UNIT - 1
SOUND

Vibration: It is a process in which body executes Too & Fro motion with some periodic time

Ex: Bar pendulum. simple pendulum. mass attached to the spring.

Types of vibration:

1. Free vibration (Natural vibration)
2. Forced vibration
3. Damped vibration

① **Free Vibration:** It is a vibration in which initial displacement is given. there after no external force is applied to the body. such type of vibration is called free vibration.

If the amplitude of the free vibration does not decreases then it is called as undamped free vibration.

If the amplitude of the free vibration decreases gradually then it is called damped free vibration

Ex. for Free vibration:
Simple pendulum given with initial displacement.

② **Forced vibration:** It is a vibration in which external force is applied to a body then such type of a vibration is called as forced vibration.

The vibration will have same frequency as that of applied external force.

Ex: Simple pendulum to which external periodic force is applied.

③ **Damped vibration:** It is a vibration in which amplitude decreases with time.

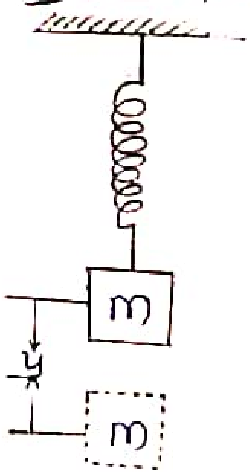
Ex: Simple pendulum under the gravitational force.

(2) <u>Natural frequency</u>: It is a frequency of vibration [OR] It is number of oscillat[ions] per second.

<u>Resonance</u>: It is a phenomena in which frequency of the applied force is equal t[o] natural frequency of the system.
There will be increase in amplitude of vibr[ation]

<u>Ex</u>: strike a tuning fork and hold it o[ver] the tube containing water. If the le[ngth] of the water in the tube is gradual[ly] decreased, the length of the air column increases. When the natural frequency [of] the air column equal to the frequen[cy of] tuning fork. A very loud sound is produced. Now the air column is sai[d] to be resonance.

Undamped vibration:



Let us consider a body o[f] mass 'm' attached to the spring of spring constant 'K'.
Let the body execute SHM, th[en] KE of a body is

$$KE = \frac{1}{2} m\left(\frac{dy}{dt}\right)^2 \text{------} (1)$$

& PE of a body is

$$PE = \frac{1}{2} Ky^2 \text{------} (2)$$

Then total energy of a body is

$$TE = KE + PE$$

$$TE = \frac{1}{2} m\left(\frac{dy}{dt}\right)^2 + \frac{1}{2} Ky^2 \text{------} (3)$$

Since body is executing SHM, the total energy is constant.

So, $TE = \frac{1}{2} m\left(\frac{dy}{dt}\right)^2 + \frac{1}{2} Ky^2 = \text{constant}$

Now differentiate above eq^n with respe[ct] to time 't'

Scanned with CamScanner

$$\text{③} \quad \frac{1}{2} m \, 2 \frac{dy}{dt} \frac{d^2y}{dt^2} + \frac{1}{2} K \, 2y \frac{dy}{dt} = 0$$

$$\frac{dy}{dt}\left(m \frac{d^2y}{dt^2} + Ky\right) = 0$$

$$\therefore \quad m \frac{d^2y}{dt^2} + Ky = 0$$

Divide throughout the eqⁿ by m

$$\frac{d^2y}{dt^2} + \left(\frac{K}{m}\right) y = 0$$

$$\frac{d^2y}{dt^2} + \omega^2 y = 0 \; \text{------} \; (4)$$

Where, ω = angular velocity or angular frequency

$$\therefore \quad \omega^2 = \frac{K}{m}$$

$$\omega = \sqrt{\frac{K}{m}} \; \text{------} \; (5)$$

Thus solution for the eqⁿ (4) is

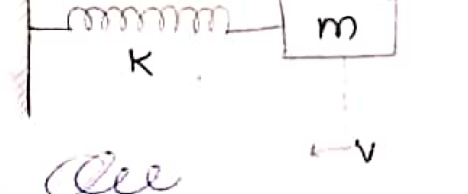
$$y = a \sin(\omega t - \alpha)$$

Eqⁿ (4) represents the eqⁿ of SHM or undamped vibration for instant of time period.

Linear frequency, $f = \frac{\omega}{2\pi}$

$$f = \frac{1}{2\pi}\sqrt{\frac{K}{m}}$$

Damped vibration:



Let us consider a mass 'm' attached to spring with a force constant K. When external force is applied to the mass along the length of the spring. It starts vibrating & after some time its vibration becomes zero. because of frictional force (dissipative force) & restoring force of spring the vibration becomes zero.

$$F_{net} = ma$$ (4)

$$-\mu v - ky = ma$$

$$ma + \mu v + ky = 0$$

$$m\frac{d^2y}{dt^2} + \mu\frac{dy}{dt} + ky = 0 \text{ ------ } (1)$$

$$\frac{d^2y}{dt^2} + \frac{\mu}{m}\frac{dy}{dt} + \frac{k}{m}y = 0 \text{ ------ } (2)$$

$\{\text{where, } 2b = \frac{\mu}{m} \text{ \& } \omega^2 = \frac{k}{m}\}$

[illegible] to gen diff eqn

$$\frac{d^2y}{dt^2} + 2b\frac{dy}{dt} + \omega^2 y = 0 \text{ ------- } (1)$$

$$(D^2 + 2bD + \omega^2)y = 0$$

$$y = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$y = \frac{-2b \pm \sqrt{(2b)^2 - 4(1)(\omega^2)}}{2(1)}$$

$$y = \frac{-2b \pm \sqrt{4b^2 - 4\omega^2}}{2}$$

$$y = \frac{-\cancel{2}b \pm \cancel{2}\sqrt{b^2 - \omega^2}}{\cancel{2}}$$

$$y = -b \pm \sqrt{b^2 - \omega^2}$$

$$y_1 = -b + \sqrt{b^2 - \omega^2}$$

$$y_2 = -b - \sqrt{b^2 - \omega^2}$$

where, $b = \frac{\mu}{2m}$

BASIC

(1) If roots are different i.e m_1 & m_2 then soln. $y = c_1 e^{m_1 t} \pm c_2 e^{m_2 t}$

