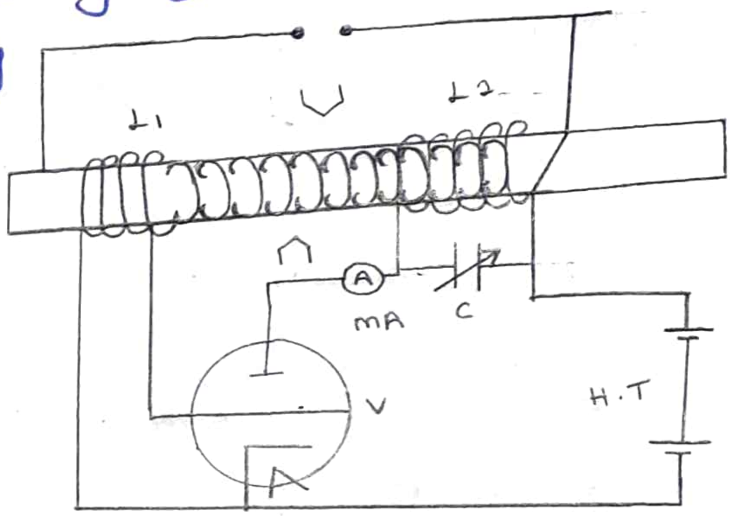
3.11.2

Sound

Magnetostriction oscillator :

This method is based on the phenomenon of magnetostriction. When a ferromagnetic material rod like iron or nickel is placed in magnetic field parallel to its length, there will be a small increase or decrease in the length. The change in length is independent of the direction of the magnetic field. It depends upon the magnitude of the field and nature of the material. When the rod is placed in a coil carrying alternating current, in each half cycle the rod suffers the same change in length. Due to this, the rod vibrates. The frequency of the rod is twice that of the a.c. usually the amplitude of the vibration of the rod is small. If, however, if the frequency of the a.c is equal to the natural frequency of the rod, resonance occurs and the amplitude increases. In this condition, sound waves are produced from the ends of the rod. If the applied frequency is of the order of ultrasonic frequency, the rod produces ultrasonic waves.



To produce ultrasonic waves, the experimental arrangement is as shown. A nickel rod is clamped at its centre. In the beginning by passing a direct current, the rod is permenently magnetised. Two coils L_1 and L_2 are wound round the rod as shown. The coil L_2 is connected to the plate of the valve and L_1 is connected to the grid. The frequency of the oscillator is adjusted with the help of the variable capacitor c connected across the coil L_2. when the frequency of the plate circuit is equal to the natural frequency of the rod, resonance occurs in the surrounding medium. Due to the coupling effect of L_1, the oscillations are maintained. The oscillation of the rod is maintained as follows.

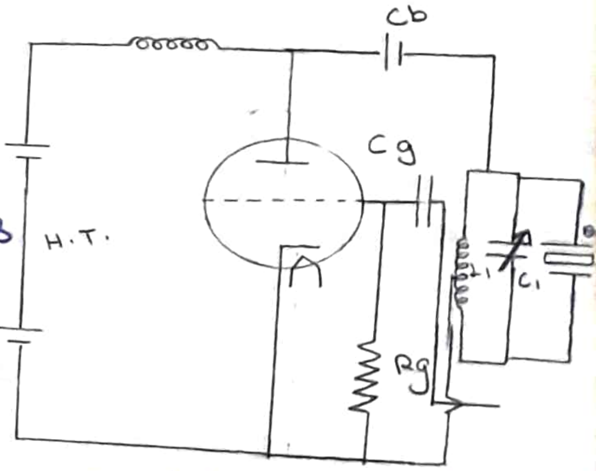
when the plate current passing through L_2 is changed, the magnetisation of the rod also changes. Thus there is a change in the length of the rod. Hence there is a variation in the magnetic flux through the grid coil L_2. Therefore there is a change in the e.m.f. developed across L_1. Since this e.m.f. is given to the grid, there is a change in the plate current. i.e the current through the coil L_2 changes. In this way the plate current builds up to a large amplitude. This frequency is determined by the vibration of the rod. Thus the vibrations of the rod are maintained. At resonance, sound wave of maximum amplitude are generated. By adjusting the length of the rod and the capacity of the condenser, different high frequency waves are produced. when the length of the nickel rod is 10 cm, the frequency of the sound wave produced is 25,000 Hz. using rod of short length. frequency upto 60,000 Hz can be produced.

