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APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER B.TECH DEGREE EXAMINATION(2019 SCHEME), DECEMBER 2019

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.

1	List any six points to compare electrical oscillator with a mechanical oscillator.	(3)
2	Distinguish between transverse and longitudinal waves. Give one example for each.	(3)
3	When a medium of $\mu \neq 1$ is introduced in the Newton's ring set up, what happens to the diameter of interference pattern? Explain it with the help of relevant equation.	(3)
4	Give 3 differences between interference and diffraction.	(3)
5	State Heisenberg's Uncertainty principle and write the three uncertainty relations .	(3)
6	Explain the optical properties of nanomaterials.	(3)
7	Distinguish between magnetic induction and magnetising field.	(3)
8	Derive the equation of continuity for time varying fields.	(3)
9	Show that superconductors are perfect diamagnets.	(3)
10	Distinguish between step index and graded index fibres.	(3)

PART B

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

Module-I

11	a)	Set up the differential equation for a forced harmonic oscillator and solve it.	(10)
	b)	A transverse wave on a stretched string is described by **y(x,t)=2sin(20t+0.021x+π/6)** where **x** and **y** are in cm and **t** is in second. Obtain (1)Amplitude (2)Initial phase (3)speed (4)frequency	(4)
12	a)	Derive an expression for the fundamental frequency of a transverse wave in a stretched string.	(10)
	b)	A sitar wire is under tension of **40 N** and length of the bridge is **80cm**. A **10m**	(4)

sample of that wire has mass **1.2g**. Find the speed and fundamental frequency of transverse wave on the wire.

Module-II

13 a) With necessary diagram, write the formation of interference pattern in an air wedge and derive an expression for the diameter of a thin wire. (10)

b) A monochromatic light of wavelength **5893 Å** is incident normally on a soap film of **μ = 1.42**. What is the least thickness of the film that will appear dark by reflection ? (4)

14 a) Derive the grating equation and describe an experiment to determine the wavelength of light. Define resolving power of a grating with expression. (10)

b) A grating has **6000 lines/cm**. Find angular separation between two wavelengths **577nm** and **579 nm** in the second order. (4)

Module-III

15 a) Derive an expression for energy eigen values and normalised wave function for a particle in a box of width L. (10)

b) Calculate the separation between the two lowest energy levels of an electron in a one dimensional box of width **4Å** in joules. Given **$m_e = 9.1 \times 10^{-31}$ kg; $h = 6.625 \times 10^{-34}$ Js** (4)

16 a) Write a note on quantum confinement and based on this explain nano sheets, nano wire and quantum dots. (10)

b) Mention any four applications of nanotechnology. (4)

Module-IV

17 a) State Gauss' law in magnetism, Ampere's circuital law, faraday's laws of electromagnetic induction and Lenz's law. Give their equations. (10)

b) A magnetising field of **1800 A/m** produces a magnetic flux of **3×10^{-5} Wb** in an iron bar of cross – sectional area **0.2 cm^2**. Calculate the permeability. (4)

18 a) Starting from Maxwell's equations derive the expression for the velocity of electromagnetic waves in vacuum. (10)

b) State and explain Poynting's theorem. (4)

Module-V

19 a) Explain the characteristics of Type I and Type II superconductors with appropriate diagrams and examples. (7)

b) Discuss BCS theory of superconductivity. Give any four applications of (7) superconductivity.

20 a) Explain construction and working of a solar cell and draw its I-V characteristics. Mention any two applications of solar cells. (10)

b) The numerical aperture of an optic fibre **is 0.295** and refractive index of core is **1.54**. Calculate refractive index of cladding and acceptance angle. (4)

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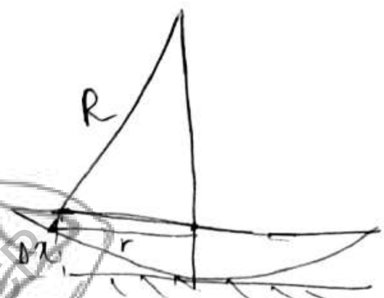
1 A)

PARAMETER	MECHANICAL OSCILLATOR	ELECTRICAL OSCILLATOR
Equation of Motion	$\frac{d^2y}{dt^2} + \frac{k}{m}y = 0$	$\frac{d^2q}{dt^2} + \frac{L}{C}q = 0$
Energy	Total mechanical Energy $\frac{1}{2}mx^2 + \frac{1}{2}kx^2 = E$	Total Electrical Energy $\frac{1}{2}Lq^2 + \frac{1}{2C}q^2 = E$
Solution	$y = r\sin(\omega t + \alpha)$ (or a cos)	$q = q_0 \sin(\omega t + \alpha)$ (or cos)
Inertia	Mass m	Inductance L
Elasticity	Stiffness k	$1/C$
What oscillates	Displacement (y) Velocity (dy/dt) Acceleration (d^2y/dt^2)	charge (q) Current (dq/dt), dI/dt
Driving Agent	Force	Induced voltage
Frequency	$\nu = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$	$\nu = \frac{1}{2\pi\sqrt{LC}}$

2 A)

LONGITUDINAL	TRANSVERSE
* The particles of medium vibrate in the same direction.	* The particles move $\perp^r$ to the direction of wave.
* They are possible in all kinds of media	* They are possible only in solids
* They consist of regions of compression and rarefraction	* They consist of crests and troughs
* Sound waves in air is an example of longitudial waves	* Vibrations in a string is an example.
* They cannot be polarised	* They can be polarised.

