MUMBAI UNIVERSITY

SEMESTER II

APPLIED PHYSICS 2 SOLVED PAPER MAY 2019

Q1)a) Explain the formation of colours in thin film when it is exposed to white light. (3M)

Ans : 1) When a thin film is exposed to white light from an extended source, it shows beautiful set of colours in the reflected system .

2) Light is reflected from the top and bottom surfaces of a thin film and the reflected rays interfere.

3) The path difference between the interfering rays depends on the thickness of the film and the angle of refraction r and hence on the inclination of the incident ray .

4) White light consists of a continuous range of wavelengths. At a particular point of the film and for a particular position of the eye (i.e. t and r constant) those wavelengths of incident light that satisfy the condition for the constructive interference in the reflected system will be seen in reflected light .

5) The colouration will vary with the thickness of the film and the inclination of the rays (i.e. with the position of the eye with respect to the film). Hence if the same point of the film is observed with an eye in different positions or different points of the film are observed with the eye in the same position, a different set of colours is observed each time .

Q1)b) Write the formula for dispersive power of the grating. Explain how it can be increased . (3M)

Ans : 1) The dispersive power of a grating is defined as the ratio of the difference in the angle of diffraction of any two neighbouring spectral lines to the difference in the wavelength between the two spectral lines .

2) The dispersive power of a grating is expressed as $d\Theta/d\lambda$.

3) The formula for Dispersive Power of a Grating is

$$d\Theta/d\lambda = m/(a+b)\cos\Theta \quad .$$

The Dispersive Power of a Grating can be increased by :

1) Increasing the order of diffraction, i.e. the value of m.
2) Decreasing the grating spectrum .
3) Decreasing the value of $\cos\Theta$, i.e. increasing the value of Θ which is the angle of diffraction .

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1)c) A bare core optical fibre with no cladding is kept in air medium and has fractional index difference of 1.2%. Calculate acceptance angle of the fibre. (3M)

Given : Δ = 1.2%=0.012 , μ_1 =1

To find : Θ

Formula : Numerical Aperture (N.A.) = $\mu_1\sqrt{2}\sqrt{\Delta}$.

Acceptance Angle = $\Theta = \sin^{-1}(N.A.)$

Solution : Numerical Aperture (N.A.) = $\mu_1\sqrt{2}\sqrt{\Delta}$.

$$N.A. = 1 \times \sqrt{2} \times \sqrt{0.012}$$

$$N.A. = 0.155$$

$$\Theta = \sin^{-1}(N.A.)$$

$$\Theta = \sin^{-1}(0.155)$$

$$\Theta = 8.917^\circ.$$

Ans : The acceptance angle of the fibre is 8.917° .

Q1)d) Differentiate between holography and photography. (3M)

Ans :

Holography	Photography
1) The light from the object is scattered directly onto the recording medium in the recording of photography .	1) A lens is required in photography to record an image.
2) A Laser is required to record a hologram.	2) A photograph can be recorded using normal light sources. Eg. Sunlight .
3) There is a need of vibrationless table in holography .	3) There is no need of vibrationless table in photography .
4) In holography, both intensity and phase of each wave is recorded to give 3D picture of an object .	4) In photography, the intensity is recorded to produce 2D image of an object .
5) When a hologram is cut into half, the whole scene can be seen in each piece .	5) When a photograph is cut into half, each piece shows half of the whole image .

Q1)e) Using cylindrical co-ordinate system, calculate volume of the cylinder of radius r and height h. (3M)

Ans : The volume of a three-dimensional region E is given by the integral ,

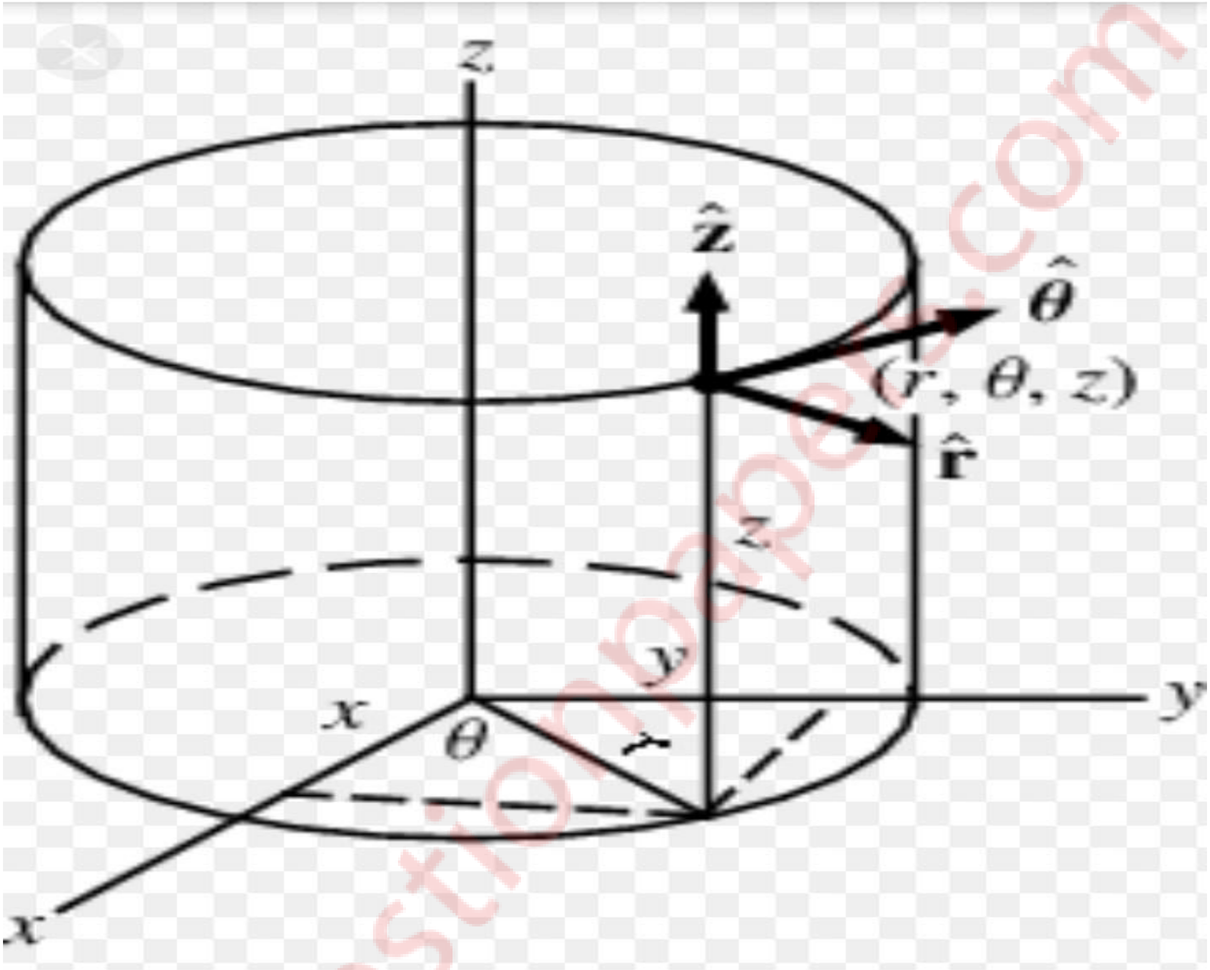
$$V = \iiint_E dV \ .$$

In the cylindrical system, we define the region E as follows ,

$$E = \{(x,y,z) \mid (x,y) \in D, u_1(x,y) \le z \le u_2(x,y)\} \ .$$

Where $(x, y) \in D$ is the notation that means that the point (x,y) lies in the region D from the xy-plane. In this case, we will evaluate the volume as follows :

$$\iiint_E f(x,y,z)\,dV = \iint_D \left[\int_{u_1(x,y)}^{u_2(x,y)} f(x,y,z)\,dz \right] dA \ .$$



This can be solved by integrating first with respect to x, we can integrate first with respect to y or we can use polar coordinates as needed .

