

EXPERIMENT – 5

Aim of the experiment: To determine the frequency of electrically maintained tuning fork by Melde's experiment.

Apparatus required: Electrically maintained tuning fork, light weight pan, weight box, analytical balance, power supply, light weight string, stand with clamp and pulley.

Theory: This experiment is based on resonance between an exciter of waves, the tuning fork and the medium that supports the wave i.e., the stretched string. The tuning fork has its own natural frequency that depends upon its physical dimensions and elasticity of the material that is used for its fabrication. So that's a constant for a particular tuning fork. Now if one end of a thin, long, flexible string is attached to one of the arms of the tuning fork, while the other end subjected to tension by whatever means, then, the string would resonate only at frequencies given by

$$f = \frac{n}{2l} \sqrt{\frac{T}{\mu}}$$

where,

T is the tension in the string ($T = mg = (\text{mass of pan} + \text{mass on the pan})g$)

μ is its mass per unit length or the linear density of the string (to be provided in the lab)

l is the length of the stretched portion of the string

As we can see from the above expression that, f being the natural frequency of the string depends on its length. If the length of the stretched portion of the string is changed to match with the frequency of the tuning fork, then the string resonates.

It is quite obvious and equally easy to see that some conditions are to be met as depicted in the following figure.

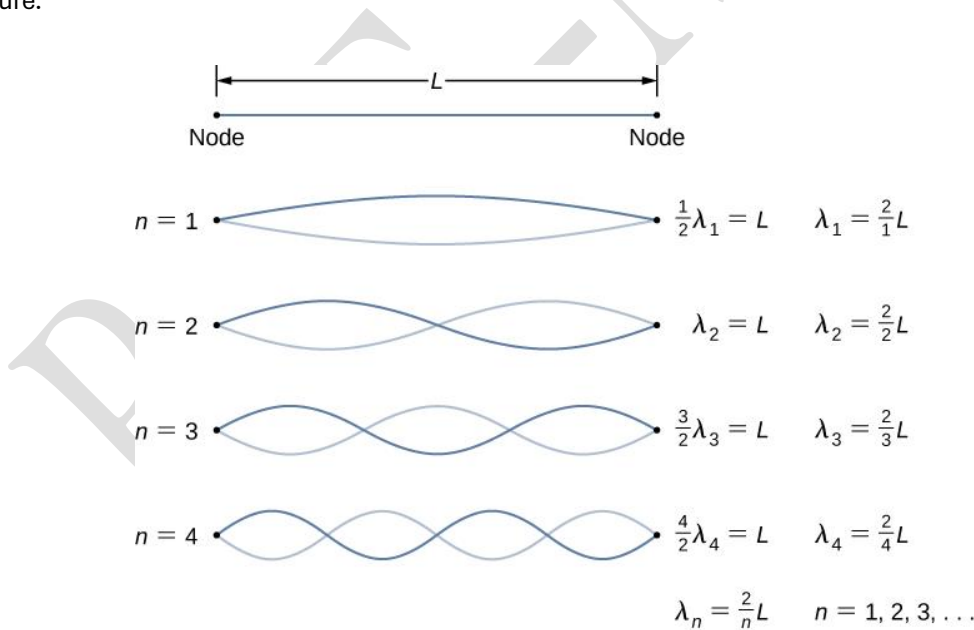


Fig. 1: Schematic representation of standing waves showing nodes and antinodes.

Also, it is worth mentioning that the waves on the string can be excited in two different ways,

- by tuning fork vibrations across the length of the string or
- by tuning fork vibrations along the length of the string.

In the first case the frequency of the exciter (tuning fork) is same as that of the waves on the string however, in the second case, the duration in which the exciter executes one complete oscillation, the string undergoes only half a cycle meaning thereby that the frequency of the exciter (tuning fork) is twice that of the wave on the string.

In order to have sustained oscillations in the string the exciter that we choose may be a tuning fork whose vibrations are maintained electrically, and the tip of one of the prongs may be attached to one end of the string. The string is made to pass over a small massless frictionless pulley and a weight hanger is attached to the other end of the string.

In this arrangement, the vibrations of the prongs of the tuning fork are in the direction perpendicular to the length of the string. The experimental setup with transverse mode arrangement is shown in Figure 2.

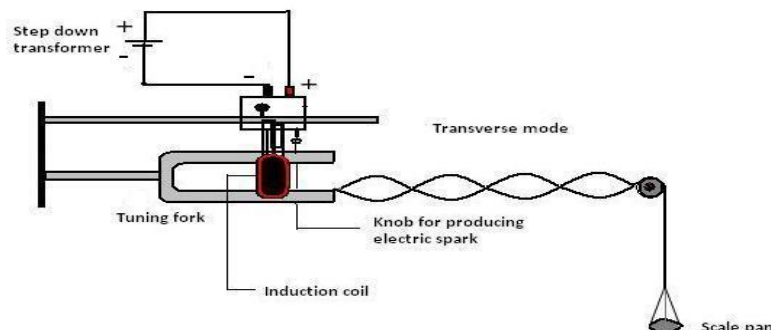


Fig. 2: Experimental setup for the determination of frequency of the tuning fork using resonance in the attached string. Here tuning fork vibrates across the length of the string.

