Q1 [6]

(a) The Earth may be considered to be a uniform sphere of radius 6.38×10^6 m. Its mass is assumed to be concentrated at its centre.

Given that the gravitational field strength at the Earth's surface is $9.81\,\mathrm{N\,kg^{-1}}$, show that the mass of the Earth is 5.99×10^{24} kg.

(b) A satellite is placed in geostationary orbit around the Earth.

(i) Calculate the angular speed of the satellite in its orbit.

angular speed = ... rad $\mathrm{s^{-1}}$ [3]

(ii) Using the data in **(a)**, determine the radius of the orbit.

radius = ... m [3]

Q2 [9]

(a) Explain

(i) what is meant by a *radian*,

....

....

....[2]

(ii) why one complete revolution is equivalent to an angular displacement of 2π rad.

....

....[1]

(b) An elastic cord has an unextended length of 13.0 cm. One end of the cord is attached to a fixed point C. A small mass of weight 5.0 N is hung from the free end of the cord. The cord extends to a length of 14.8 cm, as shown in Fig. 1.1.

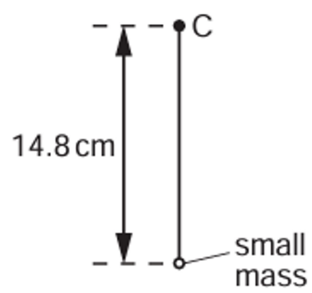


Fig. 1.1

The cord and mass are now made to rotate at constant angular speed ω in a vertical plane about point C. When the cord is vertical and above C, its length is the unextended length of 13.0 cm, as shown in Fig. 1.2.

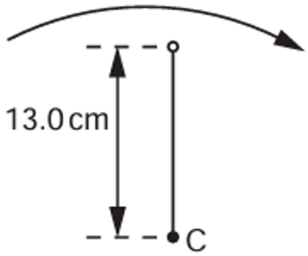


Fig. 1.2

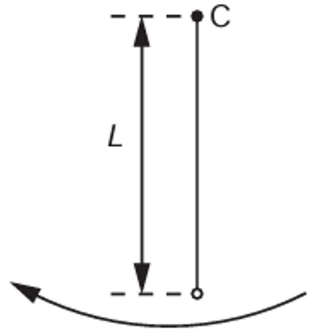


Fig. 1.3

(i) Show that the angular speed ω of the cord and mass is 8.7 rad s^{-1}.

[2]

(ii) The cord and mass rotate so that the cord is vertically below C, as shown in Fig. 1.3.

Calculate the length L of the cord, assuming it obeys Hooke's law.

L = ... cm [4]

Q3 [9]

(ii) A small mass is attached to a string. The mass is rotating about a fixed point P at constant speed, as shown in Fig. 1.1.

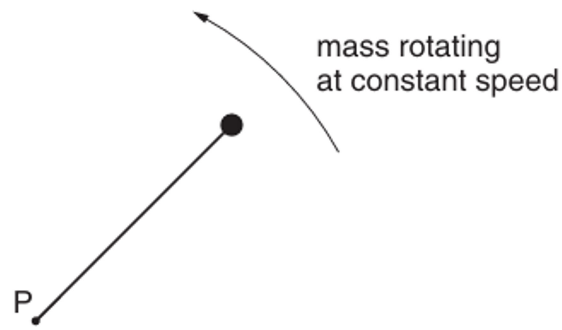


Fig. 1.1

Explain what is meant by the *angular* speed about point P of the mass.

....

....

.... [2]

(b) A horizontal flat plate is free to rotate about a vertical axis through its centre, as shown in Fig. 1.2.

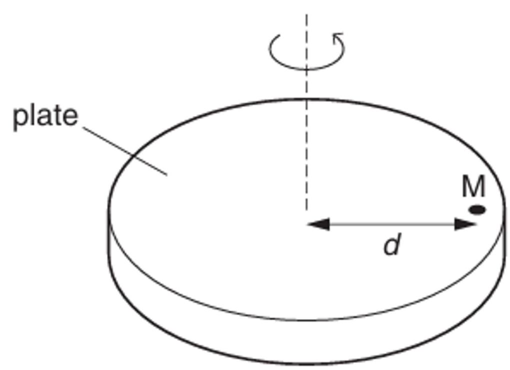


Fig. 1.2

A small mass M is placed on the plate, a distance d from the axis of rotation.
The speed of rotation of the plate is gradually increased from zero until the mass is seen to slide off the plate.

The maximum frictional force F between the plate and the mass is given by the expression

$$F = 0.72W,$$

where W is the weight of the mass M.
The distance d is 35 cm.

