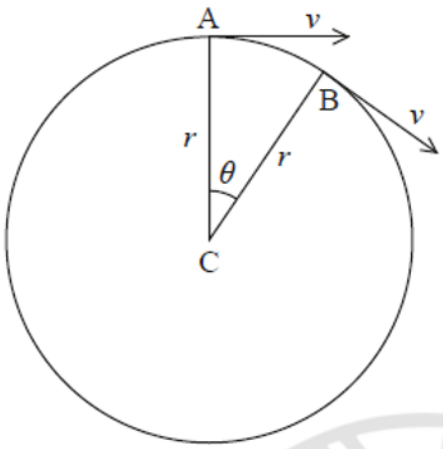
Questions

Q1.

(a) An object travels with speed v around a circular path or radius r. The diagram shows two positions, A and B on the path.



The acceleration of the object is α.

Derive the expression $a = \frac{v^2}{R}$

You should include a vector diagram.

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(b) The photograph shows a toy with small aeroplanes suspended from a canopy by wires.

As the platform rotates, the aeroplanes rise and follow a circular path.

At a particular speed, the aeroplanes follow a circular path of diameter 10.8 cm and the wires make an angle of 19° to the vertical.

(i) Complete a free body force diagram for one of the aeroplanes at this speed.

(1)

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(ii) Show that, at this speed, the time for an aeroplane to make 4 complete rotations is about 3 s.

mass of aeroplane = 5.2 g

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(iii) Student A suggests that if the radius of the canopy was increased and rotated at the same angular velocity as before, the wires supporting the aeroplanes could be vertical.

Student B suggests that the wires would be at an angle of greater than 19° to the vertical.

Explain whether either of the students is correct.

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(Total for question = 14 marks)

Q2.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

A turntable for playing vinyl records rotates at 33 revolutions per minute.

What is the angular velocity in radian s^{-1}?

☒ **A** $33 \times 60 \times 2\pi$

☒ **B** $\dfrac{33}{(60 \times 2\pi)}$

☒ **C** $\left(\dfrac{33}{60}\right) \times 2\pi$

☒ **D** $33 \times 2\pi$

(Total for question = 1 mark)

Q3.

A track for go-karts is being built in a park.

The design criteria state that the track must have semicircular ends with straight track in between, as shown.

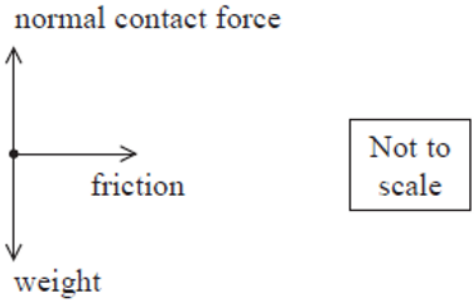
The track must allow the go-kart to travel safely at speeds up to 35.0 km per hour (9.72 m s^{-1}) on the bends.

mass of go-kart and driver = 185 kg

diameter AB of semicircular end = 30.0 m

(a) For one design the track is horizontal.

As the go-kart goes round the semicircular end of the track, centripetal force is provided by friction between the track and the tyres. This is shown in the free body force diagram below.



Show that this design meets the design criteria.

maximum frictional force = 1180 N

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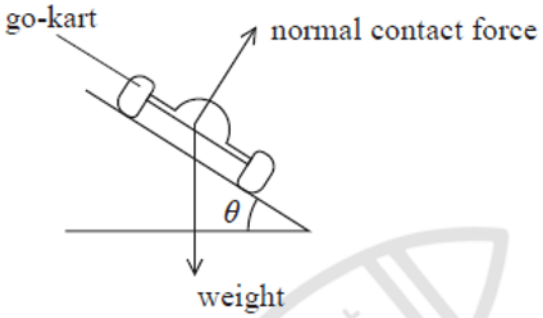
(b) A second design uses a track that is banked at the semicircular ends. The track is banked at an angle θ to the horizontal.



At a particular speed v, the go-kart can follow the track without any frictional force perpendicular to its motion. The diagram shows the forces on the go-kart as it is moving away.