3 A) Newtons Rings



→ dark fringe

→ $\mu \times \Delta x = n\lambda$

$(R-\Delta x)^2 + r^2 = R^2$

$= r^2 + \Delta x^2 \approx r_n^2$

$r_n^2 \approx 2R\Delta x$

$r_n = \sqrt{\frac{2Rn\lambda}{\mu}}$ → radius of n^{th} fringe decreases a factor of $\underline{\sqrt{\mu}}$.

4 A)

INTERFERENCE	DIFFRACTION
* Due to the superimposition of two different wave trains coming from coherent sources	* Diffraction is due to the superposition of secondary wavelets from the diff. parts of the same wavefront.
* Fringe width is generally constant	* Fringes are of varying width
* All the maxima have the same intensity.	* The maxima are of varying intensities.
* There is a good contrast b/w the maxima and minima	* There is a poor contrast between the maxima and minima.

5 A) The Heisenberg Uncertainity principle states that it is impossible to know simultaneously the exact position and momentum of a particle, that is, the more exactly the position is determined, the less known the momentum, and vice versa. Mathematically it is presented as

$$\Delta x \cdot \Delta p \geq \frac{\hbar}{2}$$

$$\Delta p \Delta x \geq \frac{1}{2}\hbar$$

$$\Delta E \Delta t \geq \frac{1}{2}\hbar$$

6 A) Nanomaterials having small particle sizes exhibit enhanced optical emission as well as non-linear optical properties due to the quantum confinement effect. Synthesis, Charecterisation, and measurement of optical properties of nanomaterials with different Anisotropic shapes have also drawn significant attention.

7 A) 1. Magnetic field: Really just somewhat like an electric field Just that it has no ~~positive~~ +ve or -ve end. This is caused by movement of charges, opposed to how electric field is produced by a charge regradless of its motion.

2. Magnetic Induction: This is a phenomenon. This is a process wherein a changing magnetic flux (that is magnetic field moving through a certain surface area) produces an electric field in the opposite direction.

8) Eqn of Continuity for time varying fields represents law of Conservation of charge.

$\rightarrow$ $$P = -\frac{dq}{dt}$$

$$i = \int j \cdot ds \qquad q = \int \rho \, dv$$

$$\Rightarrow \int j \cdot ds = -\int \frac{d\rho}{dt} dv$$

applying divergence laws

$$\int J \cdot ds = \int \nabla \cdot J \, dv$$

$$\int \nabla \cdot j dv = -\int \frac{d\rho}{dt} dv$$

$$\nabla \cdot \vec{J} = -\frac{d\rho}{dt}$$

9 A) Super conductors are perfect diamagnetic materials

· as $B = \mu_0 (H+M)$
where
$B = 0$ or $M/H = \chi = -1$

Susceptibility is negative shows that the materials behaves as diamagnetic material.

$B = 0$, does not follow from zero resistivity ($\rho = 0$)

As, from Ohm's law $J = \sigma E$

Or $E = \rho J$ if $\rho \to 0$ & J is finite, $E = 0$

From Maxwells EM field Equation: $\nabla \times E = -\frac{\partial B}{\partial t} \Rightarrow \frac{\partial B}{\partial t} = 0$

Or, B is constant, so $B \neq 0$ always

For a zero resistivity material magnetic induction is not necessarily zero; $B = 0$ is a special property of superconductors only. This strong repulsion of external magnetic field is called levitation effect.

10 A)

STEP INDEX FIBER	GRADED INDEX FIBER
1. The refractive index of the core is uniform and undergoes an abrupt change at the core cladding boundary	The refractive index of the core is made to vary gradually such that it is maximum at the center of the core.
2. The diameter of the core is about 50-200 μm in the case of multimode fiber and 10 μm in the case of single mode fiber.	2. The diameter of the core is about 50μm in the case of multimode fiber.
3. The path of light propagation is zig-zag in manner.	The path of light is helical in manner
4. Attenuation is more	Attenuation is less.

11. a) $F = -kx - r\frac{dx}{dt} + f\sin pt$

$M\frac{d^2x}{dt^2} = -kx - r\frac{dx}{dt} + f_0\sin pt$

$\Rightarrow f\sin pt = \frac{d^2x}{dt^2} + \frac{kx}{m} + \frac{r}{m}\frac{dx}{dt}$

$f\sin pt = \frac{d^2x}{dt^2} + 2\beta\frac{dx}{dt} + \omega_0^2 x$

let $x = A\sin(pt-\theta)$

$-Ap^2\sin(pt-\theta) + 2\beta Ap\cos(pt-\theta) + \omega_0^2(A\sin(pt-\theta))$

$= f\sin pt$

$= f\sin(pt-\theta+\theta)$

$= f_0\sin(pt-\theta)\cos\theta + f_0\cos(pt-\theta)\sin\theta$

Equating Co.eff of $\sin(pt-\theta)$ & $\cos(pt-\theta)$

$-Ap^2 + \omega_0^2 A = f_0\cos\theta$

$2\beta Ap = f_0\sin\theta$

Squaring and adding

$A^2(\omega_0^2 - p^2) = f_0^2\cos^2\theta$

$4\beta^2A^2p^2 = f^2\sin^2\theta$

$\Rightarrow A^2\{(\omega_0^2 - p^2) + 4\beta^2p^2\} = f^2$

$$A = \frac{f_0}{\sqrt{(\omega_0^2 - p^2) + 4\beta^2 p^2}} \qquad \tan\theta = \frac{2\beta p}{(\omega_0^2 - p^2)}$$

