Circular Motion

1.

Fig. 2.1 shows a ball at rest, hanging on a vertical thread from a fixed support, S.

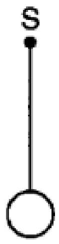


Fig. 2.1

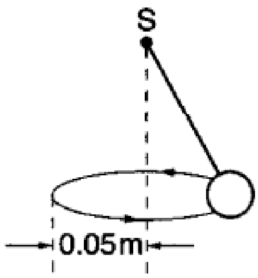


Fig. 2.2

(a) On Fig. 2.1 draw and label arrows to represent the two forces acting on the ball. [2]

(b) Fig. 2.2 represents the ball moving in a circle about a vertical axis through S. On Fig. 2.2 draw and label arrows to represent the two forces acting on the ball. Explain how they provide the force to make the ball move in a circular path.

....

....

....

....[3]

(c) The ball has a mass of 0.020 kg and moves in a circle of radius 0.050 m at 1.2 revolutions per second. Assume that the thread supporting the ball has negligible mass. Calculate

(i) the speed of the ball

speed = ... $m\,s^{-1}$ [2]

(ii) the magnitude of the force which keeps the ball moving in a circular path.

force = ... N [3]

(d) Predict and explain the difference in the path of the ball when it is rotating at a higher speed.

....

....

....

....[3]

2.

(You can skip this question and come back to it after we study 'Gravitational Fields'.)

A binary star is a pair of stars which move in circular orbits around their common centre of mass. For stars of equal mass, they move in the same circular orbit, shown by the dotted line in Fig. 2.1. In this question, consider the stars to be point masses situated at their centres at opposite ends of a diameter of the orbit.

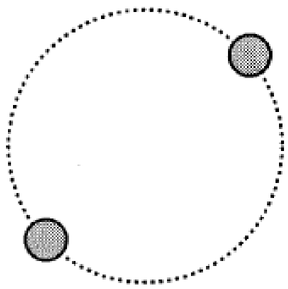


Fig. 2.1

(a) **(i)** Draw on Fig. 2.1 arrows to represent the force acting on each star. [2]

(ii) Explain why the stars must be diametrically opposite to travel in the circular orbit.

....

....

....

....

.... [2]

(b) Newton's law of gravitation applied to the situation of Fig. 2.1 may be expressed as

$$F = \frac{GM^2}{4R^2}.$$

State what each of the four symbols listed below represents.

F ....

G ....

M ....

R .... [2]

(c) **(i)** Show that the orbital period T of each star is related to its speed v by $v = 2\pi R/T$.

[1]

(ii) Show that the magnitude of the centripetal force required to keep each star moving in its circular path is

$$F = \frac{4\pi^2 MR}{T^2} .$$

[2]

(iii) Use equations from **(b)** and **(ii)** above to show that the mass of each star is given by

$$M = 16\pi^2 \frac{R^3}{GT^2} .$$

[2]

(d) Binary stars separated by a distance of 1×10^{11} m have been observed with an orbital period of 100 days. Calculate the mass of each star.

1 day = 86 400 s

mass = ... kg [2]

3.

Fig. 3.1 shows a rotating fairground ride where a seat **S** of mass m is suspended by a light chain. When the ride rotates at a constant speed v, the chain makes an angle θ with the vertical so that the seat is a distance r from the axis of rotation.

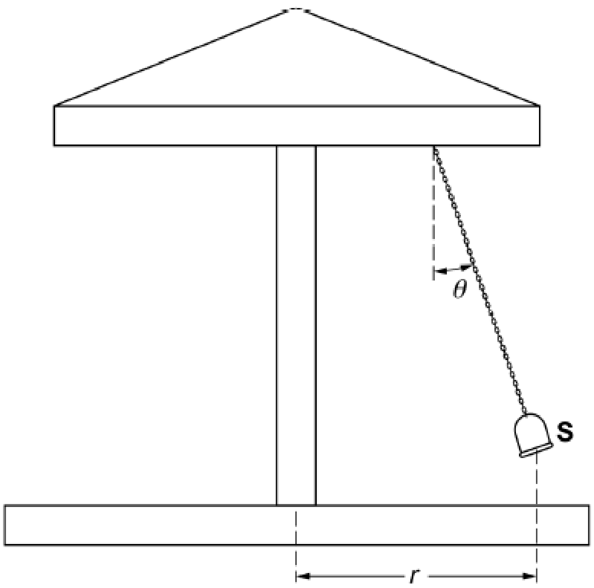


Fig. 3.1

(a) (i) On Fig. 3.1 draw and label arrows to represent the forces acting on the seat. [2]

(ii) By referring to the forces in **(i)**, explain the condition necessary for the seat to move in a horizontal circle.

