APPLIED PHYSICS-2/DEC-18/SEM-2

Q.1.a) Find the divergence of the vector function A=x^2 i+x^2y^2 j+24$x^2y^2z^3$ k.

Ans.

The diversion of vector function is

$$\nabla . F = \left(\frac{\partial}{\partial x}, \frac{\partial}{\partial y}, \frac{\partial}{\partial z}\right) . (f1. f2. f3) = \frac{\partial f1}{\partial x}, \frac{\partial f2}{\partial y}, \frac{\partial f3}{\partial z}$$

$$\nabla . F = \frac{\partial}{\partial x}(x^2)i + \frac{\partial}{\partial y}(x^2y^2)j + 24\frac{\partial}{\partial z}(x^2y^2z^3)k$$

$$\nabla . F = 2x + 2x^2y + 72x^2y^2z^2$$

Thus, divergence of vector function is $\mathbf{2x + 2x^2y + 72x^2y^2z^2}$**.**

Q.1. b) What is antireflection coating? What should be the refractive index and minimum thickness of the coating?

Ans.

When the light enters the optical instrument at the glass air interface, around 4% of light that too at single reflection is lost by reflection which is highly undesirable. In order to reduce the reflection loss, a transparent film of proper thickness is deposited on the surface. This film is known as ***antireflective coating***.

Popular material used is MgF2 because of its refractive index is ***1.38***.

The minimum thickness of coating is given by: -

2nt = mλ

n = refractive index of film

t = thickness of film

m = 1, 2, 3, …

λ = light wavelength in vacuum (air)

Q.1. c) A glass material A with an optical fibre is made has a refractive index of 1.55. This material is clad with another material whose refractive index is 1.51. The light in the fibre is launched from air. Calculate the numerical aperture of the fibre.

Ans.

Given: n1=1.55

n2=1.51

To Find: NA=?

Formula: NA=$\sqrt{n_1^2 - n_2^2}$

NA=$\sqrt{1.55^2 - 1.51^2}$

NA=0.35.

Q.1. d) What is difference between Bottom up and Top Down Approach with respect to Nanotechnology.

Ans.

In nano science, we are suppose to arrive at nano scale assembly. This can be obtained by two approaches:

1) ***Bottom Up Approach:***

In this nano materials are made by building atom by atom or molecule by molecule.

2) ***Top Down Approach:***

In this a bulk material is broken in size or pattern. The techniques developed under this tile are modified or improved one what we have in use to fabricate micro-processors, Micro-Electro-Mechanical Systems(MEMS) etc.

Q.1.e) Write difference between LED and Laser Diode.

Ans.

LASERs (also known as laser diodes or LD) and LEDs (light emitting diode) have different characteristics in the way in which they emit light. While a LASER emits converged light, the output of an LED is highly diverged.

The spectral width of an LED is bigger than that of a LD. A bigger spectral width enables higher link bandwidth on the FOC. For an LED the spectral width is about 80 nm when it operates at 1310 nm and 40 nm at 850 nm. The spectral width of a LD is 3 nm for operation at 1310 nm and 1 nm at 850 nm.

Q.1.f) How is Lissajous figures used to measure unknown frequency?

Ans.

Lissajous figure will be displayed on the screen, when the sinusoidal signals are applied to both horizontal & vertical deflection plates of CRO. Hence, apply the sinusoidal signal, which has standard known frequency to the horizontal deflection plates of CRO. Similarly, apply the sinusoidal signal, whose frequency is unknown to the vertical deflection plates of CRO

Let, $f_H$and f_V are the frequencies of sinusoidal signals, which are applied to the horizontal & vertical deflection plates of CRO respectively. The relationship between f_H and f_V can be mathematically represented as below.

$$\frac{f_V}{f_H} = \frac{n_H}{n_V}$$

From above relation, we will get the frequency of sinusoidal signal, which is applied to the vertical deflection plates of CRO as

$$f_V = (\frac{n_H}{n_V})f_H$$

Where,

$n_H$is the number of horizontal tangencies
n_V is the number of vertical tangencies
We can find the values of n_H and n_V from Lissajous figure. So, by substituting the values of n_H, n_V and f_H in Equation 1, we will get the value of f_V, i.e. the frequency of sinusoidal signal that is applied to the vertical deflection plates of CRO.

Q.1. g) A parallel beam of light of wavelength 5890 A^0 is incident on a glass plate having refractive index $\mu = 1.5$ such that the angle of refraction in the plate is 60^0. Calculate the smallest thickness of the glass plate which will appear dark by reflected light.

Ans.

