Name: ______________________________
Partners: ______________________________
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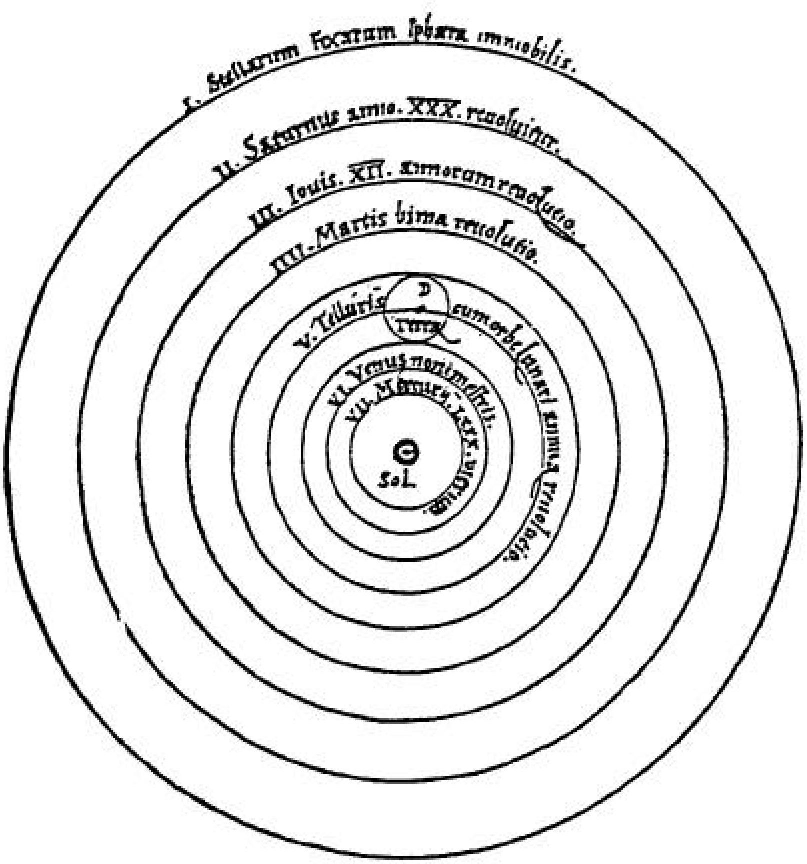
PHYSICS 220 LAB #6: CIRCULAR MOTION



The picture above is a copy of Copernicus' drawing of the orbits of the planets which are nearly circular. It appeared in a book published in 1543. Since the direction of their motion is changing the planets are accelerating. According to Newton's Second Law there must be a net force on any object if it is accelerating. It this laboratory, you will study circular motion using very simple equipment.

(equipment: plane, meter stick, stopwatch)

OBJECTIVES

1. To understand the relations between the quantities that describe uniform circular motion (radius, angular velocity, tangential speed, and centripetal acceleration).
2. To determine the amount of force keeping an object moving in a circle and compare it to what is expected from the

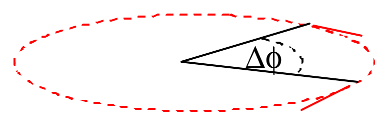
PRE-LAB (to be completed before coming to lab)

Prior to coming to lab, read through this write-up and perform all the exercises labeled "**Pre-Lab**". You will also want to copy this work onto the back pages of the lab, which I will collect during the first 5 minutes of lab.

OVERVIEW

An object moving in a circle at a constant speed is said to be undergoing <u>uniform circular motion</u>. The average angular velocity of an object moving in a circle is the angular displacement divided by the time taken. For going around a circle once:

$$\bar{w} = \frac{\Delta f}{\Delta t} = \frac{2p}{t}$$



If the rate of rotation is constant, the instantaneous angular velocity is the same as the average angular velocity. The most useful units for angular velocity are radians/second. Remember the conversions between different units for the angle:

$$2p \text{ radians} = 360° = 1 \text{ revolution}$$

An object moving in a circle always has a velocity that is tangent to the circle. The tangential speed of an object is the radius times the angular speed:

$$v_T = rw$$

Even if the speed is constant, the direction of the velocity changes during circular motion so there is an acceleration. For uniform circular motion, the acceleration is toward the center and the size of it is:

$$a_c = \frac{v^2}{r}$$

Since the acceleration is toward the center, the net force in the radial direction must also be the mass times the centripetal acceleration.

$$\sum F_{radial} = ma_c$$

PART ONE: Kinematics of Circular Motion

1. Get the plane moving in a steady motion and make the following two measurements. Try to do them back-to-back. If you wait too long between measuring T and r, the orbit could degrade.
2. Use a stopwatch to measure the time required for the plane to complete one revolution by averaging the time taken for ten revolutions.