Q1)f) An electron is accelerated through a potential difference of 18 kV in a cathode ray tube. Calculate kinetic energy and speed of the electron . **(3M)**

Solution : We know that

$$\frac{1}{2}mv^2 = eV$$ where e is the charge on the electron .

$$\therefore \frac{1}{2} X 9.1 X 10^{-31} X v^2 = 1.6 X 10^{-19} X 18 X 10^{-3}$$

$\therefore$ v = 795.6 X 10^6 m/sec .

$$K.E. = \frac{1}{2} m v^2 \ .$$

$$\therefore \ K.E. = \frac{1}{2} X 9.1 X 10^{-31} X (795.6 \ X \ 10^6)^2 \ .$$

$\therefore$ K.E = 2.88 X 10^{-13} Joules .

Q1)g) Explain top down and bottom up approaches to prepare nanomaterials . (3M)

Ans : In nano science, we are supposed to arrive at nano scale assembly .This can be achieved by two different approaches namely :

1.Bottom up Approach :In this approach, nano materials are made by building atom by atom or molecule by molecule.It involves building of nanomaterials from the atomic scale (assembling materials from atoms/molecules). For synthesis of nanomaterials, colloidal dispersion is a good example of Bottom-up Approach .

2.Top down Approach :In this approach, a bulk material is broken or reduced in size or pattern. The technique developed under this tile are modified or improved one which we have in use to fabricate micro-processors, Micro-Electro-Mechanical Systems (MEMS) etc. Attrition or ballmilling is a typical example of Top-down Approach .

Q2)a) What is anti-reflection coating ? State the conditions for refractive index and thickness of the film in order to act as anti-reflection coating ?White light is sent vertically downward onto a horizontal thin film that is sandwiched between the materials. The indices of the refraction are 1.8 for top material, 1.65 for thin film and 1.50 for the bottom material. The film thickness is 5 x 10^{-7} m. Which are the visible wavelengths (400 – 700 nm) those results in fully constructive interference at an observer above the film? (8M)

Ans: 1) When light enters the optical instrument at the glass air interface, around 4% of light (for air with n_1 = 1 and glass with n_2 = 1.5) that too at single reflection is lost by reflection which is highly undesirable. For advance telescopes the total loss comes out to be nearly 30% and can not be tolerated if working under low intensity applications.

2) In order to reduce the reflection loss, a transparent film of proper thickness is deposited on the surface. This film is known as “non Reflecting surface”.

3) Popular material used is MgF_2 because its refractive index is 1.38 (i.e. between air and glass). Cryolite (n_1 = 1.36) is also used.

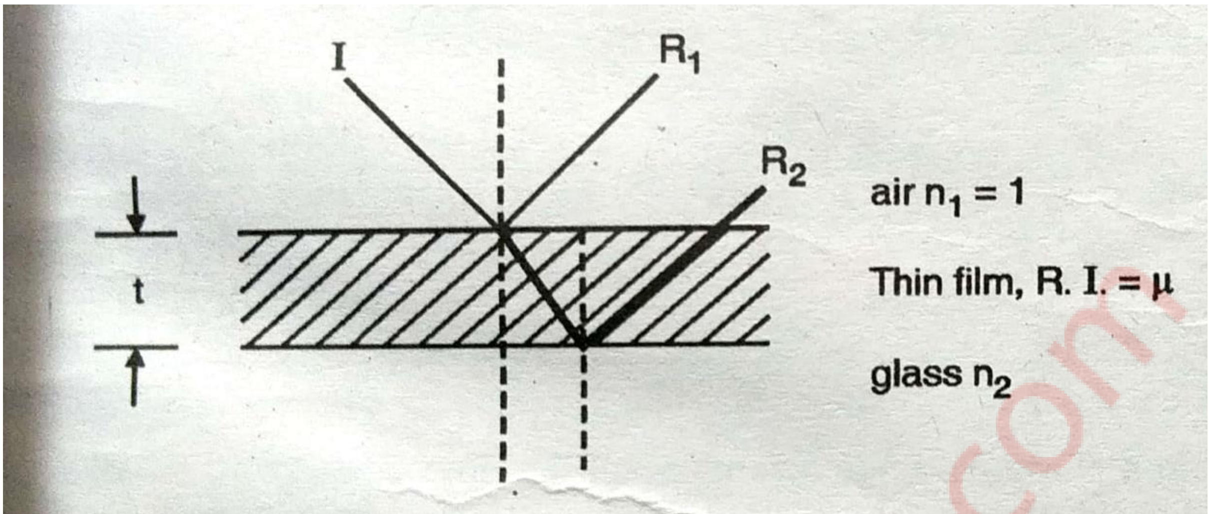


Fig. 2.6.1 : Thin film coating

4) Let a ray I be incident up on a thin film of MgF_2 coated on glass. This ray is reflected from upper surface as R_2. The optical path difference between these two rays is $n_1(2t)$. As the incident ray enters from rarer to denser medium twice i.e. at air to film and film to glass.

5) If both the rays R_1 and R_2 interfere with each other and path difference is $(2n + 1)\lambda/2$ (for n= 0,1,2, ……) then destructive interference will take place.

