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SFI GEC PALAKKAD

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

First Semester B.Tech Degree Regular and Supplementary Examination December 2020 (2019 Scheme)

Course Code: PHT100
Course Name: ENGINEERING PHYSICS A
(2019 Scheme)

Max. Marks: 100 Duration: 3 Hours

PART A

Answer all questions, each carries 3 marks. Marks

1	What is amplitude resonance? Give two examples.	(3)
2	What is the relation between path difference and phase difference in wave motion?	(3)
3	Newton's rings are circular but air wedge fringes are straight. Why?	(3)
4	Give 3 differences between Fresnel and Fraunhofer classes of diffraction.	(3)
5	What is meant by quantum mechanical tunnelling? Name two electronic devices based on this phenomenon.	(3)
6	Explain the concept of quantum confinement.	(3)
7	Define magnetic flux density and magnetic field intensity. Give the relation between them.	(3)
8	Compare displacement current and conduction current.	(3)
9	Give a qualitative account of BCS theory.	(3)
10	Explain the working of a Photo diode.	(3)

PART B

Answer one full question from each module, each question carries 14 marks

Module-I

11	a)	Frame the differential equation of a damped harmonic oscillator and deduce its solution. Compare the time-displacement curve in three cases.	(10)
	b)	The frequency of a tuning fork is **200Hz**. If its quality factor is **8×10^4**, find the time after which its energy becomes **$1/10^{th}$** of its initial value.	(4)
12	a)	Derive the differential equation for transverse wave in a stretched string and hence obtain the expression for fundamental frequency.	(10)
	b)	Calculate the fundamental frequency of a string of **1 m** long & mass **2g** when stretched by a weight of **4 kg**.	(4)

Module-II

13 a) Derive Cosine law and obtain the conditions of brightness and darkness for a thin film in reflected system. (10)

b) In Newton's ring arrangement using a light of wavelength **546nm**, the radius of the n^{th} and $(n+20)^{th}$ dark rings are found to be **0.162cm** and **0.368cm** respectively. Calculate the radius of curvature of the lens. (4)

14 a) State Rayleigh's criterion for spectral resolution. With necessary theory explain the diffraction due to a plane transmission grating. (10)

b) How many lines per meter are there in a plane diffraction grating which gives an angle of diffraction **30°** in the second order for light of wavelength **520nm** incident normally on it? (4)

Module-III

15 a) Starting from the wave equation derive Schrodinger's time dependent equation and hence deduce Schrodinger's time independent equation. (10)

b) Compute the de Broglie wavelength of an electron whose kinetic energy is **15eV**. (4)

16 a) Explain the optical, electrical and mechanical properties of nanomaterials. Give two medical applications of nanotechnology. (10)

b) Explain surface to volume ratio of nanomaterials. (4)

Module-IV

17 a) Distinguish between paramagnetic and ferromagnetic substances with two examples for each. (10)

b) Calculate the magnetic susceptibility of a paramagnetic substance at **600 K**, if its susceptibility at **200 K** is $\mathbf{3.756 \times 10^{-4}}$. (4)

18 a) Starting from Maxwell's equations show that velocity of electromagnetic waves in free space is $\mathbf{1/(\mu_0 \varepsilon_0)^{1/2}}$. (10)

b) State Gauss' divergence theorem and Stokes' theorem. (4)

Module-V

19 a) Expalin Meissner effect and show that superconductors are perfect diamagnets. Distinguish between Type I and Type II superconductors with appropriate graphs. (10)

b) Explain high temperature superconductors with two examples. (4)

20 a) Define numerical aperture and acceptance angle of an optical fibre and derive the expression for numerical aperture of a step index fibre with a neat diagram. (10)

b) Calculate the numerical aperture and acceptance angle of an optical fibre with a core of refractive index **1.62** and a cladding of refractive index **1.52.** (4)

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ENGINEERING PHYSICS A

PART - A

1) Amplitude Resonance is the phenomenon in which the amplitude of a forced harmonic oscillator becomes maximum at a particular driving frequency, which is very close to the natural frequency. The frequency of the driving force at which resonance occurs is known as resonant frequency (PR).

Amplitude $A = \dfrac{f_0}{\sqrt{(\omega_0^2 - p^2)^2 - 4k^2p^2}}$ — ①

when value of $A = A_{max}$ value of denominator is minimum.

i.e. $\dfrac{d}{dp}\left[(\omega_0^2 - p^2)^2 + 4k^2p^2\right] = 0$

$-2(\omega_0^2 - p^2) \times 2p + 8k^2p^2 = 0$

$-(\omega_0^2 - p^2) + 2k^2 = 0$

$p^2 = \omega_0^2 - 2k^2$

$p = \sqrt{\omega_0^2 - 2k^2}$

$\therefore\ A = A_{max}$

when $p = p_R = \sqrt{\omega_0^2 - 2k^2}$

$p_R = \sqrt{\omega_0^2 - 2k^2}$

then eq ① becomes.

$$A_{max} = \frac{f_0}{\sqrt{(\omega_0^2 - p_R^2)^2 + 4k^2p_R^2}}$$

$$= \frac{f_0}{\sqrt{(2k^2)^2 + 4k^2p_R^2}}$$

$$= \frac{f_0}{\sqrt{4k^4 + 4k^2p_R^2}}$$

$$= \frac{f_0}{2k\sqrt{k^2 + p_R^2}}$$

examples:

a) A tuned circuit in a radio or television receiver responds strongly to waves having frequencies near its resonant frequency and this fact is used to select a particular station and reject other.

b) A vibrating rattle in a car that occurs only at a particular engine speed or wheel rotation speed.

