1 **(a)** State Newton's law of gravitation.

....

....

.... [2]

(b) A binary star consists of star A, of mass 4.0×10^{30} kg, and star B, of mass 2.0×10^{30} kg, separated by a distance of 3.3×10^{12} m. The stars are both in circular orbit around their common centre of gravity X, as shown in Fig. 1.1.

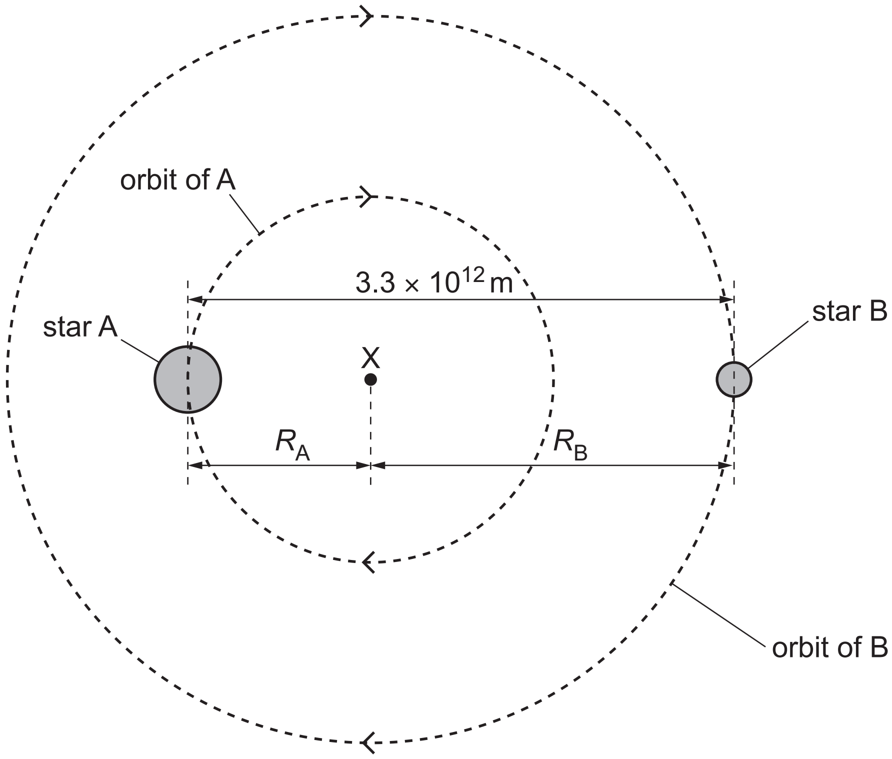

Fig. 1.1

The radius R_B of the orbit of star B is double the radius R_A of the orbit of star A.

(i) Use Newton's law of gravitation to calculate the magnitude of the gravitational force exerted by each star on the other.

force = ... N [2]

(ii) Calculate the centripetal acceleration of star A.

acceleration = ... $m s^{-2}$ [1]

(iii) Use your answer in **(b)(ii)** to determine the period of the orbit of star A.

period = ... s [3]

(iv) By placing a tick (✓) in each row, complete Table 1.1 to show how the quantities indicated for star B compare with the same quantities for star A.

Table 1.1

	B less than A	B equal to A	B greater than A
centripetal acceleration			
linear speed			
period			

[3]

1 The Earth may be considered as a uniform sphere of radius 6.37×10^6 m.

Cambridge is at a point on the Earth's surface that has a latitude of 52.2° north of the Equator, as shown in Fig. 1.1.

