A Level · OCR · Physics

44 mins · 5 questions

Structured Questions

Circular Motion

Radians / Time period & Frequency / Angular Velocity / Centripetal Force / Linear Speed / Centripetal Acceleration / Investigating Circular Motion

Medium (3 questions)	/27
Hard (2 questions)	/17
Total Marks	**/44**

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Medium Questions

1 (a) A particle-accelerator uses a ring of electromagnets to keep protons moving continuously in a **circle**. The speed *v* of the protons depends on the frequency *f* of rotation of the protons in the circular orbit.

Fig. 22 shows data points plotted on a *v* against *f* grid.

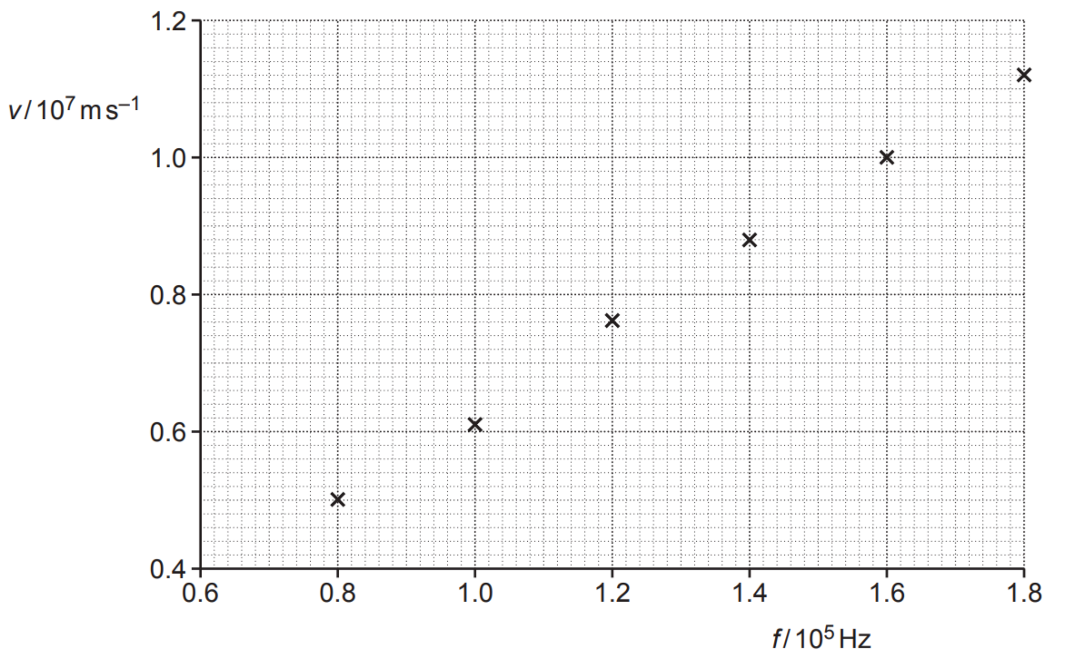

Fig. 22

i) Show that the gradient of the graph of *v* against *f* is equal to $2\pi r$, where *r* is the radius of the circular path of the protons.

[2]

ii) Show that *r* is about 10 m by determining the gradient of the line of best fit through the data points in **Fig. 22**.

[3]

iii) The maximum speed of the protons from this accelerator is 2.0×10^7 m s^{-1}.

Calculate the maximum centripetal force *F* acting on a proton at this speed.

• mass of proton = 1.7×10^{-27} kg.

F = ... N **[3]**

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(8 marks)

(b) A new particle-accelerator is now built for moving the protons in a circle of a radius 20 m.

The ring of electromagnets for this new accelerator provides the same **maximum** centripetal force as the accelerator in **(a)**.

Calculate the maximum speed of the protons in this new accelerator.

maximum speed = ... m s^{-1} **[2]**

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(2 marks)

2 (a) At an airport, the conveyor belt for suitcases moves at a constant speed of 1.5ms^{-1}.

In Fig. 4.1, a suitcase of mass 8.0kg has reached the line labelled **XX**'.