(2) If $m_1 = m_2 = m$

$y = (c_1 + tc_2)e^{mt}$

{ c is constant it may be A, B, C. }

(3) If $\alpha \pm i\beta$

$y = e^{\alpha t}(\cos\beta t \pm \sin\beta t)$

(5) $y = Ae^{(-b+\sqrt{b^2-\omega^2})t} + Be^{(-b-\sqrt{b^2-\omega^2})t}$ ------ (2)

Eqn (2) is solution of eqn (1)

$$\boxed{y = ae^{-bt}\sin(\omega t - \alpha)}$$ ------ (3) → sol^n of eq^n (1)

$\omega_1^2 = \omega^2 - b^2$

$\omega_1 = \sqrt{\omega^2 - b^2}$

$$\boxed{\omega_1 = \sqrt{\frac{K}{m} - \frac{\mu^2}{4m^2}}}$$ → angular frequency

$f_1 = \frac{\omega_1}{2\pi}$

$f_1 = \frac{1}{2\lambda}$

$y = a\sin(\omega t - \alpha)$

$y = ae^{-bt}\sin(\omega t - \alpha)$

$y = $ "

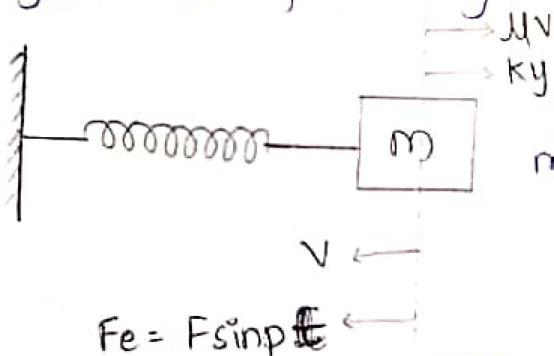
16/01/20

Forced vibration:

Let us consider a body under free vibration, after some time the body comes to rest because of damping forces namely restoring force and frictional force of air.

If external periodic force is applied to the body then body gradually gains the frequency of external periodic force.

For the forced vibration the eqn can be given as following:



$F_{net} = ma$

$F\sin pt - \mu v - ky = ma$

$m\frac{d^2y}{dt^2} + \mu\frac{dy}{dt} + ky = F\sin pt$ (1)

Here 'p' is frequency of external periodic force. The perticular solution of eqn (1) is

$y = a\sin(pt - \alpha)$ ---- (2)

Now, differentiate eqn (2) w.r.t time

$\frac{dy}{dt} = \frac{d}{dt}[a\sin(pt - \alpha)]$

$dy/dt = a\cos(pt - \alpha).p$

$dy/dt = ap\cos(pt - \alpha)$ --- (3)

Scanned with CamScanner

(6)

Again differentiate eqⁿ (3) w.r.t time.

$$\frac{d^2y}{dt^2} = -ap^2\sin(pt-\alpha) \quad \cdots\cdots (4)$$

Substituting eqⁿ (2), (3) & (4) in (1) (5)

$-map^2\sin(pt-\alpha) + \mu ap\cos(pt-\alpha) + k a\sin(pt-\alpha) = F\sin pt$

$-map^2(\sin pt\cos\alpha - \cos pt\sin\alpha) + \mu ap[\cos pt\cos\alpha + \sin pt \sin\alpha] + ka(\sin pt\cos\alpha - \cos pt\sin\alpha) = F\sin pt \quad \cdots (6)$

If $\sin pt = 1$, $\cos pt = 0$ put in (6)

$\cancel{-map^2[(1)\cos\alpha - (0)(1)] + \mu ap[(1)}$

$-map^2[\cos\alpha - 0] + \mu ap[\sin\alpha] + ka[\cos\alpha) = F$

$-map^2(\cos\alpha) + \mu ap(\sin\alpha) + ka(\cos\alpha) - F = 0 \quad \cdots (7)$

If $\sin pt = 0$, $\cos pt = 1$ put in (6)

$\cancel{-map^2(1) + \mu ap(0) + ka(1) - F = 0}$

$\cancel{-map^2 + ka - F = 0}$

$-map^2(-\sin\alpha) + \mu ap((\cos\alpha) + ka(-\sin\alpha) = 0$

$map^2\sin\alpha + \mu ap\cos\alpha - ka\sin\alpha = 0 \quad \cdots\cdots (8)$

dividing eqⁿ (8) by $\cos\alpha$

$map^2\tan\alpha + \mu ap - ka\tan\alpha = 0$

$a(mp^2\tan\alpha + \mu p - k\tan\alpha) = 0$

$mp^2\tan\alpha + \mu p - k\tan\alpha = 0$

$\tan\alpha(mp^2 - k) + \mu p = 0$

$-\tan\alpha(k - mp^2) + \mu p = 0$

$$\tan\alpha = \frac{(\mu p)}{(k - mp^2)} = \frac{A}{B}$$

where, $A = \mu p$

$B = k - mp^2$

$$\therefore \sin\alpha = \frac{A}{\sqrt{A^2+B^2}} \quad \text{and} \quad \cos\alpha = \frac{B}{\sqrt{A^2+B^2}}$$

Now dividing eqⁿ ⑦ by $\cos\alpha$

(7) $-map^2 + \mu ap \tan\alpha + ka = \frac{F}{\cos\alpha}$

$$a(-mp^2 + \mu p \tan\alpha + k) = \frac{F}{\cos\alpha}$$

$$a[(k - mp^2) + \mu p \tan\alpha] = \frac{F}{\cos\alpha}$$

$$a\left[B + A\frac{A}{B}\right] = \frac{F\sqrt{A^2+B^2}}{B}$$

$$a\left[\frac{B^2+A^2}{\cancel{B}}\right] = \frac{F\sqrt{A^2+B^2}}{\cancel{B}}$$

$$a = \frac{F\sqrt{A^2+B^2}}{\cancel{A^2+B^2}}$$

$$a = \frac{F}{\sqrt{A^2+B^2}} \quad \text{------} \quad (9)$$

Substitute eqⁿ (9) in (2)

$$y = \frac{F}{\sqrt{A^2+B^2}} \sin(pt - \alpha)$$

$$y = \frac{F}{\sqrt{\mu^2 p^2 + (k - mp^2)^2}} \sin(pt - \alpha) \quad \text{------} \quad (10)$$

particular eqⁿ of forced vibration.

