Questions and Answers

e-content for B.Sc Physics (Honours)
B.Sc Part-I
Paper-I

Dr. Ayan Mukherjee,
Assistant Professor,
Department of Physics,
Ram Ratan Singh College, Mokama.
Patliputra University, Patna

- **MULTIPLE CHOICE QUESTIONS :-**

1. Hooke's law essentially defines________
   [a] Stress [b] Strain [c] Yield Point **[d] Elastic limit**
2. The dimensional formula of stress is_____________.
   [a] $[M^0 L^1 T^2]$ [b] $[M^0 L^{-1} T^{-2}]$ **[c] $[M^1 L^{-1} T^{-2}]$** [d] $[M^0 L^1 T^1]$
3. The nearest approach to the perfectly elastic body is _______
   [a] Quartz fibre [b] Putty [c] Silver [d] Platinum
4. ____________ is the perfectly plastic material.
   [a] Quartz fibre **[b] Putty** [c] Silver [d] Platinum
5. The restoring force per unit area is called _________.
   [a] Stress [b] Strain [c] Elasticity [d] Plasticity
6. The change per unit dimension of the body is called __________.
   [a] Stress **[b] Strain** [c] Elasticity [d] Plasticity
7. The restoring force per unit area perpendicular to the surface is called _______ stress.
   [a] Longitudinal [b] Tangential **[c] Normal** [d] Tensile
8. The restoring force per unit area parallel to the surface is called _______ stress.
   [a] Longitudinal **[b] Tangential** [c] Normal [d] Tensile
9. The strain produced at right angles to the direction of force is called _________ strain.
   [a] Primary **[b] Secondary** [c] Volume [d] Shear
10. Compressibility of a material is reciprocal of _______.
    [a] Modulus of rigidity [b] Young Modulus **[c] Bulk Modulus** [d] None
11. The work done per unit volume in stretching the wire is equal to _____________.
    [a] Stress *Strain **[b] (1/2)Stress *Strain** [c] Stress /Strain [d] Strain/Stress
12. Theoretical value of poisson's ratio lies between__________
    [a] -1 and +0.5 [b] -1 and -2 [c] -0.5 and +1 [d] -1 and 0
13. The relationship between Y,η & σ is_________
    [a] Y =2 η(1+σ) [b] η = 2Y(1+σ) [c] σ =2y/(1+ η) [d] None
14. The poisson's ratio cannot have the value __________
    [a] 0.7 [b] 0.2 [c] 0.49 [d] 0.1
15. The poisson's ratio cannot have the value __________
    [a] 0.7 [b] 0.2 **[c] 0.49** [d] 0.1
16. Units of modulus of elasticity is
    [a] dyne/cm **[b] dyne/cm^2** [c] N/m [d] dyne
17. In Bulk modulus, there is a change in the volume of the body but no change in ________
    [a] Size **[b] Shape** [c] Line [d] Angle
18. Increase in the length of a wire is always accompanied by a decrease in_________
    [a] Length [b] Breadth **[c] Cross section** [d] Height
19. The ratio of longitudinal stress to linear strain is called______
    [a] Young modulus [b] Bulk modulus [c] Modulus of rigidity [d] None

20. The ratio of Tensile stress to shear strain is called______

[a] Young modulus [b] Bulk modulus **[c] Modulus of rigidity** [d] None

21. The twisting couple per unit twist of a cylinder depends on __________

[a] Young modulus [b] Bulk modulus **[c] Modulus of rigidity** [d] None

22. If the material of a beam is ___________, no bending should be produced.

[a] Homogenous [b] Isotropic [c] Elastic **[d] Plastic**

23. The unit if twisting couple is__________

[a] dyne/cm **[b] N.m** [c] N^2.m [d] $N.m^2$

24. The material of a beam should not be _________

[a] Homogenous [b] Isotropic [c] Elastic **[d] Plastic**

25. The bending moment of a beam depends on only_______.

[a] Young's modulus [b] Bulk Modulus [c] Poisson's ratio [d] None

26. The twisting couple per unit twist of wire or cylinder is also called_____________.

[a] Torsional rigidity [b] Young modulus [c] Bulk modulus [d] None

27. The twisting couple is equal and opposite to the ________.

[a] Force [b] Work [c] Pure shear **[d] Restoring couple**

28. The geometrical moment of inertia is given by__________

[a] $I_g = a^2k$ **[b] $I_g = ak^2$** [c] I_g = a2/k [d] None

29. The depression produced in the free end of a cantiviler is _________

[a] $y = \frac{W2L}{3YIg}$ [b] $y = \frac{W2L}{YIg}$ **[c] $y = \frac{WL^3}{3YIg}$** [d] None

30. The time period of a torsional pendulum is directly proportional to the square root of ________.

[a] Distance [b] Vibration **[c] Moment of Inertia** [d] Force

31. Velocity of sound waves in a gas is proportional to

[a] square root of isothermal elasticity of the medium

[b] square root of the adiabatic elasticity of the medium

[c] reciprocal of the isothermal elasticity of the medium

[d] adiabatic elasticity of the medium

32. Velocity of sound in air at a given temperature

[a] increases with increase in pressure [b] decreases with increase in pressure

[c] independent of pressure [d] None

33. At what temperature, the velocity of sound in air is double its value at 0^0.

[a] 1092^0C **[b] 819^0C** [c] 546^0C [d] 273^0C

34. The velocity of sound will be greatest in

[a] water [b] air [c] vacuum **[d] metal**

35. Under similar conditions of temperature and pressure, the velocity of sound will be maximum in

[a] nitrogen [b] oxygen **[c] hydrogen** [d] carbon dioxide

36. When the wind is blowing in the same direction in which the sound is travelling, the velocity of sound

[a] increase [b] decrease [c] no change [d] None

37. The speed of sound in air at N.T.P. in 300 m/s. If air pressure becomes four times, then the speed of sound will be

[a] 50 m/s **[b] 300 m/s** [c] 600 m/s [d] 1200 m/s

38. The value of specific heats for air is

[a] 1.21 [b] 1.31 [c] 1.41 [d] 1.51

39. According to the Newton's formula the velocity of sound in air is

[a] 280 m/s [b] 332 m/s [c] 331.6 m/s [d] 350 m/s

40. In kundt's tube experiment small heaps of powder are created at

[a] nodes [b] antinodes [c] outside the tube [d] None

41. According to the Laplace's corrections the velocity of sound in air is

[a] 280 m/s [b] 332 m/s **[c] 331.6 m/s** [d] 350 m/s

42. The sound which creates a pleasing effects on the ear is called

[a] noisy sound [b] noisy voice **[c] musical sound** [d] musical voice

43. Which of the following is not a characteristic property of a musical sound

[a] Pitch [b] loudness **[c] amplification** [d] quality

44. Pitch of sound is a_______ quantity

[a] psychological [b] illogical [c] phenomenal **[d] physiological**

45. The relation between the loudness and the intensity is expressed as

[a] L=K/log I **[b] L=KlogI** [c] L=K+logI [d] None

46. 1 bel is equal to

[a] 10 decibel [b] 1 decibel [c] 100 decibel [d] None

47. Phon is the unit of measurement of

[a] intensity of sound [b] loudness of sound [c] phase of sound [d] None

48. In case of a sound source moving away from a stationary observer, the apparent frequency is

[a] increased [b] halved [c] doubled [d] decreased

49. The relation between velocity, frequency and wavelength of a wave v is

[a] λ/f [b] f/λ **[c] λf** [d] $\lambda + f$

50. Ultrasonic waves are

[a] Longitudinal [b] Progressive [c] Transverse [d] Inverse

51. The velocity of sound in air at 0^o C temperature is

[a] 330 m/s [b] 331.6 m/s [c] 280 m/s **[d] 332 m/s**

52. Which one of the following materials is not a piezo-electric material?

[a] Quartz [b] Tourmaline [c] Rochelle Salt **[d] Aluminum**

53. In a liquid bath, ultrasonic waves make a

[a] plane diffraction grating [c] diffraction in liquids

[b] plane diffraction prism **[d] disruptive effects in liquids**

- **SHORT QUESTIONS :-**

1. Explain (i) elasticity and (ii) plasticity

Sol. **(i) Elasticity:** The property of a material; body to regain its original condition on th removal of deforming forces, is called elasticity.

Quartz fibre is considered to be the perfectly elastic body.

(ii) Plasticity: The bodies which do not show any tendency to recover their original condition on the removal of deforming forces, is called plasticity.

Putty is considered to be the perfectly plastic body.

2. Explain (i) load (ii) stress & (iii) strain

Sol. **(i) Load:** The load is the combination of external forces acting on a body and its effect is to change the form or the dimensions of the body. Any kind of deforming force are known as load.

(ii) Stress: The restoring or recovering force per unit area set up inside the body is called stress.

(iii) Strain: The unit change produced in the dimension of a body under a system of forces in equilibrium, is called strain.

3. Explain (i) Normal stress & (iii) Tangential strain.

Sol. **(i) Normal stress:** Restoring force per unit area perpendicular to the surface is called normal stress.

(ii) Tangential strain: The restoring force per unit area parallel to the surface is called Tangential stress.

4. Explain (i) linear strain (ii) volume strain & (iii) Shear strain.

Sol. **(i) Linear strain:** The ratio of change in length to the original length is called linear strain.

$$Linear\ strain = \frac{Change\ in\ length\ (l)}{Original\ length\ (L)}$$

(ii) Volume strain: The ratio of change in volume to the original volume is called volume strain.

$$Volume\ strain = \frac{Change\ in\ volume\ (v)}{Original\ volume\ (V)}$$

(iii) Shear strain: When the force is acting parallel to the surface of the body the change takes place in the shape of the body, such type of strain is shear strain.

5. Define : Young’s Modulus and Modulus of rigidity

Sol. **Young’s modulus:** The ratio of longitudinal stress to linear strain, within the elastic limit is called young’s modulus.

It is denoted by

$$Y = \frac{\text{longitudinal stress}}{\text{linear strain}} \text{ or } Y = \frac{FL}{al}$$

The unit of young’s modulus is Pascal or N/m^2 in MKS and $dyne/cm^2$ in CGS system.

Modulus of rigidity: It is defined as the ratio of tangential stress to shear strain.

It is also called shear modulus. It is denoted by η.

$$\eta = \frac{\text{tangential stress}}{\text{shear strain}}$$

6. Define : Bulk modulus

Sol. It is defined as the ratio of the normal stress to the volume strain.

