LONDON SCIENCE COLLEGE

Name:

Date:

CIRCULAR MOTION
TEST 2

A2-Level

Mark

Grade

PHYSICS

For this paper you must have:

- Ruler
- Pencil and Rubber
- Scientific calculator, which you are expected to use when appropriate

Instructions

- Answer all questions
- Answer questions in the space provided
- All working must be shown

Information

- The marks for the questions are shown in brackets

1 To determine the force and power involved when a football is kicked, a student suspended a ball from the roof of a gymnasium by a long string as shown in **Figure 1**.

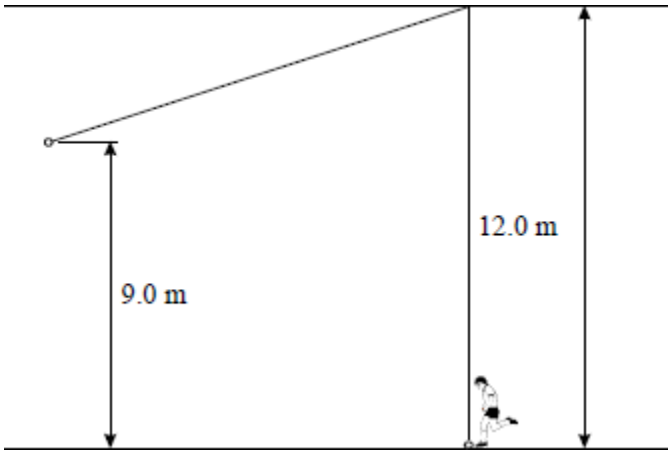

Figure 1

When the ball of mass 0.45 kg was kicked it rose to a maximum height of 9.0 m. The student measured the contact time between the ball and the boot as 0.12 s.

the acceleration of free fall, g = 9.8 m s^{-2}

(a) Assume that air resistance was negligible so that all the initial kinetic energy given to the ball was converted into gravitational potential energy.

Calculate:

(i) the velocity of the ball immediately after being kicked;

(2)

(ii) the average force exerted on the ball when in contact with the boot;

(2)

(iii) the average useful power developed by the student when the ball was kicked.

(2)

(b) (i) The ball is kicked so that its initial motion is horizontal. Explain why the tension in the supporting string increases when the ball is kicked.

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(2)

(ii) Calculate the tension in the string immediately after the ball is kicked.

(3)

(c) When it reached half its maximum height the ball was moving at 51° to the horizontal as shown in **Figure 2**.

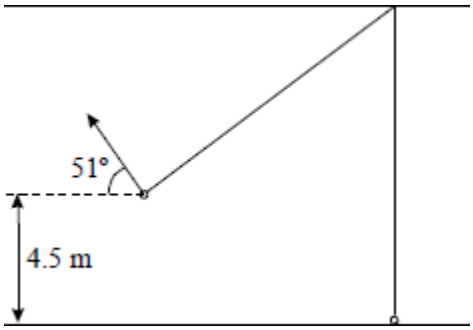

Figure 2

(i) Calculate the velocity of the ball in this position.

(2)

(ii) In one test the string broke when the ball was in the position shown in **Figure 2**. Explain why the ball reached a lower maximum height on this occasion than it did when the string did not break.

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(2)

(Total 15 marks)

2 A gymnast does a hand-stand on a horizontal bar. The gymnast then rotates in a vertical circle with the bar as a pivot. The gymnast and bar remain rigid during the rotation and when friction and air resistance are negligible the gymnast returns to the original stationary position.

Figure 1 shows the gymnast's position at the start and **Figure 2** shows the position after completing half the circle.

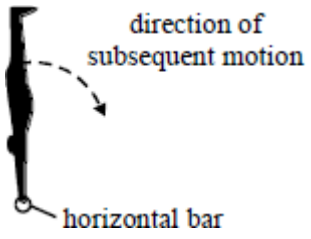


Figure 1

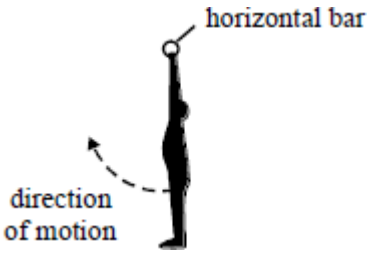


Figure 2

(a) The gymnast has a mass of 70 kg and the centre of mass of the gymnast is 1.20 m from the axis of rotation.

acceleration of free fall, g = 9.8 m s^{-2}

(i) Show clearly how the principle of conservation of energy predicts a speed of 6.9 m s^{-1} for the centre of mass when in the position shown in **Figure 2**.

(3)

(ii) The maximum force on the arms of the gymnast occurs when in the position shown in **Figure 2**.

Calculate the centripetal force required to produce circular motion of the gymnast when the centre of mass is moving at 6.9 m s^{-1}.

