CfE Advanced Higher Physics

Rotational Motion & Astrophysics Past Paper Homework

3. Rotational Dynamics

1. A yo-yo consists of two discs mounted on an axle. A length of string is attached to the axle and wound round the axle.
   With the string fully wound, the yo-yo is suspended from a horizontal support as shown below:

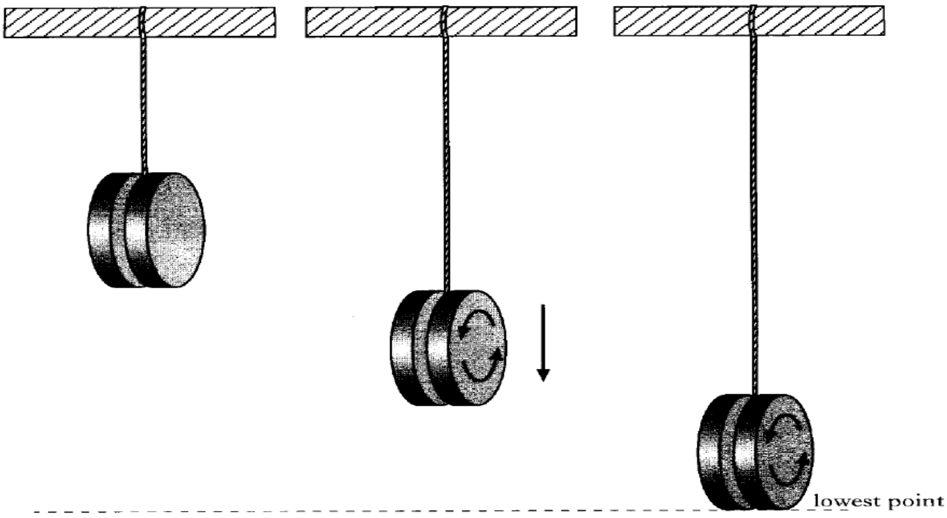


Figure 1(*a*) Figure 1(*b*) Figure 1(*c*)

The yo-yo is released from rest and rotates as it falls, as shown in Figure 1(b).
The string is fully unwound at the yo-yo's lowest point, as shown in Figure 1 (c).
The yo-yo then rises, rewinding the string.

(a) State the type(s) of energy which the yo-yo has when it is at the position shown in

(i) Figure 1 (b) 2

(ii) Figure 2 (c) 2

(b) Each disc has a mass *m* of 0.100 kg and a radius *r* of 0.050m.
The moment of inertia of a disc is given by ½ mr^2 . The moment of inertia of the axle is negligible. Calculate the moment of inertia of the yo-yo. 3

(c) When the yo-yo is at the position shown in Figure 1 (c) it has an angular velocity of 120 rads. 3
Calculate the maximum height to which the yo-yo could rise as it rewinds the string.

(10)

2. A playground roundabout has a radius of 2.0m and a moment of inertia of 500 kgm^2 about its axis of rotation. A child of mass 25 kg runs tangentially to the stationary roundabout and jumps on to its outer edge, as shown in Figure 3.

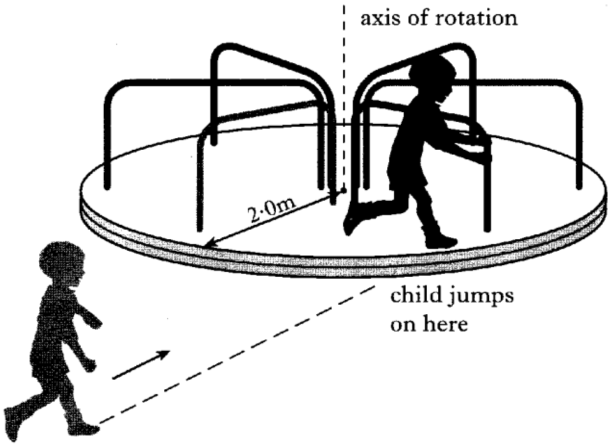


Figure 3

(a) Show that, with the child at the outer edge, the combined moment of inertia of the roundabout and child is 600 kg m^2. 2

(b) State what is meant by conservation of angular momentum. 2

(c) At the point of jumping onto the roundabout, the tangential speed of the child is 2.4 ms^{-1}. At this point, calculate :

(i) the linear momentum of the child; 2

(ii) the angular momentum of the child about the axis of rotation of the roundabout, 2

(d) Calculate the angular velocity of the roundabout and the child just after the child jumps on. 2

(e) Calculate the loss in kinetic energy as the child jumps onto the roundabout. 2

(f) The roundabout with the child onboard makes half a complete revolution before coming to rest.
Calculate the frictional torque acting on the roundabout. 2

2005

3. A circular metal disc is mounted horizontally on the side of a rotational motion sensor as shown in Figure 4.
The axle is on a frictionless bearing.

