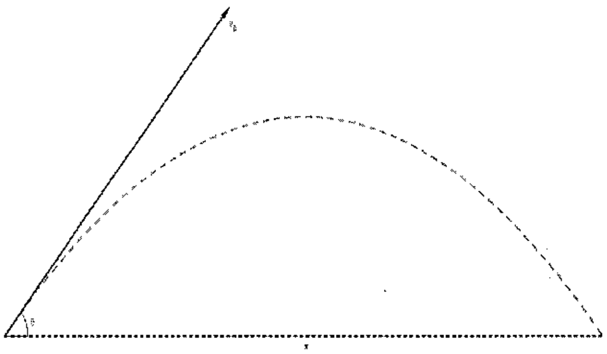
Physics SAT 1: Projectiles & Uniform Circular Motion

[Q1] A projectile is launched from ground height with an initial velocity of 17.5 ms^{-1} at an angle of
41.5° above the horizontal, as shown in the diagram below. ***Ignore the effects of air resistance.***



(a)
Find the magnitude of the horizontal component of the initial velocity and the magnitude of the vertical component of the initial velocity.

(4 points)

$V_H = V\cos\theta$ $V_V = V\sin\theta$

$= 17.5 \times \cos 41.5$ $= 17.5 \sin 41.5$

$= 13.1 \ ms^{-1}$ $= 11.60 \ ms^{-1}$

$V_H = 13.1 \ ms^{-1}$ (3sf) $V_V = 11.6 \ ms^{-1}$ (3sf

b) The time of flight of the projectile is 2.25 s. Calculate the range of the projectile.

(2 points)

$s = vt$

$= 13.1 \times 2.25$

$= 29.49 \ m$

$= 29.5 \ m$ (3sf)

i Calculate the vertical component of the velocity at time t = 2.0 s

(3 points)

$V = V_0 + at$

$= 11 \cdot 6 + -9 \cdot 8 \times 2$

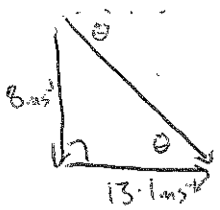
$= -8 \ ms^{-1}$

ie $8 \cdot 0 ms^{-1}$ down (2sf)

(ii) *Using a labelled vector diagram,* calculate the resultant speed of the projectile at t = 2.0 s and

the angle in degrees below the horizontal.

(4 points)



$V = \sqrt{8^2 + 15 \cdot 1^2}$

$= 15 \cdot 3 \ ms^{-1}$

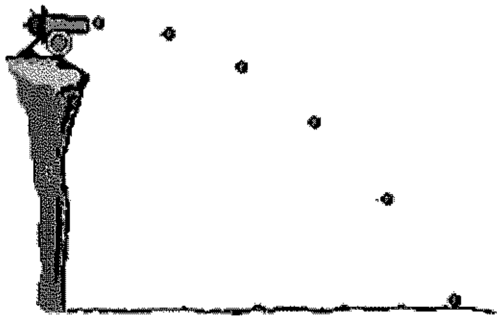
$\tan \theta = \frac{8}{13 \cdot 1}$

$\theta = \tan^{-1}\left(\frac{8}{13 \cdot 1}\right)$

$= 31 \cdot 4^\circ$

$V = 15 \ ms^{-1}$ at 31° below horizontal

[Q2] A cannon launches its projectile horizontally from a height of 4.55 m above ground level, with an initial velocity of magnitude $v_o = 60.5\ \text{ms}^{-1}$.



Ignore the effects of air resistance in parts (a) to (c) of this question.

a) Calculate the magnitude of the horizontal component of the velocity of the projectile when it hits the ground. Justify your answer (2 points)

$V_0 = V_H = 60.5\ \text{ms}^{-1}$

$\therefore V_{fH} = 60.5\ \text{ms}^{-1}$ as horizontal V is constant.

(b) Calculate the time of flight of the projectile.

(2 points)

~~$v = v_0 + at$~~ $\quad S = V_0 t + \frac{1}{2}at^2$

$S = \frac{1}{2}at^2$ as $V_0 = 0$

$t = \sqrt{\frac{2s}{a}}$

$= \sqrt{\frac{2 \times 4.55}{9.8}}$

$= 0.964\ \text{s}$ (3sf)

(c) Calculate the range of the projectile.

