# To Find the Frequency Of the AC Mains With a Sonometer

## Aim
To find the frequency of the AC mains with a sonometer.

## Apparatus
A sonometer (with soft iron wire), a set of eight tuning forks, ½ kg hanger, seven ½ kg slotted weights, clamp, stand, rubber pad, paper rider, metre scale.

## Theory
Let the alternating current have frequency v so that the frequency of magnetisation of the electromagnet ($V_E$) becomes 2v.
Let a loaded stretched soft iron wire have resonant length $l_1$ with the electromagnet. Let a tuning fork of frequency $V_T$ have resonant length $l_2$.

**Then from law of length,**

$$\nu_E l_1 = \nu_T l_2$$

or

$$\nu_E = \nu_T \frac{l_2}{l_1}$$

**Hence, frequency of alternating current,**

$$\nu = \frac{1}{2}\nu_E = \frac{1}{2}\nu_T \frac{l_2}{l_1}$$

**which can be calculated.**

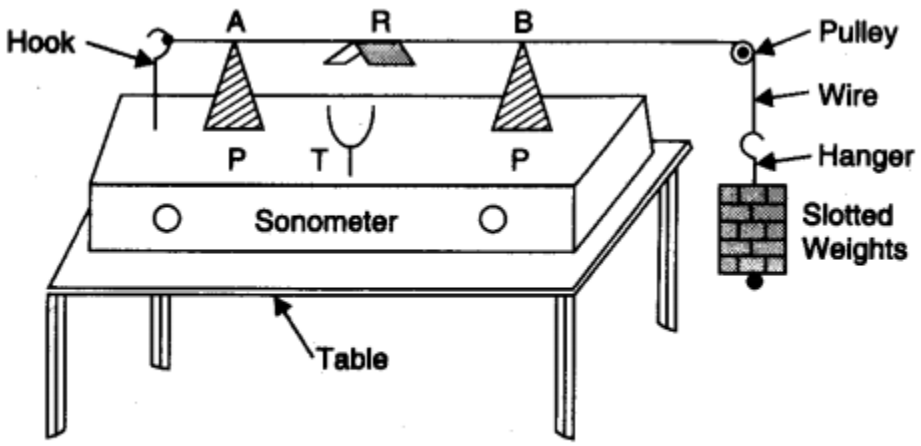
The natural frequency of oscillation for a stretched wire of length L and mass m and tension T is

$$n = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$$

Here

$$\mu = \frac{\text{mass}}{\text{length}} = \frac{m}{L}$$

## Diagram




**Sonometer in experimental set-up.**

## Procedure

1. Place the sonometer on the table as shown in figure.
2. Test the pulley and make it frictionless by oiling (if necessary).
3. Put suitable maximum weights in the hanger.
4. Move wooden bridges P, P outward to include maximum length of wire (AB) between them.
5. Decrease the length of the wire by moving both the bridges equally inwardly.
6. Go on decreasing the length till sonometer wire starts vibrating (a sound is heard).
7. Adjust the length for maximum amplitude of vibration, (maximum sound).
8. Measure the length of the wire AB between the edges of the two bridges and record it in 'length decreasing' column.
9. Bring the two bridges closer and then adjust the length for maximum amplitude by increasing it.
10. Measure the length and record it in length increasing' column.
11. Now take a tuning fork of minimum known frequency (say 256) and adjust wire length with the vibrating tuning fork.
12. Repeat step 11 above with tuning forks of other known frequencies 288, ……. 512.
13. Record your observations.

## Observations

Weight suspended to produce on the wire, $T$ = ..... kg.

Length of sonometer wire, $L$ = ..... m.

Mass of wire, $m$ = ..... kg.