Determine the maximum number of revolutions of the plate per minute for the mass M to remain on the plate. Explain your working.

number = ...[5]

(c) The plate in **(b)** is covered, when stationary, with mud.
Suggest and explain whether mud near the edge of the plate or near the centre will first leave the plate as the angular speed of the plate is slowly increased.

....

....

....[2]

Q4 [5]

(b) A stone of weight 3.0 N is fixed, using glue, to one end P of a rigid rod CP, as shown in Fig. 1.1.

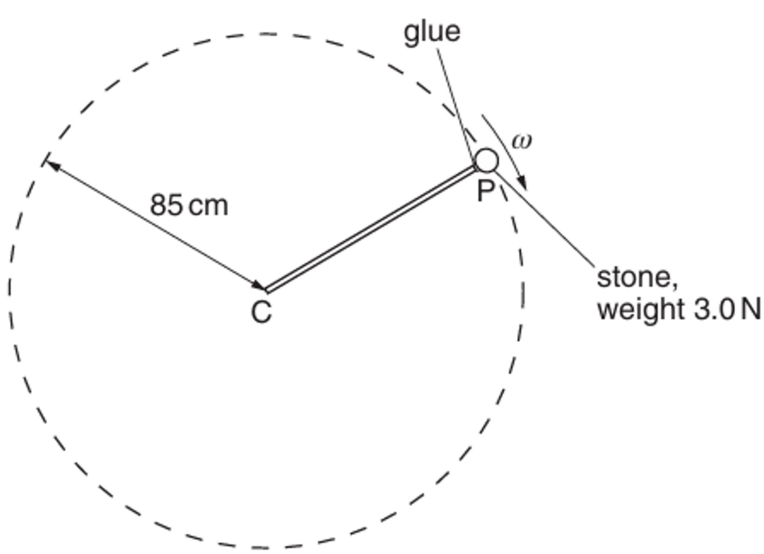


Fig. 1.1

Fig. 1.1

The rod is rotated about end C so that the stone moves in a vertical circle of radius 85 cm.
The angular speed ω of the rod and stone is gradually increased from zero until the glue snaps. The glue fixing the stone snaps when the tension in it is 18 N.

For the position of the stone at which the glue snaps,

(i) on the dotted circle of Fig. 1.1, mark with the letter S the position of the stone, [1]

(ii) calculate the angular speed ω of the stone.

angular speed = ... rad s^{-1} [4]

Q5['11]

A planet of mass m is in a circular orbit of radius r about the Sun of mass M, as illustrated in Fig. 1.1.

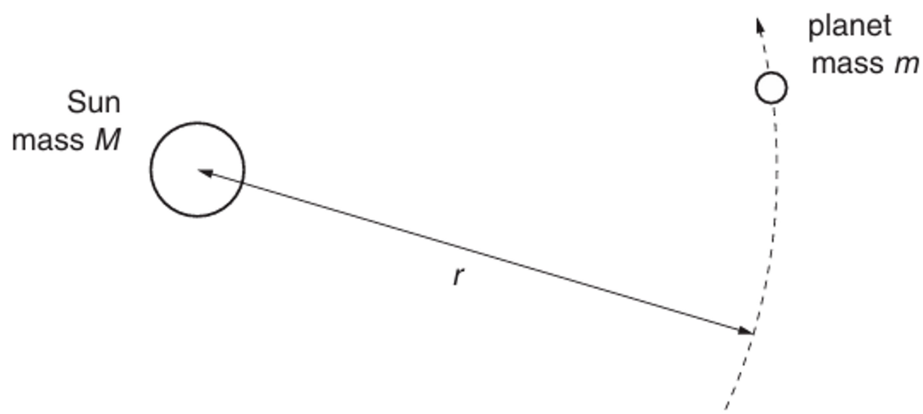


Fig. 1.1

The magnitude of the angular velocity and the period of revolution of the planet about the Sun are ω and T respectively.

(a) State

(i) what is meant by *angular velocity*,

....

....

....[2]

(ii) the relation between ω and T.

....[1]

(b) Show that, for a planet in a circular orbit of radius r, the period T of the orbit is given by the expression

$$T^2 = cr^3$$

where c is a constant. Explain your working.

[4]

(c) Data for the planets Venus and Neptune are given in Fig. 1.2.

planet	r / 10^8 km	T / years
Venus	1.08	0.615
Neptune	45.0	

Fig. 1.2

Assume that the orbits of both planets are circular.

(i) Use the expression in **(b)** to calculate the value of T for Neptune.

