Chapter 6: Motion in a Circle

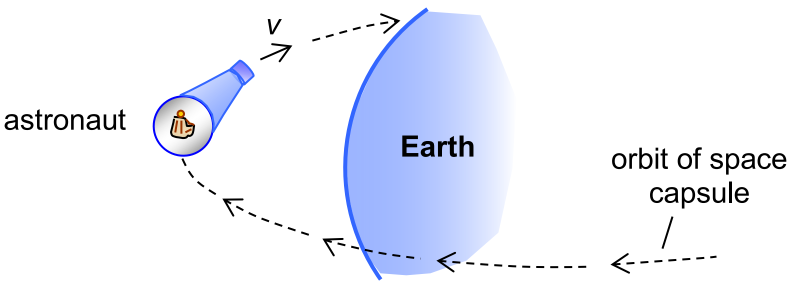
Suggested Problem-Solving Strategy:

Analysis of forces
Step 1: Draw the Free-Body Diagram.
Application of N2L
Step 2: Identify the centre of the circular motion.
Step 3: Apply $\sum F = m\dfrac{v^2}{r}$ ***or*** $mr\omega^2$ along the radial direction
Form other supporting equations
Step 4: for horizontal circular motion: apply $\sum F = 0$(vertical direction). for vertical circular motion/ any circular motion involve change in radius: apply COE.

Please note the following when drawing FBD

- DO NOT draw the centripetal force in the FBD. It is not a force but rather the other forces provide the centripetal force.
- For vertical circular motion, the FBD must be drawn at the correct position required by the question.

1 An astronaut is riding in a space capsule in a circular orbit about the Earth at a constant speed as shown in the diagram.



The resultant force on the astronaut is

A zero as the astronaut experience weightlessness.

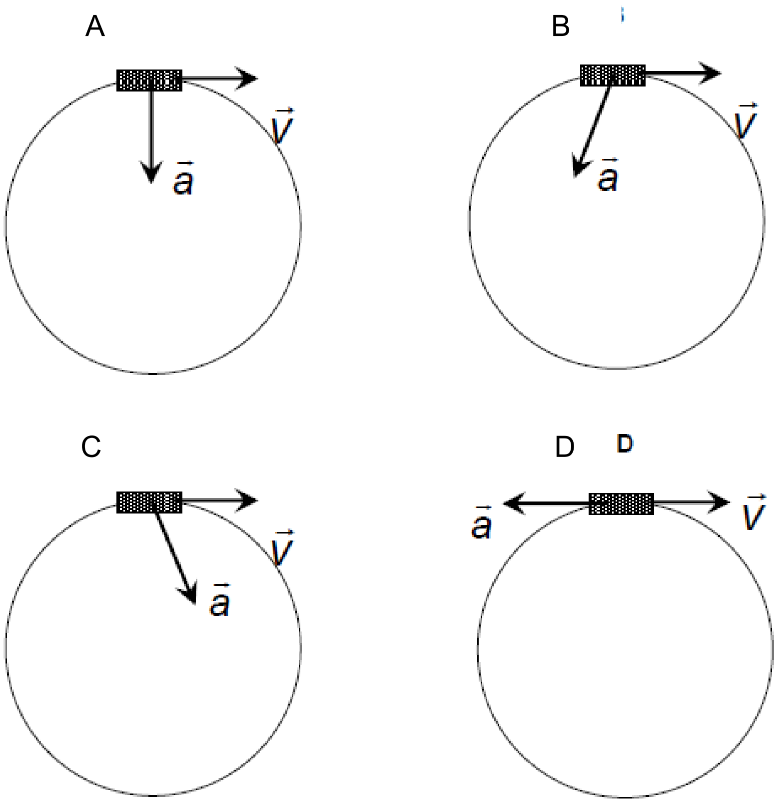
B equal to the magnitude of the normal force exerted by the seat on the astronaut.

C less than his weight, but between his weight and the normal force exerted by the seat on the astronaut.

D the gravitational force on the astronaut.

Worked Example 1

A car is moving in a horizontal circular path. Which diagram shows the acceleration of the car at the instant when it is slowing down?



2 Satellites are moving in circular orbits around the Earth. What is the relationship between the radii *r* of their orbits and their speeds *v*?

A $v \propto r^2$ **B** $v \propto r$ **C** $v \propto \frac{1}{r^2}$ **D** $v^2 \propto \frac{1}{r}$

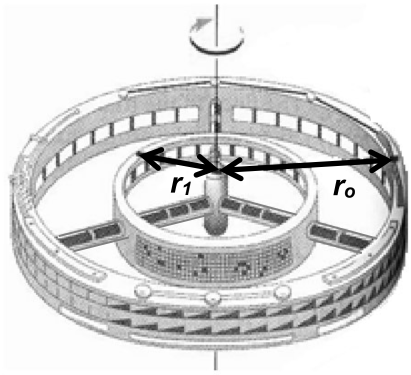
3 One end of a light, inextensible string is attached to the handle of a pail of water which has a total weight of 2.5 N. The other end is held by a hand which swings the pail in a vertical circle (the hand remains at the same position as it swings the pail of water in the vertical circle).

If the pail undergoes uniform circular motion and the maximum tension of the string is 10.0 N, the minimum tension of the string is

A 10.0 N **B** 7.5 N **C** 5.0 N **D** 0.0 N

4 A space laboratory is rotating to create artificial gravity as shown in the figure below. Its period of rotation is chosen so that the outer ring ($r_o = 2150$ m) simulates the acceleration due to gravity on Earth (9.81 m s^{-2}).

What should be the approximate radius r_1 of the inner ring, so that it simulates the acceleration due to the gravity on the surface of Mars (3.72 m s^{-2})?



