U.G. part (I) ~ Dr S. Roy

Loudness

The loudness of sound is different from the intensity. It is the degree of sensation produced in the ear and depends not only on the intensity of sound but also on ~~sensitivity~~ sensibility of the ear. The relation between the loudness and the intensity is expressed as

$$L = k \log I$$

where L is the loudness, I the intensity and k a constant. This is known as "Weber and Fechner relation". If the intensity is n decibels, then the loudness of the given sound is n phons, where 'phon' is the unit of loudness.

The intensity and loudness of sound is measured by ~~a no~~ several methods, among which "Rayleigh's disc method" is very important.

Rayleigh's Disc Method

This method is based on the famous principle of hydrodynamics that "when a flat disc is suspended in a direct or alternating fluid stream, it is acted upon by a couple tending to set its plane at right angles to the direction of flow of the stream."

Fig (1) shows the lines of flow of the fluid past a flat disc. The lines are most separated at points A and B where

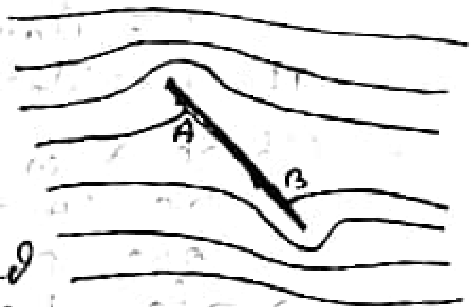

Fig (1)

the velocity is zero and by Bernoulli's theorem the pressure is maximum. Hence a clockwise couple acts on the disc tending to set it perpendicular to the lines of flow.

In case of a circular disc of radius 'a' in a fluid of density ρ, the couple is given by

$$\Gamma = \frac{4}{3}\rho a^3 \bar{u}^2 \sin 2\theta \quad \cdots\cdots (1)$$

where $\bar{u}$ is the velocity of the stream and θ the angle between the normal to the disc and the direction of flow of the fluid. In case of alternating stream, $\bar{u}$ is the root-mean-square velocity. The couple is maximum when $\theta = 45°$.

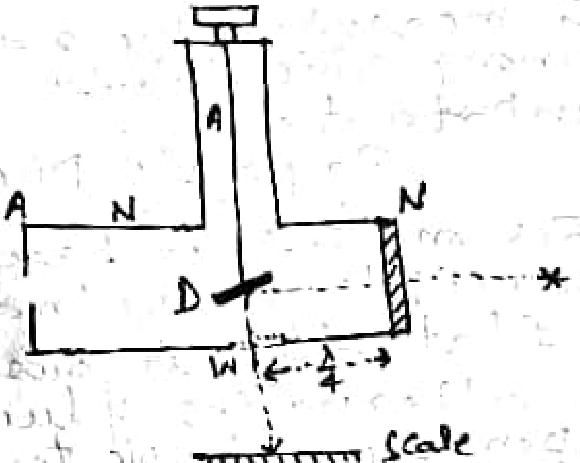

Fig (2)

The Rayleigh's disc, is shown in fig (2). It consists of a brass pipe $\frac{3}{4}\lambda$ in length, where λ is the wavelength of the sounds to be compared. The pipe is open at one end and closed with a glass plate at the other. At an antinode, distant $\frac{\lambda}{4}$ from the closed end, a light circular mirror D is hung by a fine quartz fibre. The mirror acts as a disc. The plane of mirror is adjusted at an angle of 45° with the axis of the tube when there is no twist in the fibre. Light from a lamp is made to fall on D which reflects it on to a scale through a glass window W.

When a sounding source is placed near the open end of the tube, the air in the pipe is set in vibration. Therefore a couple due to air-flow acts upon the disc which turns until brought to equilibrium by the couple due to the torsional reaction in the suspension fibre.

If ϕ be the angular twist and c the torsional couple per unit twist, then the total torsional couple will be $c\phi$. This, at equilibrium will be equal to the turning couple Γ given by (i). Therefore

$$c\phi = \frac{4}{3}\rho a^3 \overline{u^2} \sin 2\theta$$

But here $\theta = 45°$ $\therefore$ $\sin 2\theta = 1$ and hence

$$c\phi = \frac{4}{3}\rho a^3 \overline{u^2}$$

$\therefore$ $\phi \propto \overline{u^2}$. As $\overline{u^2}$ is proportional to the sound intensity I, $\phi \propto I$. Thus measuring the deflections ϕ_1 & ϕ_2 on the scale due to two sources of sound of intensity I_1 and I_2, we can compare the intensities and hence the loudness is measured.