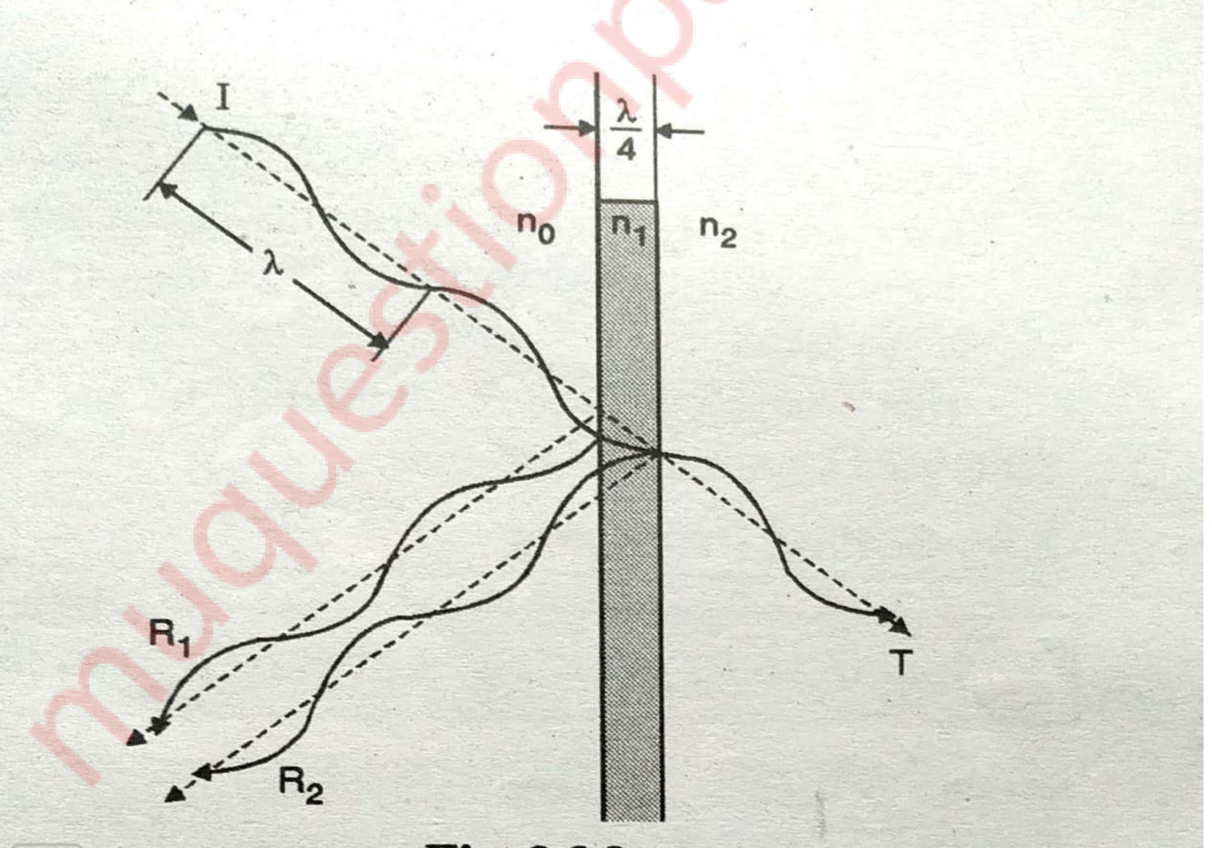


Fig. 2.6.2

Hence, $2n_1t = \lambda/2$

$n_1 t = \lambda/4\mu$

It means that in order to have destructive interference a layer of $n_1 t = \lambda/4$ is coated on glass plate .

Numerical : The resultant refractive index is $\mu = \frac{\mu_1 + \mu_2 + \mu_3}{3}$.

$$\mu = \frac{1.8 + 1.65 + 1.5}{3} .$$

$$\mu = 1.65$$

For constructive interference, the condition is $\mu t = n\lambda$.

$$\therefore 1.65 X 5 X 10^{-7} = n\lambda .$$

Putting n=1, $\lambda = 1.65 X 5 X 10^{-7}$ = 825 nm .

Putting n=2,

$$2\lambda = 1.65 X 5 X 10^{-7}$$

$$\therefore \lambda = \frac{1.65 X 5 X 10^{-7}}{2} = 412.5nm$$

Putting n=3

$$3\lambda = 1.65 X 5 X 10^{-7}$$

$$\therefore \lambda = \frac{1.65 X 5 X 10^{-7}}{3} = 2.75nm$$

Hence the visible wavelength is 412.5 nm .

Q2)b) Give the advantages of optical fibre cables on conventional electric cables. Calculate core radius required for an optical fibre to act as a single mode fibre if its core refractive index is 1.46 and cladding refractive index is 1.455 and operating wavelength is 1300 nm. (7M)

Ans: Advantages of optical fibre cables over conventional electric cables :

1) Diameter of optical fibre is very small and hence network made of optical fibre requires very less space.
2) The power required to operate optical fibre cables is very small as compared to conventional copper wire.
3) Since optical fibres are made of either silica or plastic and hence it is very cheap compared to its metallic equivalent .
4) Optical fibres are not much affected by parameters like pressure, temperature, twist , salinity, etc. (Except for specially designed fibres) .
5) Optical fibre light rays passes through using the concept of Total Internal Reflection (TIR) and hence there is no loss upto few kilometres .

Numerical : For an optical fibre to act as a single mode fibre V<2.405 .

$$V = \frac{\pi d}{\lambda} NA.$$

$$V = \frac{3.14 X 2 X r}{1300 X 10^{-9}} X 0.121 \frac{3.14 X 2 X r}{1300 X 10^{-9}} NA$$ where r is the radius required and NA is the numerical aperture .

$$NA = \sqrt{1.46^2 - 1.455^2}$$

$\therefore$ NA = 0.121

$$\therefore V = \frac{3.14 X 2 X r}{1300 X 10^{-9}} X 0.121$$

$\therefore$ V = 584523.077r .

$\therefore$ V < 2.405 .

$\therefore$ 584523.077r < 2.405

$\therefore$ r < 4114 nm .

Ans : The core radius required is less than 4114 nm .

Q3)a) Explain Fraunhofer's double slit diffraction experiment and obtain expression for resultant intensity of light on the screen and derive the formula for missing orders in the double slit diffraction pattern. (8M)

Ans : 1) The double slits have been represented as A_1B_1 and A_2B_2 . The slits are narrow and rectangular in shape. The plane of the slits are perpendicular to the plane of the paper.Let the width of both the slits be equal and it is 'e' and they are separated by opaque length 'd'. A monochromatic plane wavefront of wavelength 'λ' is incident normally on both the slits.

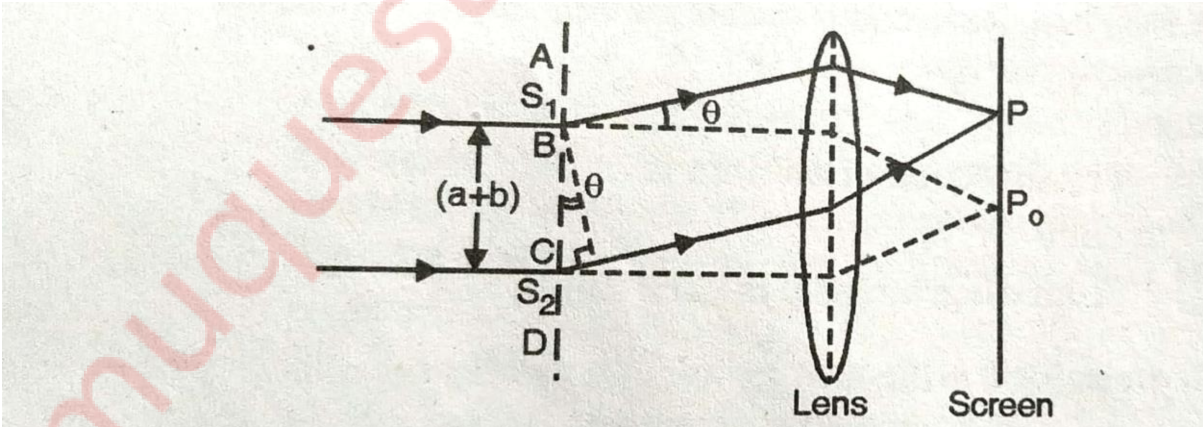


Fig. 3.5.1 : Fraunhoffer diffraction at double slit

2)Light is made incident on arrangement of double slit. The secondary wavelets travelling in the direction of OP_0 are brought to focus at P_0 on the screen SS^1 by using a converging lens L. P_0

corresponds to the position of the central bright maximum. The intensity distribution on the screen is combined effect of interference of diffracted secondary waves from the slits.

