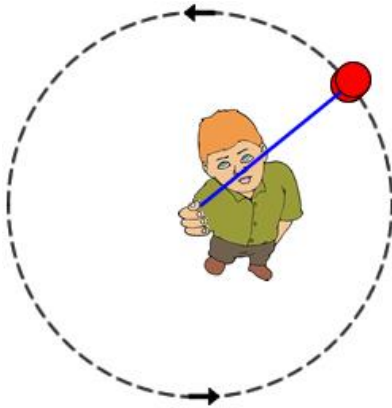Name: _____   Date: _____

Student Exploration: Uniform Circular Motion

Vocabulary: acceleration, centripetal acceleration, centripetal force, Newton's first law, Newton's second law, uniform circular motion, vector, velocity

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)


1. A boy is whirling a yo-yo above his head in a counter-clockwise direction. At the exact moment shown at left, he lets go of the string. In which direction will the yo-yo travel? Draw an arrow on the image to show the yo-yo's direction.

2. Do you think the released yo-yo's path will be straight or

   curved? Explain. _____
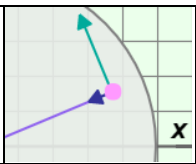
   _____

Gizmo Warm-up

The *Uniform Circular Motion* Gizmo™ shows a pink puck that is floating above a circular air table. The puck is held to the center of the table by a string so that it travels in a circle at a constant speed.

Check that the **radius** is 8.0 m and the **mass** is 5.0 kg. Set the **velocity** to 5.0 m/s.
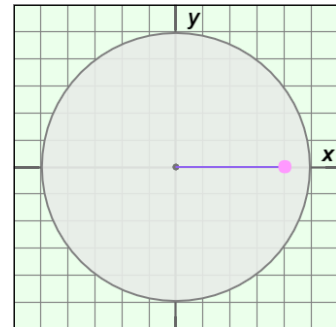
1. Turn on **Show puck position (m)**. What are the coordinates of

   the puck's position? _____

2. Click **Play** (▶), and then click **Pause** (⏸) when the puck is close to the *y*-axis.

   What is the puck's position now? _____

3. Click **Reset** (↺). Select the BAR CHART tab and select **Velocity** from the dropdown menu. The three bars represent the magnitude, the *x* component, and the *y* component of the puck's **velocity**.

   A. Click **Play**. Does the magnitude of the velocity change over time? _____

   B. Do the *x* and *y* components of the velocity change over time? _____

Activity A:	Get the Gizmo ready:	
Velocity, acceleration, and force	• Click **Reset**. • Select the DESCRIPTION tab. • Turn on **Show velocity and acceleration vectors**.	*x*

Introduction: Velocity is a `vector` quantity that describes both the speed and direction of an object's motion. Vectors are represented by arrows. While the speed of the puck is constant, its direction changes continually as it travels in a circle. Because its direction is changing, the puck undergoes `acceleration` even though its speed is constant.

Question: How is the velocity of a revolving body related to its acceleration?

1. <u>Observe</u>: On the SIMULATION pane, observe the directions of the velocity (green) and acceleration (purple) vectors.

   A. What do you notice? _____

   _____

   B. Click **Play**. What do you notice about the vectors as the puck moves in a circle?

   _____

   _____

2. <u>Infer</u>: **Newton's second law** states that a force will cause objects to accelerate in the direction of the force.

   A. Given the fact that the puck is accelerating, what can you conclude? _____

   _____

   B. What is the direction of the force on the puck as it travels in a circle? _____

   _____

3. <u>Compare</u>: Think about the force that causes a planet to orbit the Sun and the direction of this force. How does the puck on the table relate to a planet orbiting the Sun? What forces are acting on the puck and what forces are acting on the planet?