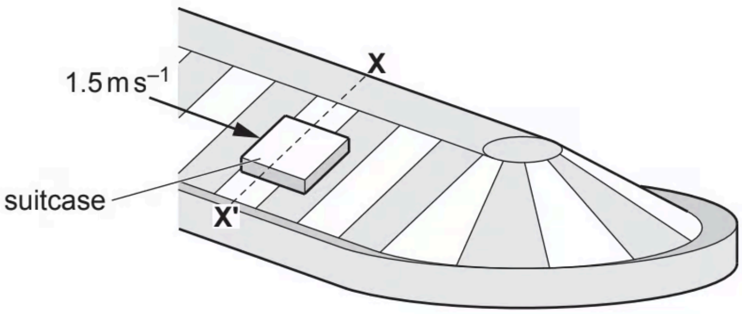

Fig. 4.1

Fig. 4.2 shows the situation in vertical cross-section. The frictional force *F* prevents the suitcase of weight *W* from sliding to the bottom of the belt. The normal contact force on the suitcase is *R*. The belt is inclined at an angle of 30° to the horizontal.

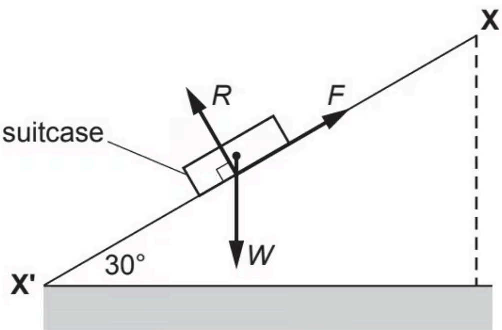

Fig. 4.2 (not to scale)

By using a vector triangle, or by resolving forces, calculate the magnitude of forces *F* and *R*.

F = ... N *R* = ... N

[3]

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(3 marks)

(b) Fig. 4.3 shows the suitcase and the forces acting on it at the line labelled **YY'**.

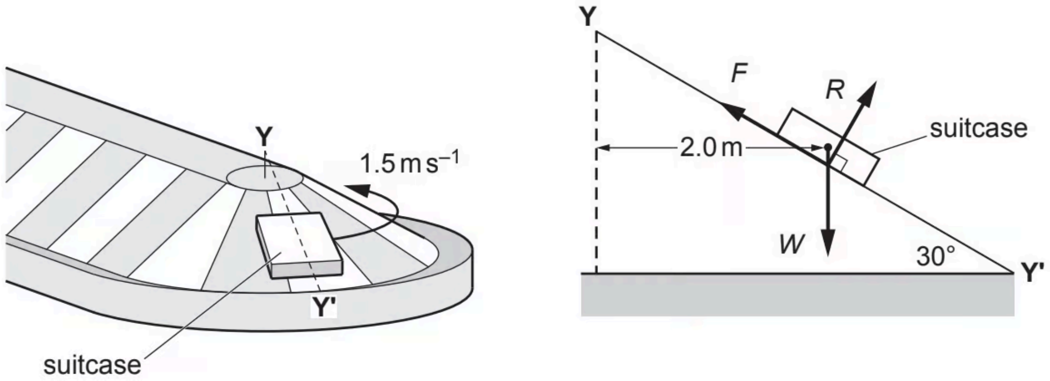

Fig. 4.3

The centre of mass of the suitcase is now moving at 1.5 ms^{-1} along a semi-circular arc of radius 2.0 m.

i) Calculate the magnitude of the centripetal force acting on the suitcase.

centripetal force = ... N **[2]**

ii) When the suitcase is at line **YY'**, the magnitude of force *F* is larger and the magnitude of force *R* is smaller than at **XX'**. Explain why this is so.

[4]

(6 marks)

3 (a) Fig. 21 shows the drum of a washing machine.

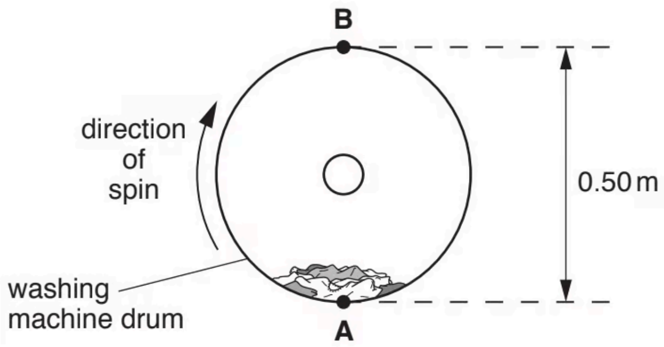

Fig. 21

The clothes inside the drum are spun in a **vertical** circular motion in a clockwise direction.

When the drum is at rest, the weight of the clothes is equal to the normal contact force on the clothes at point **A**. Explain why these two forces are **not** an example of Newton's Third Law of motion.

