Advanced Higher Physics

Past Paper Questions

1.2 Angular Motion

2. (a) As part of a lesson, a teacher swings a sphere tied to a light string as shown in Figure 2A. The path of the sphere is a vertical circle as shown in Figure 2B.

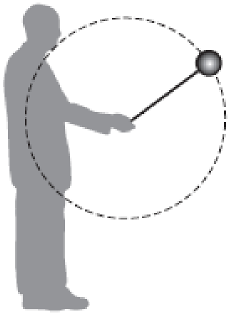

Figure 2A

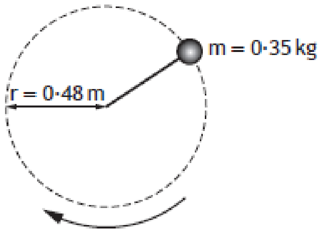

Figure 2B

(i) On Figure 2C, show the forces acting on the sphere as it passes through its highest point.

You must name these forces and show their directions. 1

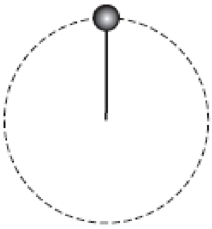

Figure 2C

(b) The speed of the sphere is now gradually reduced until the sphere no longer travels in a circular path.

Explain why the sphere no longer travels in a circular path. 2

(c) The teacher again swings the sphere with constant speed in a vertical circle. The student shown in Figure 2E observes the sphere moving up and down vertically with simple harmonic motion.

The period of this motion is 1·4 s.

Figure 2F represents the path of the sphere as observed by the student.

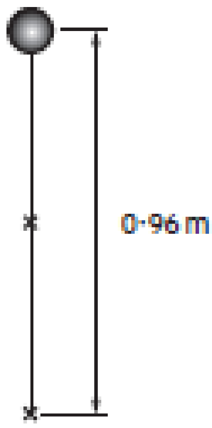

Figure 2F

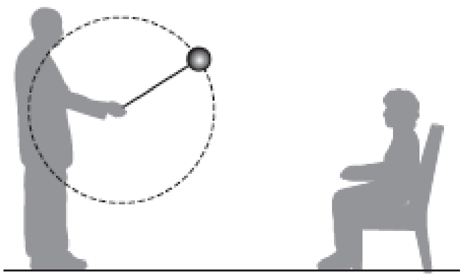

Figure 2E

2. (c) (continued)

On Figure 2G, sketch a graph showing how the vertical displacement s of the sphere from its central position varies with time t, as it moves from its highest position to its lowest position.

Numerical values are required on both axes. 3

Figure 2G

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2. (a) An ideal conical pendulum consists of a mass moving with constant speed in a circular path, as shown in Figure 2A.

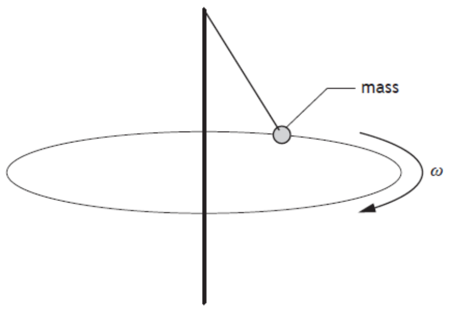

Figure 2A

(i) Explain why the mass is accelerating despite moving with constant speed. 1

(ii) State the direction of this acceleration. 1

(b) Swingball is a garden game in which a ball is attached to a light string connected to a vertical pole as shown in Figure 2B.

The motion of the ball can be modelled as a conical pendulum.

The ball has a mass of 0·059 kg.

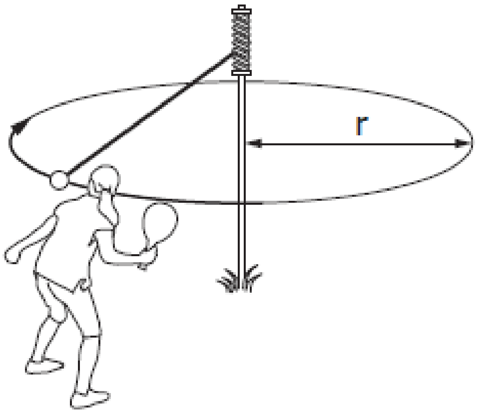

Figure 2B

(i) The ball is hit such that it moves with constant speed in a horizontal circle of radius 0·48 m.

The ball completes 1·5 revolutions in 2·69 s.

(A) Show that the angular velocity of the ball is 3·5 rad s^{-1}. **2**

(B) Calculate the magnitude of the centripetal force acting on the ball. **3**

(C) The horizontal component of the tension in the string provides this centripetal force and the vertical component balances the weight of the ball.

Calculate the magnitude of the tension in the string. **3**

(ii) The string breaks whilst the ball is at the position shown in Figure 2C.

