YEAR 12 PHYSICS: **UCM EXAM QUESTIONS** **NAME: ___________________**

QUESTION 1

The bicycle shown in the photograph below has safety reflectors on its wheels.

Each wheel is undergoing uniform circular motion.

Explain why the reflectors are accelerating even though they are travelling at a constant speed.

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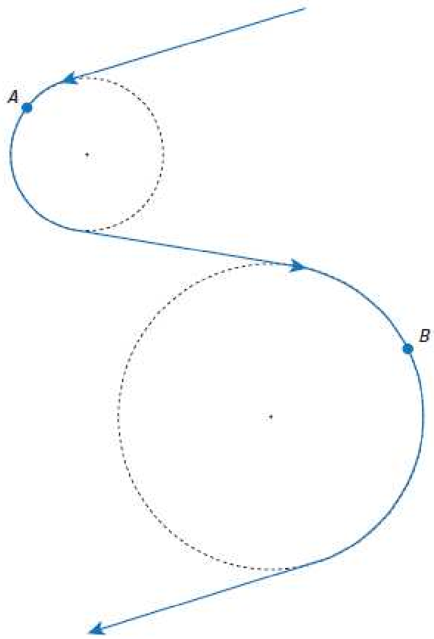
____ *(2 marks)*

QUESTION 2

The path taken by a skier (as in the photograph above) is shown in the diagram below.



The path includes two sections where the skier moves with uniform circular motion.

Point A in the diagram is on a circular section with a radius of 20 m, and point B is on a circular section with a radius of 40m.

The skier travels on all sections of the path at a constant speed of 18 m. s^{-1}

(a) Determine the magnitude of the ratio $\frac{\text{centripetal acceleration at A}}{\text{centripetal acceleration at B}}$

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____ *(3 marks)*

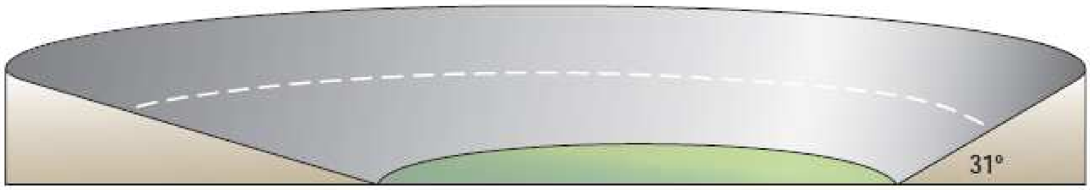
(b) On the diagram, draw vectors to show the magnitude and direction of the force causing the centripetal acceleration of the skier at points A and B.

(2 marks)

QUESTION 3

The curves in a circular car-racing track are banked at different angles, as shown in the diagram below.

The steepest curve is banked at 31°. The track has a constant radius of 150 m.



(a) Determine the speed at which a car can travel around the curve banked at 31° without relying on friction.

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____ *(3 marks)*

(a) State why the car should be able to travel at the same speed on the entire track, despite the lower banking angles of some curves.

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____ *(1 mark)*

QUESTION 4

A piece of string is used to attach a puck to the centre of an air-table, as shown in the photograph below:

The puck has a mass of 0.035 kg. It is made to move around the centre of the air-table in uniform circular motion, with a speed of 2.4 m.s^{-1}. The radius of the circular path is 0.32 m.

(a) State the force on the string that causes the centripetal acceleration of the puck

____ *(1 mark)*

(b) Calculate the magnitude of the force that causes the centripetal acceleration of the puck.

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____ *(3 marks)*

QUESTION 4

Velodromes are cycle-racing tracks with banked curves that enable cyclists to travel at high speeds.

(a) On the diagram below:

(i) Draw a vector to show the normal force F_n on a bicycle travelling with uniform circular motion around a banked curve.

(1 mark)

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

(2 marks)

(b) 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.

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___ *(1 mark)*

(c) Derive the equation $\tan\theta = \frac{v^2}{\mathrm{rg}}$, relating the banking angle θ to the speed *v* at which the cyclist is travelling and the radius of curvature r.

(3 marks)

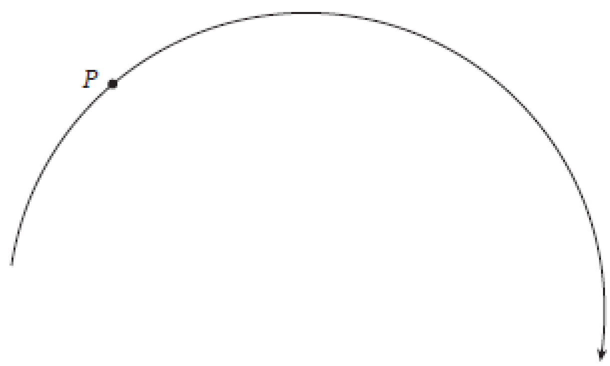
(d) A cyclist is travelling around a banked curve in a velodrome. The banked curve has a radius of 26 m and a banking angle of 42°.

Calculate the maximum speed at which the cyclist can travel around the banked curve without relying on friction.

(3 marks)

QUESTION 5

The diagram below shows a section of the path of an object moving with uniform circular motion in a clockwise direction:



(a) On the diagram above, draw and label arrows at point P to indicate the direction of the:

(i) Instantaneous velocity $\vec{v}$ of the object. *(1 mark)*

(ii) Instantaneous acceleration $\vec{a}$ of the object. *(1 mark)*

(b) The object is travelling with a speed of 5.0 m. s^{-1}. The radius of the circular path is 12 m.

Calculate the magnitude of the instantaneous acceleration $\vec{a}$ of the object.

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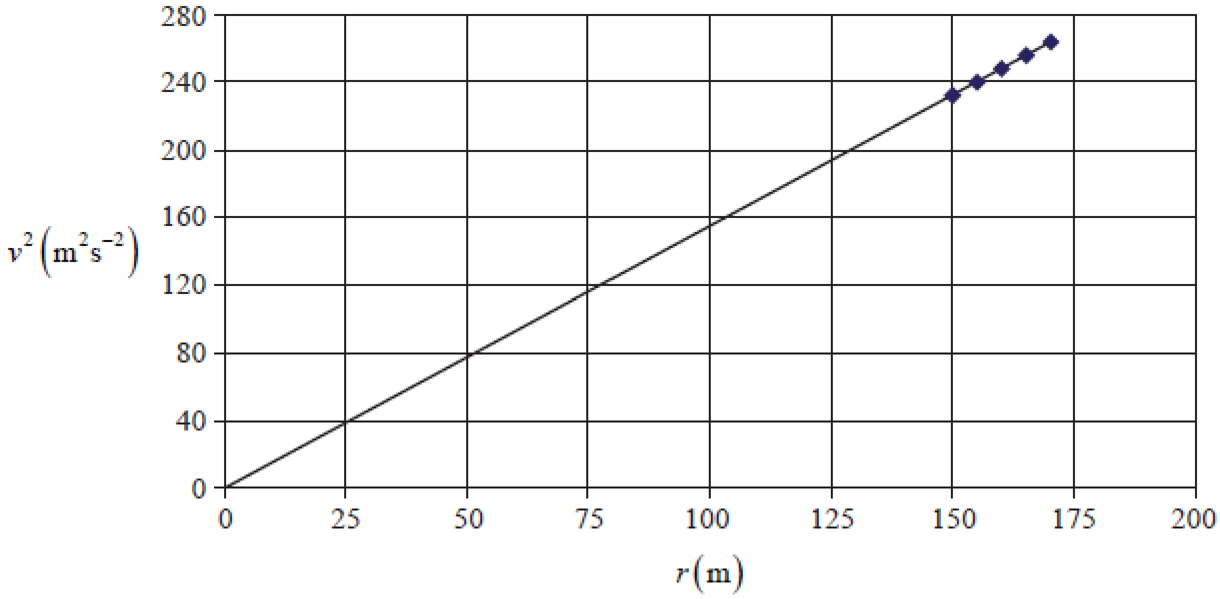
______________________________________ *(2 marks)*

QUESTION 6

A motor-racing track has banked quarter-circle turns. Racing cars travel around the turns at different radii and speeds.

Data are collected on the occasions when the centripetal acceleration is not caused by the frictional force on the tyres.

The graph below shows the data collected. The line of best fit has a gradient of magnitude 1.55.



(a) State the units of the gradient of the line of best fit.

____ *(1 mark)*

(b) State the equation of the line of best fit.

____ *(1 mark)*

(c) Using the equation of the line of best fit, calculate the banking angle of the turns.