[2]

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(2 marks)

(b) The drum has diameter 0.50 m. The manufacturer of the washing machine claims that the drum spins at 1600 ± 100 revolutions per minute.

Calculate the speed of rotation of the drum and the absolute uncertainty in this value.

speed = ... ± .... m s^{-1} **[3]**

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(3 marks)

(c) The washing machine is switched off and the speed of the drum slowly decreases. The clothes at the top of the drum at point **B** start to drop off at a certain speed *v*. At this speed *v*, the normal contact force on the clothes is zero. Calculate the speed *v*.

v = ... m s^{-1} **[3]**

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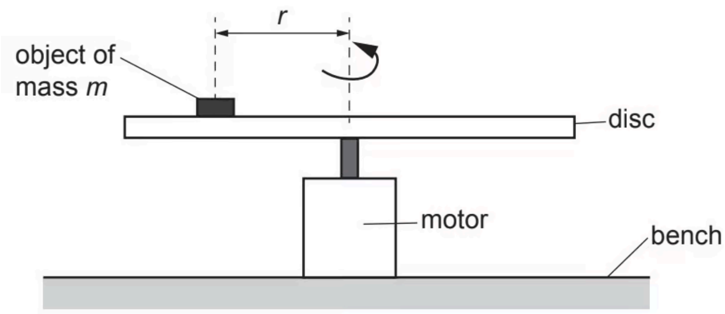
(3 marks)

Hard Questions

1 (a) A small object of mass m is placed on a rotating horizontal metal disc at a distance r from the centre of the disc.



The frequency of rotation is adjusted using a motor attached to the disc.

The frequency of rotation of the disc is slowly increased from zero, until the object slips off. At this point, the friction *F* acting on the object is equal to the centripetal force.

The friction *F* is given by the expression *F* = *kmg*, where *k* is a constant and *g* is the acceleration of free fall. The constant *k* has no units.

Show that the frequency *f* at which the object slips off is given by the equation

$$f^2 = \left(\frac{gk}{4\pi^2}\right) \times \frac{1}{r}.$$

[3]

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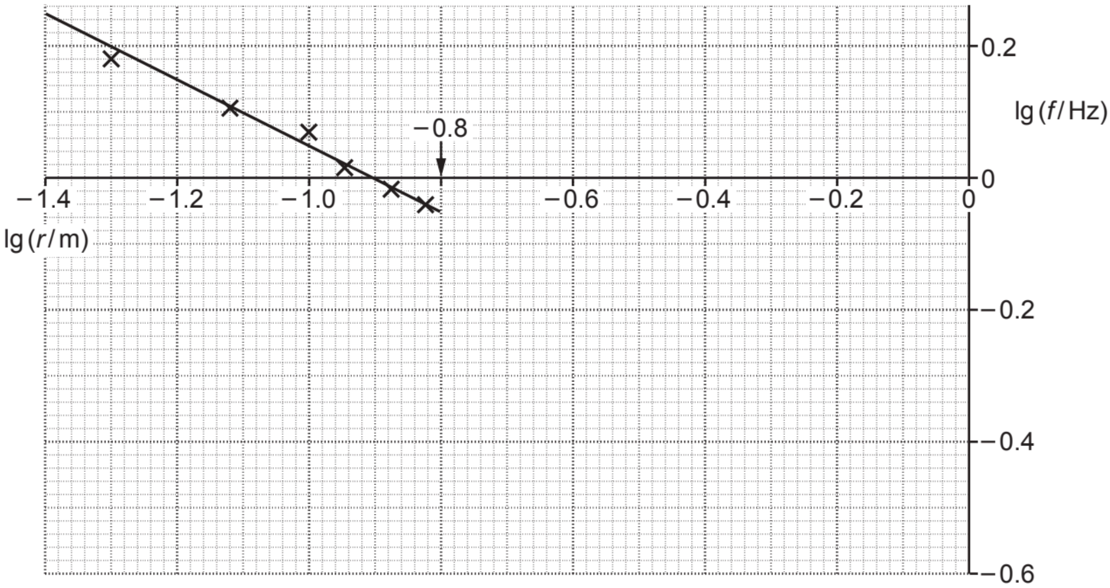
(3 marks)

(b) A student plots a graph of lg(f /Hz) against lg(r /m).



For this graph: y-intercept = $\frac{1}{2} \times lg\left(\frac{gk}{4\pi^2}\right)$

Use the graph to determine the constant k. Write your answer to 2 significant figures.

k = ... **[4]**

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(4 marks)

2 (a) The London Eye, shown rotating anticlockwise in **Fig. 6.1**, is a giant wheel which rotates slowly at a constant speed.

