Rotational Dynamics

2013 Revised AH Physics

Marks

2. The entrance to a building is through a revolving system consisting of 4 doors that rotate around a central axis as shown in Figure 2A.

Figure 2A

The moment of inertia of the system about the axis of rotation is $54\,\text{kg m}^2$. When it rotates a constant frictional torque of $25\,\text{N m}$ acts on the system.

(*a*) The system is initially stationary. On entering the building a person exerts a constant force F perpendicular to a door at a distance of 1·2 m from the axis of rotation as shown in Figure 2B.

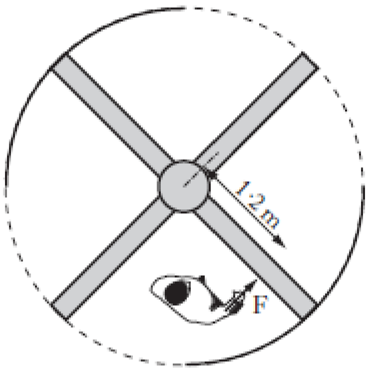

Figure 2B

The angular acceleration of the system is $2{\cdot}4\,\text{rad s}^{-2}$.

(i) Calculate the magnitude of the applied force F. **3**

(ii) The applied force is removed and the system comes to rest in 3·6 s. Calculate the angular displacement of the door during this time. **3**

Marks

2. (continued)

(*b*) On exiting the building the person exerts the same magnitude of force F on a door at the same distance from the axis of rotation.

The force is now applied as shown in Figure 2C.

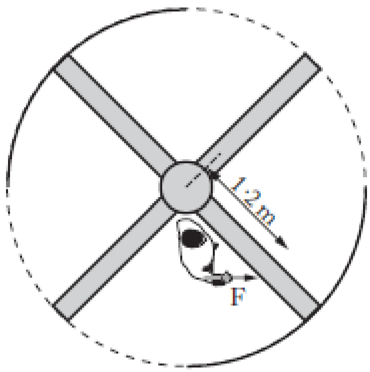

Figure 2C

How does the angular acceleration of the door system compare to that given in part (*a*)?

Justify your answer. **2**

(8)

2. A student uses two methods to calculate the moment of inertia of a cylinder about its central axis.

(*a*) In the first method the student measures the mass of the cylinder to be 0·115 kg and the diameter to be 0·030 m.

Calculate the moment of inertia of the cylinder. **2**

(*b*) In a second method the student allows the cylinder to roll down a slope and measures the final speed at the bottom of the slope to be 1·6 m s^{-1}. The cylinder has a diameter of 0·030 m and the slope has a height of 0·25 m, as shown in Figure 2.

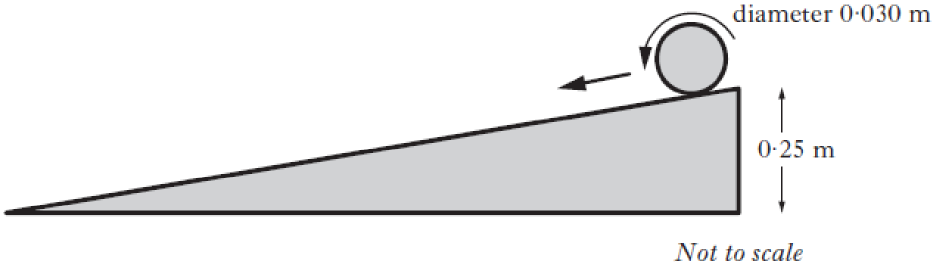

Figure 2

Using the conservation of energy, calculate the moment of inertia. **4**

(*c*) Explain why the moment of inertia found in part (*b*) is greater than in part (*a*). **1**

(7)

Marks

1. A flywheel consisting of a solid, uniform disc is free to rotate about a fixed axis as shown in Figure 1A. The disc has a mass of 16 kg and a radius of 0·30 m.

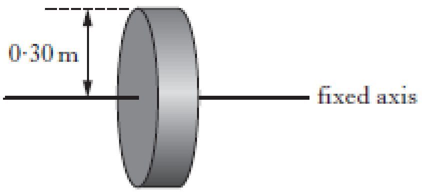

Figure 1A

(*a*) Calculate the moment of inertia of the flywheel. **2**

(*b*) A mass is attached to the flywheel by a light string as shown in Figure 1B.

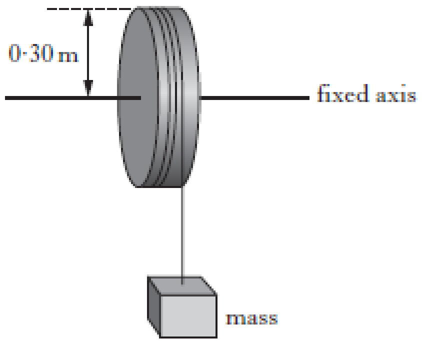

Figure 1B

The mass is allowed to fall and is found to be travelling at $3{\cdot}0\,m\,s^{-1}$ when the string leaves the flywheel. The flywheel makes 5 further revolutions before it comes to rest.