A 700 m **B** 800 m **C** 900 m **D** 1000 m

Worked Example 2

A pendulum of mass 0.20 kg is whirled in a horizontal circle of radius 0.50 m by a string inclined at 30° to the vertical as shown in Fig. 2.1. The other side of the string is connected to a fixed point.

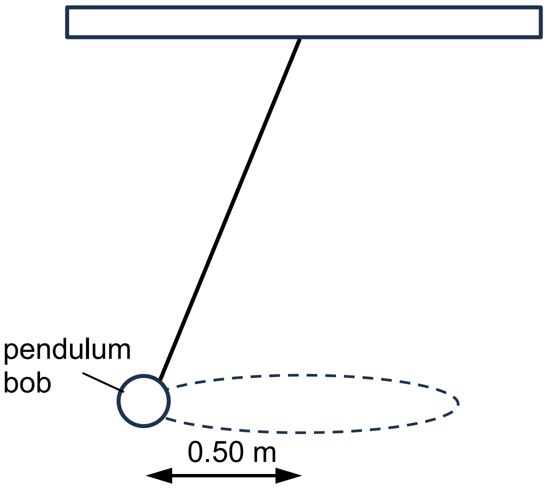


Fig. 2.1

(a) Calculate the linear speed of the particle in the horizontal circle. [3]

(b) Determine the tension in the string. [1]

5 An aircraft of weight 6.5×10^4 N is flying at a speed of 150 m s^{-1} in a horizontal circular path of radius 200 m. The lift force *L* acting on the wings of the aircraft is always perpendicular to it as shown in Fig.5.1

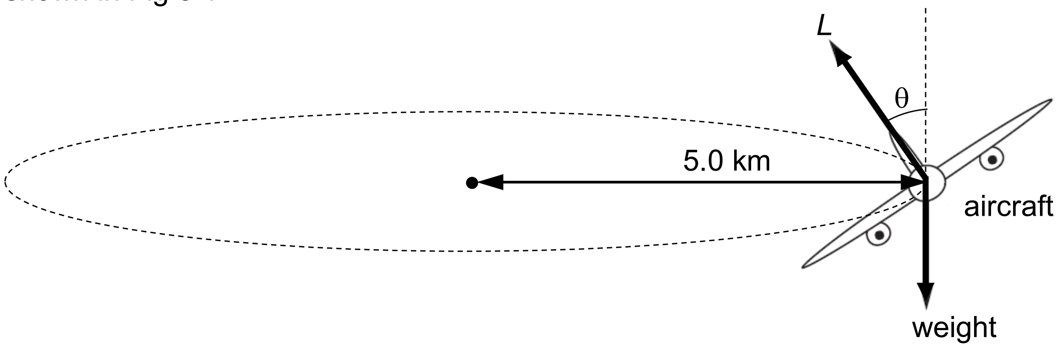


Fig. 5.1

(a) Explain why the aircraft must be tilted when making a turn. [2]

(b) Determine the angle of tilt θ of the aircraft. [4]

(c) Determine the lift force *L* acting on the aircraft. [1]

6 **(a)** The car of mass 1350 kg reaches a bend in the road which follows a circular path with radius of curvature 65 m.
Calculate the centripetal force that must act on the car to make it follow the circular path at a constant speed of 24 m s^{-1}. [2]

(b) Explain why there must be friction between the road and the car tyres for the car to go round the bend. [2]

(c) The maximum frictional force between the car and the ground is given by

$$0.70 \times \text{weight of car}$$

Explain whether the car can travel around the bend at 24 m s^{-1}. You need to carry out the calculation. [2]

7 An unpowered toy car moves freely along a smooth track that is initially horizontal. The track contains a vertical circular loop around which the car travels, as shown in Fig. 7.1.

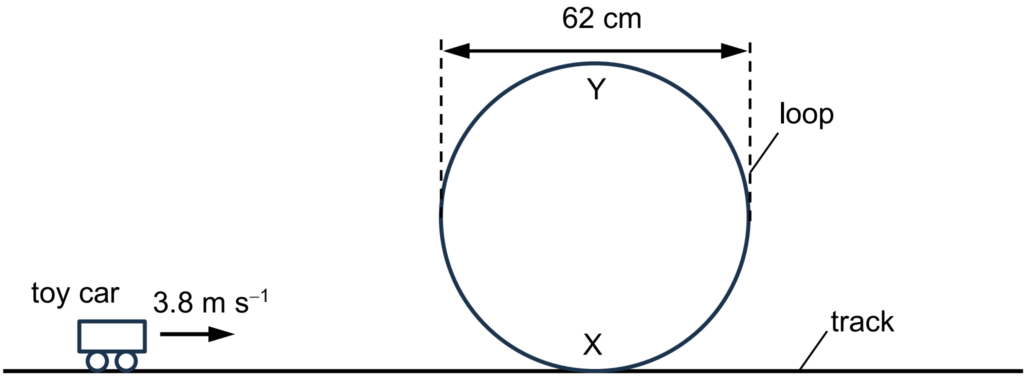


Fig. 7.1

The mass of the car is 230 g and the diameter of the loop is 62 cm. Assume that the resistive forces acting on the car are negligible. The initial speed of the car is 3.8 m s^{-1}.

(a) (i) State and explain what happens to the magnitude of the centripetal acceleration of the car as it moves around the loop from X to Y. [3]

(ii) Explain, if the car remains in contact with the track, why the centripetal acceleration of the car at point Y must be greater than 9.8 m s^{-2}. [2]

(b) (i) Determine whether the car is in contact with the track at point Y. Show your working. [3]

(ii) Determine the normal contact force acting on the toy car when it is at X. [2]