T = ... years [2]

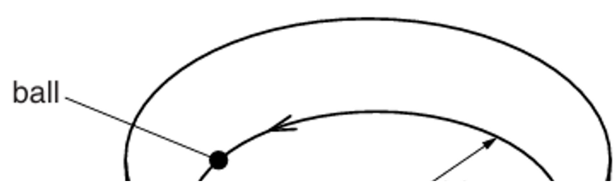
(ii) Determine the linear speed of Venus in its orbit.

speed = ... km s^{-1} [2]

Q6[8]

A large bowl is made from part of a hollow sphere.

A small spherical ball is placed inside the bowl and is given a horizontal speed. The ball follows a horizontal circular path of constant radius, as shown in Fig. 2.1.



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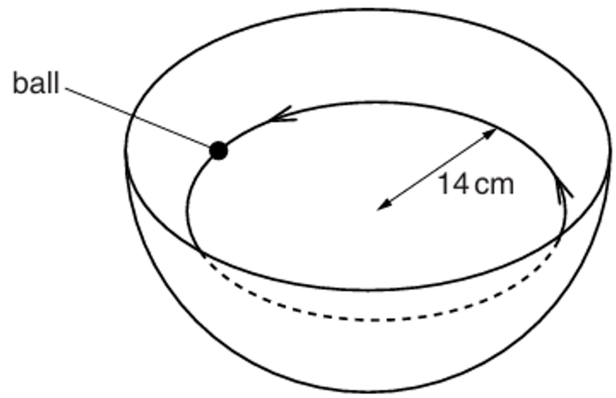

Fig. 2.1

The forces acting on the ball are its weight W and the normal reaction force R of the bowl on the ball, as shown in Fig. 2.2.

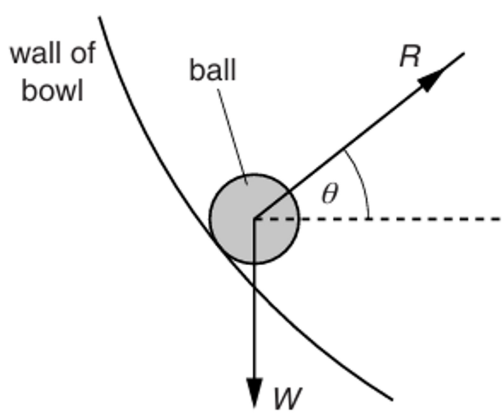

Fig. 2.2

The normal reaction force R is at an angle θ to the horizontal.

(a) **(i)** By resolving the reaction force R into two perpendicular components, show that the resultant force F acting on the ball is given by the expression

$$W = F \tan \theta.$$

[2]

(ii) State the significance of the force F for the motion of the ball in the bowl.

....

.... [1]

(b) The ball moves in a circular path of radius 14 cm. For this radius, the angle θ is 28°.

Calculate the speed of the ball.

speed = ... $m\,s^{-1}$ [3]

(b) A spherical planet has mass 6.00×10^{24} kg and radius 6.40×10^{6} m.
The planet may be assumed to be isolated in space with its mass concentrated at its centre.

A satellite of mass 340 kg is in a circular orbit about the planet at a height 9.00×10^{5} m above its surface.

For the satellite:

(i) show that its orbital speed is $7.4 \times 10^{3}\,m\,s^{-1}$

[2]

[2]

Q7 [2]

A steel ball is placed on the inside surface of a hollow circular cone. The ball moves in a horizontal circle at constant speed, as shown in Fig. 1.1.

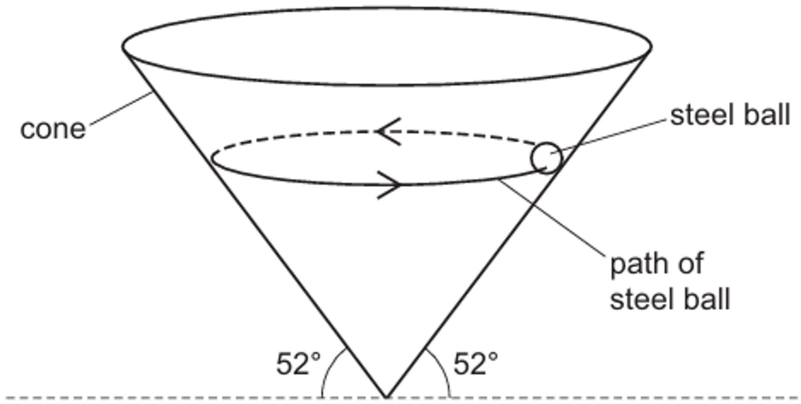

Fig. 1.1

The angle of the side of the cone to the horizontal is 52°. There is no friction between the ball and the cone.

(b) Describe how the forces acting on the ball cause its acceleration to be centripetal.

....

....

....

.... [2]