Case 1 : $\beta^2 >> \omega_0^2$, $\omega_0^2 >> p^2$

$$A = \frac{f_0}{\sqrt{\omega_0^4}} = \frac{f_0}{\omega_0^2}$$

Case - II : $p^2 >> \omega_0^2$

$$A = \frac{f_0}{\sqrt{p^4 + 4\beta^2 p^2}} \approx \frac{f_0}{p^2}$$

Case III : β is very small , $p^2 \approx \omega_0^2$

$$A = \frac{f}{\sqrt{4\beta^2 p^2}} = \frac{f_0}{2\beta p}$$

$$A_{max} = \frac{f_0}{2\beta p}$$

b) $Y(x,t) = 2\sin(20t + 0.021x + \pi/6)$

General eqn $Y(x,t) = A\sin(\omega t + kx + \phi)$

here $\omega = 20$ $A = 2$

$k = 0.021$ $\phi = \pi/6$

i) Amplitude = 2m

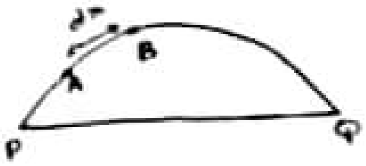
ii) Initial phase = $\pi/6$

iii) Speed = $v = \omega/k = 20/0.021 = 952.38\ ms^{-1}$

iv) frequency = f

$\omega = 2\pi f \rightarrow f = \frac{\omega}{2\pi} = 3.184\ Hz$

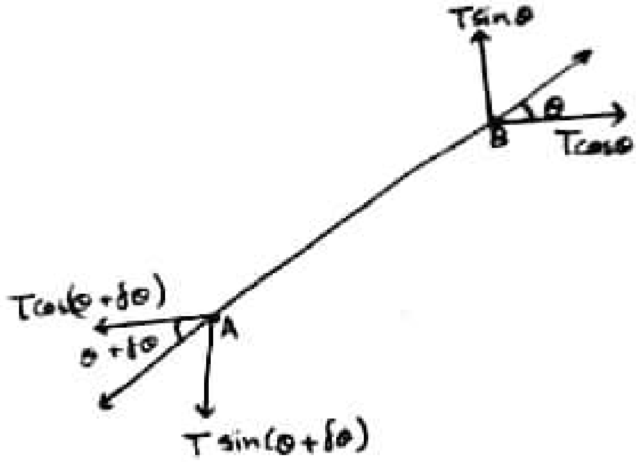
12. a)



$$\mu = \frac{m}{l\,(dx)}$$

Force on the element $= m\,\dfrac{d^2y}{dt^2}$

$$F = \mu\,\delta x \cdot \frac{d^2y}{dt^2} \quad \text{— (1)}$$



$$F_x = T\cos(\theta+\delta\theta) - T\cos\theta = 0.$$

$$F_y = T\sin(\theta+\delta\theta) - T\sin\theta \qquad (\sin\theta \approx \theta)$$

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

$$= T\delta\theta$$

$$= T\delta\tan\theta$$

$$= T\delta\left(\frac{dy}{dx}\right) = T\frac{d^2y}{dx^2}\,\delta x \quad \text{— (2)}$$

$$\mu\,\delta x\,\frac{d^2y}{dt^2} = T\,\frac{d^2y}{dx^2}\,\delta x \Rightarrow \frac{d^2y}{dt^2} = \frac{T}{\mu}\,\frac{d^2y}{dx^2}$$

$$\frac{d^2y}{dx^2} = \frac{\mu}{T}\,\frac{d^2y}{dt^2} \qquad \therefore\; v^2 = \frac{T}{\mu}$$

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

$$\nu = \frac{v}{2l} = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$$

b. $T = 40\,N$

$l = 0.8\,m$

$\mu = \dfrac{1.2\times10^{-3}}{10} = \underline{1.2\times10^{-4}}\ kg/m$

$v = \sqrt{\dfrac{T}{\mu}} = \sqrt{\dfrac{40}{1.2\times10^{-4}}} = \underline{5.77\times10^{2}\ m/s}$

Fundamental frequency.

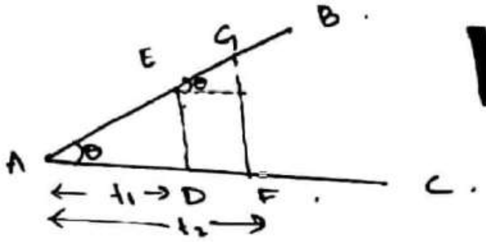
$n = 1.$

$\nu = \dfrac{1}{2l}\sqrt{\dfrac{T}{\mu}}$

$= \dfrac{1}{1.6}\times 5.77\times10^{2}$

$= \underline{3.6\times10^{2}\ Hz}$

13.) a) Air Wedge.



* 2 Glass Plates AB & AC are placed, they are in contact at one end & separated by small distance at the other end.

* A wedge shaped air film is formed b/w them.

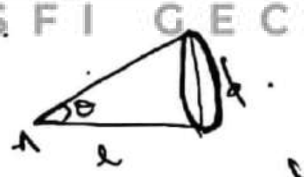
* When a beam of monochromatic light is incident on a glass plate normally the reflected rays from top and bottom surface of air film interfere each other.

* Equidistant parallel dark & bright bands are observed.

