YEAR 12 PHYSICS
ASS. 1 - PROJECTILE MOTION

NAME: SOLUTIONS **TOTAL:** $\frac{\quad}{48}$

DUE DATE: ____________________

1. A pilot drops a package from an aircraft flying horizontally at a constant speed over flat ground. Neglecting air resistance, when the package hits the ground, the horizontal location of the aircraft will:

   A. be behind the package.
   B. be directly above the package.
   C. be in front of the package.
   D. depend on the speed of the aircraft when the package was released..
   E. depend on the height of the aircraft when the package was released.

   Answer B (1) (1)

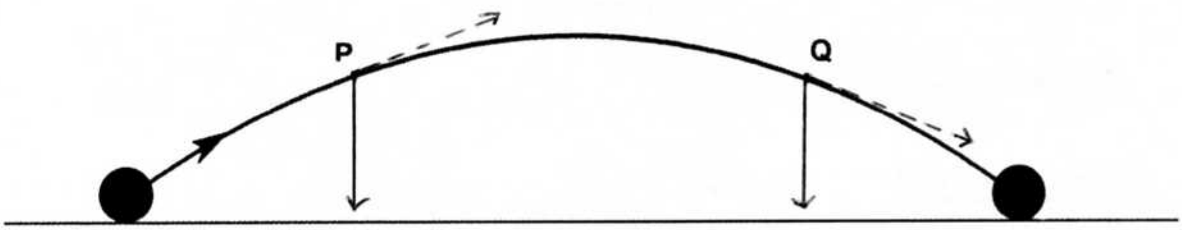
   Explain your answer.

   - The package and the plane have the same horizontal velocity. (1)
   - In the time taken for the package to fall vertically to the ground, both the plane and the package would have moved horizontally the same distance. (1)

   (2)

2. The diagram below shows the trajectory of a golf ball (ignoring air resistance and any spin). The ball moves from left to right as shown.

   ($\frac{1}{2}$ mark each arrow)



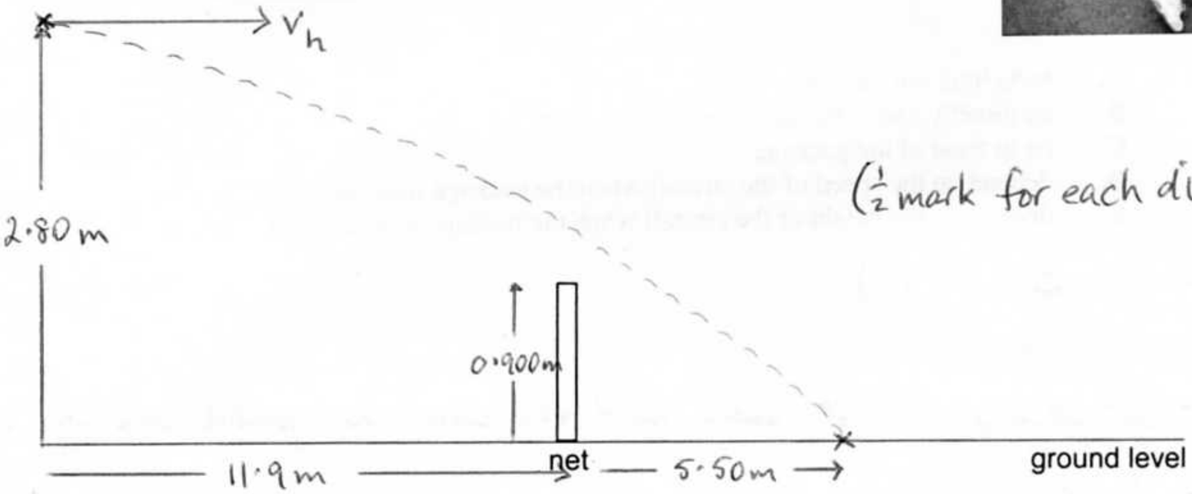
   (a) With dotted arrows (like this ┈┈┈▶), show the direction of the resultant **velocity** of the ball at positions P and Q.