[3]

(iii) Write down an algebraic expression for the magnitude F of the resultant force on the seat in terms of m, r and v.

[1]

(b) (i) When the ride rotates, the seat is travelling in a circle of radius 5.0 m at a constant speed of 4.2 m s^{-1}. Show that the angle θ is about 20°.

[4]

(ii) When a child occupies the seat during a ride at 4.2 m s^{-1}, will the angle θ remain at 20° or will it change? Explain your answer.

....

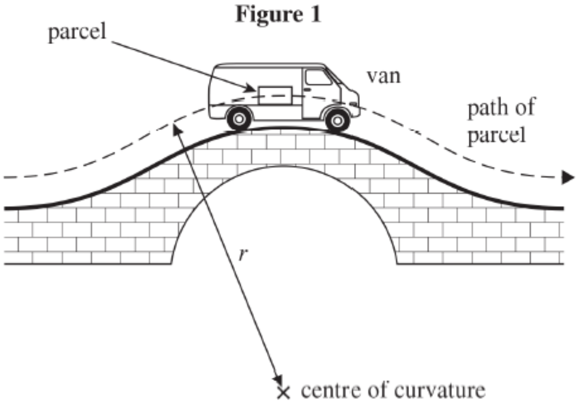
....

....[1]

4.

Figure 1 shows a parcel on the floor of a delivery van that is passing over a hump-backed bridge on a straight section of road. The radius of curvature of the path of the parcel is r and the van is travelling at a constant speed v. The mass of the parcel is m.

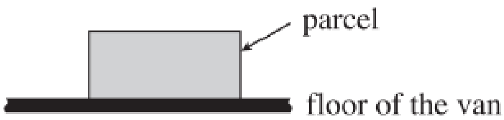
Figure 1



(a) (i) Draw arrows on **Figure 2** below to show the forces that act on the parcel as it passes over the highest point of the bridge. Label these forces.

(1 mark)

Figure 2



(a) (ii) Write down an equation that relates the contact force, R, between the parcel and the floor of the van to m, v, r and the gravitational field strength, g.

....

....

(1 mark)

(a) (iii) Calculate R if $m = 12\,\mathrm{kg}$, $r = 23\,\mathrm{m}$, and $v = 11\ \mathrm{m\,s^{-1}}$.

answer = ...N

(2 marks)

(b) Explain what would happen to the magnitude of R if the van passed over the bridge at a higher speed. What would be the significance of any van speed greater than $15\,\mathrm{m\,s}^{\ 1}$? Support your answer with a calculation.

....

....

....

....

....

(3 marks)

5.

(a) Explain why a body moving at constant speed in a circular path needs a resultant force acting on it.

....

....

....

....

(2)

(b) (i) A girl standing at the equator is in circular motion about the Earth's axis. Calculate the angular speed of the girl.

....

....

....

Angular speed = ...

(2)

(ii) The radius of the Earth is 6400 km. The girl has a mass of 60 kg. Calculate the resultant force on the girl necessary for this circular motion.

....

....

Force = ...

(2)

(iii) If the girl were to stand on weighing scales calibrated in newtons, what reading would they give?

....

....

....

