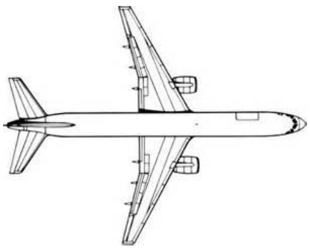
ALL SAINTS' COLLEGE
Ewing Avenue, Bull Creek, Western Australia

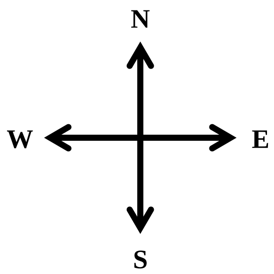
12 Physics ATAR | Motion & Forces Test 1 | February 2016

Time allowed: 50 minutes
Total marks available: 50
Show calculation answers to 3 significant figures

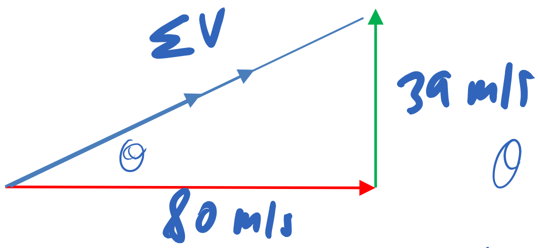
Student Name: Solutions

1. An aircraft is flying East at 80.0 m s^{-1} when it is hit by a wind acting North at 39.0 m s^{-1}.





a) Calculate the resultant velocity (magnitude and direction) of the aircraft in the wind. You **must** use a vector diagram in your answer. (4)



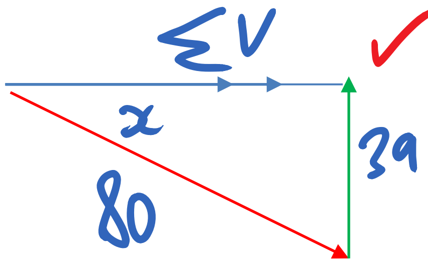
$\Sigma V = \sqrt{39^2 + 80^2}$ ✓

$\Sigma V = 89.0$ m/s ✓

$\theta = \tan^{-1}\left(\frac{39}{80}\right) = 26.0°$

$\Sigma V = 89.0$ m/s E26.0°N ✓

b) What direction should the aircraft point to achieve a resultant velocity in a direction due East. You must use a vector diagram in your answer. (2)

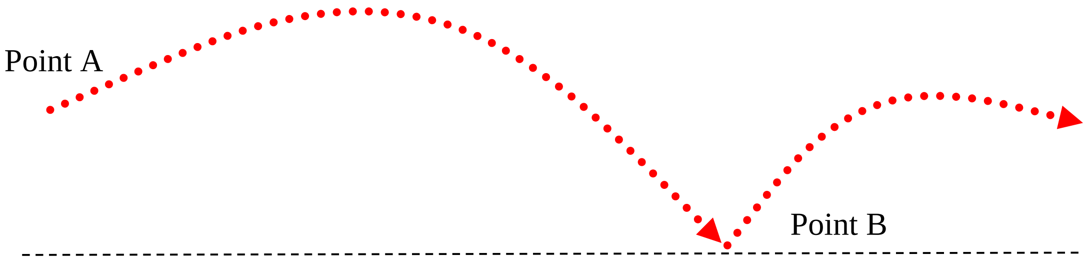


$x = \sin^{-1}\left(\frac{39}{80}\right)$

$x = 29.2°$ ✓

$x = $ E 29.2° S

2. A ping-pong (table tennis) ball is served from point A. The trajectory is shown on the diagram below. Ignore the effects of friction and air resistance.



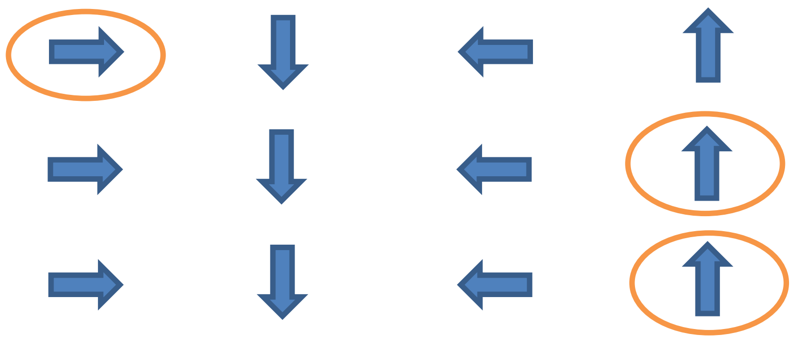
Consider the instantaneous motion of the ball when it has maximum contact with the table at point B. Circle the appropriate arrows to indicate the direction of its:

(3)

Velocity

Net acceleration

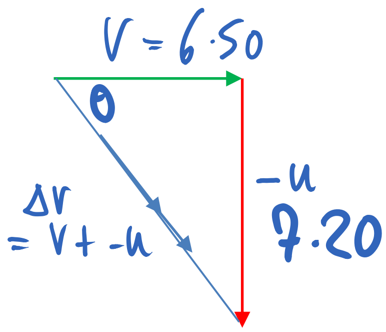
Net force



3. A golf-ball with an initial velocity of 7.20 m s^{-1} North strikes a corner post. It rebounds with a velocity of 6.50 m s^{-1} East.

a) Construct a vector diagram to show the **change in velocity** of the golf-ball in this collision.