It is denoted by K.

$K = \frac{\text{Normal stress}}{\text{Volume strain}}$ or $K = \frac{PV}{av}$

7. State and Explain Hooke's law

Sol. **Hooke's law:** The ratio of stress to strain is a constant quantity for the given material and it is called the modulus of elasticity or co-efficient of elasticity.

$E = \frac{\text{Stress}}{\text{Strain}}$

8. Define : Poisson's Ratio

Sol. **Poisson's Ratio:** The elastic limit, the lateral strain (β) is proportional to the linear strain (α) and the ratio between them is a constant, called Poisson's ratio (σ).

$\sigma = \frac{\text{lateral strain}}{\text{linear strain}} = \frac{\beta}{\alpha}$

9. Explain statical method?

Sol. This method is based on the direct application of the expression for the twisting couple

$C = \frac{\pi \eta r}{2l}$

10. What are the drawback of statical method?

Sol. (i) There being a pointer moving over the circular scale, an error is caused due to the eccentricity of the axis of the rod with respect to it.

(ii) Since the force is applied through the pulley, a side pull is produced on the rod.

11. What are the advantages of dynamical method?

Sol. (i) The total suspended mass from the wire remains same, hence value of C remains unchanged.

(ii) There is no need to find the moment of inertia of the system, hence the question of uncertainly does not arise.

12. Write the expression of Torsional rigidity of wire.

Sol. The expression of Torsional pendulum rigidity of wire :

$t = 2\pi\sqrt{\frac{I}{C}}$

13. Define : cantilever and bending of beam.

Sol. **Cantilever:** A beam fixed horizontally at one end and loaded at the other end is called cantilever.

Bending of beam: A beam is a rod or a bar of uniform cross-section of a homogenous, isotropic elastic material whose length is very large compared to its thickness.

14. Define and explain bending moment

Sol. The couple in the beam due to the load applied to the free end of the beam is called the bending couple and the moment of this couple is called the bending moment.

15. Write the formulae for the velocity of sound in gaseous and solid medium.

Sol. The formulae for the velocity of sound in gaseous medium are:

$v = \sqrt{\frac{K}{P}}$

The formulae for the velocity of sound in solid medium are:

$v = \sqrt{\frac{Y}{P}}$

16. Explain the effect of pressure on the velocity of sound in air.

Sol. If the temperature of the gas is constant then from Boyle's law we have

$p \propto 1/V$

Then from the laplace's formula we can write

$v = \sqrt{\frac{YP}{P}}$ = constant

Hence if the temperature of the gas remains constant, the speed of sound does not change with a change with a change in pressure.

17. Explain the effect of wind on the velocity of sound in air.

Sol. If the air blows in the direction of sound, then the velocity of sound is increased.

But if the air blows in the opposite direction, the velocity of sound decreases.

18. Define: Longitudinal Waves and Transverse Waves.

Sol. **Longitudinal Waves:** The longitudinal waves are such that when they pass through any medium, the particles of the medium oscillate about their mean position in the direction of prorogation of the wave.

Transverse Waves: The transverse are such that when they pass through any medium, the particles of the medium oscillate about their mean position in the direction perpendicular to the direction of prorogation of the wave.

19. Enlist any four application of Kundt's tube.

Sol. Application's of kundt's tube are :

1. Determination of sound velocities in gases.
2. Comparison of velocity of sound in different gases.
3. Determination of velocity of sound in liquids.
4. Determination of Young's modulus of the rod.
5. Determination of ratio of specific heat of gases.

20. Explain the musical sound and noise.

Sol. **Musical sound :**

1. They produce pleasant effects on ears.
2. They have regularity in their waves.
3. They have definite periodicity in their waves.
4. In musical sounds there are no sudden changes in their amplitude of waves.

Noise :

1. They produce unpleasant effects on ears.
2. They have irregularity in their waves.
3. They have not definite periodicity in their waves.
4. In noise sounds there are sudden changes in their amplitude of waves.

21. Write a short note on phon.

Sol. For the measurement of sound wave in decibel, it was assumed that zero intensity level is same for sounds of all frequencies. But it is not actual case i.e. the sound of same intensity but having different frequencies may differ in loudness. Hence, scientists have adopted standard sources of frequency 10000hz with which all sounds are compared. The unit of measuring loudness is called phon.

22. Explain the phenomenon of piezo-electric effects.

Sol. When certain crystals like quartz, Rochelle salt, tourmaline etc. are stretched or compressed along certain axis, an electrical potential difference is produced along a perpendicular axis. The converse of this effect is also true i.e. when an alternating potential difference is applied along electric axis; the crystal is set into elastic vibration along mechanical axis. The effect is known as Piezo-electric effect.

23. Enlist any four properties of ultrasonic waves.

Sol. The properties of ultrasonic waves are ;

1. Because of higher frequency they are highly energetic.
2. The speed of propagation of ultrasonic waves is given by $v = \lambda f$.
3. Intense ultrasonic radiation has disruptive effects in liquids by causing bubbles to be formed.
4. Because of higher frequency they have shorter wavelength.

24. Enlist any four application of ultrasonic waves.

Sol. 1. Detection of flows in metals
2. Sonar
3. Depth of sea
4. Cleaning and clearing
5. Directional signaling

25. What is Doppler effect?

Sol. It is apparent change in the pitch of a note due to relative motion between observer and source of sound.

26. Differentiate between musical sound and noise.

Sol. **Refer Question No. 20**

27. Why a speaker cannot be used for the production of ultrasonic sound?

Sol. A speaker cannot be used for the production of ultrasonic sound because the ultrasonic waves having very high frequencies.

28. State principle of magnetostriction.

Sol. When a rod of ferromagnetic material is placed in the magnetic field parallel to its length a small extension or contraction occurs in its length. This change of length is independent of the sign of the field and depends on the magnitude of the field and nature of material.

29. Discuss the effect of pressure on the velocity of sound wave when temperature is constant.

Sol. **Refer Question No. 16**

30. Enlist the four factors which affect the velocity of sound

Sol. Effect or pressure, temperature, humidity and wind

31. Write a short note on the loudness of musical sound

Sol. Loudness of the sound is defined as the degree of sensation on the ear
It is expressed in terms of intensity of sound through weber and fuchner relation
$L = K \log I$
Where L = Loudness, K = constant, I = intensity of sound
Here intensity of sound is the amount of energy of sound wave crossing per unit time a unit cross section area which is perpendicular to the direction of propagation of sound waves.

32. Enlist the various methods of detection of ultrasonic waves

Sol. 1. Piezo – electric detector
2. Kundle tube method
3. Sensitive flame method
4. Thermal detector method

- **LONG QUESTIONS :-**

- **Define modulus of rigidity. Derive the expression for the modulus of rigidity in case of deformation of a cube**

OR

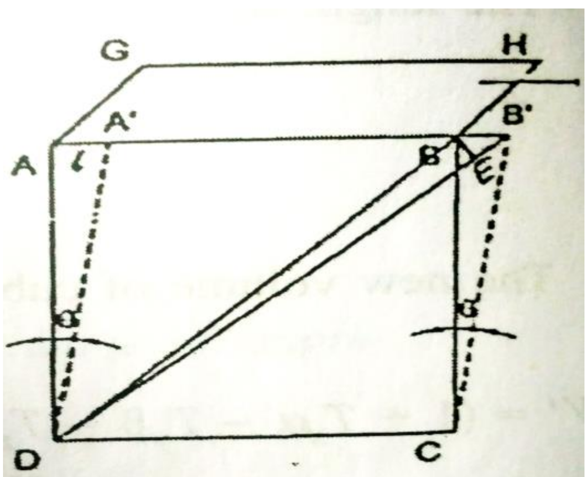
Derive the relation n = $\frac{l}{2(\alpha + \beta)}$ for deformation of cube.

Modulus of rigidity defined as the ration of tangential strees for shear strain it is denoted by n

$n = \frac{Tangential\ stress}{Shear\ strain}$

Consider a cube with an edge 'L'. Let shearing force $\vec{F}$ be applied on the tope face ABHG of a cube which prodice shear by an angle θ and linear displacement 'l'

The face ABCD becomes A'B'CD



$Tensile\ stress = \frac{F}{area\ of\ ABHG} = \frac{F}{L^2} = T,$

$Shear\ Strain = \frac{l}{L}$

$Modulus\ of\ rigidity\ n = \frac{Tensile\ stress}{shear\ strain} = \frac{T}{\theta}$

A shearing stress along AB is equivalent to a tensile stress along DB and an equal

compression stress along CA at right angle. If α and β are the longitudinal and lateral strains per unit stress respectively.

The extension along diagonal D due to tensile stress DBT α and extension along diagonal DB due to compression stress along

AC = DBT β

The total extension along

DB = DBT (α + β)

From above fig diagonal

DB = $\sqrt{L^2 + L^2}$

DB = $\sqrt{2L}$

The total extension of diagonal

EB' = $\sqrt{2L}T$ (α + β) ------------(1)

In Δ BB'E , cos BB'E = $\frac{EB'}{BB'}$

EB' = BB' cos Δ BB'E

But BB' = l and ΔBB'E = 45°

EB' = l cos 45°

$$EB' = \frac{l}{\sqrt{2}} \text{ ------------(2)}$$

Now comparing eq 1 and 2

$$\frac{l}{\sqrt{2}} = \sqrt{2\,LT}\ (\alpha + \beta)$$

$$\frac{LT}{l} = \frac{l}{2\,(\alpha + \beta)}$$

$$\frac{\frac{T}{l}}{L} = \frac{l}{2\,(\alpha + \beta)}$$

$$\frac{T}{\theta} = \frac{l}{2\,(\alpha + \beta)}$$

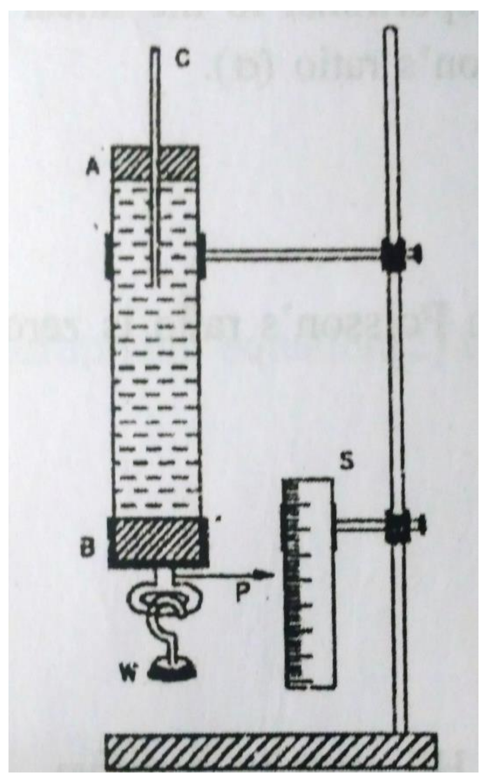
$$n = \frac{l}{2\,(\alpha + \beta)}$$

- **Define Poisson's ratio. Give it limiting values and discus method for the determination of Poisson's ratio for rubber in detail along with the necessary equations.**
  OR
  Defiene Poisson's ratio (σ)and derive formula of its determin experimentally i.e $\sigma = \frac{1}{2}\left[1 - \frac{a2}{r2} - \frac{dH}{dL}\right]$

