A-Level Physics

Circular Motion

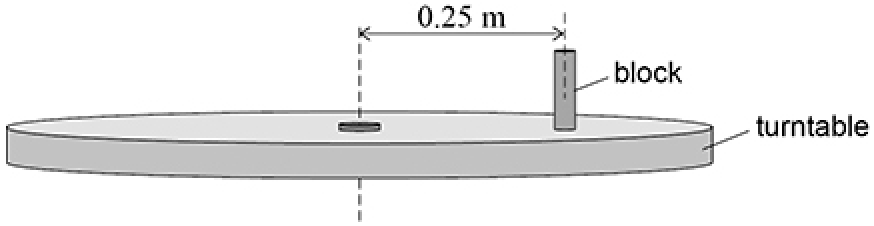
Question Paper

Time available: 53 minutes
Marks available: 39 marks

1. A teacher sets up a demonstration to show the relationship between circular motion and simple harmonic motion (SHM).

She places a block on a turntable at a point $0.25\ \text{m}$ from its centre, as shown in **Figure 1**.

Figure 1



The turntable rotates with an angular speed of $1.8\ \text{rad s}^{-1}$ and the block does not slip.

(a) Calculate the time taken for the turntable to complete one revolution.

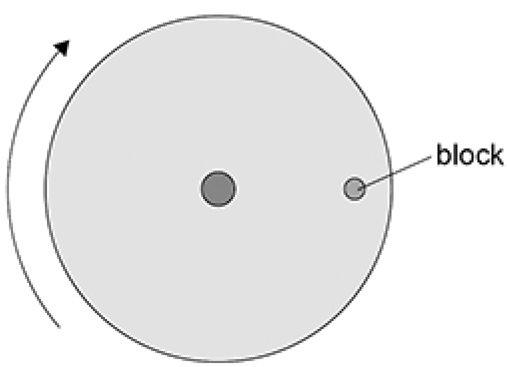
time = _______________ s

(2)

(b) **Figure 2** shows a plan view of the turntable and block.
The turntable rotates in a clockwise direction.

Draw an arrow on **Figure 2** to show the direction of the resultant force on the block.

Figure 2



(1)

(c) The mass of the block is 0.12 kg.

Calculate the magnitude of the resultant force on the block.

magnitude of force = ______________ N

(2)

(d) Describe, with reference to one of Newton's laws of motion, the evidence that a resultant force is acting on the block.

____

____

____

____

____

(2)

(e) The teacher adjusts the angular speed of the turntable so that the block completes one rotation every 2.50 s.
She sets up a simple pendulum above the centre of the turntable so that it swings in phase with the movement of the block.

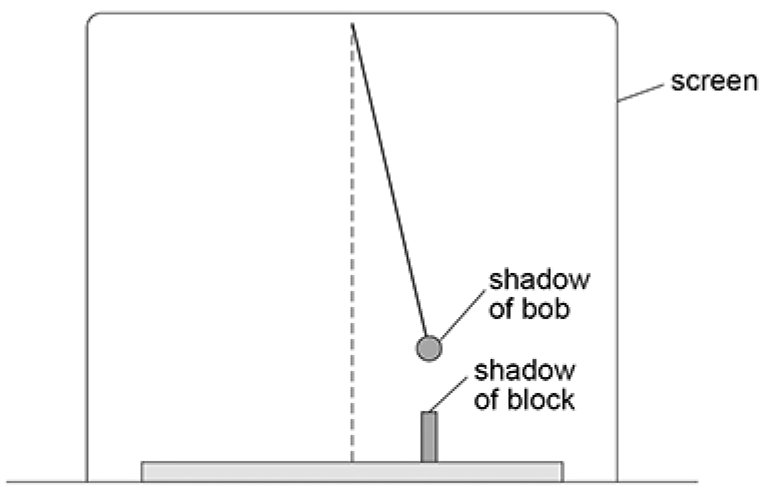
Calculate the length of the simple pendulum.

length = _______________ m

(2)

(f) A lamp is used to project shadow images of the block and pendulum bob on a screen.
Both shadows appear to move with SHM across the screen.
Figure 3 shows the images on the screen at one instant.