3)The diffracted intensity on the screen is very large along the direction of incident beam [i.e. along OP_0]. Hence it is maximum at P_0. This is known as principal maximum of zero order .

4)The intensity at point P_1 on the screen is obtained by applying the Fraunhoffer diffraction theory at single slit and interference of diffracted waves from the two slits. The diffracted wave amplitude due to single slit at an angle θ with respect to incident beam is $A\frac{\sin \propto}{\propto}$, where $2\propto$ is the phase difference between the secondary wavelets arising at the end points of the slit.This phase difference can be estimated as follows : Draw a normal from A_1 to B_1Q . Now B_1C is the path difference between the diffracted waves at an angle θ at the slit A_1B_1.

5)From the traiangle A_1B_1C

$$\text{Sin}\theta = \frac{B_1C}{A_1B_1} = \frac{B_1C}{e} \quad \text{or} \quad B_1C = e\sin\theta \ .$$

The corresponding phase difference

$$2\alpha = \frac{2\pi}{\lambda} e\sin\theta .$$

$$\text{Or} \quad \alpha = \frac{\pi}{\lambda} e\sin\theta$$

6)The diffracted wave amplitudes, $A\frac{\sin\alpha}{\alpha}$ at the two slits combine to produce interference. The path difference between the rays coming from corresponding points in the slits A_1B_1 and A_2B_2 can be found by drawing a normal from A_1 to A_2R. A_2D is the path difference between the waves from corresponding points of the slits.

7)In the triangle A_1A_2D $\frac{A_2D}{A_1A_2}$ = sinθ or the path difference $A_2D = A_1A_2 \sin\theta = (e+b) \sin\theta$.

The corresponding phase difference

$$2\beta = \frac{2\pi}{\lambda}(e+b)\sin\theta$$

Applying the theory of interference on the wave amplitudes $A\frac{\sin\alpha}{\alpha}$ at the two slits gives the resultant wave amplitude (R) .

$$R = 2A\frac{\sin\alpha}{\alpha}\cos\beta .$$

The intensity at P_1 is

$$I = R^2 = 4A^2 \frac{\sin^2\alpha}{\alpha^2}\cos^2\beta \ .$$

$$= 4 I_0 \frac{\sin^2 \alpha}{\alpha^2} \cos^2 \beta \qquad \text{since } I_0 = A^2 .$$

8)This equation represents the intensity distribution on the screen. The intensity at any point on the screen depends on α and β . The intensity of central maximum is $4I_0$. The intensity distribution at different points on the screen can be explained in terms of path difference. $\cos\beta$ corresponds to interference and $\frac{\sin^2 \alpha}{\alpha^2}$ corresponds to diffraction .

9)**Interference maxima and minima :** If the path difference $A_2D = (e+b) \sin\theta_n = \pm n\lambda$ where n = 1, 2, 3, ….. then θ_n gives the directions of the maxima due to interference of light waves coming from the two slits. The $\pm$ sign indicates maxima on both sides with respect to the central maximum. On the other hand if the path difference is odd multiples of $\frac{\lambda}{2}$ i.e.

$A_2D = (e+b) \sin\theta_n = \pm(2n-1) \frac{\lambda}{2}$,

Then θ_n gives the directions of minima due to interference of the secondary waves from the two slits on both sides with respect to central maximum .

10)The intensity distribution on the screen is due to double slit diffraction.Based on the relative values of e and b , certain orders of interference maxima are missing in the resultant pattern .

The direction of interference maxima are given as $(e+b) \sin\theta_n = n\lambda$ where n = 1, 2, 3, …. and the directions of diffraction minima are given as $e \sin\theta_m = m\lambda$ where m= 1, 2, 3……

11)**Intensity distribution due to diffraction at double slit :** For some values of θ_m , the values of e and b are satisfied such that at these positions the interference maxima and the diffraction minima are formed.The combined effect results in missing of certain orders of interference maxima. Now we see certain values of e and b for which interference maxima are missing .

i) Let e=b

Then, $2e \sin\theta_n = n\lambda$ and $e \sin\theta_n = m\lambda$

$\therefore \frac{n}{m} = 2$ or $n = 2m$.

If m = 1, 2, 3, …. Then n = 2, 4, 6, … i.e., the interference orders 2, 4, 6, … missed in the diffraction pattern .