2) Path difference and phase difference are the terms used to express the difference in state of vibration of two particles in the medium. If the difference in state is expressed in terms of angle, it is called path difference. Difference in state expressed in terms of distance is called path difference.

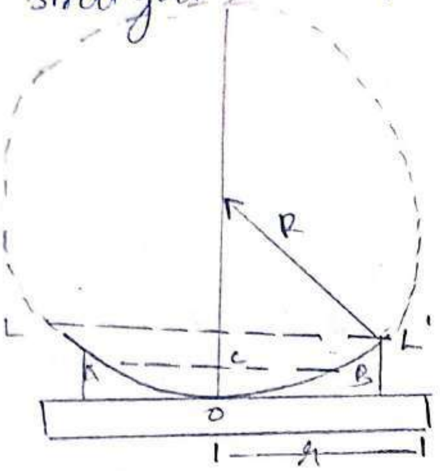
λ path length is equivalent to 2π phase.
So $\frac{2\pi}{\lambda}$ phase difference corresponds to unit path difference and is known as phase shift constant K.

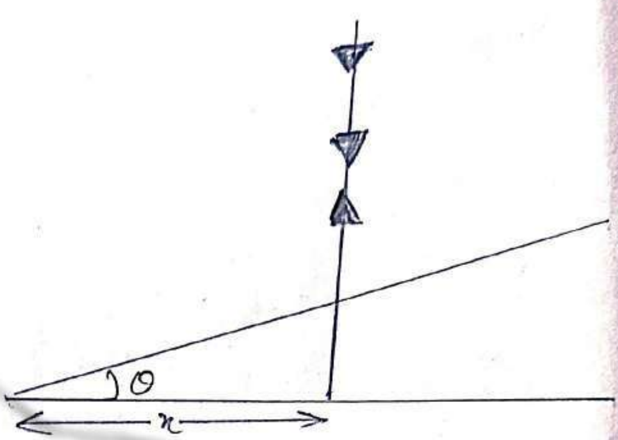
So path difference corresponding to 'x' path difference is

$$\phi = \frac{2\pi x}{\lambda}$$

3) When light from a monochromatic source is rendered parallel by a lens and then is made to fall on a glass plate inclined at an angle of 45° to the incident beam. The beam is reflected normally on to a plano-convex lens placed on a plane glass plate. Light rays reflected from the top and bottom surface of the air film interfere. Circular dark and bright fringes can be observed by looking through a travelling microscope focused on to the system. The locus of points having the same thickness of the air film falls on a circle. Therefore fringes take the form of concentric rings.

When film is illuminated by monochromatic light, interference occurs between the rays reflected from the top and bottom surface of the film. Alternate dark and bright bands are observed. The change from maximum intensity to minimum intensity in the interference pattern is due to the change in the thickness of the film. Since the locus of all points having same thickness of the film being a straight line, we get straight line fringes.





4) Fresnel diffraction:-
→ either the source of light or the screen on which the pattern is obtained or both are at finite distances from the aperture causing diffraction.
→ wavefronts that fall on the diffracting aperture and that leave it to illuminate any point P of the screen are not planes; the correspondings rays are not parallel.
→ The convex lens are not required to converge the spherical wavefronts.

Fraunhofer diffraction:-
→ If source of light and screen are at infinite distance from the aperture causing diffraction.
→ wavefronts arriving at any point P on the distant screen are plane and the corresponding rays are also parallel.
→ wavefronts are converged by means of a convex lens to produce a diffraction pattern.

5) According to classical mechanics, when a particle of kinetic energy E approaches a potential barrier V, (E<V) it bounces off without entering the otherside. But in

quantum mechanics the wave function representing the particle wave does not vanish on the other side of the barrier. This shows a finite probability of the particle penetrating the barrier. The phenomenon of penetration of particles through barrier higher than their own incident energy is known as tunnelling.

This effect is made use of in the operation of tunnel diode and electron emission through thin insulating films.

6) Quantum confinement is the restricted motion of randomly moving electron in specific energy levels, when the dimensions of a material approaches the de-broglie wavelength of electron. when this occurs the properties changes significantly because energy levels become discrete and motion of electrons become restricted. Based on the number of dimensions that are confined nanostructures are classified as quantum well, quantum wire and quantum dots.

7) Magnetic flux intensity (Magnetic induction) at a point is defined as the flux passing through unit area around the point. Its unit is Wb/m^2 or T.

The strength of the magnetic field can also be expressed by another vector quantity, called the magnetic field strength or magnetizing field (H). It represents the magnetic field produced by the external current and does not incorporate the response of the medium to this field. Its S.I unit is A/m.

$H = \frac{B}{\mu_m}$ $\quad \mu_m \rightarrow$ absolute permeability of medium.