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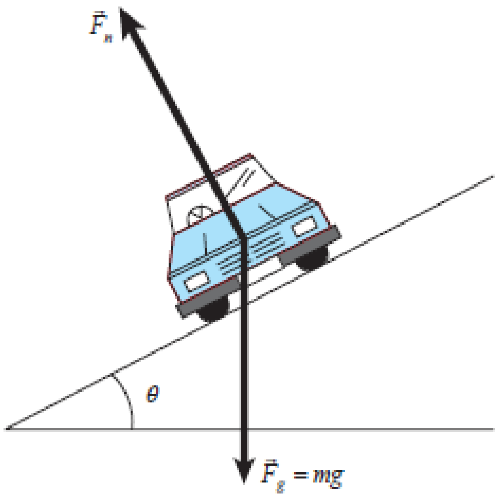
____ *(4 marks)*

QUESTION 7

The movement of a car in a circular path on a flat horizontal road relies on the friction between the road and the tyres to provide the centripetal acceleration.

One component of the normal force on a car moving with uniform circular motion round a banked curve is directed towards the centre of the circle, thus reducing the reliance on friction.

(a) On the diagram below, draw vectors to show the horizontal component $\vec{F}_H$ and the vertical component $\vec{F}_V$ of the normal force $\vec{F}_N$ on a car moving with uniform circular motion round a banked curve.



(2 marks)

(b) Show that the magnitude of the horizontal component ($\vec{F}_H$) of the normal force is given by $\vec{F}_H$ = mg tanθ

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____ *(2 marks)*

QUESTION 8

A bobsled team competing in the Winter Olympics travels on a track that has banked curves, as shown in the photograph below:

The bobsled team is travelling round a curve that has a radius of 105 m and a banking angle of 53°.

The mass of the bobsled team (including sled) is 595 kg.

The centripetal acceleration is provided by the horizontal component of the normal force ($\vec{F}_H$) on the bobsled team.

(a) Calculate the magnitude of $\vec{F}_H$ where $\vec{F}_H$ = mg tanθ

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____ *(2 marks)*

(b) Determine the speed at which the bobsled team can travel round this banked curve without reliance on friction.

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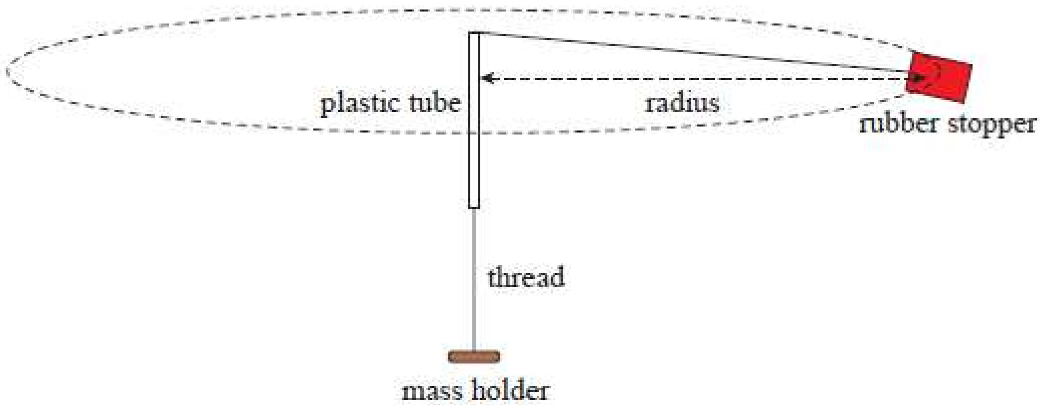
____ *(3 marks)*

QUESTION 9

A group of students attach a rubber stopper to a length of thread. The thread is passed through a short plastic tube that is held vertically.

A mass holder is attached to the other end of the thread, as shown in the diagram below. The rubber stopper moves in a circular path in a horizontal plane at a constant speed.



(a) Explain why the rubber stopper accelerates even though its speed is constant

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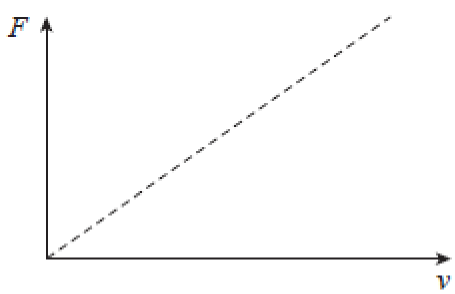
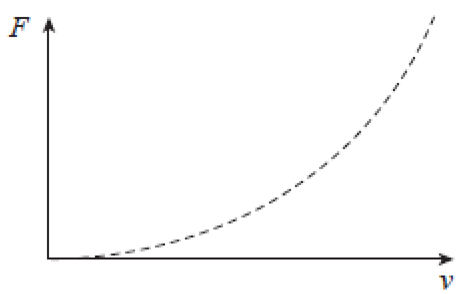
_______________________________________ *(2 marks)*

(b) The students keep the radius of rotation constant and measure the time taken for ten revolutions in order to determine the speed of the rubber stopper. Masses are placed on the mass holder to vary the force F that causes the centripetal acceleration of the rubber stopper.

State which one of Graph A and Graph B below shows the expected relationship between the force F and the speed *v*. Explain your answer.



Graph A



Graph B

Graph that shows the expected relationship between F and v:

____ *(1 mark)*

(c) Explain your answer to part (b)

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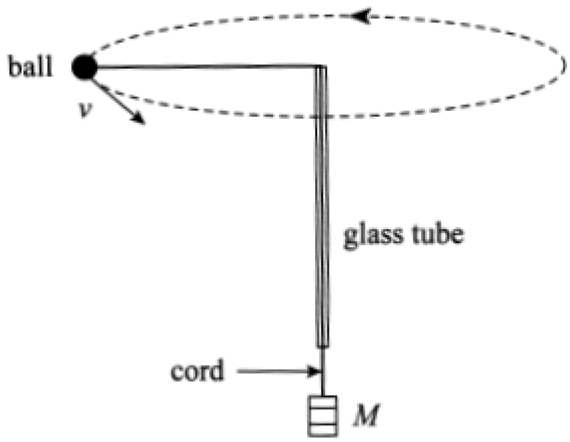
____ *(2 marks)*

QUESTION 10

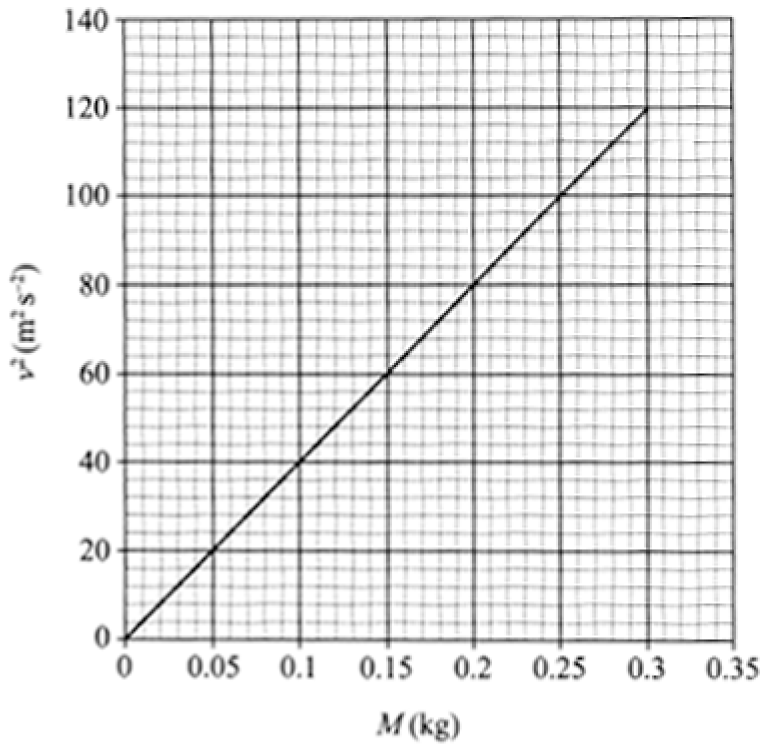
In an experiment a small ball is attached to a cord of negligible mass that passes through a glass tube, as shown in the diagram below. Also attached to the cord is amass M, which hangs vertically below the glass tube.

The ball is moving in a horizontal circle at a constant radius with a tangential speed of v $m.s^{-1}$.

During the experiment the mass M is varied and the corresponding value of the tangential speed v of the ball is measured.



The graph below shows the square of the tangential speed v^2 versus the mass M:



(a) Calculate the gradient of the line of best fit shown on the graph above. Include the unit of the gradient. Clearly label on the graph the points you have used in your calculation.

