Name ____ Date ___________ Period _________

Lab: Circular Motion and Force

CHAPTER 10: CIRCULAR MOTION

Background: Suppose that you were driving a car with the steering wheel turned in such a manner that your car followed the path of a perfect circle with a constant radius. And suppose that as you drove, your speedometer maintained a constant reading of 10 mi/hr. In such a situation as this, the motion of your car would be described to be experiencing uniform circular motion. ***Uniform circular motion*** is the motion of an object in a circle with a constant or uniform speed.

Uniform circular motion - circular motion at a constant speed - is one of many forms of circular motion. An object moving in uniform circular motion would cover the same linear distance in each second of time. When moving in a circle, an object traverses a distance around the perimeter of the circle. So if your car were to move in a circle with a constant speed of 5 m/s, then the car would travel 5 meters along the perimeter of the circle in each second of time. The distance of one complete cycle around the perimeter of a circle is known as the **circumference**. At a uniform speed of 5 m/s, if the circle had a circumference of 5 meters, then it would take the car 1 second to make a complete cycle around the circle. At this uniform speed of 5 m/s, each cycle around the 5-m circumference circle would require 1 second. At 5 m/s, a circle with a circumference of 20 meters could be made in 4 seconds; and at this uniform speed, every cycle around the 20-m circumference of the circle would take the same time period of 4 seconds. This relationship between the circumference of a circle, the time to complete one cycle around the circle, and the speed of the object is merely an extension of the average speed equation.

$$\text{Average Speed} = \frac{\text{distance}}{\text{time}} = \frac{\text{circumference}}{\text{time}}$$

The circumference of any circle can be computed using from the radius according to the equation

$$Circumference = 2 \cdot \Pi \cdot radius$$

Combining these two equations above will lead to a new equation relating the speed of an object moving in uniform circular motion to the radius of the circle and the time to make one cycle around the circle (***period***).

$$\bar{v} = \frac{2 \cdot \Pi \cdot r}{T}$$

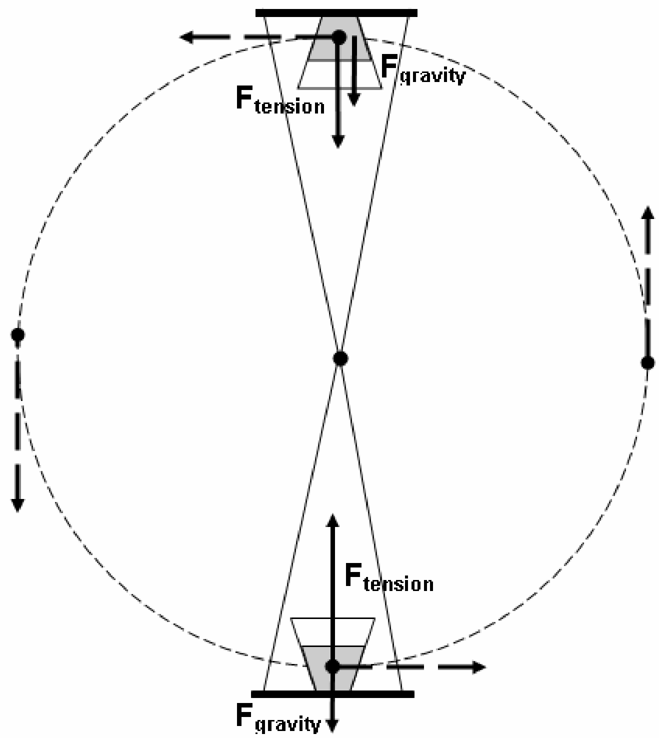
The magnitude of the ***centripetal force*** required to keep an object in a circular path depends on the **inertia** (or mass) and the **acceleration** of the object, as you know from the second law (***F=ma***). The Acceleration of an object moving in uniform circular motion is ***$a=v^2/r$***, so the magnitude of the centripetal force of an object with a mass (**m**) that is moving with a velocity (**v**) in a circular orbit of radius (**r**) can be found from:

$$F_c = \frac{mv^2}{r}$$

Procedure:

1. Form groups of 3-4 students.
2. Obtain materials for “whirling-cup” experiment (cup, plate w/ string) *One set-up per group.*
3. Fill up your plastic cup approximately **2/3rds full**. Weigh the cup on the triple-beam scale and record below. (Make sure you change from **g** to **kg**) Record in Table # 1.

