Lab 2
Vibrating Strings

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Uncertainty Review

- Experimental results are considered incomplete without the inclusion of an uncertainty estimate
- The uncertainty of an instrument is generally half the value of the smallest increment
  - Meter stick marked in mm -> 0.5 mm uncertainty
  - Frequency generator marked in 1 Hz increments -> 0.5 Hz uncertainty

Uncertainty Review

- The uncertainty of all instruments in an experiment must be **propagated** to the final measured value
  - For addition and subtraction, the uncertainties **add**
    - $Q_{exp.} = Q \pm \Delta Q,$
    - $\Delta \mathrm{Q} \; = \; \Delta \mathrm{A} + \Delta \mathrm{B} + \Delta \mathrm{C}\ldots$
    - Where $\Delta\mathrm{A}$, $\Delta\mathrm{B}$, $\Delta\mathrm{C}$, etc. are the individual uncertainties
  - For multiplication and division, we find the **fractional uncertainty** and report it as a percentage
    - $\frac{\Delta Q}{Q} = \frac{\Delta A}{A} + \frac{\Delta B}{B} + \frac{\Delta C}{C},$
    - $Q_{exp.} = Q \pm \left(\frac{\Delta Q}{Q} * 100\right)\%$

Mersenne’s Laws

- Frequency of vibration of a stretched string varies:
  1. inversely with the length of a string
  2. Directly with the square root of the stretching force
  3. Inversely with the diameter of the string
- The resonant vibrations correspond to standing waves:
  - $L = \frac{n\lambda}{2}$: length is an integer number of half wavelengths
  - $f = \frac{v}{\lambda}$: frequency is wave speed divided by wavelength
  - $v = \sqrt{\frac{F}{\mu}}$: relating wave speed to force and mass per unit length

Mersenne's Laws

- We can now derive an expression for Mersenne's laws:

$$f_0 = \frac{1}{\lambda}\sqrt{\frac{F}{\mu}} = \frac{1}{2L}\sqrt{\frac{F}{\mu}}$$

- We also need an expression for mass per unit length:

$$\mu = A\rho = \pi r^2 \rho = \frac{\pi}{4} d^2 \rho$$

Experimental Procedures (3rd Law)

Diameter	Mass	Length
Varies	Fixed	Fixed

- Mersenne's 3rd law: $\frac{f_{thick}}{f_{thin}} = \frac{d_{thin}}{d_{thick}}$
- In this portion of the experiment, we will use a mass of 300 gm and a length of 100 cm. We will vary the diameter by changing out the string
- Measure the diameter of both wires
- Find the fundamental frequency, f_0, for both wires
- Include the uncertainties and verify the relationship above

Experimental Procedures (2nd Law)

Diameter	Mass	Length
Fixed	Varies	Fixed

- Mersenne's 2nd law: $f_0 = \frac{1}{2L}\sqrt{\frac{F}{\mu}}$
- In this portion of the experiment, we will use the thin wire at a length of 100 cm. We will vary the weight from 200g up to 600g in increments of 100g.
- Plot f_0^2 vs. F and verify that the graph is linear
- Calculate the *theoretical* value of the slope using the formula above (hint: you'll need to calculate the mass per unit length)
- Compare the *theoretical* value of the slope you calculated to the *experimental* value that you extract from your graph

Experimental Procedures (1st Law)

Diameter	Mass	Length
Fixed	Fixed	Varies

- Mersenne's 1st law: $\frac{1}{f_0} = 2L\sqrt{\frac{\mu}{F}}$
- In this portion of the experiment, we will use the thin wire loaded with 300g. We will vary the length of the wire from 100 cm down to 60 cm in increments of 10 cm.
- Plot $\frac{1}{f_0}$ vs. L and verify that the graph is linear
- Calculate the *theoretical* value of the slope using the formula above (hint: you'll need to calculate the mass per unit length)
- Compare the *theoretical* value of the slope you calculated to the *experimental* value that you extract from your graph