(3 marks)

(b) Identify one random error which may occur in this procedure

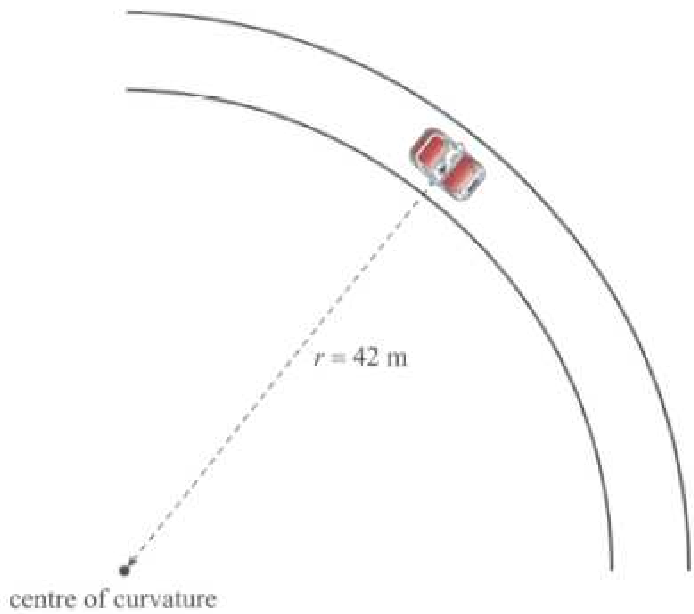
(1 mark)

(c) Identify one random error which may occur in this procedure

(1 mark)

QUESTION 11

A car travels round a circular curve on a flat, horizontal road at a radius of42 m, as shown in the diagram below:



(a) Draw an arrow on the diagram above to show the direction of the frictional force needed for the car to travel round the curve at a radius of 42 m.

(1 mark)

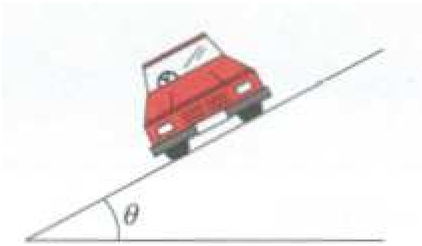
(b) The maximum frictional force between the tyres and the road is equal to 20% of the weight of the car.

Calculate the maximum speed at which the car can travel round the curve at a constant radius of 42 m.

(4 marks)

QUESTION 12

The exit of a freeway has been designed so that a car can travel safely around the curved section of the ramp when the road is wet. The banking angle θ enables a car to travel around the curved section of the ramp without relying on friction, as shown in the diagram below:



(a) On the diagram above, draw and label a vector to show the normal force acting on the car.

(1 mark)

(b) Using the vector you have drawn in part (a), explain how the banking angle enables the car to travel around the curved section of the ramp without relying on friction.

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____________________________________ *(3 marks)*

(c) The curved section of the ramp has a radius of 150 m and a banking angle of 11°.

Calculate the maximum speed at which the car can travel around the curve without relying on friction.

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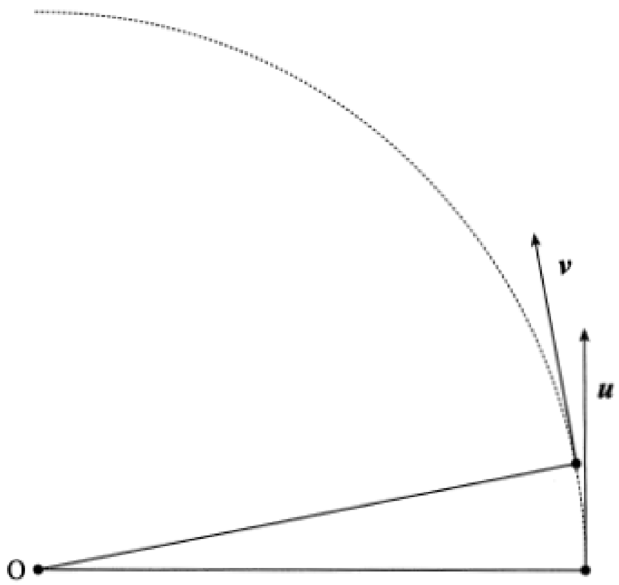
____________________________________ *(2 marks)*

QUESTION 13

The velocity of a particle moving with uniform circular motion about O is shown at two positions in the diagram below:



(a) On the diagram above, use the velocity vectors u and v to draw a labelled vector diagram showing the change in velocity Δv of the particle.

(b) Comment on the direction of the change in velocity Δv.

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(c) Hence state and explain the direction of the acceleration of the particle.

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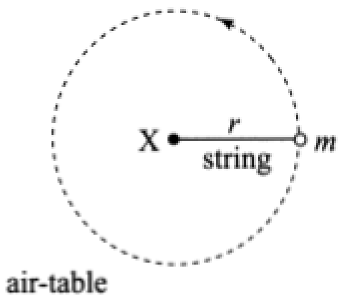
QUESTION 14

A puck of mass m = 0.30 kg is moving with uniform circular motion on a horizontal air-table.

The length of the string attached to the puck is r = 0.10 m, as shown in the diagram below.

The period of the puck's circular motion about point X is 6.28 s.



(a) Identify the force that is causing the centripetal acceleration of the puck.

____ *(1 mark)*

(b) Show that the magnitude of the tension F in the string is given by $F = \frac{4\pi^2 mr}{T^2}$

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____ *(3 marks)*

(c) Hence calculate the magnitude of the tension in the string.

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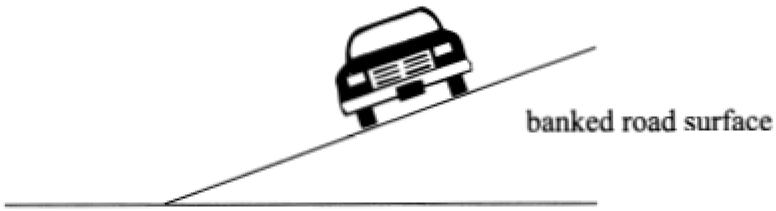
____ *(2 marks)*

QUESTION 15

A car travelling with uniform circular motion round a banked curve on a road is shown in the diagram below:



(a) On the diagram above, draw and label vectors to represent the normal force and the gravitational force acting on the car.

(2 marks)

(b) Using the diagram above, explain the cause of the centripetal acceleration that enables the car to travel round the banked curve without moving up or down the slope of the road surface.

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___ *(3 marks)*

(c) A car travels round a banked curve of radius r = 200 m at speed v = 15 $m.s^{-1}$.

Calculate the banking angle of the curve if friction does not provide any of the force required for the centripetal acceleration. The acceleration due to gravity g is 9.8 $m.s^{-2}$.

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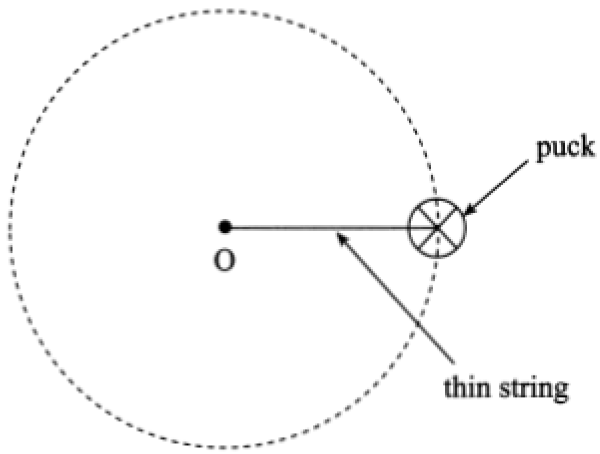
___ *(2 marks)*

QUESTION 16

A puck is attached by a thin string of fixed length to point O on a horizontal table, as shown in the diagram below. The puck rotates freely and at a constant speed about point O.

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

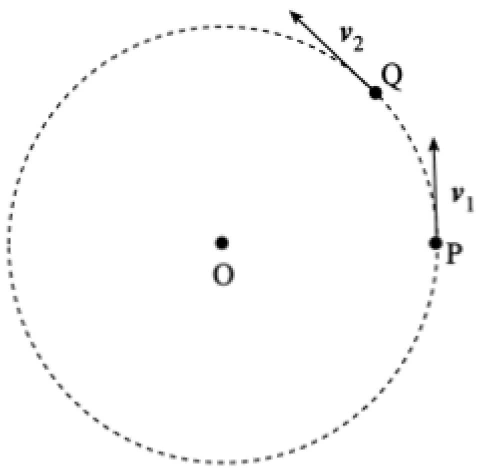


(a) Name the force acting on the puck that causes the centripetal acceleration.

____ *(1 mark)*

(b) The instantaneous velocity v_1 of the puck at point P is shown in the diagram below.

The velocity v_2 of the puck a very short time later at point Q is also shown.



On the diagram above, draw a vector diagram to determine the direction of the change in velocity Δv of the puck.

(2 marks)

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

Show that the speed of the puck is approximately 1.3 m. s^{-1}.

(2 marks)

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

(2 marks)

(e) Show that the magnitude of the force acting on the puck is approximately 0.34 N.

The mass m of the puck is 5.0×10^{-2} kg.

