UCM LAB: Centripetal Force–Constant Radius and Mass

Objectives

Students will…

- use a Force Sensor and simple equipment to measure the centripetal force of an object twirled around on the end of a string at different speeds. Or, they will analyze SAMPLE DATA (for distance learning)
- determine the period of the twirling mass from the force versus time data and calculate the LINEAR VELOCITY v of the mass from the radius and period of the circular motion.
- use LoggerPro or Graphical Analysis to plot a graph of circular speed versus average force for different circular speeds.
- state a relationship between circular speed and centripetal force when mass and radius are constant.

Research Question:

Can I use sample data and the physics of uniform circular motion to calculate the mass of the spinning object and to use graphs to better understand the relationship between centripetal force and linear velocity?

Sample Data -

Please include this sample data in your lab report. To make life easier, you may use the following absolute uncertainties: Force ± 0.3 N velocity ± 0.3 m/s centripetal acceleration ± 0.4 m/s^2

Keep in mind that YOU need to add columns to your data table, and YOU need to make sure that the precision is consistent (i.e. # decimal places) between the average measurements and the uncertainties.

Circular Speed: Constant Radius and Mass (assume mass = 0.05 kg)

Radius (m)	Time (s)	Revolutions	Period (s)	Linear Velocity (m/s)	Average Force (N)
0.5	5.73	7			0.52
0.5	4.94	7			0.31
0.5	4.23	7			1.23
0.5	3.93	7			2.04
0.5	3.45	6			2.15
0.5	2.74	7			4.06
0.5	2.32	7			8.07

Calculations - use Excel / Googlesheet formulas

1. Calculate the period by dividing the time by the number of revolutions.
2. Calculate the linear velocity (distance around the circle = circumference $2\pi r$ divided by the time - period T).

Graphs

Use logger pro to make TWO graphs.

A. One will be for average force (centripetal) vs. linear velocity. You will need to FIT a line to these data points and include error bars for both force and linear velocity. Should the fit be a CURVE or a STRAIGHT LINE in this case? Please include error bars to match the uncertainties above.

B. The second graph will be a LINEARIZED form of this graph. An easy way to do it would be to graph force vs. centripetal acceleration. Check your data booklet to confirm the variables included in the formula. Please graph the two variables so that the slope represents the MASS of the object being spun. Please include error bars based on the absolute uncertainties provided above. Also include MIN and MAX lines (in different colors) to estimate the uncertainty in the mass.

Questions

1. How does the centripetal force change as the circular speed of an object increases?

2. What is the shape of your graph of circular speed versus average force? (Example: linear, parabolic, inverse, inverse-square, etc.)

3. Using words and a mathematical expression, describe the apparent relationship between centripetal force and circular speed for uniform circular motion.

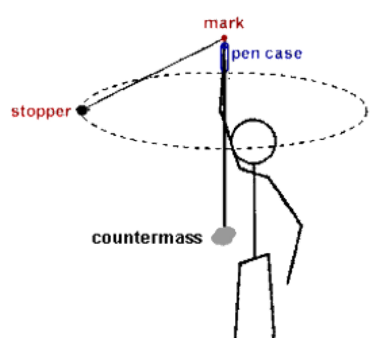
4. Please use the graph to estimate the mass of the object being spun around and the difference in the slopes between the min and max lines to estimate the uncertainty in this mass estimate.

5. Knowing that the mass is actually 0.05 kg, calculate the percent error in your calculated estimate.

$$\% \text{ Error} = \left| \frac{\text{Theoretical Value} - \text{Experimental Value}}{\text{Theoretical Value}} \right| \text{X } 100$$

Theoretical Value = Actual ... Known ...True Value

6. Imagine being in a student group where one of you was spinning the mass, and the other was timing how long it took to spin the mass for 7 or 8 revolutions. Describe a potential RANDOM ERROR and one potential SYSTEMATIC ERROR in this type of procedure. Your descriptions should be scientifically worded and specific enough to demonstrate YOUR knowledge as to what each of these types of errors represents.