ii) If 2e = b

Then $3e \sin\theta_n = n\lambda$ and $e \sin\theta_n = m\lambda$

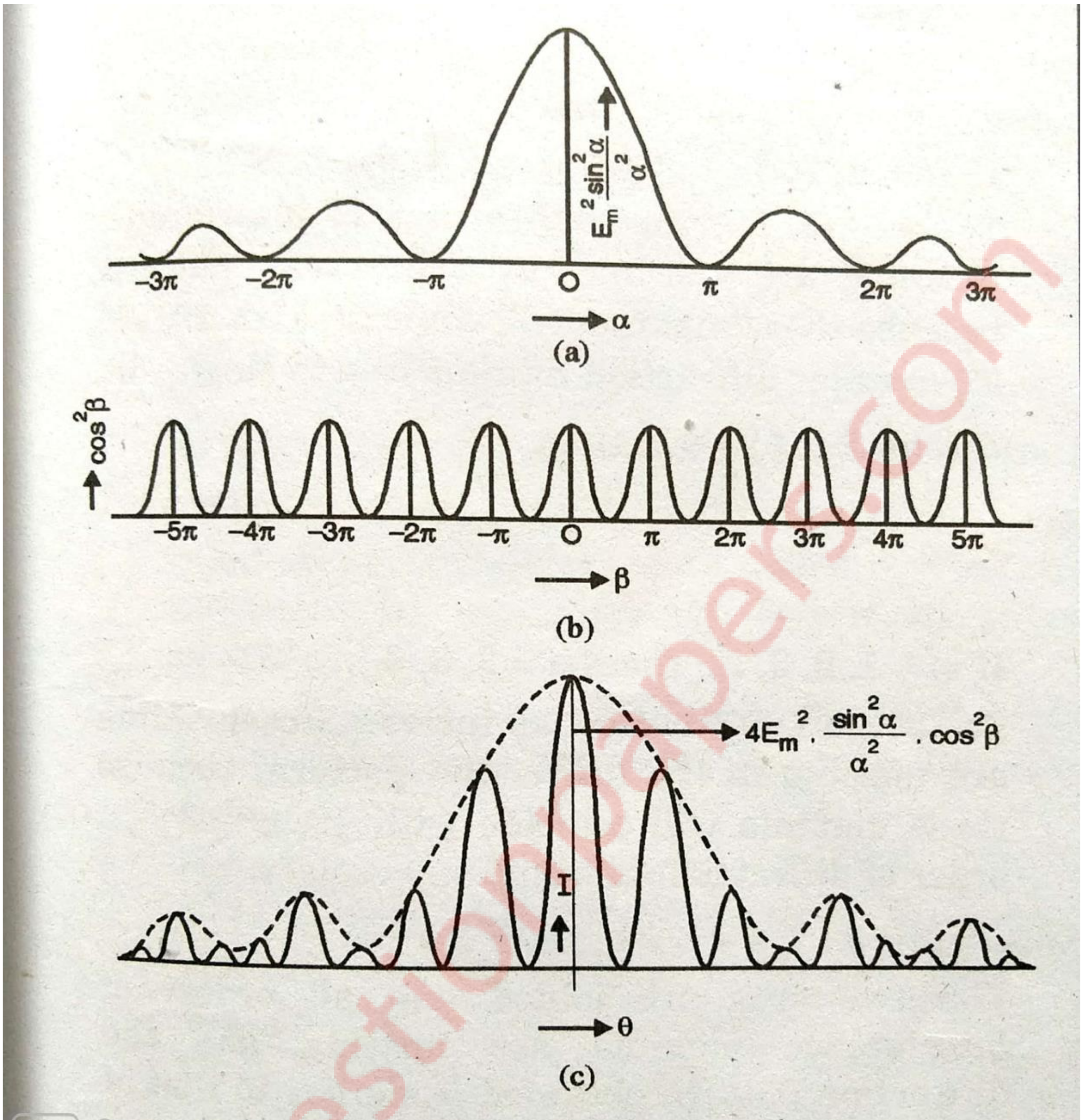


Fig. 3.5.3

$\therefore \ \dfrac{n}{m} = 3$ or $n = 2m$.

If $\mu = 1, 2, 3, \ldots$ Then $n = 3, 6, 9, \ldots$ i.e the interference orders 3, 6, 9 …. are missed in the diffraction pattern .

iii) If $e+b = e$

i.e $b = 0$

the two slits are joined .So, the diffraction pattern is due to a single slit of width 2e .

Q3)b) With energy level diagram explain the construction and working of He-Ne Laser . (7M)

Ans : A Helium-Neon laser or He-Ne laser, is a type of gas laser whose gain medium consists of a Mixture of 85% helium and 15% neon inside of a small electrical discharge. The best-known and

Most widely used HeNe laser operates at a wavelength of 6328 Å, in the red part of the visible Spectrum.

1.The tube where the lasing action takes place consists of a glass envelop with a narrow Capillary tube through the center.

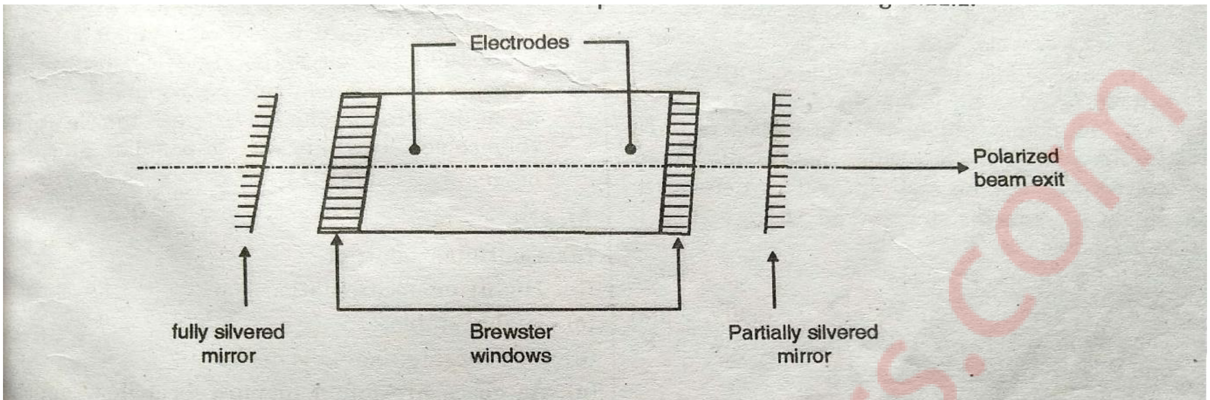


Fig. 4.11.1 : He-Ne laser tube (schematic presentation)

2.The capillary tube is designed to direct the electrical discharge through its small bore to Produce very high current densities in the gas.

3.The outer coupler and the HR (high reflection mirror) are located at the opposite ends of the Plasma tube.

4.In order to make laser tubes more economical and durable manufacturers often attach the mirrors directly to the ends of the capillary tube. This is very common with small low power lasers.

5.With high power tubes or when optically polarized output is desired, the capillary tubes ends are cut at an angle and sealed with glass planes called Brewster windows.

6.The plasma tube has a large cylindrical metallic cathode and a smaller metallic anode. The Current is directed from cathode to anode.

7.In He-Ne Laser active medium is low pressure gas mixture of Helium and Neon which is Contained in the plasma tube

WORKING OF HE-NE LASER:

1.The energetic electrons excite He atoms to excited states F2 and F3 which lies at 19 eV and 20eV above the ground state. These are metastable states for helium.

2.Though the radiative transition is forbidden, the excited He atom can return to the ground State by transferring their energy to Ne atoms through collision. Such an energy transfer can Take place only when the two colliding atoms have identical energy states. E6 and E4 level of Ne Atom nearly coincides with F3 and F2 of helium.