(2)

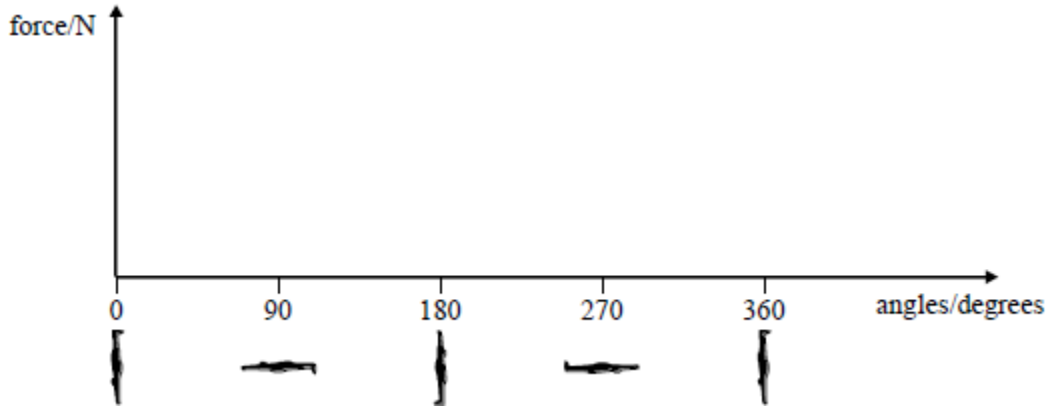
(iii) Determine the maximum tension in the arms of the gymnast when in the position shown in **Figure 2**.

(1)

(iv) Sketch a graph to show how the **vertical** component of the force **on the bar** varies with the angle rotated through by the gymnast during the manoeuvre. Assume that a downward force is positive.

Include the values for the initial force and the maximum force on the bar.

Only show the general shape between these values.



(2)

(b) The bones in each forearm have a length of 0.25 m. The total cross-sectional area of the bones in both forearms is 1.2×10^{-3} m^2 . The Young modulus of bone in compression is 1.6×10^{10} Pa.

Assuming that the bones carry all the weight of the gymnast, calculate the reduction in length of the forearm bones when the gymnast is in the start position shown in **Figure 1**.

(3)

(Total 11 marks)

3 (a) **Figure 1** and **Figure 2** each show a car travelling in a horizontal circular path.

(i) Draw and label on **Figure 1** and **Figure 2** arrows to indicate the other forces acting on the cars.

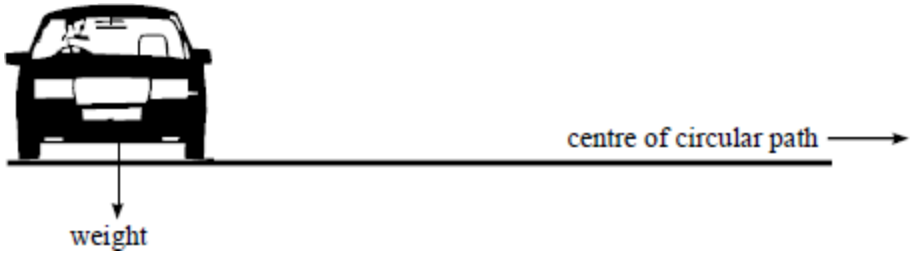


Figure 1

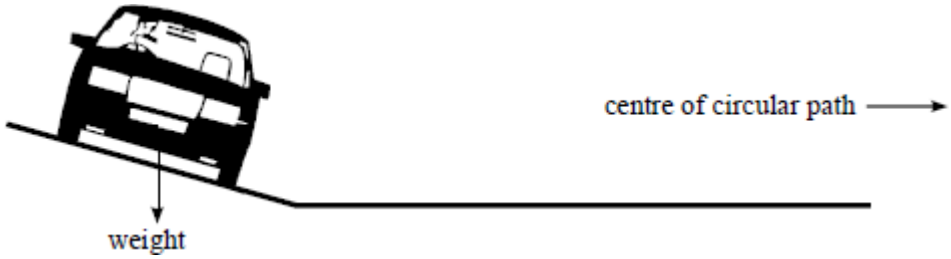


Figure 2

(2)

(ii) State the possible origins of the centripetal force on the car in **Figure 2**.

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(4)

(b) **Figure 3** shows a motorcycle stunt rider travelling around a track in a vertical circle of radius 5.2 m. At position **Q**, when the speed is the minimum necessary to keep the motorcycle in contact with the track, the centripetal force is supplied by the weight of the motorcycle and rider. The combined mass of the motorcycle and rider is 220 kg.

