Circular Motion Supplementary Questions

Study Guide 20

Part 1 - Motion in Horizontal Circles

1. The turntable on a record player rotates at 45 revolutions per minute. Calculate:
   i) the angular speed of the turntable;
   ii) the speed of a speck of dust situated 15 cm from the centre.

2. A car moves round a circular track of radius 1.2 km at a constant speed of 125 km/h. Calculate the angular speed of the car.

3. A pulley wheel rotates at 300 revs/min and has a radius of 150 mm. Calculate:
   i) the angular speed of the pulley;
   ii) the speed of a point on the rim of the pulley.

4. A sprinter of mass 70 kg is cornering at 9.4 m/s during a 200 m race. Calculate the centripetal force needed to corner at this speed if the radius of the bend is 38 m.

5. A car of mass 1000 kg is moving at 30 m/s around a bend of radius 0.60 km on a horizontal track. What centripetal force is required to keep the car moving around the bend?

6. The planet Earth travels in a near circular orbit around the Sun with a period of 1 year. The mean distance of the Earth from the Sun is 1.5×10^{11} m. The mass of the Earth is 6.0×10^{24} kg. Calculate:
   i) the angular displacement of the Earth (as it orbits the Sun) after 1 day, giving your answer in degrees;
   ii) the angular displacement of the Earth after 1 day in radians;
   iii) the speed of the Earth in its orbit;
   iv) the magnitude and direction of the Earth's acceleration;
   v) the force on the Earth.

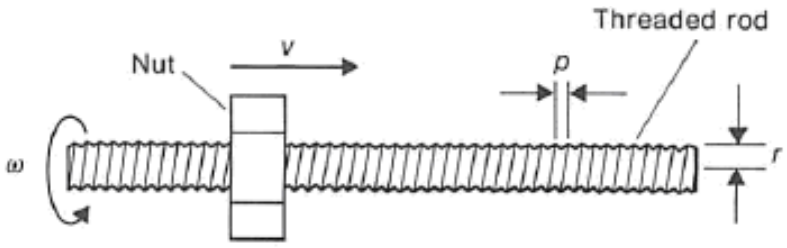
7. An object of mass 0.30 kg is attached to the end of a string and is supported on a smooth horizontal surface. The object moves in a horizontal circle of radius 0.50 m with a constant speed of 2.0 m/s. Determine:
   i) the centripetal acceleration;
   ii) the tension in the string.

8. NASA's 20-G centrifuge is used for testing space equipment and the effect of acceleration on astronauts. The centrifuge consists of an arm of length 17.8 m, rotating at constant speed and producing an acceleration equal to 20 times the acceleration of gravitational free fall. Determine:
   i) the angular speed required to produce a centripetal acceleration of 20 g;
   ii) the speed an object in the centrifuge would be travelling at with a centripetal acceleration of 20 g.

9. A car can provide a maximum sideways frictional force, between the tyres and the road, of 6000 N. The car's mass is 1100 kg. What is the maximum speed at which the car can take a bend of radius 30 m without skidding?

10. The turning circle of Concorde, when flying horizontally at a constant speed of 650 m/s, is of radius 80 km. What is the ratio of centripetal force experienced by the aircraft to the weight of the aircraft?

11*. A thread rod of radius r has a pitch, i.e. the distance between adjacent threads, of p. The rod rotates along its axis, as shown in the diagram, with an angular speed ω. When a nut is held lightly so that it cannot rotate, it is found to move along the rod with speed v. Determine the angular speed of the rod in terms of the parameters of the problem.



12*. A conical pendulum consists of a bob of mass 0.50 kg attached to a string of length 1.0 m. The bob rotates in a horizontal circle such that the angle the string makes with the vertical is 30^{o}. Calculate:
   i) the period of the motion;
   ii) the tension in the string.

Part 2 - Motion in Vertical Circles

1. A child of mass 30 kg is playing on a swing. Her centre of mass is 3.2 m below the supports when she moves through the bottom of her swing at 6.0 m/s. Determine:
   i) her centripetal force;
   ii) the reaction force of the swing's seat on her.

2. At an air show, an aircraft diving at a speed of 170 m/s pulls out of the dive by moving in the arc of a circle at the bottom of the dive.
   i) Calculate the minimum radius of this circle if the centripetal acceleration of the aircraft is not to exceed 5g;
   ii) What is the normal reaction acting on the pilot at the instant when the aircraft is at its lowest point, if the mass of the pilot is 85 kg.

3. An object of mass 4.0 kg is whirled round in a vertical circle of radius 2.0 m with a speed of 5.0 m/s. Calculate the maximum and minimum tension in the string connecting the object to the centre of the circle.