(1)



b) Determine the magnitude and direction of the change in velocity (Δv).

(3)

$\Delta V = \sqrt{6.50^2 + 7.20^2}$ $\quad \theta = \tan^{-1}\left(\frac{7.20}{6.50}\right)$

$\Delta V = 9.70$ m/s $\quad \theta = 47.9°$

$\Delta V = 9.70$ m/s E 47.9° S

4. A stunt bike and rider of mass 85 kg launches horizontally from a ledge at a speed of 11.0 m s^{-1}. The ground lies 4.61 m vertically below the launch position.

a. Calculate the **velocity** (magnitude and direction) of the stunt bike after 0.500 seconds of flight.

(4)

$u_v = 0$

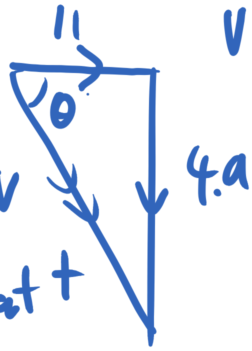
$a_v = -9.8 \text{ m/s}^2$

$t = 0.5 \text{ s}$

$u_y = 11.0 \text{ m/s}$

$V_v = u_v + at$

$V_v = 0 + (-9.8 \times 0.5) = -4.9 \text{ m/s}$



$V = \sqrt{11^2 + 4.9^2}$

$V = 12.0 \text{ m/s}$

$\theta = \tan^{-1}\left(\frac{4.9}{11}\right)$

$\theta = 24.0°$

$v = 12.0 \text{ m/s}$ @ $24.0°$ down at +

b. Calculate the time it takes for the stunt bike to reach ground level.

(2)

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

$-4.61 = 0 - 4.9t^2$

$t^2 = \frac{4.61}{4.9}$ $\quad t = 0.970 \text{ s}$

c. Calculate the horizontal range of the stunt bike.

(1)

range $= u_h \times t$

$S_h = 11 \times 0.97 = +10.7 \text{ m}$ (right)

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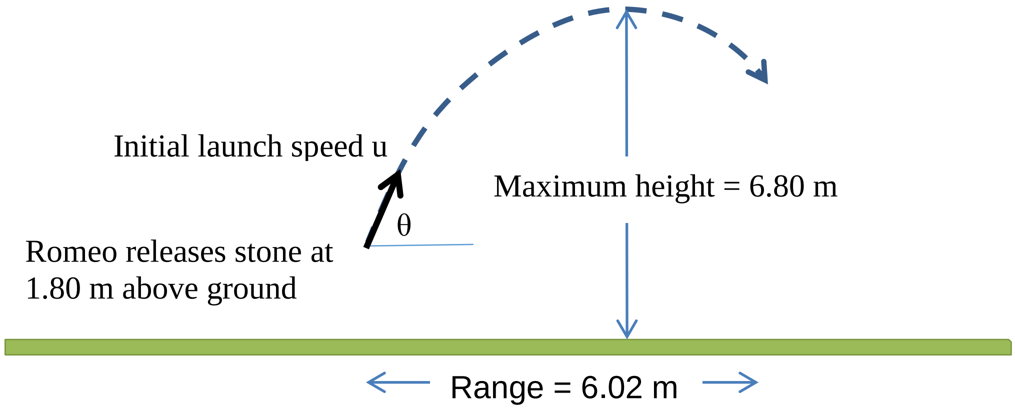
5. Romeo throws a stone towards Juliet's window at an angle θ to the horizontal from a height of 1.80 m. The stone reaches a maximum height of 6.80 m above the ground, continues and then hits a ledge at a horizontal distance of 6.02 m in front of Romeo. The flight time from launch to arriving at the ledge was 1.40 s.



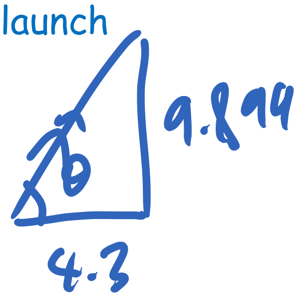
a) Calculate the initial velocity of the stone in terms of magnitude and direction.

