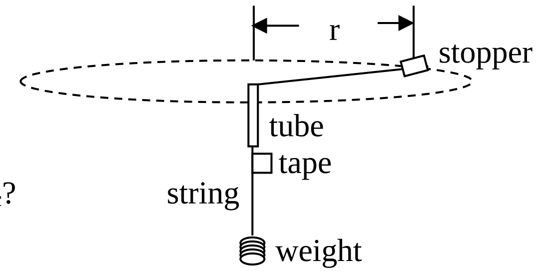
Name______________________________ period_____

Partner_________________________ lab# _____

Partner_________________________

π in the Sky

In this lab, you will accelerate a rubber stopper in a horizontal circle at the end of a string. A weight pulls down on the string. This provides a tension and the centripetal force F_c.



Q1: Do you agree to wear goggles during the entire lab?

Q2: What pulls down on the string, gives it tension and provides F_c?

Q3: What is the object that is being forced to move in a circle?

Q4: Should you hold the weight?

A. Get a timer, a meterstick and your "device."

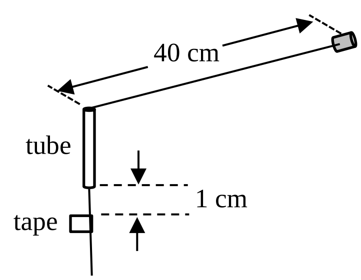
1. All partners must PUT YOUR GOGGLES ON now!
2. Check that the string is not frayed and the glass tube is not cracked. Check that the knots are not loose.
3. Record the mass of your *stopper* in grams: $m_{stopper}$ = _________ g

   Divide by 1000 to convert to kilograms: $m_{stopper}$ = _________ kg
4. A) Make sure you have room around you to spin the stopper over your head safely.

   B) Hold the tube vertically with the washers hanging below.

   C) Slowly spin the rubber stopper in a horizontal circle above your head

   D) Practice spinning the stopper at CONSTANT SPEEDS, first slower, then faster.
5. Adjust the length of the string above the tube so that the distance between the middle of the stopper and the top of the tube is 40 cm. In meters, this is **r = 0.40 m**. This is the radius of the circle.



6. To keep the radius constant, a piece of tape must be attached to the string so that it is 1 cm *below* the bottom of the tube. When ready, practice spinning the stopper as before until you can keep the tape about 1 cm below the bottom of the tube.
7. *Partner roles:* 1 spinner, 1 timer, 1 recorder. Spinner should keep spinning from 1 trial to the next….
8. Time how long it takes the stopper to make 10 complete revolutions, 10T. Record in table below. Repeat 2 more times. Make sure your data are consistent. Average the 3 times, then divide by 10 to get 1 T.

$10T_{1st}$ (sec)	$10T_{2nd}$ (sec)	$10T_{3rd}$ (sec)	$10T_{avg}$ (sec)	$T = 10T_{avg}/10$ (sec)

9. Use *r* in meters to calculate the circumference C of the circle: $C = 2\pi r$ = ___________ m
10. Use this C and the time T to calculate the speed of the stopper: $v = \frac{distance}{time} = \frac{C}{T} =$ m/s
11. The stopper is the object being accelerated. Use the equation below to calculate its centripetal acceleration. Substitute your values of *v* (in m/s) and *r* (in m) with units. Give answer with units.

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

12. Use the **stopper mass in kg** and a_c to find the centripetal force F_c that must be accelerating the stopper. Show your substitution of values with units and answer with units:

$$F_c = m_{stopper} \cdot a_c =$$

13. The tension in the string is what accelerates the stopper. But the string gets its tension from the weight hanging below. So the centripetal force you just calculated should equal the weight of the weight.

A) To verify this, measure the **mass of the weight** now and record.

mass of the weight in grams: m_{weight} = __________ g

Divide by 1000 to convert to kilograms: m_{weight} = _________ kg

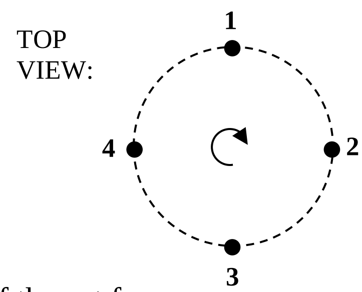
B) Calculate the weight F_g of the weight. $F_g = m_{weight} \cdot g$ = (__________ kg)(9.8 m/s^2) = _________ N

C) As mentioned above, this weight *should* equal F_c. To check, calculate the % difference` between F_c and the weight of the weight.

$$\% \text{ difference} = \left|\frac{F_c - F_g}{F_g}\right| \times 100 = \_\_\_\_\_\_\_\_ \%$$

Analysis.

Q1. Was the stopper *rotating* or *revolving* around the tube?



Q2. The diagram at right is a top view of the stopper going around in a circle. Assume the stopper is moving CW (clockwise). Four points in its path are labeled. At each point…

A) ...draw an arrow to represent the tangential velocity. Label it ***v***.

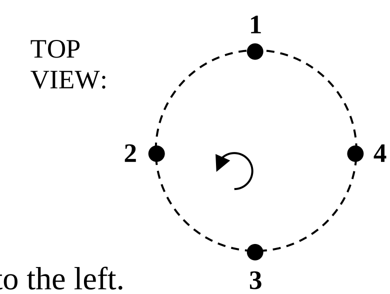
B) …and draw an arrow to represent the inward tension **T** that the string exerts on the stopper.

C) The tension T provides the net force. The acceleration is in the direction of the net force. Is the acceleration of the stopper *centripetal* (towards the center) or *tangential*?

D) Is the *speed* of the stopper changing?

E) Explain how you can tell that the stopper is accelerating just by looking at the velocity vectors.

F) If the string broke at any time, the stopper would fly off along a tangent—in the same direction as *v*. If this happened at point 1, the stopper would fly off to the right. Which way would the stopper fly off if the string broke when it was at point 2? At 3? At 4?



Q3. The same diagram is shown at right. But now the stopper is moving CCW (counterclockwise). At each of the 4 points on the diagram…

A) …draw the velocity arrows. Label them *v*.

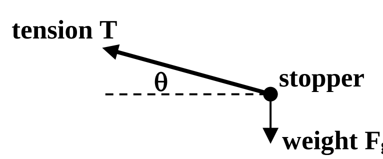
B) …draw and label the tension **T** arrows.

C) What direction are F_{net} and a?

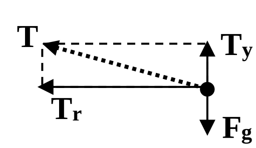
D) If the string now broke when the stopper was at 1, the stopper would fly off to the left. What if the string broke when the stopper was at point 2? At 3? At 4?

Q4. *Circle the answers:* When the motion is changed from CW to CCW, the velocities *v* (remain in the same/reverse) direction, but the *a* and F_{net} (remain in the same/reverse) direction. In both CW and CCW motion, the *v* are always (tangential/centripetal), but *a* and F_{net} are (tangential/centripetal).

Q5. The diagram at right shows a SIDE VIEW of the forces acting on the rubber stopper when it reaches point 4 in Q3 above. Notice that the tension T is angled at θ. This is because the stopper is not level with the top of the tube.



The bottom diagram shows **T** resolved into its two components, $\mathbf{T_y}$ (the *up* part) and $\mathbf{T_r}$ (the ***r*** stands for "in the direction of the circle **r**adius.")



A) Which component, T_y or T_r, balances the weight?

B) Which component is unbalanced and provides F_{net} to accelerate the stopper?