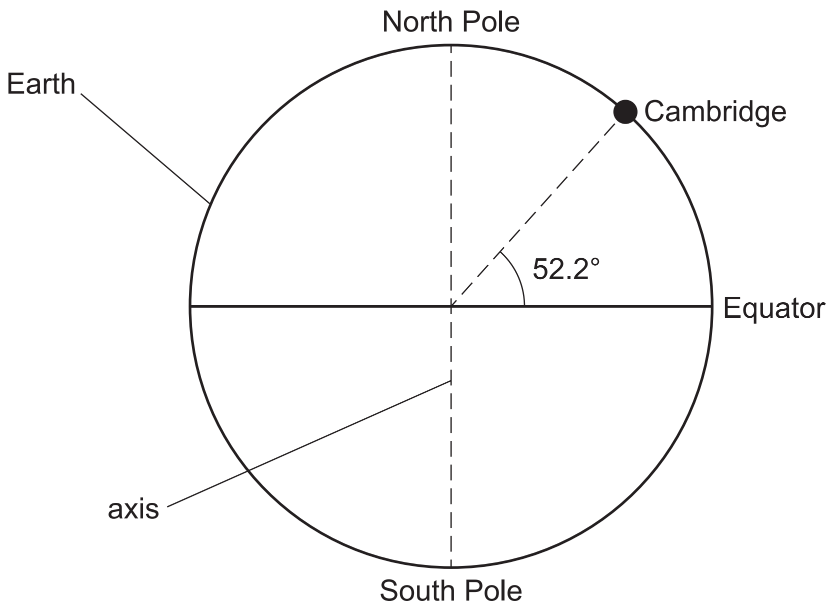

Fig. 1.1

As the Earth spins on its axis, Cambridge moves in a circle that is parallel to the Equator but with a smaller radius.

(a) (i) Show that the radius of the circle around which Cambridge moves is 3.90×10^6 m.

[1]

(ii) Calculate the speed at which Cambridge moves around the circle.

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

(b) A student of mass 58.6 kg stands on horizontal ground in Cambridge.

(i) Determine the magnitude of the resultant force that acts to cause the circular motion of the student.

resultant force = ... N [2]

(ii) On Fig. 1.2, draw an arrow to show the direction of the resultant force that acts on the student.

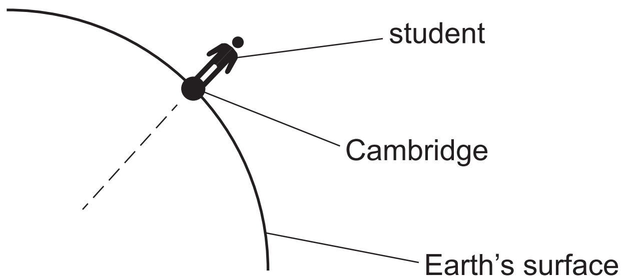

Fig. 1.2 (not to scale)

[1]

(iii) On Fig. 1.3, draw labelled arrows from the student to show the directions of the forces that act on the student to cause the resultant force in **(b)(ii)**.

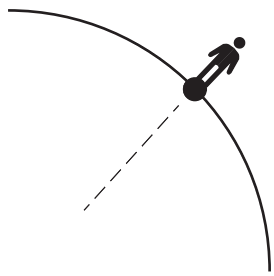

Fig. 1.3 (not to scale)

[2]

1 **(a)** In terms of velocity and acceleration, describe uniform circular motion of an object.

....

....

.... [2]

(b) Fig. 1.1 shows the view from above of a polystyrene ball undergoing horizontal circular motion of radius R.