(5)

Let up be positive (or alternative defined reference frame)

u (vertical) = u.sin θ (up)

at max height s_v = 6.80 – 1.80 = +5.00 m above launch



$v^2 = u_v^2 + 2as_v$

$0 = u_v^2 - (19.6 \times 5)$ ✓

$u_v = +9.899 \text{ m s}^{-1}$ ✓

Consider horizontal t = 1.40 s s_h = +6.02 m

$u_h = s_h / t = 6.02 / 1.40 = 4.30 \text{ m s}^{-1}$ right ✓

By Pythagoras $u = (u_v^2 + u_h^2)^{0.5} = (9.899^2 + 4.30^2)^{0.5} = 10.8 \text{ m s}^{-1}$ ✓

Elevation Angle = $\tan^{-1}(u_v / u_h) = \tan^{-1}(9.899 / 4.30) = 66.5°$ ✓

b) Calculate the height above ground of the stone when it hit the ledge. If you could not solve for the initial velocity u then use a value of 10.8 m s^{-1} at 66.5° above the horizontal. (3)

u (vertical) = u.sin θ (up) = 10.8 x sin 66.5 = +9.90 m s^{-1}

t (flight) = 1.40 s   a = -9.80 m s^{-1}

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

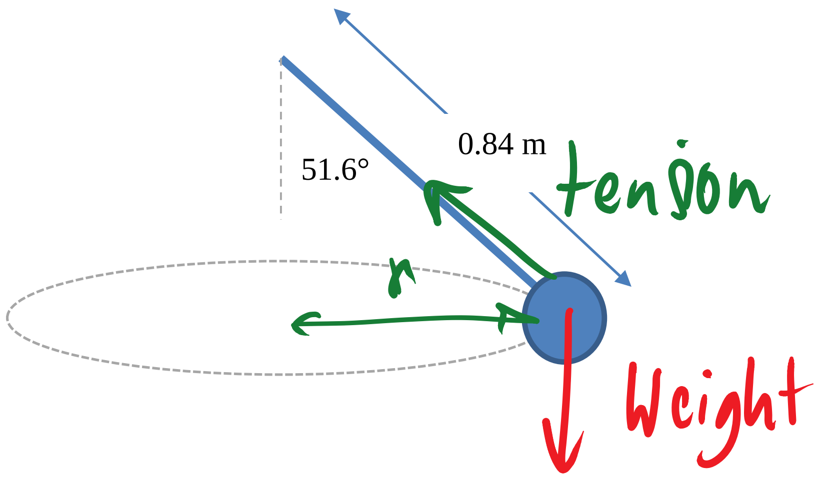
s = (9.90 x 1.40) – (4.9 x 1.40^2) ✓

s = +4.256 m ✓

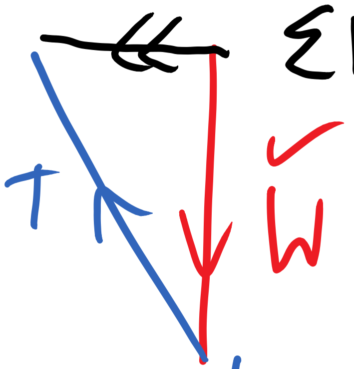
Height of stone = 1.80 + 4.256 = 6.06 m ✓

$v = u + at$ or $\rightarrow v^2 = u^2 + 2as$

6. A ball at the end of a nylon cord is following a horizontal circle as shown in the diagram. The cord has a length of 0.840 m, the ball has a mass of 300 g and the cord makes an angle of 51.6° with the vertical. You can ignore air resistance and friction in this question.



a) Explain, with the aid of a vector diagram, how the tension force can keep the ball at a fixed height **and** enable the ball to follow a circular path. (3)



$\Sigma F = \frac{mv^2}{r}$ (shown horiz)

Vertical component of tension balances weight ✓

horizontal component of tension provides centripetal force ✓

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b) Calculate the net force (centripetal force) acting on the ball.

(2)

$W = mg = 0.300 \times 9.8 = 2.94\,N$

$\tan\theta = \frac{\Sigma F}{mg}$

$\Sigma F = mg.\tan\theta = 2.94 \times \tan 51.6^\circ$ ✓

$\Sigma F = 3.709\,N = 3.71\,N$ to centre ✓

c) Calculate the time taken for the ball to make one complete revolution.