To determine the value of σ for rubber we take about a metter long tube AB and suspended vertically as shown in fig. If two ends are properly stopped with rubber corks and liquid glue. A glass tube C of half meter long and 1 cm in diameter is fitted vertically into the cork. A through suitable hole. A suitable hole W is the suspended from lower end of the tube this will increase the length and the internal volume of the tube

It results In the fall of the level of meniscus in glass tube C, both the increase in length (dL) and he decrease in the meniscus level (dH) are measured

Let L, D, and V be the original length, diameter and volume of the tube respectively, then of the cross section pf tube is



$$A = \pi r^2 = \pi \cdot (\frac{D}{2})^2 = \frac{\pi D2}{4} \text{ ------------(1)}$$

Differentiating above eq we have

$$dA = \frac{\pi}{4} \cdot 2D.dD = \frac{\pi D}{2}.dD$$

$$= \frac{\pi D}{2}.dD. \frac{D}{2}. \frac{2}{D}$$

$$dA = \frac{\pi D2}{4}.dD\frac{2}{D}$$

$$dA = \frac{2A.dD}{D} \text{ ------------(2)}$$

Now the increase in lentght of rubber tube dL and the increase in volume dV are accompanied with the decrease in area of cross section dA

Volume = area of cross section x Length

$$V + dv = (A-dA) – (L + dL)$$

$$V + dV = AL + AdL – dAL – dA.dL \text{ ------------(3)}$$

Negalting dA.dL being very small

$$V + dV = AL + A.dL – dA.L$$

$$dV = A.dL – dA.L \text{ ------------(4)}$$

substituting the value of dA

$$dV = A.dL - \frac{2A.dD}{D} . L \text{ ------------(5)}$$

dividing by dL on both sides

$$\frac{dV}{dL} = A - \frac{2AL}{D} - \frac{dD}{dL}$$

$$\frac{2AL}{D} . \frac{dD}{dL} = A - \frac{DV}{dL}$$

$$\frac{dD}{dL} . \frac{D}{2AL} [A - \frac{DV}{dL}]$$

$$\frac{dD}{dL} . \frac{D}{2AL} [\frac{A}{A} - \frac{1}{A} - \frac{DV}{dL}]$$

$$\frac{dD}{dL} . \frac{D}{2AL} [1 - \frac{1}{A} - \frac{DV}{dL}] \text{ ------------(6)}$$

Now poisson's ration is gven by

$$\sigma = \frac{lateral\ section}{linear\ section} = \frac{dD/D}{dL/L}$$

$$\sigma = \frac{L}{D} \text{ x } \frac{dD}{dL} \text{ ------------(7)}$$

Substituting the value of $\frac{dD}{dL}$

From eq 6 and 7

$$\sigma = \frac{L}{D} \text{ x } \frac{D}{2L} [1 - \frac{1}{A} - \frac{DV}{dL}]$$

$$\sigma = \frac{1}{2} [1 - \frac{1}{A} - \frac{DV}{dL}] \text{ ------------(8)}$$

A = πr^2

$$= \frac{1}{2} [1 - \frac{1}{\pi r2} - \frac{DV}{dL}] \text{ ------------(9)}$$

dV = πa^2 . dH

$$\sigma = \frac{1}{2} [1 - \frac{1}{\pi r2} - \frac{\pi a2 .dH}{dL}]$$

$$\sigma = \frac{1}{2} [1 - \frac{a2}{r2} - \frac{dH}{dL}] \text{ ------------(10)}$$

The lateral strain (B) is proportional to the linear strain (d) and the ration between them is a constant called poison's ratio σ.

$$\sigma = \frac{lateral\ section}{linear\ section}$$

- **Calculate the work done in stretching a wore of cross section area 1 mm^2 and length 2 m if the increase in length of the wire is 0.1 mm and the young's modulus of the material of the wire is 2 x 10 ^{11} N/m^2.**

Sol. Work done in stretching a

Wire = $\frac{1}{2}$ x stretching force x stretch

$$= \frac{1}{2} \text{ x F x l}$$

$$= \frac{1}{2} \text{ x } \frac{Yal}{L} \text{ x l}$$

$$= \frac{1}{2} \text{ x } \frac{2\ x\ 1011\ x\ 10{-}6\ x\ 10{-}4}{2}\ 10^{-4}$$

$$= 0.5 \text{ x } 10^{-14} \text{ x } 10^{11}$$

$$= 5 \text{ x } 10^{-4} \text{ joules.}$$

- **Prove that the work done per unit volume in stretching the wire is equal to $\frac{1}{2}$ Stress x Strain.**

OR

Derive the expression for the work done per unit volume in stretching wire.

Sol. Consider a wire of length l and area of cross section 'a' suspended from a rigid support.
Suppose that a normal force 'F' is applied at its free end and its length increases by *dl*.
The work done for a small displacement *dl* is given by

$$dW = \mathrm{F}dl \quad .... \ .... \ .... \ .... \ (1)$$

We know that,

$$\mathrm{Y} = \frac{\mathrm{FL}}{\mathrm{al}}$$

$$\mathrm{F} = \frac{\mathrm{Yal}}{\mathrm{L}}$$

Substituting this value of F in above equation (1), we get

$$dW = \frac{\mathrm{Yal}}{\mathrm{L}}dl$$

Therefore, the total work done for the stretching a wire of length 'l' given by,

$$W = \int_0^1 dW$$

$$W = \int_0^1 \frac{\mathrm{Yal}}{\mathrm{L}} dl$$

$$W = \frac{\mathrm{Ya}}{\mathrm{L}} \int_0^1 l dl$$

$$W = \frac{\mathrm{Ya}}{\mathrm{L}} \left(\frac{l^2}{2}\right)$$

$$W = \frac{1}{2}\frac{\mathrm{Ya}}{\mathrm{L}}(l)$$

$$W = \frac{1}{2} F \ x \ l$$

This work done stored in form of potential energy.

Now, the volume of the wire = *aL*

Thus, *Work done per unit volume* = $\frac{1}{2}\frac{F}{a} \mathrm{x} \frac{l}{L}$

$$= \frac{1}{2} \ (Stress \ x \ Strain)$$

- **Discuss the case of deformation of a cube and derive the necessary expression for three elastic constants and hence prove that $\frac{9}{Y} = \frac{3}{\eta} + \frac{1}{K}$**

OR

Obtain the relation connecting three elastic constants as $\frac{9}{Y} = \frac{3}{\eta} + \frac{1}{K}$

Sol. We know that relation connecting the elastic constants:

$$K = \frac{1}{3(\alpha+\beta)} \quad \text{and}$$

$$\eta = \frac{1}{2(\alpha+\beta)}$$

$$(\alpha - 2\beta) = \frac{1}{3K} \quad \ldots \ldots \ldots (1)$$

$$(\alpha + \beta) = \frac{1}{2\eta} \quad \ldots \ldots \ldots \quad (2)$$

Sutracting (2) and (1), we have

$$3\beta = \frac{1}{2\eta} - \frac{1}{3K}$$

$$3\beta = \frac{3K-2\eta}{6\eta K}$$

$$\beta = \frac{3K-2\eta}{18\eta K} \quad \ldots \ldots \ldots \quad (3)$$

Multiplying equation (2) by 2 and adding equation (1) and (2), we get

$$3\alpha = \frac{1}{\eta} + \frac{1}{3K}$$

$$3\alpha = \frac{3K+\eta}{3K\eta}$$

$$\alpha = \frac{3K+\eta}{9K\eta} \quad \ldots \ldots \ldots (4)$$

From equation of young's modulus,

$$Y = \frac{1}{\alpha} \quad \text{i.e} \quad \alpha = \frac{1}{Y} \ldots \ldots \ldots (5)$$

Using equation (5) in (4), we have

$$\frac{1}{Y} = \frac{3K+\eta}{9K\eta}$$

$$\frac{9}{Y} = \frac{3K}{K\eta} + \frac{\eta}{K\eta}$$

$$\frac{9}{Y} = \frac{3}{\eta} + \frac{1}{K} \quad \ldots \ldots \ldots (6)$$

The above equation gives the relation connecting the three elastic constants

Y, K and η.