(2 marks)

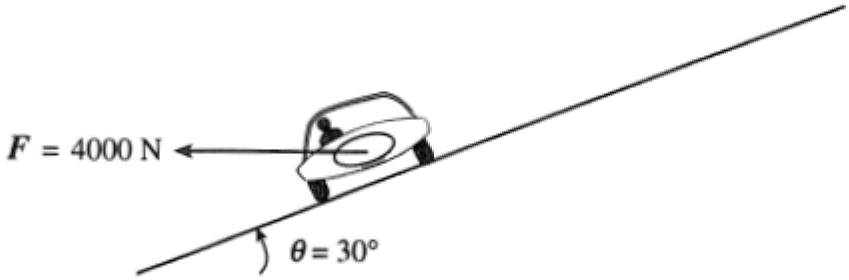
(f) Calculate the magnitude of the force acting on the puck if the speed of the puck is doubled without a change in the radius.

(3 marks)

QUESTION 17

A car travels round a curve that has a banking angle of $\theta = 30^0$, as shown in the diagram below.

The car experiences a net force of 4000N towards the centre of the curve.



(a) On the diagram, draw a vector showing the direction of the normal force acting on the car.

Label this vector F_N *(2 marks)*

(b) Calculate the magnitude of the normal force on the car. Ignore friction.

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______________________________________ *(2 marks)*

(c) A car of mass 1500 kg approaches a horizontal, circular curve of radius 55 m.

Each of the four tyres on the car can apply a maximum force of 540 N on the road before the car begins to slide.

Calculate the maximum speed at which the car can travel round the curve without sliding.

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______________________________________ *(3 marks)*

QUESTION 18

A car is driven at a constant speed v = 20.0 m s"1 round a curve of radius r = 200 m, with a banking angle θ to the horizontal, so that $tan\theta = \frac{v^2}{rg}$. Assume that g = 9.80 m.s^{-2}.

(a) State how the horizontal and vertical components of the normal force on the car would affect the motion of the car when there is no friction.

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_______________________________________ *(2 marks)*

(b) Calculate the banking angle θ.

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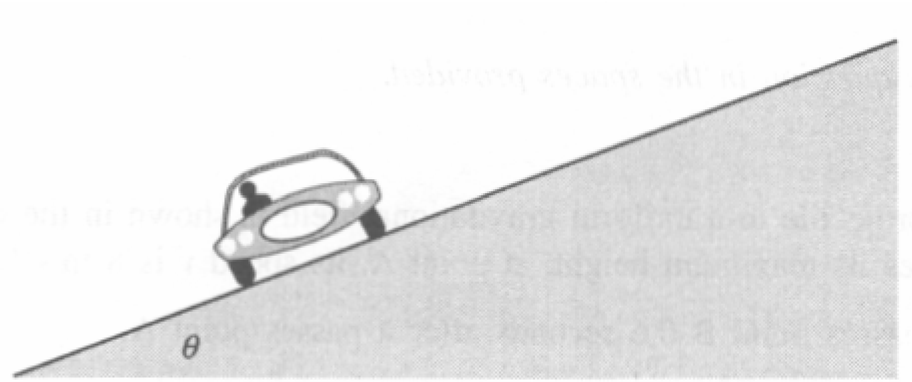
QUESTION 19

(a) On the diagram below, draw and label the forces acting on the car, of mass m, as it travels round a banked curve of radius r without relying on friction.



(4 marks)

(b) State in words the condition necessary for the car to be able to travel round a banked curve at a constant speed v without relying on friction.

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____ *(3 marks)*

YEAR 12 PHYSICS: UCM EXAM QUESTIONS NAME: ___________________

QUESTION 1

The bicycle shown in the photograph below has safety reflectors on its wheels.

Each wheel is undergoing uniform circular motion.

Explain why the reflectors are accelerating even though they are travelling at a constant speed.

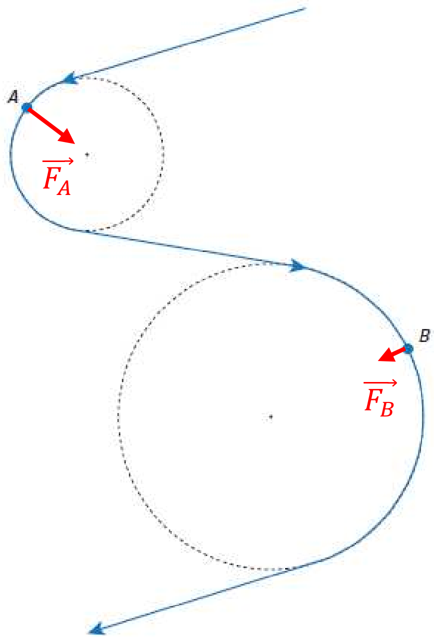
Acceleration is the rate of change in velocity.

Although the reflectors have constant speed, they are continually changing direction.

As the velocity of the reflectors is changing, an acceleration must exist.

QUESTION 2

The path taken by a skier (as in the photograph above) is shown in the diagram below.



The path includes two sections where the skier moves with uniform circular motion.

Point A in the diagram is on a circular section with a radius of 20 m, and point B is on a circular section with a radius of 40m.

The skier travels on all sections of the path at a constant speed of 18 m. s^{-1}

(a) Determine the magnitude of the ratio $\frac{\text{centripetal acceleration at A}}{\text{centripetal acceleration at B}}$

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

$$\therefore \frac{a_{cA}}{a_{cB}} = \frac{v^2}{r_A} \div \frac{v^2}{r_B}$$

$(v \text{ is the same for both points})$

$$\frac{a_{cA}}{a_{cB}} = \frac{v^2}{r_A} \times \frac{r_B}{v^2}$$

$$\frac{a_{cA}}{a_{cB}} = \frac{r_B}{r_A}$$

$$\frac{a_{cA}}{a_{cB}} = \frac{40}{20}$$

$$\frac{a_{cA}}{a_{cB}} = 2$$

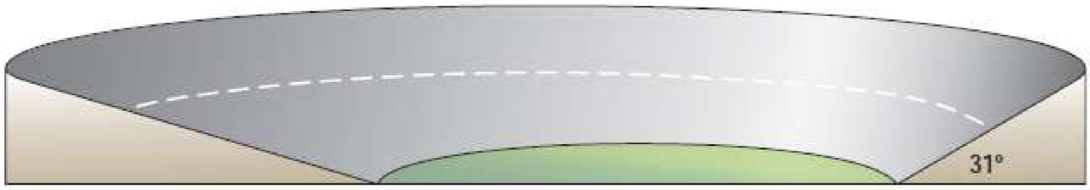
(b) On the diagram, draw vectors to show the magnitude and direction of the force causing the centripetal acceleration of the skier at points A and B. $\text{Note: } F_A = 2F_B$

(2 marks)

QUESTION 3

The curves in a circular car-racing track are banked at different angles, as shown in the diagram below.

The steepest curve is banked at 31°. The track has a constant radius of 150 m.



(a) Determine the speed at which a car can travel around the curve banked at 31° without relying on friction.

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

$$\therefore v = \sqrt{rgtan\theta}$$

$$v = \sqrt{150 \times 9.8 \times tan31°}$$

$$v = 30\ m.s^{-1}$$

(a) State why the car should be able to travel at the same speed on the entire track, despite the lower banking angles of some curves.

The lateral frictional force of the tyres will supply any extra centripetal acceleration needed above that supplied by the banking.

QUESTION 4

A piece of string is used to attach a puck to the centre of an air-table, as shown in the photograph below:

The puck has a mass of 0.035 kg. It is made to move around the centre of the air-table in uniform circular motion, with a speed of 2.4 m.s^{-1}. The radius of the circular path is 0.32 m.

(a) State the force on the string that causes the centripetal acceleration of the puck

Tension force.

(b) Calculate the magnitude of the force that causes the centripetal acceleration of the puck.

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

$$F_c = ma_c$$

$$\therefore F_c = \frac{mv^2}{r}$$

$$F_c = \frac{0.035 \times (2.4)^2}{0.32}$$

$$F_c = 0.63\ N$$

QUESTION 4

Velodromes are cycle-racing tracks with banked curves that enable cyclists to travel at high speeds.