When tuning fork vibrates across the length of the string, the string completes one vibration along with the tuning fork. Hence, in this mode, frequency of the tuning fork is equal to the frequency of the string and may be written as,

$$f = \frac{n}{2l} \sqrt{\frac{T}{\mu}} = \frac{n}{2l} \sqrt{\frac{Mg}{\mu}}$$

where,

$T (= Mg)$ is the tension in the string

M is the total mass of the pan and the weights placed on the pan

μ is the mass per unit length of the string

l is the length of the string between its two fixed ends

n loops are formed in length l

When tuning fork vibrates along the length of the string as shown in Fig-3.

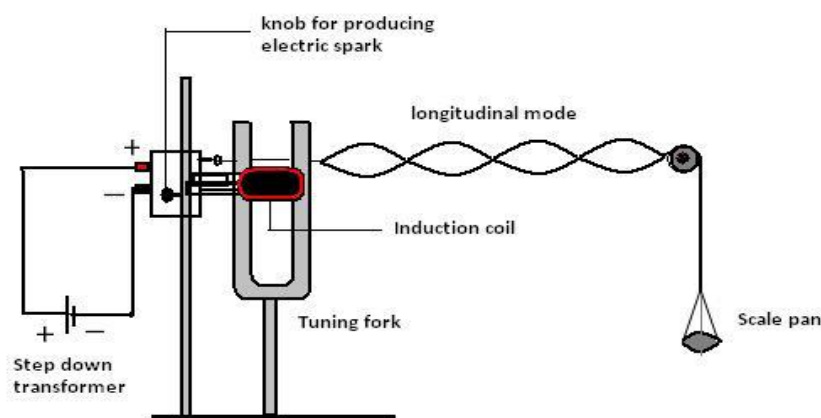


Fig. 3: Experimental setup for the determination of frequency of the tuning fork using resonance in the attached string. Here tuning fork vibrates along the length of the string.

When tuning fork vibrates along the length of the string, the string completes only one-half of the vibration while the tuning fork completes one. Hence, in this mode, frequency of the tuning fork is double the frequency of the string which may be written as,

$$f = \frac{n}{l} \sqrt{\frac{T}{\mu}} = \frac{n}{l} \sqrt{\frac{Mg}{\mu}}$$

where,

$T (= Mg)$ is the tension in the string

M is the total mass of the pan and the weights placed on the pan

μ is the mass per unit length of the string

l is the length of the string between its two fixed ends

n loops are formed in length l

Procedure & Precautions:

1. Frictions in the pulley must be minimized to the extent possible.
2. Find the mass of the pan and arrange the apparatus as shown in the figure.
3. Excite the tuning fork by switching on the power supply (advisable to use voltage between 6V to 8V) and try to get sustained vibrations in it by adjusting the screw provided for this purpose.
4. Once you are happy with the fork vibrations, make the attached string pass over the pulley and put some load on the pan attached to its other end.
5. The pulley is fixed on a stand at one end of the table. The tuning fork is stationed on a heavy base. Shift the tuning fork with its base, either towards the pulley or away from it gently, to alter its length, so that well defined loops are formed sustainably.
6. Note the length of the string and the corresponding number of antinodes. Record all the relevant data on the observation table.
7. Change the load on the pan and repeat the process.
8. Once Table-1 is populated, rotate the base of the tuning fork to make its vibrations along the length of the string and again repeat the experiment to populate Table-2.
9. Do not use very high voltage as it might produce vigorous vibrations in the tuning fork producing jitters and unstable formation of nodes and antinodes.
10. Proceed with the calculations and report the results obtained by you along with the estimated errors.

Observations and calculations:

Mass of the pan, $m' = \dots\dots\dots$ gm

Mass per unit length of the string, $\mu = \dots\dots\dots$ gm/cm

Table-1: Observations of number of loops, resonating length of the string against tension in it, for the determination of frequency of the tuning fork. (Fork vibrations across the string)

S.No.	Mass on pan m	Total mass $M = m + m'$	Tension in the string $T = Mg$	Resonating Length of the string l	No. of loops n	Tuning fork frequency $f = \frac{n}{2l} \sqrt{\frac{T}{\mu}}$	$(f_i - \bar{f})^2$
	(g)	(g)	(dyne)	(cm)		(Hz)	(Hz) ²
1							
2							
3							
4							
5							
					$\bar{f} =$		

Table-2: Observations of number of loops, resonating length of the string against tension in it, for the determination of frequency of the tuning fork. (Fork vibrations along the string)

S.No.	Mass on pan m	Total mass $M = m + m'$	Tension in the string $T = Mg$	Resonating Length of the string l	No. of loops n	Tuning fork frequency $f = \frac{n}{2l} \sqrt{\frac{T}{\mu}}$	$(f_i - \bar{f})^2$
	(g)	(g)	(dyne)	(cm)		(Hz)	(Hz) ²
1							
2							
3							
4							
5							
					$\bar{f} =$		

Results and discussion:

The experimentally determined frequency of the tuning fork when vibrating across the length of the string is

$$f = \text{average value} \pm \text{Standard error}$$

The experimentally determined frequency of the tuning fork when vibrating along the length of the string is

$$f = \text{average value} \pm \text{Standard error}$$

Put your comments on the results, its accuracy and precision as obtained through this experiment.