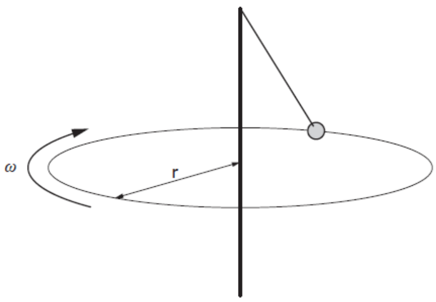

Figure 2C

On Figure 2C, draw the direction of the ball's velocity immediately after the string breaks. **1**

1. Water is removed from clothes during the spin cycle of a washing machine. The drum holding the clothes has a maximum spin rate of 1250 revolutions per minute.

Figure 1A

(a) Show that the maximum angular velocity of the drum is $131\ \text{rad s}^{-1}$. **2**

(b) At the start of a spin cycle the drum has an angular velocity of $7{\cdot}50\ \text{rad s}^{-1}$. It then takes 12·0 seconds to accelerate to the maximum angular velocity.

(i) Calculate the angular acceleration of the drum during the 12·0 seconds, assuming the acceleration is uniform. **3**

(ii) Determine how many revolutions the drum will make during the 12·0 seconds. **5**

(c) When the drum is rotating at maximum angular velocity, an item of wet clothing of mass $1{\cdot}5 \times 10^{-2}$ kg rotates at a distance of 0·28 m from the axis of rotation as shown in Figure 1B.

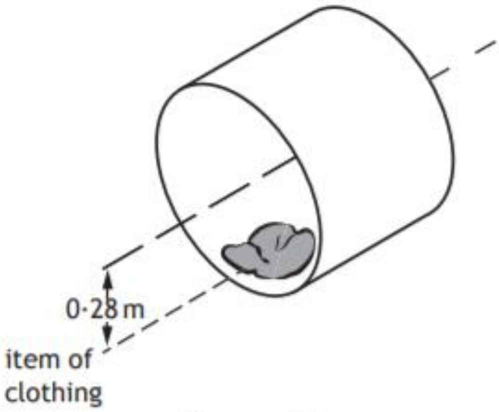

Figure 1B

Calculate the centripetal force acting on the item of clothing. **3**

(d) The outer surface of the drum has small holes as shown in Figure 1C. These holes allow most of the water to be removed.

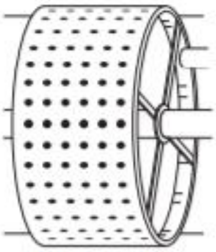
Figure 1C

(i) Explain why the water separates from the item of clothing during the spin cycle. **2**

(ii) The drum rotates in an anticlockwise direction. Indicate on Figure 1D the direction taken by a water droplet as it leaves the drum. **1**

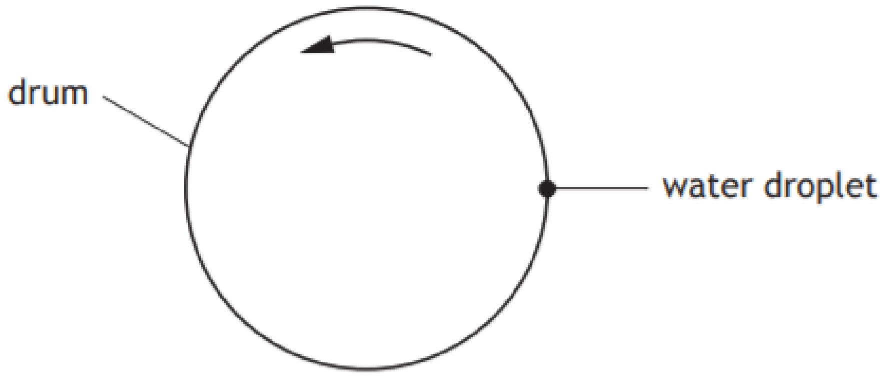

Figure 1D

(iii) Explain what happens to the value of the force on an item of clothing inside the drum as it rotates at its maximum angular velocity. **2**

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.

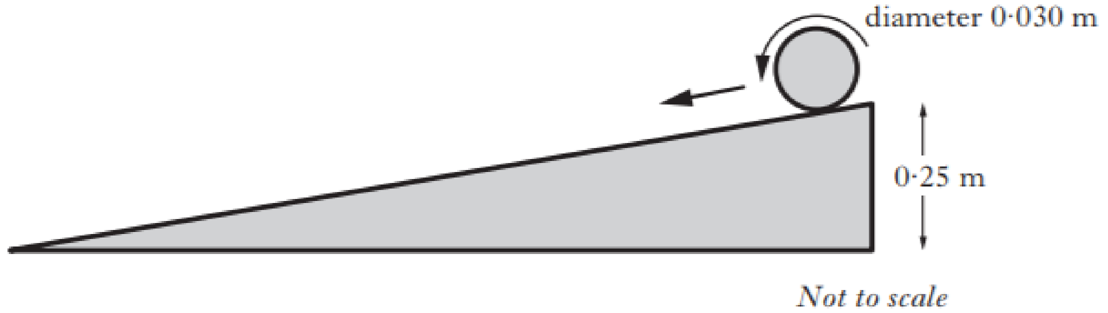

Figure 2

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)

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.

