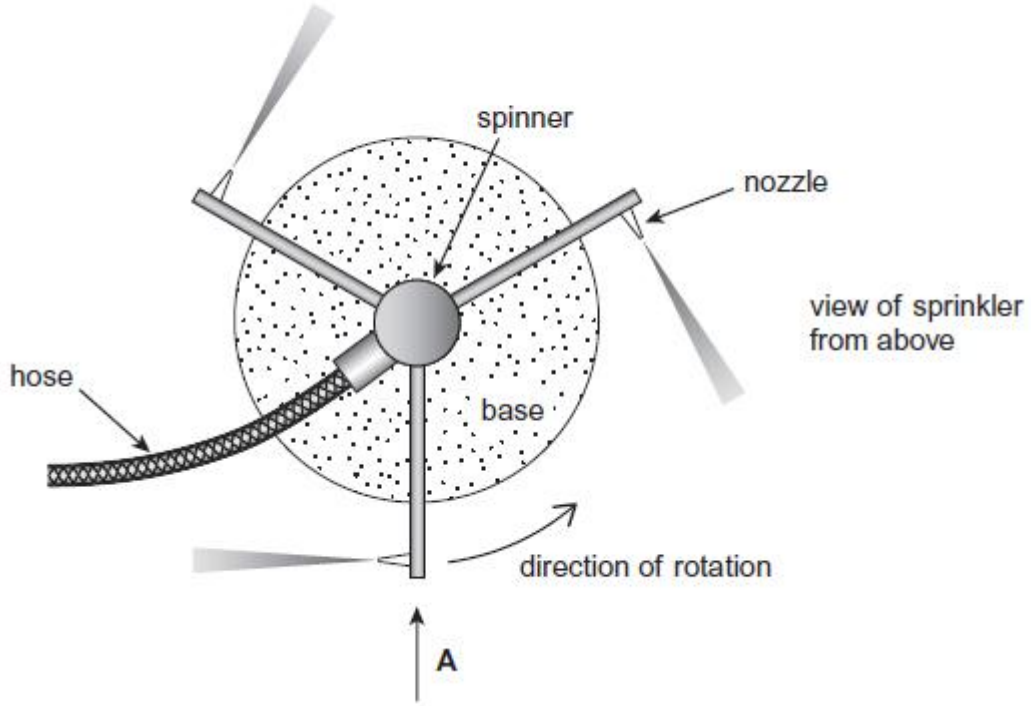
Name of the Student:_____
Max. Marks : 24 Marks **Time : 24 Minutes**

Q1.

A garden sprinkler consists of a fixed base and a rotating spinner having three arms as shown in **Figure 1**.

Figure 1



At the end of each arm is a nozzle at 90° to the arm and inclined at 45° to the horizontal. Water flows in jets at a constant rate from these nozzles when the hose water tap is turned on.

Figure 2 shows a side view of one of the nozzles viewed in the direction of arrow **A** in **Figure 1**.

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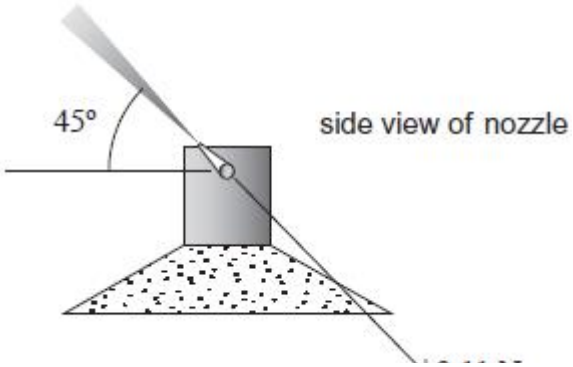
Figure 2



The water jets produce reaction forces that act on the arms which cause the spinner to rotate. The base remains fixed in position. In operation, the spinner rotates at a constant rate of 240 rev min^{-1}. The nozzles rotate in a horizontal circle of radius 120 mm.

(a) Each water jet exerts a constant force of 0.11 N on its arm at 45° to the horizontal.

Show that the torque exerted on the spinner by the jets of water is about 3×10^{-2} N m.

(2)

(b) (i) Explain why, when the water tap is turned on, the spinner accelerates initially but then reaches a constant angular speed.
Assume that, when the tap is turned on, the flow-rate of the water from the jets is constant.

_____

_____

_____

_____

_____

_____

_____

(2)

(ii) Calculate the power dissipated by the frictional torque acting between the spinner and the fixed base when the sprinkler is rotating at 240 rev min^{-1}.

power = _____ W

(2)

(c) When the water is suddenly turned off all the kinetic energy of the spinner and arms is dissipated as heat due to work done by the frictional torque and the spinner makes a further 13 rotations before coming to rest. Assume uniform deceleration.

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(i) Calculate the time taken for the spinner to come to rest.

time = _____ s

(2)

(ii) Show that the kinetic energy of the spinner when rotating at its operating speed is about 2 J.

(1)

(iii) Determine the moment of inertia of the spinner about its axis of rotation.

moment of inertia = _____ kg m^2

(1)

(Total 10 marks)

Q2.

A roundabout in a fairground requires an input power of 2.5 kW when operating at a constant angular velocity of 0.47 rad s^{-1}.

(a) Show that the frictional torque in the system is about 5 kN m.

(3)

(b) When the power is switched off, the roundabout decelerates uniformly because the frictional torque remains constant. The roundabout takes a time of 34 s to come to rest.

(i) Calculate the moment of inertia of the roundabout.
Give an appropriate unit for your answer.

moment of inertia _____ unit _____

(3)

(ii) Calculate the number of revolutions that are made before the roundabout comes to rest.

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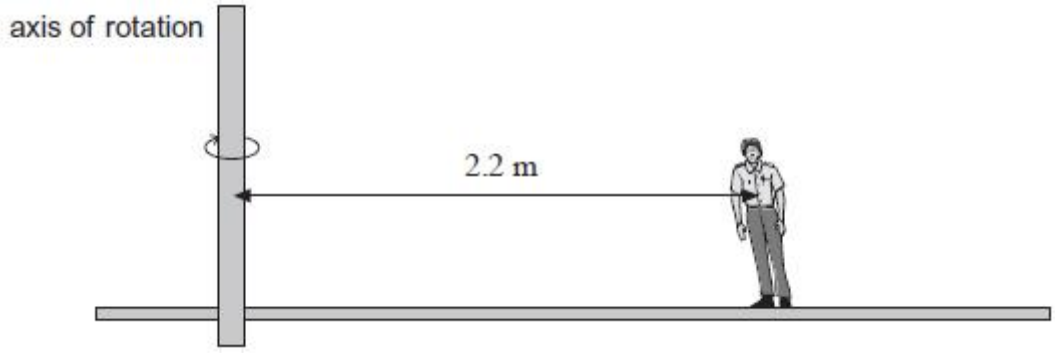
number of revolutions _____

(3)

(c) 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.

_____

_____

_____

_____

_____

(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	

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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)

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