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Related Rates Lab

Please show all of your work for full and partial credit.

In this lab you will be analyzing the rate of rotation of a spool with string wrapping around it and the rate of the string "speed." Before you begin the lab, think about how the string wraps around the spool and hypothesize how the rate of wrapping and the rate of speed of string length are related. Please write this down.

Materials

- One spool per group.
- Ruler.
- Measuring tape.
- Dry Erase Marker.
- Graphing calculator.

Procedure

1. Designate a ruler measuring person in the group.
2. Designate a tape measuring person in the group.
3. Designate a spool holder/string wrapper person in the group.
4. Designate a data recorder person in the group.
5. The data recorder should create a table with the following columns: spool rotation #, radius, Δ radius, total string length, Δ string length (or use the pre-printed handout if given).
6. Pull the spool string from the spool until it is completely unwound.
7. Have the spool holder wrap the string once around the spool and pull the string straight out (tangent) from the spool just beyond the scribe mark. The ruler measurer should mark the radius of the outside of the string at the scribe line. The ruler measurer should then measure the distance from the center of the circular spool to the mark and call it out.
8. The recorder should write down the number in the first *radius* box.
9. The tape measurer should then measure the length of the extended string from the scribe mark to the knot and call it out.
10. The recorder should write down the number in the first *total string length* box.

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11. The spool holder should wrap the string one more time around the spool and again pull the string straight out (tangent) from the spool just beyond the scribe mark. The ruler measurer should mark the radius of the outside of the string at the scribe line. The ruler measurer should then measure the distance from the first mark made on the scribe to the second mark made on the scribe and call it out.
12. The recorder should write down the distance in the second Δ *radius* box.
13. The tape measurer should then measure the length of the extended string from the scribe mark to the knot and call it out.
14. The recorder should write down the number in the second *total string length* box.
15. 11-15 should then be repeated and the appropriate measurement recorded in the appropriate boxes until either the string is too short to wrap around the spool or the string is outside of the spool circle.
16. Once the table is filled out with the values obtained above, use these values to complete all of the table entries. The L column will be the differences between the *total string length* measurements, and the ΔL column will be the differences between the entries in the L column.

Report and Analysis

For this section we will use $\frac{d}{dR}$ to denote the rate, or derivative, with respect to rotation. This is proportional to $\frac{d}{dt}$, the rate or derivative with respect to time.

1. Think about the string wrapping around the spool. The radius, r, is obviously increasing. What do you believe the rate should be? Is it constant, linear, quadratic, or something else? What does your data show?
2. Think about the relationship between the amount of string which wraps around the spool in one rotation and the current radius of the spool. Write the equation down.
3. Find the implicit derivative of the equation above with respect to R, the rotation.
4. Find the mean of ΔL and Δr
5. If you substitute the mean ΔL for $\frac{dL}{dR}$ and the mean Δr for $\frac{dr}{dR}$ into the above equation is it close to correct?
6. What is the rate of change of L, the string length, when $r = 500cm$?

Table 1: Lab variables

Variable name	Variable description
R	rotation
r	radius
L	string length

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7. Suppose an engineer wanted to use one of these types of spools for a zip line pull. In order to reel in a $500m = 50,000cm$ zip line, the spool must have a radius of $80cm$ and will rotate 195 times for $500m$ of line. If the spool is rotating at 1 rotation per second, what is the velocity when $r = 80cm, t = 195s$? *Hint: A change in velocity is acceleration, look at the change in L per rotation. Use the equation $v = at + v_0$ for a constant acceleration a.* What is the answer in km/h? Is this type of spool acceptable to use for zip line pulls?

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Table 2: Spool Data

rotation #	r (radius)	Δr	total string length	L	ΔL