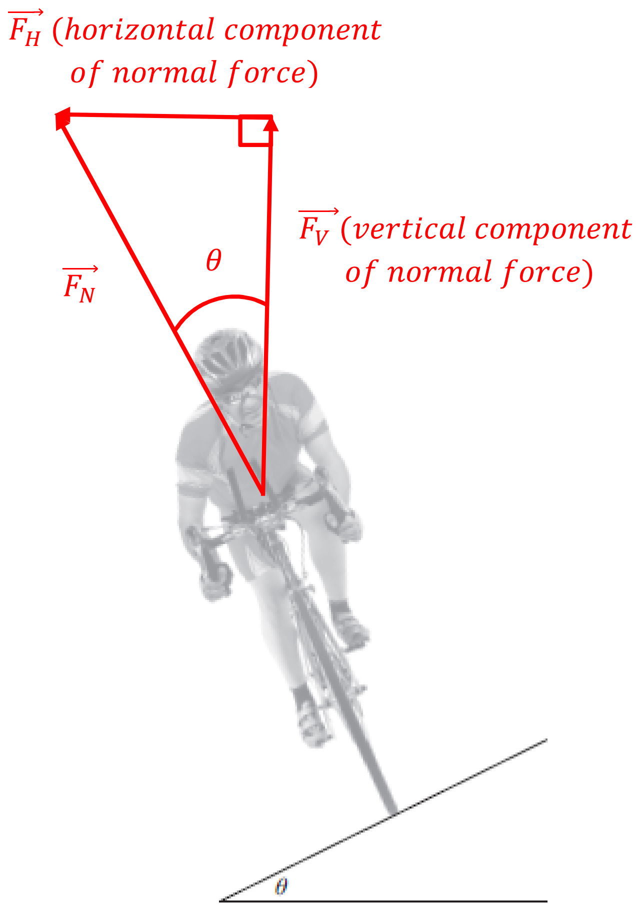
(a) On the diagram below:

(i) Draw a vector to show the normal force F_n on a bicycle travelling with uniform circular motion around a banked curve.

(1 mark)

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

(2 marks)



(b) 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.

It needs to balance the weight of the cyclist $(F_{weight} = mg)$.

i.e. it is the reaction force to the cyclists' weight.

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

$$F_V = mg$$

$$F_H = \frac{mv^2}{r}$$

$$tan\theta = \frac{F_H}{F_V}$$

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

$$tan\theta = \frac{mv^2}{rmg}$$

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

(d) A cyclist is travelling around a banked curve in a velodrome. The banked curve has a radius of 26 m and a banking angle of 42°.

Calculate the maximum speed at which the cyclist can travel around the banked curve without relying on friction.

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

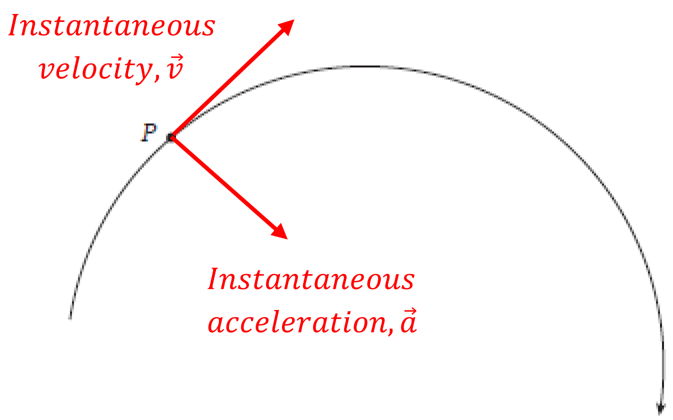
$$\therefore v = \sqrt{rgtan\theta}$$

$$v = \sqrt{26 \times 9.8 \times tan42°}$$

$$v = 15\ m.s^{-1}$$

QUESTION 5

The diagram below shows a section of the path of an object moving with uniform circular motion in a clockwise direction:



(a) On the diagram above, draw and label arrows at point P to indicate the direction of the:

(i) Instantaneous velocity $\vec{v}$ of the object. *(1 mark)*

(ii) Instantaneous acceleration $\vec{a}$ of the object. *(1 mark)*

(b) The object is travelling with a speed of 5.0 m. s^{-1}. The radius of the circular path is 12 m.

Calculate the magnitude of the instantaneous acceleration $\vec{a}$ of the object.

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

$$a = \frac{(5.0)^2}{12}$$

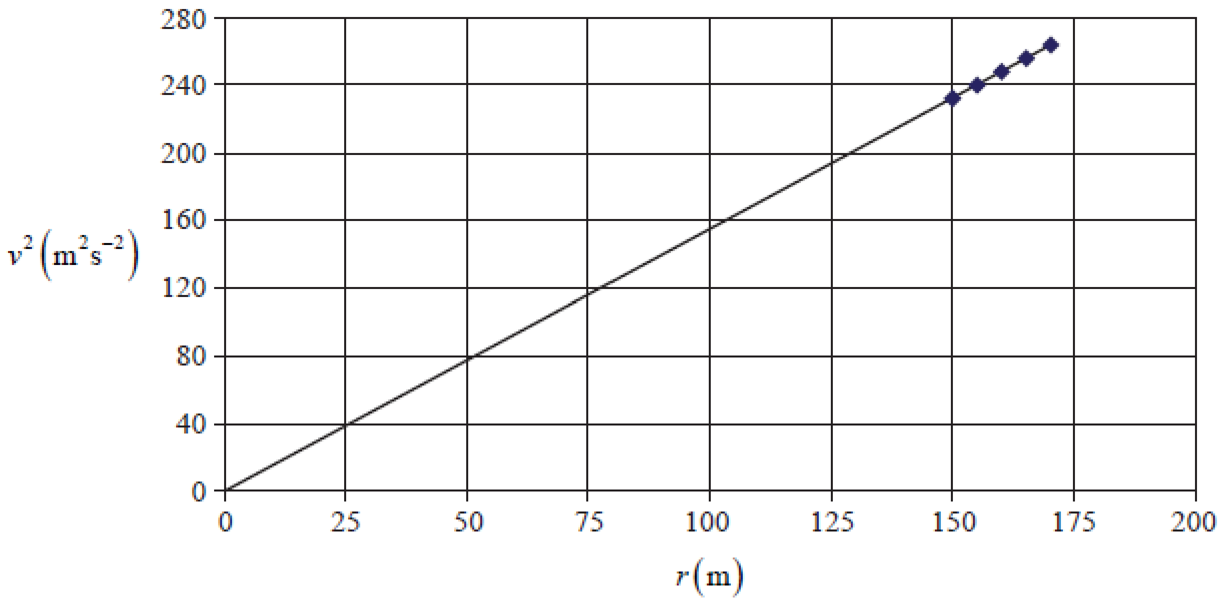
$$a = 2.1\ m.s^{-1}$$

QUESTION 6

A motor-racing track has banked quarter-circle turns. Racing cars travel around the turns at different radii and speeds.

Data are collected on the occasions when the centripetal acceleration is not caused by the frictional force on the tyres.

The graph below shows the data collected. The line of best fit has a gradient of magnitude 1.55.



(a) State the units of the gradient of the line of best fit.

$$m.s^{-2}$$

(b) State the equation of the line of best fit.

$$v^2 = 1.55\,r$$

(c) Using the equation of the line of best fit, calculate the banking angle of the turns.

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

$$\therefore v^2 = rgtan\theta$$

$$\Rightarrow 1.55 = gtan\theta$$

$$\therefore \theta = tan^{-1}\left(\frac{1.55}{g}\right)$$

$$\theta = tan^{-1}\left(\frac{1.55}{9.8}\right)$$

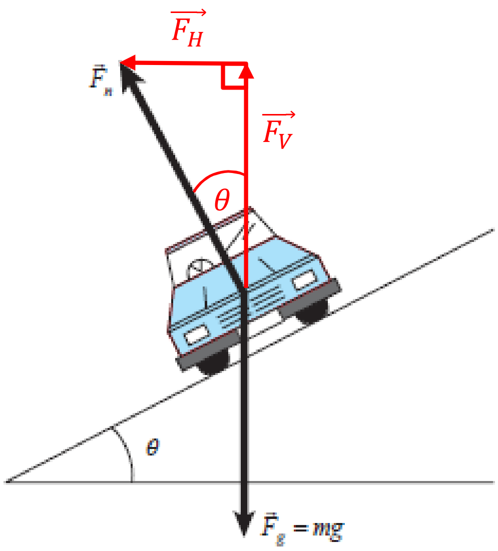
$$\theta = 8.99°$$

QUESTION 7

The movement of a car in a circular path on a flat horizontal road relies on the friction between the road and the tyres to provide the centripetal acceleration.

One component of the normal force on a car moving with uniform circular motion round a banked curve is directed towards the centre of the circle, thus reducing the reliance on friction.

(a) On the diagram below, draw vectors to show the horizontal component $\vec{F}_H$ and the vertical component $\vec{F}_V$ of the normal force $\vec{F}_N$ on a car moving with uniform circular motion round a banked curve.



(2 marks)

(b) Show that the magnitude of the horizontal component ($\vec{F}_H$) of the normal force is given by $\vec{F}_H$ = mg tanθ

$F_V = mg$

$$tan\theta = \frac{F_H}{F_V}$$

$$\therefore F_H = F_V tan\theta$$

$$F_H = mgtan\theta$$

QUESTION 8

A bobsled team competing in the Winter Olympics travels on a track that has banked curves, as shown in the photograph below:

The bobsled team is travelling round a curve that has a radius of 105 m and a banking angle of 53°.

The mass of the bobsled team (including sled) is 595 kg.

The centripetal acceleration is provided by the horizontal component of the normal force ($\vec{F}_H$) on the bobsled team.