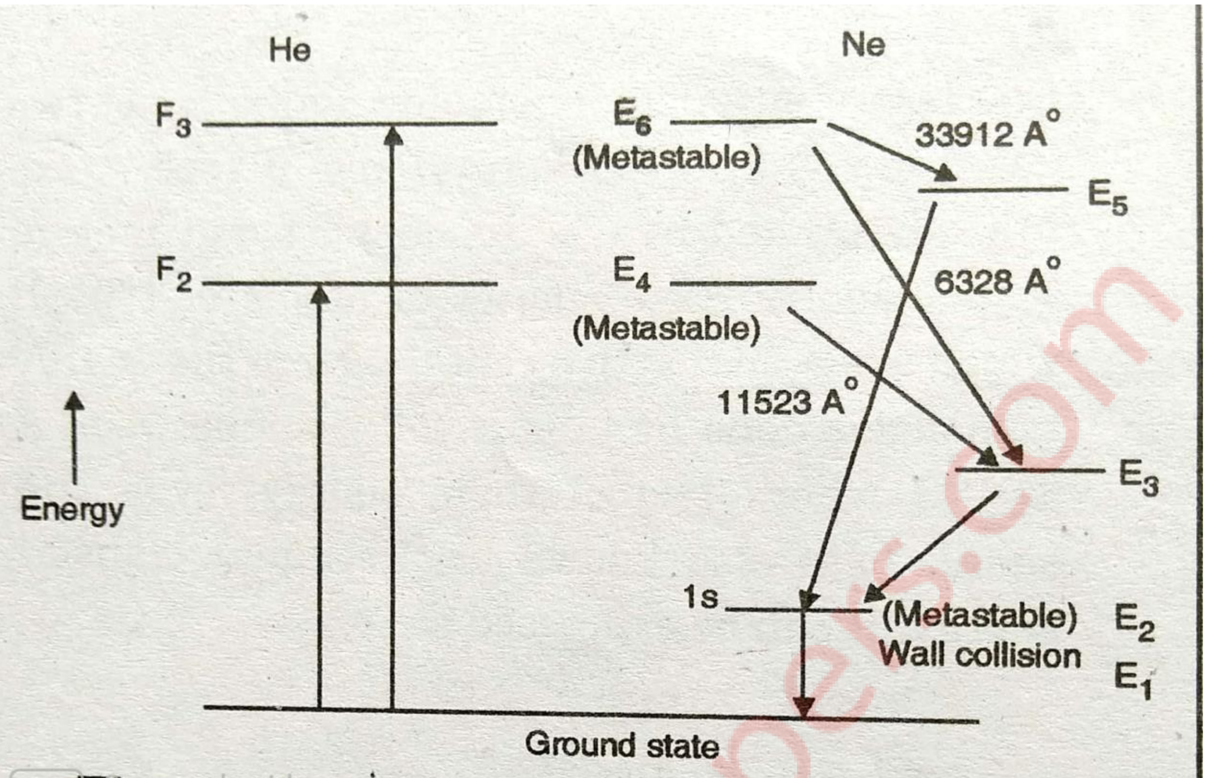


Fig. 4.11.2 : Energy level diagram of He-Ne

3.Ne atoms acquires energy and goes to excited state and helium atoms return to ground state by transferring their energy to Ne atoms. This is main pumping mechanism. Ne atoms are active Centers and helium plays the role of pumping agent.

4.The probability of energy transfer from Ne to He atom is less as there are 10 Helium atom to 1 Neon atom. E_6 and E_4 states are metastable states as collision goes on neon atoms Accumulate In these states whereas E_5 and E_3 level of neon are sparsely populated.Therefore, a state of pollution inversion is achieved between E_6 and E_5, E_6 and E_3 and E_4 and E_3.

5.Consequently, three laser transitions take place.

E_6 to E_5 33900 Å (far IR region)

E_6 to E_3 6328 Å (visible)

E_4 to E3 11500 Å (IR region)

6. As the terminal levels of lasing transitions are sparsely populated the fraction of Ne atom that Must be excited to upper level can be much less. As such the power required for pumping is Low. Random photons emitted spontaneously sets stimulated emission and coherent radiation is produced .

7.From E_5 and E level neon atom can make downward transition to E_2 level. Incoherent light is Emitted due to spontaneous transition. As lower levels depopulate faster than upper levels it is Easier to maintain population inversion throughout laser operation. E_2 is again a metastable State.

8.Therefore, Ne atoms trends to accumulate at this level again. However, they are made to collide with the walls of discharge tube and they give up their energy and returns to ground state.

Q4)a) Calculate divergence of the vector $\vec{F} = x^2y\vec{i} - (z^3 - 3x)\vec{j} + 4y^2\vec{k}$. **(5M)**

Ans : The divergence of $\vec{A}$ is given by ,

$$\vec{\nabla} . \vec{F} = \frac{\partial F_x}{\partial x} + \frac{\partial F_y}{\partial y} + \frac{\partial F_z}{\partial z} .$$

Here , $\frac{\partial F_x}{\partial x}$ = 2xy , $\frac{\partial F_y}{\partial y}$ = 0 (since there is no term of y) , $\frac{\partial F_z}{\partial z}$ = 0 (since there is no term of z) .

$$\vec{\nabla} . \vec{F} = 2xy .$$

Q4)b) Draw the block diagram of cathode ray oscilloscope (CRO) and explain the importance of time base circuit. (5M)

Ans :

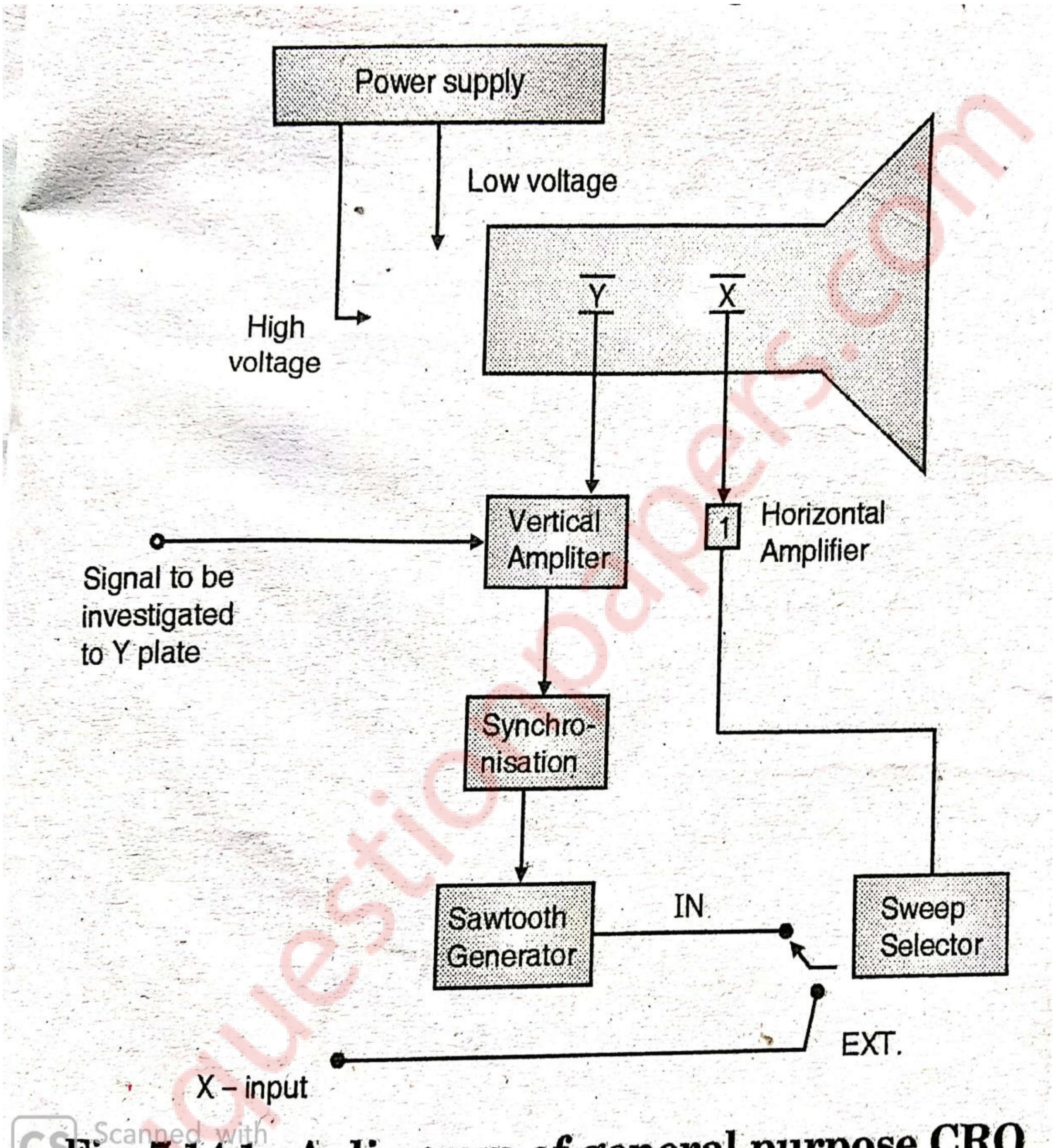


Fig. 7.14.1 : A diagram of general purpose CRO

1)A time base circuit is a special type of electronic circuit that generates a varying voltage to produce a particular waveform. These produce very high frequency sawtooth waves specifically designed to deflect the beam in cathode ray tube (CRT) smoothly across the face of the tube and then return it to its starting position .