(2 points)

$S = Vt$

$= 60.5 \times 0.964$

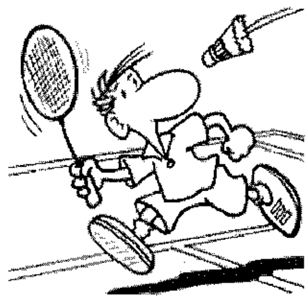
$= 58.3\ \text{m}$

d) Explain the effect that air resistance would have on the range of the ball.

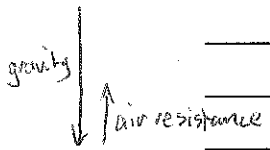
(2 points)

Air resistance would decrease the range as the horizontal velocity would decrease. (this is a larger factor than any small increase in t)

During a badminton match a shuttlecock is hit 4.55 m above ground level. It moves horizontally with an initial velocity of magnitude $\boldsymbol{v_o} = 65.5\ \text{ms}^{-1}$. Air resistance increases the time of flight of the shuttlecock by more than 0.08 s.



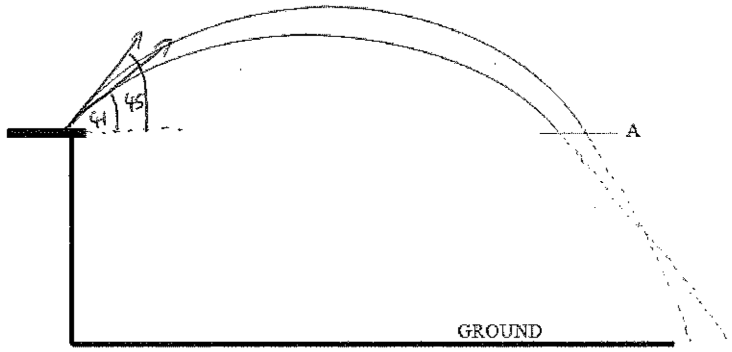
Explain with the use of a diagram why air resistance increases the time of flight of the shuttlecock. (4 points)



air resistance will decrease the acceleration due to gravity as it acts in the direction opposite to the motion.

As the shuttlecock is not accelerating downwards to the same extent, the time will increase as $t \propto \frac{1}{\sqrt{a}}$

[Q3] The diagram below shows the paths of two shot puts launched by an athlete. They both are launched at the same speed and released 1.8m above the ground. One is launched at an angle of 45°, and the other path is for a launch angle of 41°.



(a) Clearly label on the diagram the initial velocity vector for each launch angle. (1 point)

(b) On the diagram complete both paths to ground level.
(1 point)

(c) Explain with the use of formulas why the two objects travel different distances horizontally after height A. (4 points)

the horizontal component of the second velocity is greater than the first

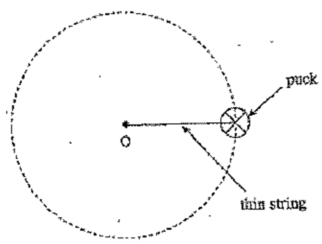
$V \cos 45 = 0 \cdot 71 V$

$V \cos 41 \cdot = 0 \cdot 75 v$

For the same time, due to the greater horizontal velocity, the second shot will travel further after point A.

[Q4] **(a)** A puck is attached by a thin string of fixed length to point O on a horizontal table, as shown The puck rotates freely and at a constant speed about point O.

Friction between the puck and the surface of the table is negligible.

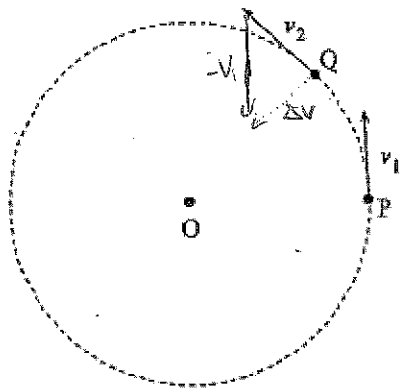


(i) In a sentence name the force acting on the puck that causes the centripetal acceleration. (1 point)

centripetal force due to tension on the string

(ii) The instantaneous velocity $\boldsymbol{v_1}$ of the puck at point P is shown The velocity $\boldsymbol{v_2}$ of the puck a very short time later at point Q is also shown.