Given: - λ=5890 x 10^{-8} cm

μ=1.5

r=60^0

To Find: - t=?

Formula: - 2 μt cos r= n λ

The smallest thickness will be for n=1,

$$2 \times 1.5 \times t \times \cos 60 = 1 \times 5890 \times 10^{-8}$$

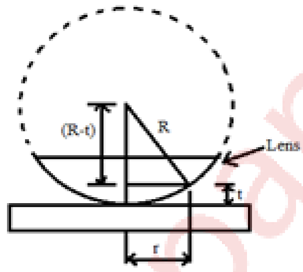
$$t = \frac{5890 \times 10^{-8}}{2 \times 1.5 \times 0.5}$$

$$\boldsymbol{t = 3926 \times 10^{-8} cm}$$

Q.2. a) With the help of proper diagram and necessary equation, explain how Newtons ring experiment is useful to determine the radius of curvature of plano convex lens. In a newton rings experiment the diameter of 5th dark ring is 0.336 cm and the diameter of 15th ring is 0.590 cm. Find the radius of curvature of plano convex lens if the wavelength of light used is 5890 A⁰.

Ans.

Consider a planoconvex lens of radius 'R' as shown.



As radius is comparatively large, the space between lens and base can be considered as wedge shaped.

Thus path difference is given by

$$\Delta = 2\mu t cos(r_e + \alpha) \pm \frac{\lambda}{2} \ldots\ldots (r_e = angle \;\; of \;\; refraction)$$

For almost normal incidence,

$$cos(r_e + \alpha) \approx 1$$

$$\Delta = 2t + \frac{\lambda}{2} \ldots\ldots (i)$$

Now,

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

$$R^2 = R^2 - 2Rt + t^2 + r^2$$

$$2t = \frac{t^2}{R} + \frac{r^2}{R}$$

$$R >> t^2, \frac{k^2}{R} \approx 0$$

$$2t = \frac{r^2}{R} = \frac{D^2}{4R} \ldots\ldots (ii) \; [D = 2r]$$

From (i) and (ii)

$$\Delta = \frac{D^2}{4R} + \frac{\lambda}{2} \ldots\ldots (iii)$$

For Bright Rings:-

$$\Delta = n\lambda$$

$$\frac{D_n^2}{4R} + \frac{\lambda}{2} = n\lambda \ldots\ldots [D_n = dia.\ \ of\ \ nth\ \ bright\ \ ring]$$

$$\frac{D_n^2}{4R} = (2n-1)\frac{\lambda}{2}$$

$$R = \frac{D_n^2}{2(2n-1)\lambda}$$

Using above formula, by calculating diameter of nth bright ring for a given wavelength of light, we can calculate the radius of curvature.

Given:- D_5= 0.336 cm

D_{15}= 0.590 cm

λ=5890 x 10^{-8} cm

To Find: - R=?

Formula: - $R = \frac{D_n^2}{2(2n-1)\lambda}$

$$R = \frac{D_5^2}{2(2\times 5-1)\times 5890\times 10^{-8}} - \frac{D_{15}^2}{2(2\times 15-1)\times 5890\times 10^{-8}}$$

Therefore,

$$R = \frac{0.336^2}{2(2\times 5-1)\times 5890\times 10^{-8}} - \frac{0.590^2}{2(2\times 15-1)\times 5890\times 10^{-8}}$$

$$R = 4.59\ cm$$

Thus radius of curvature of plano convex lens is ***4.59 cm***.

Q.2.b) What is monomode and multimode fibre? Explain the term V-number, Calculate the number of modes of a step index optical fibre of diameter 40 μm will transmit as its core and cladding refractive indices are 1.5 and 1.46 respectively. Wavelength of light used is 1.5 μm.

Ans.

Monomode:
1. It supports only 1 mode of propagation
2. It has very small core diameter of the order 5 to 10μm
3. Transmission losses are very small
4. It has higher bandwidth
5. It requires laser diode as source of light
6. It is used for long distance.
7. It is by default step index fibre
8. Mostly it is made up of glass

Multimode:
1. It supports large on of modes of propagation
2. It has larger core diameter of the order 50 to 150μm
3. Transmission losses are more
4. It has lower bandwidth
5. It can work with LED also
6. It is used for long distance communication
7. It can be step index or graded index fibre
8. It is made preferably from plastic

The normalized Frequency parameter or ***V-number*** gives the upper limit of the number of Modes that can be transmitted in a multimode optical fiber. It depends on the core diameter, dc, the NA, and the wavelength.

