Exercise 17 Melde Experiment

1. Objectives

Observing property of a standing wave on a string by Melde experiment, and measuring the frequency caused by vibration.

2. Description

Vibration generator is driven by alternative current of a power source, and it is connected to a string for producing vibration. To have standing waves with different wavelengths, we may change the tension value on strings. Vibrational frequency caused by vibration can be determined with values of wavelength of standing wave, tension on a string and mass per unit length of a string.

If a even string with arbitrary length is under a tension and it vibrates to the direction which is vertical to the length of it, any point on this string will move vertically to the direction of the movement of this wave. This kind of wave is called Transverse Wave. The relation of the frequency *f* and the period T of this transverse wave is

$$f = \frac{1}{T} \tag{1}$$

The distance between two continuous wave crests or wave troughs is a wavelength λ. Wave crest or wave trough is moving distance of a wavelength within a period *T* of time. So that the speed of a wave crest (or wave trough), or we call it wave speed *v*, is

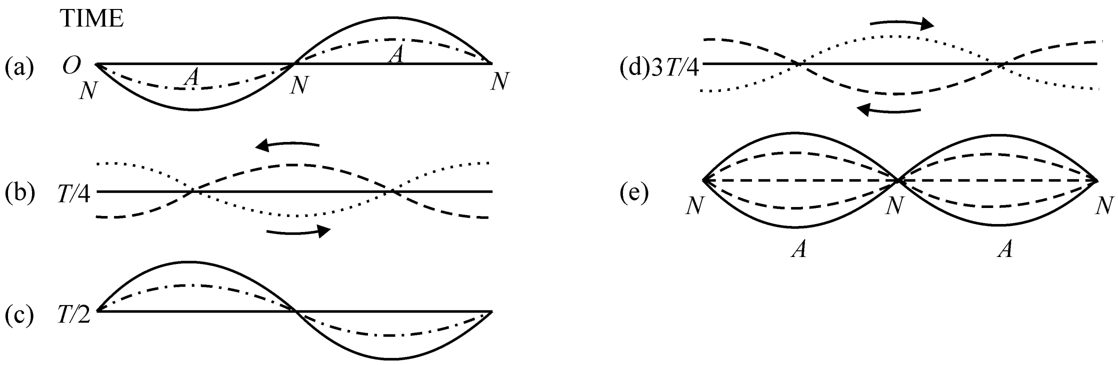
$$v = \frac{\lambda}{T} = f\lambda \tag{2}$$

The speed *v* of a transverse wave on a string is

$$v = \sqrt{\frac{F}{m/l}} \tag{3}$$

F is tension (force), *m*/*l* is the mass per unit length. For C.G.S., unit of *v* is cm/s, it of *F* is dyne, and it of *m*/*l* is g/cm.

When a transverse wave propagates on a string to its fixed end, a reflection wave is produced at the fixed end. These two similar waves moving on a same string with opposite directions, and a standing wave is formed. As plot 1 shown, dash line and dot line present moving waves with opposite directions respectively. According to the superposition theorem, displacement of the composite wave is algebraic sum of two displacements of two individual waves. When $T = 0$, each point on individual wave has equal displacement, as plot 1(a) shown. Except the amplitude of the composite wave is twice large as the individual wave, the displacement curve of the composite wave (solid line) is similar to the curve (dash line) of individual wave. When time goes one fourth of period, as plot 1 (b) shown, each wave propagates 1/4 wavelength resulting all displacements of each point on composite wave are zero. Plot 1 (c) and (d) shows displacements of individual wave and composite wave when time is half period and three fourth period respectively. When time is one period, composite wave is changing to the pattern as plot 1 (e) shown. The maximum and minimum displacement of the composite wave are called antinodes and node. The distance between adjacent node and antinode is $\lambda/4$, and it between two adjacent nodes (or two antinodes) is $\lambda/2$.

