AP Lab #9: Exploring Rotation- Angular versus Linear Quantities (Big Idea 3)

In this investigation you will explore the relationship between linear (i.e., tangential) velocity and the radius of a circle as well as the angular velocity and the radius of a circle. In this lab, you will design an experiment using a photogate to determine how the radius of a circle affects the tangential velocity of an object in circular motion. You will be able to use the photogate to measure the instantaneous velocity of an object. In this lab, you will also determine the effect of the radius of a circle on the angular velocity of an object in circular motion.

Exploring Rotation Angular versus Linear Quantities Pre-Lab:

Imagine two children riding adjacent horses on a carousel ride. This scenario involves both circular and rotational motion. The carousel rotates around its center axis while the children travel in a circular path around the center of the carousel. Student 1 says to student 2, "the children are traveling together with the same speed since they both pass us at the same time. If they are traveling together, they must be traveling at the same velocity." Student 2 says, "I disagree, the child further from the center of rotation is moving a greater distance or circumference around the carousel in the same amount of time. Therefore, this child must be moving faster."

P1) In the scenario described above, which student is correct? Please justify your response.

P2) There are actually two different ways you could measure the displacement of each child. List the two types of displacements that can be measured when an object travels in a circular path.

If the motion of an object traveling in a circle can be described using two different types of displacements, it should make sense that the motion of the object may be described by two different types of velocity.

P3) List the two different types of velocities that can be used to describe a child moving on a carousel.

P4) What is the difference between the two types of velocities you listed in question #3? What does each one measure? What does each one not measure? List an example of each type of velocity described.

P5) State the equation that relates these different velocities.

P6) Imagine a bug sitting on a fan blade located 25 cm from the center of the fan. The following velocities each describe a velocity, either in angular or linear terms. Complete the following conversions:

8.5 rad/s = _____ m/s; 33 rpm = _____ rad/s; 45 rpm = _____ m/s; 78 rpm = _____ rps

P7) If two children on a carousel are traveling together, how can we say that their velocities are both the same, yet different? Provide an explanation that clarifies this statement.

P8) State the equation that converts the linear quantity of displacement to an angular quantity.

P9) State the equation that converts the linear quantity of acceleration to an angular quantity.

Exploring Rotation Angular versus Linear Quantities Lab:

Materials: rotation apparatus, rotation disk, disk pegs, photogate, LabQuest probe, computer (w/ Logger Pro)

The rotation disk is a device specifically designed for this activity. It can be used to explore how the radius of a circle affects the tangential velocity of an object moving in the circle. The disk is placed onto the rotating platform that will rotate at a constant rate. The disk contains a series of holes located in a radial line. The peg is inserted into a hole, serving as the object whose motion can be studied. A photogate is used as a tool to measure the instantaneous velocity of the object. The figure below shows the rotation apparatus set-up for the lab:

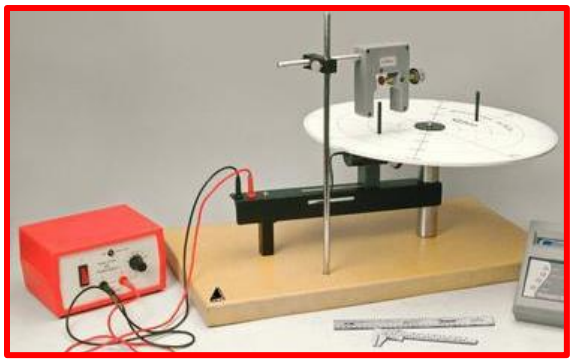

Figure 1: The rotational apparatus set-up with the power supply at 3 volts and the photogate positioned so it will not hit the pegs as it rotates. Calipers may be needed depending on your experimental design. Please turn off the power supply when it is not in use to ensure the fuse does not blow.

Vernier Photogates: The photogates need to be attached the digital ports on the LabQuest units. These ports are located on top of the unit. You will need to set the gate mode on the unit to "pulse mode". To do this, make sure you are on the meter screen, which is the screen without a graph. Then click either the "mode" or "timing" icon on the right side of screen. The mode should say "photogate timing" and the photogate mode should be set to "pulse". The pulse mode measures the time the gate is first blocked until the second time it is blocked. This allows the probe to calculate the tangential velocity with a very high degree of accuracy. The distance between gates will need to be entered and changed each time you change the peg position. To ensure the photogate is working properly, you may pass your hand through the gate and a red light should blink on and off.

Attaching Power Supply: Make sure the power supply is unplugged/turned off and the voltage is set to 3 V. Attach the banana plugs to the power supply and the rotational apparatus. Double check to ensure the red matches red and the black matches the black. Never leave the unit on for extended periods of time and never increase the voltage beyond 3 V. Do not place additional objects on the rotation platform.

Design an Experiment: Design an experiment using the provided materials to determine how the radius of a circle affects the tangential velocity of an object moving in a circle. In your lab notebook you will need to label and include the following:

- State an objective for the experiment
- State a hypothesis for the experiment
- In detail, describe the procedure you plan to use to address your objective
- Prepare an appropriate data table to organize your measurements
- At minimum, show all calculations for tangential velocity, angular velocity, period, and frequency.

Conduct the Experiment: At this time you may turn on the rotational apparatus and start collecting your data. Remember, if you are not collecting data, please turn off the power supply. Make sure the pegs on the disk will not hit the photogate. Conduct the appropriate number of trials to minimize sources of systematic and random error. At minimum, show all calculations for tangential velocity, angular velocity, period, and frequency.

Exploring Rotation Angular versus Linear Quantities Post-Lab:

Q1) Create a graph for the tangential velocity versus the radius. This graph must be ¾ -1 page in size and should include labeled axes, units, and a title. This should be a line of best fit.

Q2) Create a graph for the angular velocity versus the radius. This graph must be ¾ -1 page in size and should include labeled axes, units, and a title. This should be a line of best fit.

Q3) Using semi-quantitative reasoning, compare and contrast the effects of the radius on the tangential velocity and the radius on the angular velocity. Explain the mathematical relationship in your comparison.

Q4) Explain the significance of the slope for both graphs. Again use a semi-quantitative approach and be sure to visually show how the graph data align to $y = mx + b$.