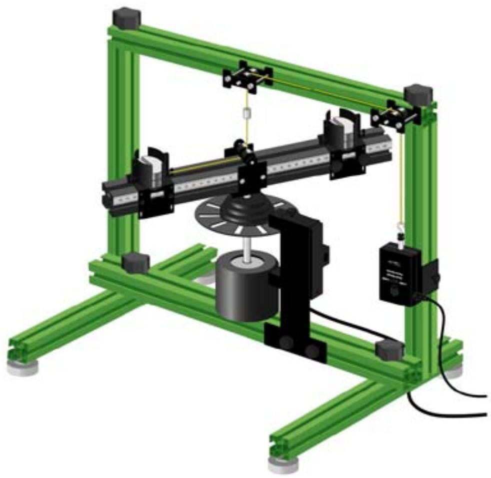
ACCELERATION AND FORCE IN CIRCULAR MOTION

In this experiment you will investigate the direction of acceleration in circular motion. You will also explore the relationship between centripetal force and angular speed.

MATERIALS



Vernier Centripetal Force Apparatus	masses
Vernier Photogate	Protractors and Rulers
Vernier Dual-Range Force sensor	

Set up the Centripetal Force Apparatus with a photogate and Force Sensor as shown below. Follow the instructions in the CFA manual to properly level the apparatus on the lab table.

Experiment File : UPJ folder → CFA-photogate-angular

Acceleration in Circular Motion

Since acceleration is the rate of change of velocity and velocity is a vector, any change in the magnitude and/or direction of velocity will produce acceleration. In this section we will use graphical method of vector addition to investigate the direction of acceleration of an object moving on a circular path for three different scenarios:

1. The object is moving on a circular path with constant speed.
2. The object is moving on a circular path and speeding up.
3. The object is moving on a circular path and slowing down.

Circular Motion with Constant Speed

Draw the two velocity vectors for an object traveling counter-clockwise on a circular path with a speed of 4.0m/s at the instances when the object passes the points marked with a dot on the diagram in the worksheet. Use tail-to-tip method of vector addition to find $\mathbf{V}_{final}$ - $\mathbf{V}_{initial}$. Notice that as the time interval between $\mathbf{V}_{final}$ and $\mathbf{V}_{initial}$ approaches zero, the direction of $\mathbf{V}_{final}$ - $\mathbf{V}_{initial}$ approaches the direction of the instantaneous acceleration.

Circular Motion – Speeding up

An object is moving counter-clockwise around a circular path and it is speeding up. The magnitude of its velocity when it passes the first point on the diagram in the worksheet is 4.0m/s and when it passes the second point is 6.0m/s. Draw the two velocity vectors. Use tail-to-tip method of vector addition to find $\mathbf{V}_{final}$ - $\mathbf{V}_{initial}$.

Circular Motion – Slowing down

An object is moving counter-clockwise around a circular path and it is slowing down. The magnitude of its velocity when it passes the first point on the diagram below is 6.0m/s and when it passes the second point is 4.0m/s. Draw the two velocity vectors. Use tail-to-tip method of vector addition to find $\mathbf{V}_{final}$ - $\mathbf{V}_{initial}$.

Centripetal Force in Circular Motion

Examine your vector diagrams above and notice that no matter how the object moves around a circular path, it will always have radial (also called *centripetal*) acceleration. The magnitude of this centripetal acceleration i**s** $a_c = v^2/r$. In terms of angular speed, expressing v as rω, centripetal acceleration can be written as $\mathbf{a_c = r\omega^2}$.

This acceleration is due to the change in direction of velocity. Based on Newton's Second Law, acceleration is the result of an unbalanced force. Therefore, in a circular motion, there must be an unbalanced force pointing toward the center of the circular path that produces the centripetal acceleration.

The graphs on the worksheet show the centripetal force (labeled as *force interpolated*) vs angular velocity-squared (ω^2). These graphs are generated using the Centripetal Force Apparatus by varying the mass of the object and the radius of its circular path. Your task is to find the combination of mass and radius that, in each case produces the same straight line with a slope within 5.0% of what is shown. Clearly explain your strategy in your report.