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.

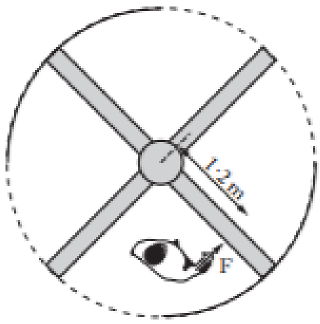

Figure 2B

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**

(*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.

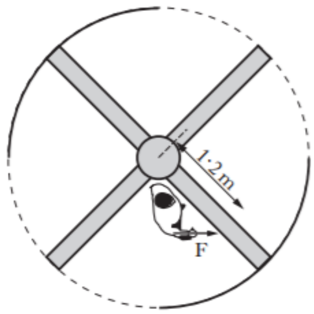

Figure 2C

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

Justify your answer. **2**

(8)

3. On a trip to a theme park, a student described what happened in the fairground spinner shown in Figure 3.

"You get thrown outwards by centrifugal force – you can feel it – it pushes you into the wall."

Figure 3

Use your knowledge of physics to discuss this statement. **(3)**

(*b*) The path taken by a short track speed skater is shown in Figure 2A. The path consists of two straights each of length 29·8 m and two semicircles each of radius 8·20 m.

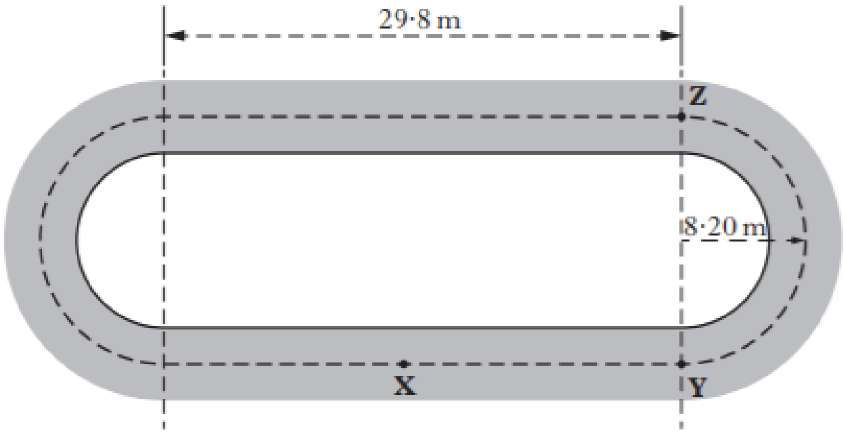

Figure 2A

Starting at point **X**, half way along the straight, the skater accelerates uniformly from rest. She reaches a speed of 9·64 m s^{-1} at point **Y**, the end of the straight.

(i) Calculate the acceleration of the skater. **2**

(ii) The skater exits the curve at point **Z** with a speed of 10·9 m s^{-1}.

Calculate the average **angular** acceleration of the skater between **Y** and **Z**. **3** (*c*) When this speedskater reaches a curve she leans inwards and digs the blade of the skate into the ice as shown in Figure 2B. Force F indicates the reaction of the ice on the skater.

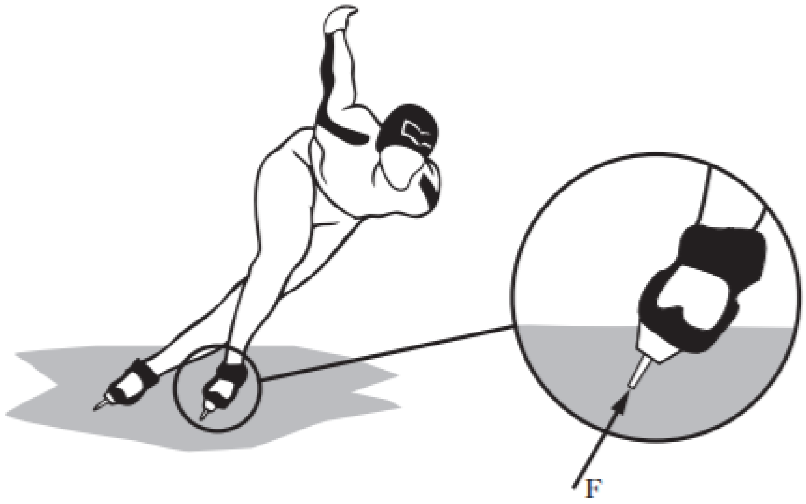

Figure 2B

(i) Explain how force F allows her to maintain a curved path. **2**

(ii) The skater approaches the next curve at a greater speed and slides off the track. Explain, **in terms of forces**, why this happens. **1**

(11)

1. A turntable, radius r, rotates with a constant angular velocity ω about an axis of rotation. Point X on the circumference of the turntable is moving with a tangential speed v, as shown in Figure 1A.

