# EXPERIMENT

## AIM

**To find the frequency of the AC mains with a sonometer.**

## MATERIAL REQUIRED

A sonometer has a soft iron wire, an electromagnet, a step-down transformer, a hanger with half kg slotted weights, a physical balance, a weight box, a meter scale and a clamp stand.

## DIAGRAM

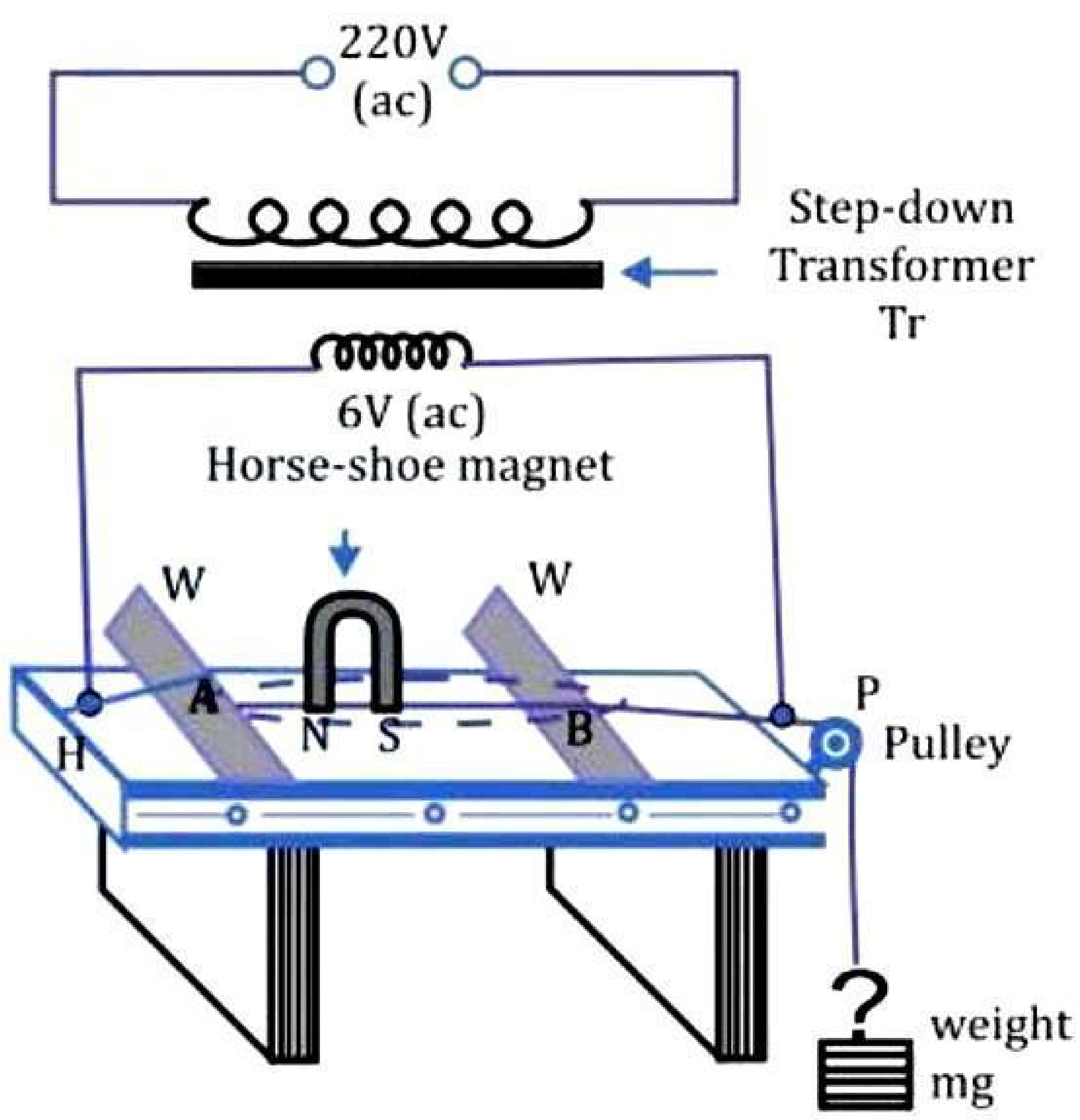


**Fig. Frequency of a.c. mains is measured using a sonometer and a horse-shoe magnet.**

## THEORY

1. Direct current is said to be a steady current if its magnitude does not change with time. The variation of current (I) and time (t) for direct current will be represented by a straight line parallel to the time axis as shown in Fig.
2. An alternating current is a current whose magnitude changes with time and whose direction reverses periodically the variation of current (I) and time (t) for alternating current can be represented by the curve as shown in Fig.
3. The frequency of the alternating current is defined as the number of cycles made by alternating currents per second. It is represented by v or f or n. Its SI unit is hertz (Hz). In India, the frequency of the alternating current is 50 cycles/second or 50 Hz.
4. An electromagnet is an artificial magnet made from a piece of soft iron by passing electric current in a coil wound around it. On placing a soft iron bar inside a solenoid as a core, the iron bar acquires magnetic properties on passing an electric current through the solenoid and loses the magnetic properties on

switching off. An electromagnet is made in two shapes, viz. I-shaped (bar magnet) and U- shape (horse-shoe magnet).

5. When a string of length $l$, mass per unit length m, under tension T executes transverse vibrations in fundamental mode, then the frequency of its vibrations is given by $v = \frac{1}{2l}\sqrt{\frac{T}{m}}$
6. For a fixed value of tension in the string, the frequency of vibration can be changed by changing its length.
7. On the other hand, if an alternating current of frequency 'f' is passed through an electromagnet, the polarity on the ends of the electromagnet changes (N pole to S pole or vice versa) once in every cycle of alternating current.