~~Eqⁿ of free~~ damped ~~vi~~

W.K.T eqⁿ of free damped vibration is

$$y = ae^{-bt} \sin(\omega t - \alpha) \quad \text{------} \quad (11)$$

The motion of forced vibration is combination of both particular eqⁿ of ~~for~~ external periodic force and eqⁿ of free damped vibration.

$y =$ eqⁿ (10) + eqⁿ (11)

$$\boxed{y = \frac{F}{\sqrt{\mu^2 p^2 + (k - mp^2)^2}} \sin(pt - \alpha) + ae^{-bt} \sin(\omega t - \alpha)}$$

23/11/20

Condition for amplitude of resonance:

In case of forced vibration the general solution for displacement at any instant is given by

$$y = ae^{-bt}\sin(\omega t-\alpha) + \frac{F}{\sqrt{\mu^2p^2+(k-mp^2)^2}}\sin(pt-\alpha) \rightarrow (1)$$

If the viscosity of the medius is less then the amplitude $a = \dfrac{F}{\sqrt{\mu^2p^2+(k-mp^2)^2}} \longrightarrow (2)$

will be maximum.

It is maximum, when the denominator is minimum. This is possible when $(k-mp^2)=0$.

$$\Rightarrow mp^2 = k$$

$$p = \sqrt{\frac{k}{m}}$$

$$\boxed{p = \omega} \longrightarrow (3)$$

It shows that amplitude will be maximum, when the natural frequency is equal to forced frequency. As this condition the oscillation is said to be under resonance.

Now, we can write the condition for amplitude of resonance as.

$$a = \frac{F}{\sqrt{\mu^2p^2 + \cancel{(k-mp^2)^2}\, 0}}$$

$$a = \frac{F}{\sqrt{\mu^2p^2}}$$

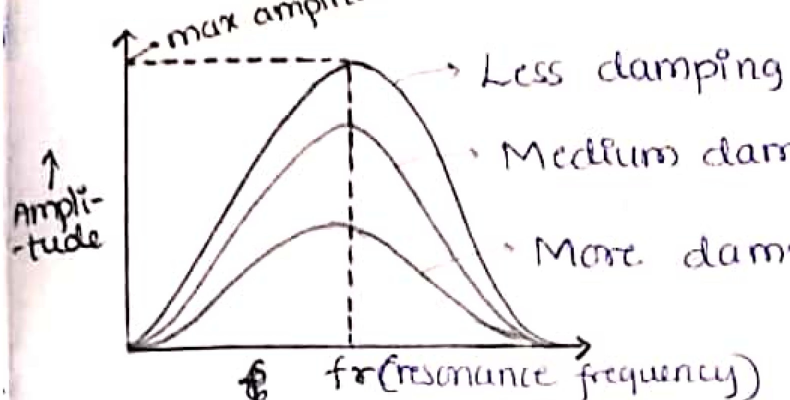
$$a = \frac{F}{\mu p}$$

$$\boxed{a = \frac{F}{\mu}\sqrt{\frac{m}{k}}} \longrightarrow (4)$$

Eq^n (4) represent the condition for amplitude of resonance.

Sharpness of Resonance:

Sharpness of Resonance means the fall in the amplitude with change in frequency on both side of maximum amplitude



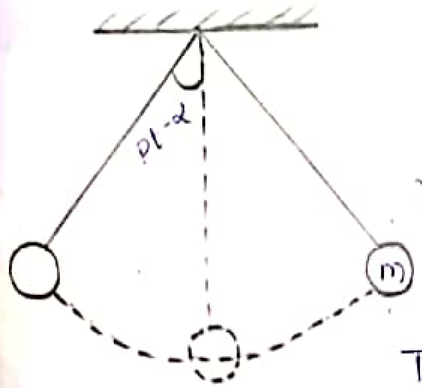
Let us consider particular solution of forced vibratition.

$$y = \frac{F}{\sqrt{\mu^2 p^2 + (k-mp^2)^2}} \sin(pt-\alpha) \longrightarrow (1)$$

Differentiate eqn (1) w.r.t time t.

$$\frac{dy}{dt} = \frac{Fp}{\sqrt{\mu^2 p^2 + (k-mp^2)^2}} \cos(pt-\alpha) \longrightarrow (2)$$

The term $\frac{dy}{dt}$ represents the velocity and it is maximum, when $\cos(pt-\alpha)$ is equal to 1, the it is possible, when particle just crosses the mean position.



$$\therefore \frac{dy}{dt} = \frac{Fp}{\sqrt{\mu^2 p^2 + (k-mp^2)^2}} \times (1)$$

$$V_{max} = \frac{dy}{dt} = \frac{Fp}{\sqrt{\mu^2 p^2 + (k-mp^2)^2}} \longrightarrow (3)$$

The K.E. is maximum when the Particle just crosses the mean position it is given by

$$KE_{max} = \frac{1}{2} m V_{max}^2$$

21/1/20

$$KE_{max} = \frac{1}{2} m \left[\frac{F^2 p^2}{\mu^2 p^2 + (k - mp^2)^2}\right] \quad \text{--- (4)}$$

The mean square of driving force per unit mass is given by $= \frac{0 + F^2}{\frac{2}{m}} = \frac{F^2}{2m}$ --- (5)

The KE per unit force is given by Dividing eq^n (4) by (5) and it is called as Response (R)

$$R = \frac{m^2 p^2}{\mu^2 p^2 + (k - mp^2)^2}$$

$$R = \frac{p^2}{\frac{\mu^2 p^2}{m^2} + \left(\frac{k}{m} - p^2\right)^2} \quad \text{--- (6)}$$

The natural frequency in absence of damping is $\sqrt{\frac{k}{m}}$, therefore the term $\left[\frac{k}{m} - p^2\right]$ in the denominator represent the extent to which the natural frequency differs from applied frequency

When, $\frac{k}{m} = p^2$ the natural frequency coinside with forced frequency.