Linear density, $\mu = \frac{m}{L}$ kg m$^{-1}$

**Table for frequency and length**

| *Serial No. of Obs.* (1) | *Frequency of electromagnet and tuning forks used* $\nu$ *(Hz)* (2) | *Resonant length of wire* | | | *Frequency of electromagnet* $\nu_E$ *(Hz)* (4) | $n = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$ (5) |
|---|---|---|---|---|---|---|
| | | *Length decreasing* $l'$ *(cm)* (3a) | *Length increasing* $l''$ *(cm)* (3b) | *Mean* $= \frac{l' + l''}{2}$ $l$ *(cm)* (3c) | | |
| 1. | $\nu_E$ | | | $l_1 =$ | | |
| 2. | 256 | | | $l_2 =$ | $256\,\frac{l_2}{l_1} =$ | |
| 3. | 288 | | | $l_3 =$ | $288\,\frac{l_3}{l_1} =$ | |
| 4. | 320 | | | $l_4 =$ | $320\,\frac{l_4}{l_1} =$ | |
| 5. | 384 | | | $l_5 =$ | $384\,\frac{l_5}{l_1} =$ | |
| 6. | 480 | | | $l_6 =$ | $480\,\frac{l_6}{l_1} =$ | |
| 7. | 512 | | | $l_7 =$ | $512\,\frac{l_7}{l_1} =$ | |

## Calculations

Using formula, $\nu_E = \frac{\nu_2 l_2}{l_1}$, calculate $\nu_E$ with observations 2 to 7.

Record these values in column 4 of the table.

Find mean of above six values of $\nu_E$.

Then, frequency of alternating current, $\nu = \frac{\nu_E}{2}$.

Use $n = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$ for each set of observation and then take the mean. Compare it with standard frequency (50 Hz).

## Result

**The frequency of the alternating current = ..... Hz.**

**Percentage Error**

**The actual frequency = 50 Hz**

**Difference = ..... Hz**

$$\text{Percentage error} = \frac{\text{Difference}}{\text{Actual value}} \times 100\%$$

**The error is within limits of the experimental error.**

## Precautions

1. All precautions of sonometer experiment should be observed.
2. The wire should be of soft iron or of any other magnetic material.
3. Tip of electromagnet should be very close to the wire in its middle*
4. Length should be noted when the amplitude of vibration is maximum.

## Sources of error

1. Wire may not be rigid and of uniform cross-sectional area.
2. Pulley may not be frictionless.
3. Weights may not be correct.
4. Knife edges (bridges) may not be sharp.
5. The main frequency may not be stable.

# Alternative method

## Aim

To find the frequency of the A.C. mains with a sonometer.

## Apparatus

Same as in Experiment 8 except a separate horse shoe magnet and a separate step down transformer.

## Theory

A low alternating current passed directly through sonometer wire imposes (forces) on it the frequency v (nu) of the A.C. main.

Let a loaded stretched soft iron wire have resonant length $l_1$ for the main frequency. Let a tuning fork of frequency $V_T$ have resonant length $l_2$.

Then, from Law of length $\nu\, l_1 = \nu_T\, l_2$

Frequency of alternating current, $\nu = \nu_T \dfrac{l_2}{l_1}$ which can be calculated.

## Diagram

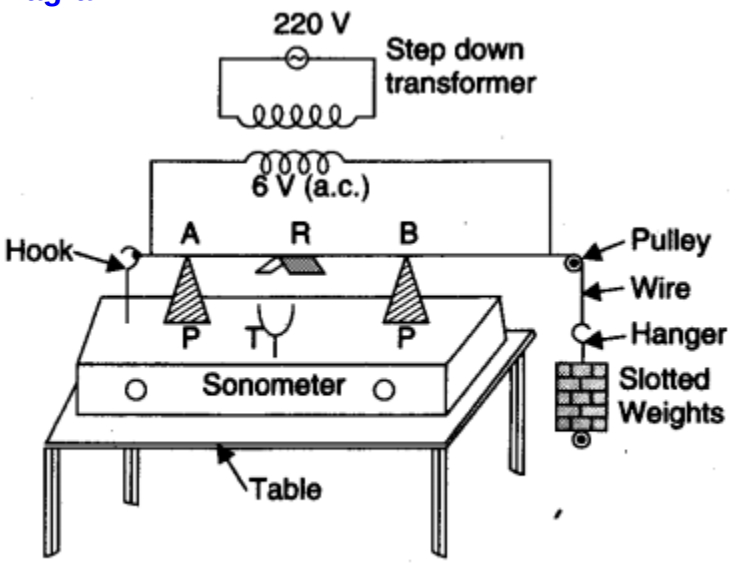



**Fig.** Sonometer in experimental set up.

## Procedure

1. Steps 1 to 4 of Experiment 10.
2. Keeping the main switch off, connect the secondary of the step down transformer to the sonometer wire to pass a low voltage alternating current through it.
3. Put the main switch on. The current imposes its frequency on the soft iron wire.
4. Take a horse shoe magnet and hold it over the middle of the wire AB with its NS line vertical. The wire will try to vibrate with the forced frequency of the current.
5. Since the long wire may have frequency less than that of the current, it may not vibrate.
6. Steps 5 to 10 of Experiment 10.
7. Switch off the main and remove the transformer.
8. Steps 11 to 13 of Experiment 10.