Figure 3



Initially the shadows move in phase with the same amplitude.

Air resistance affects the motion of the pendulum.

Suggest the effect this has on the amplitude relationship and the phase relationship between the moving shadows.

amplitude ____

____

____

phase ____

____

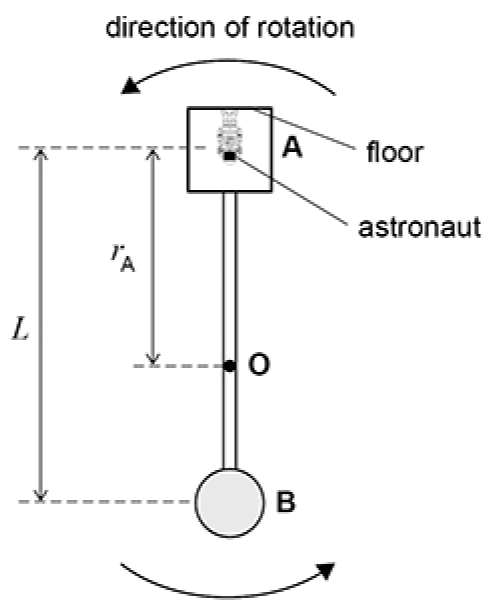
____

(2)

(Total 11 marks)

2. **Figure 1** shows a rotating spacecraft that is proposed to carry astronauts to Mars.

Figure 1



The spacecraft consists of two parts **A** and **B** connected by a rigid cylindrical rod. When the spacecraft is travelling, **A** and **B** rotate at a constant angular speed about their common centre of mass **O**.

L is the distance between the centre of mass of **A** and the centre of mass of **B**. r_A is the distance from **O** to the centre of mass of **A**.

(a) As the spacecraft rotates, a force that imitates the effect of gravity acts on an astronaut who is in contact with the floor.

Explain why.

___

___

___

___

___

___

(2)

(b) The forces exerted on **A** and **B** by the connecting rod have the same magnitude.

m_A is the mass of **A**
m_B is the mass of **B**

Show, by considering the centripetal forces acting on **A** and **B**, that r_A is given by

$$r_A = \frac{m_B L}{m_A + m_B}$$

(2)

(c) In this spacecraft $m_A < m_B$.

Deduce whether the centre of mass of **A** or the centre of mass of **B** rotates with a greater linear speed.

____

____

____

____

____

____

(2)

The astronauts live in **A** and the cargo is stored in **B**.