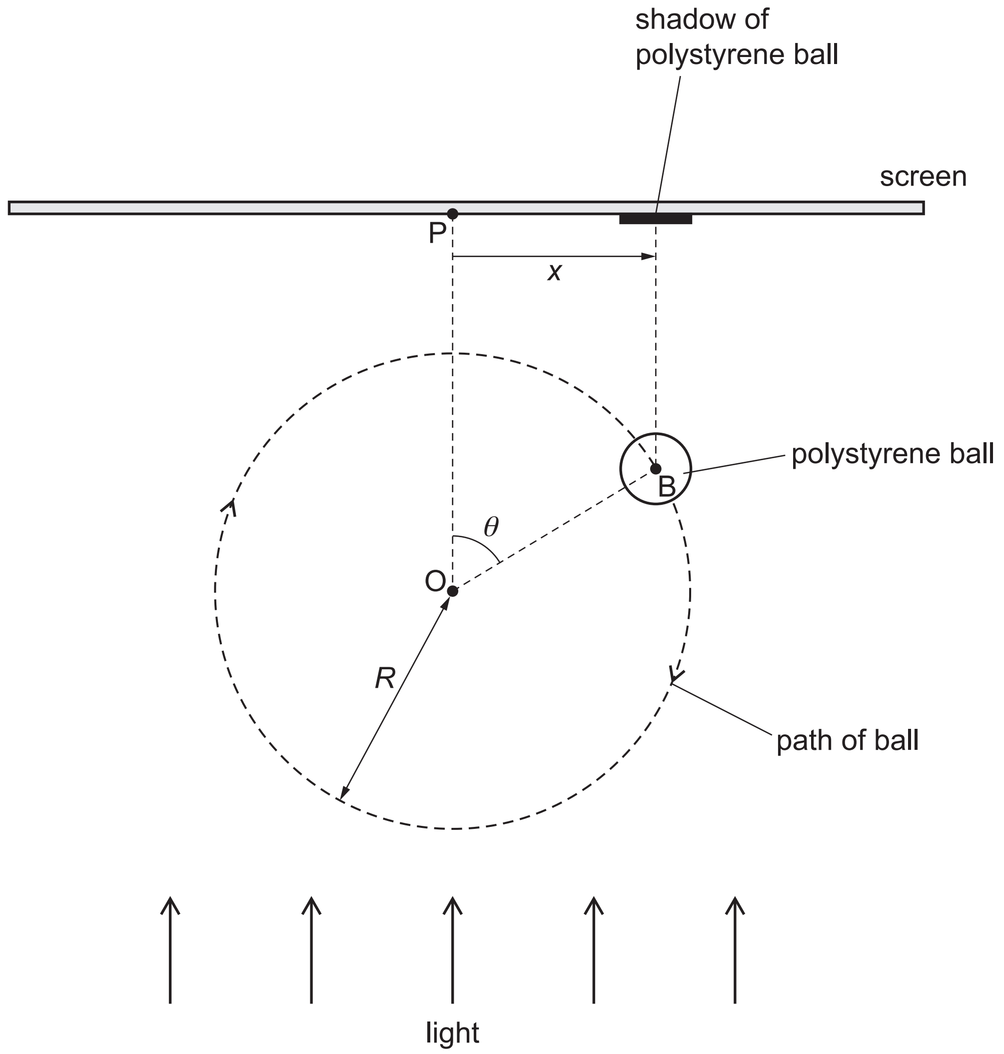

Fig. 1.1

The ball is illuminated by parallel light so that a shadow of the ball forms on a screen placed on the opposite side of the ball from the light source.

The line joining points O and P is perpendicular to the screen.

The angular speed of the circular motion is ω.

(i) State an expression, in terms of R and ω, for the speed v of the ball.

v = ... [1]

(ii) Determine an expression, in terms of v and ω, for the centripetal acceleration of the ball.

centripetal acceleration = ... [2]

(c) The ball in **(b)** is in the position shown in Fig. 1.1, such that line OB is at an angle θ to the line OP.

(i) Determine an expression, in terms of R and θ, for the displacement x of the shadow from P.

x = ... [1]

(ii) The value of θ is zero at time $t = 0$.

State an expression for θ in terms of ω and t.

θ = ... [1]

(iii) Use your answers in **(c)(i)** and **(c)(ii)** to show that x is given by

$$x = R\sin\omega t.$$

[1]

(iv) Explain, with reference to the equation in **(c)(iii)**, why the motion of the shadow of the ball on the screen may be modelled as simple harmonic.

....

.... [1]

(d) The circular motion of the ball in Fig. 1.1 has a diameter of 0.46 m and an angular speed of 1.9 rad s^{-1}.

For the simple harmonic motion of the shadow of the ball in Fig. 1.1, calculate:

(i) the amplitude

amplitude = ... m [1]

(ii) the period

period = ... s [2]

(iii) the maximum acceleration.

maximum acceleration = ... $m\,s^{-2}$ [2]

(e) On Fig. 1.1, draw, and label with the letter A, the position of the shadow on the screen when the shadow has its maximum positive acceleration. [1]

1 **(a)** Define the radian.

....

.... [1]

(b) The rear wheel and the pedals of a bicycle are connected by a chain that passes around two cogs (toothed wheels), as shown in Fig. 1.1.

