1 A lead ball of mass 0.25 kg is swung round on the end of a string so that the ball moves in a horizontal circle of radius 1.5 m. The ball travels at a constant speed of 8.6 m s^{-1}.

(a) (i) Calculate the angle, in degrees, through which the string turns in 0.40 s.

angle ..... degree

(3)

(ii) Calculate the tension in the string.
You may assume that the string is horizontal.

tension ..... N

(2)

(b) The string will break when the tension exceeds 60 N.
Calculate the number of revolutions that the ball makes in one second when the tension is 60 N.

number of revolutions .....

(2)

(c) Discuss the motion of the ball in terms of the forces that act on it. In your answer you should:

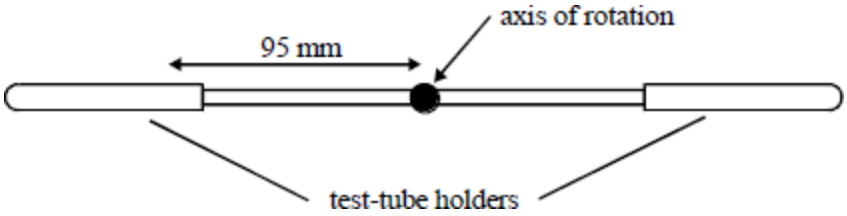
- explain how Newton's three laws of motion apply to its motion in a circle
- explain why, in practice, the string will not be horizontal.

You may wish to draw a diagram to clarify your answer.

The quality of your written communication will be assessed in your answer.

(6)
(Total 13 marks)

2 A chemical centrifuge consists of two test-tube holders which can be spun round in a horizontal circular path at very high speed as shown. The centrifuge runs at a steady speed of 3000 revolutions per minute and the test-tube holders are horizontal.



(a) Calculate the angular speed of the centrifuge in rad s^{-1}.

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(b) Calculate the magnitude of the acceleration at a point on the centrifuge 95 mm from the axis of rotation.

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(c) State the direction of the acceleration in part (ii).

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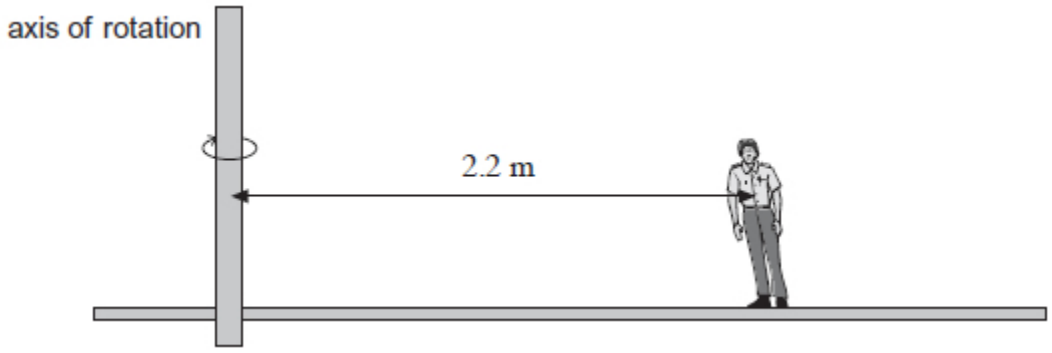
(Total 5 marks)

3

(3)

3 An operator of mass 65 kg is standing on the roundabout when the roundabout is rotating at an angular velocity of 0.47 rad s^{-1}. His centre of mass is 2.2 m from the axis of rotation. The diagram shows that his body leans towards the centre of the path.



(i) Calculate the centripetal force needed for the operator to remain at this radius on the roundabout.

centripetal force ..... N

(2)

(ii) State the origin of this centripetal force and suggest why the operator has to incline his body towards the centre of rotation to avoid falling over.

You may draw the forces that act on the operator in the diagram to help your answer.

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(2)

(iii) While the roundabout is moving, the operator drops a coin.

Which statement correctly describes and explains what happens to the coin?
Tick (✓) the correct answer in the right-hand column.

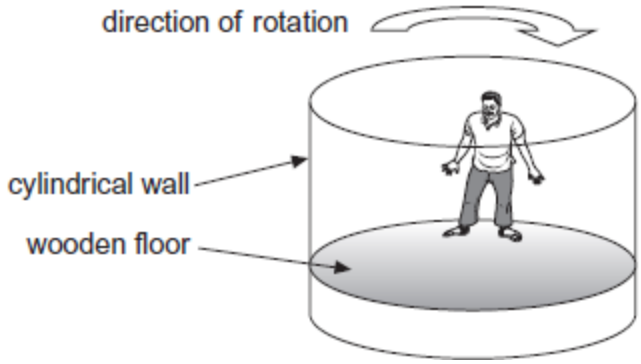
	Tick (✓)
There is no longer a centripetal force acting, so the coin falls vertically downwards and lands on the roundabout directly below the point at which it was dropped.	
The centripetal force causes the coin to have a horizontal component of velocity towards the centre of the roundabout, so that it follows a trajectory towards the centre of the roundabout.	
There is no longer a centripetal force acting, so there is a horizontal component of the coin's velocity directed away from the centre of the roundabout and it follows a trajectory directly away from the centre.	
There is no longer a centripetal force acting, so the coin has a horizontal component of its velocity tangential to its original path on the roundabout and it follows a trajectory along this tangent.	

(1)

(Total 14 marks)

4 **Figure 1** shows a fairground ride called a Rotor. Riders stand on a wooden floor and lean against the cylindrical wall.