Now, eq^n (6) becomes

$$R = \frac{p^2}{\frac{\mu^2 p^2}{m^2} + (0)}$$

$$R = \frac{\cancel{p^2}}{\frac{\mu^2 \cancel{p^2}}{m^2}}$$

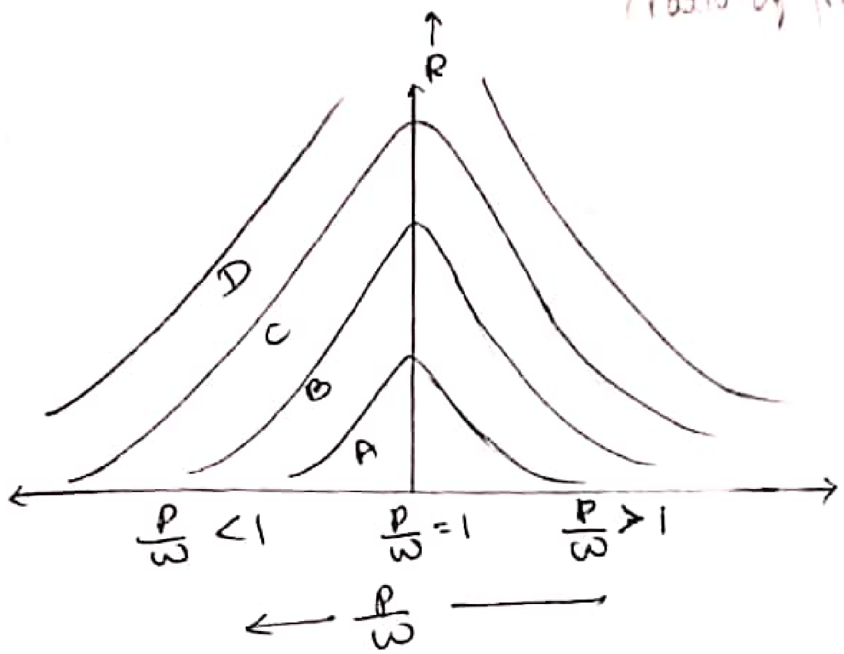
$$\boxed{R = \left(\frac{m}{\mu}\right)^2} \quad \text{--- (7)}$$

$$\boxed{R \propto \frac{1}{\mu}} \quad \text{--- (8)}$$

μ = damping force constant

(1) It means that response (R) is inversely propo-
-rtional to damping force

Let us consider a graph plotted R V/s $\frac{P}{\omega}$ (ratio of frequencies)



* When $\frac{P}{\omega} = 1$ the response (R) is high.

  For the curve C the frictional force or damping force μ is less. So its amplitude is high.

* For curve A the frictional force is large. So its amplitude of resonance is less.

* If $\mu = 0$ i.e zero frictional force, then the response (R) will be infinite.

* When μ is less, sharpness in high. When μ is high, sharpness in less

2M **Phase of Resonance :**

W.K.T. $\tan\alpha = \frac{A}{B}$

$$\tan\alpha = \frac{\mu P}{k - mp^2}$$

$$\tan\alpha = \frac{\frac{\mu P}{m}}{\frac{K}{m} - p^2} \quad \text{---} \ (1)$$

(12) Here α is phase difference between natur-
-al frequency and resultant forced frequency

At resonance $\frac{k}{m} = p^2$ ~~thatt~~

$$\Rightarrow \omega = p$$

So eq^n (1) becomes

$$\tan\alpha = \frac{\frac{\mu p}{m}}{0}$$

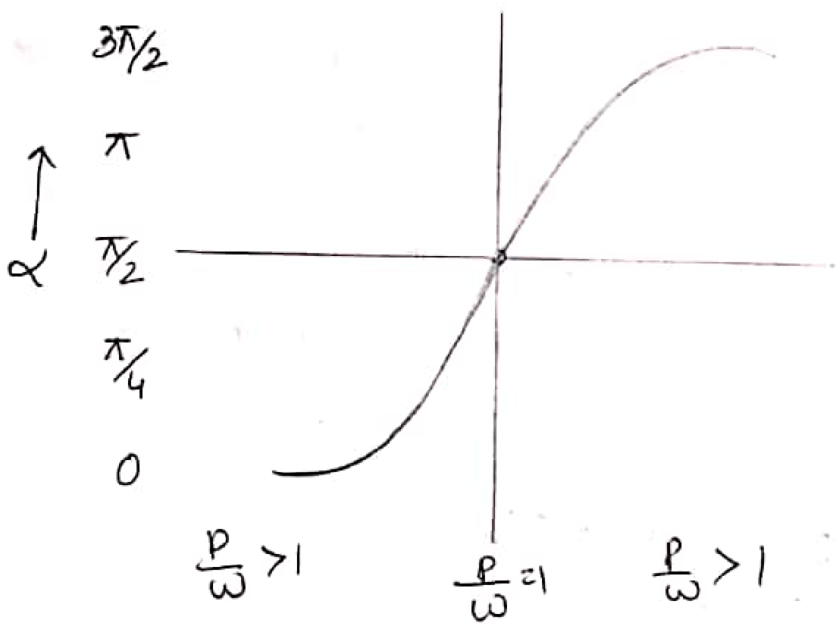
$$\tan\alpha = \infty$$

$$\alpha = \tan^{-1}(\infty)$$

$$\boxed{\alpha = \frac{\pi}{2}}$$

This means that at resonance ~~phas~~ the phase difference is 90°

If we draw the graph α v/s $\frac{p}{\omega}$ then we will get the graph as shown in below