(a) Calculate the magnitude of $\vec{F}_H$ where $\vec{F}_H$ = mg tanθ

$$F_H = mgtan\theta$$

$$F_H = 595 \times 9.8 \times tan53°$$

$$F_H = 7.74 \times 10^3\ N$$

(b) Determine the speed at which the bobsled team can travel round this banked curve without reliance on friction.

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

$$\therefore v = \sqrt{rgtan\theta}$$

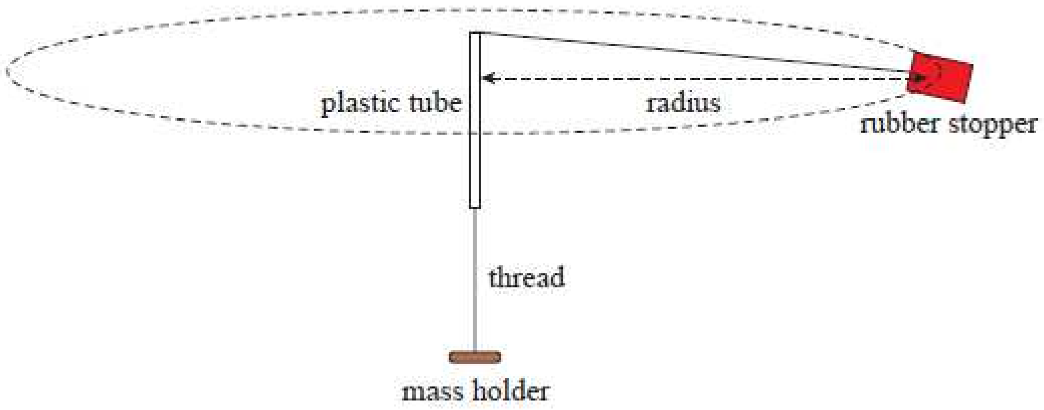
$$v = \sqrt{105 \times 9.8 \times tan53°}$$

$$v = 37.0\ m.s^{-1}$$

QUESTION 9

A group of students attach a rubber stopper to a length of thread. The thread is passed through a short plastic tube that is held vertically.

A mass holder is attached to the other end of the thread, as shown in the diagram below. The rubber stopper moves in a circular path in a horizontal plane at a constant speed.

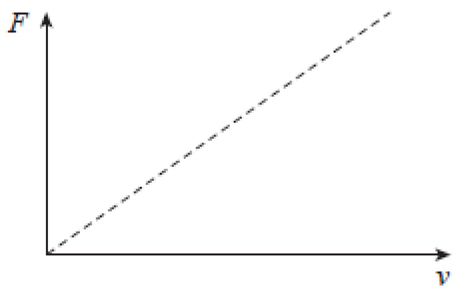


(a) Explain why the rubber stopper accelerates even though its speed is constant

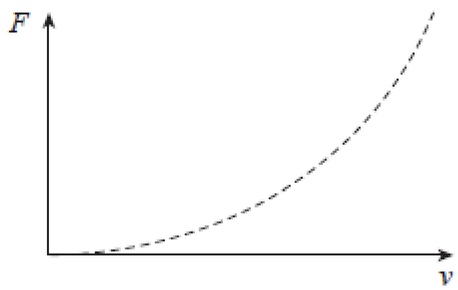
The stopper is continually changing direction, therefore the velocity of the stopper is changing. As the velocity is changing over time, an acceleration must be present.

(b) The students keep the radius of rotation constant and measure the time taken for ten revolutions in order to determine the speed of the rubber stopper. Masses are placed on the mass holder to vary the force F that causes the centripetal acceleration of the rubber stopper.

State which one of Graph A and Graph B below shows the expected relationship between the force F and the speed *v*. Explain your answer.



Graph A



Graph B

Graph that shows the expected relationship between F and v:

$$Graph\ B.$$

(c) Explain your answer to part (b)

$$F = \frac{mv^2}{r}$$

$$\Rightarrow F \propto v^2\ (m\ \&\ r\ are\ constant)$$

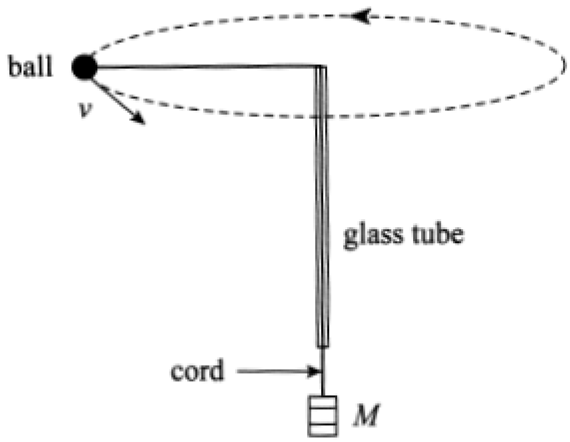
$$\Rightarrow the\ graph\ is\ exponential$$

QUESTION 10

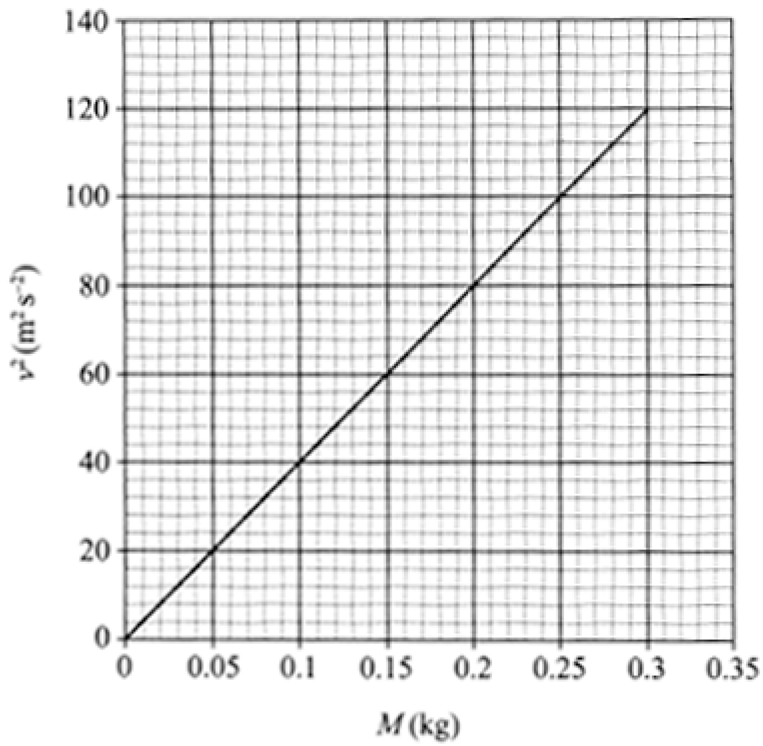
In an experiment a small ball is attached to a cord of negligible mass that passes through a glass tube, as shown in the diagram below. Also attached to the cord is amass M, which hangs vertically below the glass tube.

The ball is moving in a horizontal circle at a constant radius with a tangential speed of v $m.s^{-1}$.

During the experiment the mass M is varied and the corresponding value of the tangential speed v of the ball is measured.



The graph below shows the square of the tangential speed v^2 versus the mass M:



(a) Calculate the gradient of the line of best fit shown on the graph above. Include the unit of the gradient. Clearly label on the graph the points you have used in your calculation.

$$gradient = \frac{y_2 - y_1}{x_2 - x_1}$$

$$gradient = \frac{120 - 0}{0.3 - 0}$$

$$gradient = 400\ m^2.s^{-2}.kg^{-1}$$

(b) Identify one random error which may occur in this procedure

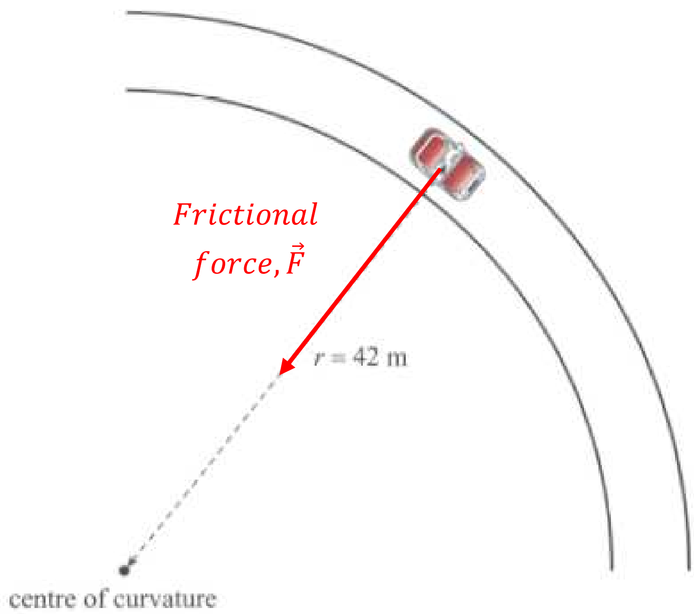
- *inability to keep r constant throughout rotation*
- *ball may spin at an angle (not horizontal)*
- *etc.*

(c) Identify one systematic error which may occur in this procedure

Friction between the cord and the glass tube will affect all measurements.

