W-17

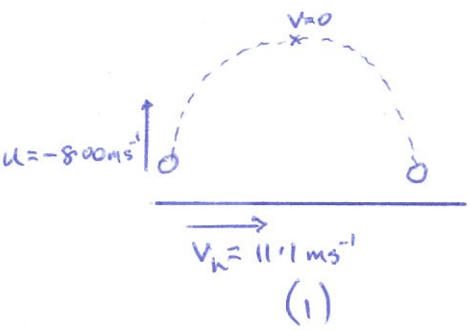
12 PHYSICS ATAR
TEST 1 - PROJECTILE MOTION

NAME: Solutions MARK: /56

When calculating numerical answers, show your working or reasoning clearly. Give final answers to **three** significant figures and include appropriate units where applicable.

1. A person on the tray of a truck travelling at 40.0 kmh^{-1} in a straight line throws a ball straight up at 8.00 ms^{-1} and catches it again at the same height. What horizontal displacement does the ball undergo whilst in flight? [4 marks]

↓ +ve



Take whole motion.

$v = ?$

$u = -8.00\ ms^{-1}$

$a = 9.80\ ms^{-2}$

$t = ?$

$s = 0\ m$

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

$\Rightarrow 0 = -8.00t + \frac{1}{2}(9.80)t^2$ (1)

$\Rightarrow t = 1.63\ s.$ (1)

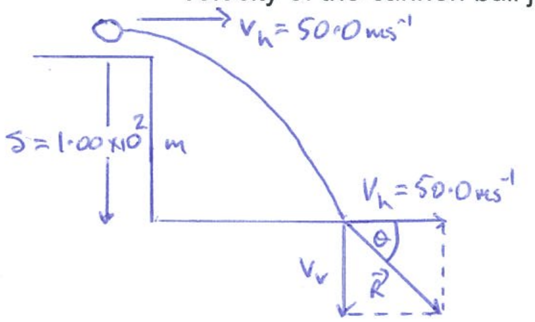
HORIZONTALLY

$s_h = v_h t$

$= (11.1)(1.63)$

$= \underline{18.1\ m}$ (1)

2. A cannon fires a cannon ball horizontally at speed of 50.0 ms^{-1} from the top of a bridge that is 1.00 x 10^2 m above the surface of a lake below. Ignoring air resistance, calculate the velocity of the cannon ball just before it hits the water. [5 marks]



VERTICALLY

$v = ?$

$u = 0\ ms^{-1}$

$a = 9.80\ ms^{-2}$

$t = ?$

$s = 1.00 \times 10^2\ m$

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

$= 0 + 2(9.80)(1.00 \times 10^2)$ (1)

$\Rightarrow v = 44.3\ ms^{-1}.$ (1)

$\vec{R} = \sqrt{(44.3)^2 + (50.0)^2}$ (1)

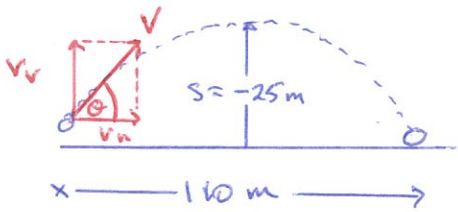
$= 66.8\ ms^{-1}$ (1)

$\tan\theta = \frac{44.3}{50.0}$

$\Rightarrow \theta = 41.5°$ (1)

$\therefore$ Impact velocity = 66.8 ms^{-1} at 41.5° to the horizontal.

3. A cricket ball (hit from near the ground) strikes the ground just over the boundary 110 m from the batsman. A spectator estimates that the ball rose to a maximum height of 25 m. Use calculations to ***estimate*** the velocity with which the ball left the bat. [6 marks]



$\downarrow$ +ve

VERTICALLY

$v = 0\ ms^{-1}$

$u = ?$

$a = 9.80\ ms^{-2}$

$t = ?$

$s = -25m$

Take movement to top.