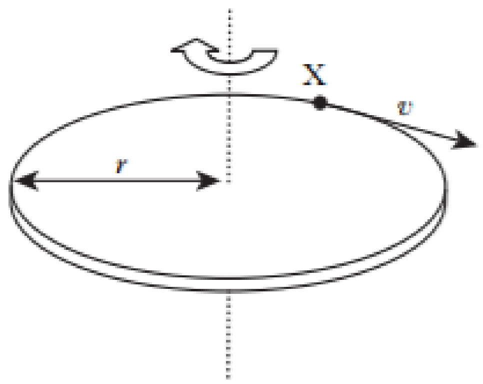

Figure 1A

(a) Derive the relationship

$$v = r\omega.$$ **2**

(b) Data recorded for the turntable is shown below.

Angle of rotation	(3·1 ± 0·1) rad
Time taken for angle of rotation	(4·5 ± 0·1) s
Radius of disk	(0·148 ± 0·001) m

(i) Calculate the tangential speed v. **2**

(ii) Calculate the percentage uncertainty in this value of v. **2**

(iii) As the disk rotates, v remains constant.

(A) Explain why point X is accelerating. **1**

(B) State the direction of this acceleration. **1**

(8)

Marks

2. A motorised model plane is attached to a light string anchored to a ceiling.

The plane follows a circular path of radius 0·35 m as shown in Figure 2A.

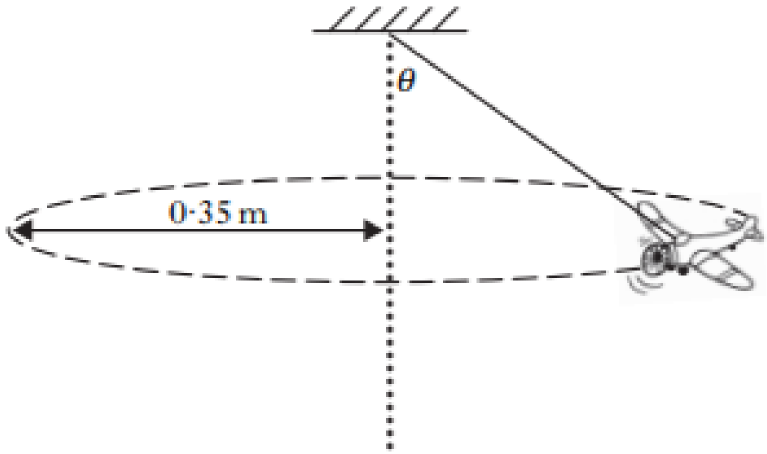

Figure 2A

The plane has a mass of 0·20 kg and moves with a constant angular velocity of 6·0 rad s^{-1}.

(*a*) Calculate the central force acting on the plane. **2**

(*b*) Calculate angle *θ* of the string to the vertical. **2**

(*c*) What effect would a decrease in the plane's speed have on angle *θ*?

Justify your answer. **2**

(6)

Marks

2. An anemometer is an instrument to measure windspeed and is shown in Figure 2A.

Figure 2A

The anemometer is tested in a wind tunnel.

The calibration graph of the angular velocity, in **revolutions per minute**, against windspeed, in $m\,s^{-1}$, is shown in Figure 2B.