For $\frac{p}{\omega} = 1$, $\alpha = \frac{\pi}{2}$

$\frac{p}{\omega} < 1$, $\alpha < \frac{\pi}{2}$

$\frac{p}{\omega} > 1$, $\alpha > \frac{\pi}{2}$

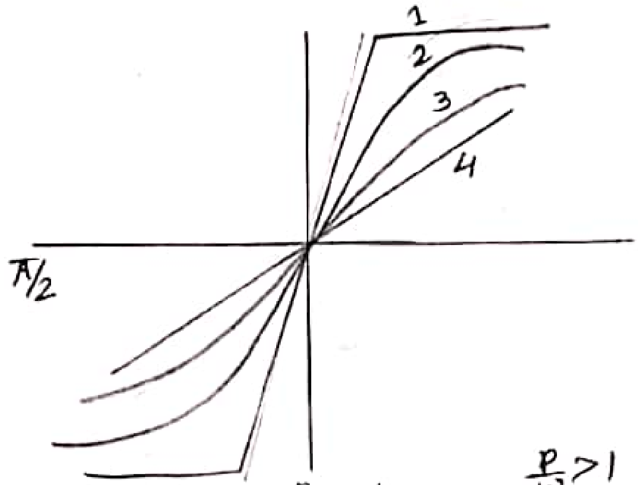
Scanned with CamScanner

(13) Effect of damping on the phase of forced vibration:

We have the eqn. $\tan\alpha = \dfrac{\frac{\mu p}{m}}{\left(\frac{k}{m} - p^2\right)}$ —— (1)

In above eqn α is the phase difference
From the above eqn we can see that
α is directly proportional to μ.

Let us consider a graph α v/s $\frac{p}{\omega}$



* When μ is very less then we will get the curve (1)
* When μ is medium the we will get the curve (2)
* When μ is sufficiently high we will get the curve (4) as shown in the above graph.
* Although the phase difference α will be $\frac{\pi}{2}$ when $\frac{p}{\omega}$ is equals to 1 or $p = \omega$ (forced frequency = natural frequency)

Halmotz Resonator:

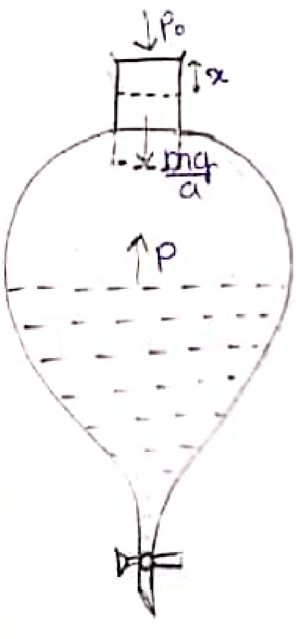
Helmholtz Resonator:

It works on the principle of vibration of air column. Helmholtz Resonator is closed vessel having two openings, the cylindrical neck at the top & the narrow pipe at the bottom, having stopper. Through which volume of air column can be varied.

When the vibrating tuning fork is held at the mouth of the resonator it sounds loudly. when the natural frequency of air column is equals to frequency of tuning fork. This process is called as Resonance.

Let us consider Helmholtz Resonator having the neck of cross-sectional area "a" and let the mass of the air contained in the neck is "m" and rest of the volume of air be "V" and let pressure inside the resonator is "P" and pressure outside the resonator is "P_0" and the pressure because of air in the neck is "$\frac{mg}{a}$".

At equilibrium, $P = P_0 + \frac{mg}{a}$ —— (1)



When the air in the flask is in resonance with particular frequency then air in the neck will move up and down. It acts like a piston.

Let at any instant the air column in the neck moves downwards by the distance "x"

$\therefore V_{new} = V - ax$

If the process is adiabatic then we can write,

Let P_1 be the new pressure.

(15) $P_1 (V-ax)^{\gamma} = P(V)^{\gamma}$ —— (2) $\boxed{\gamma = \frac{C_P}{C_V}}$

$$P_1 = \frac{PV^{\gamma}}{(V-ax)^{\gamma}}$$

$$P_1 = P\left(\frac{V}{V-ax}\right)^{\gamma}$$

$$P_1 = P\left[1 + \frac{ax}{V-ax}\right]^{\gamma}$$

By using Binomial expansion, we get

$$P_1 = P\left[1 + \frac{\gamma\, ax}{V-ax}\right]$$

$$P_1 = P + \frac{Pax\gamma}{V-ax}$$

$$P_1 - P = \frac{P\gamma ax}{V-ax} \quad \text{—— (3)}$$

$(1+x)^n = 1+nx+\frac{n(n-1)x^2}{2!} + \frac{n(n-1)(n-2)x^3}{3!} + \ldots$

x is very very small then.

$\boxed{(1+x)^n = 1+nx}$

The net downward force "F" on the air in the resonator is.

$$F = (P-P_1)\, a$$

$$\frac{F}{a} = P - P_1$$

{ Pressure $= \frac{F}{a}$; $F = Pa$ }

Now substituting the value of $P - P_1$ from eq^n (3)

$$\frac{F}{a} = \frac{-P\gamma ax}{V-ax}$$

$$F = \frac{-P\gamma a^2 x}{V-ax}$$

As ax is very small as compared to V So we can neglect ax in the denominator of above eq^n.

$$F = \frac{-P\gamma a^2 x}{V}$$

$$\text{Mass} \times \text{Acceleration} = \frac{-P\gamma a^2 x}{V}$$

$$m \times \text{acceleration} = \frac{-P\gamma a^2 x}{V}$$

(16) acceleration $= \dfrac{-P\gamma a^2 x}{Vm}$

acceleration $= \dfrac{-P\gamma a^2}{Vm}\, x$

{ Gen formula of time
$$T = 2\pi\sqrt{\frac{d}{a}}$$

The above eq^n represents SHM.

$$\frac{\text{acceleration}}{x} = \frac{-P\gamma a^2}{Vm}$$

{ $\ominus$ sign indicates the pressure moves downwards }

Now, $T = 2\pi\sqrt{\dfrac{d}{a}}$

$$T = 2\pi\sqrt{\frac{Vm}{P\gamma a^2}}$$

frequency, $f = \dfrac{1}{T}$

$$f = \frac{1}{2\pi}\sqrt{\frac{P\gamma a^2}{Vm}} \quad \text{——— (4)}$$

The velocity of sound in the air is given by. $v = \sqrt{\dfrac{K_s}{\rho}} = \sqrt{\dfrac{\gamma P}{\rho}}$

where, $K_s \Rightarrow$ Coefficient of stiffness

$K_s = \gamma P$

where, P is pressure

γ is ratio of specific heat at constant pressure to const temp.

