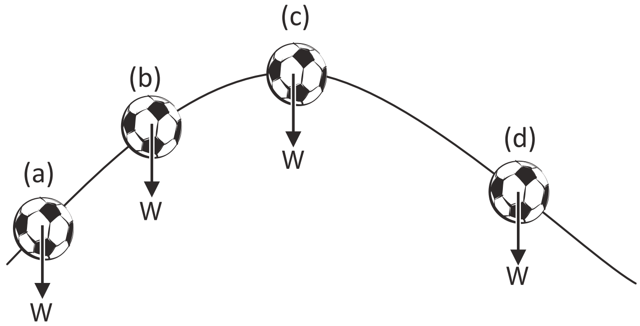
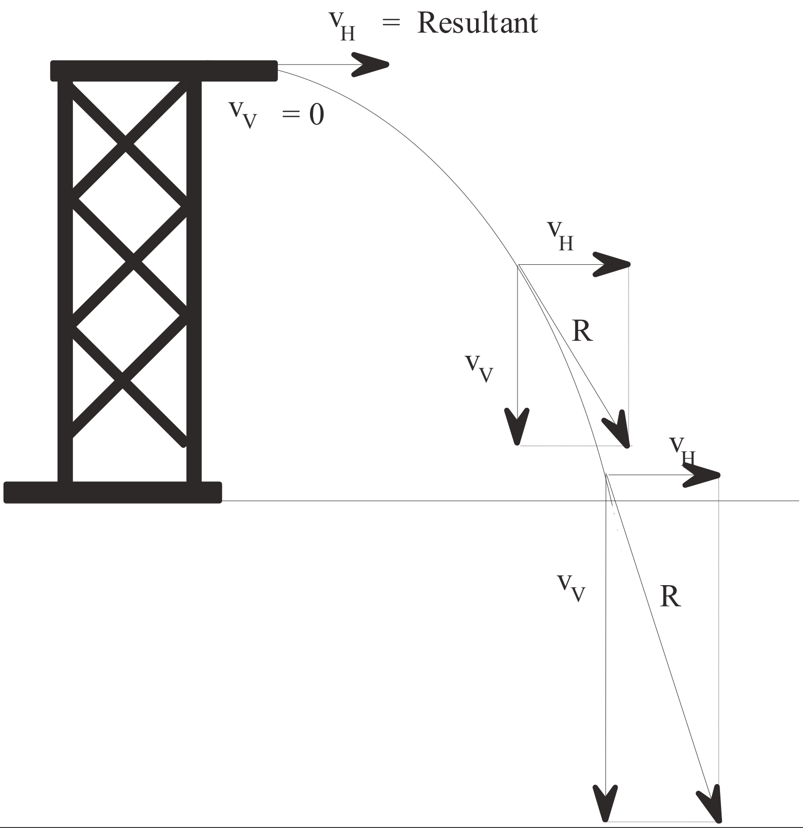
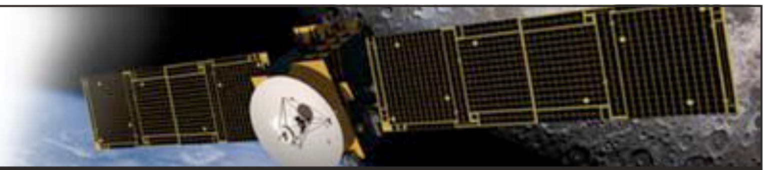
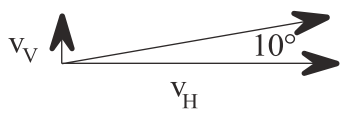
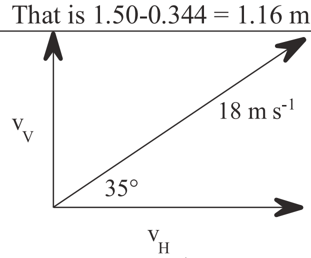
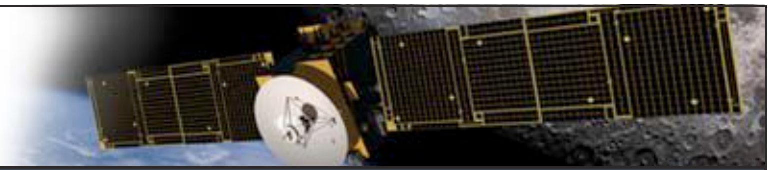
Motion and Forces in a Gravitational Field: Set 2