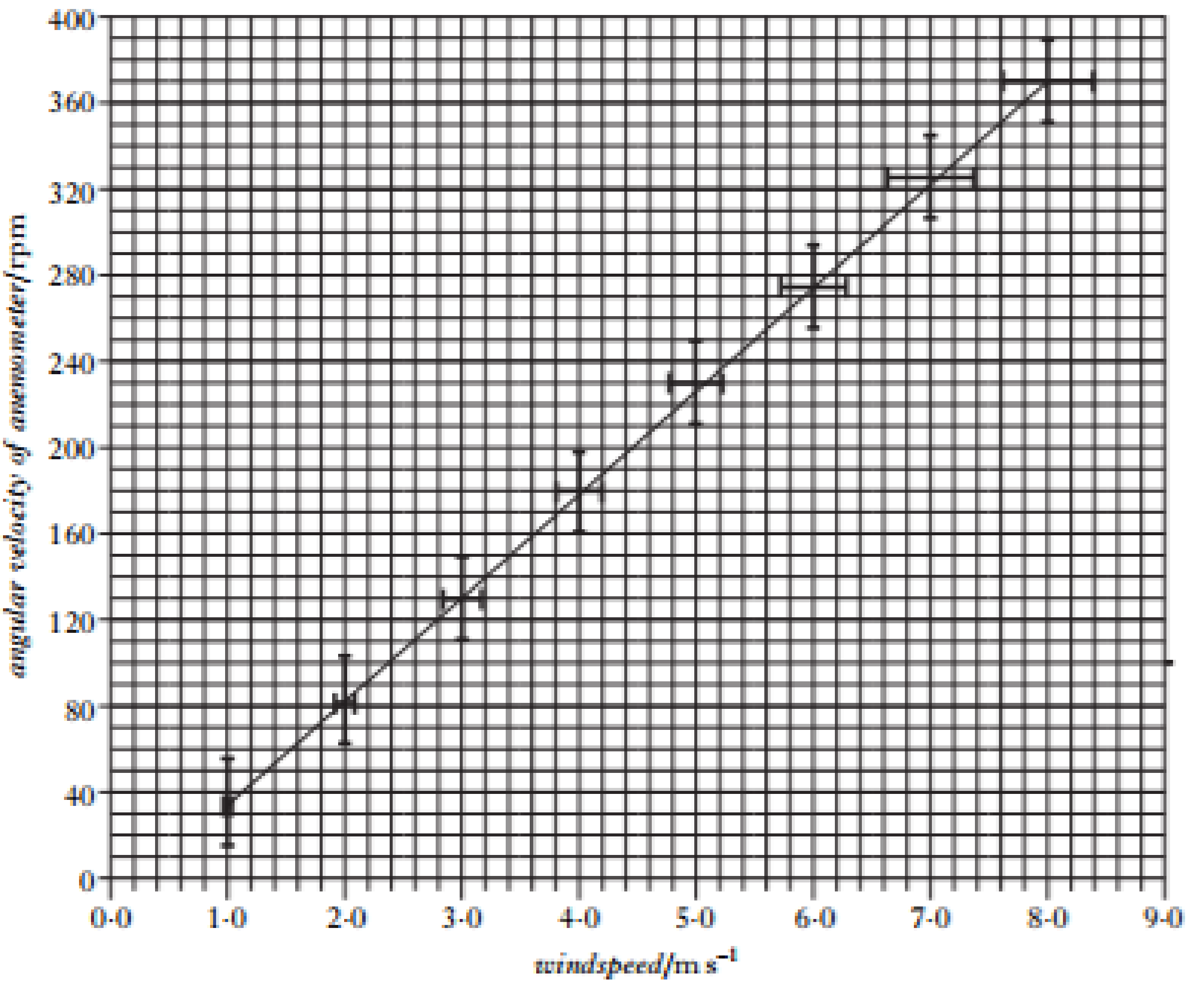

Figure 2B

The calibration graph is found not to go through the origin.

The equation for the line is $y = 48x - 12$.

(*a*) (i) During one test there is a constant windspeed of $5{\cdot}8\,m\,s^{-1}$. Show that the angular velocity of the anemometer at this windspeed is $28\,rad\,s^{-1}$. **1**

(ii) In a **second** test the windspeed is reduced from $5{\cdot}8\,m\,s^{-1}$ to $1{\cdot}6\,m\,s^{-1}$ in a time of $8{\cdot}0$ seconds. Calculate the angular acceleration of the anemometer. **3**

Marks

2. (*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 1. **2**

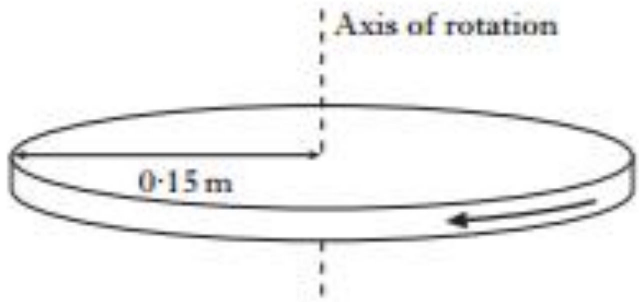

Figure 1

(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}. **1**

(B) Calculate the angular acceleration of the turntable. **2**

(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.

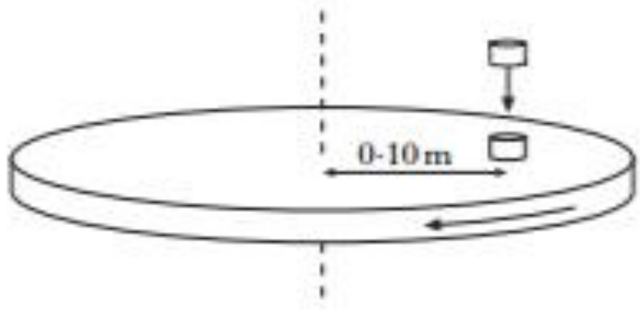

Figure 2

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. **3**

2. (*a*) (continued)

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

Explain why this happens. **2**

(*b*) An ice-skater spins with her arms and one leg outstretched as shown in Figure 3(*a*). She then pulls her arms and leg close to her body as shown in Figure 3(*b*).

Figure 3(*a*)

Figure 3(*b*)

State what happens to her angular velocity during this manoeuvre.