Frequency $n = \frac{1}{2l}\sqrt{\frac{q}{\rho}}$

where q is the young's modulus and ρ is the density of the medium.

Piezo - Electric oscillator:

This method is based on the phenomenon of piezo-electric effect. when certain crystals like quartz are stretched or compressed along certain axis, equal and opposite charges are produced on the faces of the perpendicular axis. Hence an electric potential difference is produced. This is know as piezo-electric effect. The converse of this effect is also true. when an alternating potential is applied on the opposite faces of a crystal, the opposite faces in the perpendicular axis contracts and then elongates. when the frequency of the applied voltage is equal to the natural frequency of the crystal, the crystal vibrates with maximum amplitude. This property is used in the production of ultrasonic waves. The alternating P.d. is obtained by a valve oscillator.



The high frequency alternating voltage which is applied to the crystal is obtained from Hartley oscillator. In Hartley oscillator the tuned circuit consist of an inductance coil L_1 and a condenser C_1 is parallel. one end of the tuned circuit is connected to the anode and the other end to the grid. The cathode of the value is connected to the centre of the coil L_1. The quartz crystal Q is connected in parallel with the variable capacitor C_1.

Proper bias is given to the grid using the grid leak resistance R_g and the capacitor C_g. using a radio frequency choke, d.c voltage is given to the anode. The r.f.c prevents the radio frequency current to pass through high tension battery. The blocking capacitor C_b blocks the direct current to reach the tank circuit. It by passes only the radio frequency currents. By adjusting the capacitance of the variable capacitor C_1, the frequency of the oscillator is tuned to the natural frequency of the crystal. Now the quartz crystal is set into mechanical vibrations and ultrasonic waves are produced By this method, ultrasonic waves of frequency upto 500 KHz can be produced. Frequency upto 15×10^7 Hz can be produced using a tourmalline crystal.

Properties of ultrasonic waves:

* The frequency of the ultrasonic waves are greater than 20,000 Hz.
* They are highly energetic
* The speed of ultrasonic waves depends upon their frequency.
* If the frequency is high, the speed also is high.
* Since the wavelength is very small, the diffraction effect is negligible.

* Intense ultrasonic waves have a distruptive effect on liquids by causing bubbles to be formed.

* ultrasonic waves are also reflected, refracted and absorbed just like ordinary sound wave.

* when an ultrasonic waves are passed through a liquid, stationary wave patterns are formed due to the reflection of the wave from the other end. Along the direction of propagation, the density of liquid varies from layer to layer. In this way a plane diffraction grating is formed which can diffract light.

* ultrasonic waves are easily absorbed and hence it cannot be propagated to a long distance.

Application of ultrasonic waves:

1. Detection of aircraft, submarines etc: Since the frequency of ultrasonic waves are high, it can be used for the detection of aircraft, submarines, ice bergs or even other comparatively smaller objects on the seabed. High frequency waves are produced and it is sent through water. These waves are reflected by the solid objects. The reflected waves can be detected using a quartz receiver. From this, we can identify the objects. These are called as "sonar" (Sound Navigation and Rangling).

2. Depth of the sea: Echometer is a slight modification of sonar. High frequency waves are produced and directed towards the bottom of

of the sea. The rays reflected by the bottom of the sea are received by the receiver. The time interval between the emitted signal and the echo can be determined. If the velocity of the sound wave is known. The depth of the sea can be calculated using the relation $h = vt/2$

3). Signalling: ultrasonic waves are used for directional signalling. The narrow directional sound beam provided by the ultrasonic waves of a relatively high frequency is used for the purpose of signalling to a distant ship.

4). cracks in metals: ultrasonic waves can be used to detect cracks or discontinuity in metal structures when an ultrasonic wave passed through a metal having cracks or discontinuity, they are reflected. Rays are also reflected by the other face of the metal. The reflected pulses are received by a detector. From this, the cracks can be detected.