[→ Angle b/w glass plates are called angle of air wedge 'θ']

* Diameter of a thin wire:

$$\tan\theta = \frac{d}{l}$$



thin wire of dia 'd' is placed b/w the glass plates at a distance 'l' from edge 'A'.

for small θ's

$$\tan\theta \approx \theta$$

$$\therefore \theta = \frac{d}{l}$$

$\because$ [θ for $\mu = 1$

$$\theta = \frac{\lambda}{2\beta}$$]

$$\frac{\lambda}{2\beta} = d/l$$

$$\boxed{d = \frac{\lambda l}{2\beta}}$$

for μ r.f,

$$\theta = \frac{\lambda}{2\mu\beta}$$

$$\boxed{d = \frac{\lambda l}{2\mu\beta}}$$

b) Condn for nth dark band

$2\mu t\cos r = n\lambda$ $\quad n = 1, 2 \ldots$

$r = 0$

$2\mu t = n\lambda$ — (1)

for least thickness, $n = 1$

Given,

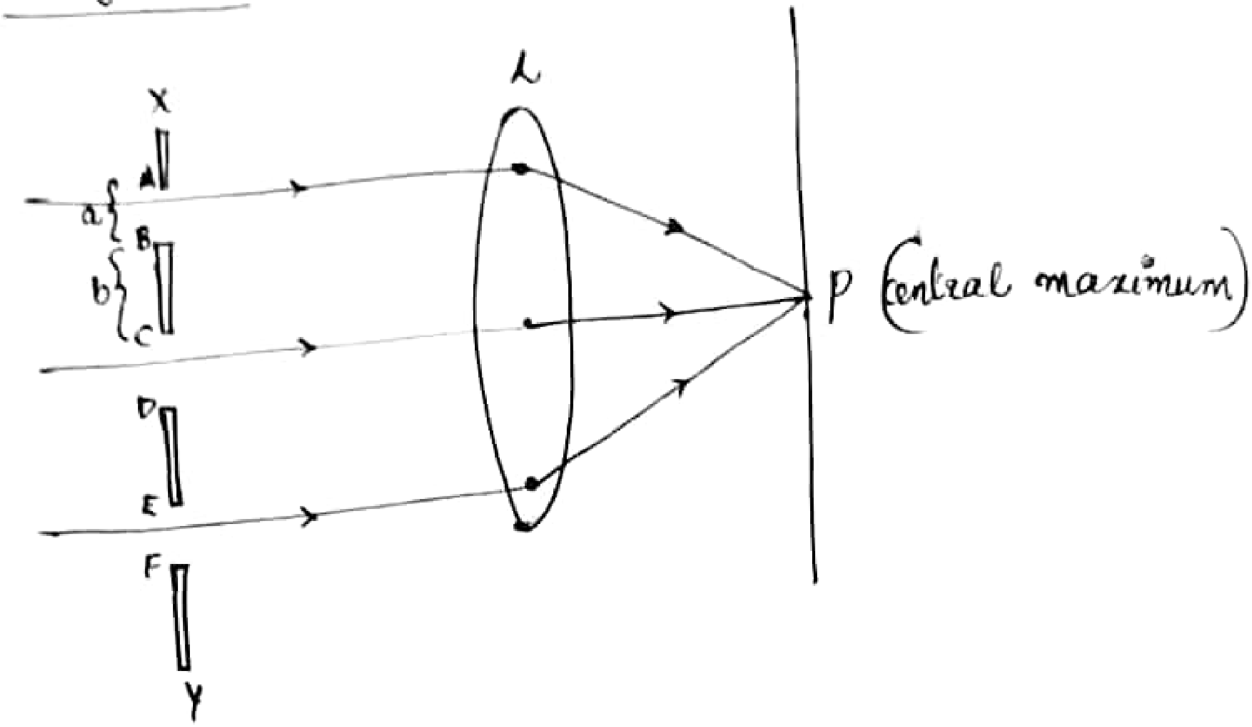
$\mu = 1.42$,

$\lambda = 5893 \mathring{A}$ $\quad$ (1) $\Rightarrow 2 \times 1.42 \times t = 5893$