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

$\Rightarrow 0 = u^2 + 2(9.80)(-25)$

$\Rightarrow u = 22.1\,ms^{-1}$ upwards. $(= V_v)$ (1)

$v = u + at$

$\Rightarrow t = \dfrac{v-u}{a}$

$= \dfrac{0-(-22.1)}{9.80}$

$= 2.25\,s.$ (1)

$\therefore t_{total} = 4.50\,s.$ (1)

HORIZONTALLY $V_h = \dfrac{s_h}{t}$

$= \dfrac{110}{4.50}$

$= 24.4\ ms^{-1}$ (1)

$V = \sqrt{(22.1)^2 + (24.4)^2}$

$= 32.9\ ms^{-1}$ (1)

$\tan\theta = \dfrac{22.1}{24.4}$

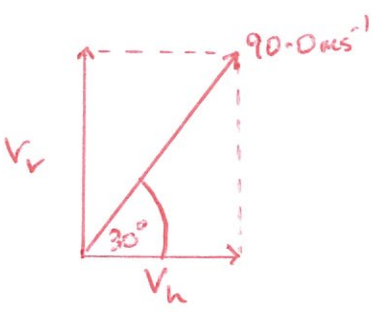
$\Rightarrow \theta = 42.2^\circ$ (1)

$\therefore$ $\underline{v = 33\,ms^{-1} \text{ at } 42^\circ \text{ to the horizontal}}$

4. An arrow is fired at 30.0° above the horizontal with a speed of 90.0 ms^{-1}. Neglect air resistance and consider the arrow to be a point mass.

(a) (i) At what instant in time after firing will the arrow be travelling the ***slowest***? [2 marks]

Travels slowest at the highest point.



$v = 0\ ms^{-1}$

$u = (-90.0\cos 60^\circ)\,ms^{-1}$

$a = 9.80\ ms^{-2}$

$t = ?$

$s = ?$

$v = u + at$

$\Rightarrow t = \dfrac{v-u}{a}$

$= \dfrac{0-(-90.0\cos 60.0^\circ)}{9.80}$ (1)

$= \underline{4.59\,s}$ (1)

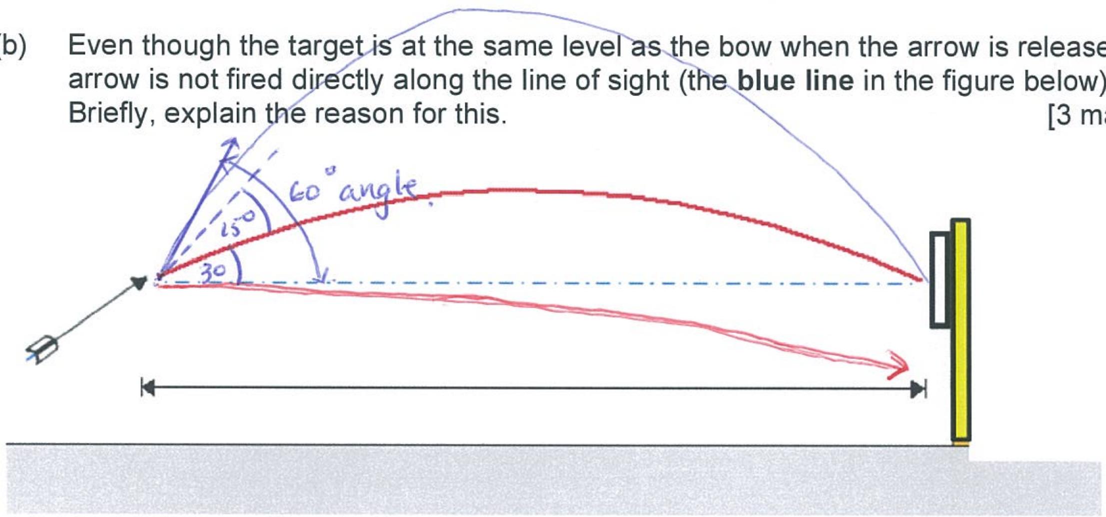
(ii) What is the velocity of the arrow at this instant of time? [2 marks]

At the top, only v_h exists.

i.e. $V_h = 90.0 \cos 30.0^\circ$ (1)

$= \underline{77.9 \text{ ms}^{-1} \text{ horizontal.}}$ (1)

(b) Even though the target is at the same level as the bow when the arrow is released, the arrow is not fired directly along the line of sight (the **blue line** in the figure below). Briefly, explain the reason for this. [3 marks]



- Firing horizontally ⇒ arrow starts to fall below the target immediately. (1)
- Firing above the horizontal increases the time of flight. (1)
- This allows the arrow to move a greater distance horizontally before returning to the target height. (1)

(c) At what different angle could the arrow be fired to achieve the same range? Show the trajectory on the diagram above. [2 marks]

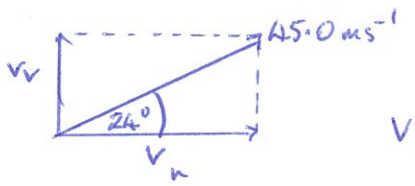
- 45° gives maximum range.
- If 30° hits the target, so does 60° (45°+15°). (1)

[Diagram - 1 mark]

5. On February 6 1971, during the Apollo 14 mission, astronaut Alan Shepard hit a golf ball on the Moon. The golf club launched the ball at an angle of 24.0° to the ground with an initial speed of 45.0 ms^{-1}.