& ρ is density of air

$$v^2 = \frac{\gamma P}{\rho}$$

$$\gamma P = v^2 \rho$$

Substitute the value of γP in eq^n (4)

$$f = \frac{1}{2\pi}\sqrt{\frac{v^2 \rho a^2}{Vm}} \quad \text{——— (5)}$$

(17) W.K.T. $\rho = \frac{m}{al}$

$\therefore m = \rho a l$

Substituting the value of m in (5)

$$f = \frac{1}{2\pi}\sqrt{\frac{v^2 \rho a^2}{V \rho a l}}$$

$$f = \frac{1}{2\pi}\sqrt{\frac{v^2 a}{V l}} = \frac{v}{2\pi}\sqrt{\frac{a}{V l}}$$

31/01/2020

$$\boxed{f \propto \frac{1}{\sqrt{V}}} \quad \text{———} \quad (6)$$

By knowing the values of length & ~~area~~ cross-sectional area of the neck & volume of resonator V. we can find out unknown frequency.

Eq^n (6) shows that frequency is inversely proportional to square root of volume V.

Transducers:

It is a device which converts one form of energy into another form.

Ex: Solar cell, dynamo, ~~photo~~ voltmeter, speaker. Bulb. etc...

If any form of energy is converted into electric signal by transducer then it is called as electric transducer.

Classification of Transducers:

The transducers can be classified.

(i) On the bases of transduction form used.

(ii) As primary & secondary transducers.

(iii) As passive & active transducers

(iv) As Analog & digital transducers

(v) As transducers & anti transducers.

1. Transduction on the bases of form:

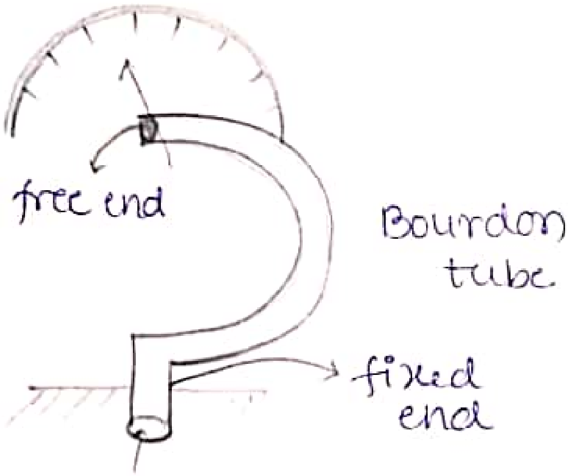
The transduction can be classified on the bases of principle of transduction as resistive. capacitive and inductive. Depending upon how they convert the input quantity into resistance, inductance. capacitance.

Ex: Thermoelectric, piezoelectric, optical and electrokinetic.
(POET)

2. Primary and Secondary Transducers

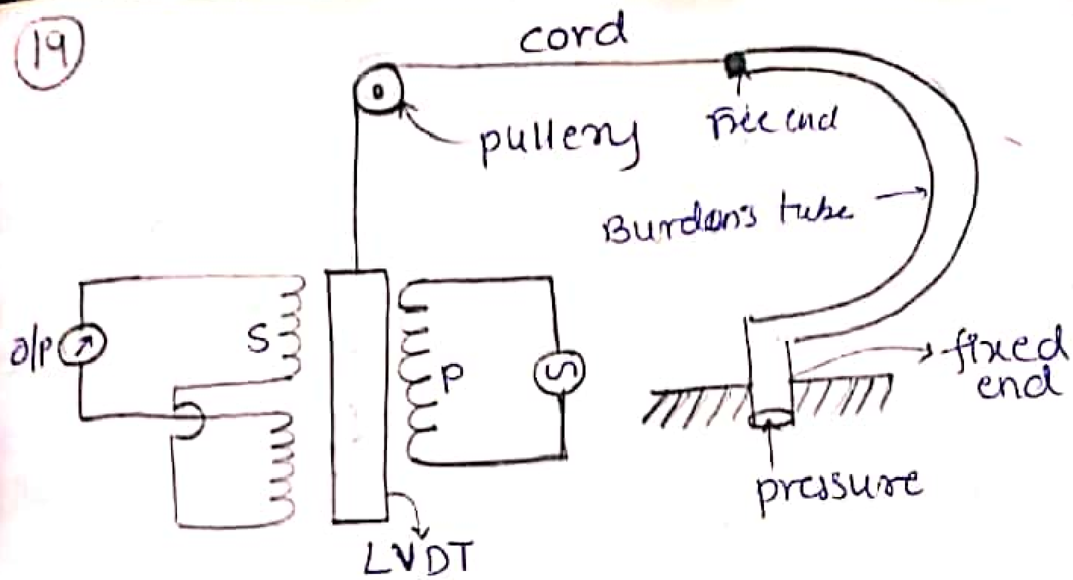
In Primary transducers any form of energy is converted into kinetic energy. and In secondary transducers the motional energy is converted into electric energy.

Ex: Ex for primary transducers: Bourdon's tube, it is C shaped tube which converts pressure into motional energy.



Ex for secondary transducers: Linear variable differential transformer

Let us consider the case of Bourdon's tube as shown in the below fig. The Bourdon tube acting as a primary detector and senses the pressure and converts into displacement of its free end.



The displacement of free end moves the cord which is connected to linearly variable differential transformer (LVDT) which produces an output voltage which is proportional to the moment of force, which is proportional to displacement of the free end which is intern proportional to pressure applied. Here Primary Bourdon tube is called P.T & LVDT is called S. Transducer

3. <u>Passive and Active Transducer</u>:

<u>Passive Transducer</u> is a transducer which requires external auxillary power source for its operation. They are also known as externally powered transducers.

<u>Ex</u>: Potentiometer, microphone, speaker

<u>Active Transducer</u>: These are the transducers which do not require any auxillary power supply for the operation.

<u>Ex</u>: Solar cell, Photovoltaic cell, chemical batteries, Thermocouple, Piezoelectrics

4. <u>Analog and Digital Transducers</u>

The transducer can be classified on the bases of output which may be continuous function of time or it may be in discrete function of time.

(2) ~~Analog transducer~~ **Analog transducer**: These transducers converts the input quantity into an analog output which is continuous function of time.
Ex: Thermocouple, Thermistor, ~~&~~ LVDT.