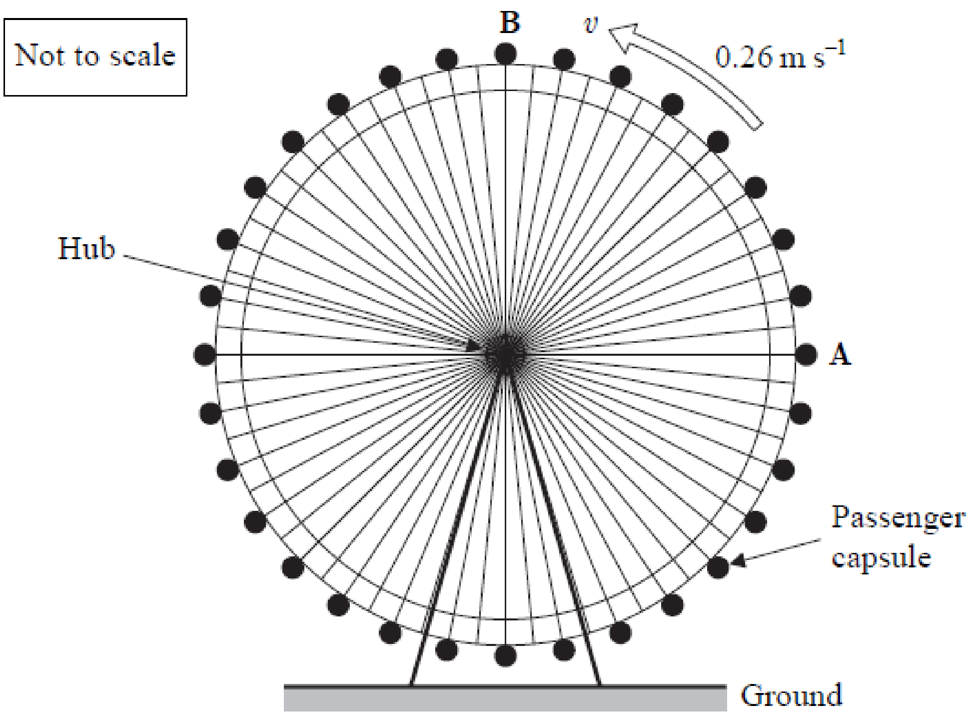
Scale reading = ...

(3)

6.

The London Eye is a tourist attraction designed to give passengers a panoramic view over London. The giant wheel completes two revolutions in one hour. Each capsule moves with a constant speed of 0.26 m s^{-1} as it follows a circular path.

Figure 1



(a) Calculate the radius of this circular path.

....

....

....

....

Radius = ...

(2)

(b) A man of mass 85 kg follows a circular path of this radius as he rides in a capsule. What is the magnitude and direction of the resultant force acting on the man?

....

....

....

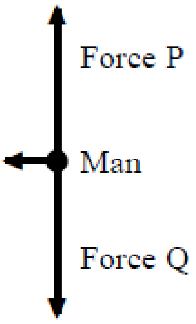
....

....

....
(3)

(c) Figure 2 shows the free-body force diagram for the man when the capsule is at position **A** as shown in Figure 1.

Figure 2



(i) Name forces P and Q

Force P: ....

Force Q: ....
(2)

(ii) When the man is at position A there is no resultant **vertical** force acting on him. In this position force P = force Q in magnitude. Explain why the man continues his motion in a circle.

....

....

....
(2)

(iii) Explain why force Q must be larger than force P when the capsule is at position B.

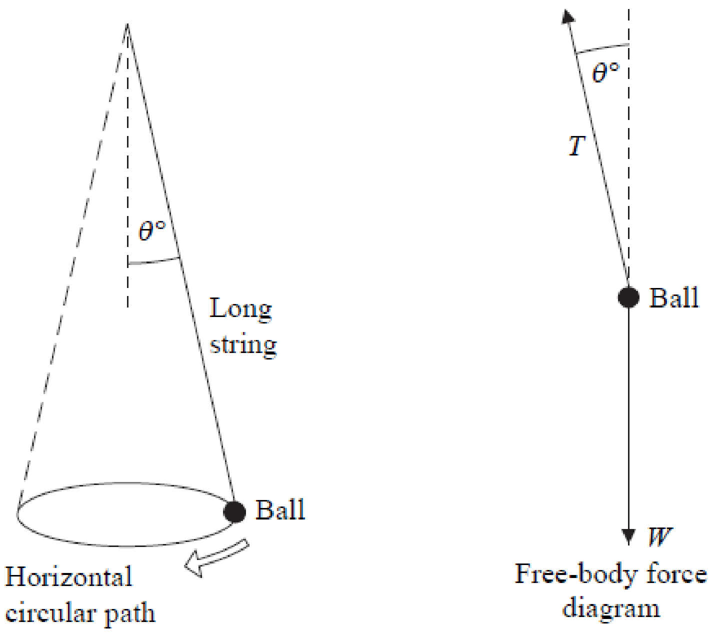
....

....

....
(1)

7.

A ball attached to the end of a long string is made to rotate in a horizontal circular path at a constant speed. The forces acting on the ball are its weight, W, and the tension, T, in the string.



With reference to the free-body force diagram, explain how it is possible for the ball to move with constant speed and yet still be accelerating.

....

....

....

....

....

....

....

....

(Total 4 marks)