# EP05 **Measurement of Tuning Fork Frequency**

**OBJECTIVE**

1. To familiarize the student with the general properties of standing wave.

2. To measure the frequency of a tuning fork with standing waves.

**THEORY**

**Standing Waves on a stretched string**

A simple sine wave traveling along a taut string can be described by the equation $y_1 = y_m \sin 2\pi(x/\lambda - t/T)$. If the string is fixed at one end, the wave will be reflected back when it strikes that end. The reflected wave will then interfere with the original wave. The reflected wave can be described by the equation $y_2 = y_m \sin 2\pi(x/\lambda + t/T)$. Assuming the amplitudes of these waves are small enough so that the elastic limit of the string is not exceeded, the resultant waveform will be just the sum of the two waves:

$$y = y_1 + y_2 = y_m \sin 2\pi(x/\lambda - t/T) + y_m \sin 2\pi(x/\lambda + t/T)$$

Using the trigonometric identity:

$$\sin A + \sin B = 2\sin\frac{A+B}{2}\cos\frac{B-A}{2}$$

the equation becomes:

$$y = 2y_m \sin(2\pi x/\lambda)\cos(2\pi t/T)$$

This equation has some interesting characteristic. At a fixed time $t_o$, the shape of the string is a sine wave with a maximum amplitude of $2y_m \cos(2\pi t_o/T)$. At a fixed position on the string $x_o$, the string is undergoing simple harmonic motion, with an amplitude $2y_m \sin(2\pi x_o/\lambda)$. Therefore, at points of the string where $x_0 = \lambda/4, 3\lambda/4, 5\lambda/4, 7\lambda/4,$ etc., the amplitude of the oscillations will be a maximum. At points of the string where = $\lambda/2, \lambda, 3\lambda/2, 2\lambda,$ etc., the amplitude of the oscillations will be zero.

This wavelength is called a standing wave because there is no propagation of the waveform along the string. A time exposure of the standing wave would show a pattern something like the one in Figure 1. This pattern is called the envelope of the standing wave. Each point of the string oscillates up and down with its amplitude determined by the envelope. The points of maximum amplitude are called antinodes. The points of zero amplitude are called nodes.

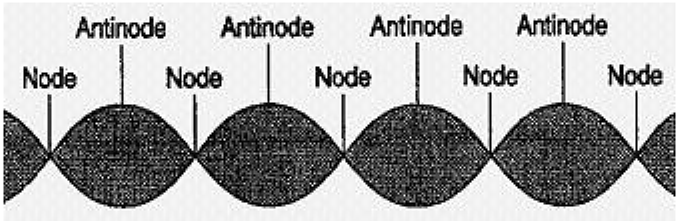


Figure 1. The Envelope of a standing wave

**Resonance**

The analysis above assumes that the standing wave is formed by the superposition of an original wave and one reflected wave. In fact, if the string is fixed at both ends, each wave will be reflected every time it reached either end of the string. In general, the multiply reflected waves will not all be in phase, and the amplitude of the wave pattern will be small. However, at certain frequencies of oscillation, all the reflected waves are in phase, resulting in a very high amplitude standing wave. These frequencies are called resonant frequencies.

In general, resonance occurs when the wavelength (L) satisfies the condition:

$$\lambda = 2l / n; n = 1,2,3,4... \qquad (1)$$

Another way of stating this same relationship is to say that the length of the string is equal to an integral number of half wavelengths. This means that the standing wave is such that a node of the wave pattern exists naturally at each fixed end of the string.

**Velocity of Wave Propagation**

Assuming a perfectly flexible, perfectly elastic string, the velocity of wave propagation (V) on a stretched string depends on two variables: the mass per unit length or linear density of the string (μ) and the tension of the string (T). The relationship is given by the equation:

$$V = \sqrt{\frac{T}{\mu}} \qquad (2)$$

**Frequency**

The relationship among the velocity of wave propagation (V) 、 wavelength(λ) and the frequency (ν) of wave is expressed :

$$V=\lambda\nu \qquad (3)$$

Using Eqs.(1)、（2）and (3) ,we obtain:

$$\nu = \left(\frac{n}{2l}\right)\sqrt{\frac{T}{\mu}} \qquad (4)$$

substituting T=Mg and μ =m/L into E q.(4) ,we obtain

$$\nu = \left(\frac{n}{2l}\right)\sqrt{\frac{MgL}{m}} \qquad (5)$$

where L = length of string

$l$ = length of n stand waves

n = number of antinodes

m = mass of string

M = mass of balancing weight.

**PROCEDURE**

(1) Measure the length and mass of the string using a meter and an electrical balance.

(2) Fix one end of the string to either arm of the tuning fork with a screw on it, make the string stride over the fixed pulley and suspend a hook at the other end of the string. Put proper weight on the hook.

(3) Adjust the fixed pulley knob so that the string is horizontal and tangent.

(4) Turn on the tuning fork power supply, adjust the screw on one side of the tuning fork until spark be created and the tuning fork will vibrate, at the same time, the string will vibrate, then lock the screw.

(5) Adjust the distance between the fixed pulley and the tuning fork until a steady stand wave with a larger amplitude is formed.

(6) Measure the length of several stand waves except the first one counting from the tuning fork with a meter. The length should be measured 3 times. Record the number of the stand waves, the mass of weights and the length of several stand waves in table.

(7) Change the mass of weight, then repeat procedure (5) and (6).

**PRE-QUESTIONS**

in the lab, which quantities need be measured? Use what devices to measure them?

**DATA RECORDING AND PROCESSING**

the standard frequency of the tuning fork $\nu_s$=

length of string L =

mass of string m =

| Item / Group | The length of several stand wave: $l$ (m) | The number of stand wave:n | The mass of the weight and the hook: M (Kg) | Frequency of the tuning fork: $\nu(s^{-1})$ |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| average | | | | |
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| average | | | | |

Calculate the uncertainty $U_\nu$ using the following equation:

$$\frac{U_\nu}{\nu} = \sqrt{(\frac{U_l}{l})^2 + \frac{1}{4}(\frac{U_M}{M})^2 + \frac{1}{4}(\frac{U_L}{L})^2 + \frac{1}{4}(\frac{U_m}{m})^2}$$

the result is :

**QUESTION**

you need measure the length of several standing wave 5 times, and every time you must move the tuning fork and adjust it until it is steady over again, then measure it, why?