Circular Motion 1

Exercise A

1 A car windscreen-wiper moves back and forth through an angle of 2.0 radians. Assume that the wiper blade changes direction instantly at the end of its motion.
(a) What is this angle in degrees?
(b) It takes 1.0 s to move from one end of its motion to the other. Plot a graph of its angular displacement in radians starting from the rest position against time for a period of 4.0 s.
(c) Plot a graph of its angular velocity against time for the same time period.
(d) How are the two graphs related?

2 Passengers on a fairground roundabout are 4.0 m from its rotation axis. It rotates once every 12 s.
(a) Write down the angular displacement in degrees and radians of a passenger after a time of 2 s, 6 s, 9 s and 12 s. Is it easier to work in degrees or in radians expressed as a number, or in radians expressed in units of π?
(b) How long does it take for a passenger to move through an angle of $\pi/2$ radians?
(c) The ticket collector walks radially towards a passenger from the centre of the roundabout at 1.5 m s^{-1}. Through what angle, in degrees and in radians, has the roundabout turned when she reaches the passenger? Sketch her path relative to the ground viewed from above.

Exercise B

1 For a passenger in Question 2 of spread 1.2.1, what is his
(a) angular speed?
(b) linear speed?
(c) acceleration?

2 The radius of the Moon's orbit is 3.84×10^8 m. It takes 2.36×10^6 s to rotate around the Earth. Calculate
(a) the speed of the Moon in its orbit
(b) the acceleration of the Moon towards the Earth.

3 All astronauts undergo training inside a rotating test rig to simulate, among other things, the large g-forces experienced at take-off. An astronaut moves in a circle of radius 9.0 m at a rotational frequency of 0.50 Hz.
Calculate her
(a) speed
(b) centripetal acceleration in m s^{-2} and in units of g.

4 In a particle accelerator, electrons travel very close to the speed of light, 3.0×10^8 m s^{-1}. The LEP (large electron–positron collider) accelerator at CERN has a length of 27 km. Calculate the centripetal acceleration of the electrons and positrons in this machine.

Exercise C

1 Figure 3 shows a child of mass 29 kg sitting on a playground roundabout. Her speed is 1.7 m s^{-1}.

(a) Calculate the centripetal force on her.

(b) What provides this centripetal force? Draw a free-body diagram of the girl, and label with values the three forces acting on the girl.

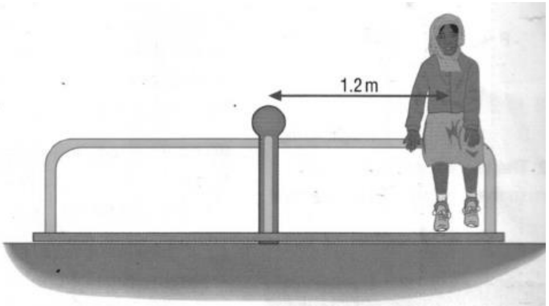

Figure 3

2 The weight of a person at the Equator is different from his weight at the North or South Pole. One of the reasons for the difference is the rotation of the Earth.

(a) Calculate the change in measured weight caused by the rotation. Take the radius of the Earth to be 6.4×10^6 m and the mass of the person to be 70 kg. One day is 8.64×10^4 s.

(b) Is the person's measured weight greater at the Equator or at the North Pole? Explain.

3 A cyclist pedals around a corner in a circular arc of radius 7.0 m at a constant speed of 4.0 m s^{-1}.

(a) What is the resultant force on her and her bicycle of total mass 85 kg?

(b) When going round the corner the cyclist leans inwards towards the centre of the curve. Why is this? Draw a free-body diagram of the cyclist and bicycle, showing the forces acting on them, to illustrate your answer.

Exercise D

1 A mass of 200 g is tied to the end of a string of length 0.99 m so that one pass of its swing is almost exactly 1.0 s. The mass is pulled sideways until it is at a vertical height of 5.0 cm above its rest position. The mass is released. Calculate for the instant that the mass is at the lowest point of its swing:

(a) its speed

(b) its acceleration

(c) the tension in the string.

2 The hammer thrown in athletic events consists of a 7.3 kg metal ball at one end of 1.2 m of strong wire cable. The other end of the cable is a handle. To increase the speed of the ball before release, the athlete whirls it around his body on the end of the wire, as shown in Figure 6.

The radius of the swing is approximately 2.0 m. A good hammer-thrower can release the ball at 25 m s^{-1}. Estimate the pull in the athlete's arms just before releasing the hammer.

Figure 6

3 The curved banking of the cycle racing track in a velodrome is carefully designed. Figure 7 shows the front view of a cyclist travelling in a horizontal circle on a banked section of track at angle θ. The combined weight of cycle and rider is W. The force at right angles to the track that the track exerts on the cycle is R. The dotted line shows the line of action of the resultant force.

(a) Show that $W = R \cos\theta$.

(b) Use (a) to show that $\tan\theta = v^2/gr$, where v is the cyclist's speed and r is the radius of the curve.

(c) For a velodrome with banked track of radius 35 m, calculate the angle θ of the banking for the cyclist riding at 15 m s^{-1}.

(d) For a value of W equal to 785 N, calculate R.

C is the combined centre of mass of the cyclist and bicycle

Figure 7