$H = \frac{B}{\mu_0} - M \quad \Rightarrow B = \mu_0(H+M)$

$\mu_0 = 4\pi \times 10^{-7}$ H/m.

8) Conduction current:-

→ It is the current due to drift of electric charges under the influence of an electric field in a conductor and it obey's ohm's law

→ Conduction current density is represented by

$$J_c = \frac{I_c}{A} = \sigma E$$

→ In empty space conduction current is zero

→ It is the actual current.

Displacement current:-

→ The current which is set up in the dielectric medium due to the variation of induced displacement charge produced by the varying electric field applied across the dielectric

→ Displacement current density is represented by

$$J_d = \frac{\varepsilon_0 dE}{dt}$$

→ Displacement current is responsible for the production of magnetic field in empty space

→ It is the apparent ~~pro~~ current produced by time varying electric field.

9) To explain superconductivity, a theory developed by Bardeen, cooper and schrieffer. It is based on formation of copper pair of electrons.

Consider an electron moving through the lattice. The positive ions are attracted to this electron due to coulomb attraction. As a result the positive ions get displaced from their mean position. This interaction is called electron-phonon interaction. Now the region of increased charge density attracts another electron and it also experiences a coulomb attractive force. we can consider the process as interaction of two electrons through lattice. Because of this interactions an apparent force of attraction develops between the electrons and they tend to move in pairs called cooper pairs.

Thus cooper pair is defined as a pair of electrons formed by the interaction between electrons with opposite spin and momenta in a phonon field.

At normal temperatures the attractive force is too small and pairing of electrons doesn't takes place. But, below the transition temperature (T_c) the force of attraction between electrons reaches maximum for any two electrons of equal and opposite spin.

- Spin of a cooper pair is zero. so it is a boson (single electron is a fermion).
- The dense cloud of copper pairs move together in the same direction. As a result the substance posses infinite electrical conductivity i.e. zero resistivity.
- Due to the very low pairing energy of the cooper pair a small rise in temperature can destroy the copper pair. As a result of this material changes to normal state since motion of normal electron leads to resistance.

10) Junction photodiode is connected in a circuit in reverse biased condition. If the reverse biased voltage is very low, a constant current flows through the diode. This current is called reverse saturation current, which flows due to thermally generated minority carriers namely electrons in the P type and holes in the N type that are attracted towards the junction. The motion of minority carriers form a current known as leakage current. It depends on the reverse biased voltage, ambient temperature and series resistance in the circuit. It does not allow majority carriers to cross the junction.

When a photon is absorbed from the incident light by the P or N region, an electron is released from the valence band and it goes to the conduction band. This create a hole in the valence band. Thus the incident light causes the creation of a large number of electron hole pairs. These electron hole pairs are called photo carriers and produce a current known as photocurrent in the external circuit in addition to leakage current. The leakage current should be minimised to increase the sensitivity of the device. Width of the depletion region should be increased to absorb a large quantity of light. The resulting o/p current or voltage can be measured.

PART-B

Module I

11. a) Consider a particle of mass 'm' executing ~~[illegible]~~ oscillation.

In Damped Harmonic Oscillations.

$$F_{applied} = F_{restoring} + F_{Damping}.$$

$$\frac{md^2x}{dt^2} = -Kx - \frac{bdx}{dt} \quad \left(\frac{dx}{dt} = v\right)$$

$$\frac{md^2x}{dt^2} + \frac{bdx}{dt} + Kx = 0$$

$$\frac{d^2x}{dt^2} + \frac{b}{m}\frac{dx}{dt} + \frac{K}{m}x = 0$$

$$\frac{d^2x}{dt^2} + 2\gamma\frac{dx}{dt} + \omega_0^2 x = 0$$

$$\left[\begin{array}{l} \frac{b}{m} = 2\gamma \\ \sqrt{\frac{K}{m}} = \omega_0 \end{array}\right]$$

Solution:

Let $x = Ae^{\alpha t}$

then $\frac{dx}{dt} = \alpha A e^{\alpha t}$

$$\frac{d^2x}{dt^2} = \alpha^2 A e^{\alpha t}$$

$$\frac{d^2x}{dt^2} + 2v\frac{dx}{dt} + \omega_0^2 x = 0$$

$$\alpha^2 A e^{\alpha t} + 2v\alpha A e^{\alpha t} + \omega_0^2 A e^{\alpha t} = 0$$