QUESTION 11

A car travels round a circular curve on a flat, horizontal road at a radius of42 m, as shown in the diagram below:



(a) Draw an arrow on the diagram above to show the direction of the frictional force needed for the car to travel round the curve at a radius of 42 m.

(1 mark)

(b) The maximum frictional force between the tyres and the road is equal to 20% of the weight of the car.

Calculate the maximum speed at which the car can travel round the curve at a constant radius of 42 m.

The frictional force supplies the centripetal acceleration necessary to

keep the car in a circular path.

$$i.e. 0.2mg = \frac{mv^2}{r}$$

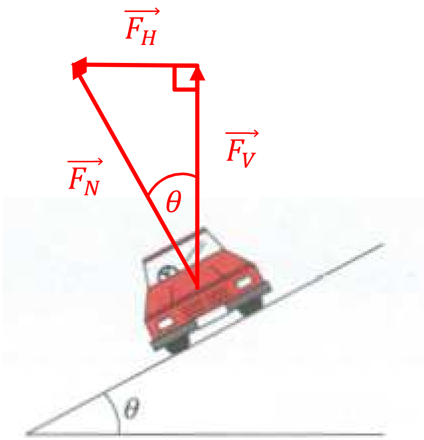
$$\therefore v = \sqrt{0.2rg}$$

$$v = \sqrt{0.2 \times 42 \times 9.8}$$

$$v = 9.1\ m.s^{-1}$$

QUESTION 12

The exit of a freeway has been designed so that a car can travel safely around the curved section of the ramp when the road is wet. The banking angle θ enables a car to travel around the curved section of the ramp without relying on friction, as shown in the diagram below:



(a) On the diagram above, draw and label a vector to show the normal force acting on the car.

(1 mark)

(b) Using the vector you have drawn in part (a), explain how the banking angle enables the car to travel around the curved section of the ramp without relying on friction.

The horizontal component of the normal force supplies the centripetal acceleration necessary to keep the car in a circular path.

(c) The curved section of the ramp has a radius of 150 m and a banking angle of 11°.

Calculate the maximum speed at which the car can travel around the curve without relying on friction.

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

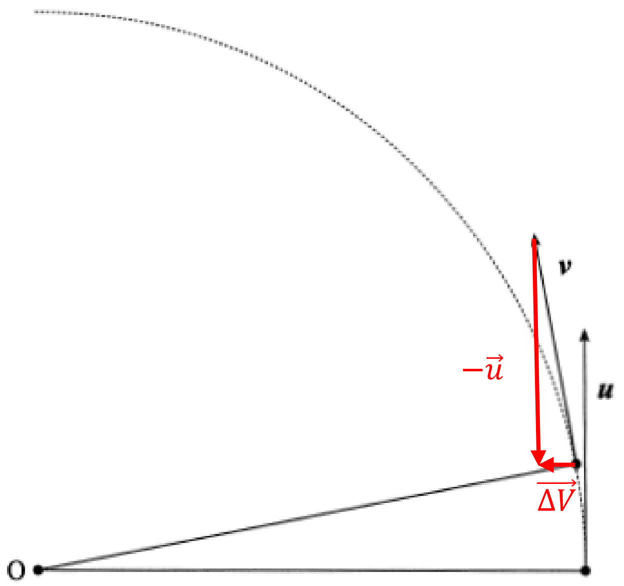
$$\therefore v = \sqrt{rgtan\theta}$$

$$v = \sqrt{150 \times 9.8 \times tan11°}$$

$$v = 17\ m.s^{-1}$$

QUESTION 13

The velocity of a particle moving with uniform circular motion about O is shown at two positions in the diagram below:



$\overrightarrow{\Delta V} = \vec{v} - \vec{u}$

$\overrightarrow{\Delta V} = \vec{v} + (-\vec{u})$

(a) On the diagram above, use the velocity vectors u and v to draw a labelled vector diagram showing the change in velocity Δv of the particle.

(b) Comment on the direction of the change in velocity Δv.

It is directed towards the centre of the circle.

(c) Hence state and explain the direction of the acceleration of the particle.

Acceleration is the rate of change in velocity.

As the change in velocity if directed towards the centre of the circle,

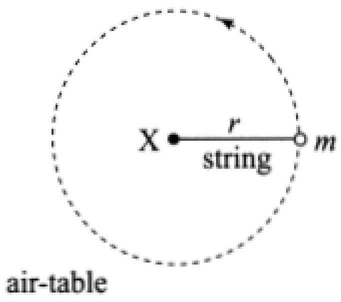
the acceleration is also directed towards the centre.

QUESTION 14

A puck of mass m = 0.30 kg is moving with uniform circular motion on a horizontal air-table.

The length of the string attached to the puck is r = 0.10 m, as shown in the diagram below.

The period of the puck's circular motion about point X is 6.28 s.



(a) Identify the force that is causing the centripetal acceleration of the puck.

$$Tension\ force.$$

(b) Show that the magnitude of the tension F in the string is given by $F = \frac{4\pi^2 mr}{T^2}$

$$Tension\ force\ suplies\ centripetal\ acceleration.$$

$$\Rightarrow F = \frac{mv^2}{r}\ where\ v = \frac{2\pi r}{T}$$

$$F = m.\left(\frac{2\pi r}{T}\right)^2 \div r$$

$$F = \frac{4\pi^2.m.r^2}{rT^2}$$

$$F = \frac{4\pi^2.m.r}{T^2}$$

(c) Hence calculate the magnitude of the tension in the string.

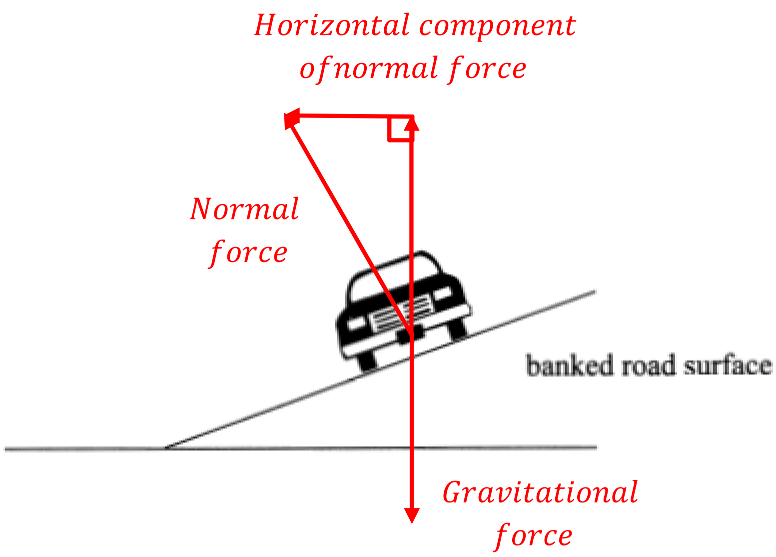
$$F = \frac{4\pi^2.m.r}{T^2}$$

$$F = \frac{4 \times \pi^2 \times 0.3 \times 0.1}{(6.28)^2}$$

$$F = 0.030\ N\ (3.0 \times 10^{-2}\ N)$$

QUESTION 15

A car travelling with uniform circular motion round a banked curve on a road is shown in the diagram below:



(a) On the diagram above, draw and label vectors to represent the normal force and the gravitational force acting on the car.

(2 marks)

(b) Using the diagram above, explain the cause of the centripetal acceleration that enables the car to travel round the banked curve without moving up or down the slope of the road surface.

The horizontal component of the normal force supplies the centripetal acceleration necessary to keep the car in a circular path.

(c) A car travels round a banked curve of radius r = 200 m at speed v = 15 m.s^{-1}.

Calculate the banking angle of the curve if friction does not provide any of the force required for the centripetal acceleration. The acceleration due to gravity g is 9.8 m.s^{-2}.

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

$$\therefore \theta = tan^{-1}\left(\frac{v^2}{rg}\right)$$

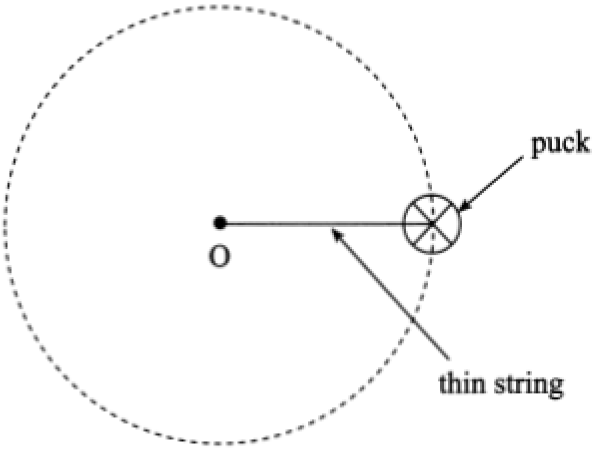
$$\theta = tan^{-1}\left(\frac{15^2}{200 \times 9.8}\right)$$

$$\theta = 6.5°$$

QUESTION 16

A puck is attached by a thin string of fixed length to point O on a horizontal table, as shown in the diagram below. The puck rotates freely and at a constant speed about point O.