   (b) With solid arrows (like this ——▶), show the direction of the resultant **acceleration** of the ball at positions P and Q.

   (2)

3. While serving a tennis ball, a tennis player aims to hit the ball horizontally so that it lands in the opponent's court 5.50 m from the net. The height of the net is 0.900 m, the distance between the service point and the net is 11.9 m and the ball is hit from as height of 2.80 m above the court.

(a) On the diagram below, draw the path of the ball with all the relevant distances labelled.



($\frac{1}{2}$ mark for each distance)

(2)

(b) Calculate the time taken for the tennis ball to reach the net and the minimum initial velocity that the ball would need to just clear the net.

VERTICALLY

$\downarrow$ +ve

$v = ?$

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

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

$t = ?$

$s = 1.90\ m$

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

$$\Rightarrow 1.90 = 0 + \frac{1}{2}(9.80)t^2 \quad (1)$$

$$\Rightarrow t = \underline{0.623\ s} \quad (1)$$

HORIZONTALLY

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

$$= \frac{11.9}{0.623} \quad (1)$$

$$= \underline{19.1\ ms^{-1}\ \text{horizontally}} \quad (1)$$

(4)

(c) Calculate the time it takes for the ball to hit the court.

VERTICALLY

↓ +ve.

$v = ?$

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

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

$t =$

$s = 2.80m$

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

$\Rightarrow 2.80 = 0 + \frac{1}{2}(9.80)t^2$ (1)

$\Rightarrow \underline{t = 0.756\ s}$ (1)

(2)

(d) Calculate the distance from the net that the ball will land on the court on the opponent's side.

If you were unable to determine an answer in part (c), assume that the time of flight is 0.900 s.
If you were unable to determine an answer in part (a), assume that the initial speed is 20.0 ms^{-1}.

HORIZONTALLY

$s_h = v_h t$

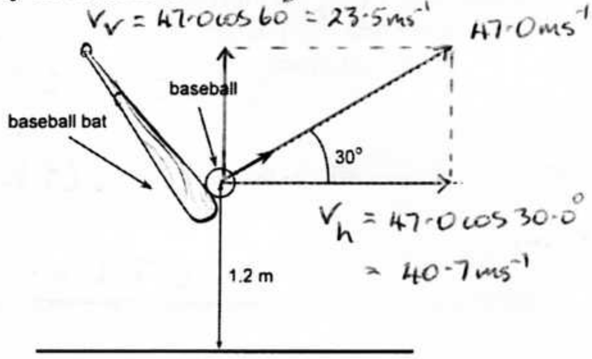
$= (19.1)(0.756)$ (1)

$= 14.4m$ (1)

$\therefore$ <u>Ball lands 2.50m from the net</u>. (1)

(3)

4. A baseball leaves a bat at an angle of 30.0 ° to the horizontal when struck 1.20 m above the ground. It moves with an initial velocity of 47.0 ms^{-1}.



Assume that the air resistance is negligible. Working **must** be shown to gain full marks for this question.

(a) Calculate the maximum height above the ground reached by the baseball.

VERTICALLY

Consider movement to the top. ↓ +ve.

$v = 0.0\,ms^{-1}$

$u = -23.5\,ms^{-1}$ (1)

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

$t = ?$

$s = ?$

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

$\Rightarrow 0 = (-23.5)^2 + 2(9.80)s$ (1)

$\Rightarrow s = -28.2\,m.$ (1)

∴ Height = 29.4 m above the ground. (1)

(4)

(b) Calculate the vertical component of the velocity when the ball impacts the ground.

If you were unable to determine an answer to part (a), use 27.0 m as a value for the maximum height.

VERTICALLY

Consider the whole motion. ↓ +ve

$v = ?$

$u = -23.5\,ms^{-1}$

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

$t = ?$

$s = 1.20\,m$

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

$= (-23.5)^2 + 2(9.80)(1.20)$ (1)

$= 5.758\times10^2$

$\Rightarrow v = 24.0\,ms^{-1}$ down. (1)

(2)

(c) Calculate the time of flight of the baseball.

