Physics ATAR - Year 12

Gravity and Motion
Test 1
2017

Name: SOLUTIONS	Mark: / 58 = %

Time Allowed: 50 Minutes

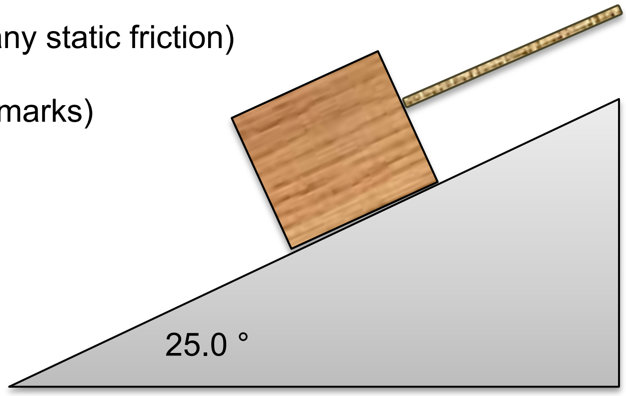
Notes to Students:

1. You must include **all** working to be awarded full marks for a question.
2. Marks will be deducted for incorrect or absent units and answers stated to an incorrect number of significant figures.
3. **No** graphics calculators are permitted – scientific calculators only.

Question 1 **(8 marks)**

A box of mass 5.00 kg sits 1.20 m up an incline of 25.0 ° as shown in the diagram. A rope parallel to the incline keeps the box at rest.

(a) Calculate the tension of the rope (ignoring any static friction) (3 marks)



$\sum F = 0 = T - mg\sin\theta$ ½

$T = mg\sin\theta$ ½

$= (5)(9.8)\sin 25$ 1

$= 20.7$ N 1

The rope is then cut and the box is allowed to slide down the incline. It is measured to take 0.980 seconds to travel 1.20 m down the incline.

(b) Calculate the frictional force that acts as the box is sliding. (5 marks)

$s = ut + 1/2at^2$ ½

$a = \frac{2s}{t^2}$ ½ $= \frac{2(-1.20)}{0.98^2}$ ½ $= -2.50\ ms^{-2}$ 1

$\sum F = ma = F_f - mg\sin\theta$ ½

$F_f = ma + mg\sin\theta$ ½

$= (5)(-2.5) + (20.7)$ ½

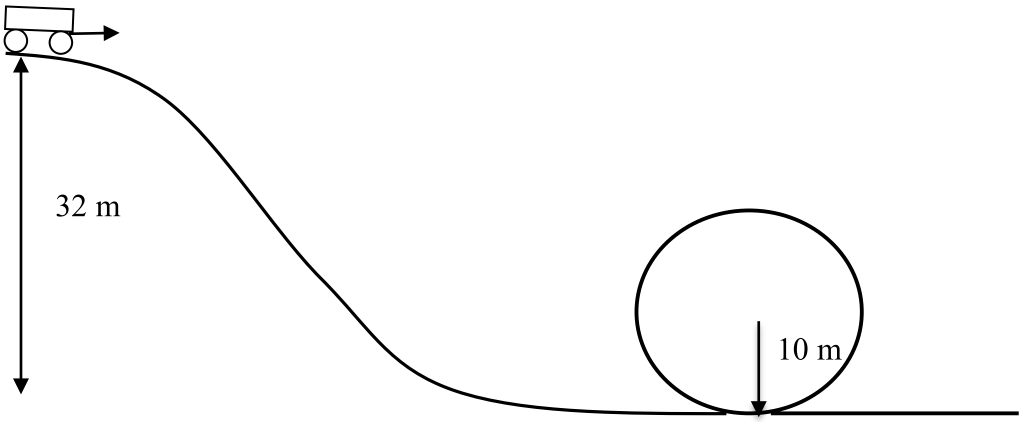
$= +8.20$

$= 8.20$ N up the incline 1

Students can use energy considerations but acceleration must still be first determined to then find v.

Question 2 **(10 marks)**

A rollercoaster car has a mass of 9.20×10^2 kg and starts from a height of 32.0 m above the ground. The car relies on mechanical energy only to go around the loop. The bottom of the circular loop is at ground level and the loop has a radius of 10.0 m as shown in the diagram below. The car is initially moving at a speed of 4.50 ms^{-1}.