On the diagram draw a vector diagram to determine the direction of the change in velocity $\boldsymbol{\Delta v}$ of the puck.
(2 marks)



(iii) The puck moves in a circle of radius r = 0.25 m, with period T = 1.2 s.

(a) Show that the speed of the puck is approximately 1.3 ms^{-1}.
(2 points)

$V = \frac{2\pi r}{T}$

$= \frac{2 \times \pi \times 0.25}{1.2}$

$= 1.3 \text{ ms}^{-1}$ (2sf

(b) Calculate the magnitude of the acceleration of the puck.

(2 points)

$a = \frac{v^2}{r}$

$= \frac{1.3^2}{0.25}$ $a = 6.85 \text{ ms}^{-2}$

(c) Show that the magnitude of the force acting on the puck is approximately 0.34 N. The mass m of the puck is 5.0 x 10^{-2} kg. (2 points)

$F = ma$

$= 5 \times 10^{-2} \times 6{\cdot}85$

$= 0{\cdot}34$ N (2sf)

(d) Calculate the magnitude of the force acting on the puck if the speed of the puck is doubled without a change in the radius. (3 points)

$F_1 = \frac{mv^2}{r}$ $\quad F_2 = \frac{m(2v)^2}{r}$

$F \propto v^2$ $\quad F_2 = 4\frac{mv^2}{r}$

$F_2 = 4 \times F_1$

$\therefore$ Force is multiplied by 4.

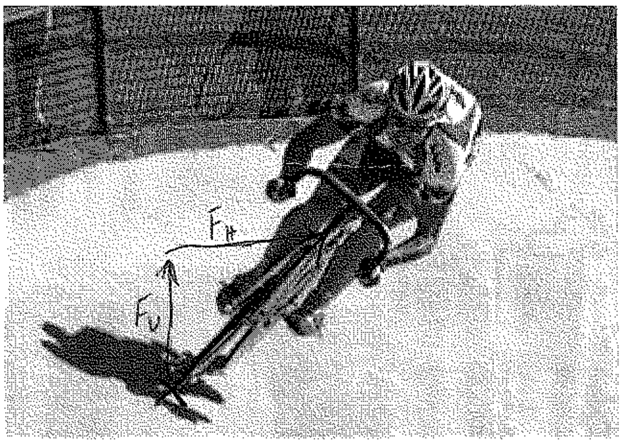
[Q5] Velodromes are cycle-racing tracks with banked curves that enable cyclists to travel at high speeds:

On the diagram below:

(a)

(i) Using the marked cross as a reference point, draw a vector to show the normal force F_n on a bicycle travelling with uniform circular motion around a banked curve. (1 point)

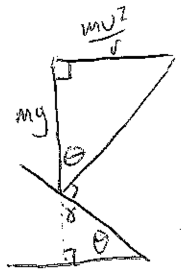
(ii) Resolve the normal force vector into its horizontal and vertical components, labelling each component. (2 points)



(b) (i) State why the vertical component of the normal force vector has a magnitude of *mg* , where *m* is the total mass of the cyclist and the bicycle. (1 point)

mg acts downwards as acceleration due to gravity is down. Normal (vert) is equal and opposite

(ii)Derive the equation $\tan\theta = v^2/rg$, relating the banking angle θ to the speed *v* at which the cyclist is travelling and the radius of curvature *r* . (3 points)



$\gamma = 90 - \theta$

$\therefore \theta = \theta$

vert. component = mg

hor. component = $\frac{mv^2}{r}$ as this is ~~doe~~ providing centrip. acc.

$\tan\theta = \frac{\frac{mv^2}{r}}{mg}$ cancel m

$\tan\theta = \frac{v^2}{rg}$

(c) A cyclist is travelling around a banked curve in a velodrome. The banked curve has a radius of 25 m and a banking angle of 44°. Calculate the maximum speed at which the cyclist can travel around the banked curve without relying on friction. (3 marks)

$\tan\theta = \frac{v^2}{rg}$

$v = \sqrt{rg\tan\theta}$

$= \sqrt{25 \times 9.8 \times \tan 44}$

$= 15.4\ ms^{-1}$

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Note: Work is graded against the performance standards. Points are an indication of the detail required in responses. The performance standards are the criteria against which work is assessed.