(a) Construct a labelled free body diagram below, showing the force(s) acting on the golf ball about halfway between it being struck and its highest point. [2 marks]

(b) Calculate the horizontal and vertical components of the initial velocity. [2 marks]



Answer u_h ......41.1..........ms^{-1}

Answer u_v ......18.3.........ms^{-1}

$$V_v = 45.0 \cos 66.0^\circ$$
$$= 18.3 \text{ ms}^{-1} \quad (1)$$

$$V_h = 45.0 \cos 24.0^\circ$$
$$= 41.1 \text{ ms}^{-1} \quad (1)$$

(c) Assuming the golf ball travelled over a level surface, a horizontal distance of 9.00×10^2 m, calculate:

(i) time taken to hit the surface. [2 marks]

HORIZONTALLY $\quad V_h = \dfrac{S_h}{t}$

$$\Rightarrow t = \frac{S_h}{V_h}$$
$$= \frac{9.00 \times 10^2}{41.1} \quad (1)$$
$$= \underline{21.9 \text{ s}} \quad (1)$$

(ii) the value of the acceleration due to gravity on the Moon. [4 marks]

↓+ve

$v = ?$

$u = -18.3\,ms^{-1}$

$a = ?$

$t = 21.9\,s$

$s = 0\,m$ (1).

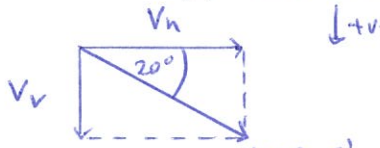
$s = ut + \frac{1}{2}at^2$

$\Rightarrow 0 = (-18.3)(21.9) + \frac{1}{2}a(21.9)^2$ (2)

$\Rightarrow a = \underline{1.67\,ms^{-2}\ \text{down}}.$ (1)

6. An explosion in a tall building projects window glass outward ***and downward*** at 40.0 ms^{-1} at an angle of 20.0° below the horizontal. If the glass strikes the ground 4.50 s later:

(a) how far from the ground was the room in which the explosion occurred? [3 marks]



↓+ve

VERTICALLY:

$v = ?$

$u = (40.0\cos 70.0°)\,ms^{-1}$ (1)

$a = 9.80\,ms^{-2}$

$t = 4.50\,s$

$s = ?$

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

$= (13.7)(4.50) + \frac{1}{2}(9.80)(4.50)^2$ (1)

$= 1.61 \times 10^2\,m$ (1)

∴ Room was 161 m above the ground.

(b) how far from the base of the building does the glass land? [3 marks]

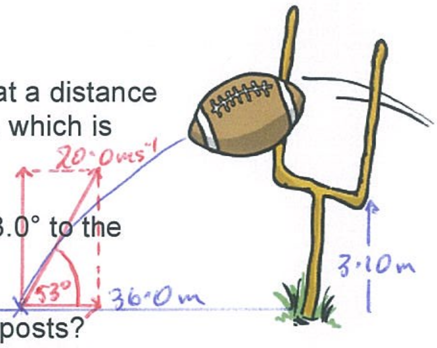
HORIZONTALLY:

$s_h = v_h t$ (1)

$= (40.0\cos 20.0°)(4.50)$ (1)

$= \underline{169\,m}$ (1)

7. In a football game, a place kicker kicks a football from the ground at a distance of 36.0 m from the goalposts, and the ball must clear the crossbar, which is 3.10 m from the ground as shown in the diagram.



When kicked, the ball leaves the foot at 20.0 ms^{-1} at an angle of 53.0° to the horizontal.