(a) Calculate the total mechanical energy of the car. (3 marks)

$E_T = E_p + E_k$ ½ $E_p = mgh$ $E_k = ½ mv^2$ ½

$= 920(9.8)(32) + ½(920)(4.5^2)$ 1

$= 2.98 \times 10^5$ J 1

(b) Calculate the speed of the car at the top of the loop (4 marks)

$E_k = E_T - E_P$ 1 ½

$= 2.98 \times 10^5 - 920(9.8)(20)$

$= 117507$ 1

½ 1

$v = \sqrt{\frac{2Ek}{m}} = \sqrt{\frac{2(117507)}{920}} = 16.0\ ms^{-1}$

(c) Calculate the normal reaction force acting on the car at the top of the loop. (3 marks)

$\sum F = FC = W + N$ ½

$N = FC - W$ ½

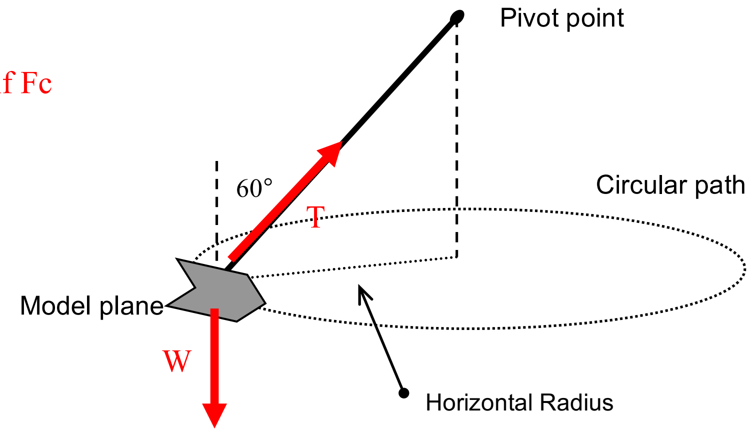
$= \frac{mv^2}{r} - (mg)$ $= -\frac{920(16.0)^2}{10} - (920 \times -9.8)$ $= -14536$ $= 1.45 \times 10^4$ N Down

½ ½ 1

Question 3 **(8 marks)**

A model plane of mass 245 g is suspended from a light rigid wire. When in horizontal circular motion it is noted that it makes ten revolutions in 15.0 seconds and that the wire is at an angle θ of 60.0° to the vertical.

No marks if Fc is drawn



(a) On the diagram above, draw the forces acting on the model plane

(1 mark)

(b) Calculate the tension along the wire.

(3 marks)

$\sum F_y = 0$ (½)

$= T_y - W = 0$ (½)

$T\sin 30 = mg$ (½)

$T = \dfrac{mg}{\text{Sin}30} = \dfrac{(0.245)(9.8)}{\sin 30}$ (½) $= 4.80\text{N}$ (1)

(c) Calculate the horizontal radius of the circular motion of the model plane.

(4 marks)

$\sum F = ma$ (½)

$\sum F_x = F_c = 4.80 \sin 60$
$= 4.16$ (½)

$F_c = \dfrac{m4(\pi)^2 r}{T^2}$ (½)

$r = \dfrac{F_c T^2}{m4(\pi)^2} = \dfrac{4.8\sin 60(1.5^2)}{0.245(4)(\pi)^2}$ (½)

$= 0.967\text{m}$ (1)

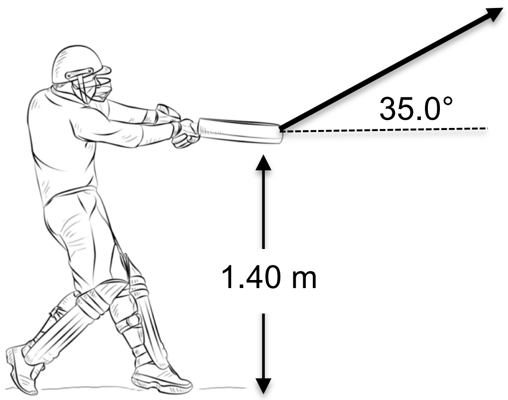
Since $v = \dfrac{2\pi r}{T}$ (½)

$v^2 = \dfrac{4\pi^2 r^2}{T^2}$

$T = \dfrac{15}{10} = 1.5\text{s}$ (½)

Question 4 **(13 marks)**

A cricketer strikes a ball at 20.0 ms^{-1} at an angle of 35.0° above the horizontal. The ball leaves the bat at a height of 1.40 m above the ground.



(a) Calculate maximum height above the ground that the cricket ball reaches. (Ignoring air resistance)

(3 marks)

$u_y = u\sin\theta$

$= 20\sin 35$

$= 11.5 ms^{-1}$ (1)

$v^2 = u^2 + 2as$ (½)

$s = \frac{v^2-u^2}{2a} = \frac{0^2-11.5^2}{2(-9.8)} = 6.71$ (½)

6.71 + 1.40 = 8.11 m (1)

(b) Calculate the time that the ball is in the air for. (Ignoring air resistance)

(3 marks)

$v^2 = u^2 + 2as$ (½)

$v = \sqrt{11.5^2 + 2(-9.8)(-1.40)}$

$= 12.61 ms^{-1}$ Down (1)

$t = \frac{v-u}{a}$ (½)

$= \frac{-12.61-11.5}{-9.8}$

= 2.46 s (1)

A fielder is standing at the boundary, 60.0 m from the batsman. The ball is struck directly towards the fielder who immediately starts running at a constant speed of 8.50 ms^{-1} towards the ball.