NOTE: Now that you have clarity, think about the various resources you have to do well on this short lab report.

Here's what you need to turn in to Turnitin.com (PDF please)

1. RQ (restated from that provided)
2. Data Table (no raw data needed)
3. Two Graphs
4. All appropriate questions answered neatly and professional

How can you make sure you are meeting the requirements?

- The rubric on Turnitin.com
- Support videos on Cooper's website / YouTube / Khan Academy etc..
- The lab checklist available on Cooper's IA webpage. See screenshot below for data collection / graphs.

Data Collection and Processing	***achievement level ....***	
1. Recording raw data	• Records all **raw** (not calculated) data appropriately.	
	• Presents raw data clearly and correctly in **tables**. ➢ Each table is numbered and has a title. ➢ Each column has a correct **heading.** ➢ Each column has correct **units**. ➢ Each column has **estimated** uncertainties. ➢ Each value in a column has the same number of **decimal places**.	
	• **Uncertainties** in **all** quantitative data rounded up to **1 significant figure**. (i.e. +/- 0.2 not +/- 0.13) • Significant digits in the data and the uncertainty in the data are **consistent**. The number of decimal places in the data does not exceed the limit of the uncertainty (i.e. if the uncertainty is +/-0.2, the measurement should only be quoted to one decimal place) • Even if you will later calculate an uncertainty, there must be estimated uncertainties in the header of each column. • Uncertainties reflect the precision of the measurement. (i.e. uncertainties are reasonable) • **Comment** on how you arrived at the uncertainty in the table.	
	• Comment on any observations you made that might be relevant later. (There may be none).	
	• If students have pooled data, students have clearly **indicated** which data is their own.	
2. Processing raw data (Data Tables not containing raw data)	• Calculations and uncertainty calculations are done **correctly** with correct significant figures.	
	• Puts **results** of calculations in **tables**. ➢ Each table is numbered and has a title. ➢ Each column has a correct **heading.** ➢ Each column has correct **units**. ➢ Each value has a **calculated** uncertainty. ○ You may want to create another column for the uncertainties of each value. ➢ Each value in a column has the same number of **decimal places**.	
	• **Uncertainties** in **all** quantitative data rounded **up** to **1 significant figure**. (i.e. +/- 0.2 not +/- 0.13) • Significant digits in the data and the uncertainty in the data are **consistent**. The number of decimal places in the data does not exceed the limit of the uncertainty (i.e. if the uncertainty is +/-0.2, the measurement should only be quoted to one decimal place)	
	• **Sample** calculations are shown. ➢ Calculations are explained and presented logically. ➢ Formula, substitution and answer shown for one sample calculation. ➢ Formula, substitution and answer shown for one sample uncertainty calculation. (i.e. for repeated measurements: greatest residual)	
3. Presenting processed data (graphs)	• **Graphs** are **correctly** drawn. ➢ If the data represents a straight line, the best fit line is straight. ➢ If the date represents a curve, the best fit line is curved. ➢ Curved graphs are straightened. ➢ Slope calculated. ➢ The equation of the line has been stated (y=mx+b) ➢ Dots have not been connected. • If the data represents a straight line, the **slope** is calculated **correctly** including the units.	
	• **Graphs** are numbered and have clear titles, appropriate **scales**; axes **labelled** correctly with **units**, and accurately plotted **data points.**	
	• Includes **uncertainty bars** on both axes, unless explicitly justified because they are too small. • Uncertainty bars are on every point.	
	• Using the error bars from the first and the last data points, draws lines of **minimum and maximum slopes.** Minimum and Maximum lines should go through all error bars. Use the first and last points to start, but your lines may need to be adjusted to intersect all error bars. • Determine the **uncertainty** in the best straight-line **slope using** the **minimum** and **maximum** slopes.	