**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 $R$.

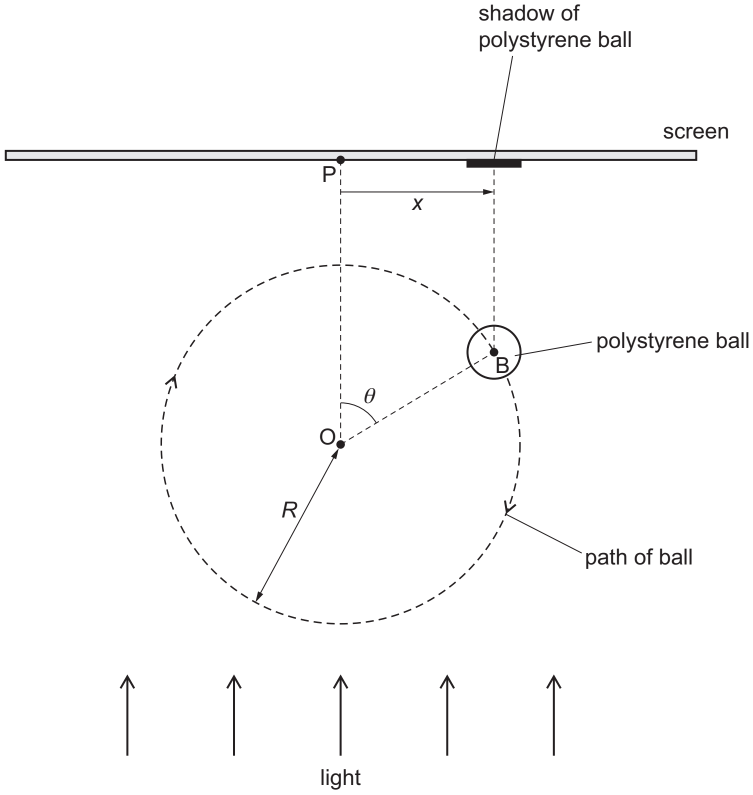


**Fig. 1.1**

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 $\omega$.



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**(i)** State an expression, in terms of $R$ and $\omega$, for the speed $v$ of the ball.

$v$ = ........................................................ [1]

**(ii)** Determine an expression, in terms of $v$ and $\omega$, 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 $\theta$ to the line OP.

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

$x$ = ........................................................ [1]

**(ii)** The value of $\theta$ is zero at time $t = 0$.

State an expression for $\theta$ in terms of $\omega$ and $t$.

$\theta$ = ........................................................ [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]

[Total: 15]





**1** The Earth may be considered as a uniform sphere of radius $6.37 \times 10^6$ 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.

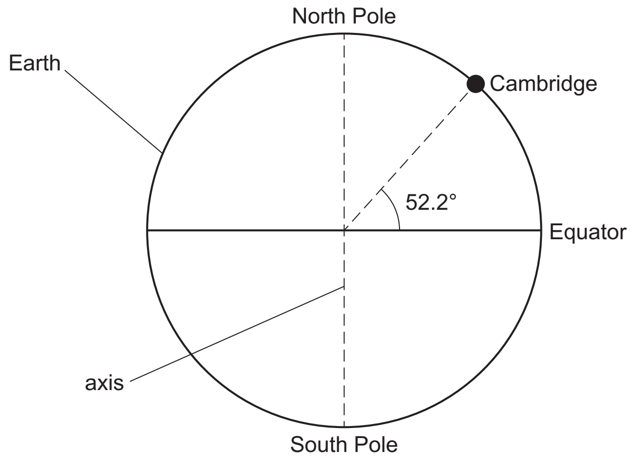


**Fig. 1.1**

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 $3.90 \times 10^6$ m.

[1]

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

speed = ............................................... $m s^{-1}$ [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.

