Experiment - 02

Objective: To determine the frequency of the A.C. mains using sonometer and an electromagnet.

Apparatus: A sonometer with soft iron wire, an electromagnet, a step down transformer, hanger with slotted weights, a calamp stand, meter scale, screw gauge, a sensitive balance, connecting wires.

Theory: If a wire of length l and mass per unit length m is stretched over two bridges with a tension T and plucked, it vibrates with a frequency given by

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

In this experiment, the length of the wire and the tension are so adjusted that the natural frequency of the wire is equal to the frequency of the electromagnet.

The electromagnet has a soft iron cylindrical core on which enameled copper wire is wrapped. Current through the a.c. mains is stepped down by a step-down transformer and then passed through the copper wire of the electromagnet. The current magnetises the cylindrical core twice during each cycle-first with one polarity when the current flows in one direction and then with the opposite polarity when the current flows in opposite direction. When the tip of this cylindrical core is kept very close to the stretched soft iron wire of the sonometer, the wire will be pulled towards the tip twice during each cycle. Thus, if the frequency of the a.c. mains is 50 Hz, the wire will be pulled towards the tip of the core 100 times per second.

So the natural frequency n of the sonometer wire is double the frequency f of the a.c. mains,

or

$$f = \frac{n}{2} = \frac{1}{4l}\sqrt{\frac{Mg}{m}}$$

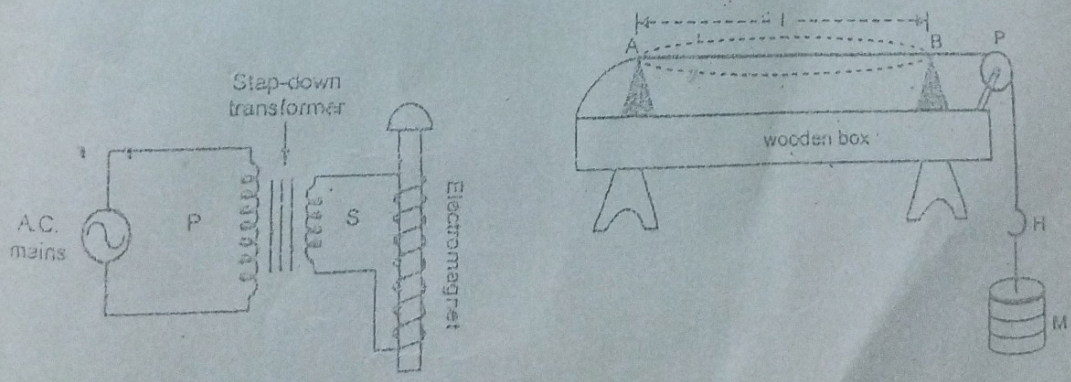

Fig. 3.1

As T, l and m can be measured, n and hence f can be determined. The value of mass per unit length m can be determined either by weighing a definite length of the wire or by measuring the radius r and taking

R 9

the density ρ of the material of the wire from the table (for soft iron, ρ = 7.8 gm/cc). Then mass per unit length of the wire is given by the formula $m = \pi r^2 \rho$.

Procedure

1. Set-up the sonometer as shown in Fig. 3.1.
2. Hold the electromagnet vertically in a clamp-stand about 2 to 3 mm above the sonometer wire.
3. Bring the two wedges *A* and *B* close to each other. Cut a small piece of paper (about 2 cm × 0.5 cm), fold it into a ^ shape and hang it (the rider) on the wire between the wedges.
4. Suspend a load of 2 kg on the hanger and switch on the a.c. supply. Slide the wedges gradually away from each other till the wire starts vibrating and the rider begins to flutter. Make minor adjustments until the amplitude of the vibration of the wire is maximum and the rider flies off.
5. Measure the length of the wire between the two wedges *A* and *B* with a metre-scale.
6. Increase the distance between the two wedges by a few centimetres. Repeat the above process by again putting the rider on the wire between the wedges but this time slide the wedges gradually towards each other till the rider again flies off. Again measure the length between the wedges. The mean of the two lengths gives the resonant length *l*.
7. Increase the load in steps and find out the resonant length *l* in each case. Take five such observations.
8. Switch off the a.c. mains and remove the magnet. Take about 1 metre of wire and find its weight by a sensitive balance and hence find the mass per unit length *m*. Another way to find *m* is using the formula $m = \pi r^2 \rho$ where *r* is the radius of the wire and ρ is the density of the material of the wire (ρ = 7.7 gm/cc for iron).