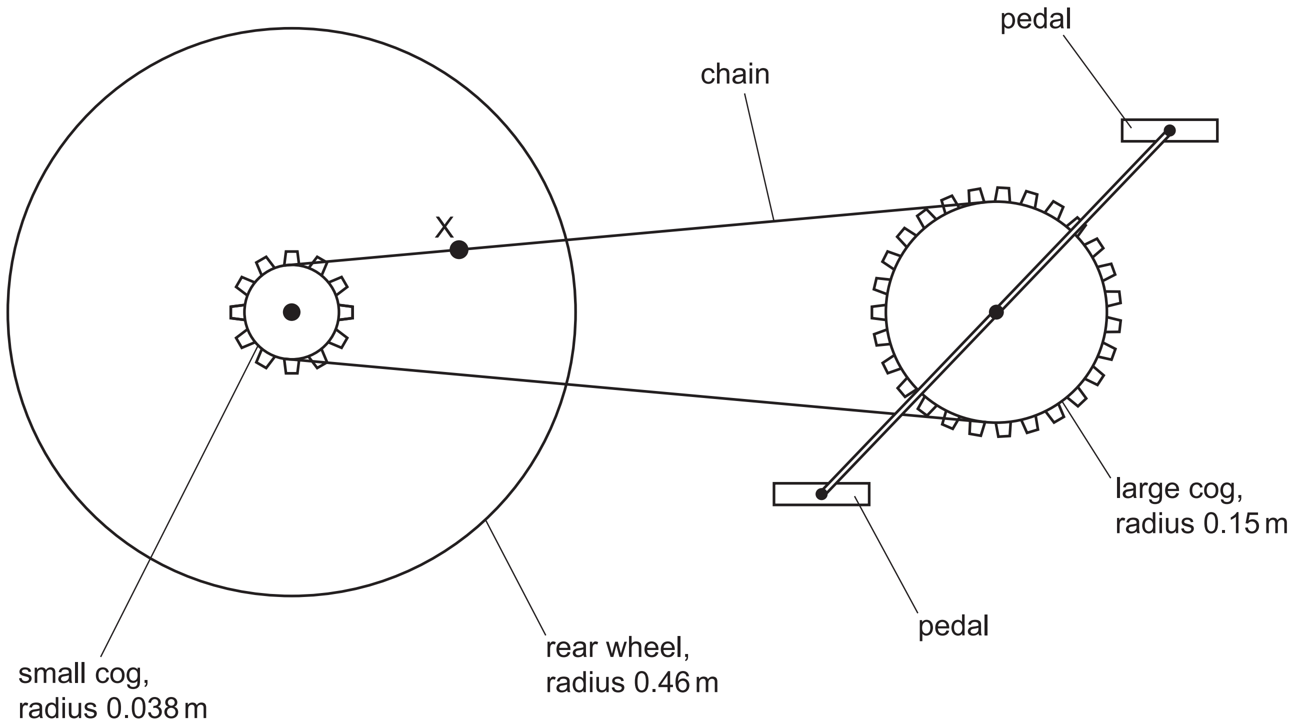

Fig. 1.1 (not to scale)

The small cog has a radius of 0.038 m and is fixed to the rear wheel so that it rotates with it.
The large cog has a radius of 0.15 m and is fixed to the pedals so that it rotates with them.
The rear wheel has a radius of 0.46 m.

The bicycle is being pedalled so that it moves in a straight line at a constant speed of 17 m s^{-1}.

(i) Calculate the angular speed of the rear wheel.

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

(ii) Calculate the period of rotation of the small cog.

period = ... s [2]

(iii) Show that the distance moved by point X on the chain during one full rotation of the small cog is 0.24 m.

[1]

(iv) Use the information in **(b)(iii)** to determine the angle through which the large cog rotates during one full rotation of the small cog.

angle = ... rad [2]

(c) The chain of the bicycle in **(b)** is moved onto a smaller cog fixed to the rear wheel. The speed of the bicycle does not change.

Explain, without calculation, the effect of this change on the angular speed of the pedals.

....

....

.... [2]

1 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.