(a) How long does the ball take to travel the distance to the goalposts?
[3 marks]

HORIZONTALLY :

$s_h = v_h t$

$\Rightarrow t = \dfrac{s_h}{v_h}$

$= \dfrac{36{\cdot}0 \quad (1)}{20{\cdot}0 \cos 53{\cdot}0^\circ \quad (1)}$

$= \underline{2{\cdot}99\,s} \quad (1)$

(b) How far above or below the crossbar is the ball when it passes through the goal posts?
[4 marks]

VERTICALLY :

$v = ? \quad (1)$

$u = (-20{\cdot}0 \cos 37{\cdot}0^\circ)\,ms^{-1}$

$a = 9{\cdot}80\,ms^{-1}$

$t = 2{\cdot}99\,s$

$s = ?$

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

$= (-16{\cdot}0)(2{\cdot}99) + \frac{1}{2}(9{\cdot}80)(2{\cdot}99)^2 \quad (1)$

$= 4{\cdot}03\,m \quad (1)$

$\therefore$ Passes over the bar by $4{\cdot}03 - 3{\cdot}10$

$= \underline{0{\cdot}93\,m} \quad (1)$

(c) Show on a sketch the path of the football. Include the goalposts in your sketch. Explain why you have drawn the path this way, ***showing any necessary working***.
Label this path P. [5 marks]

Time to highest point:

$v = 0\ ms^{-1}$

$u = -16.0\ ms^{-1}$

$a = 9.80\ ms^{-2}$

$t = ?$

$s = ?$

$v = u + at$

$\Rightarrow t = \frac{v-u}{a}$

$= \frac{0-(-16.0)}{9.80}$ (1)

$= 1.63s.$ (1)

Time horizontally to posts:

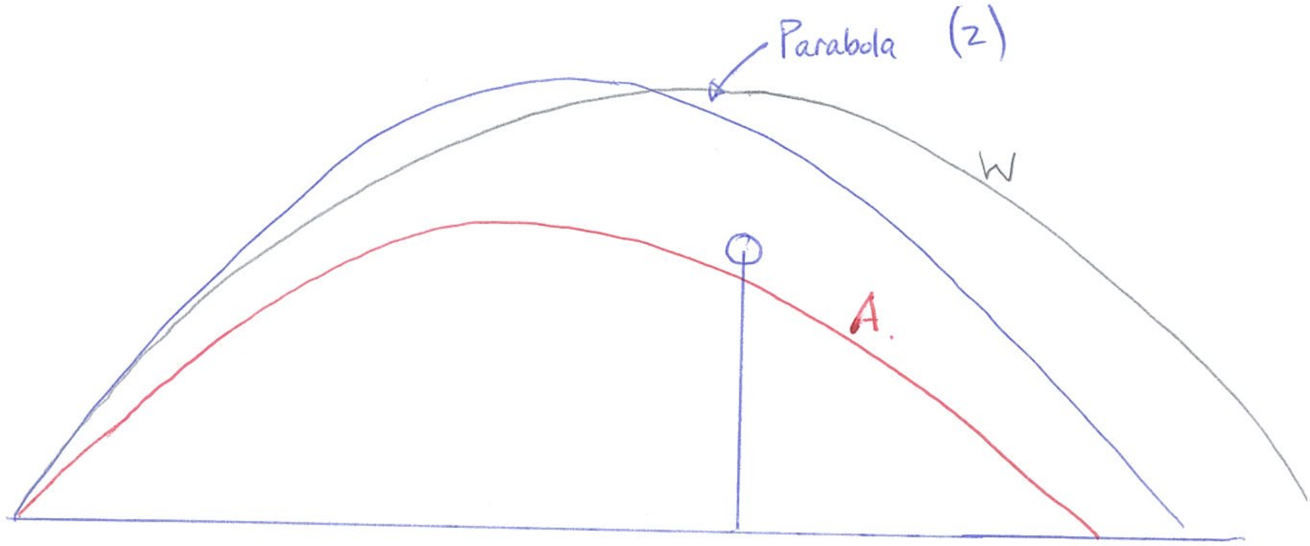
$s_h = \frac{v_h}{t}$

$\Rightarrow t = \frac{v_h}{s_h}$

$= \frac{12.0}{36.0}$

$= 3.00s.$

Since the highest point is at 1.63s, it is past half-way to the posts. (1)



(d) On the sketch in (c) above, sketch the path of the football would take if air resistance was not negligible.
Label this path A. [2 marks]

Lower height (1)
Shorter range (1)

(e) On the sketch in (c) above, sketch the path of the football would take if a tail-wind was present and the air resistance was negligible.
Label this path W. [2 marks]

Same height (1)
Greater distance (1)