(i) Calculate the angular acceleration of the flywheel after the string leaves the flywheel. **3**

(ii) Calculate the frictional torque acting on the flywheel. **2**

(*c*) The experiment is repeated with a flywheel made from a more dense material with the same physical dimensions. The string, falling mass and all frictional forces are the same as in part (*b*).

As the string detaches from the flywheel, is the speed of the falling mass greater than, the same as or less than $3{\cdot}0\,m\,s^{-1}$?

You must justify your answer. **2**

Marks

1. **(continued)**

(*d*) A Kinetic Energy Recovery System (KERS) is used in racing cars to store energy that is usually lost when braking.

One of these systems uses a flywheel, as shown in Figure 1C, to store the energy.

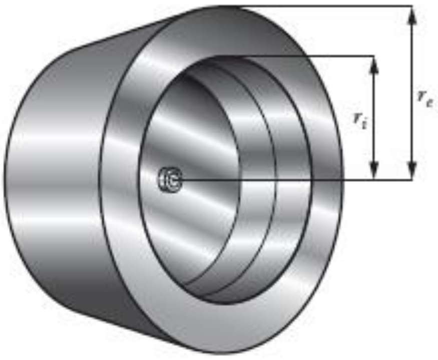

Figure 1C

Data for this KERS flywheel is given below.

Internal radius r_i = 0·15 m

External radius r_e = 0·20 m

Mass of flywheel M = 6·0 kg

Maximum rate of revolution = $6{\cdot}0 \times 10^4$ revolutions per minute

(i) Using the expression

$$I = \tfrac{1}{2} M(r_i^2 + r_e^2)$$

determine the moment of inertia of the flywheel. **1**

(ii) Calculate the maximum rotational kinetic energy that can be stored in the flywheel. **3**

(13)

MARGIN

3. A student uses a solid, uniform circular disc of radius 290 mm and mass 0·40 kg as part of an investigation into rotational motion.

The disc is shown in Figure 3A.

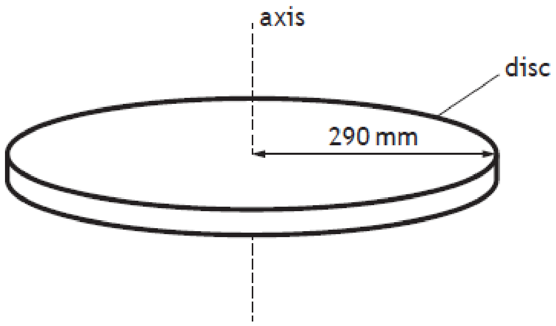

Figure 3A

(a) Calculate the moment of inertia of the disc about the axis shown in Figure 3A. 3

Space for working and answer

(b) The disc is now mounted horizontally on the axle of a rotational motion sensor as shown in Figure 3B.

The axle is on a frictionless bearing. A thin cord is wound around a stationary pulley which is attached to the axle.

The moment of inertia of the pulley and axle can be considered negligible.

The pulley has a radius of 7·5 mm and a force of 8·0 N is applied to the free end of the cord.

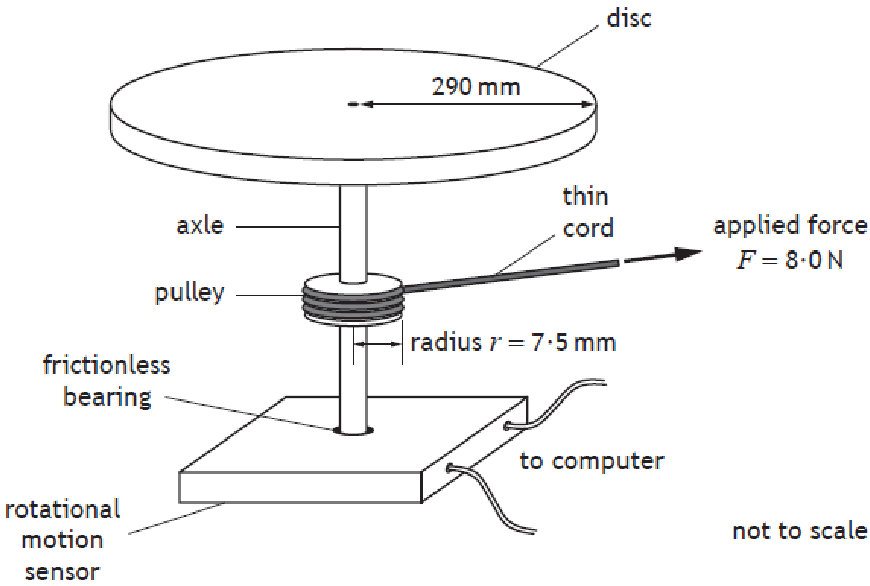

Figure 3B

(i) Calculate the torque applied to the pulley. **3**

Space for working and answer

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3. (continued)

(c) In a second experiment the disc has an angular velocity of 12 rad s^{-1}.