   _____

   _____

   _____

(Activity A continued on next page)

Activity A (continued from previous page)

4. Infer: **Newton's first law** states that an object will continue at
   the same velocity (speed and direction) unless acted upon by
   an unbalanced force. Click **Pause** when the puck is in
   approximately the position shown at right. Imagine at this
   moment the string connecting the puck to the center is cut.
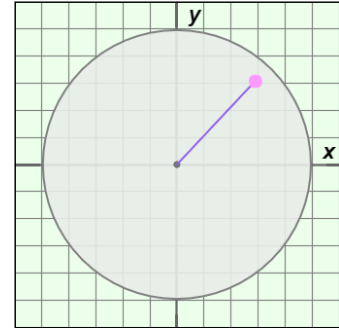
   A. Is any force acting on the puck now? _____

   B. Draw an arrow on the image to represent the direction
      of the puck's motion.

   C. Would the path of the puck be straight or curved? _____

5. Apply: If the string connecting the puck to the center is cut, there will be no net force on the
   puck. (The force of gravity is offset by the turntable.) The puck will not accelerate or change
   direction, so it will move at a constant speed in the direction it was moving at the time the
   string was cut.

   How does this relate to the boy whirling a yo-yo given at the start of this Exploration sheet?

   _____

   _____

6. Think and discuss: If you are sitting in the back seat of a car that makes a hard left turn, you
   will feel pushed toward the right side of the car. Why does your body move to the right?

   _____

   _____

   _____

   _____

Activity B: Centripetal acceleration	Get the Gizmo ready: • Click **Reset**. • Set the **radius** to 2.0 m, the **mass** to 1.0 kg, and the **velocity** to 10.0 m/s.	10.00 -10.00

Introduction: The acceleration toward the center that keeps objects in uniform circular motion (circular motion at a constant speed) is called centripetal acceleration. An understanding of centripetal acceleration was one of the key elements that led to Newton's formulation of the law of universal gravitation.

Question: How is centripetal acceleration related to radius, mass, and velocity?

1. Record: Select the BAR CHART tab, select **Acceleration** from the dropdown menu, and turn on **Show numerical values**. The bar on the left shows the magnitude of the acceleration, or |a|. The units of acceleration are meters per second per second, or m/s^2.

   What is the current magnitude of the acceleration? _____

2. Predict: How do you think the magnitude of the acceleration will depend on radius, mass, and velocity? Record your predictions by completing each sentence.

   When the radius increases, the centripetal acceleration will _____.

   When the mass increases, the centripetal acceleration will _____.

   When the velocity increases, the centripetal acceleration will _____.

3. Gather data: Keeping the **mass** at 1.0 kg and the **velocity** at 10.0 m/s, record the magnitude of centripetal acceleration for each given radius value. Include units.

Radius:	2.0 m	4.0 m	6.0 m	8.0 m	10.0 m
Acceleration:					
Radius factor:					
Acceleration factor:					

4. Calculate: To calculate the radius factor, divide each radius by the original radius (2.0 m). To calculate the acceleration factor, divide each acceleration value by the original acceleration (50.00 m/s^2).

5. Analyze: How does the acceleration change when the radius is multiplied by *x*? _____

   _____

(Activity B continued on next page)

Activity B (continued from previous page)

6. Explore: Move the **mass** slider back and forth. Does the puck's mass have any effect on its

   acceleration? Explain. _____

   _____

7. Gather data: Set the **radius** to 2.0 m and the **velocity** to 1.0 m/s. Keeping the radius the
   same, record the magnitude of centripetal acceleration for each given velocity. Include units.

Velocity:	1.0 m/s	2.0 m/s	3.0 m/s	4.0 m/s	5.0 m/s
Acceleration:					
Velocity factor:					
Acceleration factor:					

8. Calculate: To calculate the velocity factor, divide each velocity by the original velocity
   (1.0 m/s). To calculate the acceleration factor, divide each acceleration value by the original
   acceleration (0.50 m/s^2).

9. Analyze: How does the acceleration change when the velocity is multiplied by x? _____

   _____

10. Make a rule: Based on your investigations, create an equation for centripetal acceleration
    (a_c) based on the velocity and radius. Test your equation using the Gizmo.

    $$a_c =$$

11. Apply: Without using the Gizmo, use your equation to calculate the acceleration of a puck

    that is in uniform circular motion with a radius of 3.0 m and a velocity of 9.0 m/s: _____

    Check your answer with the Gizmo.

12. Challenge: Newton's second law states that force is equal to the product of mass and
    acceleration: $F = ma$. Based on Newton's second law, what is the **centripetal force** (F_c) on
    a puck in uniform circular motion with mass m and velocity v?

    $$F_c =$$