2)Time bases are used by radar systems to determine range to a target, by comparing the current current location along the time base to the time of arrival of radio echoes. Analog television systems using CRTs had two time bases, one for deflecting the beam horizontally in a rapid movement, and another pulling it down the screen 60 times per second.

3)Oscilloscopes often have several time bases, but these may be more flexible function generators able to produce many waveforms as well as a simple time base.

4)To generate a time base waveform in a CRO or a picture tube, the deflecting voltage increases linearly with time. Generally, a time base generator is used where the beam deflects over the screen linearly and returns to its starting point. A cathode ray tube and also a picture tube works on the principle of Scanning. The beam deflects over the screen from one side to the other (generally from left to right) and gets back to the same point. This phenomenon is termed as Trace and Retrace.

5) The deflection of the beam over the screen from left to right is called as Trace, while the return of the beam from right to left is called as Retrace or Fly back. Usually this retrace is not visible. This process is done with the help of a saw tooth wave generator which sets the time period of the deflection with the help of RC components used .

6)In the above signal, the time during which the output increases linearly is called as Sweep Time (T_S) and the time taken for the signal to get back to its initial value is called as Restoration Time or Fly back Time or Retrace Time (T_r). Both of these time periods together form the Time period of one cycle of the Time base signal.

Q4)c) Interference fringes are produced by monochromatic light falling normally on a wedge shaped film of refractive index 1.4. The angle of wedge is 20 seconds of an arc and the distance between successive bright fringes is 0.25 cm. Calculate wavelength of the light used . (5M)

Given : $\mu = 1.4$, θ = 20 seconds of an arc = 20 X $\frac{\pi}{180} X \frac{1}{3600}$ = 96.96 X 10^{-6} radians , $\beta = 25 \times 10^{-4}$ m

To find : λ

Formula : $\beta = \frac{\lambda}{2\mu\theta}$.

$\therefore \lambda = 2\mu\theta\beta$

Solution : $\lambda = 2 \times 1.4 \times 96.96 \times 10^{-6} \times 25 \times 10^{-4} = 6787$ ˚A .

The wavelength of the light used is 6787 ˚A .

Q5)a) Write Maxwell's equations in differential form and give their physical significance. (5M)

Ans : The Maxwell's equation and their physical significances are :

1.Maxwell's first equation is $\nabla . D = p$

Integration this over an arbitrary volume V we get

$\int v\nabla \cdot D \cdot dV = \int vp\, dV$

But from Gauss Theorem, we get

$\int s\ D.ds = \int v\ p\ DV = q$

Here, q is the net charge contained in volume V.S is the surface bounding volume V. Therefore,

Maxwell's first equation signifies that: The total electric displacement through the surface enclosing a volume is equal to the total charge within the volume.

2. Maxwell's second equation is $\nabla . B = 0$

Integrating this over an arbitrary volume V, we get

$\int v \nabla \cdot B = 0$

Using gauss divergence theorem to change volume integral into surface integral, we get

$\int s\ B.ds = 0.$

Maxwell's second equation signifies that: The total outward flux of magnetic induction B through any closed surface S is equal to zero.

3. Maxwell's third equation is $\nabla \times E = (-\partial B/\partial t).ds$

Converting the surface integral of left hand side into line integral by stoke's theorem, we get
$\emptyset\ c\ E. = -\int s\ \partial B\ /\ \partial t. ds.$

Maxwell's third equation signifies that: The electromotive force (e.m.f.e = $\int C\ E.dl$) around a closed path is equal to negative rate of change of magnetic flux linked with the path (since magnetic flux $\emptyset = \int s\ B.ds$)

4. Maxwell's fourth equation is $\nabla \times H = J + \partial D\ /\ \partial t$

Taking surface integral over surface S bounded by curve C, we obtain

$$\int s\ \nabla \times \mathrm{H.ds} = \int \mathrm{s}\ (\mathrm{J} + \partial \mathrm{D}\ /\partial t) ds$$

Using stoke's theorem to convert surface integral on L.H.S of above equation into line integral, we get $\emptyset c. H. dl = \int s(J + \partial D\ /\ \partial t). ds$

Maxwell's fourth equation signifies that:

The magneto motive force (m.m.f. = $\emptyset c. H. dl$ around a closed path is equal to the conduction current plus displacement current through any surface bounded by the path.

Q5)b) The ground state and excited state of the laser is separated by 1.8 eV. Calculate the ratio of number of atoms in the excited state to the ground state and wavelength of the radiation emitted at 27˚C. [5M]

Given : ΔE = 1.8 eV = 1.8 X 1.6 X 10^{-19} J =2.88 X 10^{-19} , T = 27 + 273 = 300 K .

To Find : Ratio of number of atoms ($\frac{N}{N_0}$).

Formula : $N = N_0 e^{\frac{-\Delta E}{KT}}$.

Solution : $\frac{N}{N_0} = e^{\frac{-\Delta E}{KT}}$.

$\frac{N}{N_0}$ = $e^{\frac{-2.88 X 10^{-19}}{1.38 X 10^{-23} X 300}}$.

$\frac{N}{N_0}$ = 6.141 X 10^{-31} .

Now, ΔE = $\frac{hc}{\lambda}$.

2.88 X 10^{-19} = $\frac{6.6 X 10^{-34} X 3 X 10^{8}}{\lambda}$.

∴ λ = 0.0687 nm

Q5)c) Explain construction and working of atomic force microscope (AFM). [5M]

Ans : **An Atomic Force Microscope (AFM) consists of following components:**

1.LASER

2.Photodiode

3.Cantilever with a sharp tip

4. Detector and feedback circuit

5.Pizoelectric scanner

Working of Atomic Force Microscope:

1.AFM consists of microscope cantilever with a sharp tip (probe) at its end used to scan the Specimen surface.

2.The cantilever is typically silicon or silicon nitride with the tip radius of curvature of the orders Of nm. Basically, AFM is modified TEM in which limitations of TEM is overcomed. When the tip is bought close to the sample, force between the tip and sample leads to the deflection of the cantilever according to the Hook's law. Instead of using an electrical signal, the AFM relies on forces between the atom on the tip and in the sample.

3.The force present in the tip is kept constant and the scanning is done. As the scanning continues, the tip will have vertical movements depending upon the topography of the sample. The force presents in the tip is kept constant and the scanning is done. As the scanning continue the tip will have vertical movement depending upon the topography of the sample.

4. A Laser beam is used to have a record of vertical movement of the needle. This information is later converted into visible from using photo diode. Depending upon the situation, AFM Measures different types of forces like a Vander Waal's forces, capillary forces, mechanical Contact force etc.

5. Atomic force microscope is high resolution type of scanning probe of microscope with resolution of 1A.U. Because of these it is one of the foremost tool in the field of Nano-science.

