Vertical Circles

Some common examples of circular motion in a vertical plane are given below:

Example 1
A $0.150\ kg$ ball on the end of a $1.10\ m$ long cord is swung in a vertical circle.

(a) Determine the minimum speed the ball must have at the top of its arc so that the ball continues moving in a circle.

(b) Calculate the tension in the cord at the bottom of the arc, assuming the ball is moving at twice the speed in part (a).

Example 2
The pilot of an airplane, which has been diving at a speed of $540\ km/h$, pulls out of the dive at constant speed in a circular path of radius $328\ m$. If the $80\ kg$ pilot were sitting on a scale (calibrated in Newtons) what would the scale read at the lowest point of the pull-out?

Example 3
At what minimum speed must a roller coaster be traveling when upside down at the top of a circle so that the passengers will not fall out? Assume a radius of curvature of $7.4\ m$.

Circular Motion Worksheet #3

1. A ball on the end of a string is cleverly revolved at a uniform rate in a vertical circle of radius $85.0\ cm$. If its speed is $3.25\ m/s$ and its mass is $0.335\ kg$, calculate the tension in the string when the ball is

   a) at the top of its path. ($0.88\ N$)

   b) at the bottom of its path. ($7.45\ N$)

2. The condition of apparent weightlessness for the passengers can be created for a brief instant when a plane flies over the top of a vertical circle. At a speed of $215\ m/s$, what is the radius of the vertical circle that the pilot must use? ($4717\ m$)

3. A fighter pilot dives his plane toward the ground at $230\ m/s$. He pulls out of the dive in a vertical circle. What is the minimum radius of the circle, so that the normal force exerted on the pilot by his seat never exceeds three times his weight? ($2699\ m$)

4. The maximum tension that a $0.50\ m$ string can tolerate is $14\ N$. A $0.25\ kg$ ball attached to this string is being whirled in a vertical circle. What is the maximum speed that the ball can have

   a) at the top of the circle? ($5.74\ m/s$)

   b) at the bottom of the circle? ($4.81\ m/s$)

5. A $2100\ kg$ demolition ball swings at the end of a $15\ m$ cable on the arc of a vertical circle. At the lowest point of the swing, the ball is moving at a speed of $7.6\ m/s$. Determine the tension in the cable. ($28666\ N$)

6. A stunt driver drives a car so fast that it leaves the ground as it tops a hill. If the hill can be approximated by a $165\ m$ radius vertical circle, what speed must the car exceed if it is to leave the ground? ($40.2\ m/s$)

7. A stunt pilot in an airplane diving vertically downward at a speed of $220\ km/h$ turns vertically upward by following an approximately semicircular path with a radius of $180\ m$.

   a) How many g's does the pilot experience due to his motion alone? (2.12)

   b) By what factor does the pilot's weight appear to increase at the bottom of the dive? (3.12)

8. Snoopy is flying his vintage war plane in a "loop the loop" path chasing the Red Baron. His instruments tell him the plane is level (at the bottom of the loop) and traveling with a speed of $180\ km/h$. He is sitting on a set of bathroom scales, and notes that they read four times the normal force of gravity on him. What is the radius of the loop? ($85\ m$)