**Centripetal Force Lab**

**Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Partners: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

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**Purpose:**

1. To study the nature of Centripetal Force
2. To measure the relationship between Centripetal Force, mass, and velocity

**Materials: (Requires a minimum of 3 people in a group: Spinner, timer, counter.)**

1. PVC tubing
2. ~1.5 m Nylon cord
3. One hole Rubber stopper
4. 3 Hooked masses: 2 x 200g, 100 g
5. Stop Watch (or timing app on a phone)
6. Triple Beam Balance
7. Paper Clip

**Introduction:**

An object moving with a changing speed in the same direction is undergoing acceleration. If an object moves with a constant speed but is changing direction, it is also undergoing acceleration. Both types of accelerations require a force. A change in direction is called *centripetal acceleration*, and the force producing it is called *centripetal force*. Consider the figure below:

Mass *m*1 is traveling in uniform circular motion with radius *r*, at a constant tangential speed of *v*t. Because the mass is constantly changing direction it is subject to centripetal acceleration given by the equation:

*r* is the radial distance from the top of the tubing to the center of the rotating rubber stopper of mass *m*1. The force causing the centripetal acceleration, the centripetal force, must obey Newton’s Second Law:

or

In our experiment, mass *m*1 will be the mass of a rubber stopper moving at a constant tangential speed of *v* at the end of a nylon cord of length *r*. The centripetal force will be supplied by a mass *m*2 that is attached to the bottom of the nylon cord. See the above figure. The weight of this hanging mass is determined by the equation:

The weight of the hanging mass is the centripetal force applied to mass *m*1, keeping it in a horizontal circular orbit.

or

The measured tangential velocity is determined as follows:

where *t* is the time required for a N revolutions of the stopper.

We will verify the idea that the hanging mass creates the centripetal force and that the direction of the centripetal force is towards the center of the rotation, not outward. We will calculate both Fc and Fw  and determine a percent difference. Percent difference is the absolute value of the difference divided by the mean.

**Procedure:**

**Preliminary measurements:**

1. Measure the mass of the rubber stopper using a triple beam balance, and record this value as mass *m*1 in the data table below. Measure the height of the stopper to 0.1 cm and record this value as *h*.
2. Measure the mass of a 100 g hooked mass on a triple beam balance and record this value as mass “100”. Label two 200 g masses with masking tape and Sharpie as “A” and “B”. Measure the mass of “A” and record this value. Measure the mass of “B” and record this value.

**Apparatus construction:**

1. Pass the nylon cord through the hole of the rubber stopper and tie it securely to the end of the cord such that the long end of the cord exits the stopper at the smaller side’s hole. Trim any significant excess cord beyond the knot you make. Pass the long cord through the PVC tubing and form a loop in the end. (Hint: Tie around a pencil, then remove the pencil.) Hang the 100 g mass from the loop to start.
2. Adjust the length of the cord between the top of the tubing and the center of the rubber stopper to approximately 80 cm. Mark the location of the cord by darkening the cord one centimeter below the tubing. Place a paper clip over the mark, as shown in the figure.

**Spinning:**

1. Support the 100 g mass with one hand and hold the tubing in the other hand. Whirl the rubber stopper in a horizontal orbit above your head, by revolving the tubing. Slowly release the 50 g mass assembly and adjust the speed of the revolution so that the paper clip hovers just one centimeter below the bottom of the tube. Say “Ready” when you’ve got it balance and are ready to go. When the timing is over grab the end of the tube with the cord, preserving the radius you were spinning with before the speed of the stopper changes. Measure the distance between the top of the tube and the top of the stopper with a meter stick and record to the nearest 0.1 cm as length, *l*.

**Timing:**

1. When the spinner has learned how to keep the rotation speed and position of the paper clip constant, and the counter is ready and says “Set”, start a timer and say “Go”. Say “Stop” when 30.00 seconds have passed. If you miss saying stop at exactly 30 seconds, say stop as soon as you can after that. Record the time elapsed as *t*. You may want to count along with the counter as a backup for consensus, or security if your counter loses count.

**Counting:**

1. Watch the spinner carefully after they say “ready” and say “Set”. When you hear “go”, visually mark where the stopper is in its revolution. Each time the stopper returns to this position, count. (Remember to start counting at **zero** for go, and one after one complete revolution.). When you hear “stop”, note the last number you counted and estimate how far along in the next revolution to stopper was. Record your number of revolutions as *N* to one decimal place. (#.2 if just a bit into next revolution, #.5 if about halfway round and #.7 if not yet to the counting position. If right on the count, record as #.0.)

