Speed of waves

Name:

Group Members:

Date:

TA's Name:

Apparatus: Long spring, meter stick, spring scale, stopwatch (or cell phone stopwatch)

Objectives
  1. To directly calculate the speed of waves in a stretched spring.
  2. To investigate the dependence of wave speed in a spring on its tension.

Part 1: Introduction
In class you learned about propagation of waves in a stretched spring. The speed of waves (periodic waves or pulses) on a spring depends on the tension and the linear density, \( \mu \), of the spring. One way to make direct measurements of wave speed is to create a transverse pulse in a tight spring of known stretched length and then measure the time taken by that pulse to move from one end of the spring to the other end. In this experiment we are going to investigate how the speed of pulses in a given long spring depends on its tension.

  1. Predict how the speed of a pulse will change if we stretch the spring more (that is, we increase the tension \( T \) in the spring). Will it increase, decrease, or stay the same? Explain why you think so.

  2. How would you measure the speed of pulses, \( v \), in the spring?
3. For the pulses travelling in the spring, is your measurement going to be more or less accurate if you measure time for longer travel distance?

4. If the answer is more accurate for Question# 3, how can you measure the travel time for distances longer than the length of the spring?

**Part 2: Data Collection**

With the spring stretched to 250 cm, determine the tension in the spring with a spring scale. Figure 1 shows how you can hold one end of the spring fixed. Figure 2 shows how you can measure the tension (T) for a particular length of spring (L). Then remove the spring scale and measure the time it takes a transverse pulse to travel between the ends 16 times (8 times there and 8 times back) starting from one end. Be sure to remove the spring scale and use your hand to hold that end of the spring at the chosen length when you measure the time. Use one-meter or two-meter sticks to measure the stretched length of the spring. Repeat this measurement three times and get the average time. Collect data for a range of spring lengths (for example from 250 to 450 cm).

![Figure 1](image1.png)

![Figure 2](image2.png)

<table>
<thead>
<tr>
<th>T (N)</th>
<th>L (m)</th>
<th>16L (m)</th>
<th>Time to travel 16L (s)</th>
<th>( v ) (m/s)</th>
</tr>
</thead>
<tbody>
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<td>( t_1 )</td>
<td>( t_2 )</td>
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5. Using a spring scale measure and record the mass of the spring.

Mass of the spring = ____________________
Part 3: Data Analysis

6. Look carefully at the data in your table. Is your prediction made in question #1 correct?

7. What can you conclude from your data about the relationship between the tension in the spring and of the wave speed of the pulses?

The textbook suggests that $v = \sqrt{\frac{T}{\mu}}$, where $T$ is the tension and $\mu$ is the linear density or mass per unit length. We will use our data to test this theory.

8. Does the linear density (mass per unit length) of the spring change as the spring is stretched? Explain your answer.

9. Enter your values for tension, spring length, wave speed, and spring mass into an Excel spreadsheet and then from those data use formulas to calculate the remaining 3 quantities in the table below. Don't forget the units.

<table>
<thead>
<tr>
<th>$T$</th>
<th>$L$</th>
<th>$v$</th>
<th>$m$</th>
<th>$\mu = \frac{m}{L}$</th>
<th>$\frac{T}{\mu}$</th>
<th>$\sqrt{\frac{T}{\mu}}$</th>
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10. In Excel plot $v$ vs. $\sqrt{\frac{T}{\mu}}$ and draw a trend line and find out the equation of the line. Label your graph axes including units. **Print out the graph and attach it to this report.** Copy the equation for the trendline below.

11. Based on your data analysis do you agree that $v = \sqrt{\frac{T}{\mu}}$?

12. Justify and defend your conclusion in Question 11 using features of the graph.

13. Justify and defend your conclusion in Question 11 using the equation you found for the trendline.
Part 4: Conclusions

14. What are the main sources of uncertainty in this experiment? Don't say human error, we'll assume you did it as well as possible given the equipment and method we used. What limitations of the equipment and method created the most uncertainty in the results?

15. What conclusion do you make from this experiment about the relationship between wave speed and tension for transverse waves on a spring?