If you were unable to determine an answer to part (b), you should use 20.0 ms^{-1} as a value for the vertical component of velocity when the ball hits the ground.

VERTICALLY.

$v = 24.0 ms^{-1}$

$u = -23.5 ms^{-1}$

$a = 9.80 ms^{-2}$

$t = ?$

$s = 1.20 m$

↓+ve.

$v = u + at$

$\Rightarrow t = \frac{v-u}{a}$ (1)

$= \frac{24.0 - (-23.5)}{9.80}$ (1)

$= \underline{4.85 s}$ (1)

(3)

(d) Calculate the horizontal range of the baseball.

If you were unable to determine an answer to part (c), use 3.00 s as a value for the time of flight.

HORIZONTALLY

$s_h = v_h t$

$= (40.7)(4.85)$ (1)

$= \underline{1.97 \times 10^2 m}$. (1)

(2)

5. A cork can leave a champagne bottle with a velocity greater than 15.0 ms^{-1}. In 1988, a world record was set when a cork travelled a horizontal distance of 54.1 m. In competition, champagne corks are fired at 40.0 ° to the horizontal. In this question, ignore the effects of air resistance and assume the cork is fired from ground level.

The range s of a projectile is given by the equation: $\mathbf{s = v_0 t\cos\theta}$,
where v_o is the initial velocity, t is the time of flight and θ is the angle to the horizontal.

The time of flight of a projectile is given by the equation: $\mathbf{t = \frac{2v_0\sin\theta}{g}}$,

where g is the acceleration due to gravity.

(a) Use the two equations above to show that the initial velocity for a projectile is:

$$v_o = \sqrt{\frac{g\,s}{2\cos\theta\sin\theta}}$$

$$s = v_0 t \cos\theta$$

$$= v_0 \left(\frac{2v_0 \sin\theta}{g}\right)\cos\theta. \quad (1)$$

$$\Rightarrow \quad s = \frac{v_0^2\, 2\sin\theta\cos\theta}{g} \quad (1)$$

$$\Rightarrow \quad v_0 = \sqrt{\frac{g\,s}{2\sin\theta\cos\theta}}. \quad (1)$$

(3)

(b) Calculate the initial velocity of the record-breaking champagne cork.

$$V_0 = \sqrt{\frac{g\,s}{2\sin\theta\cos\theta}}$$

$$= \sqrt{\frac{(9.80)(54.1)}{2\sin 40.0^\circ \cos 40.0^\circ}} \quad (1)$$

$= \underline{23.2\ \text{ms}^{-1}\ \text{at } 40.0^\circ \text{ to the horizontal}}$ (1)

(2)

(c) Calculate the maximum height reached by the cork.

VERTICALLY

Consider motion to the top $\downarrow$ +ve

$v = 0.0 ms^{-1}$

$u = -(23.2 \cos 50.0^\circ) ms^{-1}$ (1)

$a = 9.80 ms^{-2}$

$t = ?$

$s = ?$

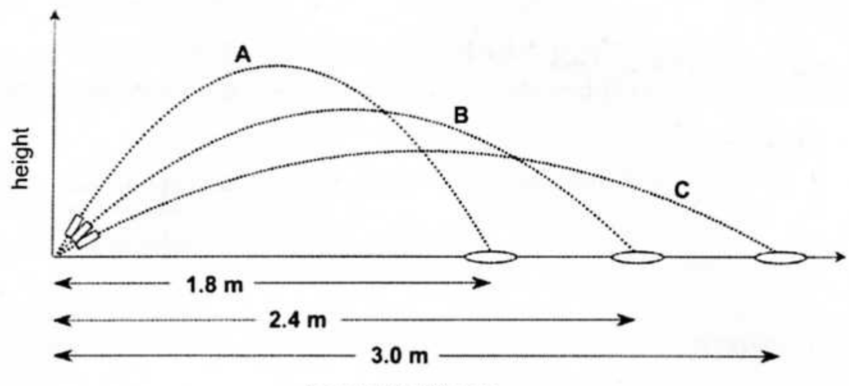
$v^2 = u^2 + 2as$

$\Rightarrow \quad 0 = (-23.2 \cos 50.0^\circ)^2 + 2(9.80)s$ (1)