5). uses in Industry:

* ultrasonic waves are used to bore holes in glass, steel and other alloys.
* These are used to remove grease, dust and metal filings from the manufactured parts of cars, cameras etc..
* These are used in cleaning clothes
* ultrasonic waves are used for soldering the metals.

6). chemical application:

* ultrasonic waves act like catalytic agents and accelerate chemical reactions.
* It is used in the preparation of photographic film and face creams etc.

* It is used to produce a small uniform crystals.

7). Biological applications :

* potato treated with ultrasonic waves give increased yields.
* Germs can be killed using ultrasonic waves.
* milk exposed to ultrasonic waves, pasteurise in a few seconds.

8). medical application : ultrasonic waves find many applications in the field of medicine.

* ultrasonic waves are used as a pain reliever. the waves produce a smoothing massage action and relieves' pain.
* ultrasonic waves are used to restore the contracted fingers.
* These are used by dentists for the proper extraction of broken teeth.
* ultrasonic are used in bloodless surgery. The ultrasonic waves are focussed on a sharp instrument and the tissues are destroyed without any loss of blood. These are also used for brain operations.

composition of two S.H.Ms

(i) Along a straight line :

Two simple harmonic motions of amplitude a_1 and a_2 act along the same straight line. Let ϕ_1, ϕ_2 be initial phases. At any instant of time, Let y_1, y_2 be the displacement of the particles.

$$y_1 = a_1 \sin(\omega t + \phi_1) \rightarrow (1)$$

$$y_2 = a_2 \sin(\omega t + \phi_2) \rightarrow (2)$$

The two S.H.Ms have the same frequency. since the two motions are in the same straight line, then their resultant motion will also be in the same straight line.

$\therefore y = y_1 + y_2$

$= a_1 \sin(\omega t + \phi_1) + a_2 \sin(\omega t + \phi_2)$

$= a_1 [\sin \omega t . \cos\phi_1 + \cos\omega t . \sin\phi_1] + a_2 [\sin \omega t . \cos\phi_2 + \cos \omega t . \sin\phi_2]$

$\therefore y = (a_1 \cos\phi_1 + a_2 \cos\phi_2) \sin \omega t + (a_1 \sin\phi_1 + a_2 \sin\phi_2) \cos\omega t \rightarrow (4)$

Let $a_1 \cos\phi_1 + a_2 \cos\phi_2 = A \cos\phi \rightarrow (5)$

$a_1 \sin\phi_1 + a_2 \sin\phi_2 = A \sin\phi \rightarrow (6)$

$\therefore y = A \sin\omega t . \cos\phi + A \cos\omega t . \sin\phi$

$\therefore y = A \sin(\omega t + \phi) \rightarrow (7)$

This is an equation for S.H.M. Hence the resultant motion is also simple harmonic motion whose amplitude is A and the phase ϕ. But there is no change in frequency.

using equation (5) and (6) we can calculate the amplitude and the phase of the resultant motion.

Squaring and adding equ (5) and (6) we get.

$A^2(\cos^2\phi + \sin^2\phi) = a_1^2(\cos^2\phi_1 + \sin^2\phi_1) + a_2^2(\cos^2\phi_2 + \sin^2\phi_2) + 2a_1a_2(\cos\phi_1 \sin\phi_2 + \cos\phi_2 \sin\phi_1)$

$A^2 = a_1^2 + a_2^2 + 2a_1a_2 \cos(\phi_1 - \phi_2)$

$\therefore$ Amplitude $A = \sqrt{a_1^2 + a_2^2 + 2a_1a_2\cos(\phi_1 - \phi_2)} \rightarrow (8)$

dividing equation (6) by eqn (5) we get

$$\tan\phi = \frac{a_1 \sin\phi_1 + a_2 \sin\phi_2}{a_1 \cos\phi_1 + a_2 \cos\phi_2}$$

Equation (8) and (9) give the amplitude and phase of the resultant motion.

(ii) At Right angle to each other

Two S.H.Ms act in perpendicular directions along x, y axis. The displacement of the particles may be written as

$$x = a \sin \omega t \quad \longrightarrow (1)$$

$$y = b \sin(\omega t + \phi) \quad \longrightarrow (2)$$

where a and b are the amplitudes and ϕ the phase difference.