(i) Show that $\tan\theta = \dfrac{2v^2}{gd}$

where d is the diameter AB of the curved part of the track.

(3)

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(ii) Calculate the angle θ using the stated design criteria for this track.

(2)

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Angle = ...

(c) A banked track will cost more to build.

Suggest whether there are any significant advantages that would justify the cost.

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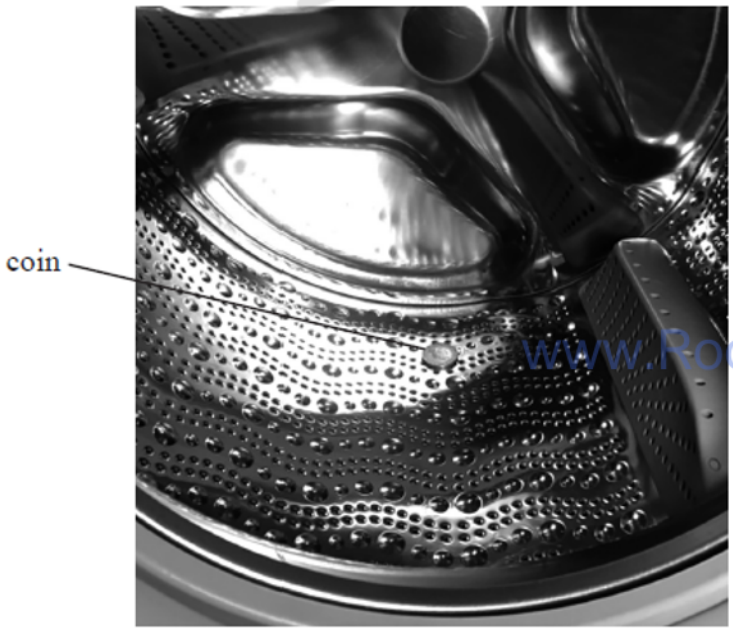
(Total for question = 9 marks)

Q4.

The photograph shows a coin in contact with the drum inside a washing machine.



The washing machine drum rotates about a horizontal axis at 600 revolutions per minute.

Calculate the maximum normal contact force exerted by the drum on the coin.

mass of coin = 12 g

diameter of washing machine drum = 48 cm

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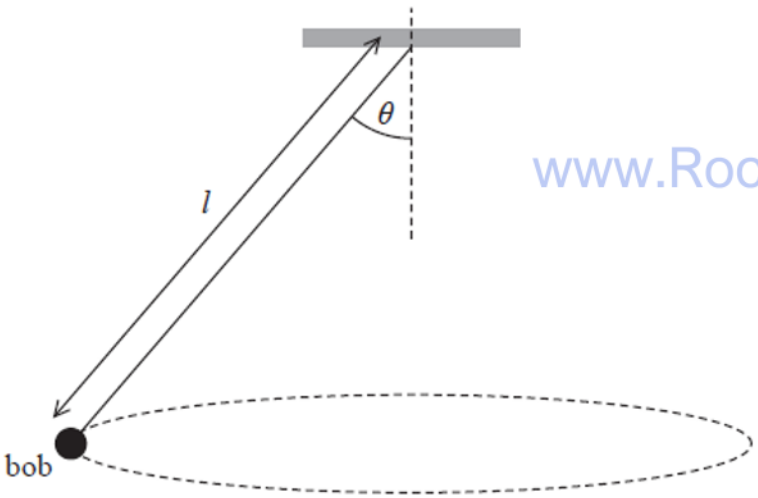
Maximum normal contact force = ...

(Total for question = 5 marks)

Q5.

18th century clocks sometimes used a conical pendulum to measure regular periods of time. A conical pendulum consists of a bob of mass *m* fixed to the end of a wire of length *l* as shown. The bob is set to follow a circular path in the horizontal plane. The wire makes an angle θ with the vertical.



(a) Add to the diagram to show the two forces acting on the bob.