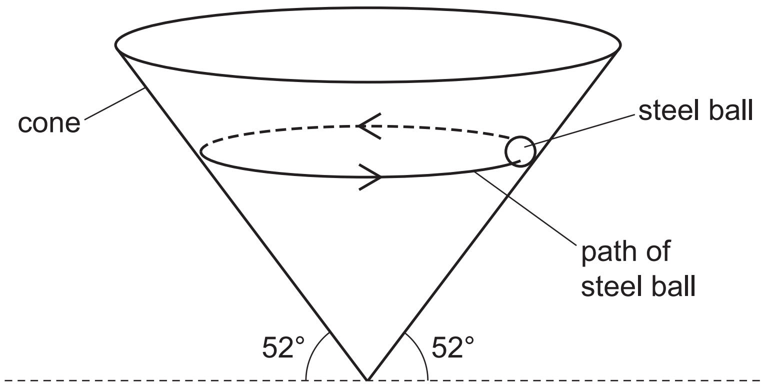

Fig. 1.1

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

(a) Fig. 1.2 shows a cross-section through the cone and the steel ball.

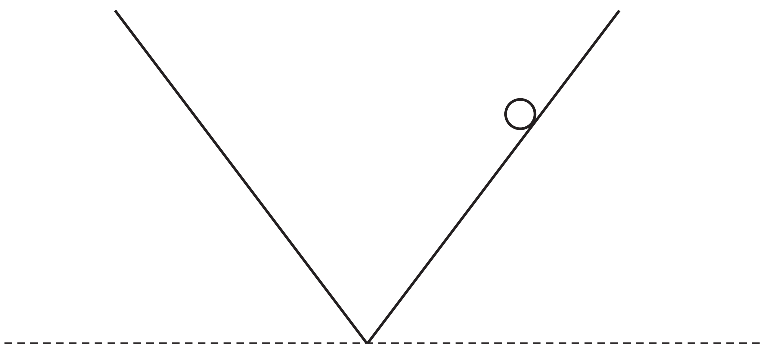

Fig. 1.2

On Fig. 1.2, draw labelled arrows to show the **two** forces acting on the ball. [1]

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

....

....

....

.... [2]

(c) The ball moves in a circle of radius 0.15 m.

Show that the speed of the ball is $1.4\,\text{m}\,\text{s}^{-1}$.

[3]

(d) Calculate the angular speed ω of the ball.

ω = ... $\text{rad}\,\text{s}^{-1}$ [2]

(e) The speed of the ball is increased.

Explain why the radius of the circular path of the ball increases.

....

....

.... [1]

1 A metal wheel consists of an axle A, eight spokes and a rim, as shown in Fig. 1.1.

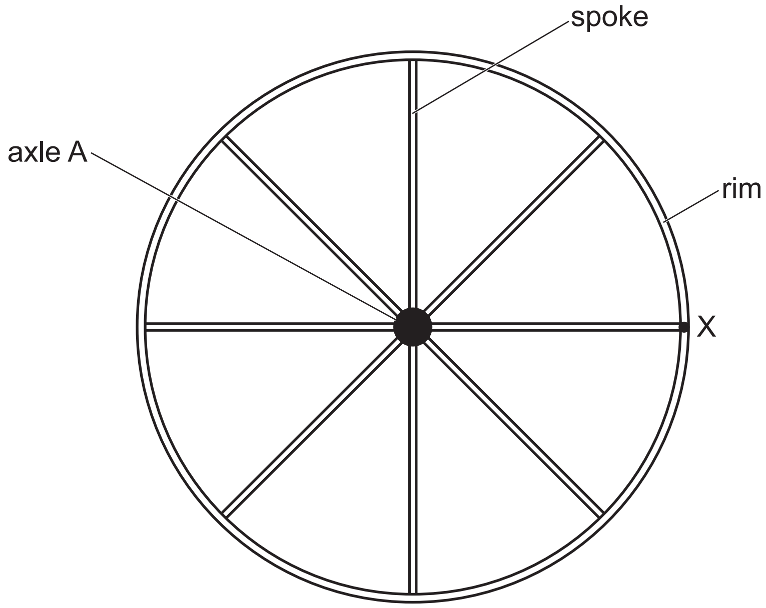

Fig. 1.1

Point X is on the rim at the end of one of the spokes.

The rim has a radius of 0.85 m.
The wheel is rotating clockwise with an angular speed of 140 rad s^{-1}.

(a) For point X, determine:

(i) the speed

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

(ii) the centripetal acceleration.

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

(b) There is a uniform magnetic field of flux density 0.18 T into the plane of the page.

(i) State Lenz's law of electromagnetic induction.

....