Observations :

Length of wire = 150 cm = ... m

Mass of wire = 912 gm = ... kg

Mass per unit length, *m* = ... gm/cm = kg/m. 0.06

Acceleration due to gravity, *g* = 980 cm/s² = 9.8 m/s²

No.	Load, M* (gm)	Length for resonance, l			Frequency $f = \frac{1}{4l}\sqrt{\frac{Mg}{m}}$ (Hz)
		Wedges moving outward (cm)	Wedges moving inward (cm)	Mean l (cm)	
1.					
2.					
3.					
4.					
5.					

Mean frequency = ... Hz

* It includes the weight of hanger.

The frequency of the a.c. mains = ... Hz
standard value = 50 Hz
percentage error = ... %

...tions and Sources of Error

...ring should be uniform, inextensible and kink free.

...riction in the pulley should be negligibly small otherwise the tension would be less than that of ...eight M in the formula should include the weight of the hanger.

...sonance position should be obtained carefully first by increasing the distance between the wedges ... by decreasing it.

...onometer wire should be of a magnetic material like iron so that it is attracted by the electro-...p of the core of the magnet should be 2-3 mm vertically above the centre of sonometer wire.

...s per unit length is determined by using the formula $m = \pi r^2 \rho$, the diameter of the wire should be ...ed very accurately with a screw gauge.

...riction at the pulley can not be eliminated. Due to this, the value of the tension acting on the wire ...n that actually applied. This results in a lower value of the frequency determined in the experiment. ..., to avoid this error a vertical type of sonometer which does not need a pulley, can be used. ...ng a pulley with ball-bearings can also reduce the friction considerably.

VIVA-VOCE QUESTIONS

Why is the sonometer box hollow?

When the stem of a vibrating tuning fork is gently pressed against the top face of sonometer box, the air enclosed in the box also vibrates. This increases the intensity of sound.

What are stationary waves? Why are they called so?

When two wave motions of equal period and amplitude travel in opposite directions along the same line, they give rise to a resultant wave motion in which the amplitude varies from point to point. This is called stationary wave. Stationary waves are called so because the disturbance is not propagated.

What type of wire is used in a sonometer?

The wire should be flexible, should have uniform density throughout and its length should not vary while it is vibrating.

Can a rubber cord be used here?

No.

11 4

Q.5 *Why a step down transformer is used between A.C. mains and electromagnet?*

Ans. The voltage of A.C. mains is 220 volts. If this high voltage is directly supplied to the windings of the coils of an electromagnet, the current in the electromagnet will become very large and will be damaged due to overheating. So the step down transformer lowers the alternating voltage before supplying it to the electromagnet.

Q.6 *What is alternating current? What is its frequency?*

Ans. It is the current which changes its direction many times in a second. The number of times the current changes direction in one second is called its frequency.

Q.7 *What do you mean by A.C. mains?*

Ans. A.C. mains stands for the main wires which supply alternating current or voltage to a place.

Q.8 *What is the frequency of mains in your laboratory?*

Ans. 50 Hz.

Q.9 *How is the frequency of magnetisation of the electromagnet related to the frequency of the a.c. which magnetises it?*

Ans. It is twice the frequency of the alternating current.

Q.10 *How will you detect that the condition of resonance has reached?*

Ans. A small piece of paper is placed near the middle of sonometer wire. The length of vibrating wire between the bridges is adjusted with the help of the bridges. The piece of paper shall fall off when resonance occurs.

Q.11 *Why does the wire of the sonometer vibrate?*

Ans. *With electromagnet,* the wire is pulled up or pushed down in accordance with the polarity of the face of the electromagnet near it. As the polarity changes with a frequency twice that of the ac mains, the wire vibrates with a frequency twice that of the a.c. mains.

→ To determine the frequency of a.c. mains using sonometer.

ations →

nometer is a diagnostic instrument used to ure the tension, frequency or density of ations.

Sonometer is used to determine hearing sensitivity.

ical bone sonometer measures bone density to determine such conditions as the risk of osteoporosis.

is also used to test for hearing loss and other ders of the ear.

determine the frequency of a.c. mains.