The student now drops a small 25 g cube vertically onto the disc. The cube sticks to the disc.

The centre of mass of the cube is 220 mm from the axis of rotation, as shown in Figure 3C.

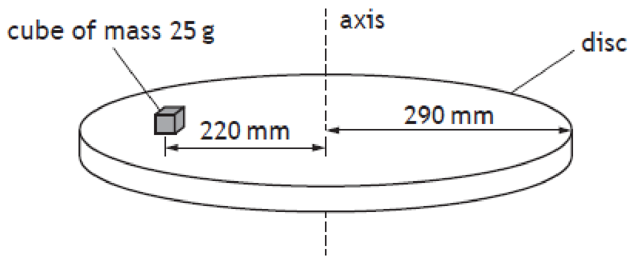

Figure 3C

Calculate the angular velocity of the system immediately after the cube was dropped onto the disc. **5**

Space for working and answer

3. A student uses two methods to calculate the moment of inertia of a cylinder about its central axis.

(a) In the first method the student measures the mass of the cylinder to be 0·115 kg and the diameter to be 0·030 m.

Calculate the moment of inertia of the cylinder. **3**

Space for working and answer

(b) In a second method the student allows the cylinder to roll down a slope and measures the final speed at the bottom of the slope to be 1·6 m s^{-1}. The slope has a height of 0·25 m, as shown in Figure 3.

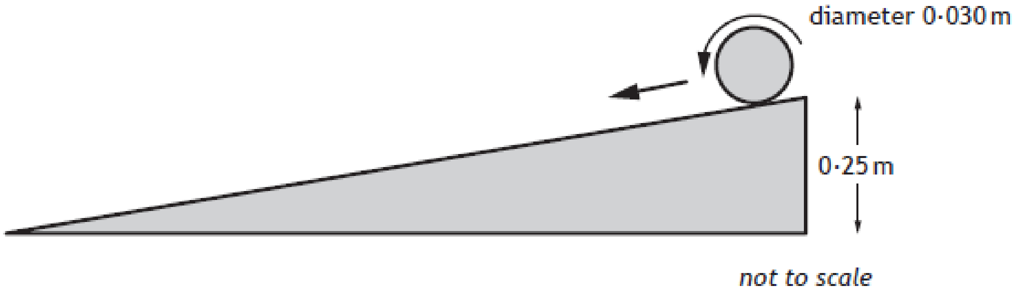

Figure 3

Using the conservation of energy, calculate the moment of inertia of the cylinder. **5**

Space for working and answer

3. (continued)

(c) Explain why the moment of inertia found in part (b) is greater than in part (a). **1**

2. A disc of mass 6·0 kg and radius 0·50 m is allowed to rotate freely about its central axis as shown in Figure 2A.

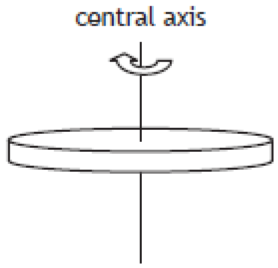

Figure 2A

(a) Show that the moment of inertia of the disc is 0·75 kg m^2. **2**

Space for working and answer

(b) The disc is rotating with an angular velocity of 12 rad s^{-1}. A cube of mass 2·0 kg is then dropped onto the disc. The cube remains at a distance of 0·40 m from the axis of rotation as shown in Figure 2B.

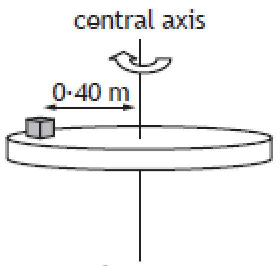

Figure 2B

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2. (b) (continued)

(i) Determine the total moment of inertia of the disc and cube. 3

Space for working and answer

(ii) Calculate the angular velocity of the disc after the cube lands. 3

Space for working and answer

(iii) State one assumption you have made in your response to b(ii). 1

(c) The cube is removed and the disc is again made to rotate with a constant angular velocity of 12 rad s^{-1}. A sphere of mass 2·0 kg is then dropped onto the disc at a distance of 0·40 m from the axis as shown in Figure 2C.

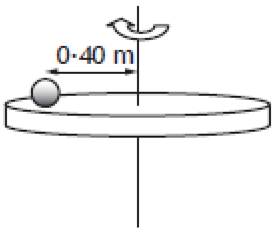

Figure 2C

State whether the resulting angular velocity of the disc is greater than, the same as, or less than, the value calculated in b(ii).

You must justify your answer. 2