## Observations

Constant tension on the wire, T = (4) kg.

1. **Table for frequency and length**
   Same as in Experiment 10 except column (2) which records frequency of alternating current in place of frequency of electromagnet.

## Calculations

Using formula $\nu = \frac{\nu_2 l_2}{l_1}$, calculate $\nu$ with observations 2 to 7.

Record these values in column 4 of the table.

Find mean of above six values of $\nu$.

## Result

The frequency of alternating current =……. Hz.
Percentage Error
Same as in Experiment 10.

## Precautions

Same as in Experiment 10.

# Viva Voce

**Question. 1. What do you mean by A.C. and D.C.?**
**Answer.** Alternating current (A.C.) is the current whose magnitude changes every instant of time and direction changes periodically. Direct current (D.C.) is the current which has one direction. Steady current is the current whose magnitude and direction does not change with time.

**Question.2.How does A.C. differ from D.C.?**
**Answer.** D.C. has same (constant) magnitude and same direction, while A.C. has a changing magnitude and changing direction. D.C. repels but A.C. attract.

**Question.3.What is fluctuating current?**
**Answer.** A current having changing magnitude (but not becoming zero) and same direction, is called fluctuating current.

**Question.4.What is unidirectional current?**
**Answer.** A current having magnitude changing between maximum and zero and same direction, is called unidirectional current.

**Question.5.How is A.C. produced?**
**Answer.** A.C. is produced by dynamo (alternator) in which a coil rotates in a magnetic field.

**Question.6.What do you mean by one cycle of A.C.?**
**Answer.** One cycle of A.C. means current from zero becoming maximum positive, then zero, then maximum negative and finally zero again.

**Question.7.Why is the instrument called a sonometer?**
**Answer.** Sono means sound. Therefore, a sonometer is an instrument which measures the frequency of sound.

**Question.8.What is the unit of frequency of A.C.?**
**Answer.** Unit of frequency of A.C. is hertz (Hz) or per second.

**Question.9.What is frequency of alternating current supplied to us in our houses?**
**Answer.** The frequency is 50 hertz (Hz) [hertz means cycles per sec.].

**Question.10.Define root mean square or virtual or effective value of alternating current.**
**Answer.** It is that value of steady current which, when passed through a given resistor for certain time (time of one complete cycle), shall produce the same quantity of heat as the given alternating current shall produce when passed through same resistor for same time.

**Question.11.What is resonance?**
**Answer.** When the natural frequency of a particle is equal to the frequency of driving force, then resonance takes place. The vibrations are called resonant vibrations.

**Question.12.Give expression for r.m.s. value of A.C.**
**Answer.**For an alternating current having maximum (peak) value 70,

$$I_{r.m.s.} = \frac{I_0}{\sqrt{2}} = 0.707\, I_0$$

**Question.13.Why does D.C. repel?**
**Answer.** Main line carrying D.C. has same polarity (positive or negative) throughout. On touch¬ing it, the body of the person acquires same polarity as that of the main line. The person touching the line is repelled.

**Question.14.Why does A.C. attract?**
**Answer.** Main line carrying a.c. has quickly changing polarity. On touching it, the polarity of the body of the person also changes. Due to time lag, the body polarity remains opposite to that of the main line. The person touching the line is attracted.