$t = 2075 \mathring{A}$

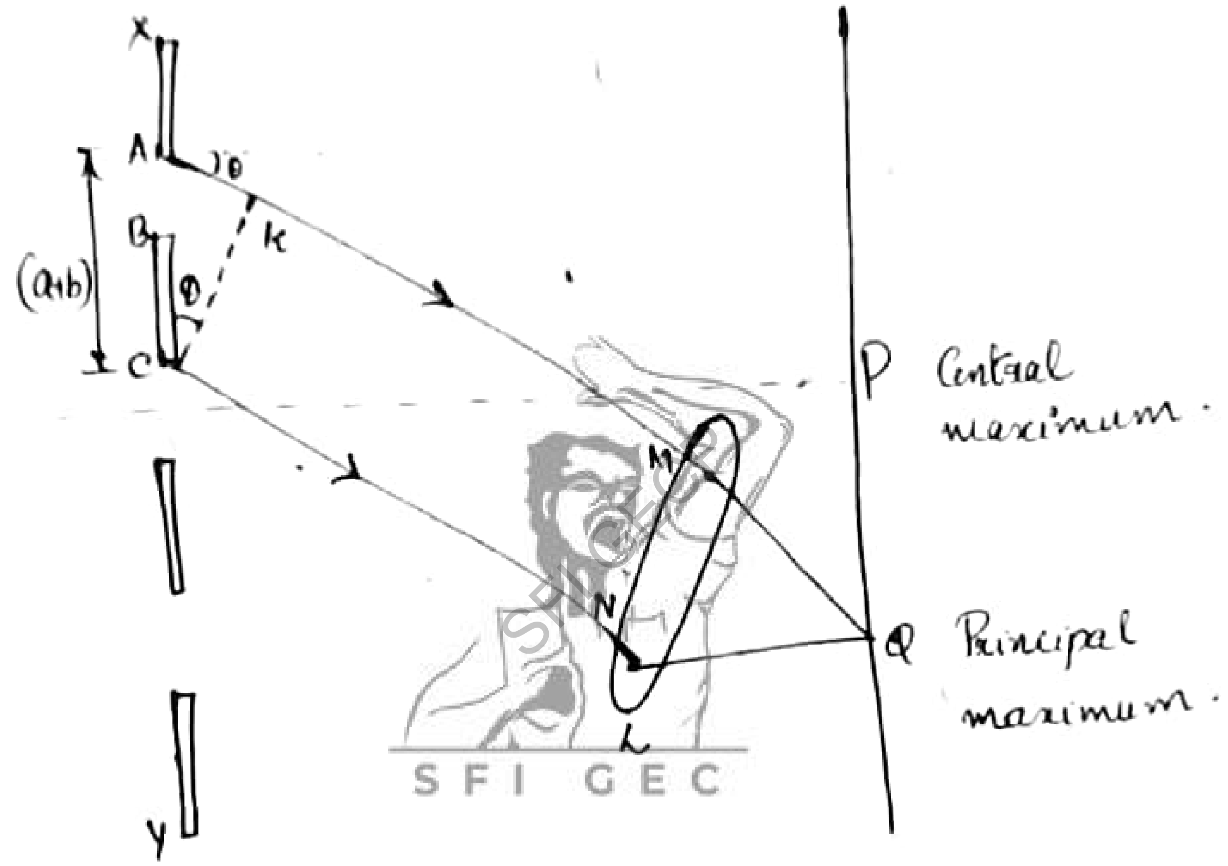
$= 2.075 \times 10^{-7} m$

(14) Grating equation



Let a plane wavefront be incident normally on the grating. Each part of the wavefront passing through the slits sends out secondary waves in all directions. Most of the waves travel straight in the same direction of incident light. When focussed using a convex lens, they give a line of maximum intensity at P, on screen. This is called central maximum. The position of the central maximum is the same for all wavelengths. Therefore, the central maximum will have the same colour as the incident light.

Since the width of the slits is of the order of the wavelength of light, a part of light gets diffracted in different directions. Consider two waves diffracted from two corresponding points A and C of adjacent slits. Let λ be the wavelength and θ be the angle of diffraction with the normal to the grating. They travel along AM and CN. Draw CK perpendicular to AM. There is no path difference between the waves beyond CK. Then the path difference between the two waves is AK.



From triangle ACK, $\sin\theta = \frac{AK}{AC}$.

Then the path difference, $AK = AC\sin\theta$.

$= (a+b)\sin\theta$ —— (1)

$(a+b)$ → distance b/w a consecutive slit and an opaque spacing and is called grating element or grating constant.

If the path difference $(a+b)\sin\theta = n\lambda$ ... (2) where $n = 0,1,2,3$ ..., the two waves interfere constructively. All the waves of wavelength λ starting from different corresponding points and diffracted at angle θ reinforce and give a bright line at Q., when focussed by a lens. This is called the principal maximum. For different values of 'n', there are different values of θ such that $(a+b)\sin\theta = n\lambda$;

If $n=1$, it is the 1st order principal maximum.

If $n=2$, it is the 2nd order principle maximum. and so on.

Exactly similar principal maxima are obtained above P due to the waves diffracted upward at angle θ. Thus on either side of the central maximum, a number of principal maxima are obtained. If there are N lines/unit length of the grating, there are N slits also.

$$\therefore N(a+b) = 1 \text{ (unit length)}$$

Grating element, $(a+b) = 1/N$

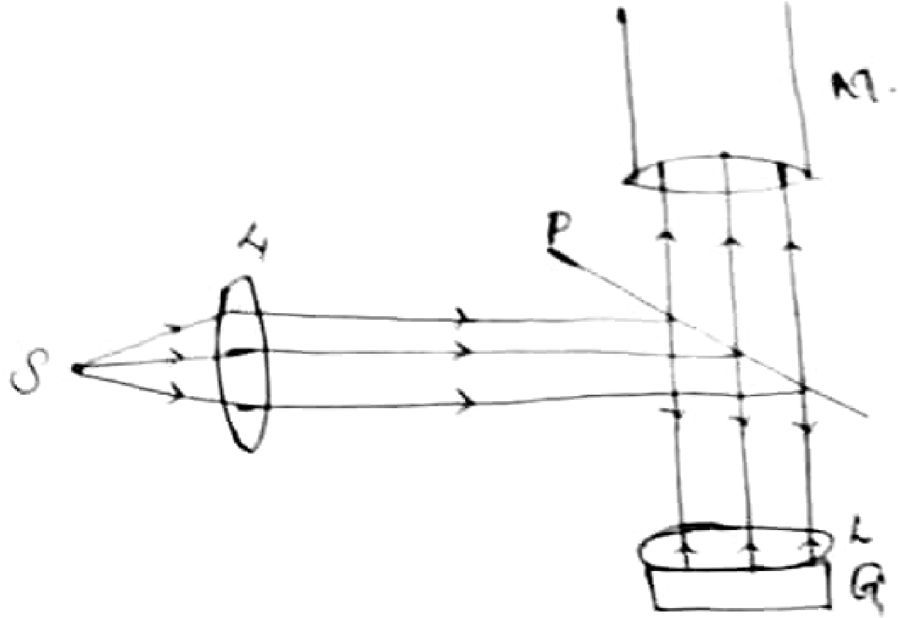
Substituting in eq (5); $\frac{1}{N}(\sin\theta) = n\lambda$

$$\Rightarrow \sin\theta = Nn\lambda \quad \text{—— (3)}$$

$$(a+b)\sin\theta = n\lambda \quad \text{—— (4)}$$

Eq (3) and (4) is known as the grating law or the grating eqn.

