EXPERIMENT

AIM

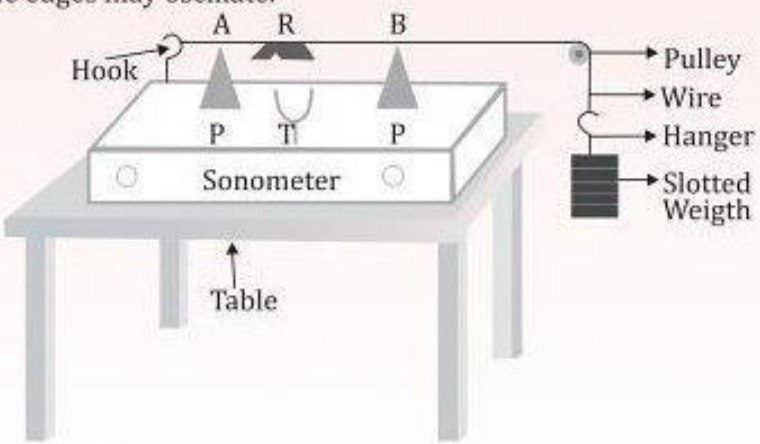
To study the relation between frequency and length of a given wire under constant tension using a sonometer.

MATERIAL REQUIRED

Sonometer with hanger and slotted weight of each, a set of six tuning forks having different frequenting rubber pad, meter scale screw gauge, paper rider and spring balance.

THEORY

1. **Sonometer** is a device used for studying the vibrations and sound produced by stretched strings. consists of a cuboidal wooden box nearly in dimensions. There are holes on cite of its side faces so that the air inside and outside the box is under the same conditions of temperature and pressure. At the top of the box on one end a peg is inserted and on the other end a pulley is fixed. A thin wire of uniform cross section is stretched along the length of box with its one end securely tied to the peg and the other end passed over the pulley and attached to a hanger-weight. A meter scale a mounted at edges along the length of the box and two bridges with knife edge are placed under the wind so that the length of the wire between the knife edges may oscillate.



2. **Laws of vibrations of stretched strings:** When a string stretched between two points is disturbed (plucked, bowed, hammered) in the middle, the transverse stationary waves produced in it set it to vibrate in a single loop. This is the simplest mode of vibration of the string with lowest frequency for the given length, called as the fundamental mode of vibration. In fundamental model $= \frac{\lambda}{2}$ i.e.,

   ∴ Frequency,

$$v = \frac{v}{\lambda} = \frac{1}{2l}\sqrt{\frac{T}{m}} \quad \ldots \left(v = \sqrt{\frac{T}{m}}, \text{ where v is the velocity of transverse wave}\right)$$

This implies the three laws of vibrating strings:

1. **Law of length:** For a given wire under constant tension the frequency of vibration varies inversely with length,
   i.e.,
   $$v \propto \frac{1}{l} \text{ or } vl = \text{constant.}$$
2. **Law of tension:** For a given wire of fixed length the frequency of vibration is directly proportional to the square root of tension in it,
   i.e.,
   $$v \propto \sqrt{T} \text{ or } \frac{v^2}{T} = \text{constant. m and } l \text{ are constant)}$$
3. **Law of mass:** For wires having same lengths and tensions the frequency of vibration is inversely proportional to the square root of the mass per unit length of the wire,
   i.e.,
   $$v \propto \frac{1}{\sqrt{m}} \text{ or } v^2 m = \text{constant}$$
   (l and T are constant)
   When a string is set into resonant vibrations with a tuning fork of frequency v, the string vibrates with frequency of tuning fork.
   i.e., $$v = v_S = \frac{1}{2l}\sqrt{\frac{T}{m}}$$
   Where, vibrating length of string at resonance.
   T = tension in the string.
   m = mass per unit length of the string.
   The above relation shows:
   (i) The graph between v and l will be a rectangular hyperbola.
   (ii) The graph between v and $\frac{1}{l}$ will be a straight line.

PROCEDURE

1. Place the sonometer on the table so that the hanger weight hangs without touching the table or floor. Remove the wire from the pulley and make sure that it is frictionless. Oil the pulley if need be. Replace the wire on the pulley and let weight on the hanger stretch it. Measure the weights hanged with the help of spring balance.
2. Check that there are no kinks in the wire and that it is spread horizontally along the sonometer. Place two bridges under the wire.
3. Make a small V-shaped paper rider and place it inverted (like) on the wire just in the middle of its length between the bridges.
4. Start with the tuning fork of highest frequency, hold its stem, strike its prongs on the rubber-pad, and press the pointed end of the stem of vibrating tuning fork on the top face of the sonometer.

5. Starting with the minimum distance increase the separation between the bridges and repeat step-4 till we reach a stage when the rider flutters and falls. Measure the length of sonometer wire between the bridges resonating under tuning fork of frequency.
6. Repeat steps 4 and 5 for five more tunning forks and record corresponding resonating lengths between the bridges.
7. Repeat steps 4, 5 and 6 for each of the above tuning forks with more than the resonating length and repeat steps 4, 5 and 6 with decreasing length.
8. Find the mean of resonating lengths between the bridges for increasing and decreasing distance corresponding to each frequency.
9. Plot a graph between v and l and between v and $\frac{1}{l}$.