8. If the electromagnet is held close to the string (which is made of ferromagnetic material) of a sonometer wire, near its centre, the string will be attracted towards it when the electromagnet is magnetized and thrown away when it is demagnetized. Thus, the sonometer wire will vibrate under the electromagnet. Now as the ferromagnetic string will be attracted by the electromagnet whether there is a north pole on its nearer end or a south pole, the frequency of vibration of the string will be twice the frequency of the ac fed in electromagnet (i.e., 2f ).

   If we adjust the length of the string, so that, it resonates in fundamental mode (indicated by its maximum amplitude). Then

$$2f = v = \frac{1}{2l}\sqrt{\frac{T}{m}} \text{ or frequency of ac, } f = \frac{1}{4l}\sqrt{\frac{T}{m}} \text{ Hz}$$

   Knowing T, l and m frequency of ac mains may be calculated.

   **Caution:** Dealing directly with the mains may be fatal even with a little carelessness, therefore, the stepped-down voltage is used with the help of a step-down transformer.

## FORMULA

Frequency of ac mains using a sonometer,

$$f = \frac{1}{2l}\sqrt{\frac{T}{m}}$$

Where,

$l$ = resonance length

T = tension in the string

m = mass per unit length of the wire

## PROCEDURE

1. Check that the pulley attached to the sonometer is frictionless. Oil it if need be.
2. Place a sonometer parallel to one edge of the working table, such that, the pulley remains projected out of its perpendicular edge. See that there are no kinks in the string of the sonometer and its one end is rigidly fixed. Pass string over the pulley such that it stretches horizontally over the box of the sonometer and attach a hanger of 1 *kg* weight on its free end.
3. Connect the electromagnet to the secondary of the step-down transformer and plug the primary of the transformer in *ac* mains. Hold the electromagnet in a stand and bring it close to the sonometer wire just above the centre of its length.
4. Switch on the mains and adjust the wedges on the sonometer, starting from minimum separation till you get the maximum amplitude of oscillation of the sonometer wire. At this resonance condition, the rider

flies off. Note the length of the sonometer wire between the wedges and also note the load suspended on the string.

5. Increase load on the hanger in steps of $\frac{1}{2}\ kg$ weight and measure the resonating length in each case. Take at least 5 observations with different loads.
6. Repeat the experiment for the same load while decreasing the loads.
7. Switch off the *ac* supply and take out the sonometer wire. Measure its length and also measure its mass with the help of a sensitive balance.