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



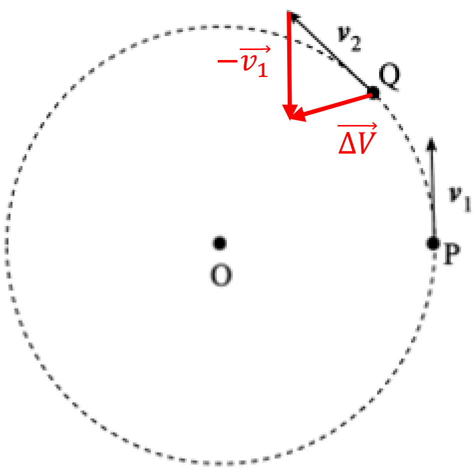
(a) Name the force acting on the puck that causes the centripetal acceleration.

$Tension\ force.$

(b) The instantaneous velocity v_1 of the puck at point P is shown in the diagram below.

The velocity v_2 of the puck a very short time later at point Q is also shown.

$$\overrightarrow{\Delta V} = \overrightarrow{v_2} - \overrightarrow{v_1}$$
$$\overrightarrow{\Delta V} = \overrightarrow{v_2} + (-\overrightarrow{v_1})$$



Note: diagram is poorly drawn. These points are too far apart to give a direction towards the centre.

On the diagram above, draw a vector diagram to determine the direction of the change in velocity Δv of the puck.

(2 marks)

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

Show that the speed of the puck is approximately 1.3 m. s^{-1}.

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

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

$$v = 1.3\ m.s^{-1}$$

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

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

$$a = \frac{(1.3)^2}{0.25}$$

$$a = 6.8\ m.s^{-2}$$

(e) 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.

$$F = ma$$

$$F = 5.0 \times 10^{-2} \times 6.8$$

$$F = 0.34\ N$$

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

$$F = \frac{mv^2}{r} \Rightarrow F \propto v^2\ (m\ \&\ r\ are\ constant)$$

$$v \to 2v \Rightarrow F \to 4F$$

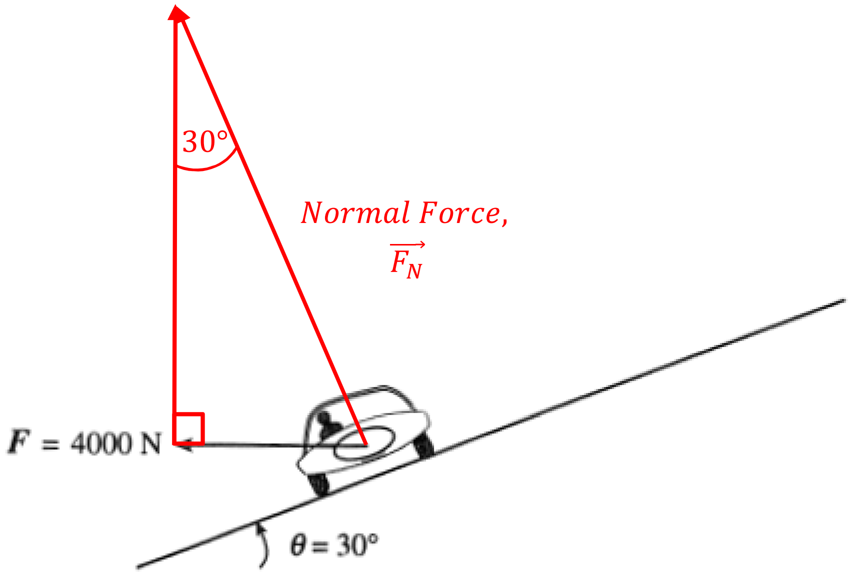
$$F = 4 \times 0.34$$

$$F = 1.4\ N$$

QUESTION 17

A car travels round a curve that has a banking angle of $\theta = 30^0$, as shown in the diagram below.

The car experiences a net force of 4000N towards the centre of the curve.



(a) On the diagram, draw a vector showing the direction of the normal force acting on the car.

Label this vector F_N *(2 marks)*

(b) Calculate the magnitude of the normal force on the car. Ignore friction.

$$sin30° = \frac{4000}{F_N}$$

$$\therefore F_N = \frac{4000}{sin30°}$$

$$F_N = 8000\ N$$

(c) A car of mass 1500 kg approaches a horizontal, circular curve of radius 55 m.

Each of the four tyres on the car can apply a maximum force of 540 N on the road before the car begins to slide.

Calculate the maximum speed at which the car can travel round the curve without sliding.

$$Total\ force, F = 4 \times 540$$

$$F = 2160\ N$$

$$F = \frac{mv^2}{r} \qquad \therefore v = \sqrt{\frac{Fr}{m}}$$

$$v = \sqrt{\frac{Fr}{m}}$$

$$v = \sqrt{\frac{2160 \times 55}{1500}} = 8.9\ m.s^{-1}$$

QUESTION 18

A car is driven at a constant speed v = 20.0 m s^{-1} round a curve of radius r = 200 m, with a banking angle θ to the horizontal, so that $tan\theta = \frac{v^2}{rg}$. Assume that g = 9.80 m.s^{-2}.

(a) State how the horizontal and vertical components of the normal force on the car would affect the motion of the car when there is no friction.

The horizontal component of the normal force supplies the centripetal acceleration necessary to keep the car moving in a circular path.

The vertical component of the normal force has no effect.

(b) Calculate the banking angle θ.

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

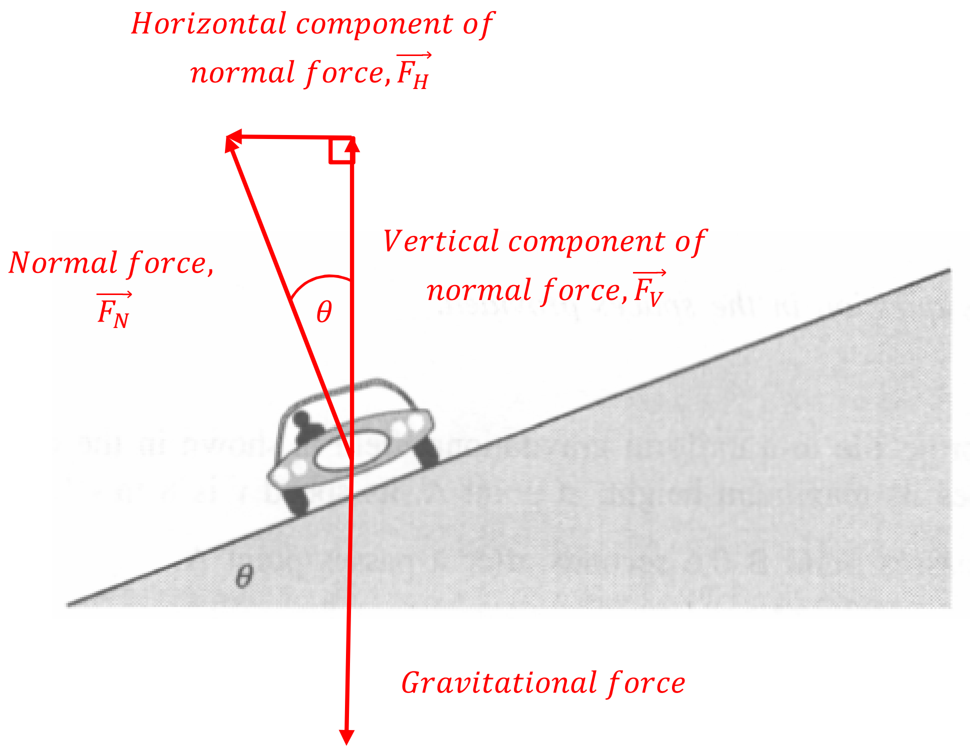
$$\therefore \theta = tan^{-1}\left(\frac{v^2}{rg}\right)$$

$$\theta = tan^{-1}\left(\frac{20^2}{200 \times 9.8}\right)$$

$$\theta = 11.5°$$

QUESTION 19

(a) On the diagram below, draw and label the forces acting on the car, of mass m, as it travels round a banked curve of radius r without relying on friction.



(4 marks)

(b) State in words the condition necessary for the car to be able to travel round a banked curve at a constant speed v without relying on friction.

The horizontal component of the normal force must supply all of the centripetal acceleration necessary to keep the car in the circular path.