$$(\alpha^2 + 2v\alpha + \omega_0^2) A e^{\alpha t} = 0$$

i.e. $\alpha^2 + 2v\alpha + \omega_0^2 = 0$

$$\alpha = \frac{-2v \pm \sqrt{4v^2 - 4\omega_0^2}}{2}$$

$$\therefore \alpha_1 = -v + \sqrt{v^2 - \omega_0^2}$$

and $\alpha_2 = -K - \sqrt{v^2 - \omega_0^2}$

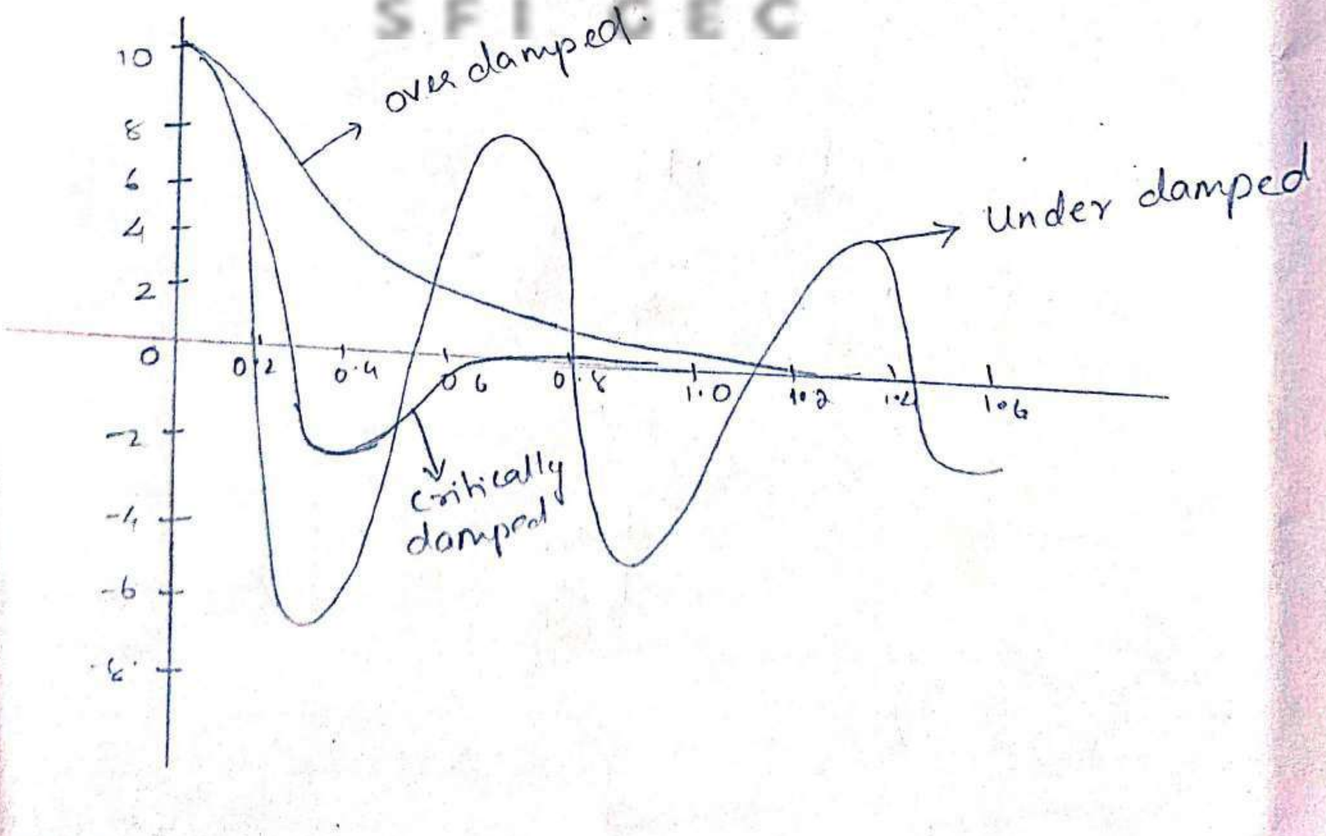
Hence general solution is

$$x = A_1 e^{\alpha_1 t} + A_2 e^{\alpha_2 t}$$

$$x = A_1 e^{(-K + \sqrt{K^2 - \omega_0^2})t} + A_2 e^{(-K - \sqrt{K^2 - \omega_0^2})t}$$

$$= e^{-Kt}\left[A_1 e^{(\sqrt{K^2 - \omega_0^2})t} + A_2 e^{-(\sqrt{K^2 - \omega_0^2})t}\right]$$

where A_1 & A_2 are constants, whose values depends on the initial conditions of motion.



b) $E \propto e^{-\frac{1}{Q}\omega t}$

$\omega = 2\pi \times 200$
$= 400\pi$

$\frac{E_{final}}{E_{initial}} = \frac{1}{10}$

$\frac{e^{-\frac{1}{Q}\omega t_2}}{e^{-1/Q\,\omega t_1}} = \frac{1}{10}$

$e^{-\frac{1}{Q}\omega(t_2 - t_1)} = \frac{1}{10}$

$e^{-1/Q\,\omega\Delta t} = \frac{1}{10}$

$\frac{1}{Q}\omega\Delta t = \ln 10$

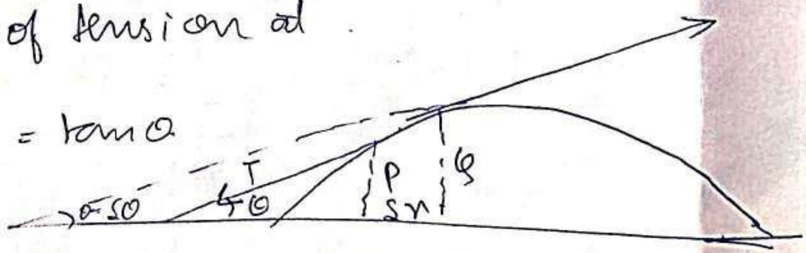
$\Delta t = \frac{Q \times \ln 10}{\omega}$

$= \frac{8 \times 10^4 \times 2.3}{400\pi}$

$\simeq \underline{146.42 \text{ sec}}$

12. Consider a string of length l, stretched between two points by a tension.

downward component of tension at
$P = T\sin\theta$



$\sin\theta$ is small, $\sin\theta = \tan\theta$
$\simeq T\tan\theta$.

