*Air resistance is negligible
Circular Motion

1. A student swings a bucket of water in a vertical circle with a radius of 1.5 meters. What minimum speed must the bucket have at the top of the circle so water does not spill out?
2. A 0.5 kg ball is attached to a 1.2-meter-long massless string and is swung in a horizontal circle such that the string makes a constant angle of 20° with the vertical. The ball moves at a constant speed of $3\ m/s$.
    a. What is the radius of the circular path?
    b. What is the tension in the string?
    c. What is the period of the motion?
3. A car of mass 1000 kg is traveling around a flat, circular track with a radius of 80 meters. The coefficient of static friction between the car's tires and the road surface is 0.6. Assume the acceleration due to gravity is $9.8\ m/s^2$.
    a. Determine the maximum speed the car can maintain without skidding off the track.
    b. Calculate the maximum static frictional force that can act on the car without causing it to skid.
    c. Calculate the centripetal acceleration of the car at this maximum speed.
    d. Find the minimum time required for the car to complete one full lap around the track at this speed.
4. A satellite is orbiting Earth, which has a mass of $6 \times 10^{24} kg$ in a circular orbit where the acceleration due to gravity is $5\ m/s^2$.
    a. Calculate the orbital radius of the satellite from the center of Earth.
    b. Determine the altitude of the satellite above the Earth's surface.
    c. Calculate the orbital speed of the satellite.
    d. Find the orbital period of the satellite.
    e. Compute the centripetal acceleration and verify that it equals $5\ m/s^2$.
5. A roller coaster car of mass 600 kg passes over the top of a circular hill with a radius of curvature of 15 meters. The car is moving at a speed of $10\ m/s$ at the hill's highest point. Assume the acceleration due to gravity is $9.8\ m/s^2$. Friction is negligible.
    a. Calculate the normal force exerted by the track on the car at the top of the hill.
    b. Determine the maximum speed the car can have at the top of the hill without losing contact with the track.
    c. If the car's speed is increased to $12\ m/s$, will the car maintain contact with the track at the top of the hill?
    d. Compute the car's centripetal acceleration at the top of the hill when moving at 10 m/s.

6. A conical pendulum consists of a small bob of mass 1.5 kg attached to a 2-meter-long massless string. The bob swings in a horizontal circle at a constant speed such that the string maintains an angle of 25° with the vertical. Assume the acceleration due to gravity is $9.8\ m/s^2$.
    a. Determine the radius of the circular path.
    b. Calculate the tension in the string.
    c. Find the speed of the bob.
    d. Calculate the period of the motion.
    e. Compute the centripetal acceleration of the bob.
    f. Explain how the tension in the string changes if the angle with the vertical increases, assuming the length of the string remains the same.
7. An object of mass 0.5 kg is attached to a massless string and swung in a vertical circle with a radius of 0.8 meters. At the top of the circle, the tension in the string is measured to be 15 N. Assume the acceleration due to gravity is $9.8\ m/s^2$.
    a. Calculate the speed of the object at the top of the circle.
    b. Compute the centripetal acceleration of the object at the top of the circle.
    c. Determine the tension in the string when the object is at the bottom of the circle, assuming it maintains the same speed.
    d. Find the speed at the top of the circle that would make the tension in the string zero.
    e. Explain why the tension is different at the top and bottom of the circle.
    f. If the string can withstand a maximum tension force of 40 N, what is the maximum speed the object can have at the bottom of the circle without breaking the string?
8. A car of mass 1200 kg is moving over a hill that has a circular arc shape with a radius of curvature of 20 meters. The hill can be approximated as the arc of a circle in the vertical plane. Assume the acceleration due to gravity is $9.8\ m/s^2$. Friction is negligible.
    a. Calculate the maximum speed at which the car can travel over the top of the hill without losing contact with the road.
    b. If the car is moving at maximum speed, as calculated in part (a), what is the normal force exerted by the road on the car at the top of the hill?
    c. Explain why the car loses contact with the road if it exceeds the maximum speed calculated in part (a).
    d. Compute the car's centripetal acceleration when it is moving at maximum speed over the top of the hill.
    e. Determine the normal force exerted by the road on the car when it is moving at a speed of 8 m/s over the top of the hill.

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