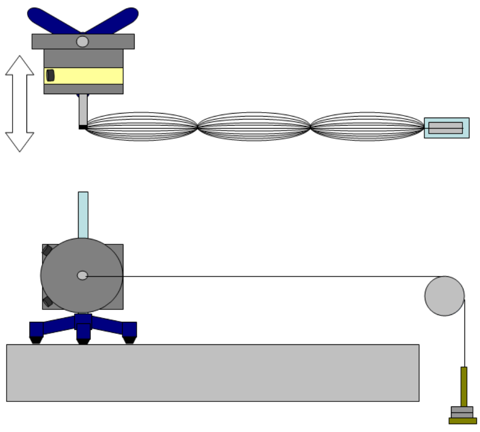


Plot 1

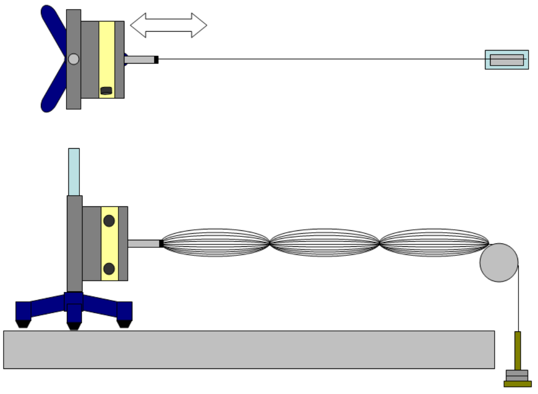
Plot 2 and plot 3 present two methods to produce a standing wave on a string with the vibrational source. If the frequency of driving unit is the same as the nature frequency of vibrational string, vibrational displacement on a string has maximum value. Thus, vibration and vibration source are having resonance and then leading standing wave on the string. There are many nature frequencies on a stretched string. Both ends of the string for these nature frequencies are both nodes, and the distance between them are integer multiple of the half wavelength. During resonance period, frequency f of vibration generator can be determined by equation (2) and (3).

$$f = \frac{1}{\lambda}\sqrt{\frac{F}{m/l}} \tag{4}$$

$$\frac{F}{\lambda^2} = \frac{f^2 m}{l} = \text{constant} \tag{5}$$



Plot 2 Vibration direction is vertical to the string.



Plot 3 Vibration direction is parallel to the string.

3. Materials

Vibration generator set, pulley set, function signal generator, mobile digital multimeter, weight set, strings, electronic balance, measure tape and cables.

4. Procedure

(1) Measure the mass per unit length of a string: place string on a electronic balance and measure its weight and length. Take three measurements and average them.

(2) Adjust input frequency to the one instructor assigned by using function signal generator and mobile digital multimeter.

(3) Method 1: vibrational direction of the vibration generator is vertical to the string.

1. Set up experiment device as plot 2. Fix one end of a string on the vibration generator, and let the other end across the pulley and hang one scale pan.

2. Switch on power to have vibration generator vibrate steadily.

3. Adjust length of a string or mass of weights to have standing wave on the string. (You can also slightly hold up weight or increase string’s tension.)

4. Measure the length ℓ from vibration generator to pulley, and antinode number n of the standing wave for determining wavelength λ. Measure total mass (weights and scale pan) to determine tension F。 of the string.

5. Adjust the length of a string and weights. Repeat steps 3 and 4, and then obtain data five times.

Method 2: vibrational direction of the vibration generator is parallel to the string.

Adjust device as plot 3, repeat steps 2~5 as mentioned above.

5. Questions

(1) For this exercise, what factors may cause result errors?

(2) What may be the reason that a string cannot form a oscillation with standing mode ? (Out of order of the vibration generator is not under consideration.)

(3) When there is prominent standing wave on a string, is the amplitude of the antinode larger than it of the vibration generator? Why?

(4) Using the method of empirical equation(exercise 10), draw a diagram on the whole logarithm graph paper by taking $\ln\lambda$ as y, and $\ln F$ as x.