- **Derive the equation for the bending moment of the beams having rectangular and circular cross section**

Let a beam AB be fixed at A and loaded at B as shown in fig (a) EF is the neutral axis of the beam let us consider a section PBCP’ cut by a plane PP’ at right angles to its length. An equal and opposite reactional force W must be acting vertically upward direction along PP’. the beam bead or rotate in circle wise direction. The couple produced in the beam due to the load applied to the free end of the beam is called the bending couple and the moment of this couple is called bending moment

Let a small part of the beam bent in the form of a circular are as shown in fig,. this are subtending angle θ at 0. Let r be the radius of curvature of this part of neutral axis let a’b’ be an element at a distance Z from the neutral

axis arc = radius x angle subtended

a’b’ = (R + z). θ

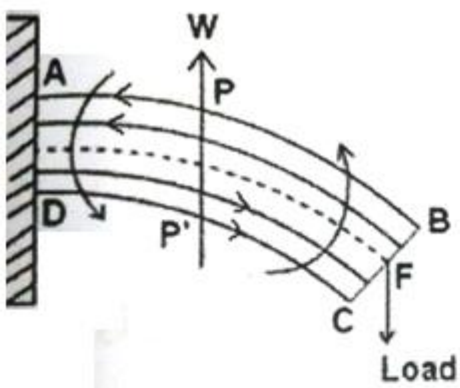


Figure : (a)

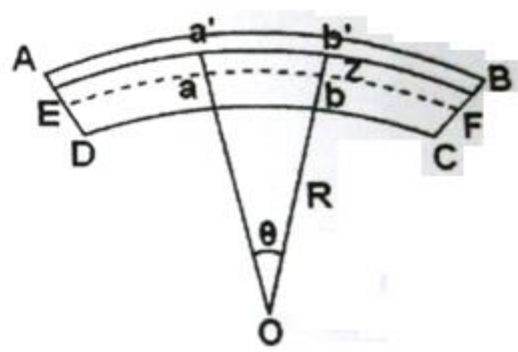


Figure : (b)

The original length ab = R. θ

Increase in length = a’b’ – ab

$=(R+Z) . \theta - R. \theta$

$= Z. \theta$ … …. …. ….. (1)

Strain = $\frac{change\ in\ length}{original\ length}$

$= \frac{Z.\theta}{R.\theta} = \frac{Z}{R}$ … …. …. ….. 2)

Young modulus y = $\frac{Stress}{Strain}$

Stress = $\frac{Y}{Strain}$

$\frac{F}{\delta\, a}$ = y X$\frac{Z}{R}$

The force F on area δa =

y x $\frac{Z}{R}$ x δa … …. …. ….. (3)

the moment of this force = Force x distance

$$y \times \frac{Z}{R} \times \delta a \times z$$

$$= y \times \frac{z^2}{R} \times \delta a \quad \ldots \ldots \ldots \ldots (4)$$

the total moment of forces acting on all the filament is given by

$$\sum \frac{Y.\delta a.z^2}{R} = \frac{Y}{R} \sum \delta a \,.\, z^2 \quad \ldots \ldots \ldots \ldots (5)$$

$$\sum \delta a \,.\, z^2 = Ig$$

$$Ig = \sum \delta a \,.\, z^2 = aK2 \quad \ldots \ldots \ldots \ldots (6)$$

Where 'a' is the area of the surface and 'k' is the radius of gyration

The moment of forces = $\frac{Y}{R}$. ak^2

$\frac{Y}{R}$ .Ig … …. …. ….. (7)

The bending moment M of beam is M = $\frac{Y}{R}$ .Ig … …. …. ….. (8)

Y.Ig = Y.aK^2 is called the flexural rigidity of the beam

Rectangular cross section

$$A = b \times d$$

$$K^2 = \frac{d^2}{12}$$

$$Ig = aK^2 = bd \times \frac{d^2}{12}$$

$$= \frac{bd^3}{12}$$

The bending moment for rectangular cross section

$$M = \frac{Ybd^3}{12R} \quad \ldots \ldots \ldots \ldots (9)$$

For circular cross section

$$a = \pi r^2 \text{ and } K^2 = \frac{r^2}{4}$$

$$Ig = a\,K^2 = \pi r^2 . \frac{r^2}{4} = \frac{\pi r^4}{4}$$

$$M = \frac{Y\pi r^4}{4R} \quad \ldots \ldots \ldots \ldots (10)$$

- **Derive the equation for the couple per unit twist produced in a cylindrical wire or shaft with the help of necessary figure.**

Sol. Consider a cylindrical rod of length l radius r and coefficient of rigidity n. its upper end is fixed and a couple is applied to its length at lower end as shown in fig

Consider a cylinder is consisting a large number if co-axial hollow cylinder of radius x and radical thickness dx as shown in if let θ is the twisting angle. The displacement is greatest at the rim and decreases as the center is approached where it becomes zero. Let AB be the line parallel to the axis 00' before twist produce and on twisted B shifts to B then line AB become AB'

Before twisting if hollow cylinder cut along AB and flatted out it will form the rectangular ABCD as shown in fig but if it will be cut after twisting it takes the shape of a parallelogram AB'C'D

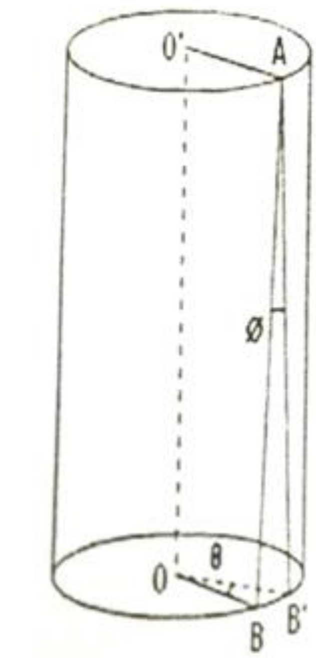


Figure : (a)

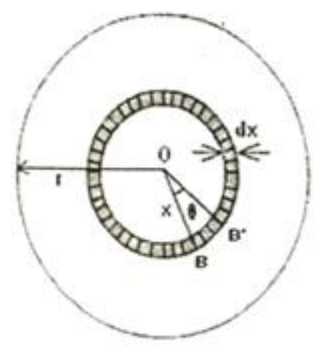


Figure : (b)

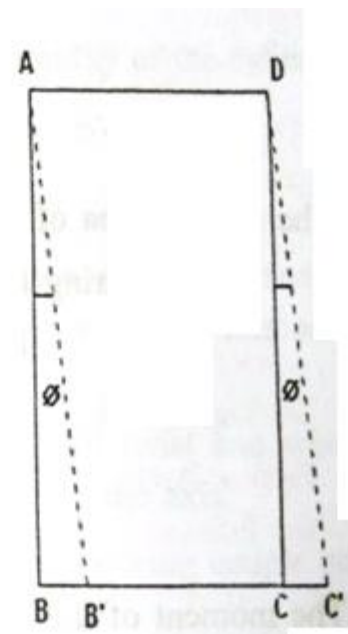


Figure : (c)

The angle of shear ∟BAB = ϕ

Fig c BB' = l ϕ

Fig b BB' = x θ

$$l\,\phi = x\,\theta$$

$$\phi = \frac{x\,\theta}{l}$$

The modules of rigidity is

$$N = \frac{Shearing\ stress}{2langle\ of\ shear} = \frac{F}{\emptyset}$$

$$F = n\,.\,\emptyset = \frac{n\,x\,\emptyset}{l}$$

The surface area of this hallow cylinder = 2πx dx

Total shearing force on this area = 2πx dx . $\frac{n\,x}{l}$

$$= 2\pi\, n\, .\, \frac{\theta}{l}\, x^2.dx$$

The moment of this force

$$= 2\pi\, n\, .\, \frac{\theta}{l}\, x^2.dx.x$$

$$=2\pi\, n\, .\, \frac{\theta}{l}\, x^3.dx$$

Now integrating between the limits x = 0 and x =x

$$\int_0^r 2\pi\, n\, .\frac{\theta}{l}\, x3.\, dx$$

$$=\frac{2\pi\, n\theta}{l} \int_0^r x3.\, dx$$

$$= \frac{2\pi\, n\theta}{l} [\, \frac{x^4}{4}]r0$$

Total twisting couple = $\frac{\pi\, n\theta r4}{2l}$

Then twisting couple per unit twist $(\theta - I)$ is

$$C = \frac{\pi\, n r^4}{2l}$$

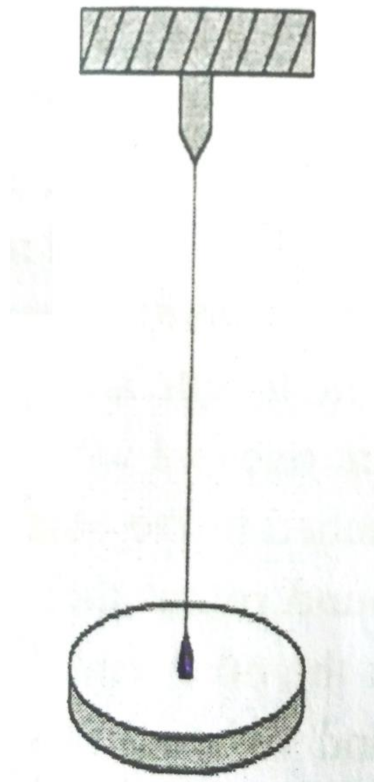
This twisting couple per unit twist is also called the Torsional rigidity of the cylinder or wire.

- **Define torsional pendulum and derive the equation for its time period**

A heavy cylindrical rod or disc suspended from the end of a fine wire whose upper end is fixed is called torsional pendulum.

The rod or disc is turned the wire will twist and when released it execute torsional vibrations about the axis.

Let θ be the twisting angle then the restoring couple set up in it is



$$C\,\theta = \frac{\pi n \theta r^4}{2l} \text{ ----------- (1)}$$

This produces an angular acceleration

dw/dt in the rod or the disc.

$$I\,\frac{dw}{dt} = -\,C\,\theta \;(\tau = I\,\alpha)$$

$$\frac{dw}{dt} = -\,\frac{C}{I}\,.\,\theta \text{ ----------- (2)}$$

Where I is the moment of inertia of the rod or disc the motion of the rod or disc is simple harmonics. Its time periods is given by

$$t = 2\pi\,\sqrt{\frac{displacement}{angular\ acceleration}}$$

$$= 2\pi\,\sqrt{\frac{\theta}{\frac{C}{I})\theta}}$$

$$t = 2\pi\sqrt{\frac{T}{C}}$$

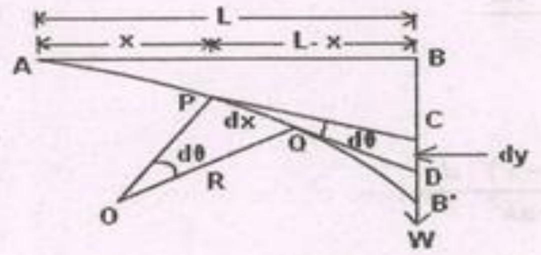
This is called the equation of time period for torsional pendulum

- **What is cantilever? Find the expression of depression produced in the beam when the cantilever loaded at free end and at the centre.**

Sol.

A beam fixed horizontally at one end and loaded at the other end is called cantilever.

When the weight of the beam is ineffective :



Let AB be the natural axis of the cantilever of length L as shown in Figure. It is fixed at end and loaded at B with a weight W. Then the end B is depressed into the position B' and the natural axis takes up the position AB'. Consider a section P of the beam at a distance 'x' from the fixed end A.

The bending moment = W × PB'

$$= W(L - x)$$

Since the beam is in equilibrium.

$$W(L - x) = \frac{YI_g}{R} = \frac{Yak^2}{R} \quad \dots \quad \dots \quad \dots \quad (1)$$

Where, R is the radius of curvature.