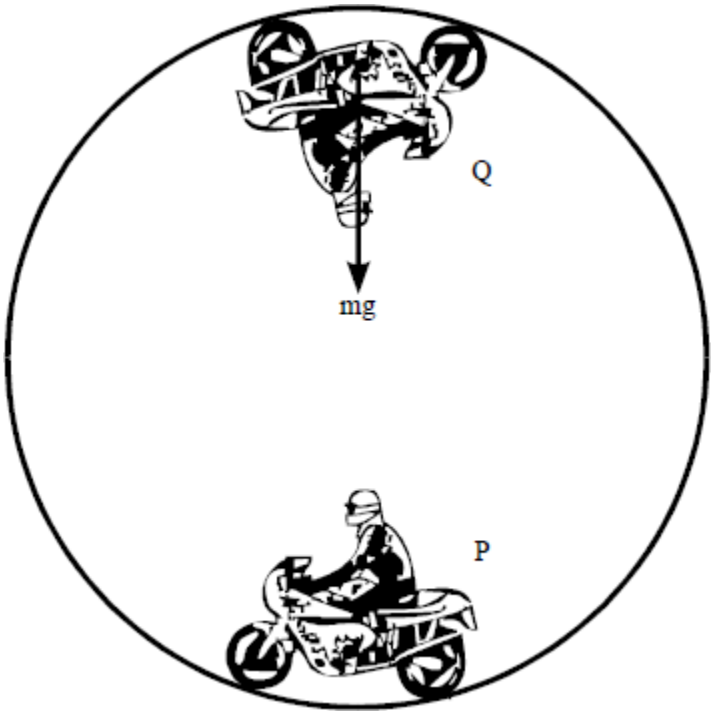


Figure 3

Calculate the minimum speed which will keep the motorcycle in contact with the track at position **Q**. The acceleration due to gravity, g, is 9.8 m s^{-2}.

(3)

(Total 9 marks)

4 A particle moves in a circular path at constant speed. Which one of the following statements is correct?

A The velocity of the particle is directed towards the centre of the circle.

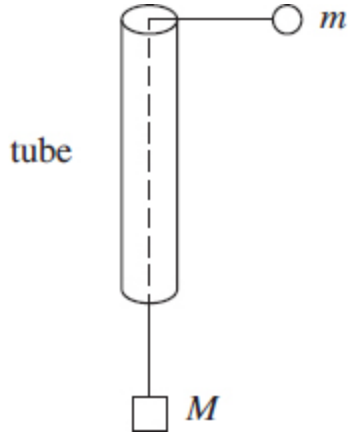
B There is no force acting on the particle.

C There is no change in the kinetic energy of the particle.

D The particle has an acceleration directed along a tangent to the circle.

(Total 1 mark)

5 The diagram shows a smooth thin tube through which passes a string with masses *m* and *M* attached to its ends. The tube is moved so that the mass *m* travels in a horizontal circle of constant radius *r* at constant speed *v*.



Which one of the following expressions is equal to *M*?

A $\frac{mv^2}{2r}$

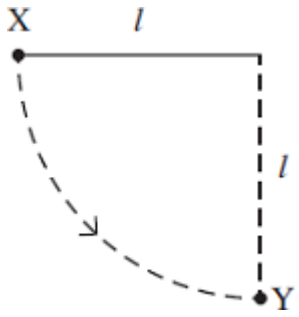
B mv^2rg

C $\frac{mv^2}{rg}$

D $\frac{mv^2g}{r}$

(Total 1 mark)

6 A ball of mass m, which is fixed to the end of a light string of length l, is released from rest at X. It swings in a circular path, passing through the lowest point Y at speed v.



If the tension in the string at Y is T, which one of the following equations represents a correct application of Newton's laws of motion to the ball at Y?

A $T = \frac{mv^2}{l} - mg$

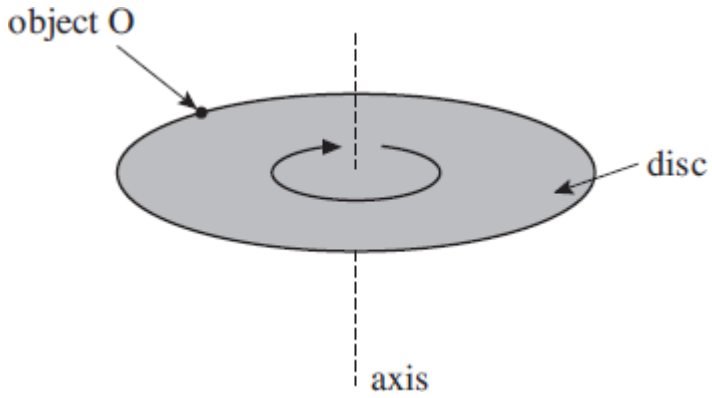
B $mg - T = \frac{mv^2}{l}$

C $T - mg = \frac{mv^2}{l}$

D $T + \frac{mv^2}{l} = mg$

(Total 1 mark)

7 A disc of diameter D is turning at a steady angular speed at frequency f about an axis through its centre.



What is the centripetal force on a small object O of mass m on the perimeter of the disc?

