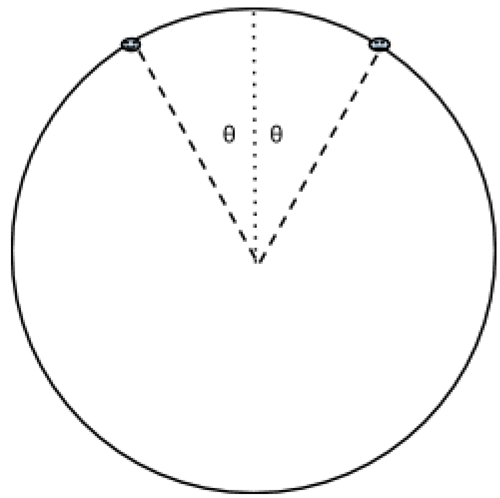
Circular Reasoning

Acceleration Derivation

1. State the three ways for an object to accelerate.
    a.
    b.
    c.



2. On the diagram at the right, draw the velocity vectors for a block traveling in a clockwise circle at a constant speed. Label these $\mathbf{v_i}$ and $\mathbf{v_f}$.

3. At this point, we are going to impose a "normal" coordinate system on the object with +x toward the right of the page and +y toward the top of the page. Sketch the x and y components of velocities on the diagram.

4. Assume the block is traveling with a speed **v**. Use trigonometry to find the x- and y-components of the two velocities shown.

    $\mathbf{v_{ix}=}$ $\mathbf{v_{iy}=}$

    $\mathbf{v_{fx}=}$ $\mathbf{v_{fy}=}$

5. Using the components you calculated, determine the change in the velocity in each direction.

    $\mathbf{\Delta v_x =}$

    $\mathbf{\Delta v_y =}$

6. The distance along the arc of a circle is determined by multiplying the radius of the circle by the angle given in radians. Knowing the block travels at a constant speed, derive an expression for the time it takes to travel from the initial position to the final position in terms of **r, v, s,** and **θ.**

    t =

7. Combine your answers for #5 and #6 to find an expression for the acceleration of the block.

    a =

8. For small angles, $\frac{\sin\theta}{\theta} \approx 1$. Simplify your equation for small angles. This is the magnitude of the centripetal acceleration.

9. What direction is this acceleration?

Practice Problems

10. When the carousel at Santa Monica Pier is up to speed, it takes 8.2 seconds to complete a single loop. The outer horse is traveling 3.1 m/s.
    a. Calculate the angular velocity of the ride.
    b. Determine the radius for the outer horse.

11. Two children are on a merry-go-round that is rotating at 0.5 rad/s. One is standing 1.0 m from the center, while the other is 1.5 meters from the center.
    a. Calculate the linear speed of each child.
    b. Calculate the centripetal acceleration for each child.
    c. Draw a free body diagram for one of the children.
    d. Suppose the child on the outer edge falls off. Draw a diagram to show his path as seen from above.

12. A spin cycle of a washing machine can spin the clothes at a rate of 900 revolutions per minute. Using force arguments, explain the purpose of spinning the clothes at such a high angular velocity.

13. A 25 gram stopper is twirled on the end of a 0.75 m string in a vertical circle. At the top, the stopper is traveling 5.0 m/s.
    a. Draw a free body diagram for the stopper at the top of the motion.
    b. Calculate the centripetal acceleration of the stopper.
    c. Calculate the force of the rope on the stopper at the top of the motion.

14. The same 25 gram stopper and 0.75 m string are used to again produce a vertical circle. This time, the stopper is traveling 5.0 m/s at the bottom.
    a. Draw a free body diagram for the stopper at the bottom of the motion.
    b. Calculate the centripetal acceleration of the stopper.
    c. Calculate the force of the rope on the stopper at the bottom of the motion.

15. A car is traveling 20 m/s when it reaches the top of a hill that has an approximate radius of 75 m. The driver has a mass of 80 kg.
    a. Draw a free body diagram for the driver of the car.
    b. Calculate the centripetal acceleration for the driver of the car?
    c. Determine the apparent weight of the driver.

16. A car is traveling 20 m/s when it reaches the bottom of a valley that has an approximate radius of 75 m. The driver has a mass of 80 kg.
    a. Draw a free body diagram for the driver of the car.
    b. Calculate the centripetal acceleration for the driver of the car.
    c. Determine the apparent weight of the driver.

17. A car is driving around a curve with a radius of 20 m at a constant 20 mi/h.
    a. Calculate the centripetal acceleration of the car.
    b. State the tangential acceleration of the car.
    c. Draw the free body diagram for the 60 kg driver.
    d. Calculate the net force on the driver.
    e. Identify the real force that causes this net force.