(2)

(b) (i) Derive the following equation for the angular velocity ω of the bob.

$$\omega = \sqrt{\frac{g}{l\cos\theta}}$$

(4)

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(ii) A clock requires the period of the bob to be 5.0 s.

l = 6.4 m
θ = 13.9°

Deduce whether this arrangement leads to the required period.

(3)

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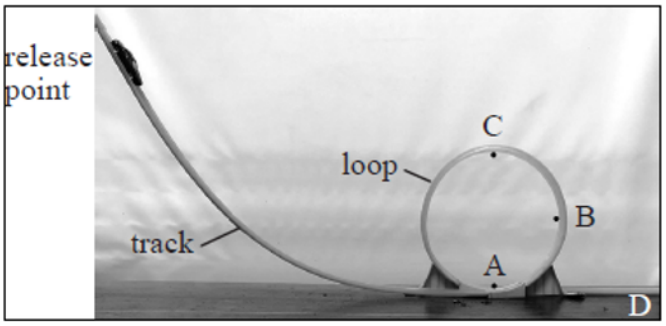
(Total for question = 9 marks)

Q6.

The photograph shows a track for a toy car. The car moves down the track towards a circular loop. The loop starts at point A.



If the release point of the car is high enough, the car moves fast enough to pass point C and complete the loop, continuing to the end of the track at point D.

If the release point is too low, the car falls off the track between point B and point C.

Deduce whether a car released from a vertical height of 25 cm above point A will complete the loop and reach point D. You should assume that friction is negligible.

vertical height of point C above point A = 22 cm
mass of toy car = 33 g

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(Total for question = 6 marks)

Q7.

Select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A website states: "The radius of the orbit of the Moon around the Earth is increasing by a small amount each year, however the time period of the orbit remains constant."

Which row of the table is correct if the statement is true?

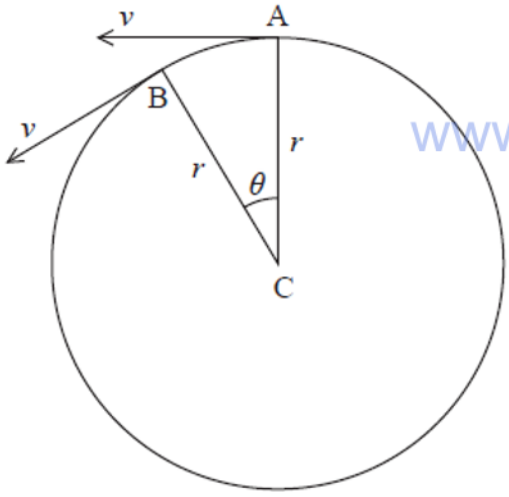
		Angular velocity of Moon	Speed of Moon
☒	**A**	constant	constant
☒	**B**	constant	increasing
☒	**C**	increasing	constant
☒	**D**	increasing	increasing

(Total for question = 1 mark)

Q8.

An aeroplane flies in a horizontal circular path whilst waiting to land at an airport.

(a) The aeroplane flies at a constant speed v around a horizontal circular path of radius r. The diagram shows two positions A and B of the aeroplane, on its circular path.



The acceleration of the aeroplane is a.

Derive the expression $a = \frac{v^2}{r}$

You should include a vector diagram.

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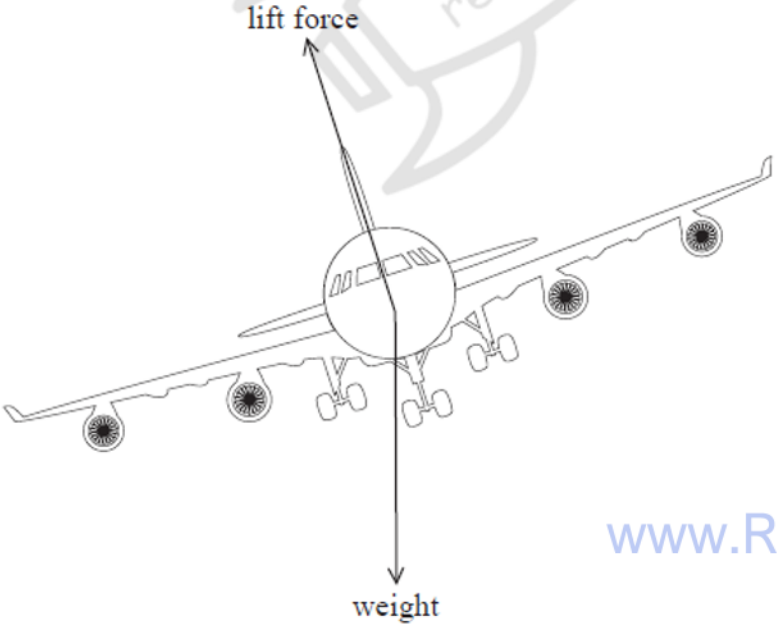
(b) The aeroplane flies in a horizontal circle by tilting to one side in a movement called 'banking'.