Thus, for point Q at a small distance dx from P, we have

$$PQ = R \cdot d\theta$$

$$\therefore \quad dx = R \cdot d\theta$$

$$\therefore \quad R = \frac{dx}{d\theta}$$

$\therefore$ Equation (1) becomes,

$$W(L - x) = \frac{Y \cdot ak^2 \cdot d\theta}{dx}$$

$$\therefore \quad d\theta = \frac{W(L-x) \cdot dx}{Y \cdot ak^2} \quad \dots \quad \dots \quad \dots \quad (2)$$

Now, the depression of Q below P is equal to CD or equal to dy, then

$$dy = (L - x)\, d\theta$$

$$= \frac{(L-x) \cdot W\,(L-x) \cdot dx}{Yak^2}$$

$$dy = \frac{W \cdot (L-x)^2 \cdot dx}{Yak^2} \quad \dots \quad \dots \quad \dots \quad (3)$$

Now, the total depression

$$y = \int_0^L dy = \int_0^L \frac{W\,(L-x)^2\, dx}{Y \cdot ak^2}$$

$$= \frac{W}{Y \cdot ak^2} \int_0^L \left(L^2 - 2Lx + X^2\right) dx$$

$$= \frac{W}{Y \cdot ak^2} \left[L^2 x - 2L\frac{x^2}{2} + \frac{x^3}{3} \right]_0^L$$

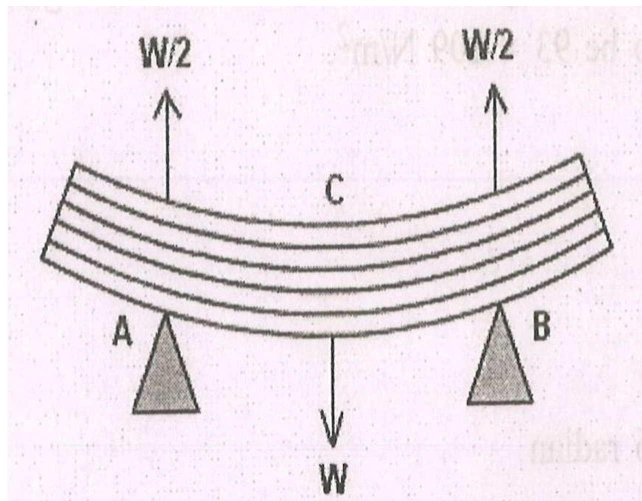
$$= \frac{W}{Y \cdot ak^2}\left[L^3 - L^3 + \frac{L^3}{3}\right]$$

$$\therefore \quad y = \frac{WL^3}{3Yak^2} = \frac{WL^3}{3YI_g}$$

- **Obtain the formula for the depression of a beam supported at the ends and loaded at the centre**
-

Sol. Let a beam be supported on two knife edges at its two ends A and B and let it loaded in the middle at C with weight W as shown in fig.

Since the middle part of the beam is horizontal then the beam may be considered as equivalent to two inverted cantilevers fixed at C and loaded at tends A and B by weight W/2.



Then the depression of C below A and B is given by

$$Y = \frac{\left(\frac{w}{2}\right).\left(\frac{l}{2}\right)}{3.y.ak2}$$

$Y = WL^3/48y.ak^2$

$= WL^3/48Y.Ig$ …. ….. …. ….. ….. (1)

If the beam is having a circular cross section then

$Ig = ak^2 = \pi r4/4$

$Y = WL^3/48.y\ .4/\ \pi r4$

$Y = WL^3/12\ \pi r4\ .\ y$ …. ….. …. ….. ….. (2)

Where r is the radius of cross section. If the beam is having a rectangular cross section

$Ig = ak^2 = bd^3/12$

$Y = WL^3/48\ y.\ 12\ /\ bd^3$

$Y = WL/4Y.bd^3$ …. ….. …. ….. ….. (3)

- **Describe dynamical method (Maxwell's vibrating needle method) of determination of modulus of rigidity.**

Sol.

A hollow tube, open at both ends is suspended at the middle with the torsion wire whose modulus of rigidity is to be measured.

It is suspended vertically from a support and a small piece of mirror attached to it, as shown in figures.

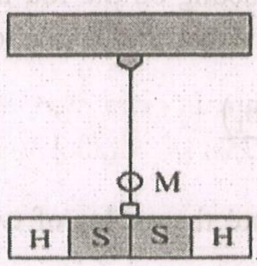


Figure : (a)

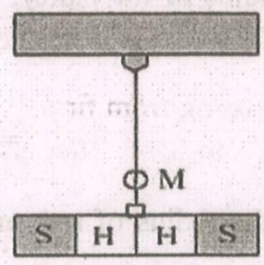


Figure : (b)

As shown in fig. (a), two hollow and two solid cylinder of equal length fitted into tube end to end. The solid cylinders are first into the inner position and hollow cylinders in the outer position as shown in fig. (a). The time period of a given system is given by

$$t_1 = 2\pi\sqrt{\frac{I_1}{C}} \quad \ldots \ldots \ldots (1)$$

Where I_1 is the moment of inertia of the loaded tube and C is couple per unit twist of the wire.

Now, the position of hollow and solid cylinder are interchanged as shown in fig. (b), Then ,time period t_2 of second adjustment is given by

$$t_2 = 2\pi\sqrt{\frac{I_2}{C}} \quad \ldots \ldots \ldots (2)$$

Where, I_2 is the moment of inertia of the tube in new position.

Squaring equation (1) and (2) , we set

$$t_1^2 = \frac{4\pi^2 I_1}{C} \quad \ldots \ldots \ldots (3)$$

And $$t_2^2 = \frac{4\pi^2 I_2}{C} \quad \ldots \ldots \ldots (4)$$

Subtracting (3) from (4), we have

$$t_2^2 - t_1^2 = \frac{4\pi^2}{C}(I_2 - I_1) \quad \ldots \ldots \ldots (5)$$

Now, let m_1 be the mass of each hollow cylinder and m_2 be the mass of each solid cylinder.

Hence, in changing from first to second position an extra mass $(m_2 - m_1)$ transferred from a distance 1/4 to 3a/4. Then using the principal of parallel axes, we have

$$I_2 = I_1 + 2(m_2 - m_1)\left[\left(\frac{3a}{4}\right)^2 - \left(\frac{a}{4}\right)^2\right]$$

$$= I_1 + 2(m_2 - m_1)\left[\frac{9a^2}{16} - \frac{a^2}{16}\right]$$

$$= I_1 + 2(m_2 - m_1)\frac{a^2}{2}$$

$$I_2 - I_1 = (m_2 - m_1)a^2 \qquad \ldots \quad \ldots \quad \ldots \quad (6)$$

Substituting this value of $I_2 - I_1$ in equation (5) we get

$$t_2^2 - t_1^2 = \frac{4\pi^2}{C}(m_2 - m_1)a^2$$

$$= \frac{4\pi^2}{\pi\eta r^4 / 2l}(m_2 - m_1)a^2$$

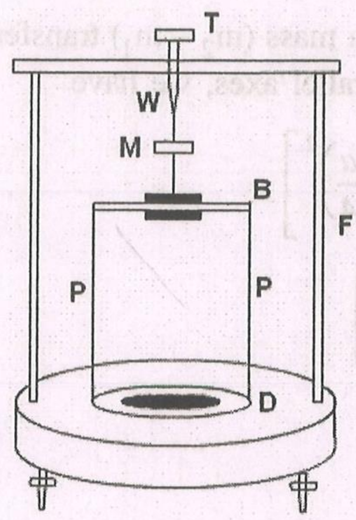
$$= \frac{8l\pi^2 a^2}{\pi\eta r^4}(m_2 - m_1)$$

$$\eta = \frac{8\pi l a^2 (m_2 - m_1)}{r^4 (t_2^2 - t_1^2)} \qquad \ldots \quad \ldots \quad \ldots \quad (7)$$

Thus, if we know l, a, m_1, m_2, t_1, t_2, and r, the modulus of rigidity (η) of the wire can be determined.

- **With the help of necessary figure explain how it can be used to determine the moment of inertia of an object.**

Sol.



The apparatus used here is called the inertia table. As shown in figure. It consists of a horizontal aluminum disc D about 15 cm in diameter, which is fitted with pair of small vertical pillars P with cross bar B. The whole assembly is suspended by a thin wire W from torsion head T inside frame F. The frame is mounted on a heavy iron base. A small piece of mirror M fixed on the cross bar B. The entire apparatus is enclosed in a glass cover.

The disc D is set into torsional vibrations and its time period to is measured. If I0 is the moment of inertia of the inertial table and C is the twisting couple per unit twist of the wire then,

$$t_0 = 2\pi\sqrt{\frac{I_o}{C}} \qquad \text{... ... ... (1)}$$

The object whose moment of inertia I is to be determined is now placed centrally on the inertia table and its time period t_1 is measured.

$$\therefore \quad t_1 = 2\pi\sqrt{\frac{(I_o + I)}{C}} \qquad \text{... ... ... (2)}$$

The given body is replaced by an object of a known moment of inertia (I_1) and the time period t_2 is measured

$$\therefore \quad t_2 = 2\pi\sqrt{\frac{(I_0 + I_1)}{C}} \qquad \text{... ... ... (3)}$$

Now squaring equation (1) and (2) we get

$$t_0^2 = \frac{4\pi^2 I_0}{C} \qquad \text{... ... ... (4)}$$

$$t_1^2 = \frac{4\pi^2 (I_0 + I)}{C} \qquad \text{... ... ... (5)}$$

Dividing equation (5) by (4)

$$\frac{t_1^2}{t_0^2} = \frac{I_0 + I}{I_0} = 1 + \frac{I}{I_0}$$

$$\therefore \quad \frac{I}{I_0} = \frac{t_1^2}{t_0^2} - 1$$

$$\therefore \quad \frac{I}{I_0} = \frac{t_1^2 - t_0^2}{t_0^2} \qquad \text{... ... ... (6)}$$

Now squaring equation (3) we have

$$t_2^2 = \frac{4\pi^2 (I_0 + I_1)}{C} \qquad \text{... ... ... (7)}$$

Dividing equation (7) by (4), we set

$$\frac{t_2^2}{t_0^2} = \frac{I_0 + I_1}{I_0} = 1 + \frac{I_1}{I_0}$$

$$\therefore \quad \frac{I_1}{I_0} = \frac{t_2^2}{t_0^2} - 1$$

$$\therefore \quad \frac{I_1}{I_0} = \frac{t_2^2 - t_0^2}{t_0^2} \quad \ldots \quad \ldots \quad \ldots \quad (8)$$