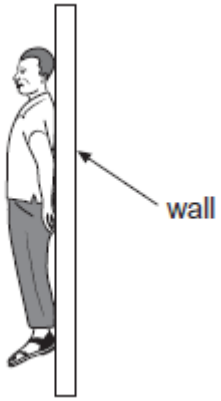
Figure 1



The fairground ride is then rotated. When the ride is rotating sufficiently quickly the wooden floor is lowered. The riders remain pinned to the wall by the effects of the motion. When the speed of rotation is reduced, the riders slide down the wall and land on the floor.

(a) (i) At the instant shown in **Figure 2** the ride is rotating quickly enough to hold a rider at a constant height when the floor has been lowered.

Figure 2



Draw onto **Figure 2** arrows representing all the forces on the rider when held in this position relative to the wall.
Label the arrows clearly to identify all of the forces.

(3)

(ii) Explain why the riders slide down the wall as the ride slows down.

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(2)

A Rotor has a diameter of 4.5 m. It accelerates uniformly from rest to maximum angular velocity in 20 s.
The total moment of inertia of the Rotor and the riders is 2.1×10^5 kg m^2.

(b) (i) At the maximum speed the centripetal acceleration is 29 m s^{-2}.

Show that the maximum angular velocity of a rider is 3.6 rad s^{-1}.

(2)

(ii) Calculate the torque exerted on the Rotor so that it accelerates uniformly to its maximum angular velocity in 20 s.
State the appropriate SI unit for torque.

torque ..... SI unit for torque .....

(3)

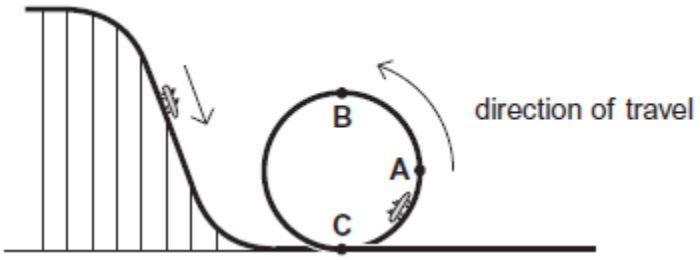
(iii) Calculate the centripetal force acting on a rider of mass 75 kg when the ride is moving at its maximum angular velocity.
Give your answer to an appropriate number of significant figures.

centripetal force ..... N

(1)

(c) **Figure 3** shows the final section of a roller coaster which ends in a vertical loop. The roller coaster is designed to give the occupants a maximum acceleration of $3g$. Cars on the roller coaster descend to the start of the loop and then travel around it, as shown.

Figure 3



(i) At which one of the positions marked **A**, **B** and **C** on **Figure 3** would the passengers experience the maximum reaction force exerted by their seat?
Circle your answer below.

A **B** **C**

(1)

(iii) Explain why the maximum acceleration is experienced at the position you have chosen.

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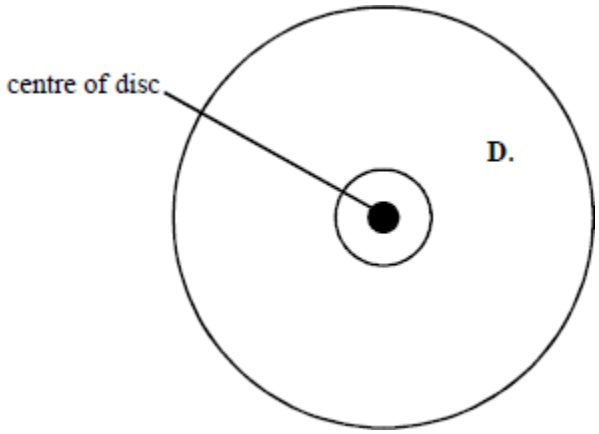
(2)
(Total 14 marks)

5 The figure below shows a dust particle at position **D** on a rotating vinyl disc. A combination of electrostatic and frictional forces act on the dust particle to keep it in the same position.



The dust particle is at a distance of 0.125 m from the centre of the disc. The disc rotates at 45 revolutions per minute.

(a) Calculate the linear speed of the dust particle at **D**.

(3)

(b) (i) Mark on the diagram above an arrow to show the direction of the resultant horizontal force on the dust particle.

(1)

(ii) Calculate the centripetal acceleration at position **D**.

(2)

(c) On looking closely at the rotating disc it can be seen that there is more dust concentrated on the inner part of the disc than the outer part. Suggest why this should be so.

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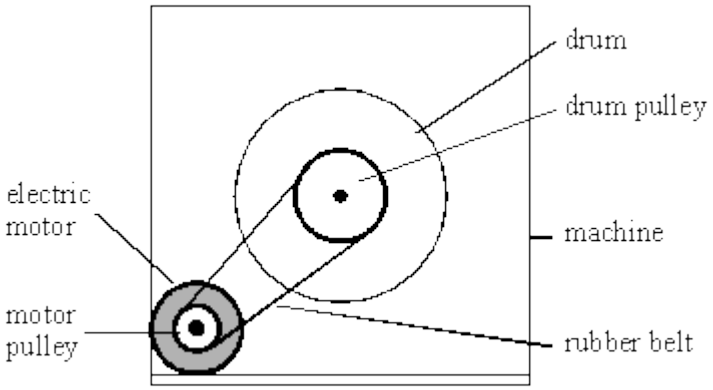
(3)
(Total 9 marks)

6 An electric motor in a machine drives a rotating drum by means of a rubber belt attached to pulleys, one on the motor shaft and one on the drum shaft, as shown in the diagram below.



(a) The pulley on the motor shaft has a diameter of 24 mm. When the motor is turning at 50 revolutions per second, calculate

(i) the speed of the belt,

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(ii) the centripetal acceleration of the belt as it passes round the motor pulley.

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(5)

(b) When the motor rotates at a particular speed, it causes a flexible metal panel in the machine to vibrate loudly. Explain why this happens.

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(2)
(Total 7 marks)