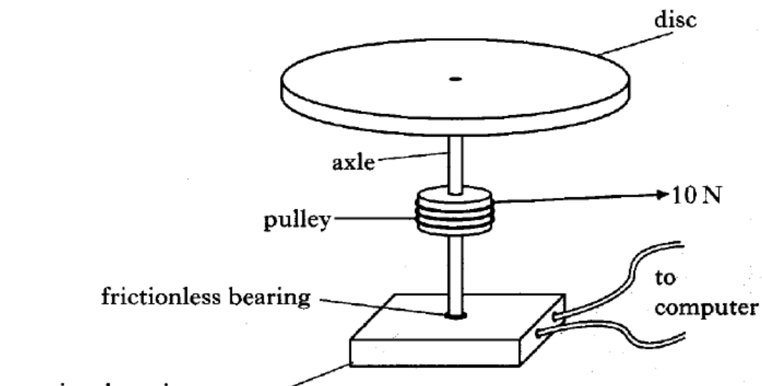


Figure 4.

A thin cord is wound round a light pulley which is attached to the axle. The pulley has a radius of 20 mm and a force of 10 N is applied to the free end of the cord.

The cord fully unwinds from the pulley in a time of 3.0 s.
The rotational motion sensor is interfaced to a computer which is programmed to display a graph showing the variation of the angular velocity of the metal disc with time.
The graph displayed on the monitor is shown in Figure 5.

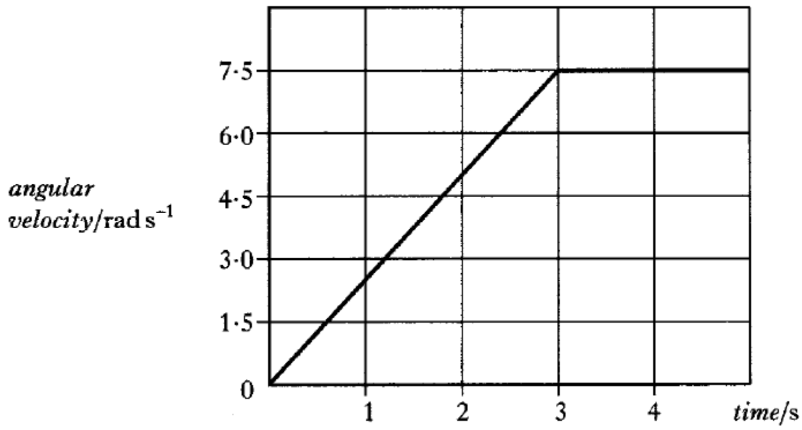


Figure 5.

(a) (i) Calculate the torque exerted by the cord.

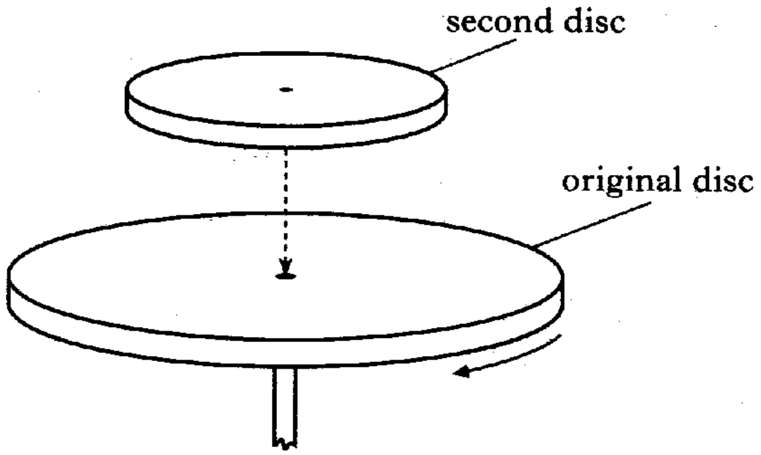
(ii) Using information from the graph, determine the angular acceleration of the disc.

(iii) Calculate the moment of inertia of the disc.

(b) After the cord is fully unwound, a second uniform disc with mass of 3.2 kg and radius 0.12m is gently dropped on top of the original disc as shown in Figure 6.

Both discs now rotate with a new angular velocity.