Now, dividing equation (6) by (8), we have

$$\frac{I/I_0}{I_1/I_0} = \frac{t_1^2 - t_0^2}{t_0^2} \times \frac{t_0^2}{t_2^2 - t_0^2} = \frac{t_1^2 - t_0^2}{t_2^2 - t_0^2}$$

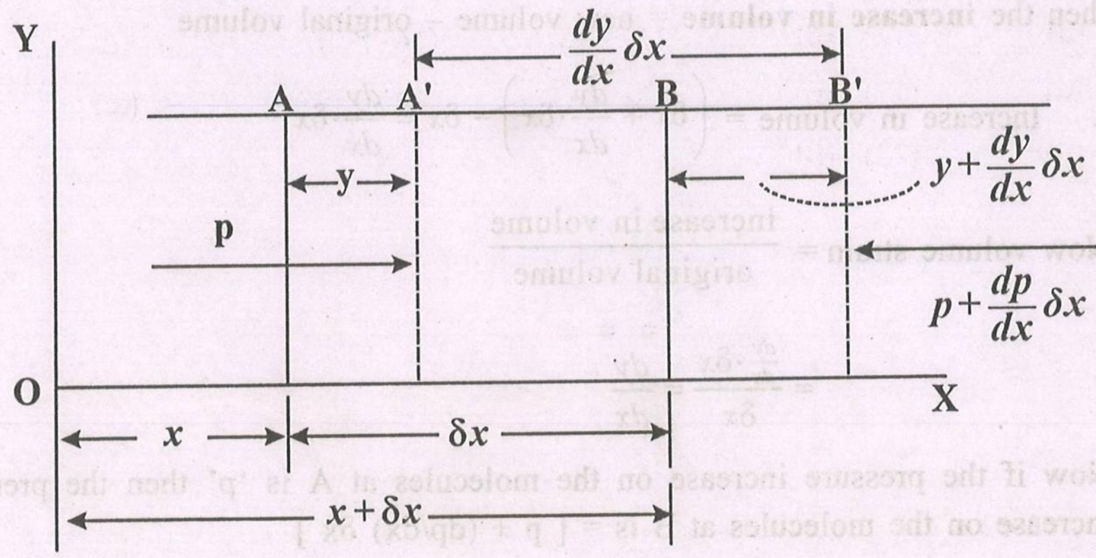
$$\therefore \quad \frac{I}{I_1} = \frac{t_1^2 - t_0^2}{t_2^2 - t_0^2}$$

$$\therefore \quad I = I_1 \times \frac{t_1^2 - t_0^2}{t_2^2 - t_0^2} \quad \ldots \quad \ldots \quad \ldots \quad (9)$$

- **Derive the formula for the velocity of longitudinal waves in a gaseous medium (air) with the help of necessary diagrams.**

Sol.

Let's consider a tube of unit cross-section area having length L lying along x – axis as shown in the figure below.



Also let's consider two cross-sections A and B of the tube perpendicular to the axis of the tube having a separation δx between them.

When a wave passes through the tube, the planes A and B are displaced and acquires positions A' and B'.

AA' and BB' represent the displacements of the particles at the planes A and B respectively.

If the displacement at A is 'y', then the displacement at B is given by $[y + (dy/dx)\,\delta x]$.

Thus the wave produces a change in the volume of the gas contained within the volume of the tube between the planes A and B.

Since the tube is having a unit cross section area, the ***original*** volume of the gas between A and B is

$$= \text{cross section area} \times \text{original length}$$

$$= 1 \cdot [(x + \delta x) - x] = \delta x$$

The volume of the gas confined between the planes A' and B' is the **new volume** and is given by the equation

New Volume = cross section area × new length

$$= 1 \times \text{new length}$$

$$= \left[(x+\delta x) + \left(y+\frac{dy}{dx}\cdot\delta x\right)\right] - (x+y) = \left(\delta x+\frac{dy}{dx}\cdot\delta x\right)$$

then the **increase in volume** = new volume – original volume

$$\therefore \quad \text{Increase in volume} = \left(\delta x + \frac{dy}{dx}\cdot\delta x\right) - \delta x = \frac{dy}{dx}\cdot\delta x$$

Now volume strain $= \dfrac{\text{increase in volume}}{\text{original volume}}$

$$= \frac{\frac{dy}{dx} \cdot \delta x}{\delta x} = \frac{dy}{dx}$$

Now if the pressure increase on the molecules at A is 'p' then the pressure increase on the molecules at B is = [p + (dp/dx) δx]

These two pressures will act on the sample of the gas confined between the planes A' and B'.

This pressure will constitute a restoring force on the sample of the gas between the two planes. So the Bulk Modulus (K) of the gas is

$$K = \frac{Stress}{Strain} = \frac{-p}{\left(\frac{dy}{dx}\right)}$$

Where the negative sign indicates the increase in the pressure with the decrease in volume. We can write,

$$p = -K\frac{dy}{dx}$$

The restoring force is also given by

$$\frac{dp}{dx} \cdot dx = \frac{d}{dx}\left(-K\frac{dy}{dx} \cdot \delta x\right)$$

$$= -K\frac{d^2y}{dx^2} \cdot \delta x \qquad \text{... (1)}$$

This force can also be given using the Newton's Second Law of motion as F = ma, where mass 'm' is defined as

= Volume × density = $\delta x \times 1 \times \rho = \rho \cdot \delta x$

Acceleration from B' to A' $= \dfrac{-d^2y}{dt^2}$

∴ Resultant force from B' to A'

= mass × acceleration

$$= \rho\, \delta x \times \left(\frac{-d^2y}{dt^2}\right)$$

$$= -\rho \cdot \delta x \cdot \frac{d^2y}{dt^2} \qquad \text{... (2)}$$

Hence the equation of motion is [comparing eq. (1) & (2)]

$$-\rho \cdot \delta x\, \frac{d^2y}{dt^2} = -K \cdot \frac{d^2y}{dx^2} \cdot \delta x$$

or $$\frac{d^2y}{dt^2} = \frac{K}{\rho} \cdot \frac{d^2y}{dx^2}$$

Where ρ is the density of the medium.

The differential equation for a progressive wave is given by the equation

$$\frac{d^2y}{dt^2} = v^2 \frac{d^2y}{dx^2}$$

Then comparing the last two equations we get the velocity of sound waves propagating in a medium to be

$$v = \sqrt{\left(\frac{K}{\rho}\right)}$$

- **Analyze the effect of pressure and temperature on the velocity of sound in air**

Sol. **Effect of Pressure**

If the pressure(p) on a gas changes, the volume(V) and density(ρ) of the gas also changes.

If the temperature of the gas is constant then from Boyle's law we have

$$p \propto 1/V$$

We know that the density

$$\rho \propto 1/V$$

Hence $p \propto \rho$, i.e., p/ρ = constant

Then from Laplace's formula we can write

$$v = \sqrt{\left(\frac{\gamma p}{\rho}\right)} = \sqrt{\left(\frac{1.41p}{\rho}\right)} = \text{constant}$$

Hence if the temperature of the gas remains constant, the speed of sound does not change with a change of pressure.

Effect of Temperature

When the temperature of the gas changes, its density also changes without affecting the pressure.

Due to this, the speed of sound also changes with temperature.

Let ρ_0 and ρ_t be the densities of the gas at 0°C and t°C respectively.

The speed of sound at the temperature will be

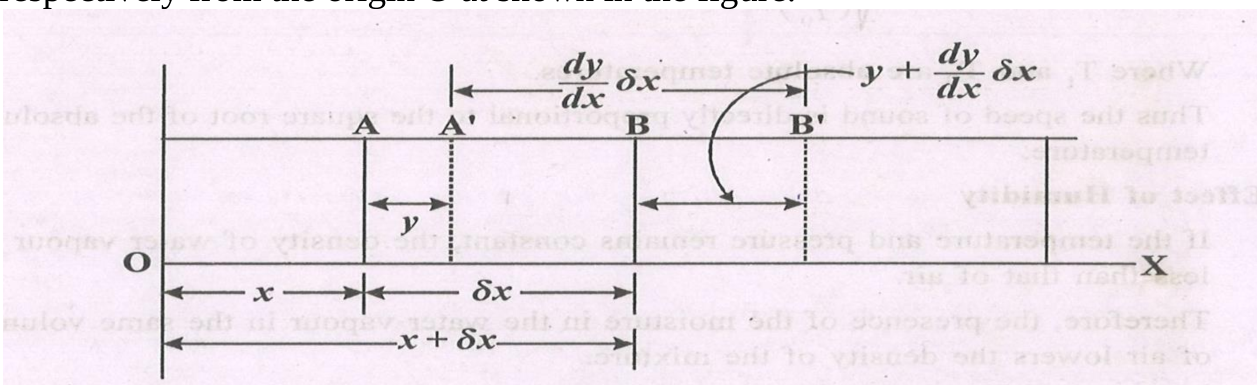
$$v_o = \sqrt{\left(\frac{\gamma p}{\rho_o}\right)} \quad \text{and} \quad v_t = \sqrt{\left(\frac{\gamma p}{\rho_t}\right)}$$

$$\frac{v_1}{v_0} = \sqrt{\frac{\rho_0}{\rho_t}}$$

According to Charle's law, $\rho_o = \rho_t\ (1 + \alpha t)$, where á is the coefficient of expansion of the gas and is equal to 1/273 per °C.

- **Deduce the expression for the velocity of sound in a metal rod with the help of necessary diagrams and equation.**

Sol. Consider a solid rectangular metallic rod placed along the X-axis.
Suppose that A and B are he two planes of the rod at distance x and x + δ x respectively from the origin O at shown in the figure.