Measurement of wavelength λ



S is a sodium vapour lamp. Monochromatic light from the lamp, rendered parallel by a convex lens L falls on a glass plate P kept inclined at 45°. These parallel rays are reflected vertically downward and fall on a convex lens L of large radius of curvature placed on a plane glass plate G. A thin layer of air of varying thickness is formed between the lens and glass plate. The light reflected from the top surface of the air film and the top surface of the glass plate interference. A large number of concentric alternate dark and bright rings are formed. These rings are observed through a microscope M arranged vertically above the glass plate P. The microscope is focussed well so that the rings are clearly seen.

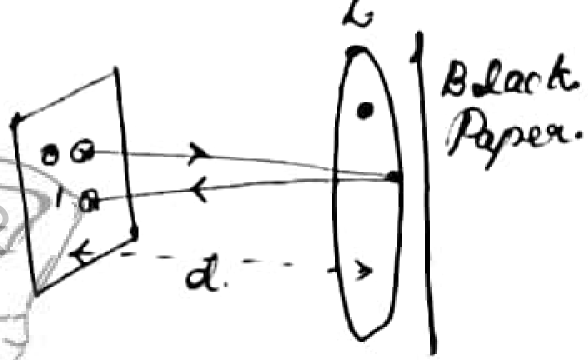
The centre of the rings system is dark in reflected light. The cross-wire of the microscope is kept at the central dark spot. Then by working the tangential screw of the microscope, the cross-wire is moved to the left and counting the number of dark rings, the cross-wire is kept tangential to the 22nd dark ring on the left. The tangential screw is then slowly adjusted so that the cross-wire is tangential to the 20th dark ring on the left. The main scale and vernier scale readings of the microscope are taken.

By working the tangential screw, the cross-wire is kept tangential to the 18th, 16th, 14th etc dark rings upto the 2nd dark ring on the left side, taking the readings corresponding to each ring. Then by working the tangential screw, the cross wire is moved in the same direction until the cross wire is tangential to the 2nd dark ring on the right side. The corresponding reading is taken. Similarly readings are taken keeping the cross-wire tangential to the 4th, 6th, 8th etc. dark rings upto the 20th dark ring on the right side. (The tangential screw is worked only in one direction from the position of the 20th ring on the left side to the position of the 20th ring on the right side. This is to avoid backlash error).

The difference in readings on the left and right of each ring gives its diameter D. The value of D^2 is found. From the readings, the values of $(D_{n+k}^2 - D_n^2)$ is found for a value of $k=10$. Then the mean value of $(D_{n+k}^2 - D_n^2)$ is calculated.

The focal length f of the convex lens L is determined by plane mirror method. The radius of curvature R of the lower surface of the lens is found by Boys method. For this, the convex lens L is placed infront of an illuminated wire gauze, with the marked surface away from the wire gauze. With the black paper held behind the lens the position of the lens is adjusted so that a clear image of the wire gauze is formed side by side with it. The distance d between the lens and the wire gauze is measured. This is repeated 2 or 3 times and the mean value of 'd' is found. Then the radius of curvature of the surface of the lens away from the wire gauze is

$$R = \frac{fd}{f-d}$$



The wavelength of sodium light used is calculated using the formula

$$\lambda = \frac{D_{m+k}^2 - D_n^2}{4kR}$$

Resolving power of grating is the ability of a grating to separate two very close spectral lines.

$$R = \frac{\lambda}{d\lambda}$$

λ : wavelength of spectral line.

$d\lambda$: diff. of wavelength of the spectral line which are just resolved.

14. b) Given

$N = 6000$

$a+b = \frac{1}{6000}$ cm.

$(a+b)\sin\theta = n\lambda$.

$\lambda_1 = 577$ nm.

$= 577 \times 10^{-9}$ m. $= 577 \times 10^{-7}$ cm.

$\frac{1}{6000}\sin\theta_1 = 2 \times 577 \times 10^{-7}$

$\sin\theta_1 = 2 \times 577 \times 10^{-7} \times 6000$.

$\theta_1 = 43.8204°$.

$\lambda_2 = 579$ nm $= 579 \times 10^{-7}$ cm.

$\frac{1}{6000}\sin\theta_2 = 2 \times 579 \times 10^{-7}$.

$\sin\theta_2 = 2 \times 579 \times 10^{-7} \times 6000$.

$\theta_2 = 44.0113°$

Angular separation $= \theta_2 - \theta_1$

$= 44.0113 - 43.8204$

$= 0.1909°$.