Figure 6.



(i) Calculate the moment of inertia of the second disc.

(ii) Calculate the new angular velocity of the disc.

(c) The experiment is repeated, except that a **ring**, with the same mass and diameter as the second disc, is gently dropped on top of the original disc as shown in Figure 7.

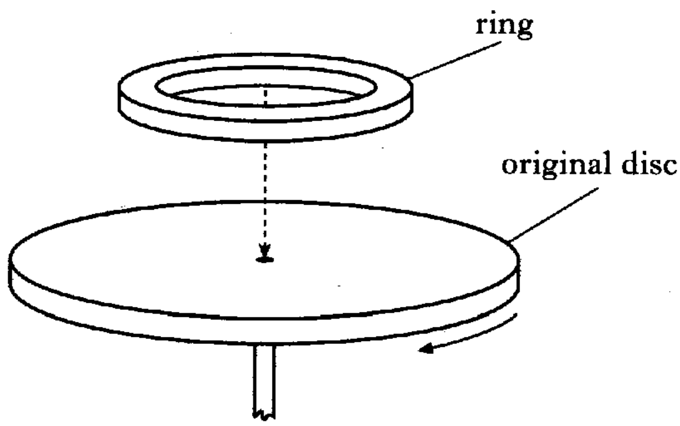


Figure 7.

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

You must justify your answer. **2006**

4. (a) A turntable consists of a uniform disc of radius 0.15 m and mass 0.60 kg.

(i) Calculate the moment of inertia of the turntable about the axis of rotation shown in Figure 8.

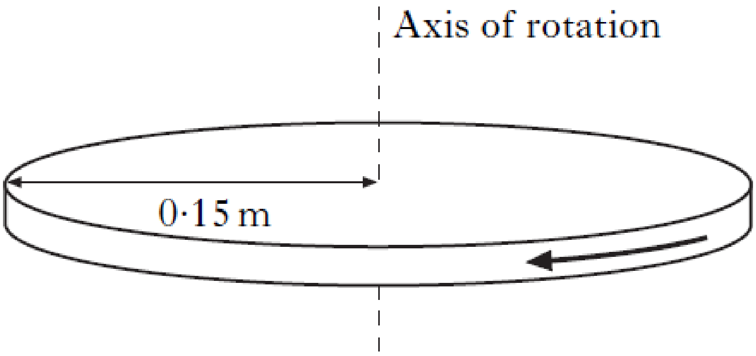


Figure 8.

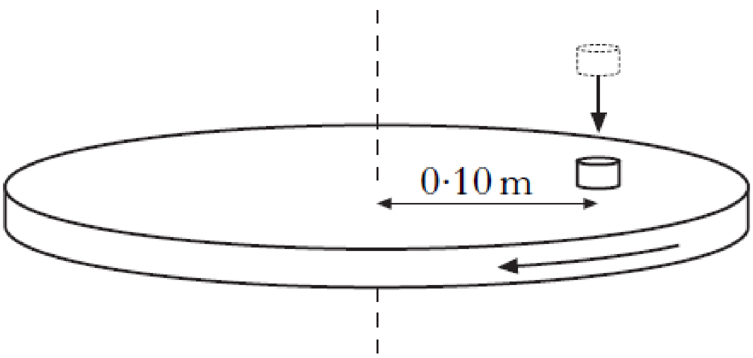
(ii) The turntable accelerates uniformly from rest until it rotates at 45 revolutions per minute. The time taken for the acceleration is 1·5 s.

(A) Show that the angular velocity after 1·5 s is 4·7 rad s^{-1}.

(B) Calculate the angular acceleration of the turntable.

(iii) When the turntable is rotating at 45 revolutions per minute, its motor is disengaged. The turntable continues to rotate freely with negligible friction.

A small mass of 0·20 kg is dropped onto the turntable at a distance of 0·10 m from the centre, as shown in Figure 2.



The mass remains in this position on the turntable due to friction, and the turntable and mass rotate together.

Calculate the new angular velocity of the turntable and mass.

4 (a) (continued)

(iv) The experiment is repeated, but the mass is dropped at a distance greater than $0{\cdot}10$ m from the centre of the turntable. The mass slides off the turntable.

Explain why this happens.

(*b*) An ice-skater spins with her arms and one leg outstretched as shown in Figure 10a She then pulls her arms and leg close to her body as shown in Figure 10b

Figure 10 (a)

Figure 10 (b)

State what happens to her angular velocity during this manoeuvre.

Justify your answer. **2007**

Total Marks