From equation (1)

$$x/a = \sin \omega t \quad \longrightarrow (3)$$

squaring equation (3) and adding $\cos^2 \omega t$ on both sides, we get

$$x^2/a^2 + \cos^2 \omega t = \sin^2 \omega t + \cos^2 \omega t$$

$$x^2/a^2 + \cos^2 \omega t = 1$$

$$\cos \omega t = \sqrt{1 - x^2/a^2}$$

From equation (2),

$$y/b = \sin(\omega t + \phi)$$

$$= \sin \omega t . \cos\phi + \cos \omega t . \sin\phi \quad \longrightarrow (5)$$

substituting the value of $\sin \omega t$ and $\cos \omega t$ from equation (3) and (4) we get

$$y/b = x/a \cos\phi + \sqrt{1 - x^2/a^2} . \sin\phi$$

$$y/b - x/a \cos\phi = \sqrt{1 - x^2/a^2} . \sin\phi \quad \longrightarrow (6)$$

Squaring equation (6), we get

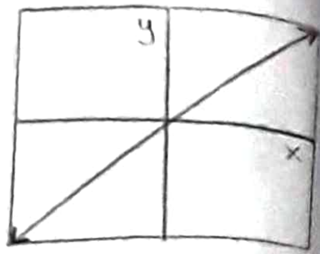
$$y^2/b^2 - (2xy/ab) \cos\phi + (x^2/a^2) \cos^2\phi = (1 - x^2/a^2) \sin^2\phi$$

$$y^2/b^2 - (2xy/ab) \cos\phi + x^2/a^2 = \sin^2\phi \quad \longrightarrow (7)$$

Equation (7) is an equation for an ellipse. Hence the resultant motion of two S.H.Ms acting perpendicular to one another is an ellipse whose major and minor axes are inclined to x and y co-ordinates axes.

Special cases:

(i) If $\phi = 0$, $\cos\phi = 1$ and $\sin\phi = 0$ i.e there is no no phase difference between the two motions. If these values are substituted in equation (7) we get



$y^2/b^2 - 2xy/ab + x^2/a^2 = 0$

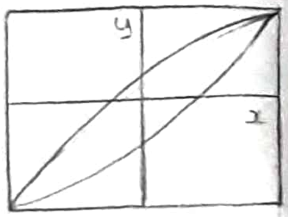
$y/b - x/a = 0$

$y = (b/a) \cdot x \quad \rightarrow (8)$

This is an equation for a straight line. Hence the resultant motion is a straight line inclined at an angle $\tan^{-1}(b/a)$ with the x axis.

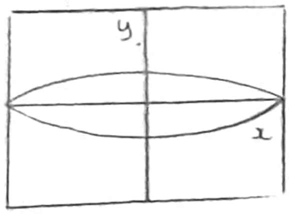
ii) If $\phi = \pi/4$, $\cos\phi = 1/\sqrt{2}$ and $\sin\phi = 1/\sqrt{2}$. Substituting these values in equation (7) we get

$y^2/b^2 - \sqrt{2}\,xy/ab + x^2/a^2 = 1/2 \quad \rightarrow (9)$



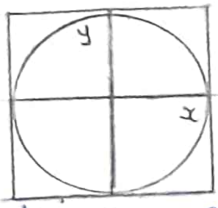
This is an equation for an ellipse

iii) If $\phi = \pi/2$, $\cos\phi = 0$ and $\sin\phi = 1$. Substituting these values in eqn (7) we get,



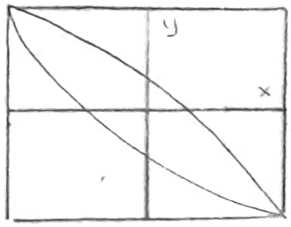
$y^2/b^2 + x^2/a^2 = 1 \quad \rightarrow (10)$

this equation represents an ellipse whose major and minor axes coincide with the x and y axes.



If the amplitudes of the two motions are equal i.e $a = b$, then

$x^2 + y^2 = a^2 \quad \rightarrow (11)$



this equation represents a circle

iv) if $\phi = 3\pi/4$, $\cos\phi = -1/\sqrt{2}$ and $\sin\phi = 1/\sqrt{2}$. Substituting these values in equation (7) we get.