Digital Transducer: These transducers convert the input quantity into an electric output which is in the form of pulses.
Ex: Full wave bridge rectifier and Half wave bridge rectifier.

~~Moving coil loud speaker.~~ 06/02/20

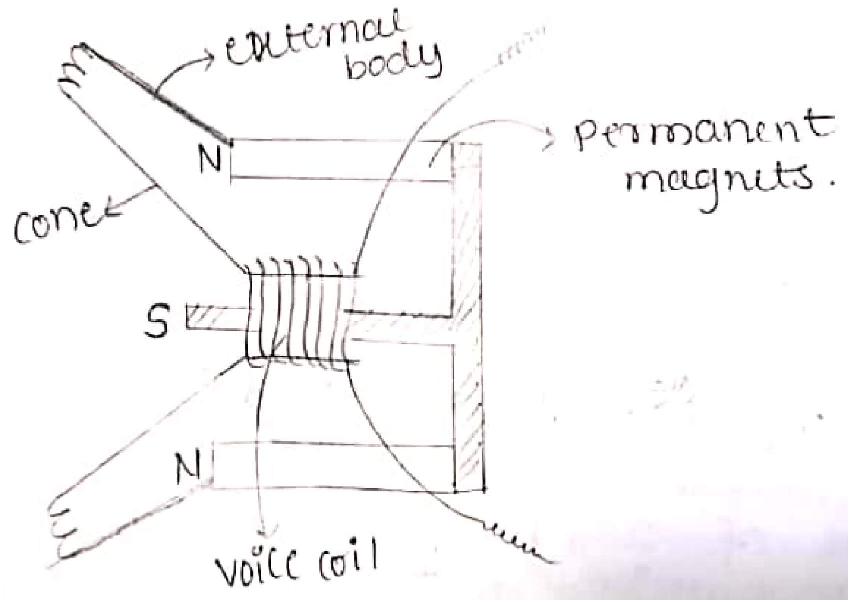
5. **Transducers & Anti Transducers.**

Transducers: It is a device which converts any form of energy into electric form

Antitransducers: It is a device which converts electric energy into other form of energy
Ex: Speaker.

Moving coil loud speaker

It is a device which converts electric energy into sound energy. It is made up of voice coil, which is placed in the magnetic field of permanent magnets & a cone is attached to this voice coil.



The voice coil is free to move up and down.

21) **Working:** When the variable current or audio signal is applied to the voice coil, it moves up and down, with the frequency of audio signal applied. Here the coil works as primary transducer. As the coil is attached to the cone it also vibrates. & creates pressure wave in the air. That we perceive as sound. Here the cone acts as secondary transducer.

If every frequency is accurately we produced to the listeners without adding or removing any information Then probably its a good speaker.

There are several factors that determines speaker quality.

1. Frequency response
2. Distortion (Noise)

Frequency response : Frequency response is how loud the output of speaker will be at different frequency.

Ex: Laptop speaker unable to produce bass.

Distortion : If the speaker adds frequencies to the music that where not present in original signal then there will be distortion in output sound.

Scanned with CamScanner

Problems

① A Helmholtz resonator has the volume of 1 litre. The radius of the neck is 0.01 m & the length of the neck is 0.05 m. Calculate the natural frequency of resonator. If the velocity of sound is 350 m/s at room temperature

Soln: $V = 1$ litre $= 10^{-3} m^3 = 1000 cc$ $\qquad v = 350\ m/s$

$l = 0.05\ m$

$a = 0.01\ m$

$f = ?$

$$f = \frac{1}{2\pi}\sqrt{\frac{v^2 a}{Vl}} = \frac{v}{2\pi}\sqrt{\frac{a}{Vl}}$$

$$= \frac{350}{2\times 3.142}\sqrt{\frac{0.01}{10^{-3}\times 0.05}}$$

$$= \frac{350}{6.284}\sqrt{\frac{0.01}{0.05\times 10^{-3}}}$$

1 litre = 1000 cc – cubic cm
= $1000\,(cm)^3$ $\qquad cm = 10^{-2}$
= $10^3\,(10^{-2})^3$
= $10^3\,(10^{-6})$
= $10^{-3}\,m^3$

$$= 55.69\sqrt{\frac{1}{5\times 10^{-3}}}$$

$$= 55.69\sqrt{0.2\times 10^{3}}$$

$$= 55.69\sqrt{200}$$

$$= 55.69 \times 14.142$$

$$\boxed{f = 787.56\ Hz}$$

② In the Helmholtz resonator the resonating volume is $90\times 10^{-5} m^3$ when the frequency of tuning fork is 512 Hz. Calculate the resonating volume for the tuning fork of frequency of 480 Hz.

Soln: $V_1 = 90\times 10^{-5}\ m^3 \qquad V_2 = ?$

$f_1 = 512\ Hz \qquad f_2 = 480\ Hz$

WKT $f_1 = \frac{1}{\sqrt{V_1}}$ — ①

$f_2 = \frac{1}{\sqrt{V_2}}$ — ②

÷ eqⁿ ① by ②

$$\frac{f_1}{f_2} = \frac{\sqrt{V_2}}{\sqrt{V_1}}$$

$$\sqrt{V_2} = \sqrt{V_1}\,\frac{f_1}{f_2}$$

$$V_2 = V_1 \frac{f_1^2}{f_2^2}$$

$$V_2 = 90\times10^{-5} \times \frac{(512)^2}{(480)^2}$$

$$V_2 = 90\times10^{-5} \times \frac{262144}{230400}$$

$$V_2 = 90\times10^{-5} \times 1.137$$

$$\boxed{V_2 = 102.33\times10^{-5}\ m^3}$$

07/02/20

③ In Helmholtz resonator the resonating volume is 102 cc for tuning fork of frequency 480 Hz. What is the frequency of tuning fork when it resonates with the volume of 90 cc

Soln: $V_1 = 102\,cc = 102\times10^{-6}\ m^3$

$f_1 = 480 zz$

$V_2 = 90\,cc = 90\times10^{-6}\ m^3$

$f_2 = ?$

$$\frac{f_1}{f_2} = \sqrt{\frac{V_2}{V_1}}$$

$$\frac{f_1^2}{f_2^2} = \frac{V_2}{V_1}$$

$$f_2^2 = \frac{f_1^2 V_1}{V_2}$$

$$f_2 = \sqrt{\frac{f_1^2 V_1}{V_2}}$$

$$f_2 = f_1\sqrt{\frac{V_1}{V_2}}$$

$$f_2 = 480\sqrt{\frac{102\times\cancel{10^{-6}}}{90\times\cancel{10^{-6}}}}$$

$$f_2 = 480\times1.06$$

$$\boxed{f_2 = 508.8\ Hz}$$

(4) A Helmholtz resonator has a volume of 900 cc. The length & area of cross-section of the neck (24) are 6 cm & 3.8 cm^2 respectively. Calculate the natural frequency of the resonator. If the velocity of the sound is 345 m/s at room temp.