$\tan\theta = \frac{dy}{dx}$.

$\therefore P = T\frac{dy}{dx}$

rate of change of slope w.r.t length of the element.

$= \frac{d}{dx}\left(\frac{dy}{dx}\right) = \frac{d^2y}{dx^2}$

$\therefore$ change in slope for a distance δx is

$= \frac{d^2y}{dx^2}\delta x$

slope at point φ, $\tan(\theta - \delta\theta) = \frac{dy}{dx} - \frac{d^2y}{dx^2}\delta x$.

upward component of tension at φ

$$= T\sin(\theta - \delta\theta)$$

$$= T\tan(\theta - \delta\theta)$$

$$= T\left(\frac{dy}{dx} - \frac{d^2y}{dx^2}\delta x\right)$$

$\therefore$ The resultant downward tension

$$F = T\frac{dy}{dx} - T\left[\frac{dy}{dx} - \frac{d^2y}{dx^2}\delta x\right]$$

$$= T\frac{d^2y}{dx^2}\cdot\delta x$$

Let 'm' be mass per unit length of string.

Mass of element $= m\delta x$.

Force acting on element = mass $\times$ acceleration

ie, $F = (m\delta x)\frac{d^2y}{dt^2}$

$$m\delta x\frac{d^2y}{dt^2} = T\frac{d^2y}{dx^2}\delta x$$

$$\therefore \frac{d^2y}{dx^2} = \frac{T}{m}\frac{d^2y}{dx^2}$$

$$\boxed{\frac{d^2\psi}{dt^2} = v^2\frac{d^2\psi}{dx^2}} \rightarrow \text{1-D wave equations.}$$

comparing two equations.

$$v = \sqrt{\frac{T}{m}}$$

$v \rightarrow$ velocity of propagation of wave.

If ν is the fundamental frequency of vibration of string.

$$v = \nu\lambda$$

$$\therefore \nu = \frac{1}{\lambda}\sqrt{\frac{T}{m}}.$$

when $l = \frac{\lambda}{2}$ $\lambda = 2l$.

$$\therefore \nu = \frac{1}{2l}\sqrt{\frac{T}{m}}$$

$AN = 2\mu t \tan r \sin r$.

$$\Delta = \frac{2\mu t}{\cos r} - 2\mu t \tan r \sin r$$

$$= \frac{2\mu t}{\cos r} - \frac{2\mu t \sin^2 r}{\cos r}$$

$$= \frac{2\mu t}{\cos r}(1-\sin^2 r) = \frac{2\mu t \cos^2 r}{\cos r}$$

$$\Delta = 2\mu t \cos r \rightarrow \text{cosine law.}$$

whenever light is reflected from an interface beyond which the medium has a higher R.I, the reflected wave undergoes a phase change of π. ($\lambda/2$)

Effective path difference

$$= \mu(AE+EB) - (AN + \frac{\lambda}{2})$$

$$= \mu(AE+EB) - AN - \frac{\lambda}{2}$$

$$= 2\mu t \cos r - \frac{\lambda}{2}$$

Film will appear bright when

$$2\mu t \cos r - \frac{\lambda}{2} = n\lambda$$

ie. $2\mu t \cos r = n\lambda + \frac{\lambda}{2}$

$$= (2n+1)\frac{\lambda}{2}$$

where $n = 0, 1, 2, 3 \ldots$

The film will appear dark when

$$2\mu t \cos r - \frac{\lambda}{2} = (2n+1)\frac{\lambda}{2}$$

$$2\mu t \cos r = (n+1)\frac{\lambda}{2}$$

$n = 0, 1, 2, 3 \ldots$

b) $\lambda = 546\text{nm}$

$$r = \sqrt{\frac{(2n+1)R\lambda}{2}}$$

$$n = \frac{r^2}{R\lambda} - \frac{1}{2}$$

$$n+20 = \frac{r^2}{R\lambda} - \frac{1}{2}$$

b) length - 1m

mass = 2g = 2×10^{-3} kg

Tension = $4 \times 10 = 40$ N.
= mg

fundamental frequency = $\frac{1}{2l}\sqrt{\frac{T}{M}}$

$$= \frac{1}{2 \times 1}\sqrt{\frac{40}{2 \times 10^{-3}}}$$

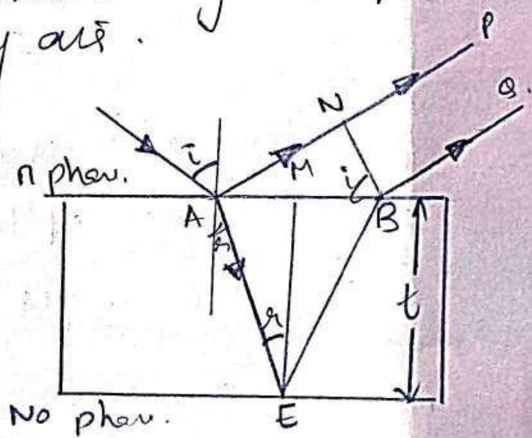
$$= \frac{1}{2}\sqrt{20 \times 10^{3}}$$

$$= \frac{1}{2} \times 141.42$$

$$= \underline{70.71 \text{ hz}}$$

Module II

13) a) Consider a thin transparent film of thickness t and refractive index μ bounded by two plane parallel surface surrounded by air.