Justify your answer. **2**

(12)

Marks

1. A child's toy consists of a model aircraft attached to a light cord. The aircraft is swung in a vertical circle **at constant speed** as shown in Figure 1.

X is the highest point and Y the lowest point in the circle.

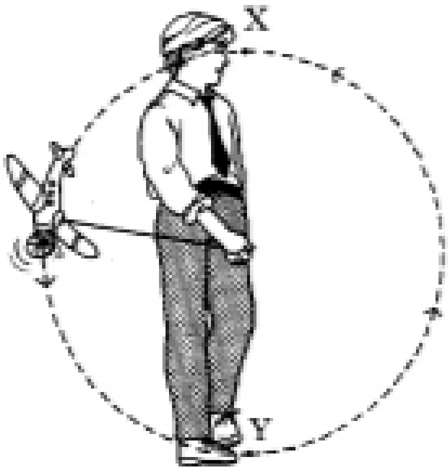

Figure 1

(*a*) The time taken for the aircraft to complete 20 revolutions is measured five times.

The mass of the aircraft and the radius of the circle are also measured. The following data is obtained.

Time for 20 revolutions: 10·05 s; 9·88 s; 10·30 s; 9·80 s; 9·97 s.
Radius of circle = 0·500 ± 0·002 m.
Mass of aircraft = 0·200 ± 0·008 kg.

(i) (A) Calculate the average period of revolution of the aircraft.

(B) Assuming that the scale reading uncertainty and the calibration uncertainty of the timer are negligible, calculate the absolute uncertainty in the period. **3**

(ii) Show that the centripetal force acting on the aircraft is 15·8 N. **2**

(iii) Calculate the absolute uncertainty in this value for the centripetal force. Express your answer in the form

$$F = (15{\cdot}8 \pm \qquad)\,\text{N}.$$ **4**

(iv) Draw labelled diagrams to show the forces acting on the aircraft:

(A) at position X;

(B) at position Y. **2**

(v) Calculate the minimum tension in the cord. **2** (*b*) The aircraft has a small air siren which produces a note of frequency 1000 Hz.

One student swings the aircraft in a vertical circle at constant speed. A second student listens to the note while standing in front of the first student, as shown in Figure 2.

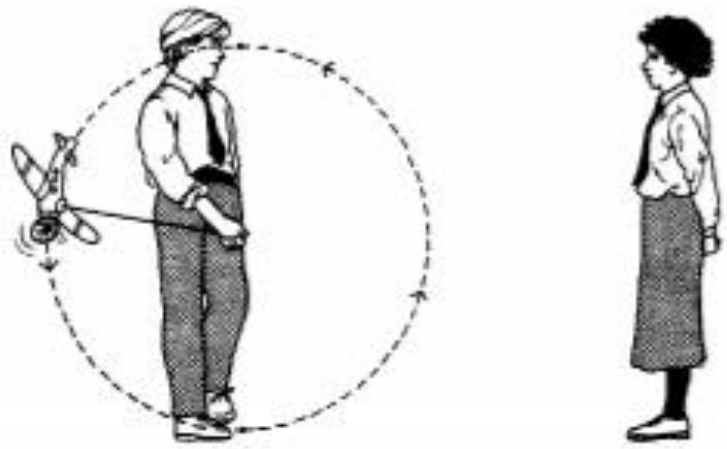

Figure 2

State what happens to the pitch of the note heard by the second student as the aircraft passes through its highest point. **1**

(14)

[Turn over

Marks

1. A compact disc (CD) stores information on the surface as shown in Figure 1.

Figure 1

The information is retrieved by an optical reader which moves outwards as the CD rotates, as shown in Figure 2.

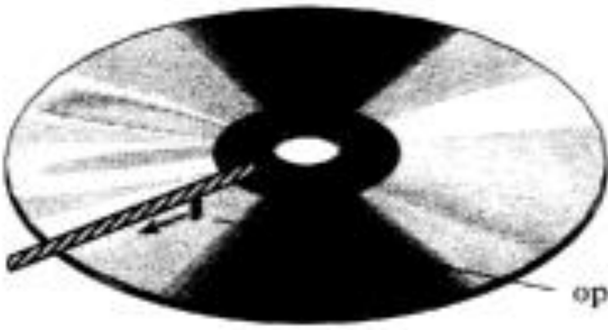

Figure 2

The part of the CD below the reader must always have a tangential speed of $1{\cdot}30\,\text{m}\,\text{s}^{-1}$.

(a) The reader starts at a radius of 23·0 mm from the centre of the CD. Calculate the angular velocity of the CD at the start. **2**

(b) Show that the CD rotates at $22{\cdot}4\,\text{rad}\,\text{s}^{-1}$ when the reader reaches the outer edge of the disc. **1**

(c) Explain why the angular velocity of the CD decreases as the CD plays. **1**

(d) The CD makes a total of $2{\cdot}80 \times 10^4$ revolutions from start to finish.