When loaded,

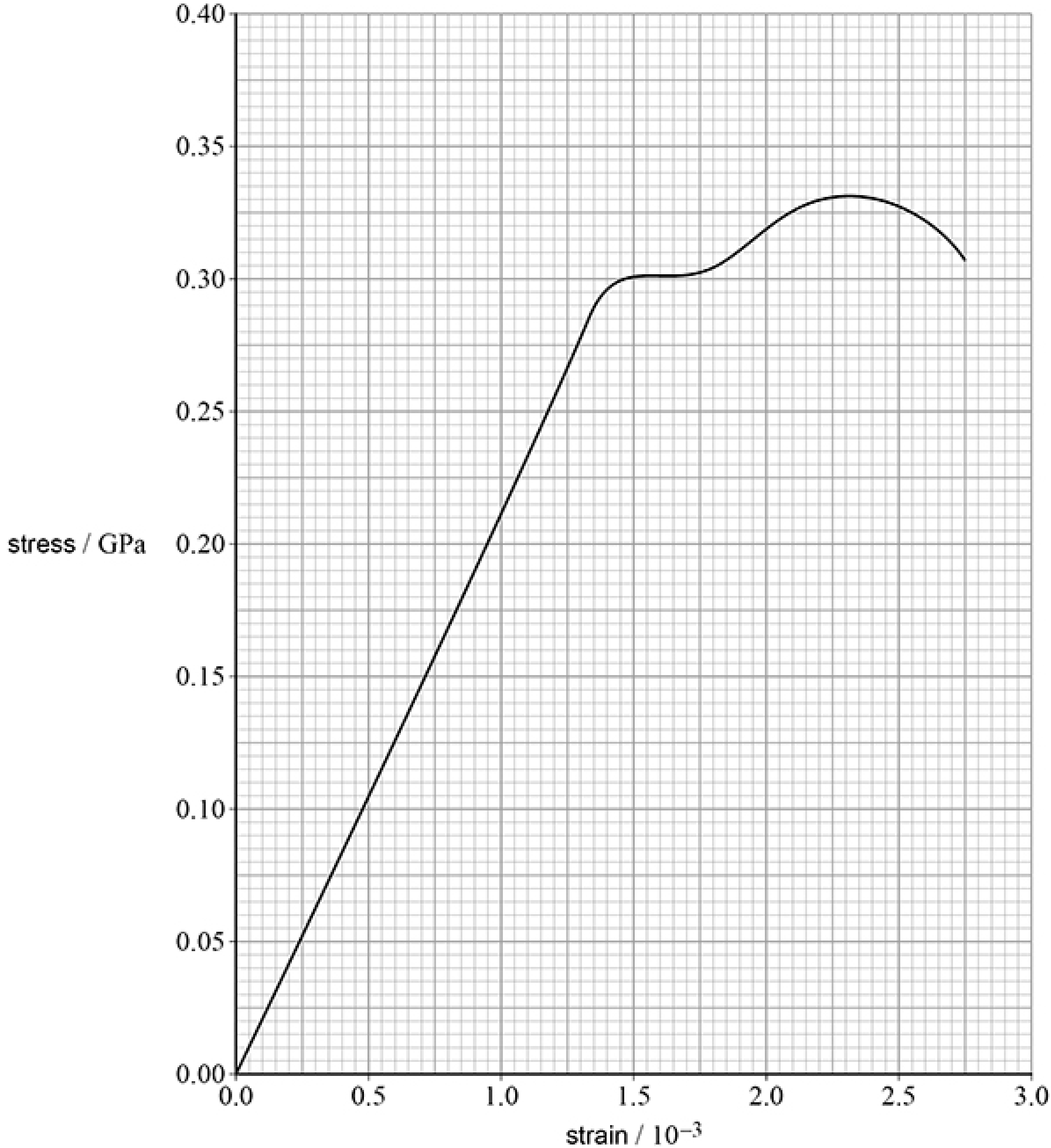
$m_A = 1.32 \times 10^6$ kg

$m_B = 3.30 \times 10^6$ kg.

The spacecraft imitates the gravity of Mars where $g = 3.7$ m s^{-2}.

Figure 2 shows a stress–strain curve for the metal used for the rigid rod.

Figure 2


stress / GPa
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.0
0.5
1.0
1.5
2.0
2.5
3.0
strain / 10^{-3}

(d) Suggest a suitable diameter for the rod.
Justify your answer.

diameter = _______________ m

____

____

____

____

____

____

(5)

(Total 11 marks)

3. **Figure 1** shows a side view of an act performed by two acrobats. **Figure 2** shows the view from above.

Figure 1

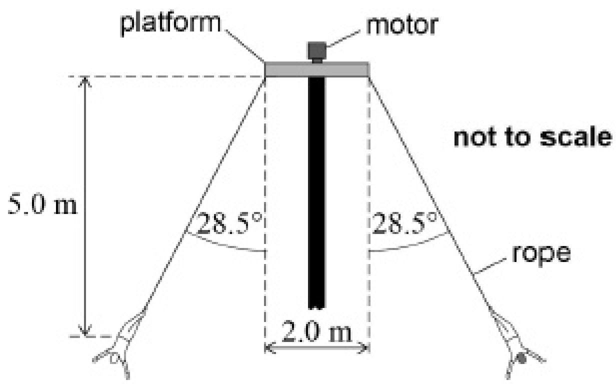
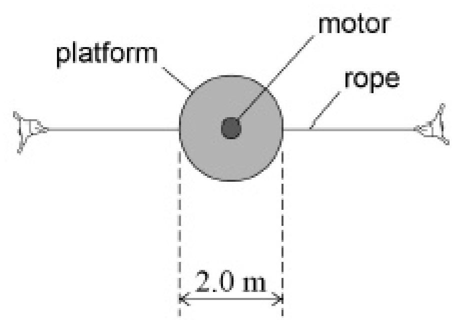