path difference = $\mu(AE + EB) - AN$
(Δ)

($AE = EB$, $AE + EB = 2AE$)

$$\Delta = 2\mu AE - AN$$

In Δ^{le} AEM $t = AE\cos r$ or $AE = \frac{t}{\cos r}$

In Δ^{le} ANB $AN = AB\sin i$
($AM = MB$, $AB = 2AM$)

$AN = 2AM\sin i$

In Δ^{le} AEM, $AM = t\tan r$.

$\therefore AN = 2t \times \tan r \times \sin i$

$\mu = \frac{\sin i}{\sin r}$ (from snell's laws)

$\therefore \sin i = \mu \sin r$

$$R = \frac{r_{20}^2 - r_1^2}{20\lambda} = \frac{(0.368)^2 - (0.162)^2}{20 \times 546 \times 10^{-7} cm}$$

$$= \underline{\underline{100 cm}}$$

14) When two objects or their images are very close together, they may appear as one, and it may be impossible for the eye to see them as separate. In those cases we use an optical instrument such as lens, microscope etc. The process of separating such images is called resolution. The ability of an instrument to produce separate images of two objects very close together is called its resolving power.

To measure the resolving power of an optical instrument, Lord Rayleigh suggested that two sources or their images should be regarded as separate if the central maximum of one pattern falls over the first minimum of the other. This is equivalent to the condition that the distance between the centres of the patterns should be equal to the radius of the Airy's disc or the radius of the first dark ring. This condition is called Rayleighs criterion or Rayleigh's limit of resolution.

Let λ and $\lambda + d\lambda$ be just resolved if following equations are satisfied.

$$(a+b)\sin\theta = n(\lambda + d\lambda) \quad : \text{principal maximum}$$

$$(a+b)\sin\theta = n\lambda + \frac{\lambda}{N'} \quad : \text{secondary maximum}$$

$$n\lambda + nd\lambda = n\lambda + \frac{\lambda}{N'}$$

$$nd\lambda = \frac{\lambda}{N'}$$

$$R = \frac{\lambda}{d\lambda} = \underline{\underline{nN'}}$$

A ~~plane transmission~~ diffraction grating consists of a very large number of extremely narrow parallel slits separated by equal opaque spaces.

A plane transmission grating is one made by ruling fine lines at equal distances on an optically plane glass plate with a diamond point.

~~Theory~~:
Consider the case of plane transmission grating XY placed with its slits parallel each other and perpendicular to plane of paper. Let 'a' be width of each slit and 'b' width of each opaque portion. a+b is grating element
path difference b/w wavelets originating from

A at C is $AK = (a+b)\sin\theta$

If $(a+b)\sin\theta = n\lambda$, $n = 1, 2, 3 \ldots$

These wavelets reinforce.

Let N be number of lines in one meter of grating

$$N(a+b) = 1$$

$$a+b = \frac{1}{N}$$

$$\frac{1}{N}\sin\theta = n\lambda$$

$$\underline{\underline{\sin\theta = Nn\lambda}}$$

b)

$\theta = 30^\circ$ $\sin 30^\circ = \frac{1}{2}$

$n = 2$

$\lambda = 520\,nm$

$= 520 \times 10^{-9}\,m.$

$$\sin\theta = Nn\lambda$$

$$\frac{1}{2} = N \times 2 \times 520 \times 10^{-9}$$

$$N = \frac{1}{4 \times 520 \times 10^{-9}}$$

$$= 0.0004807 \times 10^{9}$$

$$= \underline{\underline{4.807 \times 10^{5}}}\ \text{lines per m}.$$

15) a). Assuming the simplest wave equation;

$$\psi = A e^{i(kx-\omega t)} \quad \text{——— (1)}$$

$$\psi = A e^{\frac{i}{\hbar}(\hbar kx - \hbar\omega t)}$$

$$\psi = A e^{\frac{i}{\hbar}(px - Et)} \quad \text{——— (2).}$$

$\hbar k = \frac{h}{2\pi} \times \frac{2\pi}{\lambda} = \frac{h}{\lambda} = p$

$\hbar \omega = \frac{h}{2\pi} \times 2\pi\nu = E$

Differentiating eqn. (2) w.r.t x.

$$\Rightarrow \frac{\partial \psi}{\partial x} = \frac{i}{\hbar} p \, A e^{\frac{i}{\hbar}(px - Et)} \quad \text{——— (3)}$$

$$\frac{\partial \psi}{\partial x} = \frac{i}{\hbar} p \psi$$

$$\frac{\hbar}{i} \frac{\partial \psi}{\partial x} = p\psi \quad \text{——— (x).}$$