Also assume that a longitudinal wave is passing along the axis of the rod at a particular time t.
The displacement of plane A is y and the disaplcemnet of plane b is

$$[y + (dy/dx) – x]$$

Hence increase in length of the rod

$$= (y = dy/dx . \delta x) – y$$

$$= dy/dx. \delta x$$

Longitudinal strain

$$= (dy/dx). \delta x/ \delta x = dy/dx$$

If y is the young modulus of the material of the rod the restoring force acting per unit area in the layer A' is given by

$$F= y x dy/dx$$

$$y = stress/strain = f/(dy/dx)$$

Similarly force acting on plane B' per unit area

$$F + df = y (d/dx) . (y = dy/dx. \ \delta x)$$

$$= y . dy/dx = y d^2y/dx^2. \delta x$$

Thus force acting on the rod of length δ x

$$Df = (f + df) –f$$

$$= y.dy/dx + y d^2y/dx^2. \delta x – y dy/dx$$

$$= y d^2y/dx^2. \delta x \text{ ------------ } (1)$$

According to Newton's law
Force = mass per unit area x acceleration

$$Df = \rho. \delta x \ d^2y/dt^2 = y . d^2y/dt^2 \delta x$$

or

$$d^2y/dt^2 = y/ \rho . d^2y/dx^2 \text{ ------------- } (3)$$

Comparing it with characterization differential eq of wave motion

$$d^2y/dt^2 = V^2 . d^2y/dx^2$$

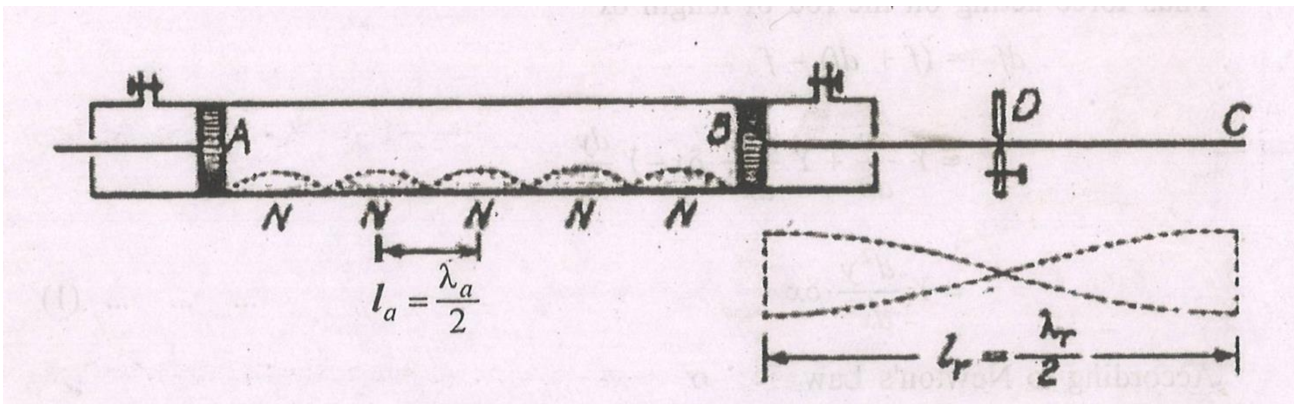
$$V^2 = y / \rho \text{ or}$$

$$V = \sqrt{\frac{y}{\rho}}$$

- **Discuss the Kundt's tube method of determination of velocity of sound in a metal rod and derive the necessary equation.**

Sol. Kundt's derived as experimental method to study the velocities of sound in different materials

The method is used to determine the velocity of sound in solids in the form of rods and also in gases.



As shown in fig the Kundt's tube consist of horizontal glass tube about 1 meter long and 5 cm in diameter.

At the one end of the tube an adjustable piston A is fitted. The other end is closed by a loosely fitted cardboard cap B which is firmly attached to a metal rod BC

The rod is clamped in the middle at D. Initially the tube is dried completely. Then a small amount of lycopodium power is scattered in the gap AB of the tube.

Then the DC part of the rod is rubbed with a resined cloth S_0 the rod is set up in longitudinal vibrations with node in the middle and the antinodes at the ends.

The disc B vibrates backward and forward putting the air column of the tibe resound loudly to the note produces by the rod

This is indicated by the violent motion of the powder at the various places along the tube.

When the distance between A and B is integral multiple of the wave length of the sound in air λa.

The stationary wave pattern is formed inside the tube. The powder is gathered in small heaps at nodes and is displaced from antinodes

The distance between several of these heaps is measured and then the average distance nodes is calculated.

If la is the distance between the adjacent heaps then

$$l_a = \lambda_a/2 \text{ or } \lambda_a = 2l_a$$

if lr is the length of the rod and λr is the wavelength of sound waves in the rod then

$$lr = \lambda_r/2 \text{ or } \lambda r = 2l_r$$

If Va and Vr are the velocities of sound in air and rod respectively and n is the frequency of the sound emitted by the rod then

$V_a = n\, \lambda_a = n\, 2\, l_a$ and

$Vr = n\, \lambda_r = n\, 2l_r$

$V_r/V_a = I_r/I_a$

i.e. velocity of in rod /velocity of sound in air

= length of the rod /distance between two consecutive nodes

$V_r = V_a \times I_r/I_a$

Thus measuring I_r and I_a and knowing the velocity of sound in air V_r i.e. the velocity of sound in the rod can be calculated.

- **Stationary waves are produced in a Kundt's tube filed with air by vibrating one meter long rod tied at middle. If the frequency of steel rod be 2480 per sec and distance between the heaps of the powder in the tube be 6.9 cms speed of sound 1) steel rod and 2) air**

Sol. 1) If la be the length of steel rod then

$l_r = \lambda_r/2$ or $\lambda_r = 2l_r$

speed of sound in steel rod is given by

$V_r = nl_r = n.2l_r$

$= 2480 \times 2x\ 1$

$= 4960$,/sec

2) if la be the distance between two consecutive nodes then.la = 6.9 cms

= 0.069 meters

$\lambda_a = 2l_a$

$= 2 \times 0.069$ meters

Speed of sound in air is given by

$V_a = n\, \lambda_a = 2480 \times 2 \times 0.069$

$=342.24$ m/sec

- **What is Doppler Effect? With the help of necessary diagrams and equation. Explain the phenomenon of Doppler Effect in detail.**

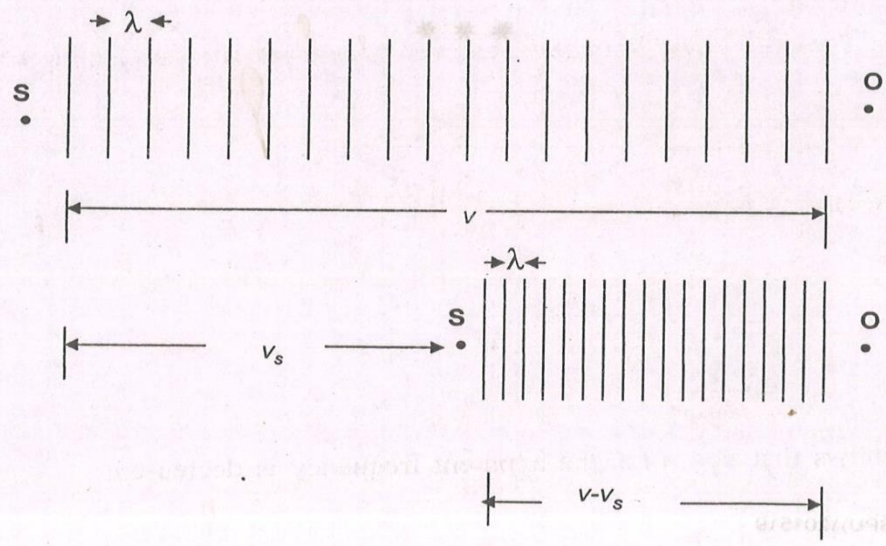
Sol.

Doppler Effect : It is the apparent change in the pitch of a note due to relative motion between observer and source of sound.

Consider the following cases :

(1) Source in motion and observer at rest :

Let S and O are the relative positions of sound and observer in the beginning as shown in the figure.



Let,

v = velocity of sound

n = true frequency of source

v_1 = velocity of the source

When the source is stationary, then the number of waves received by the observer per sec. is n. As v is the velocity of sound wave, the actual wavelength λ is

$$\lambda = \frac{v}{n}$$

When the source moves towards observer, the first vibration is emitted at its first position which has reached a distance v in one second while the n^{th} vibration is emitted at a distance v_s, because in one second, the observer has also moved a distance v_s. in this way all the n^{th} vibrations are now confined in a distance $v - v_s$ as shown in the figure.

The apparent wavelength is given by

$$\lambda_1 = \frac{v - v_s}{n}$$

The apparent frequency is given by,

$$n_1 = \frac{v}{\lambda_1} = \frac{v}{\frac{(v - v_s)}{n}}$$

$$= \frac{vn}{v - v_s}$$

Since the denominator is less than the numerator, the new frequency n_1 is greater than the original frequency n.

If the source is moving away from the observer, the apparent wavelength λ'_1 is given by

$$\lambda'_1 = \frac{v + v_s}{n}$$

The apparent frequency is given by,

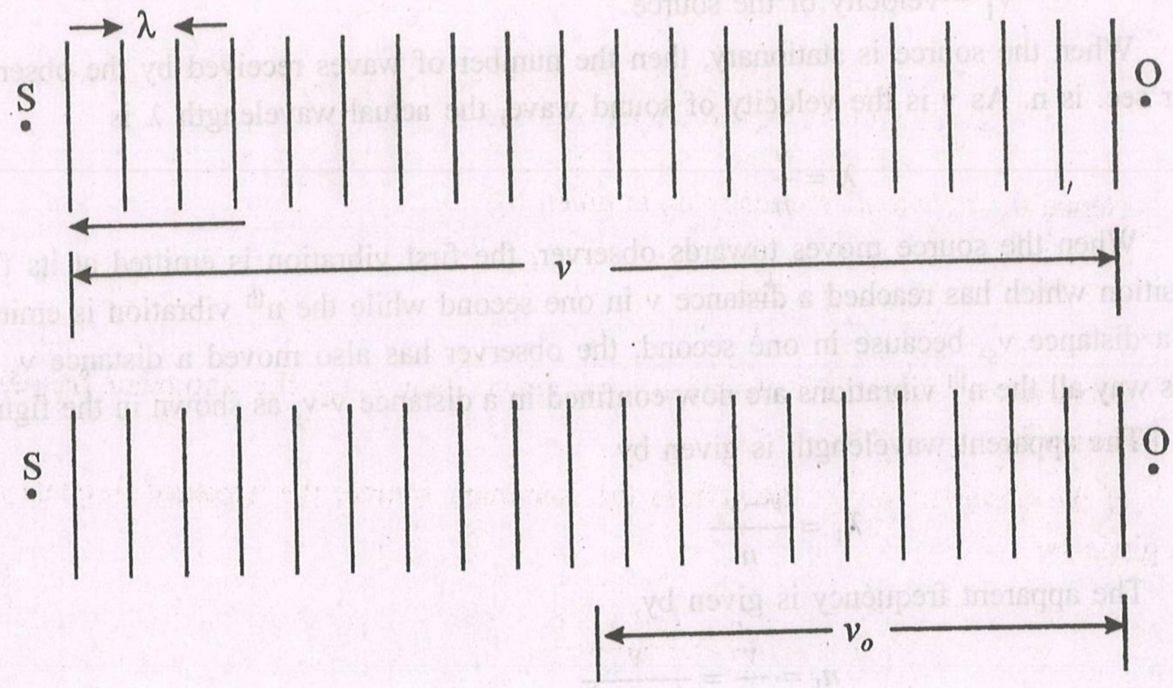
$$n_1 = \frac{v}{\lambda_1} = \frac{v}{\frac{(v + v_s)}{n}}$$

$$= \frac{vn}{v + v_s}$$

This equation shows that $n_1 < n$ i.e. the apparent frequency is decreased.