$$V = \frac{2\pi a}{\lambda} \times \sqrt{n_1^2 - n_2^2}$$

$$V = \frac{2\pi a}{\lambda} \times NA$$

where, a=core radius

λ=wavelength in vacuum

n_1=maximum refractive index of core

n_2=refractive index of cladding

Given: - $d=40\ \mu m$

$n_1=1.5$

$n_2=1.46$

$\lambda=1.5\ \mu m$

Formula: - $NA=\sqrt{n_1^2-n_2^2}$

$M=\frac{1}{2}\left(\frac{\pi d}{\lambda}\times NA\right)^2$

$NA=\sqrt{1.5^2-1.46^2}$

NA=0.344

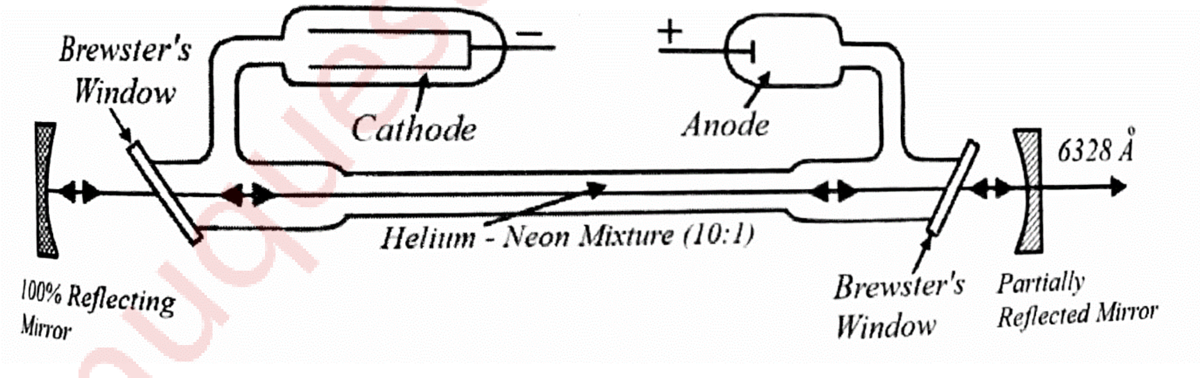
$$M=\frac{1}{2}\left(\frac{\pi\times 40\times 10^{-6}}{1.5\times 10^{-6}}\times 0.344\right)^2$$

M=415

Q.3.a) With a neat energy level diagram describe the construction and working of He-Ne Laser. What are the merits and demerits?

Ans.

It consists of a long discharge tube of length 50 cm and diameter 1 cm. The tube is filled with a mixture of He and Ne in the ratio 10:1. Electrodes are provided to produce a discharge in the gas and they are connected to high voltage power supply. The tube is sealed by inclined windows arranged at its end. On the axis of tube two reflectors are fixed which forms resonator.



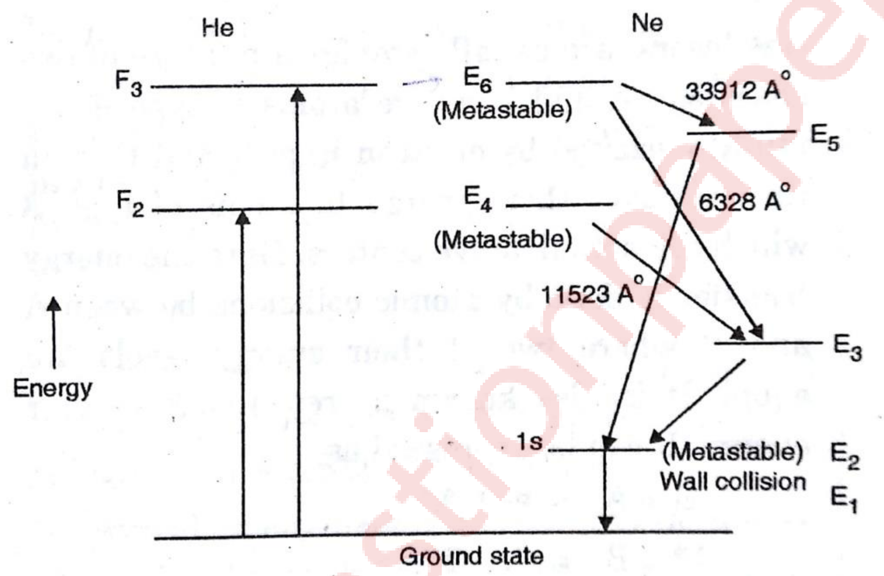
He Ne gas laser employ four level pumping schemes. When the power is switched on the electric field ionizes some of the atoms in the mixture of He and Ne gases. Due to electric field, the electrons and ions will be accelerated towards anode and cathode. Since electron have smaller mass they acquire higher velocity and He atoms are lighter in weight and therefore readily excitable.