....

.... [2]

(ii) Show that the time taken for point X to complete one revolution is 45 ms.

[1]

(iii) Calculate the magnetic flux cut by spoke AX during one revolution of the wheel.
Give a unit with your answer.

magnetic flux = ... unit .... [3]

(iv) Determine the magnitude of the electromotive force (e.m.f.) induced across spoke AX.

induced e.m.f. = ... V [2]

(v) Use Lenz's law to explain whether the potential is higher at end A or end X of the spoke.

....

....

.... [1]

1 **(a)** Define the radian.

....

.... [1]

(b) A circular metal disc spins horizontally about a vertical axis, as shown in Fig. 1.1.

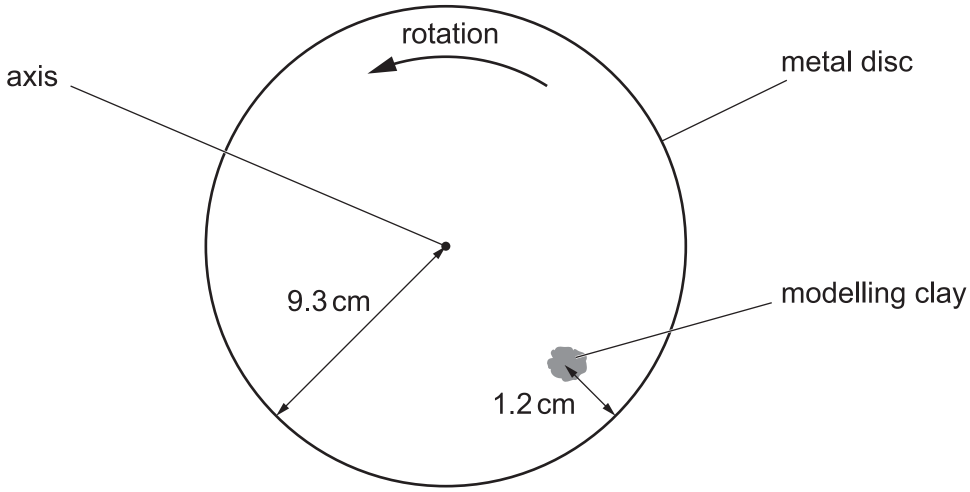

Fig. 1.1 (not to scale)

A piece of modelling clay is attached to the disc.

For the instant when the piece of modelling clay is in the position shown, draw on Fig. 1.1:

(i) an arrow, labelled V, showing the direction of the velocity of the modelling clay [1]

(ii) an arrow, labelled A, showing the direction of the acceleration of the modelling clay. [1]

(c) The metal disc in Fig. 1.1 has a radius of 9.3 cm.
The centre of gravity of the modelling clay is 1.2 cm from the rim of the disc and moves with a speed of $0.68\,\text{m}\,\text{s}^{-1}$.

(i) Calculate the angular speed ω of the disc.

ω = ... $\text{rad}\,\text{s}^{-1}$ [2]

(ii) Calculate the acceleration a of the centre of gravity of the modelling clay.

a = ... $\mathrm{m\,s^{-2}}$ [2]

(d) A second piece of modelling clay is attached to the disc in the position shown in Fig. 1.2.