Figure 2



The acrobats, each of mass 85 kg, are suspended from ropes attached to opposite edges of a circular platform that is at the top of a vertical pole. The platform has a diameter of 2.0 m
A motor rotates the platform so that the acrobats move at a constant speed in a horizontal circle, on opposite sides of the pole.

When the period of rotation of the platform is 5.2 s, the centre of mass of each acrobat is 5.0 m below the platform and the ropes are at an angle of 28.5° to the vertical as shown in **Figure 1**.

(a) Show that the linear speed of the acrobats is about 4.5 m s^{-1}

(2)

(b) Determine the tension in each rope that supports the acrobats.

tension = ____________________ N

(3)

(c) Discuss the consequences for the forces acting on the pole when one acrobat has a much greater mass than the other.

____

____

____

____

____

____

____

____

____

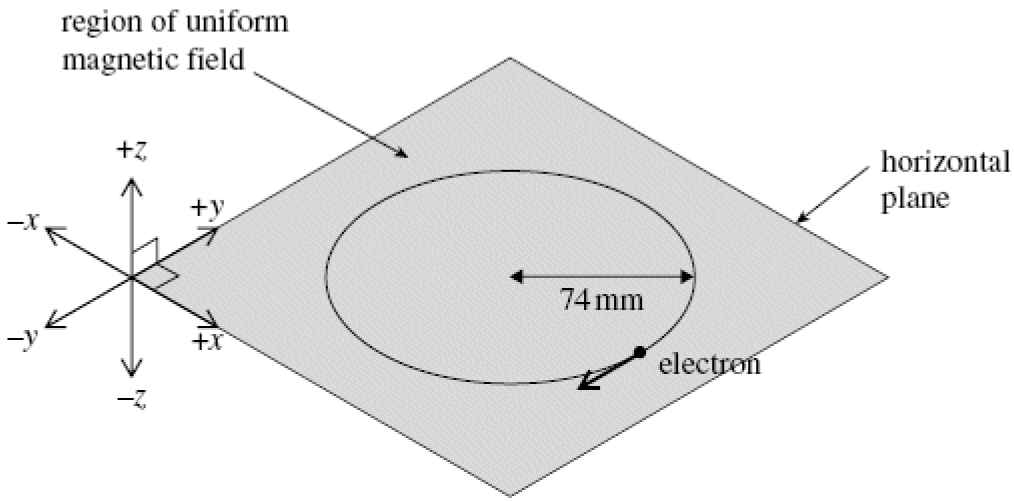
____

____

(3)

(Total 8 marks)

4. When travelling in a vacuum through a uniform magnetic field of flux density 0.43 m T, an electron moves at constant speed in a horizontal circle of radius 74 mm, as shown in the figure below.



(a) When viewed from vertically above, the electron moves clockwise around the horizontal circle. In which one of the six directions shown on the figure above, +*x*, –*x*, +*y*, –*y*, +*z* or –*z*, is the magnetic field directed?

direction of magnetic field ______________________

(1)

(b) Explain why the electron is accelerating even though it is travelling at constant speed.

____

____

____

____

____

____

(2)

(c) (i) By considering the centripetal force acting on the electron, show that its speed is 5.6×10^6 m s^{-1}.

(2)

(ii) Calculate the angular speed of the electron, giving an appropriate unit.

answer = ______________________

(2)

(iii) How many times does the electron travel around the circle in one minute?

answer = ______________________

(2)

(Total 9 marks)