4. Walk outside with your group and find a spot away from the other students where you can swing the cup in a vertical circle without hitting anyone else.
5. Using a meter stick, measure the **radius** (**r**) of the motion. Put into table #1 (express in meters)
6. Your job will be to try and calculate the minimum ***period*** (***T***) of the swinging cup that maintains the water in the cup. You may want to start swinging it faster and then slow down until it almost looks like the cup will "fall out" of the tray. Have one of your group time **10** complete revolutions and calculate the period (**T**) *Note: Take the time (in seconds) for 10 revolutions and divide by 10. Put into Table # 1.*
7. Now that you know the time it takes for one revolution (the period), calculate the ***rotational speed*** in ***RPM*** (revolutions per minute) *Note: Divide 60 by the period you calculated above to calculate the rotational speed in RPM.* Put into table #1



8. Using the information in Table 1 below, calculate the minimum ***average velocity (tangential speed)*** that was required to keep the cup full of water and swinging in a circle. (See equation on page 1). Put into Table # 1.
9. Using the equation for centripetal force (F_c) on page 1, calculate the minimum ***centripetal force*** required to keep the cup swinging in a circle. Put into Table # 1.
10. To calculate the ***Tension*** in the string, you will need to look at the centripetal force you calculated above and also calculate the force of gravity (weight) of the cup with water. Look at the diagram to the right to help you conceptualize what is going on. Remember: $F_g = m \cdot g$ Put into table #1
11. When you consider the direction of the force of gravity (down-remember that force has a direction-it is a **vector** quantity). You will have to subtract the weight (force of gravity) when the cup it at the top of the circle and add it to the centripetal force when the cup is at the bottom of the circle. Enter the values into Table # 1.
12. When you have completed Table # 1, answer the questions on the following page

Table # 1		
Mass of cup (**m**)	(g)	(kg)
Weight of cup ($F_g = mg$)	(N)	
Length of string (**r**) in meters	(m)	
Period of rotation (**T**) in seconds	(s)	
Rotational speed (**RPM**)	(RPM)	
Minimum Average velocity =	(m/s)	
Minimum centripetal force (F_c) =	(N)	
Tension at top of circle (F_{net})	(N)	
Tension at bottom of circle (F_{net})	(N)	

Conclusion Questions

1. What is the difference between **rotational speed** and **tangential speed**?

2. What is the definition of **period** (**T**)?

3. If the strings were <u>twice</u> as long when you were swinging the cup and you had the <u>same</u> **rotational speed**, what effect would it have on the **tangential speed** of the cup?

4. What would happen to the **centripetal force** if the mass of the cup were <u>doubled</u> and the **velocity** was the <u>same</u>?

5. Why is the **tension** of the string <u>greater</u> when the cup is at the bottom of the revolution than it is at the top of the revolution?

6. What would happen to the **tangential velocity** of the cup if the **period** were cut in <u>half</u>?

7. How would you describe the "**force of gravity**"?

8. How did you calculate the "***net force***" ?

9. Did the **net force** change during the circular motion of the cup? How?

10. When you buy fishing line for a fishing pole, it is rated as 1 pound test, 5 pound test, etc. How do you think this relates to forces and tension? *(what do you think this means and why is it important)*

Extra Credit Question (10 points):

1. Suppose they wanted to create a roller coaster with a loop as shown below. The only thing holding the cart on the track was gravity or centripetal force and had to consider velocity, centripetal forces, force of gravity etc. How high would they have to make the initial run of the roller coaster in order for it to have enough velocity so that you would not fall out at the top of the loop. (assume that the only force involved in the acceleration of the roller coaster is gravity and that the track was "frictionless". The mass of the roller coaster and its occupants was 500 kg) **How high would the initial hill have to be in order for the occupants to remain in their seats at the top of the loop?** In order to receive extra credit you need to show all of your work including equations you used!