The aeroplane creates an upwards lift force, which acts in a direction perpendicular to its wings.

(i) The diagram shows this lift force when the aeroplane is banking.



(Source: © Nadezda0704/Shutterstock)

Explain how banking allows the aeroplane to fly in a horizontal circular path.

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(ii) During banking, the angle between the wings and the horizontal is 5.2°.

Calculate the radius of the circular path when the aeroplane flies at a constant speed of 530 m s^{-1}.

mass of aeroplane = 4.1×10^5 kg

(4)

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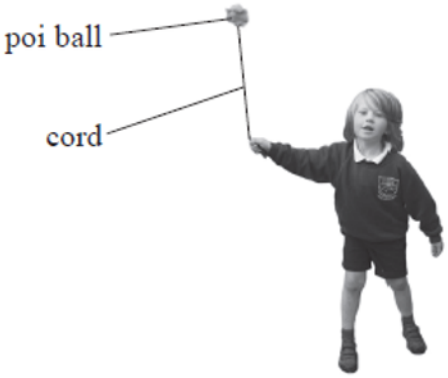
Radius = ...

(Total for question = 13 marks)

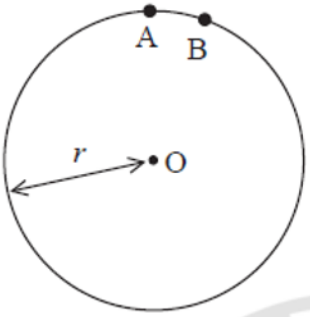
Q9.

A poi ball is a ball attached to a person's hand by a cord. A child makes the poi ball undergo circular motion in a vertical plane as shown in the photograph.



(a) The poi ball moves clockwise in a circle of radius *r*, centre O, with a constant speed *v*.

The diagram shows two positions, A and B, of the poi ball.



Derive the equation for centripetal acceleration $a = \frac{v^2}{r}$ by considering the velocity of the poi ball at these two positions.

Your answer should include a vector diagram.

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(b) The poi ball completes 1.3 revolutions per second.

Calculate the acceleration of the poi ball.

radius of circular motion = 0.58 m

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Acceleration = ...

(c) The child comments that as the ball goes round the circle with a constant speed, the size of the force on his hand changes.

Discuss whether this comment is correct.

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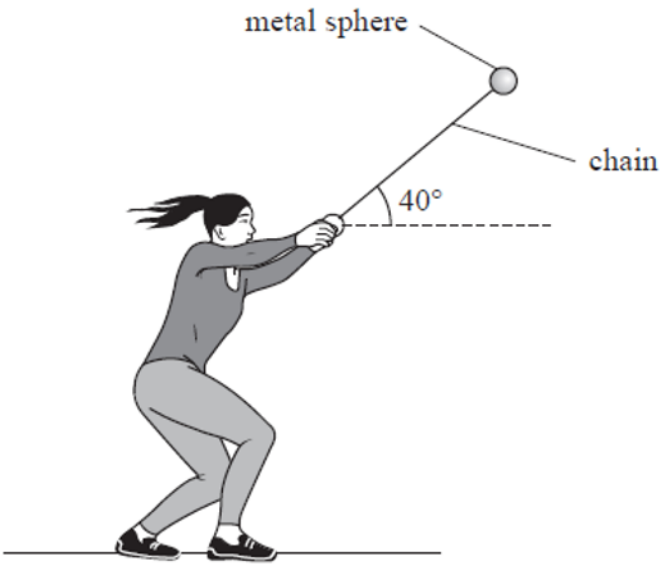
(Total for question = 12 marks)

Q10.