Soln: $V = 900\,cc = 900 \times 10^{-6}\,m^3$ $\qquad \cancel{f = \frac{v}{2\pi}\sqrt{\frac{a}{Vl}}}$

$l = 6\,cm = 6 \times 10^{-2}\,m$

$a = 3.8\,cm^2 = 3.8 \times 10^{-4}\,m^2$

$f = ?$

$v = 345\,m/s$

$$f = \frac{v}{2\pi}\sqrt{\frac{a}{Vl}}$$

$$f = \frac{345}{2 \times 3.143}\sqrt{\frac{3.8 \times 10^{-4}}{900 \times 10^{-6} \times 6 \times 10^{-2}}}$$

$$f = \frac{345}{6.286}\sqrt{\frac{3.8 \times 10^{-4}}{5400 \times 10^{-8}}}$$

$$f = 54.88\sqrt{0.0007037 \times 10^{4}}$$

$$f = 54.88\sqrt{7.037}$$

$$f = 54.88 \times 2.65$$

$$\boxed{f = 145.48\ Hz\ Hz}$$

(5) In Helmholtz resonator the resonating volume is 70 cc. For tuning fork of frequency 512 Hz. What is the resonating volume for the tuning fork of frequency 256 Hz.

<u>Soln</u>: $V_1 = 70\,cc = 70 \times 10^{-6}\,m^3$

$f_1 = 512\,Hz$

$V_2 = ?$

$f_2 = 256\,Hz$

$$\frac{f_1}{f_2} = \sqrt{\frac{V_2}{V_1}} \Rightarrow \frac{f_1^2}{f_2^2} = \frac{V_2}{V_1}$$

$$f_1 = f_2\sqrt{\frac{V_2}{V_1}} \Rightarrow V_2 = V_1 \frac{f_2^2}{f_1^2}$$

$$V_2 = 70\times10^{-6}\times\frac{(512)^2}{(256)^2}$$

$$V_2 = 70\times10^{-6}\times\frac{262144}{65536}$$

$$= 70\times10^{-6}\times 4$$

$$\boxed{V_2 = 280\times10^{-6}\ m^3}$$

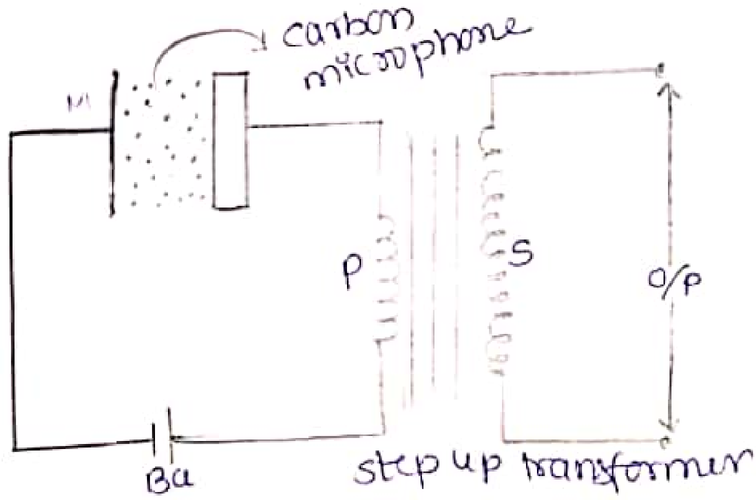
$$\cancel{= 70\times10^{-6}\times\frac{65536}{262144}}$$

$$\cancel{= 70\times10^{-6}\times 0.25}$$

$$\cancel{= 17.5\times10^{-6}}$$

Carbon microphone:

~~Micropho~~ Carbon micro phone is a device which converts sound energy into electric signals.



The basic diagram of carbon microphone is shown in above fig

~~Principle~~: The basic principle is based on the variation of resistance of carbon granuales, which are enclosed in between two plates. One of which is movable called as diaphragm & another one is fixed. These two plates are connected in series with battery. & primary coil of step up transformer.

2) When vibration of sound is strikes the diaphragm it moves too & fro motion. i.e it starts vibrating. When two plates moves closer to each other then the resistance of the granuals decreases and when they are away from each other, the resistance of grannuals increases. So there will be oscillation of current in the circuit, which is amplified either by step up transformer or amplifier or both.

If R is the resistance of the circuit when there is no displacement of diaphragm & let dR be the ~~resistance~~ varying resistance due to displacement of diaphragm, which is given by

$$dR = Ka \sin \omega t$$

So the ~~res~~ total resistance at the moment is

$$R_1 = R + dR$$

$$R_1 = R + Ka \sin \omega t$$

So we can write the current as.

$$I = \frac{V}{R + Ka \sin \omega t}$$

$$I = \frac{V}{R\left(1 + \frac{Ka}{R} \sin \omega t\right)}$$

$$I = \frac{V}{R}\left(1 + \frac{Ka}{R} \sin \omega t\right)^{-1}$$

By using Binomial expansion

$$I = \frac{V}{R}\left[1 - \frac{Ka}{R} \sin \omega t + \frac{K^2 a^2}{R^2} \sin^2 \omega t \cdots\cdots\right]$$

$$I = \frac{V}{R} - \frac{VKa \sin \omega t}{R^2} + \frac{VK^2 a^2 \sin^2 \omega t}{R^3} \cdots$$

The first term ~~indicates~~ in above eqn indicates steady current when diaphragm is at rest & second term indicates the alternating current when diaphragm is vibrating.