

- 1 (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 N kg^{-1} , show that the mass of the Earth is 5.99×10^{24} kg.

[2]

- (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 s^{-1} [3]

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

radius = m [3]

- 2 The orbit of the Earth, mass 6.0×10^{24} kg, may be assumed to be a circle of radius 1.5×10^{11} m with the Sun at its centre, as illustrated in Fig. 1.1.

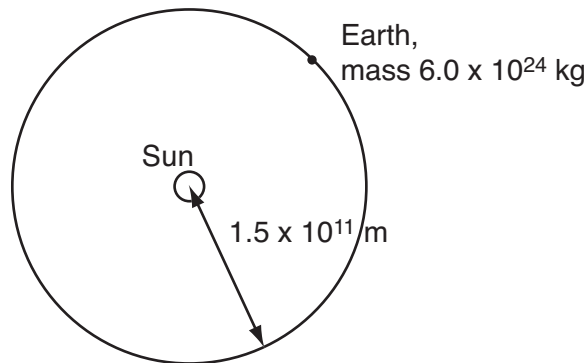


Fig. 1.1

The time taken for one orbit is 3.2×10^7 s.

(a) Calculate

- (i) the magnitude of the angular velocity of the Earth about the Sun,

angular velocity = rad s^{-1} [2]

- (ii) the magnitude of the centripetal force acting on the Earth.

force = N [2]

(b) (i) State the origin of the centripetal force calculated in (a)(ii).

.....
.....[1]

(ii) Determine the mass of the Sun.

mass = kg [3]

Mega Lecture

3 (a) (i) Define the *radian*.

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.....
.....[2]

(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.

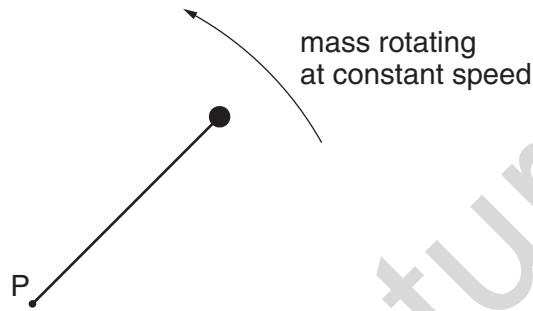


Fig. 1.1

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

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.....[2]

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

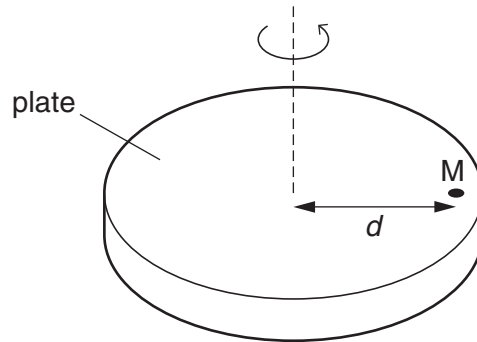


Fig. 1.2

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]

- 4 A particle is following a circular path and is observed to have an angular displacement of 10.3° .
- (a) Express this angle in radians (rad). Show your working and give your answer to three significant figures.

angle =rad [2]

- (b) (i) Determine $\tan 10.3^\circ$ to three significant figures.

$\tan 10.3^\circ =$

- (ii) Hence calculate the percentage error that is made when the angle 10.3° , as measured in radians, is assumed to be equal to $\tan 10.3^\circ$.

percentage error = [3]

5 (a) Explain

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

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.....
..... [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.

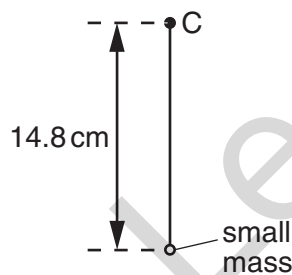


Fig. 1.1

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.

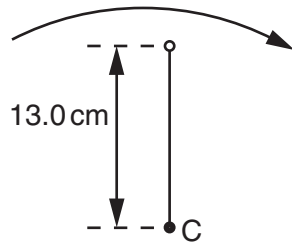


Fig. 1.2

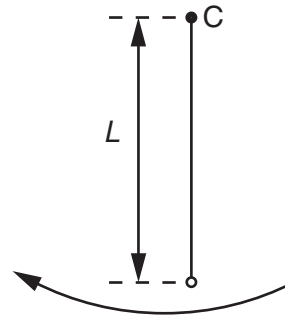


Fig. 1.3

- (i) Show that the angular speed ω of the cord and mass is 8.7 rads^{-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.

$L = \dots\dots\dots \text{cm}$ [4]

- 6 A spherical planet has mass M and radius R .
 The planet may be assumed to be isolated in space and to have its mass concentrated at its centre.
 The planet spins on its axis with angular speed ω , as illustrated in Fig. 1.1.

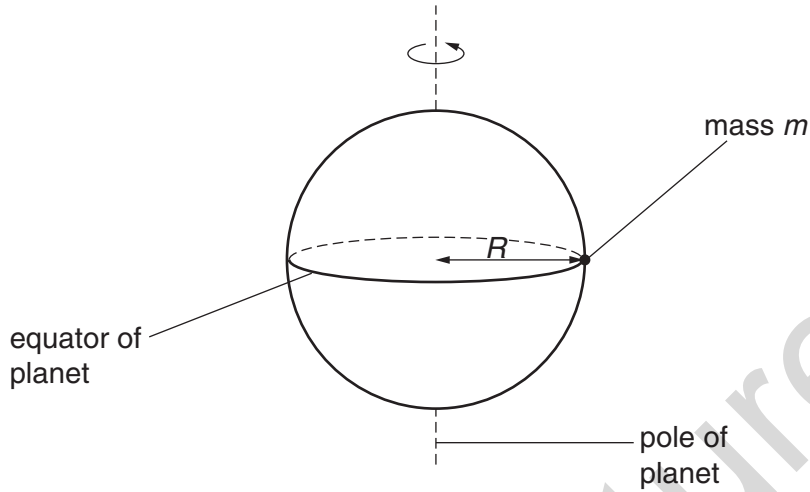


Fig. 1.1

A small object of mass m rests on the equator of the planet. The surface of the planet exerts a normal reaction force on the mass.

- (a) State formulae, in terms of M , m , R and ω , for
- (i) the gravitational force between the planet and the object,
 [1]
 - (ii) the centripetal force required for circular motion of the small mass,
 [1]
 - (iii) the normal reaction exerted by the planet on the mass.
 [1]
- (b) (i) Explain why the normal reaction on the mass will have different values at the equator and at the poles.

 [2]

(ii) The radius of the planet is 6.4×10^6 m. It completes one revolution in 8.6×10^4 s.
Calculate the magnitude of the centripetal acceleration at

1. the equator,

acceleration =ms⁻² [2]

2. one of the poles.

acceleration =ms⁻² [1]

(c) Suggest two factors that could, in the case of a real planet, cause variations in the acceleration of free fall at its surface.

1.

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2.

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[2]