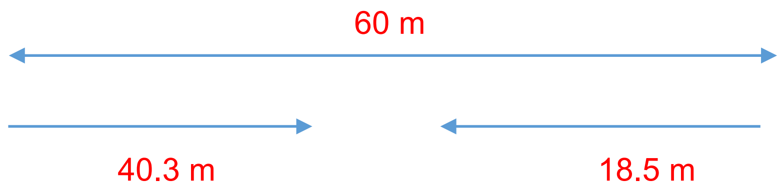
(c) Determine if the fielder manages to arrive at the cricket ball before it strikes the ground. Show all reasoning behind your answer.

(4 marks)

Range = ux . t (½)

=20cos(35) x 2.46

= 40.3 m (1)



S(fielder) = vt (½)

= 8.50 x 2.46

= 20.9 m (1)

Yes, the fielder can get to (60-20.9) 39.1 m away from batter when the ball lands. (1)

Students can also use time considerations to solve. Logic must be evident and clear. Allow error carried forward from (4b)

(d) For this scenario, explain whether air resistance will benefit the batsman in reducing the chances of getting caught or benefit the fielder in increasing the chances of getting caught out.

(3 marks)

Benefit the batsman

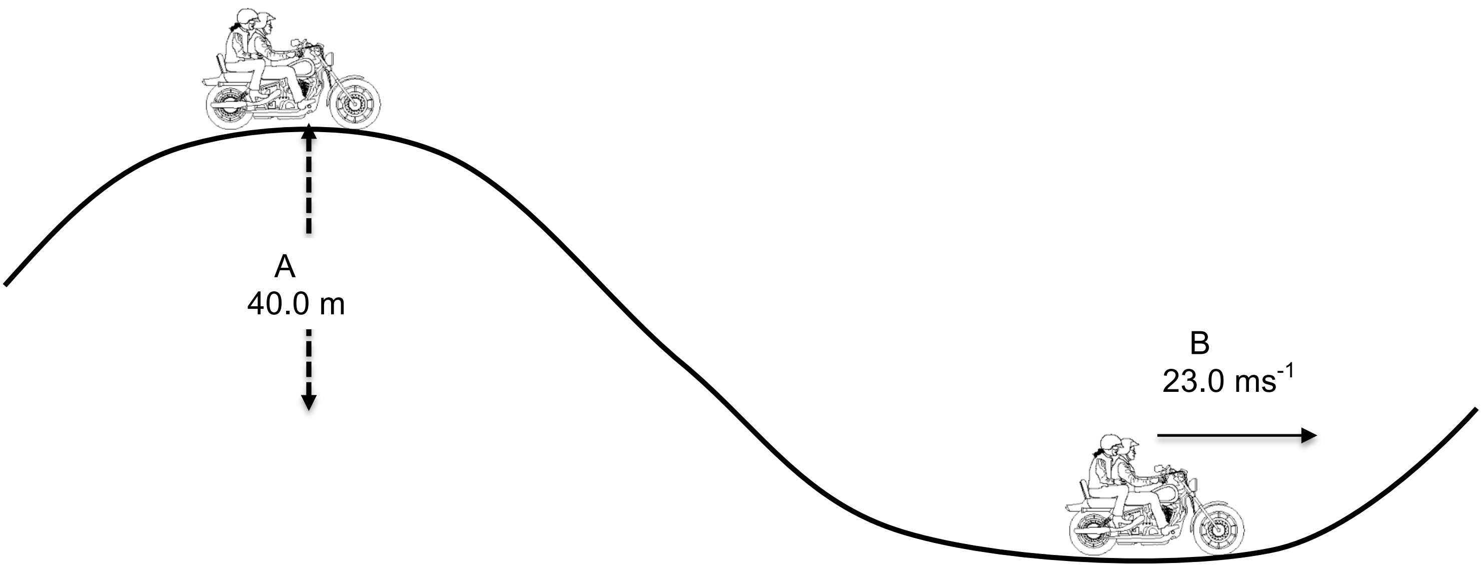
Air resistance will act in the direction opposite to the motion of the ball, hence on the horizontal component in the horizontal so range will be reduced.

Making the distance the fielder must travel greater.

(Also accept time of flight will also be reduced.)