(2) Observer in motion, source at rest :

Let S and O are the relative positions of sound and observer in the beginning as shown in the figure.



Let,

v = velocity of sound

n = true frequency of source

v_o = velocity of the observer

As v is the velocity of sound wave hence the actual wavelength λ is

$$\lambda = \frac{V}{n}$$

∴ Number of additional waves = $\frac{v_o n}{v}$

∴ Total number of vibrations received = $n + \frac{v_o n}{v}$

Hence the apparent frequency n_2 is given by

$$n_2 = n + \frac{v_o n}{v}$$

From above equation it clear that n_2 is greater than n i.e. **the apparent frequency is increased.**

If the observer moves away from the stationary source, the apparent frequency n_2' is given by

$$n_2 = n - \frac{v_o n}{v} = \frac{(v - v_o)\, n}{v}$$

(3) Source and observer both in motion :

When observer is at rest and source is moving towards observer, the apparent frequency n_1 is given by

$$n_1 = \frac{vn}{v - v_s} \quad \dots \dots \dots (1)$$

Where, v = velocity of sound

v_s = the velocity of source and

n = the actual frequency of sound.

When the observer is also moving away from the source with velocity v_o, then apparent frequency is given by

$$n_3 = n_1 \frac{(v - v_o)}{v} \quad \dots \dots \dots (2)$$

Substituting the value of n_1 we have

$$n_3 = \frac{v_n}{(v - v_s)} \cdot \frac{(v - v_o)}{v}$$

$$n_3 = \frac{(v - v_o)\, n}{v - v_s} \quad \dots \dots \dots (3)$$

If the observer is moving towards the source

$$n_3' = n_1 \frac{(v + v_o)}{v}$$

Substituting the value of n_1 we have

$$n_3' = \frac{v_n}{(v - v_s)} \cdot \frac{(v + v_o)}{v}$$

$$n_3 = \frac{(v + v_o)\, n}{(v - v_s)} \quad \dots \dots \dots (4)$$

The above equation shows that the **apparent frequency will increase.**

Effect of wind :

If the wind blows with velocity w in the direction of sound, then the sound wave covers a distance (v + w) instead of v in one second. If wind blows in the opposite direction of sound then the sound wave covers a distance (v – w) instead of v in one second.

Using equations of the apparent frequency when source and observer both are moving the effect of wind can be estimated. Consider,

(1) When observer is moving away form the source and wind blows in the direction of sound

$$n_4 = \frac{(v + w - v_o)\, n}{(v + w - v_s)}$$

(2) When observer is moving away from the source and wind blows in the opposite direction of sound

$$n_4' = \frac{(v - w - v_o)\, n}{(v - w - v_s)}$$

(3) When observer is moving towards the source and wind blows in the direction of sound

$$n_5 = \frac{(v+w+v_o)\,n}{(v+w-v_s)}$$

(4) When observer is moving towards the source and wind blows in the opposite direction of sound

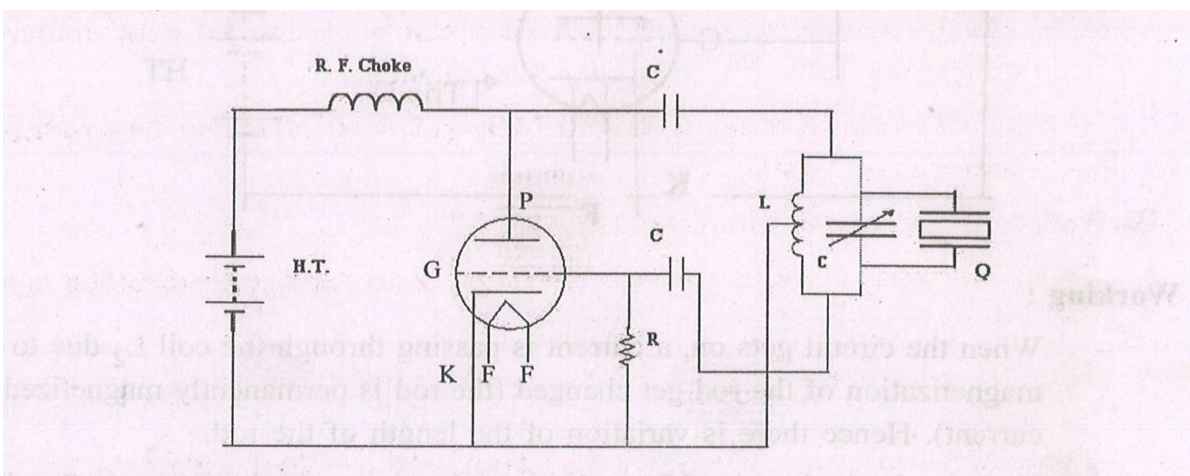
$$n_5 = \frac{(v-w-v_o)\,n}{(v-w-v_s)}$$

- **Explain piezo electric effect discuss the piezo electric method of production of ultrasonic waves with the help of necessary fig ure and equation**

Principle: - When certain crystals like quartz, Rochelle, salt, tourmaline etc are stretched or compressed along certain axis an electric potential difference is produced along a perpendicular axis. The converse of this effect is also true i.e. when an alternating potential difference is applied along electric axis the crytal is set into elastic vibration along mechanical axis this effect is known as Piezo-electric effect.

Construction:-

Above Fig shows experimental arrangement of Piezo-electirc oscillator



It consists circuit in the above oscillator circuit consists of parallel combination of centrally trapped inductor L1 and variable capacitor C1

A Quartz crystals Q is connected in parallel to the variable capacitor C1

One end of the tank circuit is connected to the grid circuit of the triode through grid capacitor Cg

Other end of the tank circuit is connected to the [plate circuit of the triode through the blocking capacitor Cb

The positive of high supply is connected to the help of through RF choke whole the negative terminal of HT is connected to the cathode

Working :-

Grid resistor Cg and Rg provides proper biasing to the grid circuit

HI dc voltage is applied to the plate P through the RF chaike which prevents high frequency current to reach the HT battery

The blocking capacitor Cb is used to block dc current and to pass only high frequency current

The frequency of the Hartley oscillator is set to the natural frequency of the quartz crystal Q with help of the variable capacitor C1

Hence resonance is achieved and crystal is set into mechanical vibration with the maximum amplitude

The ultrasonic wave up to 500kw can be produced with moderate size quartz crystal using above arrangement

The ultrasonic wave up to 150Mh can be produced with tourmaline crystal

When resonance is set up the velocity of quartz crystal along X-direction is given by

$$V=\sqrt{\frac{Y}{\rho}}$$

$$Y = 7.9 \times 10^{10} M/m^2$$

$$\rho = 2650\ kg/m3$$

$$V = \sqrt{\frac{7.9 \times 1010}{2650}} = 5450\ m/s$$

Thickness of quartz U = n > =n(2t)

Where n is the frequency

$$n = \frac{V}{2t} = \frac{5450}{2t} = \frac{2725}{t}\ H$$

If t is expressed in mm

$$n = \frac{V}{2t} = \frac{5450}{2t} = 2725000\ H$$

$$n = \frac{1}{2\pi\sqrt{4c1}}$$ Frequency of quartz crystals.

- **Discuss the different methods of detection of ultrasonic waves**

1. Piezo- electric detector:-

The quartz crystals can also be used for the detection of ultrasonic sound one pair of faces of quartz crystal is subjected to ultrasonic sound.

On the other perpendicular faces electric charges are produced and hence we get current. The current is amplified and then frequency of current is determined which may be of the range of ultrasonic waves.

2. Kundt’s tube method:-

A Kundt’s tube is used for the measurement of the velocity of audible sound. In a same way it can be used for the measurement of velocities of ultrasonic waves having longer wavelength. The ultrasonic sound passed through the tube, lycopodium powder collects in the form of heaps at the nodal points and displaces from the antinodes so from the distance between the successive nodal points the velocity of ultrasound can be calculated.

3. Sensitive flame method:-

When a sensitive flame is moved in a medium where ultrasonic waves are present the flame remains stationary at antinodes and flickers at then nodes.

4. Thermal detector method:-

When ultrasonic waves pass through the medium the temp of the medium changes due to alternate compression and rarefactions. The temperature remains constant at antinodes and it changes at the nodal points when a fine platinum wire is moved in the medium the resistance of the platinum wire with respect to time can be detected by using a sensitive bridge method. The bridge remains in the balanced condition when the platinum wire is at antinodes.

- **Write a note on characteristic of musical sound**

Musical sounds are characteristic by the following factors:

1) Pitch

2) Loudness

3) Quality

1. Pitch / frequency;-

Pitch is a physiological quantity it is a sensation conveyed to our brain by the sound waves falling on the ears. It is a characteristic of sound waves which differentiates between shrill sound and grave sound. It directly depends upon frequency. Higher the frequency higher is the pitch.

Frequency of a note is a physical quantity which can be measured accurately while pitch is merely a mental sensation feeling by an observer.

2. Loudness;-

Loudness of the sound is defined as the degree of sensation on the ear

It is expressed in terms of intensity of sound through Weber and Fechner relation

$L = K \log I$
Where
L= loudness
K = Constant
I = intensity of sound

Here intensity of sound is the amount of energy of sound wave crossing per unit time a unit cross section area which is perpendicular to the direction of propagation of sound wave.

3. Quality:-

This characteristic of sound enables one to distinguish between the same notes produced by different musical instruments or voices even thought they have the same pitch and loudness

If a same note is produced by a violin and a piano by two musician one will definitely feel some difference between them due to difference in their quality

Quality of sound produced by any two instruments producing the same note is different due to associated harmonics with fundamental frequency. These associated harmonics are the characteristics of a musical instrument.