**Question.15.Why A.C. is more dangerous than D.C.7**
**Answer.** It is due tθ following two reasons :

1. A.C. attracts while D.C. repels (Q. 13,14).
2. A.C. gives a huge and sudden shock which becomes fatal.

**Question.16.Give merits (advantages) of A.C. over D.C.**
**Answer.** A.C. has following merits (advantages) over D.C.:

1. A.C. can be produced and transmitted easily and cheaply than D.C.
2. A 3-phase A.C. Dynamo can produce more energy than a single phase D.C. Dynamo of same cost.
3. A.C. Dynamo (using slip rings) has less loss of energy and wear and tear than a D.C. Dynamo (using split ring commutator).
4. A.C. voltage can be transformed to any desired value with the help of a transformer.
5. Transmission of A.C. at <high-voltage' and Tow-voltage' reduces line losses.
6. A.C. motors or other A.C. appliances are robust and easier to operate.
7. A.C. can easily be converted into D.C. when required.
8. In A.C. circuits, current can be controlled by a choke coil without much loss of energy.

**Question.17.Give demerits (disadvantages) of A.C. over D.C.**
**Answer.** A.C. has following demerits (disadvantages) over D.C.:

1. A.C. attracts a person who touches its line whereas D.C. gives a repelling shock.
2. A.C. gives a huge and sudden shock which becomes fatal.
3. A.C. is conducted over the surface of a conductor (skin effect). It increases effective resistance of the conductor.
4. Commercial generators do not produce pure A.C.
5. In certain applications like electroplating, battery charging, etc. Only D.C. is required.

**Question.18.What is skin effect?**
**Answer.** It is found that in an alternating current, the tendency of the moving electrons is to drift towards the surface of the conductor while moving along its axis. This tendency increases with the frequency of A.C. In very high frequency A.C., electrons flow only on the surface of the conductor. This phenomenon (flow of electron on the surface of the conductor), is called skin effect.

**Question.19.What is an electromagnet?**
**Answer.** A magnet magnetised by electric current, is called an electromagnet.

**Question.20.Howls frequency of magnetisation of the electromagnet related with frequency of the alternating current which magnetises it?**
**Answer.** It is twice the frequency of the alternating current.

**Question.21.Why is frequency of magnetisation of electromagnet double of that of the alternating current?**
**Answer.** It is because the electromagnet is magnetised twice during one cycle of alternating current.

**Question.22.Which material is used to make sonometer wire? And Why?**
**Answer.** Iron. Because it is a ferromagnetic material.

**Question.23. What is a timing fork?**
**Answer.** A timing fork is metallic bar bent into U-shape and having a heavy steps attached to the middle of the bent portion.

**Question.24. What is function of a sounding board?**
**Answer.** When the vibrating tuning fork is placed on it, it is set into forced vibrations. Once the area of vibrating body increases the amplitude of vibration of the board wire system also increases.

**Question. 25. What is the function of holes in the sonometer box?**
**Answer.** To make the inside air in communication with external air.

**Question. 26. What are natural vibrations?**
**Answer.** When a body is vibrating with its own natural way then it has natural vibrations. The frequency with which the body vibrate is, called its natural frequency.

**Question. 27. What are forced vibrations?**
**Answer.** When a body is vibrating with frequency of driving force, other than its natural frequency then it has forced vibrations.

**Question.28. What is the natural frequency of sonometer wire?**
**Answer.**

$$f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}, \qquad \text{where } T = \text{Tension in wire}$$

$$\mu = \frac{m}{l} = \text{Linear mass density}$$

$$l = \text{length of wire}$$

**Question.29. What are stationary waves?**
**Answer.** When two identical waves of same frequency, amplitude travelling in a medium with same speed but in opposite directions superpose, they produce stationary waves.

**Question. 30. What are nodes and antinodes?**
**Answer.** Nodes are the points of zero amplitude and antinodes are points of maximum amplitude.

**Question.31. Define wavelength for a stationary wave.**
**Answer.** The distance between the centres of two successive crests or troughs is called the wavelength of a stationary wave.

**Question.32. How does the wire begin to vibrate in this case?**
**Answer.** When a current carrying wire is placed in magnetic field then magnetic force act on the wire which tends to move it in a direction which is perpendicular to current and field. The current is A.C., the force which act on the wire is also oscillating and hence the wire vibrate.

**Question.33. When will the wire resonate?**
**Answer.** When the frequency of A.C., mains is equal to the natural frequency of the vibration of the wire.

**Question.34. Why does the string of the sonometer vibrate?**
**Answer.** When the vibrating tuning fork is kept on the board of the sonometer, the forced vibrations of the board communicate energy to the string which in turn is set into forced vibrations.