$\Rightarrow \quad s = -11.4$ m above release point. (1)

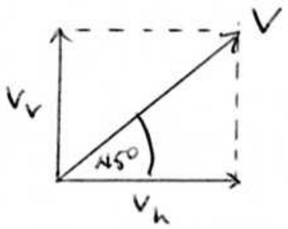
(3)

6. The diagram below shows part of a water fountain. It consists of three nozzles at ground level that fire three short jets of water in parabolic paths (A, B and C) through the air. The jets of water fall into three different holes in the ground. The centres of the holes are at the distances shown.



(a) The nozzle for B is directed at 45.0 ° above the horizontal. The water jet is in the air for 0.700 s and lands in the middle of the hole. Calculate the initial velocity of the water jet.

<u>HORIZONTALLY</u>



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

$= \frac{2.40}{0.700}$ (1)

$= 3.429\ ms^{-1}$. (1)

$V_h = V \cos 45.0$

$\Rightarrow V = \frac{3.429}{\cos 45.0}$ (1)

$= \underline{4.85\ ms^{-1}\text{ at }45.0^\circ\text{ to the horizontal}}$ (1).

(4)

(b) What is the maximum height reached by the water jet from nozzle B?

<u>VERTICALLY</u> Consider motion to the top. ↓+ve

$v = 0.0\ ms^{-1}$

$u = -(4.85 \cos 45.0^\circ)$ (1)

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

$t = ?$

$s = ?$

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

$\Rightarrow 0 = (-4.85 \cos 45.0^\circ)^2 + 2(9.80)s$ (1)

$\Rightarrow s = -0.600\ m$ (1)

$\therefore$ <u>Height = 0.600 m above the nozzle</u>.

(3)

(c) The holes in the ground each have a diameter of 20.0 cm. The diameter of the water jet is 2.0 cm. If the wind is blowing horizontally with a constant velocity of 0.280 ms^{-1} in the direction that the water travels, will the water jet following trajectory B still land in the hole? Show sufficient working to justify your answer.

HORIZONTALLY $\quad v_h = 3.43 + 0.280 = 3.71 ms^{-1}$ (1)

$s_h = v_h t$

$= (3.71)(0.700)$

$= 2.60 m.$ (1)

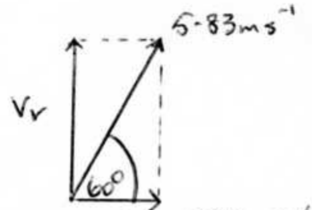
$\therefore$ Jet will miss the hole by around 10cm. (1)

(3)

(d) The nozzle for A is directed at an angle of 60.0° above the horizontal and the nozzle for C is directed at an angle of 30.0 ° above the horizontal. The initial velocity of A is 5.83 ms^{-1} and the initial velocity of C is 4.52 ms^{-1}.

If all three water jets leave at the same instant, in what order will they land in their respective holes? Show sufficient working to justify your answer.

A.



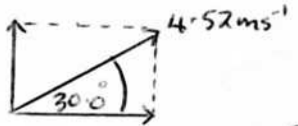
$v_h = 5.83 \cos 60.0^\circ$
$= 2.92 ms^{-1}$

$s_h = v_h t$

$\rightarrow t = \frac{1.80}{2.92}$ (1)

$= 0.616 s.$

C.



$v_h = 4.52 \cos 30.0^\circ$
$= 3.91 ms^{-1}$

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

$= \frac{3.00}{3.91}$ (1)

$= 0.767 s.$

$\therefore$ Order is A, B, C. (1)

(3)

NOTE If the vertical components are used, then the order is C, B, A.
The question is poorly written - the velocities for A and C are not correct!