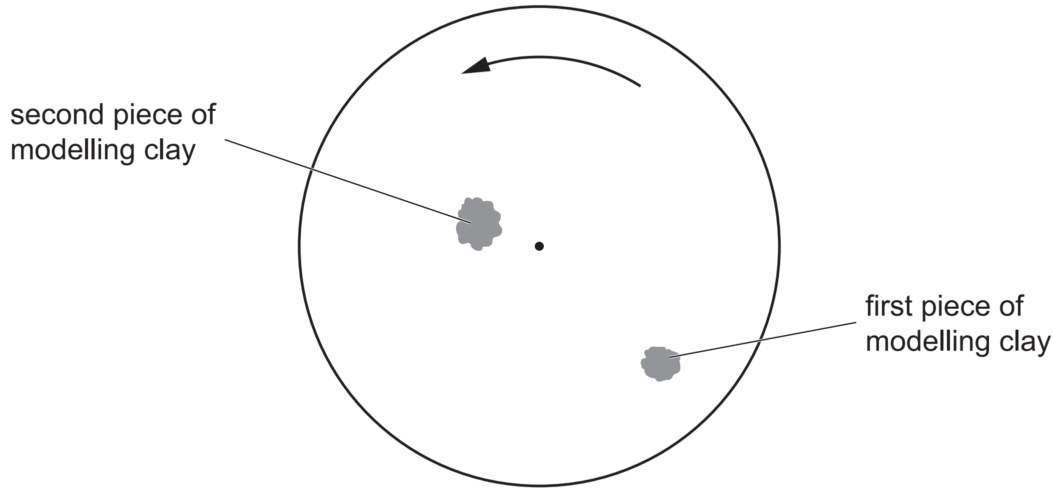

Fig. 1.2

The second piece of modelling clay has a larger mass than the first piece.

By placing **one** tick (✓) in each row, complete Table 1.1 to show how the quantities indicated compare for the two pieces of modelling clay.

Table 1.1

quantity	less for second piece than first piece	same for both pieces	greater for second piece than first piece
angular speed			
linear speed			
acceleration			

[3]

5 **(a)** An object travels in a circle at constant speed.

State the names of **two** quantities that vary during the motion of the object.

1 ....

2 ....
[2]

(b) A charged particle of mass m and with charge q enters a region of uniform magnetic field, perpendicular to the field lines. The magnetic flux density is B.

The particle travels in a circle with period T and radius r.

(i) By considering the magnetic force acting on the particle, show that

$$B = \frac{2\pi m}{qT}.$$

[3]

(ii) The particle is an alpha particle. The period of the circular motion is 2.5 μs.

Calculate B.

B = ... T [2]

(iii) A second alpha particle is in the same uniform field. It travels in a circle of radius $2r$.

State and explain how the periods of the motion of the two particles compare.

....

....

.... [1]

(iv) The speed of the alpha particle in **(b)(ii)** is $1.1 \times 10^6\,\mathrm{m\,s^{-1}}$. An electric field is applied so that this particle now moves with constant velocity.

Use your answer in **(b)(ii)** to calculate the electric field strength E. Give the unit with your answer.

E = ... unit .... [2]

1 **(a)** Define the radian.

....

.... [1]

(b) The minute hand of a clock revolves at constant angular speed around the face of the clock, completing one revolution every hour. A small piece of modelling clay is attached to the hand with its centre of gravity at a distance L from the fixed end of the hand, as shown in Fig. 1.1.

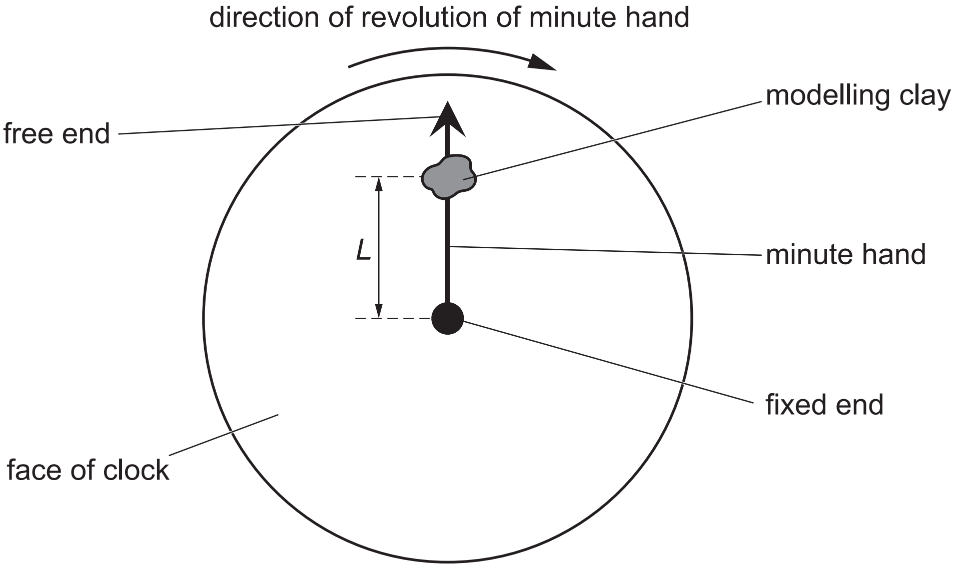

Fig. 1.1

Calculate the angular speed ω of the minute hand.