Hammer throwing is an Olympic sport. A hammer is a metal sphere attached to a chain.
An athlete holds the chain and spins around so that the sphere moves in a circle.
The chain is inclined at 40° to the horizontal, as shown.



(a)(i) The tension in the chain, acting on the sphere, is *T*.

Draw the free-body force diagram for the sphere at the position shown in the diagram.

(2)

(ii) Explain why the sphere moves with circular motion.

(2)

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(iii) The sphere completes 2.8 revolutions per second.

Calculate the acceleration of the sphere.

distance from sphere to centre of circle = 1.5 m

(3)

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Acceleration = ...

(b) The athlete finally releases the sphere with a velocity of 28 m s^{-1} at an angle of 40° to the horizontal. She releases the sphere at a height of 1.5 m above the ground.

The women's Olympic record distance for the hammer throw is 83 m.

Deduce whether this throw would break the record.

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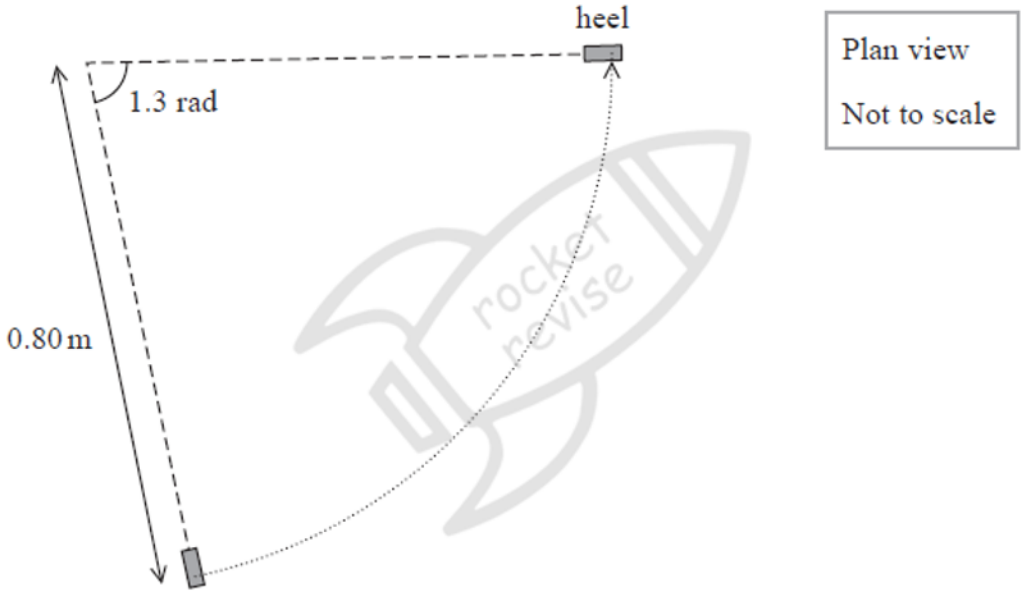
(Total for question = 12 marks)

Q11.

Hockey is a sport played with a stick and a ball. The player tries to hit the ball with part of the stick called the 'heel', as shown.

(Source: © Studio77 FX vector/Shutterstock)

(a) The player swings her stick so that the heel moves horizontally in a circle of radius 0.80 m across the ground, as shown below.



It takes a time of 0.22 s for the heel to move through an angle of 1.3 radians.

Calculate the speed of the heel.

(3)

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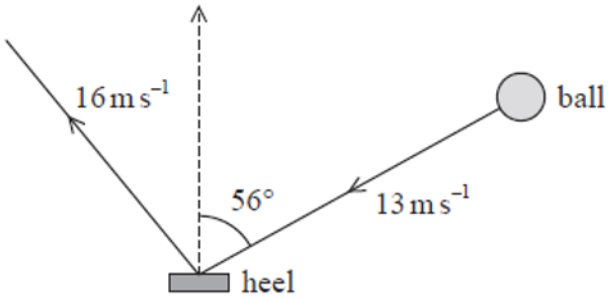
Speed of heel = ...

