CIRCULAR MOTION

1. The drawings on the accompanying pdf show a mass on the end of a string as it is spun counterclockwise in a vertical circle. A pair of scissors is used to cut the string cleanly and instantly at four different positions. Sketch the subsequent trajectory of the mass until it lands on the ground.

2. Which device(s) on a car can be used to control its speed?
   Which device(s) on a car can be used to control its velocity but not its speed?

3. A car driving on a circular test track shows a constant speedometer reading of 200 km / h for one lap.
   a) Describe the car's speed during this time.
   b) Describe its velocity.
   c) How do the two compare?

4. In an unusual move by the New York Department of Transportation, all of the “speed limit” signs in the state were replaced with “velocity limit” signs.
   a) What would such a sign look like?
   b) How could one travel faster than the old speed limit without violating the new velocity limit?

5. Draw a free-body diagram for each of the following situations.
   a) A car turning a corner on level ground;
   b) A model airplane on the end of a string flying in a horizontal circle;
   c) A roller coaster at the top of a vertical loop. (The roller coaster is upside-down.);
   d) A car rounding a banked curve;
   e) A pendulum released from a 60° angle at three points in its motion…
      i. immediately after it’s been released,
      ii. halfway to the bottom, and
      iii. at its lowest point; and

6. A 500 kg race car rounds a curve with a radius of 100 m.
   a) What type of force is the centripetal force in this example?
   b) Find the magnitude of the centripetal force acting on the car when it rounds the curve at 20 m / s.
   c) Find the magnitude of the centripetal force acting on the car when it rounds the curve at 60 m / s.
   d) How does the centripetal force at 60 m / s compare to the centripetal force at 20 m / s?

7. Some people rejected the notion that the earth is rotating when it was first proposed. Since the earth is so large, points on the equator would be moving quite fast and it was thought that objects on the equator would be flung off into space. Show that the acceleration due to gravity is more than sufficient to keep this from happening through the following calculations.
   a) Find the speed of a point on the equator.
   b) How does this speed compare to the speed of sound in air?
   c) Find the centripetal acceleration needed to remain on the equator.
   d) How does the acceleration provided by gravity compare to the centripetal acceleration?

8. A cylindrical space station of diameter 500 m is set spinning to provide the sensation of normal earth gravity. Determine...
   a) the speed of a point on the floor of the space station,
   b) the period of one complete revolution, and
   c) the number of revolutions per minute.

9. In 1959, R. Flanagan Gray, a physician at the Aviation Medical Acceleration Laboratory in Johnsville Pennsylvania, subjected himself to 31.25 g of transverse acceleration for five seconds. This performance, in a water-filled aluminum capsule incorrectly nicknamed the "Iron Maiden", established a new record for centrifugal acceleration tolerance. Given that the capsule was positioned 15 m (50 feet) from the center of rotation, determine...
   a) the speed of the capsule,
   b) the period of rotation, and
   c) the number of rotations during the five seconds of peak acceleration.

10. A stunt motorcycle track has a section which is a vertical loop of radius 5.0 m. At what minimum speed should a motorcycle be driven through...
   a) the top of the loop?
   b) the bottom of the loop?

11. A 0.10 kg solid rubber ball is attached to the end of an 0.80 m length of light thread. The ball is swung in a vertical circle. The speed of the ball is kept constant at 6.0 m/s throughout this experiment. Determine the tension in the thread at...
   a) the top of the circle and
   b) the bottom of the circle.

12. A rock of mass m is tied to a string and spun in a vertical circle of radius r at a constant speed. At the top of the circle, the tension in the string is twice the weight of the rock. Determine the following quantities in terms of g, r, and m...
   a) the tension in the string at the top of the circle
   b) the speed of the rock at the top of the circle
   c) the speed of the rock at the bottom of the circle
   d) the tension in the string at the bottom of the circle

13. As a highway engineer, you wish to design a safe curve for a highway with a speed limit v of 24 m/s (54 mph). Rubber tire on dry pavement has a coefficient of static friction μ_s of 0.75.
   a) What is the relation between the radius r of a turn and the known quantities in this problem for a car that is not skidding out of control? That is, state r as a function of v, μ_s, and g. (Note: a variety of vehicles with different masses will be traveling on this highway. Somehow you must eliminate mass from your equation.)
   b) Given the numbers in this problem, determine the radius of a curve that is just safe enough to allow a car traveling at the speed limit to safely round the corner.
   c) Engineers often "overdesign" their projects to reduce the probability of failure. For example, bridges are built many times stronger than is necessary to just support the weight of traffic. Name at least two things that should be done to ensure that this highway curve is overdesigned.