Question 5 **(12 marks)**

Two motorcyclists with a total mass of 249 kg take a road trip through a rural hilly area. At one section (part A) they approach a crest with a radius of curvature of 40.0 m. At another section of a trough (part B), the motorcycle is travelling with a speed of 23.0 ms^{-1}.



(a) Calculate the maximum speed the motorcycle can travel at Part A without losing contact with the ground

(4 marks)

$\sum F = ma$ (½)

$\sum F_y = F_c = N - W$ (½)

Set N = 0 (½)

$\frac{mv^2}{r} = mg$ (½) $v^2 = rg$ (½) $v = \sqrt{rg}$ (½) $= \sqrt{40 \times 9.8} = 19.8\ ms^{-1}$ (1)

(b) At Part B, the riders suddenly feel 80.0% heavier. Calculate the vertical radius of curvature of the road in order for the riders to experience this.

(4 marks)

Set N = 1.8mg (1)

= 1.8 x (249 x 9.8)

= 4329 N (1)

$F_c = N - W$ (½)

$\frac{mv^2}{r} = +4329 - (2400)$ = + 1951 N (upwards) (½)

r = $\frac{mv^2}{Fc} = \frac{(249)(23^2)}{1951} = 67.5\ m$ (1)

When building roads and identifying safety hazards, engineers must consider any vertical radius of curvature and the horizontal turning radius when determining safe turning speeds.

(c) Explain how a banked curve enables a driver to still turn a corner at the speed limit even in a wet day.

(4 marks)

On a wet day, friction between the road and tyres is reduced

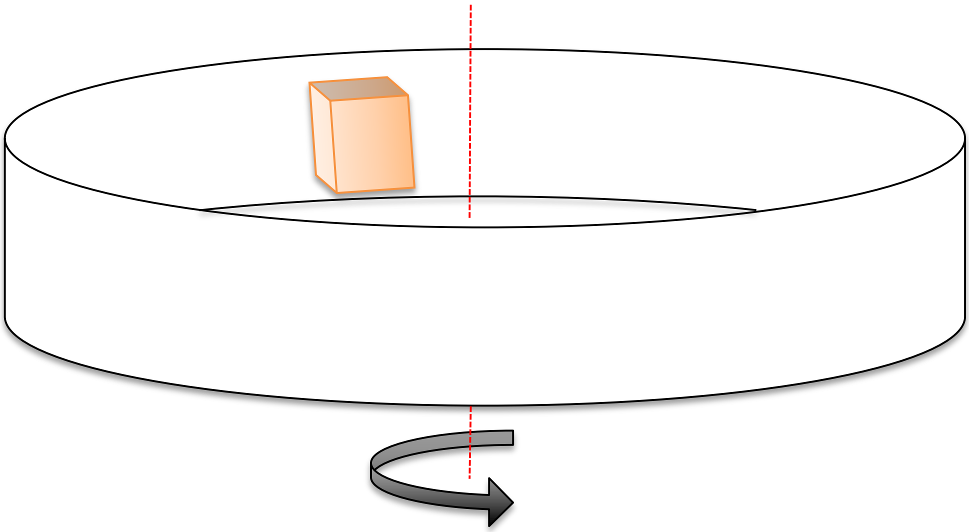
A banked curve has a horizontal component of the normal force.

Which provides the force required for centripetal acceleration

Allowing the car to travel at the required speed without relying solely on friction

Question 6 **(7 marks)**

A thin cylindrical shell of inner radius 1.50 m rotates horizontally about a vertical axis at a constant rate. A wooden block rests against the inner surface and rotates with it. The coefficient of static friction μ_s is 0.300. The equation for static friction is $F_s = \mu_s N$



(a) Calculate the minimum speed the block must be travelling at to not slip and fall. (4 marks)

$\sum F_y = 0$ (½)

$= F_F - W = 0$

$\mu F_N = mg$ (½)

$F_N = \dfrac{mg}{\mu}$ (1)

$F_c = F_N = \dfrac{mv^2}{r}$ (½)

$\dfrac{mg}{\mu} = \dfrac{mv^2}{r}$

$v = \sqrt{\dfrac{gr}{\mu}} = \sqrt{\dfrac{(9.8)(1.5)}{0.3}} = 7.00\ ms^{-1}$ (½) (1)

(b) Calculate the minimum revolution rate in rpm the disc must spin at for the block not to slip and fall. (if you could not answer (a), use v = 3.50 ms^{-1}) (3 marks)

$v = 2\pi r f$ (½)

$f = \dfrac{v}{2\pi r} = \dfrac{7.00}{2\pi(1.5)} = 0.743\ Hz \quad \times 60 \quad = 44.6\ rpm$ (½) (1) (1)

Allow error carried forward from (6a)