Differentiating (3) w.r.t x

$$\Rightarrow \frac{\partial^2 \psi}{\partial x^2} = \left(\frac{i}{\hbar} p\right)^2 A e^{\frac{i}{\hbar}(px - Et)}$$

$$= \frac{\cancel{i^2}^{\,-1}}{\hbar^2} p^2 \psi \quad (\because i^2 = -1)$$

$$\Rightarrow -\hbar^2 \frac{\partial^2 \psi}{\partial x^2} = p^2 \psi$$

$\therefore$ Throughout by $2m$

$$\Rightarrow -\frac{\hbar^2}{2m} \frac{\partial^2 \psi}{\partial x^2} = \frac{p^2}{2m} \psi$$

$$\Rightarrow -\frac{\hbar^2}{2m} \frac{\partial^2 \psi}{\partial x^2} = K\psi \quad \text{——— (4)}$$

Diff. Eqn ② w.r.t t

$$\Rightarrow \frac{\partial \psi}{\partial t} = -E\frac{i}{\hbar} A e^{\frac{i}{\hbar}(px - Et)}$$

$$\Rightarrow -\frac{\hbar}{i}\frac{\partial \psi}{\partial t} = E\psi$$

$$\Rightarrow i\hbar\frac{\partial \psi}{\partial t} = E\psi \quad \text{——— ⑤}$$

For any conservative system;

$$E = K + U$$

$$\Rightarrow \psi E = \psi K + \psi U$$

$$\Rightarrow i\hbar\frac{\partial \psi}{\partial t} = -\frac{\hbar^2}{2m}\frac{\partial^2 \psi}{\partial x^2} + \psi V.$$

1 dimensional Time Dependent Schrodinger Eqn.

$$\Psi = Ae^{\frac{i}{\hbar}(px - Et)}$$

$$\Psi = Ae^{\frac{i}{\hbar}px} \cdot e^{-\frac{i}{\hbar}Et}$$

$$\Psi = \psi_{(x)} \cdot e^{-\frac{i}{\hbar}Et}$$

$$\therefore i\hbar\frac{\partial}{\partial t}\left(\psi e^{-\frac{i}{\hbar}Et}\right) = -\frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2}\left(\psi e^{-\frac{i}{\hbar}Et}\right) + U_{(x)}$$

$$i\hbar\frac{\partial}{\partial t}\left(e^{-\frac{i}{\hbar}Et}\right)\psi = -\frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2}(\psi)\left[e^{-\frac{i}{\hbar}Et}\right] + U(\psi)$$

$$\Rightarrow \frac{i}{\cancel{\hbar}}E i\cancel{\hbar}\, \cancel{e^{-\frac{i}{\hbar}Et}}\psi = -\frac{\hbar^2}{2m}\frac{\partial^2 \psi}{\partial x^2}\cancel{e^{-\frac{i}{\hbar}Et}} + U\psi \cancel{e^{\frac{i}{\hbar}Et}}$$

$$\Rightarrow \boxed{E\psi = -\frac{\hbar^2}{2m}\frac{\partial^2 \psi}{\partial x^2} + U\psi}$$

$$E\psi = \left[U + -\frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2}\right]\psi$$

$$E\psi = H\psi$$

Hence deduced Time Independent Schrodinger Eqn. from Time Dependend Schrodinger Eqn.

b) $k = 15eV = 15 \times 1.6 \times 10^{-19} J$

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mk}} = \frac{6.67 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 15 \times 1.6 \times 10^{-19}}}$$

$$= \frac{6.67 \times 10^{-34}}{20.899 \times 10^{-25}}$$

$$= 0.319 \times 10^{-9} m$$

$$= \underline{319 \, nm}$$

16) (a) Optical Properties

→ The reduction of material dimension has pronounced effect on optical properties.

* Size dependence is due

i) Surface Plasmon Resonance (SPR)

ii) Quatum Size effects.

Mechanical Properties

* Mechanical properties Increase with decrease in size.

Mechanical properties improves with decrease in size

→ Strength of material improves with decrease

→ Hardness & yield strength improves with decrease in size.

→ Elastic Modulus and toughness also increases with decrease in size.

Electrical

* Unlike other materials, the conductivity of nanomaterials changes with change in dimensions like area or diameter.

Medicinal Applications

① Drug Delivery - Used in Cancer Therapy

② Apelled in Contact lenses, dental implants and artifical Values.

(b) Surface to Volume Ratio

For spherical nanoparticles;

$$\frac{S \cdot A}{Volume} = \frac{4\pi R^2}{\frac{4}{3}\pi R^3} = \frac{3}{R}$$

17) a) Paramagnetic

→ Those substances that are slightly attracted by the magnetic field

→ Doesn't retain magnetic property when the external field is removed.

→ Magnetic susceptibility is low are +ve

→ Examples → Chromium, Aluminium, Manganese.