(i) Show that the total angular displacement of the CD is $1{\cdot}76 \times 10^5$ radians. **1**

(ii) Calculate the average angular acceleration of the CD as the disc is played from start to finish. **2**

(iii) Calculate the total playing time of the CD. **2**

(9)

2. 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 in Figure 1(*a*).

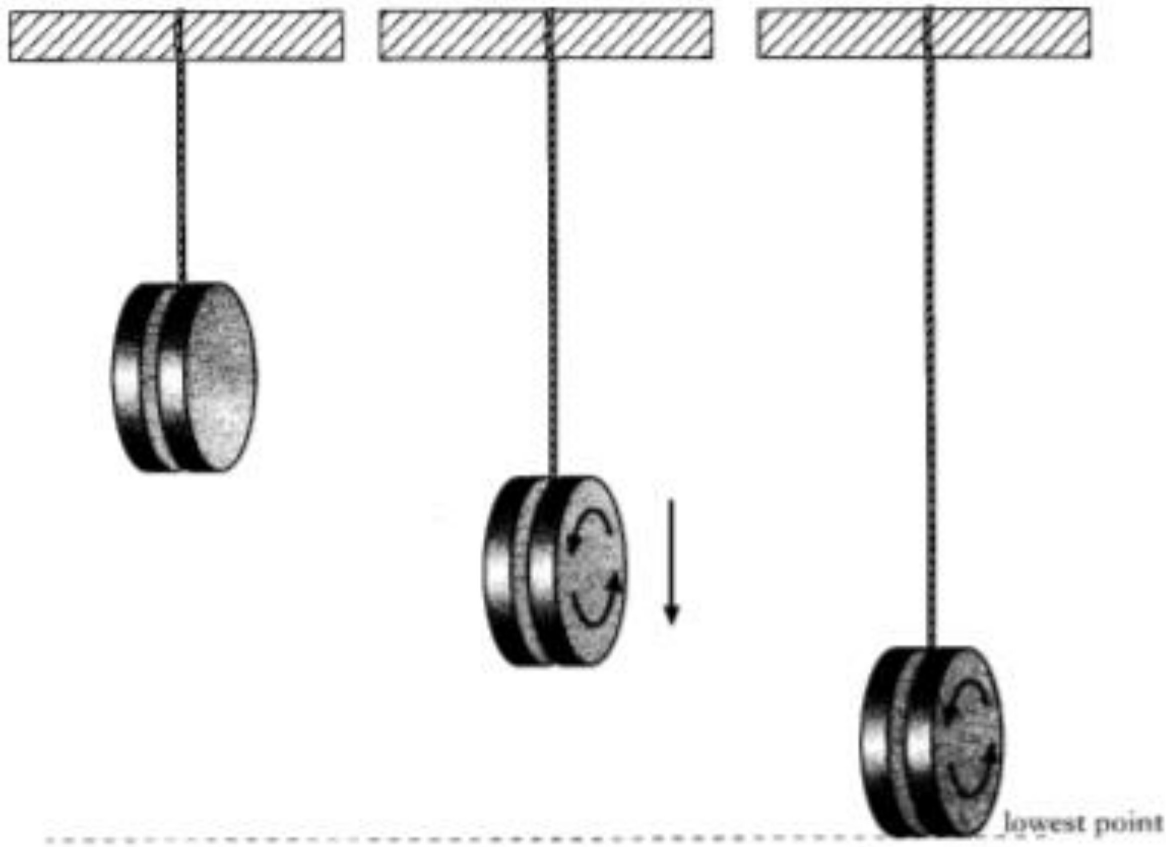

Figure 1(*a*) Figure 1(*b*) Figure 1(*c*)

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*);

(ii) Figure 1(*c*). **2**

(*b*) Each disc has a mass *m* of 0·100 kg and a radius *r* of 0·050 m.

The moment of inertia of a disc is given by $\frac{1}{2}mr^2$.

The moment of inertia of the axle is negligible.

Calculate the moment of inertia of the yo-yo. **2**

(*c*) When the yo-yo is at the position shown in Figure 1(*c*) it has an angular velocity of 120 rad s^{-1}.

Calculate the maximum height to which the yo-yo could rise as it rewinds the string. **2**

Marks

2. **(continued)**

(*d*) One type of yo-yo has four friction pads inside each disc. Each friction pad is held in place by a spring which exerts a force of 5·00 N. At low angular velocities the friction pads grip the axle as shown in Figure 2.