6. Atomic force microscope is a modified TEM to overcome which works as the probe in Touch with sample using a microstable cantilever.

7.When the tip is brought in touch with the sample surfaces, force between the tip and the Sample lead to the deflection to the cantilever.

8.The force presents in the tip is kept constant and the scanning is done. As the scanning Continues, the tip will have vertical movement depending upon topography of the Sample.

9.The tip has a mirror on the top of it, a laser beam is used to have the record of vertical Movements of needle. Interformator is also for accuracy.

10.The Information is later converted to visible one.

11.It overcome the difficulty of TEM i.e.the problem associated with no-conduction material as AFM does not generate any current.

12.Depending on the situation forces that are measured in AFM include mechanical contact force, vander wall forces, capillary forces, electrostatic and magnetic forces.

Q6)a) Explain sputtering method for synthesis of nano materials. **[5M]**

Ans :

1) Sputtering is a process by whereby particles are ejected from a solid target material due to bombarding of target by energy particles .In sputtering method, it is necessary to have kinetic energy of incoming particles much greater than conventional thermal energies .
2) In this technology, the substrate is placed in a vacuum chamber with source material, named target, and an inert gas (such as Argon) is introduced at low pressure. A gas plasma is struck using an RF power source, causing the gas to be ionized .
3) The ions are accelerated towards the surface of the target, causing atoms of the source material to break from the target in vapour form and condense on all the surfaces .
4) The sputtering method consists of the bombardment of the target material by fast moving, heavy, inert gas ions from a plasma. The bombarding ions cause atoms to be ejected from the target material by momentum transfer between the colliding ions and the target atoms .
5) The advantages of sputtering method are that it is a non-thermal process, hence no heating is required and low vacuum (10^{-3} torr) is needed .
6) The limitations of sputtering method is that controlling Deposition parameters is difficult. The sputtering method is expensive .

Q6)b) Explain experimental arrangement of Newton's rings experiment and show that diameters of dark rings are proportional to square root of natural numbers. **(5M)**

Ans :

Newton's ring experiment:

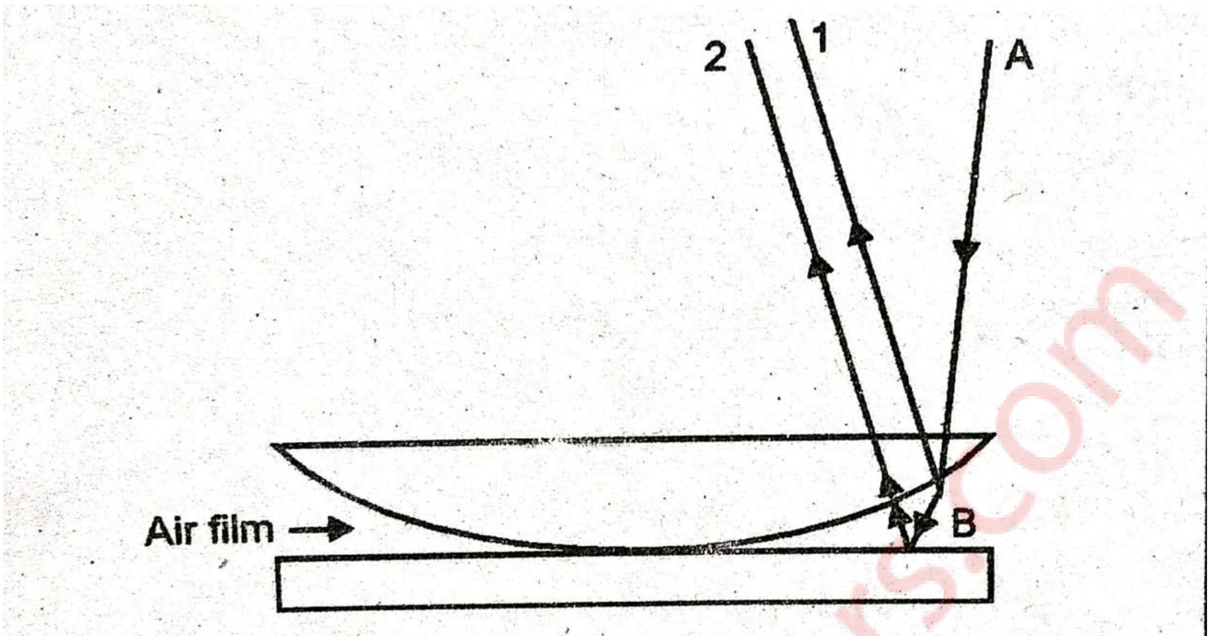


Fig. 1.9.1 : Formation of Newton's rings

1.When a plano-convex lens of large radius of curvature is placed on a plane glass plate, an air film is formed between the lower surface of the lens and upper surface of the plate.

2.The thickness of the film gradually increases from the point of contact outwards.

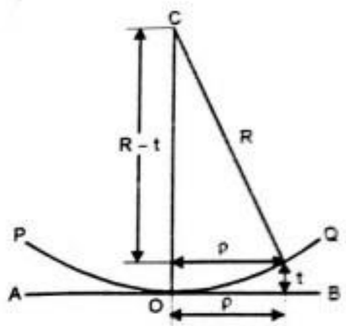
3.If monochromatic light is allowed to fall normally on this film, a system of alternate bright and dark concentric rings, with centre dark is formed in the air film.

4.These rings were first studied by newton and hence they are known as Newton's rings.

5.They can be seen through a low power microscope focused on the film.

6.Newton's rings are formed as a result of interference between the waves reflected from the top and bottom surfaces of the air film formed between the lens and the plate.

Let p be the radius of a newton's rings corresponding to the constant film thickness t.



Path difference between two interfering rays= $2\mu t\cos(r+\Theta)+\lambda/2$

$R^2 = P^2 + (R - t)^2$

$p^2 = 2Rt - t$

$t \ll R$

$2t = \frac{p^2}{R}$

Path difference between the interfering rays is $\frac{P^2}{R} + \frac{\lambda}{2}$

For dark rings :

Path difference = $\frac{p^2}{R} + \frac{\lambda}{2}$

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

If D is the diameter of newton's rings

$P = \frac{D}{2}$

$\frac{D^2 n}{4R} = n\lambda$

$\boldsymbol{D_n^{\alpha}\sqrt{n}}$

Thus proved that the diameter of nth dark rings are proportional to square root of natural numbers.

Q6)c) An electron enters in a uniform magnetic field B=0.23 x 10^{-2} Wb/m^2 at 45° angle to B. Determine radius and pitch of the helical path. Assume electron speed to be 3 x 10^7m/sec. (5M)

Ans : The Radius of helical path R = $\frac{mv\sin\theta}{qB}$.

$\therefore$ R = $\frac{9.1X10^{-31}X3X10^{7}Xsin(45)}{1.6X10^{-19}X0.23X10^{-2}}$

$\therefore$ R = 0.052 m .

The pitch of the helical path = $\frac{2\pi mv\cos\theta}{qB}$.

= $\frac{2\pi X9.1X10^{-31}X3X10^{7}X\cos(45)}{1.6X10^{-19}X0.23X10^{-2}}$.

= 0.33 m .

The radius of the helical path is 0.052 m and the pitch of the helical path is 0.33 m .