Ferromagnetic

→ Those substances that are strongly attracted by magnetic field

→ Does retain the magnetic properties when the external magnetic field is removed

→ Magnetic susceptibility large and +ve

→ Examples → Fe, Co, Ni

b) $\chi_1 = ?$ $T_1 = 600\,K$

$\chi_2 = 3.756 \times 10^{-4}$ $T_2 = 200\,K$

$$\chi \propto \frac{1}{T}$$

$$\Rightarrow \frac{\chi_1}{\chi_2} = \frac{T_2}{T_1} \Rightarrow \chi_1 = \frac{T_2}{T_1} \times \chi_2$$

$$= \frac{\cancel{200}}{3\,\cancel{600}} \times 3.756 \times 10^{-4}$$

$$= \frac{3.756 \times 10^{-4}}{3}$$

$$= 1.252 \times 10^{-4}$$

18) In free space;

$D = \varepsilon_0 E$

$B = \mu_0 H$

Maxwell's Eqn. Becomes;

1. $\nabla \cdot E = 0$

2. $\nabla \cdot H = 0$

3. $\nabla \times E = -\mu_0 \dfrac{\partial H}{\partial t}$

4. $\nabla \times H = \varepsilon_0 \dfrac{\partial E}{\partial t}$.

$$\nabla \times \nabla \times A = \nabla(\nabla \cdot A) - \nabla^2 A \quad \text{——— (1)}$$

taking curl on either sides of Maxwell's 3rd Eqn;

$$\nabla \times \nabla \times E = -\mu_0 \left(\nabla \times \frac{\partial H}{\partial t}\right) \quad \text{——— (2)}$$

Comparing ~~Equating~~ (2) (1)

$$\Rightarrow +\mu_0 \left(\nabla \times \frac{\partial H}{\partial t}\right) = \cancel{\nabla(\nabla \cdot E)}^{\,0} + \nabla^2 E$$

$$\Rightarrow \nabla^2 E = \mu_0 \left(\nabla \times \frac{\partial H}{\partial t}\right)$$

$$\nabla^2 E = \mu_0 \varepsilon_0 \frac{\partial E}{\partial t} \qquad \left(\because \nabla \times \frac{\partial H}{\partial t} = \varepsilon_0 \frac{\partial E}{\partial t}\right)$$

taking curl on either sides of Maxwell's 4th eqn;

$$\nabla \times \nabla \times H = \varepsilon_0 \left(\nabla \times \frac{\partial E}{\partial t}\right) \quad \text{——— (3)}$$

Comparing (3), (1)

$$\Rightarrow \varepsilon_0 \left(\nabla \times \frac{\partial E}{\partial t}\right) = \nabla \times \nabla \times H.$$

$$\Rightarrow \cancel{\nabla(\nabla \cdot H)}^{\,0} - \nabla^2 H = \varepsilon_0 \left(\nabla \times \frac{\partial E}{\partial t}\right)$$

$$\Rightarrow +\nabla^2 H = +\varepsilon_0 \mu_0 \frac{\partial H}{\partial t} \qquad \left(\because \nabla \times \frac{\partial E}{\partial t} = \mu_0 \frac{\partial H}{\partial t}\right) \quad \text{——— (4)}$$

$\therefore$ from Eqn. of Wave Motion

$$\nabla^2 \psi = \frac{1}{V^2} \frac{\partial^2 \psi}{\partial t^2}$$

Comparing Eqn ③, ④

$$\Rightarrow \quad V = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$$

(b) Gauss Divergence Theorem;

$$\int_S A \cdot ds = \int_V \nabla \cdot A \, dV$$

Stokes Theorem

$$\int_l A \cdot dl = \int_S \nabla \times A \, ds.$$

19) (a) The phenomenon of complete expulsion of magnetic lines from a superconductor is termed as Meissner Effect.

→ When a specimen is kept in a magnetic field at Temperature $T > T_c$; magnetic field lines enter the specimen.

→ When the temperature is reduced to $T = T_c$; magnetic field lines suddenly gets expelled from thus reducing B to 0.

→ This reversible effect is called Meissner Effect

In normal state,

$$B = \mu_0 (H + M)$$

$$= \mu_0 H \left(1 + \frac{M}{H}\right)$$

$$B = \mu_0 H (1 + \chi)$$

In superconducting state; $B = 0$

$$\Rightarrow \quad 0 = \mu_0 H (1 + \chi)$$

$$\Rightarrow \quad 1 + \chi = 0$$

$$\Rightarrow \quad \underline{\underline{\chi = -1}}$$

⇒ Superconductors get magnetised in direction opposite to applied field. Thus they are perfectly diamagnetic

ⓑ High Temperature Super Conductors

→ Any material with a transition temperature $T_c > 24$ K is termed as High temp superconductor.

→ Example → Lanthanum Barium Cuprate
→ YBCO : Most commonly used high temp. superconductor

20) ⓐ Numeracial Appertune $NA = \sin\theta_a = nN\lambda$

n : Order of spectral lines

N : No. of lines per unit length of grating

λ : Wave length of light

θ_a : Acceptance Angle.

ⓑ
$$NA = \sqrt{n_1^2 - n_2^2}$$

$$= \sqrt{(1.62)^2 - (1.52)^2}$$

$$= \sqrt{0.314}$$

$$= \underline{\underline{0.560}}$$

$$\theta_a = \sin^{-1}(0.560)$$

$$= \underline{\underline{34^\circ}}$$