A $2\pi mfD$

B $2\pi mf^2D$

C $2\pi^2 mf^2D$

D $2\pi mf^2D^2$

(Total 1 mark)

8 What is the angular speed of a car wheel of diameter 0.400 m when the speed of the car is 108 km h^{-1}?

A 75 rad s^{-1}

B 150 rad s^{-1}

C 270 rad s^{-1}

D 540 rad s^{-1}

(Total 1 mark)

9 For a particle moving in a circle with uniform speed, which one of the following statements is correct?

A The kinetic energy of the particle is constant.

B The force on the particle is in the same direction as the direction of motion of the particle.

C The momentum of the particle is constant.

D The displacement of the particle is in the direction of the force.

(Total 1 mark)

10 A young child of mass 20 kg stands at the centre of a uniform horizontal platform which rotates at a constant angular speed of 3.0 rad s^{-1}. The child begins to walk radially outwards towards the edge of the platform. The maximum frictional force between the child and the platform is 200 N. What is the maximum distance from the centre of the platform to which the child could walk without the risk of slipping?

A 1.1 m

B 1.3 m

C 1.5 m

D 1.7 m

(Total 1 mark)

11 A particle travels at a constant speed around a circle of radius *r* with centripetal acceleration *a*. What is the time taken for ten complete rotations?

A $\frac{\pi}{5}\sqrt{\frac{a}{r}}$

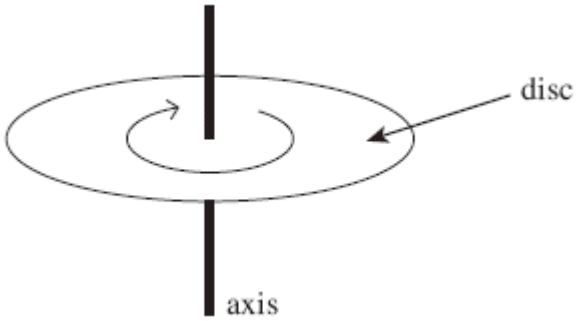
B $\frac{\pi}{5}\sqrt{\frac{r}{a}}$

C $20\pi\sqrt{\frac{a}{r}}$

D $20\pi\sqrt{\frac{r}{a}}$

(Total 1 mark)

12 The diagram shows a disc of diameter 120 mm that can turn about an axis through its centre.



The disc is turned through an angle of 30° in 20 ms. What is the average speed of a point on the edge of the disc during this time?

A 0.5π m s^{-1}

B π m s^{-1}

C 1.5π m s^{-1}

D 2π m s^{-1}

(Total 1 mark)

13 A particle of mass *m* moves in a circle of radius *r* at a uniform speed with frequency *f*. What is the kinetic energy of the particle?

A $\frac{mf^2r^2}{4\pi^2}$

B $\frac{mf^2r}{2}$

C $2\pi^2 mf^2r^2$

D $4\pi^2 mf^2r^2$

(Total 1 mark)

14 A mass on the end of a string is whirled round in a horizontal circle at increasing speed until the string breaks. The subsequent path taken by the mass is

A a straight line along a radius of the circle.

B a horizontal circle.

C a parabola in a horizontal plane.

D a parabola in a vertical plane.

(Total 1 mark)

15 A particle of mass *m* moves in a circle of radius *r* at uniform speed, taking time ***T*** for each revolution. What is the kinetic energy of the particle?

A $\frac{\pi^2 mr}{T^2}$

B $\frac{\pi^2 mr^2}{T^2}$

C $\frac{2\pi^2 mr^2}{T}$

D $\frac{2\pi^2 mr^2}{T^2}$

(Total 1 mark)

16 What is the angular speed of a point on the Earth's equator?

A 7.3×10^{-5} rad s^{-1}

B 4.2×10^{-3} rad s^{-1}

C 2.6×10^{-1} rad s^{-1}

D 15 rad s^{-1}

(Total 1 mark)

17 Which one of the following does **not** involve a centripetal force?

A an electron in orbit around a nucleus

B a car going round a bend

C an α particle in a magnetic field, travelling at right angles to the field

D an α particle in a electric field, travelling at right angles to the field

(Total 1 mark)

18 A mass M on a spring oscillates along a vertical line with the same period *T* as an object O in uniform circular motion in a vertical plane. When M is at its highest point, O is at its lowest point.

What is the least time interval between successive instants when the acceleration of M is exactly in the opposite direction to the acceleration of O?

A $\frac{T}{4}$

B $\frac{T}{2}$

C $\frac{3T}{4}$

D T

(Total 1 mark)