$y^2/b^2 + \sqrt{2}\,xy/ab + x^2/a^2 = 1/2 \quad \rightarrow (12)$

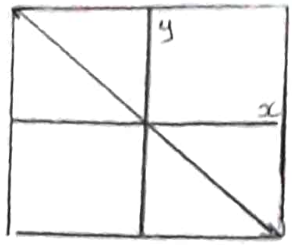
this is an equation for an ellipse. Hence the resultant motion is elliptical as shown in fig 2.4

v) If $\phi = \pi$, $\cos\phi = -1$, $\sin\phi = 0$

$$y^2/b^2 + 2xy/ab + x^2/a^2 = 0$$

$$y/b + x/a = 0$$

$$y = -(b/a) . x \rightarrow (1)$$



Acoustic of Buildings :

Buildings are constructed for some specific purposes. They should form according to their purposes. The branch of physics which deals with the design and construction of building with good acoustics is known as Acoustics of Buildings.

The essential features about the good acoustic

1) Each syllable of the speech or song should be heard sufficiently loudly in every part of the hall.
2) The quality of sound must remain unaltered
3) The successive sounds of speech must remain distinct and must be free from one another and form extraneous noise.
4) Echoses, except those required to maintain the necessary continuitity, must be eliminated
5) undesirable concentration of sound at one place and regions of poor audilibity must be avoided.
6) All the extraneous noises must be shut out as far as possible.
7) The reverberation should be quite proper i.e., neither too large nor too small.

Requisities for Good Auditorium :

By using a large sounding boards behind the speaker and facing the audience, necessary sound can be produced. In such an arrangement the listner will receive the reflected sound after 0.05 second receiving the direct sound. Hence there will be no confusion in the sound intensity.

The reverberation time of an auditorium should be brought to the optimum level. If there is no reverberation, then the auditorium is said to be dead auditorium. This type of auditorium can be realised in practice by having open theatres. Music without reverberation loses its charm. So it is not desirabe to completely eliminate reverberation. But on the other hand if the sound reverberates for a long time, the audience cannot differentiate each notes. Hence it is necessary to reduce the time of reverberation. But it should not fall below a certain level.

* The reverberation time for a hall can be adjusted by providing for absorption of sound in a number of ways. They are,
* provision of windows and openings
* By covering the ceiling, walls and even backs of chairs with sound absorbing materials like fibre board
* using a number of curtains
* by carpeting the floor
* by decorating the wall with pictures and
* having a good-sized audience
* Echoes result from sound getting reflected at walls. Echoes are particularly trouble some in large halls. They can be removed almost entirely by making the surface of the

walls rough and by inclining the walls outward. However, a point echoes are necessary for the enhancement of musical effects.

Resonance of a large hall is inversely proportional to the square root of the volume of the hall. Hence the volume of the auditorium should depend upon the frequency.

Focussing of sound gives unpleasent effect to the listner. Hence focusing should be reduced. For this, in an auditorium, ornamental lamps, protrudding parts etc are provided.

Define Audible range.

when a body vibrates, sounds are produced If the frequency of vibration lies between 20HZ to 20,000 HZ. the sound is audible to our ear. This range is known as audible range.

Define ultrasonics or supersonic waves.

If the frequency of the sound wave is greater than 20,000 HZ, it is not audible to our ear. These are known as ultrasonics or supersonic waves. The wavelength of ultrasonics waves are very small compared to audible sound.

ultrasonic waves can be detected by some birds like bats.

Define infrasonics.

The sound waves whose frequency is less than audible limit are called infrasonics

Define Simple Harmonic motion

A particle is said to execute simple Harmonic motion, if its acceleration is directly proportional to the displacement from the fixed point and is always directed towards that fixed point.