(b) A ball has a speed of 13 m s^{-1}. The heel has a momentum p_{heel} of 3.0 N s, in the direction of the dashed line, as shown.

The heel collides with the ball and stops.

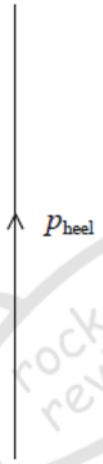
The speed of the ball after being hit by the heel is 16 m s^{-1}.



(i) Deduce whether momentum is conserved for this collision by completing the vector diagram below. A scaled line representing p_{heel} is shown.

mass of ball = 160 g

(5)



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(ii) Deduce whether the collision is elastic.

speed of heel before collision = 5.0 m s^{-1}

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(Total for question = 12 marks)

Q12.

The photograph shows children on a roundabout in a playground.

(Source: © Juice Flair/Shutterstock)

The roundabout is a flat platform with bars. The children make the platform rotate by running on the ground whilst pushing on the bars.

It takes 12 s for the roundabout to make 2 complete rotations.

A child is standing on the platform 1.8 m from the centre of the roundabout.

Calculate the speed of the child.

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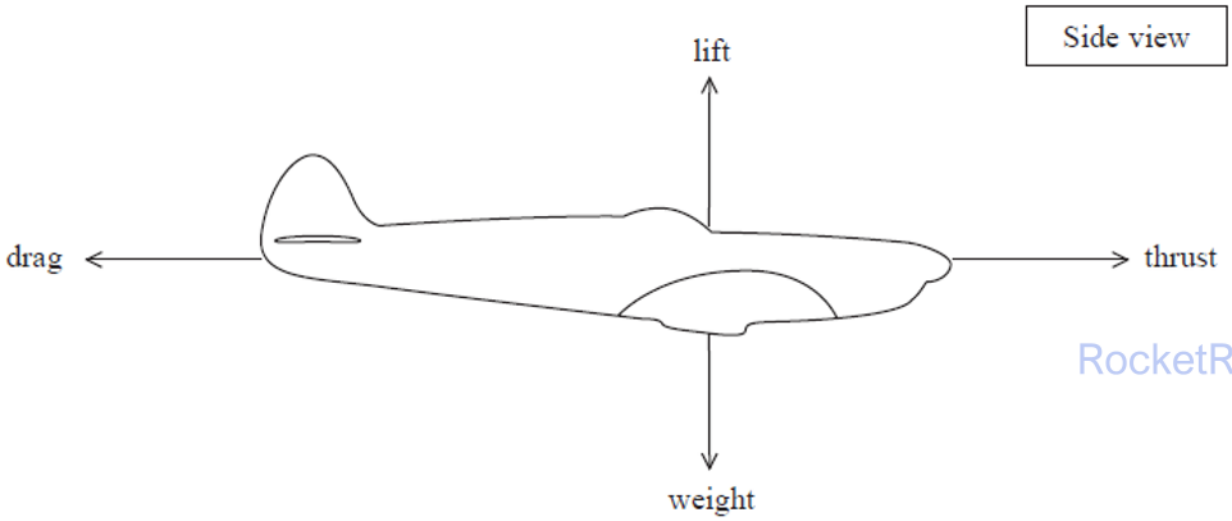
Speed of child = ...

(Total for question = 3 marks)

Q13.