OBSERVATION

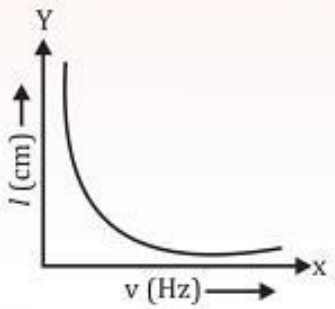
1. Range of spring balance = 0 – 5 kg f
2. Least count of spring balance = ___ gf
3. Weights of hanger and weights on it, w = _____ kg f.
4. Tension in the string T = w × g N

TABLE FOR REASONING LENGTHS CORRESPONDING TO DIFFERENT FREQUENCY

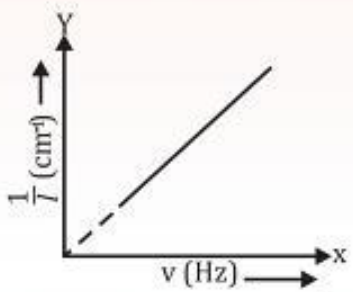
S. No.	Frequency of tuning fork V (Hz)	Resonation length of wire			$1/l$ (cm^{-1})
		Length increasing l_1 (cm)	Length decreasing l_2 (cm)	Mean $l = \frac{l_1 + l_2}{2}$ (cm)	
1.					
2.					
3					
4.					
5.					

PLOTATION OF GRAPH

(i) Plot a graph between frequency (v) and resonating length (l), taking v along x-axis and l along y-axis.



Graph between Frequency v and length l



Graph between v and $\frac{1}{l}$

(ii) Plot a graph between frequency (v) and reciprocal of length $\left(\frac{1}{l}\right)$ taking v along x-axis and $\frac{1}{l}$ along y-axis.

RESULT

For a given wire, under constant tension, i.e,

(i) The product is a *vl* constant under limits of experimental error:

$$vl = \text{constant}$$

or $$v \propto \frac{1}{l}$$

(ii) The graph between v and *l* is a rectangular hyperbola.

(iii) The graph between v and $\frac{1}{l}$ is a straight line as shown in Fig.

These results are in tune with the law of length i.e.,

$$V \propto \frac{1}{l}$$

PRECAUTIONS

1. Make sure that the sonometer wire is of uniform cross section and free of kinks.
2. Make the pulley frictionless by oiling and greasing before you start the experiment.
3. The load applied should not exceed $\frac{1}{3}$rd the breaking stress. For this measure the diameter of sonometer with the help of screw gauge and note down the value of breaking stress from the table of constants.
4. Use good quality tuning forks which vibrate for more than one minute. Take care that they are not struck with any hard surface.
5. Don't rely on the weight marked on hanger and slotted weights, verify the true weight using a spring balance.
6. Hold the tuning fork from its stem and place the tip of the stem of vibrating tuning fork gently on the top face of sonometer.
7. After completing the experiment do not forget to remove the load from the wire or else it may get permanently stretched.

SOURCES OF ERROR

1. The cross section or composition of wire may not be uniform.
2. Pulley may not be completely frictionless. Then the effective tension would be less than the applied load.
3. The knife edges over the bridges may not be sharp causing an error in measurement of length.
4. The formula, $v = \frac{1}{2l}\sqrt{\frac{T}{m}}$ has been derived under assumption that the wire is perfectly flexible. So, rigidity of wire may cause an error.

VIVA VOCE

Q1. What is a sonometer?

Ans. A sonometer is a laboratory device used to study the vibrations in strings.

Q2. Why is it called so?

Ans. Because it helps us to find the frequency of various sources of sound.

Q3. What type of waves are produced in sonometer wire?

Ans. Transverse stationary waves.

Q4. How are these waves set up in a string?

Ans. When a string supported at its two ends is disturbed, the disturbance travelling in opposite directions get reflected from fixed ends. As the process continues the direct and reflected waves

superimpose to give rise to stationary waves.

Q5. Name the simplest mode of vibration of a string.

Ans. Fundamental vibration.

Q6. In how many segments does the string fixed at its two ends vibrate in its fundamental mode of vibration?

Ans. In one segment.

Q7. State the function of two knife edges which are used as bridge in sonometer.

Ans. It reflects the sound wave and produces stationary waves.

Q8. Is it necessary to keep the sonometer horizontal only or you can keep it vertical also?

Ans. Vertically held sonometer is better arrangement.

Q9. What roles do the wooden box and bridges play in the working of sonometer?

Ans. Wooden box amplifies the vibrations of tuning fork which are communicated to the wire through the bridges.

Q10. Which part of the tuning fork is set into vibrations?

Ans. Vibrations are set in the prongs as well as stem of the tuning fork.