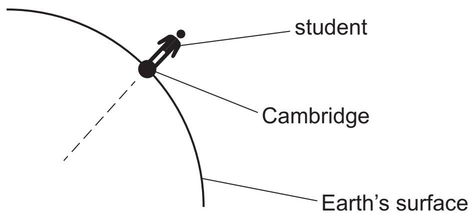


**Fig. 1.2** (not to scale)

[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)**.

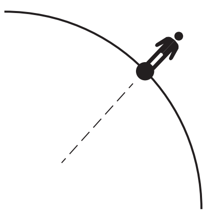

**Fig. 1.3** (not to scale)

[2]

[Total: 9]





**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.

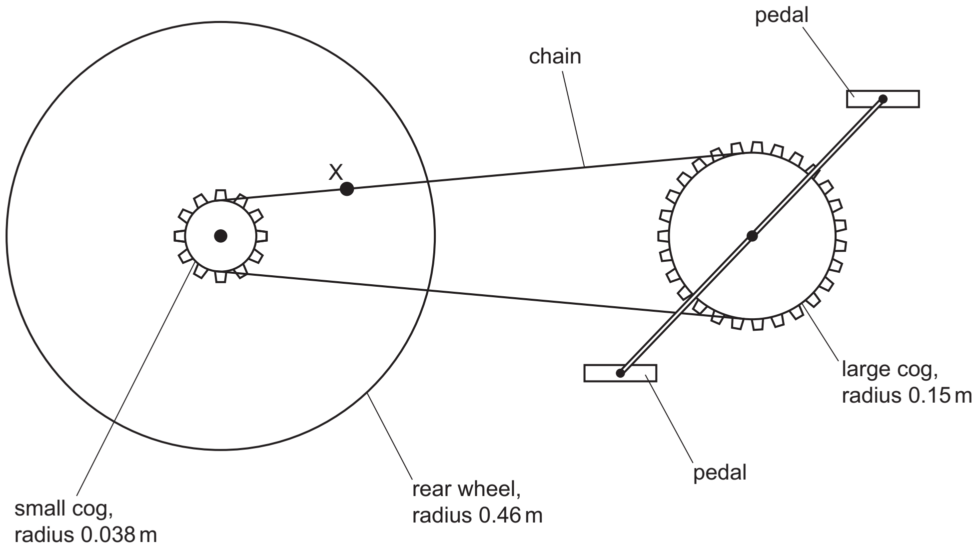


**Fig. 1.1** (not to scale)

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 $17\,\mathrm{m\,s^{-1}}$.

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

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

[Total: 10]





**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.

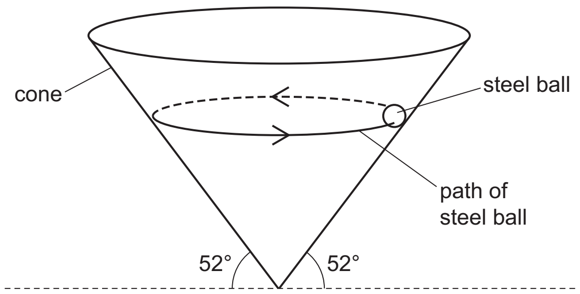


**Fig. 1.1**

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.

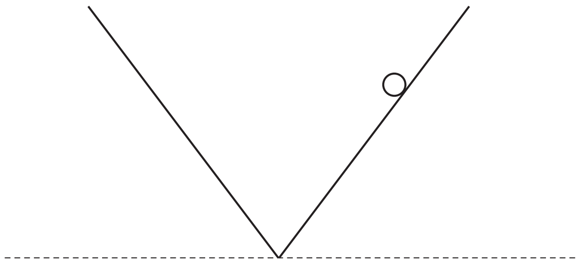

**Fig. 1.2**

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 m s$^{-1}$.

[3]

**(d)** Calculate the angular speed $\omega$ of the ball.

$\omega$ = ............................................. rad s$^{-1}$ [2]

**(e)** The speed of the ball is increased.

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

...................................................................................................................................

...................................................................................................................................

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

[Total: 9]