   T = _______________

3. Measure the radius of the circle around which the plane is traveling (use the location where the plane is attached to the string). If it's easier, you could measure down from the ceiling to the plane to find its height, h, and from that and L find r.

r =_______________

4. Calculate the angular velocity of the plane in radians per second. Show your work.

w = ______________

5. Calculate the tangential velocity of the plane. Show your work.

v_T = ______________

6. Calculate the centripetal acceleration of the plane. Show your work.

a_c = ______________

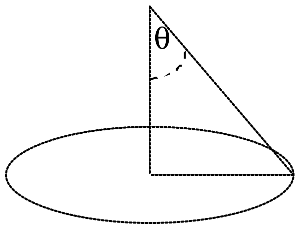
PART TWO: Dynamics of Circular Motion

1. Stop the plane and bring it, and it's string down from the ceiling.
2. Measure the length of the string attached to the plane.

L = ______________

Pre-Lab: Write an expression for the angle θ (see picture below) in terms of r and L.

3. Determine the angle that the string made with vertical when the plane was in motion. Show your work (a picture will be helpful).



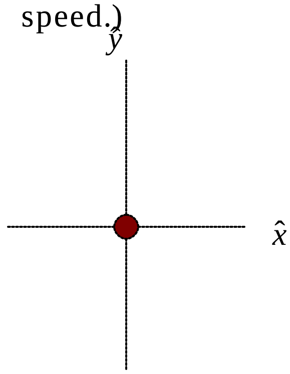
$\theta =$ ______________

4. Measure the mass of the plane.

m = ______________

The goal here will be to find the net force in the radial direction (step 7), steps 5 and 6 help you along the way.

5. **Pre-Lab:** Draw and label a free-body diagram for the plane as pictured from the front. (Don't worry about the forces in the forward and backwards directions due to the propeller and air resistance; they cancel each other when the plane is moving at a constant speed.)



6. **Pre-Lab:** Use the free-body diagram and Newton's Second Law in the vertical direction to determine the vertical component of tension, T_y, in terms of m and g.

7. Give a numerical value for this:

T_y = ______________ N

8. **Pre-Lab:** Use the free-body diagram / a trig. function to find the net force in the radial direction (T_x) from T_y and θ. Show your work.

9. Give a numerical value for this:

$\sum F_{\text{radial}} = T_x =$ __________________ N

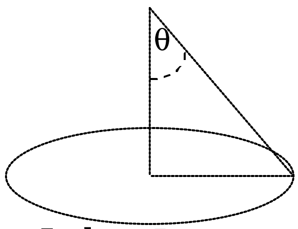
Question: The geometry of circular motion tells us $a_c = \frac{v_t^2}{r}$ while Newton's second law tells us $\sum F_x = ma_x$, taking the x direction to be radially inward, i.e., toward the circle's center, $a_x = a_c$. So we should $\sum F_{rad} = ma_c$ or $\sum F_{rad} - ma_c = 0$. Let's see how close we are: Calculate the percentage difference. $\left(\frac{\sum F_{rad} - ma}{\sum F_{rad}}\right) \times 100\%$

Before Proceeding: *Check with the instructor that your percent error is acceptable (<10%).*

Question: Explain likely sources of error in you measurements.

Note: The percentage difference, in terms of your direct measurements is $\left(1 - \left(\frac{2p}{t}\right)^2 \frac{h}{g}\right) \times 100\%$ where $h = \sqrt{L^2 - r^2}$. This should help you see the repercussions of any miss-measurements.

Pre-Lab: Write an expression for the angle θ (see picture below) in terms of r and L



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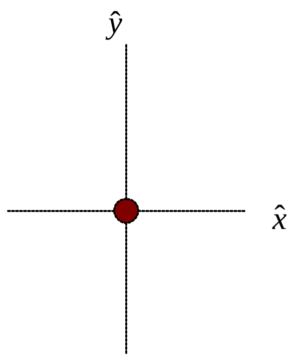

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Pre-Lab: Use the free-body diagram / a trig. function to find the net force in the radial direction (T_x) from T_y and θ. Show your work.