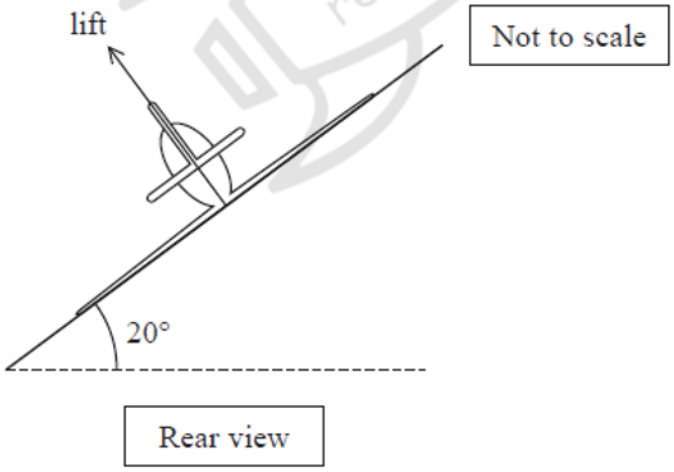
There are four forces acting on an aeroplane in flight, as shown.



(a) The lift force is perpendicular to the wings.

To change direction, the aeroplane 'banks' so that one wing is lower than the other wing.
The lift force is then no longer vertical.
The aeroplane flies in a horizontal circular path at a speed of 52 m s^{-1}.

The diagram below shows the aeroplane banking at an angle of 20° to the horizontal.



(i) Show that the radius of the circular path is about 800m.

mass of aeroplane = 1200 kg
speed of aeroplane = 54 m s^{-1}

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(ii) Determine the time taken by the plane to move through 90° of the circular path.

speed of aeroplane = 54 m s^{-1}

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Time = ...

(b) The wings of the aeroplane are now levelled, as shown below.

The speed and the magnitude of the lift force remain the same.

Explain what will happen to the vertical motion of the aeroplane.

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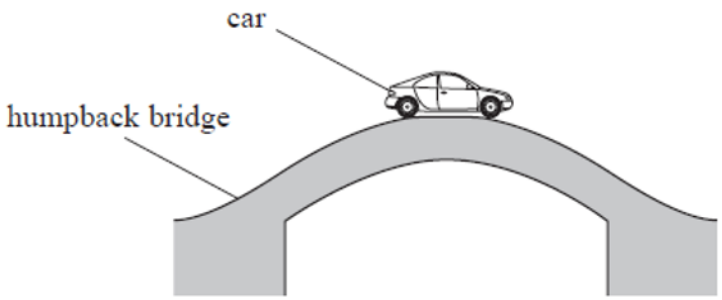
(Total for question = 9 marks)

Q14.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A car travels over a humpback bridge, as shown. The bridge forms part of a circle of radius *r*. The car has mass *m* and travels with constant speed *v*.



The car is at the top of the bridge.

Which of the following expressions gives the force, from the bridge, on the moving car?

☒ **A** mg

☒ **B** $mg + \frac{mv^2}{r}$

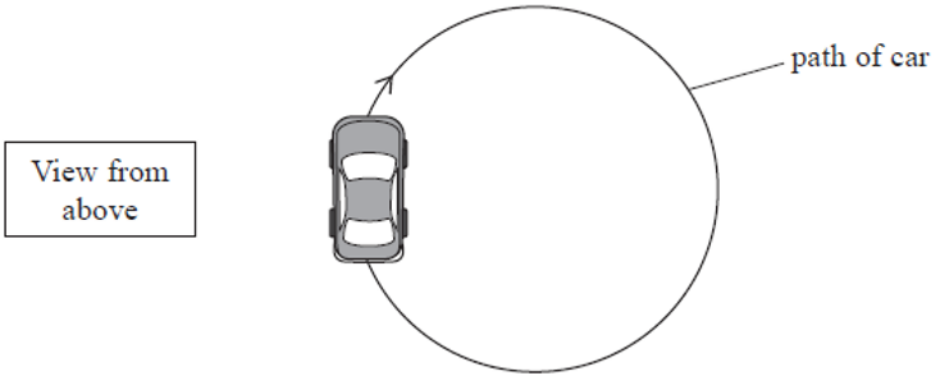
☒ **C** $mg - \frac{mv^2}{r}$

☒ **D** $\frac{mv^2}{r} - mg$

(Total for question = 1 mark)

Q15.

A car travelled in a circular path as shown.



A passenger in the car made the following claim.

"When the car was travelling at high speed around the circular path, I was thrown outwards due to a force acting on me. The outward force acting on me was the centrifugal force."