Set	Number	Solution
2	1	Theoretically $R = \frac{v^2}{g}sin2\theta$ which will give the largest value when $\sin 2\theta = 1$, which corresponds to $\theta = 45^o$.
	2	Force due to gravity is directed in a vertical direction. It has no component in the horizontal direction.
	3	
	4	
	5	As the bullet travels towards the target it is subjected to an acceleration downwards (due to gravity). It will therefore begin to fall. The sights are adjusted so that the rifle is aimed a distance above the target equal to the distance the bullet will fall as it travels from the gun to the target.
	6	$t = \frac{s_H}{v_H} = \frac{16 m}{80 m s^{-1}} = 0.20 s$ $s_v = \frac{1}{2}at^2 = \frac{1}{2} \times 9.8 m s^{-2} \times 0.2 s^2 = 0.196 m$ From the centre of the target to the beginning of the 5 point scoring region, the distance is only 18 cm, therefore since the arrow will hit 19.6 cm below the centre of target, the archer will only score 5 points.
	7	$v = u + at$ $0 = 7.9 m s^{-1} x \sin(16.5^o) - (9.8 m s^{-2} \times t)$ gives t = 0.23 s so the total jump time = 0.46 s therefore, his jump range, $s_H = ut = 7.9 m s^{-1} \times \cos(16.5^o) \times 0.46 s = 3.48 m$

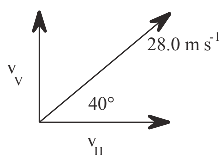
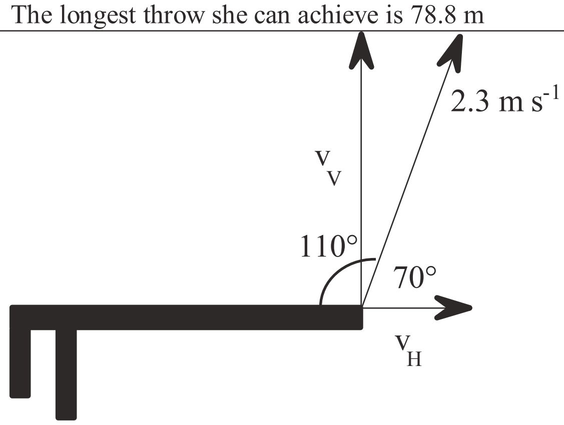


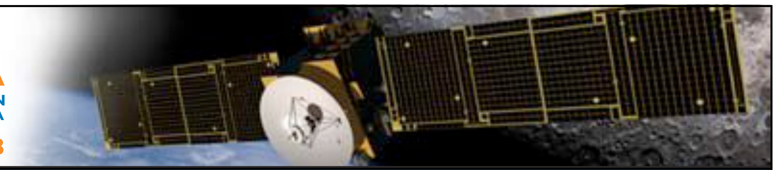
Motion and Forces in a Gravitational Field: Set 2

Set	Number	Solution
2	8	Throwing the balls fast requires that they be aimed only slightly above the cans. Throwing the balls slowly requires that the balls be aimed at some significant distance above the cans. In both cases if the balls are aimed a distance above the cans equal to the distance the balls will fall in the time taken to reach the cans, they will hit the cans.
	9	Upwards part of her somersault: $v = u + at$ $0 = 4.0\ m\ s^{-1} - (9.8\ m\ s^{-2} \times t)$ gives $t = 0.41\ s$ and $v^2 = u^2 + 2as$ gives $s = \frac{u^2}{2a} = \frac{(4.0\ m\ s^{-1})^2}{2 \times 9.8\ m\ s^{-2}} = 0.82\ m$ Downwards part of her somersault: $v^2 = u^2 + 2as$ so $v^2 = 2 \times a \times s_{total}$ gives $v = \sqrt{[2 \times 9.8\ m\ s^{-2} \times (0.82\ m + 1.1\ m)]} = 6.13\ m\ s^{-1}$ and $v = u + at$ $6.13\ m\ s^{-1} = 0 + (9.8\ m\ s^{-2} \times t)$ gives $t = 0.63\ s$ total time of somersault = up time + down time = 0.41 s + 0.63 s = 1.04 s
	10	$v = 22.5\ m\ s^{-1}$ $s = 19.4\ m$ $g = 9.8\ m\ s^{-2}$  $v_V = 22.5 \sin 10° = 3.90\ m\ s^{-1}$ $v_H = 22.5 \cos 10° = 22.2\ m\ s^{-1}$ $t = \frac{s}{v_H} = \frac{19.4}{22.2} = 0.876 s$ $s_V = ut + \frac{1}{2}at^2$ $= -3.9(0.876) + \frac{1}{2}(9.8)(0.876)^2$ $= 0.344 m$ The ball arrives at the batter 0.344 m below the point from which it was pitched. That is 1.50-0.344 = 1.16 m above the ground.
	11a	 $u_v = -10.32\ m\ s^{-1}$ $v_v = 10.32\ m\ s^{-1}$ $g = 9.8\ m\ s^{-2}$ $t = ?$ $v_v = 18 \sin 35° = 10.32\ m\ s^{-1}$