15) a) $\psi = 0$

$\psi = 0$

$V = 0$ for $0 < x < l$

$V = \infty$ for $x \leq 0$, $x \geq L$

from Schrödinger eqn

$$\frac{d^2\psi}{dx^2} + \frac{2M}{\hbar^2}(E - V)\psi = 0$$

$$\frac{d^2\psi}{dx^2} + \frac{2ME}{\hbar^2}\psi = 0$$

$$\frac{2ME}{\hbar^2} = k^2$$

$$E = \frac{\hbar^2 k^2}{2M}$$

$\therefore$

$$\frac{d^2\psi}{dx^2} + k^2\psi = 0 \qquad (\alpha^2 + k^2 = 0 . \ \alpha = \pm ik)$$

$$\psi = C_1 e^{+ikx} + C_2 e^{-ikx}$$

at $x = 0$ $\psi = 0$

$0 = C_1 + C_2$ $\therefore$ $C_1 = -C_2$

at $x = L$ $\psi = 0$

$\Rightarrow$ $C_1 \, 2i \sin kL = 0$

$\Rightarrow \sin kL = 0 \Rightarrow kL = \frac{n\pi}{L}$

$$E = \frac{n^2 h^2 \pi^2}{2ML^2} = \frac{n^2 \pi^2 h^2}{2ML^2}$$

$$E(n) = \frac{n^2 \pi^2 h^2}{4\pi^2 \, 2ML^2} = \frac{n^2 h^2}{8ML^2}$$

b) $$E = 4\left[\frac{(6.625\times10^{-34})^2}{8\times 9.1\times10^{-31}\times(4\times10^{-10})^2}\right] - \frac{(6.625\times10^{-34})^2}{8\times9.1\times10^{-31}\times16\times10^{-20}}$$

$$= 3.768\times10^{-19}[4-1]$$

$$= 1.130\times10^{-18}\ eV\ J$$

16. a) Quantum Confinement :

The phenomenon of the nonzero lowest energy and quantization of the allowed energy levels arising from the confinement of electrons within a limited space.

The physical properties of semiconducting nanostructures arise from quantum confinement.

Nanosheets :- They are 2-D structures in which quantum confinement act only in one direction.

Nanowire :- It is a 1-D structure. Two directions have quantum confinement. Only one direction is free for motion with any kinetic energy.

Quantum dot :- They are zero dimensional structures in which the e^- is confined in all three dimensions. Their energy states are quantized in all three directions.

b) Application.

(1) Electronics : Carbon nanotubes are close to replacing silicon as a material for making smaller, faster & more efficient microchips.

(2) Environment : Air purification with ions, wastewater purification with nanobubbles or nanofiltration systems.

(3) Food : Nanobiosensor could be used to detect the presence of pathogens.

(4) Textile : Nanotechnology makes it possible to develop smart fabrics that don't stain or wrinkle.

17.

a) Gauss's Law in Magnetism.

Magnetic flux enclosed by a closed surface 'S' is zero

$$\phi_B = \oint_S \vec{B} \cdot \vec{ds} = 0.$$

Gauss's law of magnetism states that the magnetic field lines going into the closed surface is exactly balanced by field lines coming out. It tells magnetic monopoles do not exist.

Ampere Circuital Theorem

The line integral of magnetic flux density is μ_0 times current enclosed by the path.

$$\oint_C \vec{B} \cdot \vec{dl} = \mu_0 i_{en}$$

Faraday's law of electromagnetic induction.

When magnetic flux linked with the circuit changes an EMF is induced in it. The induced EMF is equal to the rate of change of magnetic flux linked with the coil. It always opposes the change in magnetic flux.

$$\mathcal{E} = \frac{-d\phi}{dt}.$$

Lenz's law

Lenz's law states that the direction of the current induced in a conductor is such that the current opposes the change that induced it.

$$\varepsilon = \frac{-d\phi}{dt}.$$

b) Given

$H = 1800\ A/m$

$\Phi = 8 \times 10^{-5}\ Wb$

$A = 0.2\ cm^2$

$$\mu = \frac{B}{H} = \frac{\Phi}{AH}$$

$$= \frac{3 \times 10^{-5}}{0.2 \times 10^{-4} \times 18 \times 10^{2}} =$$

$$= \frac{\cancel{3}}{0.2 \times \cancel{18}\,6} \times 10^{-3}$$

$$= \frac{10}{2 \times 6} \times 10^{-3}$$

$$= \frac{5}{6} \times 10^{-3} = 0.833 \times 10^{-3}\ Wb/mA.$$

8) a) Maxwell's equations are

$$\nabla \cdot \bar{D} = \rho$$

$$\nabla \cdot \bar{B} = 0$$

$$\nabla \times \vec{E} = -\frac{\partial B}{\partial t}$$

$$\nabla \times \vec{H} = \vec{J} + \frac{\partial D}{\partial t}$$

for free space

$$\rho = 0. \quad \varepsilon_r = 1 \quad \mu_r = 1$$

$$J = \sigma \vec{E} = 0, \vec{E} = 0$$

$$\varepsilon = \varepsilon_0 \varepsilon_r = \varepsilon_0 \quad \mu = \mu_r \mu_0 = \mu_0$$

$$\therefore \quad \nabla \times \vec{H} = \frac{\partial \bar{D}}{\partial t} \quad \nabla \times \vec{E} = -\frac{\partial B}{\partial t}$$

taking equation

$$\nabla \times \bar{H} = \varepsilon_0 \frac{\partial \bar{E}}{\partial t}$$

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

$$\nabla(\nabla \cdot \bar{H}) - \nabla^2 \bar{H} = \varepsilon_0 \frac{\partial}{\partial t}(\nabla \times \vec{E})$$

$$0 - \nabla^2 \bar{H} = \varepsilon_0 \frac{\partial}{\partial t}\left[-\mu_0 \frac{\partial \bar{H}}{\partial t}\right]$$

$$\Rightarrow \quad \nabla^2 \bar{H} = \varepsilon_0 \mu_0 \frac{\partial^2 \vec{H}}{\partial t^2}$$

taking equation

$$\nabla \times \vec{E} = -\mu_0 \frac{\partial \vec{H}}{\partial t}$$

$$\nabla \times (\nabla \times \vec{E}) = -\mu_0 \frac{\partial}{\partial t}(\nabla \times \vec{H})$$

$$-\nabla^2 E = -\mu_0 \frac{\partial}{\partial t}\left(\varepsilon \cdot \frac{\partial E}{\partial t}\right)$$

$$\Rightarrow \nabla^2 E = \varepsilon_0 \mu_0 \frac{\partial^2 E}{\partial t^2}$$

let $c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$ $\Rightarrow \nabla^2 E = \frac{1}{c^2} \frac{\partial^2 \vec{E}}{\partial t^2}$