ω = ... rad s^{-1} [2]

(c) During a time interval of 1400 s, the centre of gravity of the piece of modelling clay in Fig. 1.1 moves through a total distance of 0.44 m.

(i) Calculate the angle through which the minute hand moves in this time interval.

angle = ... rad [1]

(ii) Determine distance *L*.

L = ... m [2]

(iii) Calculate the magnitude of the centripetal acceleration of the piece of modelling clay.

centripetal acceleration = ... $m\,s^{-2}$ [2]

(d) Use your answer in **(c)(iii)** to explain why the variation with time of the magnitude of the force exerted by the minute hand on the piece of modelling clay is negligible as the minute hand undergoes one full revolution.

....

....

.... [2]

2 A steel sphere of mass 0.29 kg is suspended in equilibrium from a vertical spring. The centre of the sphere is 8.5 cm from the top of the spring, as shown in Fig. 2.1.

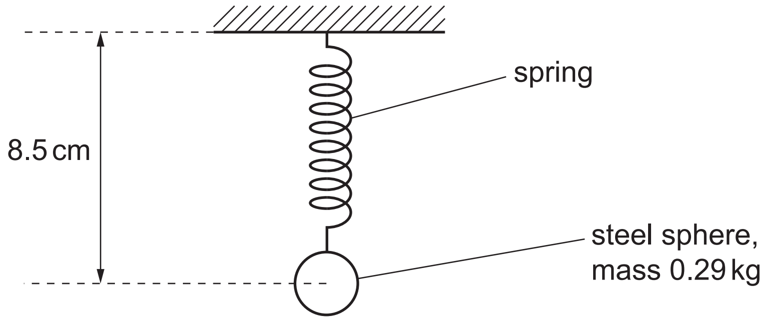

Fig. 2.1

The sphere is now set in motion so that it is moving in a horizontal circle at constant speed, as shown in Fig. 2.2.

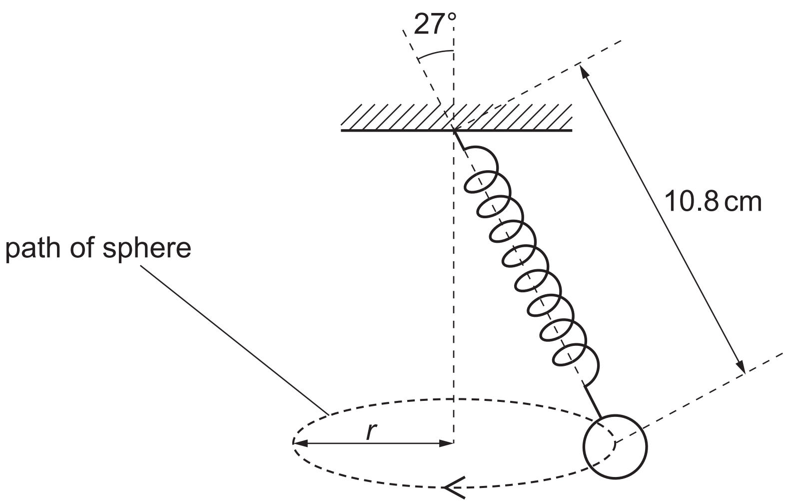

Fig. 2.2

The distance from the centre of the sphere to the top of the spring is now 10.8 cm.

(a) Explain, with reference to the forces acting on the sphere, why the length of the spring in Fig. 2.2 is greater than in Fig. 2.1.

....

....

....

....

.... [3]

(b) The angle between the linear axis of the spring and the vertical is 27°.

(i) Show that the radius r of the circle is 4.9 cm.

[1]

(ii) Show that the tension in the spring is 3.2 N.

[2]

(iii) The spring obeys Hooke's law.

Calculate the spring constant, in $N\,cm^{-1}$, of the spring.

spring constant = ... $N\,cm^{-1}$ [2]

(c) **(i)** Use the information in **(b)** to determine the centripetal acceleration of the sphere.

centripetal acceleration = ... $m\,s^{-2}$ [2]

(ii) Calculate the period of the circular motion of the sphere.

period = ... s [2]