.9t)$

$t = 0$ or 5.71

The time of flight of the particle is 5.71 seconds

Horizontally: $u = 56\cos 30° = 28\sqrt{3}$

$$s = ut = 28\sqrt{3} \times \frac{28}{4.9} = 277$$

The horizontal range of the particle is 277 m.

7) Vertically: $u = 700\sin 15°$

$s = 0$

$a = -9.8$

$t = ?$

$s = ut + \frac{1}{2}at^2$

$0 = 700\sin 15° t + \frac{1}{2} \times -9.8t^2$

$0 = t(700\sin 15° - 4.9t)$

$t = 0$ or $\frac{700\sin 15°}{4.9}$

Horizontally: $x = ut = 700\cos 15° \times \frac{700\sin 15°}{4.9} = 25000$ m

The range is 25 km.

8) Vertically: $u = 10\sin 30° = 5$ $\quad$ $v^2 = u^2 + 2as$

$s = -100$ $\quad$ $= 5^2 + 2 \times -10 \times -100$

$a = -10$ $\quad$ $= 2025$

$v = ?$ $\quad$ $v = \pm 45$

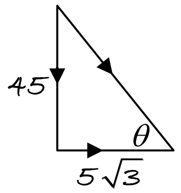
Vertical speed on landing is 45 ms^{-1} downwards.

Horizontally: $u = 10\cos 30° = 5\sqrt{3}$

Speed on landing $= \sqrt{45^2 + (5\sqrt{3})^2} = \sqrt{2100} = 46$

$\tan\theta = \dfrac{45}{5\sqrt{3}}$

$\theta = 79°$ (2 s.f.)



The speed on landing is 46 ms^{-1} at 79° to the horizontal.