(4)

$\sin 51.6 = \frac{r}{l} = \frac{r}{0.84}$ ✓

$r = \sin 51.6 \times 0.84 = 0.6583\,m$ ✓

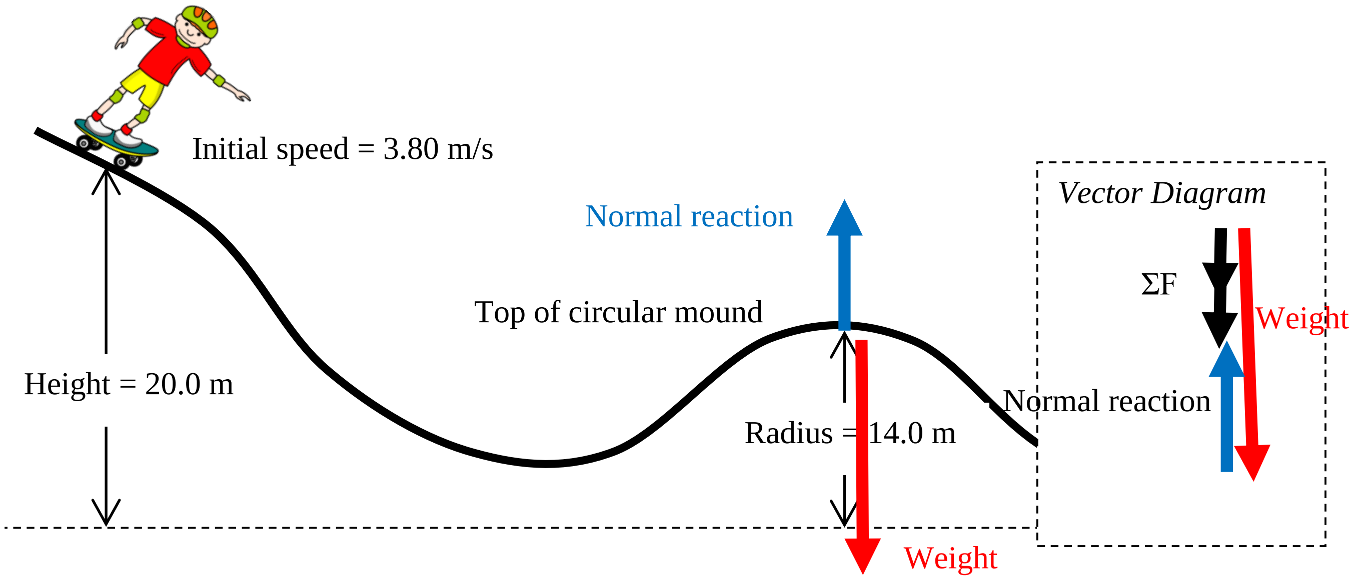
$\Sigma F = \frac{mv^2}{r}$ $\quad 3.709 = \frac{0.3 \times v^2}{0.6583}$

$v = 2.85286\,m/s$ $\quad T = \frac{2\pi r}{v} = \frac{2\pi\, 0.6583}{2.85286}$ ✓

$T = 1.45\,s$ ✓

period

7. The diagram below shows a skateboarder of mass 80 kg on a frictionless slope. He has a speed of 3.80 m s^{-1} at a height of 20.0 m. He descends and then follows a circular path of radius 14.0 m whilst going over a mound.



a) Use the principle of conservation of mechanical energy to demonstrate that the speed of the skateboarder at the top of the circular mound is 11.5 m s^{-1}.

(4)

TME (start) = TME (top of mound)

$\frac{1}{2}mu^2 + mgh_1 = \frac{1}{2}mv^2 + mgh_2$ (concept ✓)

$\frac{1}{2}u^2 + gh_1 = \frac{1}{2}v^2 + gh_2$

$\frac{1}{2}3.8^2 + 9.8 \times 20 = \frac{1}{2}v^2 + 9.8 \times 14$

✓ ✓

v = 11.5 m s^{-1} ✓

b) On the diagram show the forces acting on the skateboarder at the top of the mound, then transfer these forces to a *vector diagram* that shows the sum of these forces (ΣF) in the space provided.

(2)

As above shows ΣF = W – N ✓✓

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c) Calculate the normal reaction force acting on the skateboarder at the top of the circular mound.

(3)

ΣF = W - N

$\frac{mv^2}{r} = mg - N$

$N = mg - \frac{mv^2}{r}$ ✓ (by deduction)

$N = 80 \times 9.8 - \frac{80 \times 11.49^2}{14}$ ✓

N = 28.3 N (up) ✓

d) Describe and explain the sensation of apparent weight that he experiences at the top of the circular mound compared to the sensation when stationary on a flat surface.

(2)

Normal reaction force on mound is less than stationary Normal reaction force which equals mg (up) = 784 N (up) ✓
So his apparent weight is reduced. ✓

e) If the height of the mound could be kept constant but the radius of the mound changed, explain what would happen to the normal reaction if the radius was increased.

(2)

$N = mg - \frac{mv^2}{r}$, if r increases $\frac{mv^2}{r}$ decreases ✓, so N increases ✓

End of test