1. Repeat this procedure five times with the 100 g mass. Then swap the 100 g for the “A” mass for 200 g and do five more trials. “A” + 100 for 300 g. “A” + “B” for 400 g and all three masses for 500 g.). Rotate the roles of Spinning, Timing and Counting to avoid any possible bias in the data

**Calculations:**

1. Determine the mass of the hanging mass, *m2* in kg using the relevant preliminary data. NOT JUST 0.1 kg.
2. Determine the weight, *Fw* for the hanging mass.
3. Determine the radius of the motion *r* for each trial by adding half of the height of the stopper *h* to the length *l* because you need the distance between the center of mass for the rotating object and the pivot.
4. Determine the tangential velocity *v* using the formula above.
5. Determine the centripetal force for each trial.
6. Determine the average centripetal force *Fc* for the given hanging mass.
7. Find the difference and mean for *Fw* and *Fc.*  Use these values to determine the % difference between *Fw* and *Fc*.

**Prelab Questions:**

1. What is the direction of the force acting on the spinning mass m1 as it is spinning in

a circle above your head?

2. What provides this force?

3. What would be the centripetal force acting on a spinning mass of 130 g circling at a radius of 15 cm with a velocity of 0.875 m/s?

4. Describe the motion of the stopper if the cord would break.

5. When a car travels in a circular path what provides the force necessary to keep it moving in a circle?

6. A rider in the car may claim to be “pushed outward by a centrifugal force”. How can you respond to this person?

7. If you swing a bucket of water over your head in a vertical circle at a great enough speed, the water will not spill out of the bucket. Why not?

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**Preliminary Data Table**

Mass of Rubber stopper: *m1:*\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Height of Rubber stopper: *h*: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Mass of 100 g: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Mass of 200 g “A”: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Mass of 200 g “B”: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Data and Calculations Tables

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 100 g Trials | *l*to 0.1 cm | *r = l + h/2*in m | Nto 0.1 | tto 0.0 sec | *v* | *Fc* |
| 1 |  |  |  |  |  |  |
| 2 |  |  |  |  |  |  |
| 3 |  |  |  |  |  |  |
| 4 |  |  |  |  |  |  |
| 5 |  |  |  |  |  |  |
| *m2*  in kg | Fw |  | Ave *Fc* |
| |*Fw – Fc*| | *(Fw+Fc)/2* |  | % Difference |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 200 g Trials | *l* | *r = l + h/2* | *N* | *t* | *v* | *Fc* |
| 1 |  |  |  |  |  |  |
| 2 |  |  |  |  |  |  |
| 3 |  |  |  |  |  |  |
| 4 |  |  |  |  |  |  |
| 5 |  |  |  |  |  |  |
| *m2* | Fw |  | Ave *Fc* |
| |*Fw – Fc*| | *(Fw+Fc)/2* |  | % Difference |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 300 g Trials | *l* | *r = l + h/2* | *N* | *t* | *v* | *Fc* |
| 1 |  |  |  |  |  |  |
| 2 |  |  |  |  |  |  |
| 3 |  |  |  |  |  |  |
| 4 |  |  |  |  |  |  |
| 5 |  |  |  |  |  |  |
| *m2* | Fw |  | Ave *Fc* |
| |*Fw – Fc*| | *(Fw+Fc)/2* |  | % Difference |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 400 g Trials | *l* | *r = l + h/2* | *N* | *t* | *v* | *Fc* |
| 1 |  |  |  |  |  |  |
| 2 |  |  |  |  |  |  |
| 3 |  |  |  |  |  |  |
| 4 |  |  |  |  |  |  |
| 5 |  |  |  |  |  |  |
| *m2* | Fw |  | Ave *Fc* |
| |*Fw – Fc*| | *(Fw+Fc)/2* |  | % Difference |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 500 g Trials | *l* | *r = l + h/2* | *N* | *t* | *v* | *Fc* |
| 1 |  |  |  |  |  |  |
| 2 |  |  |  |  |  |  |
| 3 |  |  |  |  |  |  |
| 4 |  |  |  |  |  |  |
| 5 |  |  |  |  |  |  |
| *m2* | Fw |  | Ave *Fc* |
| |*Fw – Fc*| | *(Fw+Fc)/2* |  | % Difference |

**Questions:**

1. If a percent difference is less than 5 % one can conclude that the two quantities being compared are equal. Can you conclude that the centripetal force and the weight of the hanging mass are equal for any of the 5 kinds of hanging masses? If so, which ones?

2. For those trials that didn’t meet the condition of equality, consider what sources of error might explain this result. Describe HOW each error in the measured values would effect the calculated value of either Fw  or Fc. Cite at least 2 sources of error.

3. In an experiment using this apparatus the mass and centripetal force are kept constant, by how much must the velocity change to increase the radius a factor of four(4X)?

4. Suppose you find that a centripetal force of 12 N is required to keep a given object in a particular circular path when it is moving with uniform speed. Assume you are able to double the mass, velocity, or radius individually at will. a) What will the magnitude of the centripetal force be for each of these individual changes? b) Which change modifies the centripetal force the most and why?

5. a) Write the equation for centripetal force in terms of: mass m, revolutions N, radius r, and period T (using any constants needed). b) What effect would an error in time measurement have on the F in time was too large? c) What effect on the calculated F would a radius have if the value used for radius was too small?