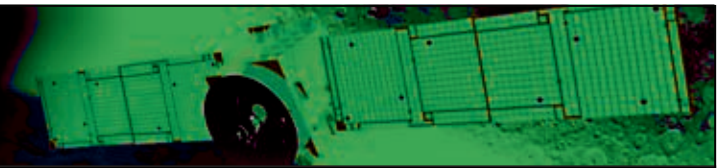
Motion and Forces in a Gravitational Field: Set 2

Set	Number	Solution
2		$v_h = 18 \cos 35° = 14.74 \text{ m s}^{-1}$ $t = \frac{v - u}{a}$ $= \frac{10.32 - (-10.32)}{9.8}$ $= 2.106 \text{s}$ Time to make position = 2.1 s
	11b	Range = $s_h = v_h t = 14.74 \times 2.106 = 31$ m
	12	The longest throw she can achieve requires a launch angle of 40°  $v_V = 28 \sin 40° = 18.0 \text{ m s}^{-1}$ $v_H = 28 \cos 40° = 21.45 \text{ m s}^{-1}$ $t = \frac{2v_V}{g} = \frac{2(18.0)}{9.8} = 3.67 \text{s}$ $s_H = v_H t$ $= 21.45 \times 3.67$ $= 78.8 \text{m}$ The longest throw she can achieve is 78.8 m
	13	 $s = 3.0 \text{ m}$ $u = -v_v = -2.16 \text{ m s}^{-1}$ $a = 9.8 \text{ m s}^{-2}$ $t = ?$ $s = ut + \frac{1}{2}at^2$ $3.0 = -2.16t + \frac{1}{2}(9.8)t^2$ $4.9t^2 - 2.16t - 3 = 0$ $t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ $= \frac{-(-2.16) \pm \sqrt{(-2.16)^2 - 4(4.9)(-3)}}{2(4.9)}$ $= 1.03 \text{s}$ $s_h = v_h \times t = 0.79 \times 1.03 = 0.82 \text{ m}$ The diver will hit the water 0.82 m from end of board
	14	Time for the water to travel 160m:



