Cambridge A2 Physics

(Code: 9702)

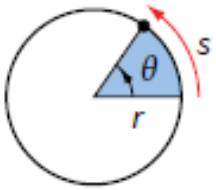
Chapter 17
Circular motion

Describing circular motion

The angle θ through which the object has moved is known as its *angular displacement.*

Angles in radians

$$\theta = \frac{s}{r}$$



$$\theta = \frac{circumference}{radius}$$

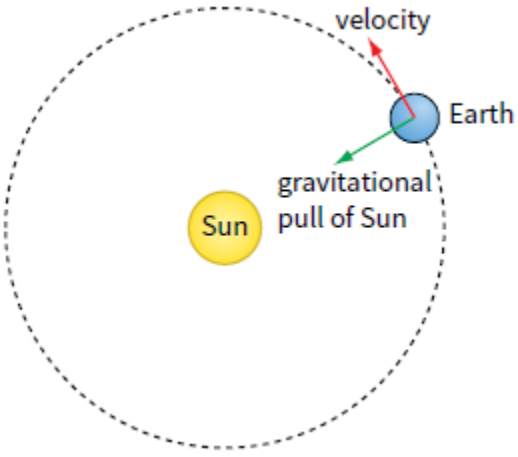
Angular velocity

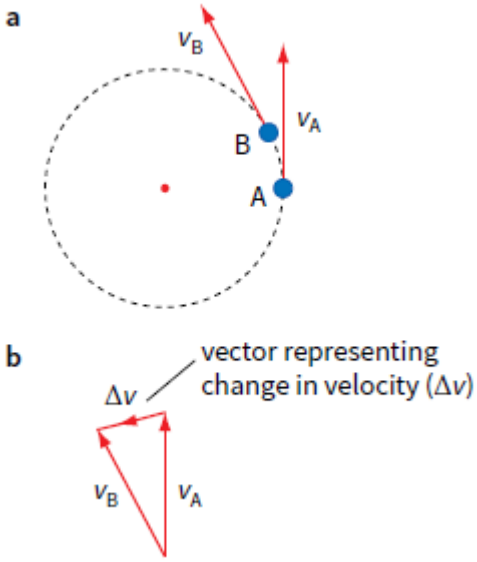
$$\omega = \frac{\Delta\theta}{\Delta t}$$

$$v = \omega r$$

Centripetal force

A force that acts on a body moving in a circular path and is directed towards the centre around which the body is moving.

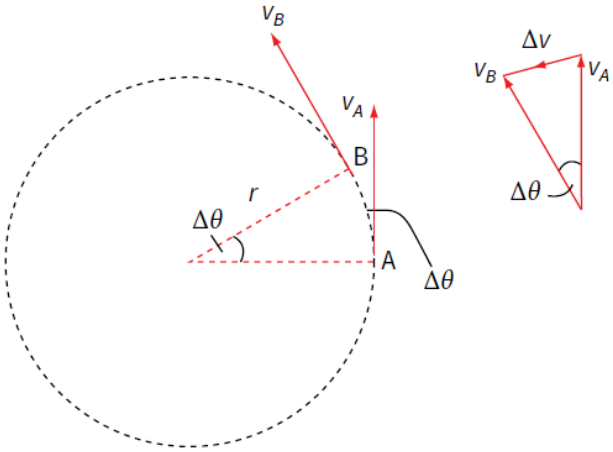




The centripetal force F and acceleration are always at right angles to the object's velocity.

Calculating acceleration and force

$$a = \frac{v^2}{r}$$

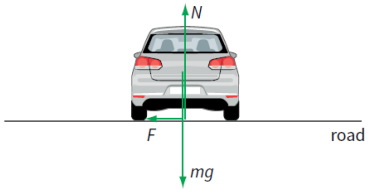


Using newton's laws of motion,

$$F = \frac{mv^2}{r} = mr\omega^2$$

Origins of centripetal force

1.



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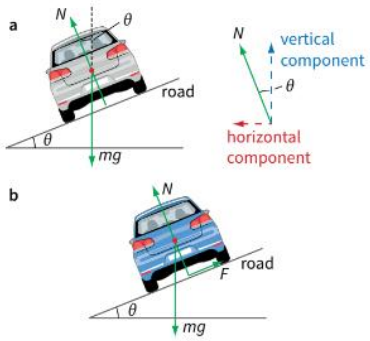

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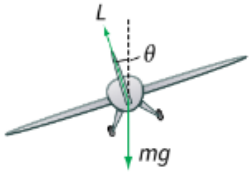

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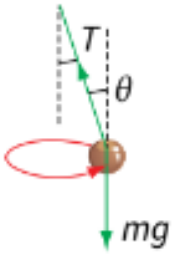

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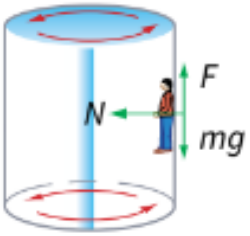


EXCERSISE

1. 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.

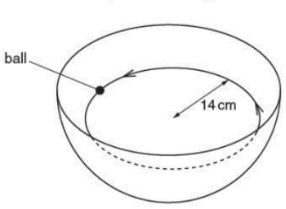


Fig. 2.1

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.

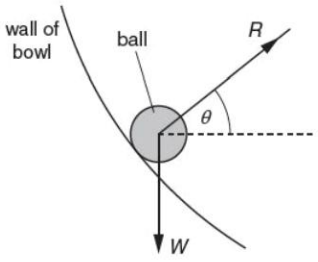


Fig. 2.2

The normal reaction force R is at an angle 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 0.

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

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

2.

a. Define the radian.

b. A telescope gives a clear view of a distant object when the angular displacement between the edges of the object is at least 9.7 x 10-6 rad.

i. The Moon is approximately 3.8x105 km from Earth. Estimate the minimum diameter of a circular crater on the Moon's surface that can be seen using the telescope.

ii. Suggest why craters of the same diameter as that calculated in (i) but on the surface of Mars are not visible using this telescope.

3.

a. 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 5.0N 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.

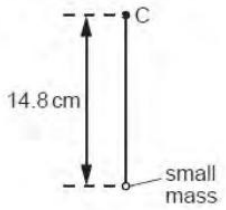
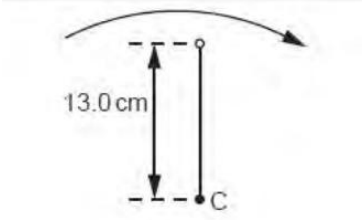


Fig. 1.1

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.



i. Show that the angular speed ω of the cord and mass is 8.7 rads^{-1}.

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.

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.
   b.
      i. Determine tan10.3° to three significant figures.
      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°.

5.
   a.
      i. 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. Explain what is meant by the angular speed about point P of the mass.

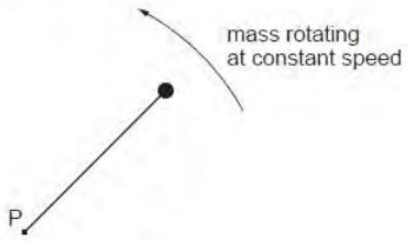


Fig. 1.1

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

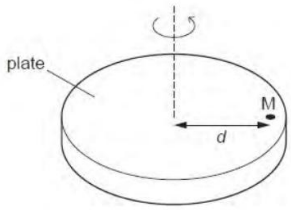


Fig. 1.2

$$F = 0.72W,$$

      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.
   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.