This resembles

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

$\therefore$ $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$ is the velocity of propogation of em waves

b) The quantity $\vec{S} = \vec{E} \times \vec{H}$ is called poynting vector. It represents energy flow $\perp r$ to both $\vec{E}$ and $\vec{H}$ per second per unit area of medium.

we know $\nabla \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

The term $\int_v \vec{E} \cdot \vec{J} dv = \int_v \vec{E} \cdot \sigma \vec{E} \, dV$

This rep Joule's law of heating the 2nd term $\frac{\partial}{\partial t} \int_v \left(\frac{1}{2} \mu H^2 + \frac{1}{2} \varepsilon E^2 \right) dV$ rep. rate of flow of energy over a surface S enclosing volume V. The quantity $E \times H$ is called poynting vector.

19. a)

Type I Superconductors	Type II Superconductors
* The material loses it magnetization abruptly.	* The material loses it magnetization gradually.
* Exhibit complete Meissner effect.	* Do not exhibit complete Meissner effect.
* There is only one critical magnetic field (H_c).	* There are two critical magnetic fields: lower critical field (H_{c1}) and upper critical field (H_{c2})
* No mixed state.	* Mixed state is present.
* Highest known critical magnetic field is 0.1 tesla.	* Critical magnetic field is much greater.
* They are called soft superconductors.	* They are called hard superconductors.
* Eg: Al, Indium, Tin	* Eg: Germanium, Vanadium, Niobium

b) BCS theory was proposed by Bardeen, Cooper and Schrieffer in 1957.
In a superconducting material, a finite fraction of electrons forms a superfluid (Cooper pairs). It is capable of motion as a whole. At low

temperatures, the condensation is complete and all the electrons participate in forming the superfluid. As the temperature is increased, a fraction of electron evaporate and form a normal fluid. As the temperature approaches a critical value, the system undergoes a second order phase transition from the superconducting to the normal state.

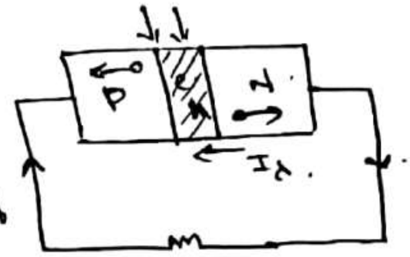
Cooper pair: When an $\bar{e}$ moves through the lattice, positively charged ions are attracted to it. The neighbouring ions come together and a region of increased charge density is formed. This attracts another electron and it forms a pair with the former electron. This pair is called a cooper pair. According to Pauli's Exclusion principle, two or more electrons cannot occupy ground state. But bosons can. So, a cooper pair is a boson.

20. a) Solar Cell / photo galvanic cell

converts solar energy to electrical energy

Principle: Photovoltaic Effect.

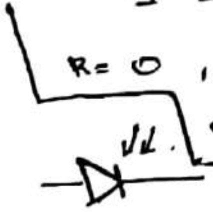
Construction:



$I = I_\lambda - I_f$.

$R = 0$, $I_{max} \rightarrow I_{sc}$ (short circuit)

$R = \infty$, $V_{max} \rightarrow V_{oc}$ (open circuit)



Solar cell symbol.

Solar cell (crystalline Si) consists of a n-type semiconductor (emitter) layer and p-type semiconductor layer (base). The two layers are sandwiched and hence there is formation of pn junction.

The surface is coated with anti reflection coating to avoid the loss of incident light energy due to reflection.

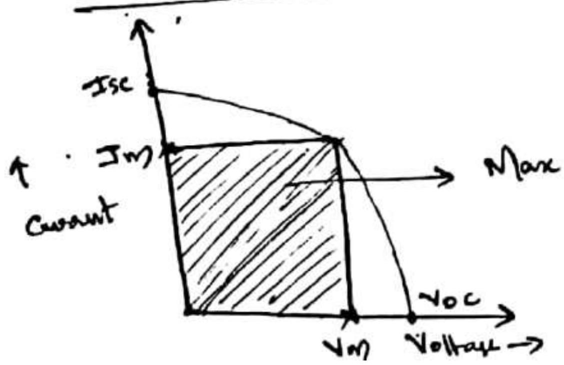
Working.

→ When a solar panel exposed to sunlight, the light energies are absorbed by a semi conduction materials.

→ Due to this absorbed energy, the electrons are liberated and produce the external DC current.

→ The DC current is converted into 240 V AC current using an inverter for different applications.

I-V Characteristics.



Applications.

* Only source of power in artificial satellites.

* Solar cells are widely used in watches, calculators etc....

b) $NA = \sqrt{n_1^2 - n_2^2}$

n_1 - core r.i
n_2 - cladding r.i.

Given

$NA = 0.295$

$n_1 = 1.54$

$0.295 = \sqrt{(1.54)^2 - n_2^2}$

$n_2 = \underline{\underline{1.512}}$

$\sin\theta_a = NA$

$\theta_a = \sin^{-1}(NA) = \sin^{-1}(0.295)$

$= \underline{\underline{17.157^\circ}}$