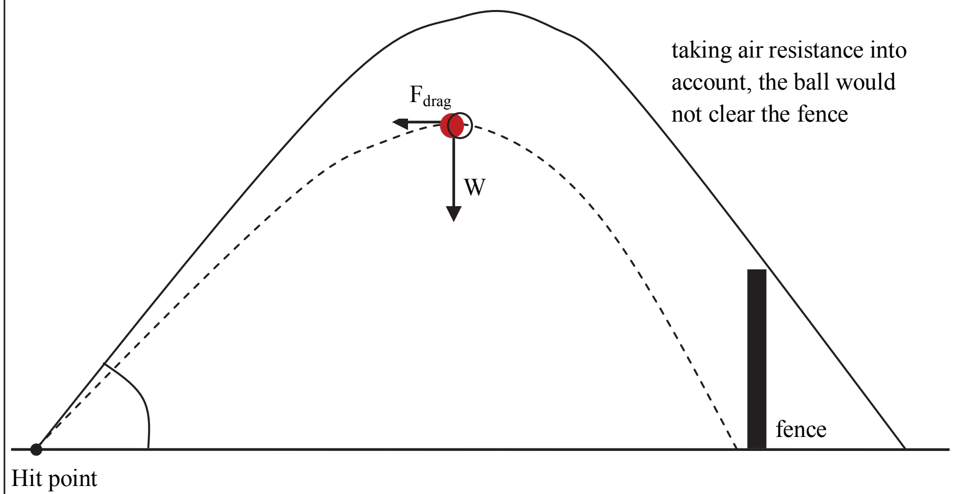
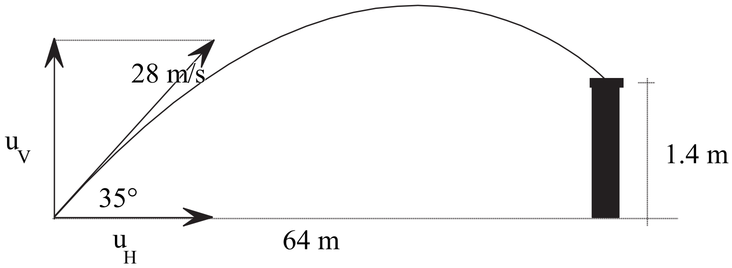
Motion and Forces in a Gravitational Field: Set 2

Set	Number	Solution
2		$t = \frac{s_h}{u_h} = \frac{160\,m}{21\,m\,s^{-1}} = 7.62\,s$ Height to allow 7.62s travel time: $s = \frac{1}{2}at^2 = \frac{1}{2} \times 9.8\,m\,s^{-2} \times (7.62\,s)^2 = 284.5\,m$ Must release from a minimum height of 285 m in order to reach fire.
	15a	Resolve vertically: 11 m s^{-1} × sin 55° = 9.0 m s^{-1} upward Resolve horizontally 11 m s^{-1} × cos 55° = 6.3 m s^{-1}, then add forward motion of shotputter 6.3 m s^{-1} + 2.8 m s^{-1} = 9.1 m s^{-1}
	15b	Maximum height when v =0. $s = \frac{-u^2}{2a} = \frac{9^2}{2\times-9.8}$ =4.1m, add height released from, 4.1m + 2.4m = 6.5 m 6.5 m
	15c	First need to determine t. $t = \frac{s-u}{t} = \frac{-2.4-9.0}{-9.8}$=1.16s Then use t to calculate horizontal distance s= u×t = 9.1 m s^{-1} ×1.16s = 18.9 m
	16a	$108\,km\,h^{-1} = 108\times\frac{1000}{3600} = 30.0\,m\,s^{-1}$ u_h = u cos θ = 30.0 × cos 15° = 29.0 m s^{-1} and u_V = u sin θ = 30.0 × sin 15° = 7.76 m s^{-1}
	16b	The acceleration is always 9.8 m s^{-2} acting vertically downwards. Or Since the direction of the car's path is always changing, then velocity (a vector) is always changing so there must always be an acceleration
	16c	Vertically, the velocity is zero Horizontally, the velocity (which remains constant) = 29.0 m s^{-1} So the resultant velocity = 29.0 m s^{-1} (⟶), to the right
	16d	Assuming she hits the ramp with her foot already fully down, then at point A. On hitting the ramp, gravity will slow her down so her speed at point B will be less. At point C her speed will be its minimum since there is no vertical speed. Air resistance (drag) will gradually reduce the horizontal speed, so the speed at D will be less than that at B and likewise, the speed at E will be less than that at point A. Ignoring air resistance, the speed at point A should equal the speed at point E.
	16e	Vertically (up to maximum point): s = ? u = u sin 15° v = 0 a = 9.8 m s^{-2} t = x need to find u using v = u + at gives: 0 = u sin 15° - 9.8x and x = u sin15/9.8 Horizontally: s = range = 38 m u = u cos 15° t = 2x using u = s/t gives u cos 15° = 38/2x and x = 19/(u cos15) combining both equations gives: u sin15/9.8 = 19/(u cos15) so u^2 = 19 x 9.8/(sin15 x cos15) = 186.2 / 0.25 = 745 giving a minimum successful speed of 27.3 m s^{-1}

