W5.03

Circular Motion

1. For each of the following situations, give the source of the centripetal force. Be precise. For example, if only one component of a force supplies the centripetal force, indicate that component.
   a. a stone on a rope swung in a horizontal circle in deep space.
   b. a bobsled rounding a frictionless, banked turn.
   c. a satellite in Earth orbit.
   d. a ball swung in a conical pendulum.
   e. a ball on a rope swung in a vertical circle – at the top point with tension = 0.
   f. a car rounding a level turn on the highway.

2. A 1 kg stone is whirled in a horizontal circle that is 2 m in radius by a string which breaks if the tension exceeds 500 N.
   a. What is the maximum speed of the stone?
   b. What is the frequency at this speed?
   c. What is the magnitude and direction of the centripetal acceleration at this speed?

3. A highway curve is designed for a speed of 30 m/s (~65 mph) and is level. If the curve has a radius of 400 m, what μ must the car's tires have with the road in order for the car to negotiate the turn?

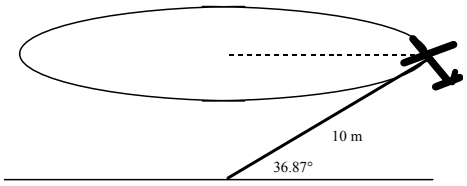
4. An astronaut in training is seated at the end of a horizontal arm 7.0 m long. How many revolutions per second must the arm make for the astronaut to experience a horizontal acceleration of 4.0*g*.

5. What is the centripetal force needed to keep a 3.0 kg mass moving in a circle of radius 0.50 m at a speed of 8.0 m/s?

6. A string 1.0 m long breaks when the tension is 100 N. What is the greatest speed at which it can be used to whirl a 1.0 kg stone? (Neglect the gravitational pull of the earth on the stone.)

7. A 2000 kg car is rounding a curve of radius 200 m on a level road. If the coefficient of static friction between the tires and the road surface is 0.2, what is the highest speed at which the car can round the curve?

8. A dime is placed 10 cm from the center of a record. The coefficient of static friction between the coin the record is 0.30. Will the coin remain on the turn table when the record turns at $33^1/_3$ rpm? At 78 rpm?



9. A 500 g model airplane flies around a horizontal circle while attached to a wire 10 m long that is at an angle of 36.87° above the ground. If the airplane makes one revolution every 5.0 s, what is the tension in the wire? (HINT: What component of the tension in the wire causes the plane to fly in a horizontal circle? What is the magnitude of this component?)

10. A tether-ball pole is spun at 40 rpm with a 2 kg ball at the end of a 1 m rope. What angle does the rope make with the pole?

11. A 2 kg ball is swung in a vertical circle at the end of a 3 m string. At the "3 o'clock" position on the way down, the tension in the rope is found to be 96 N.
    a. What is the speed of the ball at this point?
    b. Using energy methods find the speed of the ball at the bottom of the circle.
    c. What is the tension in the rope at the bottom of the circle?
    d. Mathematically prove whether or not the ball reaches the top of the circle.

12. A bucket of water is whirled in a vertical circle fast enough to keep the water from spilling out. By estimating the length of a person's arm, find
    a. the minimum speed of the bucket in the circle.
    b. the maximum force of the arm on the bucket if the bucket's mass in 10 kg.

ANSWERS:

1. a. Tension
   b. F_{Nx}
   c. F_g
   d. T_x
   e. Mg
   f. F_f

2. a. 31.6 m/s
   b. 2.52 Hz (rps)
   c. 500 m/s^2

3. $\mu = 0.225$

4. $f = 0.38$ Hz (T = 2.63 sec)

5. $F_c = 384$ N

6. v = 10 m/s

7. v = 20 m/s (≈43 mph)

8. With a $\mu = 0.3$, the max frequency is 0.87 Hz (52.3 rpm). Therefore, dime is OK at 33 $^1/_3$ rpm and even at 45 rpm but not at 78 rpm.

9. Tension = 7.9 N

10. $\theta = 55.3°$. Remember the x-component of the tension in the rope (T sin θ) supplies the centripetal force. The y-component of the tension (T cos θ) is equal to the weight of the ball. But don't forget that the radius of the circle isn't 1 m, it's R sin θ.

11. a. v = 12 m/s
    b. v = 14.3 m/s
    c. $T_{bottom} = 156$ N
    d. $v_{crit} = 5.48$ m/s; $v_{top} = 9.17$ m/s by energy methods which is greater than the critical speed.

12. a. $v_{min} = v_{crit} = 3.16$ m/s
    b. $F_{max} = F_{bottom} = W + F_c = 600$ N. Note: $v_{bottom} = \sqrt{5gR}$ if $v_{top} = \sqrt{gR}$ (by energy methods).