Assess the claim made by the passenger.

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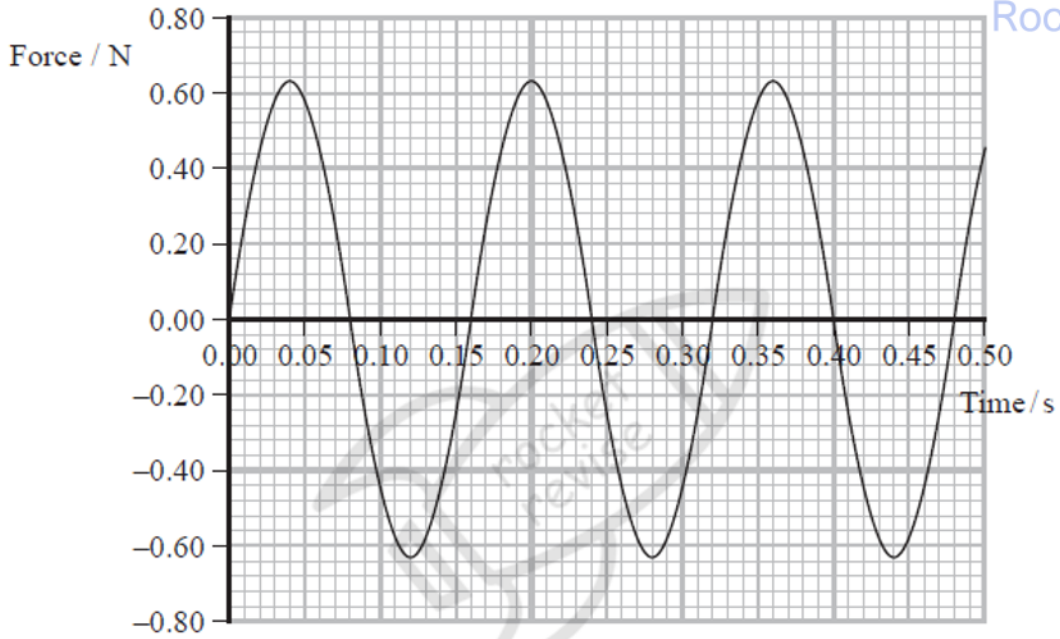
(Total for question = 4 marks)

Q16.

The photograph shows a toy car inside a plastic ball. The car has an electric motor and follows a circular path in a vertical plane. The car travels at a constant speed.

A student determined how the resultant vertical force on the car varied over a period of time.

The graph shows the student's data. A positive value represents an upwards force.



(a) (i) Show that the angular velocity of the car's motion about the centre of the ball is about 40 radian s^{-1}.

(3)

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(ii) The student took measurements of the ball and wrote down a value of 86 mm.

Deduce whether 86 mm was the radius or the diameter of the ball.

mass of car = 9.5 g

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*(b) The magnitude of the force exerted by the ball on the car was greatest at 0.04 s and least at 0.12 s.

Discuss the position of the car at these two times.

You should consider the forces acting on the car.
You do not need to do any further calculations.

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(Total for question = 13 marks)

Q17.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A toy aeroplane is travelling in a circular path. The toy aeroplane completes 12 revolutions in 6 s.

Which of the following gives the angular velocity, in rad s^{-1}, of the toy aeroplane?

☒ **A** $\frac{12 \times \pi}{6}$

☒ **B** $\frac{12 \times 2\pi}{6}$

☒ **C** $\frac{6 \times \pi}{12}$

☒ **D** $\frac{6 \times 2\pi}{12}$

(Total for question = 1 mark)

Q18.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A laboratory centrifuge rotates at 1500 revolutions per minute.

Which of the following expressions gives the angular velocity in radians per second?

☒ **A** $\frac{1500}{60 \times 2\pi}$

☒ **B** $\frac{60}{1500 \times 2\pi}$

☒ **C** $\frac{60 \times 2\pi}{1500}$

☒ **D** $\frac{1500 \times 2\pi}{60}$

(Total for question = 1 mark)