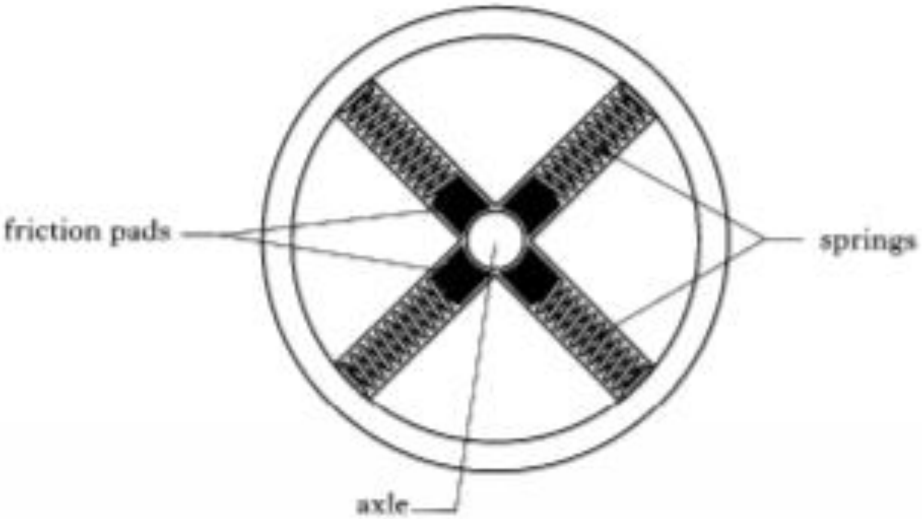

Figure 2

At higher angular velocities the pads move away from the axle and compress the springs. This releases the axle and allows the discs to spin freely.

(i) Explain why the friction pads move away from the axle.

(ii) Each friction pad can be considered as a point mass of 12·0 g at a radius of 10·0 mm from the centre of the axle.

Calculate the minimum angular velocity at which the axle is released from the friction pads. **3**

(9)

Marks

1. (continued)

(*b*) The student now places the car, which has a mass of 2·5 kg, on a horizontal circular track as shown in Figure 2.

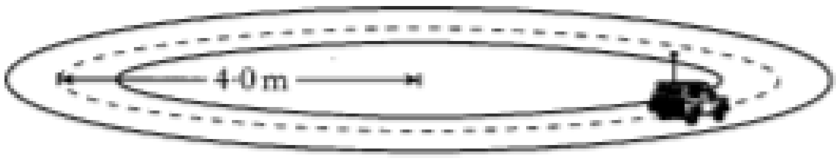

Figure 2

She uses the radio control to make the car travel with a constant speed of $6{\cdot}0\,m\,s^{-1}$ around a circular path of radius 4·0 m.

(i) Calculate the car's radial acceleration.

(ii) The radial friction between the car's tyres and the track has a maximum value of 23 N.

Show that this force is sufficient to prevent the car skidding off the track. **4**

(*c*) The student now places the car on a banked track as shown in Figure 3.

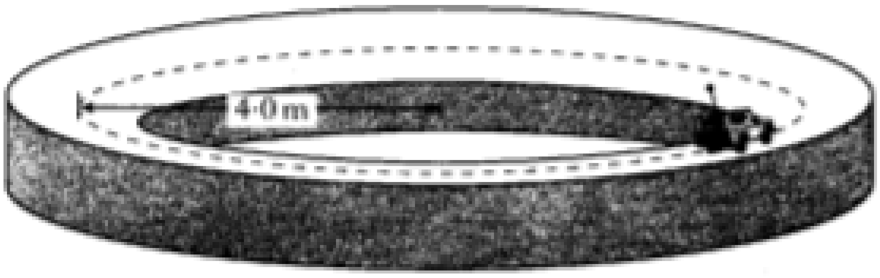

Figure 3

She again uses the radio control to make the car follow a circular path of radius 4·0 m.

Explain why the car can now travel much faster than $6{\cdot}0\,m\,s^{-1}$ without skidding off the track. **2**

(13)

2. The flywheel shown in Figure 1 consists of a uniform disc of diameter 0·80 m and moment of inertia 180 kg m^2.

The flywheel is spinning at 2500 revolutions per minute on a friction-free bearing.

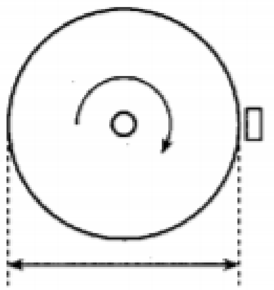

Figure 1

(*a*) (i) Show that the angular velocity of the flywheel is 260 rad s^{-1}.

(ii) Calculate the rotational kinetic energy of the flywheel. **4**

(*b*) A brake pad now applies a constant force to the rim of the flywheel, bringing it to rest in 40 s.

Calculate:

(i) the angular deceleration of the flywheel;

(ii) the force between the brake pad and the flywheel. **5**

(*c*) The flywheel is replaced with one of the same mass and diameter, but with most of the mass concentrated near the rim. This new flywheel also spins at 2500 revolutions per minute.

The same braking force is applied.

Is the time taken for this flywheel to come to rest less than, equal to or greater than 40 s? **You must justify your answer.** **2**

(11)