Directions for collecting data with the Centripetal Force Apparatus

- The fixed carriage serves as counterweight and keeps the apparatus balanced. Be sure to maintain its mass and radius the same as that of the sliding carriage.
- To adjust the radius of the sliding carriage you must move the force sensor up or down along the vertical arm of the apparatus. Set the radius to the desired value while the string is taut.
- Make sure the force probe reads zero when the string attached to the sliding carriage is slack. If not, zero it by clicking on the blue **0** button at the top of the screen.
- Data is collected while rotation is slowing down. Spin the beam by twisting the knurled spindle with your fingers. Begin collecting data and let go of the spindle. Collect data for at least 30 seconds. You won't see all the graphs till the data collections stops. Use the friction between your fingers and the knurled spindle to stop the beam.
- You can change the quantity that is plotted along a certain axis by clicking on the label for that axis and selecting the desired quantity.
- To fit the data with a straight line click on  from the top menu.
- You must produce all three sets of lines on the same graph. When you have a set of data you want to keep, in LoggerPro, click on "Experiment" from the menu bar and select "Store Latest Run".

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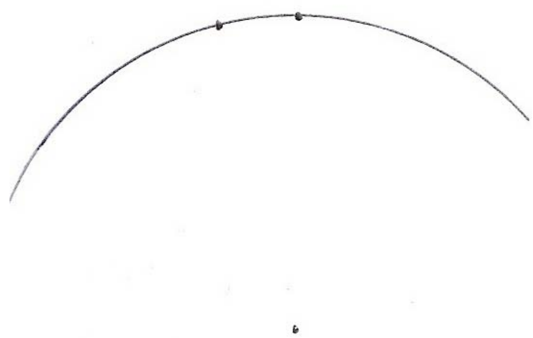
WORKSHEET

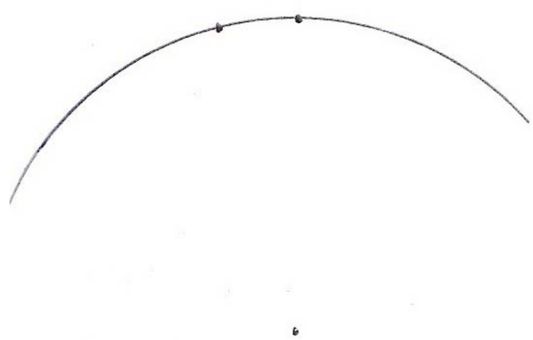
In all the following vector diagrams use this scale: **1.0m/s → 1.0cm**

Circular Motion with Constant Speed



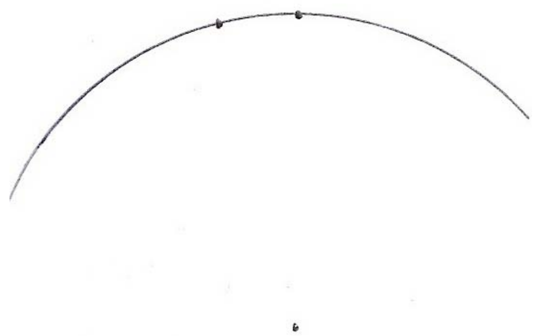
Does the acceleration have a radial component? Does it have a tangential component? Explain.

Circular Motion – Speeding up



Use a different color to show the radial and tangential components of the acceleration. Clearly mark them with a_r (or a_c for *centripetal acceleration*) and a_t. Is the direction of tangential acceleration the same or opposite to the direction of instantaneous velocity? Does this make sense to you? Explain.

Circular Motion – Slowing down



Use a different color to show the radial and tangential components of the acceleration. Clearly mark them with a_r and a_t. Is the direction of tangential acceleration the same or opposite to the direction of instantaneous velocity? Does this make sense to you? Explain.