Lissajous Figures

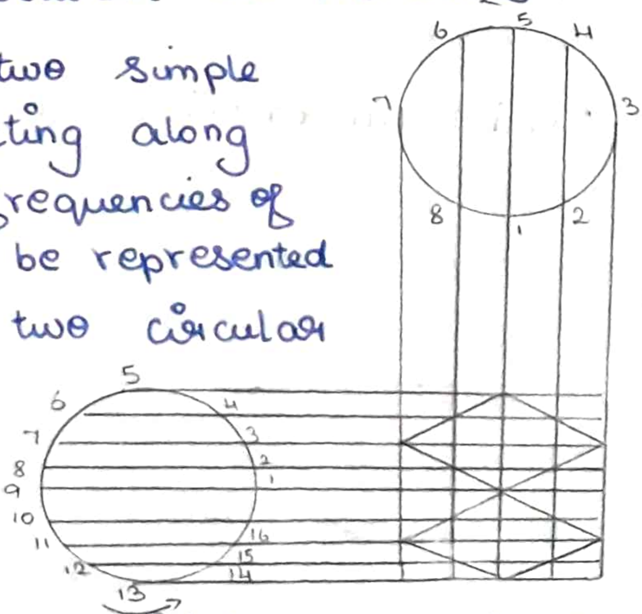
In 1857, Lissajous demonstrated that when a particle is acted upon simultaneously by two simple harmonic motions at right angles to each other, the resultant path traced out by the particle is a curve. The curves obtained by Lissajous, are called as Lissajous figures.

The nature of the figures depends upon the following factors.

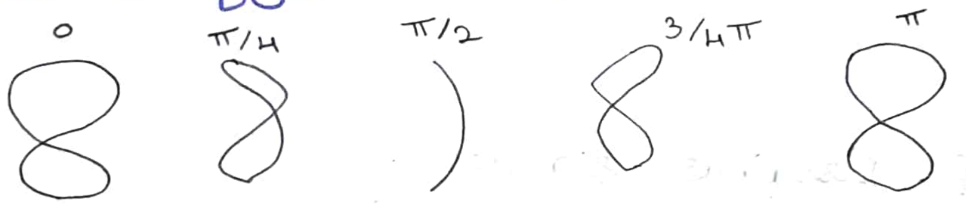
(i) Amplitudes of the vibration

(ii) Frequencies of two vibrations and

(iii) Phase difference between the vibrations



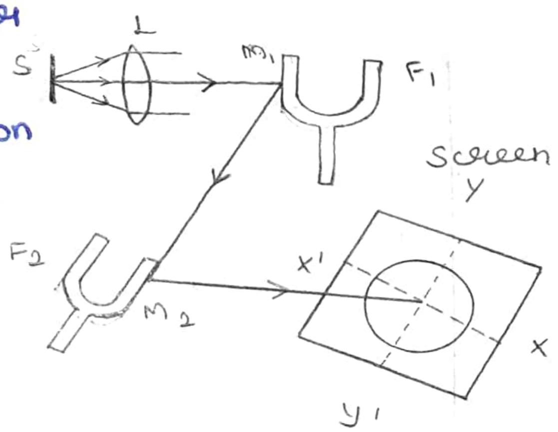
Let us consider two simple harmonic motions acting along x, y directions. The frequencies of the two motions can be represented by the projections of two circular motions P and Q with centres O_1 and O_2. The circular motion Q generates S.H.M along x- direction while P generates S.H.M along y- direction. Depending upon the frequency, by the time P complete one revolution, Q will complete two revolutions. Hence if the circle P is divided into 16 parts and that of Q is divided into 8 parts, by the time P moves through one division in its circle Q also will move through one division in its circle. When P moves to 10, Q would have completed one revolution and will be at 2. Now the position of the particle is (10, 2). The trace of the different positions of the particle will give the resultant of the two S.H.Ms. Such a figure is known as Lissajous figure.



Here the phase difference between the two S.H.Ms is zero. Hence the resultant will be like the number 8.

Demostration of Lissajou's figures

This method was devised by Lissajous. In this method the figures can be projected on a screen. F_1 and F_2 are two tuning forks. On the prongs of the tuning forks, two mirrors M_1 and M_2 are attached. The two tuning forks are arranged such that their vibrations are right angle to each other. i.e if the vibration of F_1 is along the x-axis, then the vibration of F_2 is along the y-axis. Light from the source S is made convergent with the help of the lens L.