4. A chairoplane rider is travelling at 8.0 m/s in a circle of radius 10.0 m. The mass of the rider and seat is 75 kg. Calculate:
   i) her acceleration;
   ii) the horizontal force in the chain;
   iii) the vertical force in the chain;
   iv) the angle the chain makes with the vertical.

5. The designer of an amusement park ride wants a centripetal acceleration of 19.6 m/s^2 at the top of a loop of radius 7.0 m. Calculate the minimum speed he must ensure the car has at the top of the loop.

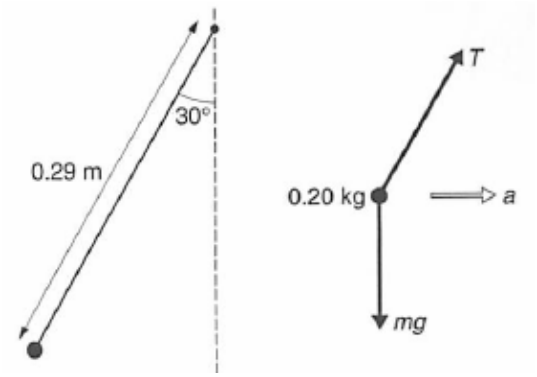
6. A car of mass 950 kg is driven over a hump-backed bridge at a speed of 17 m/s. The road surface of the bridge forms parts of a circular arc of radius 50 m. Calculate:
   i) the normal reaction acting on the car at the top of the bridge;
   ii) the greatest speed at which the car may be driven over the bridge if its wheels are not to lose contact with the road.

7*. An explorer of mass 75 kg measures his weight by standing on a set of weighing scales. He does this at two different locations: the north pole and the equator. Determine the reading on the scales, in newtons, at:

i) the north pole;

ii) the equator.

8*. A metal bob is whirled on the end of a string once every second as shown in the diagram. A free-body force diagram for the bob is also shown. The bob has a mass of 0.20 kg.



Determine:

i) the radius of the circle in which it is moving;

ii) the constant speed v as the bob moves round the circle;

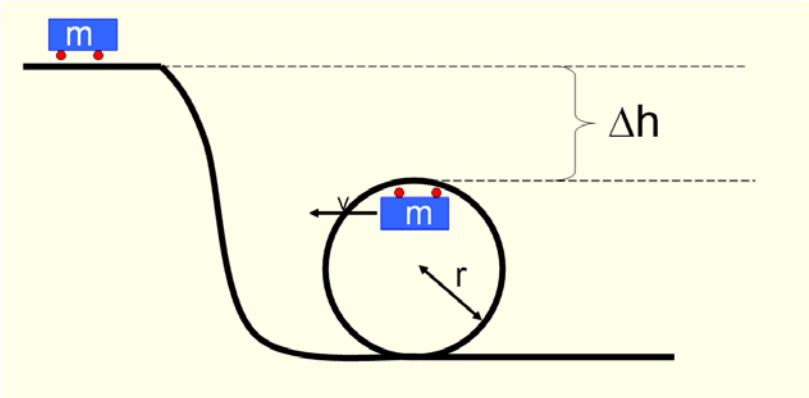
iii) the size of the bob's centripetal acceleration a;

iv) the size of the centripetal force needed to produce the acceleration;

v) the tension T in the string connected to the bob.

9*. A rollercoaster car of mass m is allowed to roll from an elevated platform with negligible initial speed down a track to ground level after which the track is a vertical circle of radius r and the car loops the loop.

Find the minimum extra height, Δh the platform must be above the top of the circle so that the car just stays on the track.



Answers - Circular Motion Supplementary Questions

Part 1

1. i) 4.71 rad/s ii) 0.707 m/s
2. 0.0289 rad/s
3. i) 31.4 rad/s ii) 4.71 m/s
4. 163 N
5. 1500 N
6. i) 0.986^{o} per day ii) 0.0172 rad/day iii) 2.99×10^{4} m/s
   iv) 5.94×10^{-3} m/s^2 v) 3.57×10^{22} N
7. i) 8 m/s^2 ii) 2.4 N
8. i) 3.32 rad/s ii) 59.1 m/s
9. 12.8 m/s
10. 0.538
11*. $2\pi v/p$
12*. i) 1.87 seconds ii) 5.66 N

Part 2

1. i) 338 N ii) 632 N
2. i) 589 m ii) 5000N
3. Min = 10.8 N; Max = 89.2 N
4. i) 6.4 m/s^2 ii) 480 N iii) 736 N
   iv) 33.1^{o}
5. 11.7 m/s
6. i) 3830 N ii) 22.1 m/s
7*. i) 736 N ii) 733 N
8*. i) 0.145 m ii) 0.911 m/s iii) 5.72 m/s^2
   iv) 1.14 N v) 2.27 N
9*. r/2