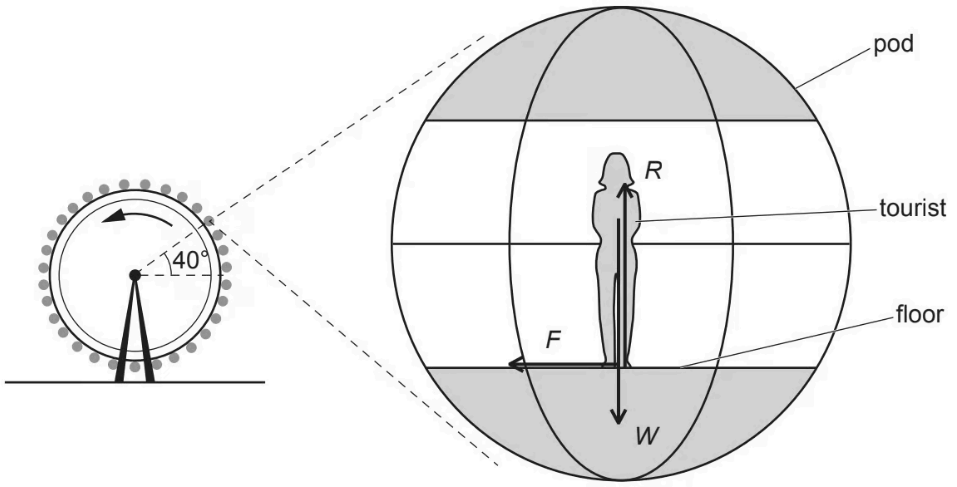

Fig. 6.1	**Fig. 6.2**

Tourists stand in pods around the circumference of the wheel.

The floor remains horizontal at all times.

At time $t = 0$, a tourist who has a weight W of 650 N enters a pod at the bottom of the wheel.

Fig. 6.2 shows the forces acting on the tourist at a later time, when the angle between the pod's position and the centre of the wheel is 40° above the horizontal. R is the normal contact force and F is friction.

The resultant upward force (R – W) on the tourist changes during the 30 minutes of the rotation of the London Eye as shown in **Fig. 6.3**.

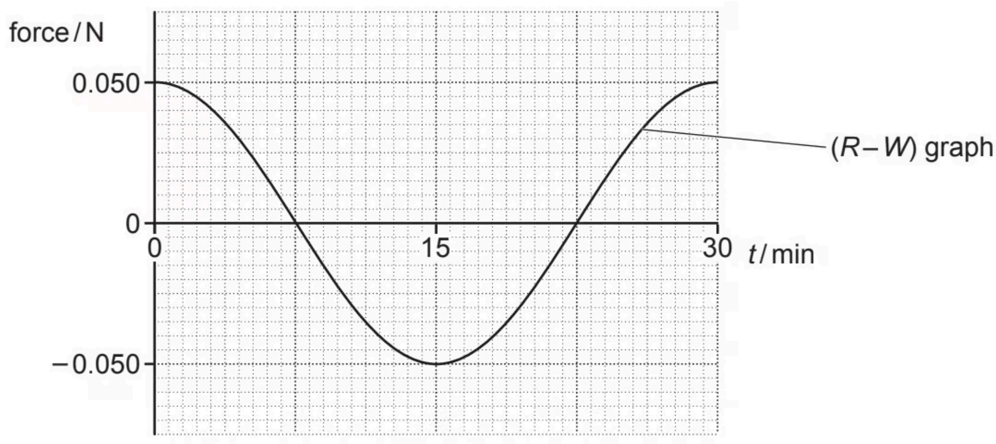

Fig. 6.3

Explain how the graph in **Fig. 6.3** shows that the magnitude of the centripetal force on the tourist during the rotation is 0.050 N.

[1]

(1 mark)

(b) i) Explain why the horizontal force F between the floor and the tourist is necessary.

[2]

ii) Draw on **Fig. 6.3** the variation of the horizontal force F during the 30 minutes of the anticlockwise rotation of the London Eye. Take forces to the right to be positive.

[2]

iii) Calculate the magnitude of force F when the pod is at the position shown in **Fig. 6.2**, at 40° above the horizontal.

F = ... N **[2]**

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(6 marks)

(c) Calculate the distance *d* of the centre of mass of the tourist from the centre of rotation of the London Eye.

d = ... m **[3]**

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(3 marks)