## OBSERVATIONS

1. Length of sonometer wire, $l$ = ______ cm = ______ m
2. Mass of sonometer wire, M = _______g = ________kg
3. Mass per unit length of sonometer wire, $m = \frac{M}{l}$ = ________ kg/m
4. Mass of hanger, x = _______ kg

### TABLE FOR RESONATING LENGTH WITH VARYING TENSION

| No. of obs. | Mass of hanger and weights (kg) $[M' = (x + m')]$ (kg) | Tension $T = M'g$ (N) | Resonating length | | | Mean length $l$ (cm) | $V = \frac{1}{2l}\sqrt{\frac{T}{M}}$ (Hz) |
|---|---|---|---|---|---|---|---|
| | | | Load increasing $l_1$ (cm) | Load decreasing $l_2$ (cm) | Mean $l = \frac{l_1+l_2}{2}$ | | |
| 1. | | | | | | | |
| 2. | | | | | | | |
| 3. | | | | | | | |
| 4. | | | | | | | |
| 5. | | | | | | | |

Mean value of the frequency of sonometer wire, v = __________Hz

## CALCULATION

The frequency of ac mains, $f = \frac{v}{2}$ = ___________Hz

## PERCENT ERROR

The standard value of frequency of *ac* mains in India, $f_0$ = _________Hz

$\therefore$ Percent error = $\frac{f - f_0}{f_0} \times 100$ =________ %

## RESULT

The frequency of *ac* mains as determined using sonometer and electromagnet is _______Hz.

## PRECAUTIONS

1. The sonometer wire should be held horizontally between the bridges and it should be free of kinks.
2. The magnet should always remain in the middle of the vibrating segment and its poles as close to the wire as possible.
3. The resonance position should be ensured by noting oscillations of wire of maximum amplitude.
4. After completion of the experiment do not forget to remove weights from the hanger.

## SOURCES OF ERROR

1. The slotted weights may not have a standard value marked on them.
2. Knife edges may not be sharp.
3. Pulley may not be frictionless.

**4.** Sonometer wire may not be of uniform cross-section.

**5.** The relation $v = \frac{1}{2l}\sqrt{\frac{T}{m}}$ holds for a perfectly elastic string which we may not realize in practice.

## VIVA- VOCE

**Q 1. Does the magnitude of current remain constant in *c* ?**

**Ans.** Yes, in steady dc, the magnitude of the current remains constant.

**Q 2. What is the voltage and frequency of *ac* in India?**

**Ans.** 220 V, 50 Hz.

**Q 3. Which is more dangerous *ac* or *dc*? Why?**

**Ans.** Alternating current (ac) is more fatal than dc because:

(i) the peak value of ac is about 40%, and hence, more severe damage is caused by it.

(ii) *ac* attracts while *dc* repels.

**Q 4. What is a sonometer?**

**Ans.** A sonometer is a device used to find the frequency of sound.

**Q 5. What is the principle of working on a sonometer?**

**Ans.** The vibrations of the *ac* under study are transferred to a string through a transformer. By adjusting the tension in the string or by changing its length, its natural frequency may be changed. When resonance occurs, the frequency of vibration of the string is equal to the frequency of ac.

**Q 6. What is meant by resonance?**

**Ans.** Increase in intensity of oscillations due to mutual reinforcement in forced oscillations when the frequency of the driver is equal to the frequency of the driven.

**Q 7. What is the expression for the fundamental frequency of a vibrating string?**

**Ans.** $v = \frac{1}{2l}\sqrt{\frac{T}{m}}$

**Q 8. Do you connect the sonometer wire or electromagnet directly to *ac* mains? Why?**

**Ans.** No, we do it through a step-down transformer. Due to safety considerations, Operations at low voltages are safer.

**Q 9. Is the frequency of the low voltage *ac* output of the transformer the same as that of the *ac* input?**

**Ans.** Yes, the transformer changes the level of voltage without any change in frequency.

**Q 10. When wire resonates under the influence of electromagnet, what is the relation between the frequency of *ac* mains and the frequency of sonometer wire?**

**Ans.** The frequency of *ac* mains is half the frequency of magnetization of the electromagnet or frequency of vibration of the sonometer wire.

**Q 11. How do you change the natural frequency of the sonometer wire to match it with the frequency of magnetization of the electromagnet?**

**Ans.** By changing the length between the bridges or by changing the tension in the string.