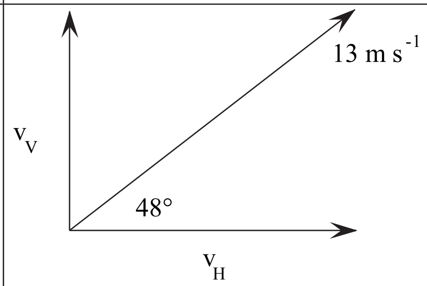


STAWA
SCIENCE TEACHERS' ASSOCIATION OF WESTERN AUSTRALIA
EXPLORING PHYSICS STAGE 3

Motion and Forces in a Gravitational Field: Set 2

Set	Number	Solution
2	17a & b	
	17c	 Horizontal motion: Time to reach the fence;- $t = \frac{s_h}{u_h} = \frac{64\ \text{m}}{28\ \text{m s}^{-1} \times \cos\ 15^\circ} = 2.37\ \text{s}$ Vertical motion: Maximum height reached:- $s = \frac{u^2}{2a} = \frac{(28\text{ms}^{-1} \times \sin 35^\circ)^2}{2 \times 9.8\text{m s}^{-2}} = 13.16\text{m}$ Time to reach maximum height: $t = \frac{v - u}{a} = \frac{0 - (-28\ \text{m s}^{-1} \times \sin 35^\circ)}{9.8\ \text{m s}^{-2}} = 1.64\ \text{s}$ so, the time it has to fall before reaching the fence = 2.37 s – 1.64 s = 0.73 s Drop in height during 0.73 s:- $s = \frac{1}{2}at^2 = \frac{1}{2} \times 9.8\ \text{m s}^{-2}\ ?\ (0.73\text{s})^2 = 2.61\ \text{m}$ so, the height above the ground as the ball reaches the fence = 13.16 m – 2.61 m = 10.55 m The ball will clear the fence by (10.55 m – 1.4 m) = 9.2 m.
	18	Vertically: s = 0.45 m – 1.35 m = -0.9m Vertically: $v = (2as)^{0.5} = (2\times-9.8\ \text{m s}^{-2} \times -0.9\ \text{m})^{0.5} = 4.2\ \text{m s}^{-1}$ To find time $t = \frac{v-u}{a} = \frac{4.2\ ms^{-1}}{9.8 ms^{-2}} = 0.43\text{s}$ Horizontally $s_h = u \times t = 83\ \text{m s}^{-1} \times 0.43\ \text{s} = 35.6\ \text{m}$ 35.6 m
	19	Horizontally: $t = \frac{s_h}{u_h}$ Subsitute for t into $s_v = u_v t + \frac{1}{2}at^2$ Leads to $1.2 = \frac{u \times 5.3 \times \sin 48}{u \times \cos 48} + -9.8 \times \frac{1}{2} \times \frac{5.3^2}{u^2 \cos 48^2}$ Multiply through by $u^2\cos^2 48$, leads to $-2.098u^2 = -137.64$ $u = 8.10\ \text{m s}^{-1}$

Motion and Forces in a Gravitational Field: Set 2

Set	Number	Solution
	20a	 $v_v = 13 \sin 48° = 9.66 \text{ m s}^{-1}$ $v_h = 13 \cos 48° = 8.70 \text{ m s}^{-1}$ vertical motion: $v^2 = u^2 + 2as$ $s = \frac{u^2}{2a} = \frac{(9.66 \text{ m s}^{-1})^2}{2 \times 9.8 \text{ m s}^{-2}} = 4.76 \text{ m}$ since the ceiling is 6.0 m high, the ball will not hit it.
	20b	time to reach maximum height: $t = \frac{v - u}{a} = \frac{0 - (-9.66 \text{ m s}^{-1})}{9.8 \text{ m s}^{-2}} = 0.986 \text{ s}$ total flight time = 2 × t = 2 × 0.986 s = 1.972 s horizontal motion: $s_h = u_h t_{total} = 8.70 \text{ m s}^{-1} \times 1.972 \text{s} = 17.2 \text{ m}$ since the court is 18 m long, then the ball will land in the court
	21	Long jump requires a long low jump, the jumper needs to generate a large horizontal speed but less vertical speed. Sprinters are good at large horizontal speeds.