The converged light is allowed to incident on the mirror M_1. This ray of light after reflection by the mirror M_2 incident on the screen S. When the two forks are at rest, a spot of light is produced in the screen.

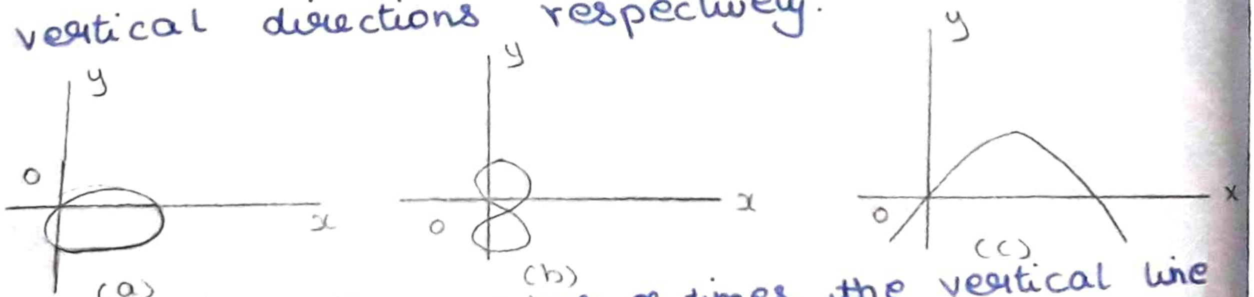
If the fork F_1 alone is excited, the spot of light moves along the x-axis. On the other hand if the fork F_2 alone is excited, the spot of light moves along the y-axis. When both the forks are excited simultaneously, the spot traces a Lissajous figure. The shape of the figure depends upon the amplitudes of M_1 and M_2, the frequencies of the two forks and the phase difference between two vibrations.

Uses of Lissajous figures

(i) To compare the frequencies: If the ratio of the two frequencies is a whole number i.e $n_1/n_2 = 1, 2, 3 \ldots$, then the Lissajous figures produced will be a steady one. With the help of the figure, the ratio of the frequencies of the forks can be compared. For this we have to draw a horizontal and a vertical line on any point of the figure. If the horizontal line cuts the figure m times and the vertical line n times, then

$$T_1 / T_2 = n_2/n_1 = m/n$$

where T_1 and T_2 are the time periods and n_1 and n_2 are the frequencies in the horizontal and vertical directions respectively.



$$\frac{\text{Frequency along x-axis}}{\text{Frequency along y-axis}} = \frac{\text{number of times the vertical line cut the figure}}{\text{number of times the horizontal line cut the figure}}$$

In fig (a) the horizontal and vertical line cut the curve twice. Hence the ratio of frequencies

$$n_1/n_2 = n/m = 2/2 = 1/1$$

$$\therefore n_1 : n_2 = 1 : 1$$

In fig (b), $n_1/n_2 = 4/2 = 2/1$

$$\therefore n_1 : n_2 = 2 : 1$$

In fig (c), $n_1/n_2 = 1/2$

$$\therefore n_1 : n_2 = 1 : 2$$

(ii) To determine the frequency of a fork: The frequency of the given fork A can be determined as follows. Let B be another fork whose frequency is nearly equal to A. Let the frequency of B be n. If the two forks A and B are made to vibrate perpendicular to one another, Lissajous figure will be formed. Since the frequencies of the two forks are slighty different, the shape of the Lissajous figure continuously changes. Let t be the time taken for the change of one complete cycle.

Difference in frequency between A and B = $1/t$.

$\therefore$ Frequency of A = $n \pm 1/t$

Now a little wax is attached to the fork A. The experiment is repeated again and the time taken for one complete change is noted. Let it be t_1.

If t_1 is less than t the frequency of the fork A = $n + 1/t$

If t_1 is greater than t, the frequency of the fork A = $n - 1/t$

In this way, using Lissajous figures, the frequency of the fork can be determined.

Define Periodic motion :

If a body describes the same path in the same way again and again in equal intervals of time, the motion is called periodic motion. Periodic motion is also called harmonic motion.

Define oscillatory

If the body moves back and forth repeatedly about a mean position, its motion is called oscillatory.