Centripetal Acceleration

Unit: Kinematics (Motion)

NGSS Standards: N/A

MA Curriculum Frameworks (2006): 1.8

AP Physics 1 Learning Objectives: 3.A.1.1, 3.A.1.3

Knowledge/Understanding Goals:

- why an object moving in a circle is constantly accelerating

Skills:

- calculate the centripetal force of an object moving in a circle

Language Objectives:

- Understand and correctly use the terms "rotation," "centripetal force," and "centrifugal force."
- Explain the difference between centripetal force and centrifugal force.

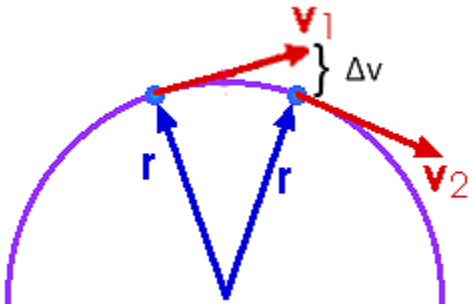
Labs, Activities & Demonstrations:

- Have students swing an object and let it go at the right time to try to hit something. (Have them observe the trajectory.)

Notes:

If an object is moving at a constant speed around a circle, its speed is constant, its direction keeps changing as it goes around. Because ***velocity*** is a vector (speed and direction), this means its velocity is constantly changing. (To be precise, the magnitude is staying the same, but the direction is changing.)

Because a change in velocity over time is acceleration, this means the object is constantly accelerating. This continuous change in velocity is toward the center of the circle, which means *there is continuous acceleration toward the center of the circle.*



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centripetal acceleration (a_c): the constant acceleration of an object toward the center of rotation that keeps it rotating around the center at a fixed distance.

The formula for centripetal acceleration (a_c) is:

$$a_c = \frac{v^2}{r} = \frac{(r\omega)^2}{r} = r\omega^2$$

(The derivation of this formula requires calculus, so it will not be presented here.)

Sample Problem:

Q: A weight is swung from the end of a string that is 0.65 m long at a rate of rotation of 10 revolutions in 6.5 s. What is the centripetal acceleration of the weight? How many "g's" is that? (*I.e.,* how many times the acceleration due to gravity is the centripetal acceleration?)

A: The angular velocity is:

$$\left(\frac{10\,\text{rev}}{6.5\,\text{s}}\right)\left(\frac{2\pi\,\text{rad}}{1\,\text{rev}}\right) = \frac{20\pi}{6.5} = 9.67\,\tfrac{\text{rad}}{\text{s}}$$

The centripetal acceleration is therefore:

$$a_c = r\omega^2$$

$$a_c = (0.65)(9.67)^2 = (0.65)(93.44) = 60.7\,\tfrac{\text{m}}{\text{s}^2}$$

This is $\frac{60.7}{10} = 6.07$ times the acceleration due to gravity.

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