The energetic electrons excite He atoms to excited states F_2 and F_3which lies at 19 ev and 20 ev above the ground state. These are metastable states for helium.

Though the radiative transitions 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. E_6 and E_4 level of Ne atom nearly coincides with F_3 and F_2 of Helium. 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.

The probability of energy transfer from Ne to He atom is less as there are 10 Helium atoms 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 population inversion is achieved between E_6 and E_5, E_6 and E_3 and E_4 and E_3. Consequently, three laser transitions take place.
E_6-----E_5 33900 A° (far IR region) E_6-------E_3 6328 A° (visible) E_4----E_3 11500 A° (IR region)

Energy level diagram :



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.

From E_5 and E_3 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.
Therefore, Ne atoms tends 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.

Merits:

- Continuous output laser source
- Highly stable
- No separate cooling is required

Demerits:

- Low efficiency and low power output
- Gases are novel medium for laser as gases are found in the purest form so their optical properties are well defined.

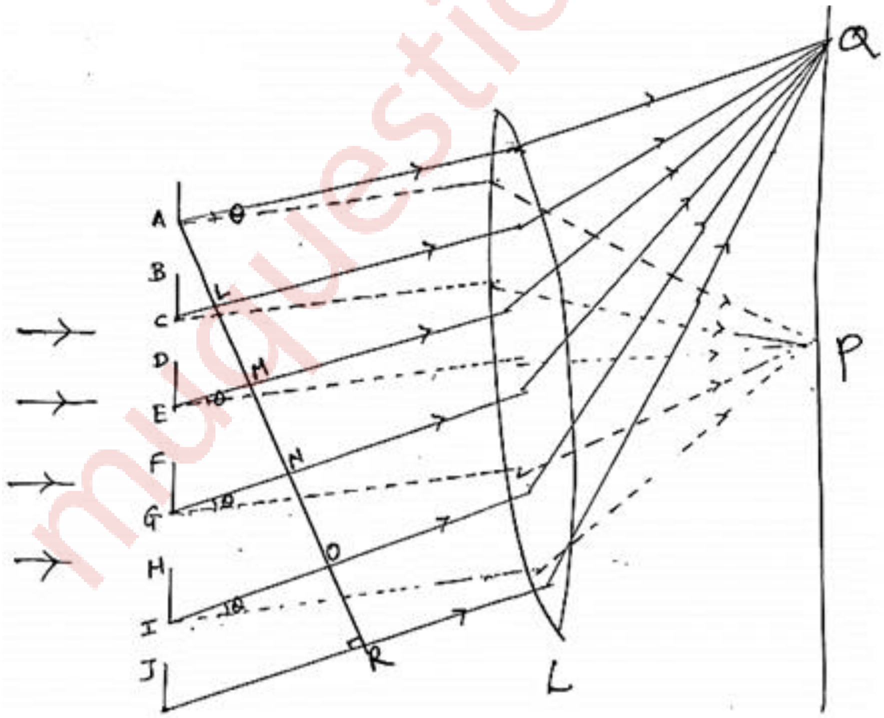
Q.3.b) What is diffraction grating and grating element? Explain experimental method to determine the wavelength of the spectral line using diffraction grating?

Ans.

A ***diffraction grating*** consists of a closely spaced aperture of width 'a' separated by opaque interval of width 'b'. AB, CD, EF …. are apertures and BC, DE, FG are opaque parts. Consider point A and C on grating. These are called corresponding points. The distance between any such pair of points equals to (a+b) and is called grating element or grating constant. If there are N apertures and N opaque interval in 1 m then N(a+b) = 1

∴a+b=1/N

Grating element is equal to the reciprocal of number of lines per cm on grating.



Let a train of plane waves be incident normally on grating. Considering light rays passing through the grating straight will be conveyed at 'P' As the wavelets through the various slits reach the point 'p' after covering equal distance. 'P' is called as zero order principle maxima.

Let us consider the light leaving the various slits at an angle θ with that of incident beam. From point A draw the normal. There is the path difference between the rays starting from various slit and reaching θ

Suppose θ is such that CL = λ , EM = 2λ, GN = 3λ and so on.

The waves from all these elements are in phase at grating and are also in phase along the line AR and reach Q in phase.

Therefore, the reinforce each other and produced first order principle maxima at Q.

If θ such that CL = 2λ then again waves will be in phase and produce second order maxima.

In ΔACL $\sin\theta = \lambda / (a+b)$

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

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

Each slit in the grating produces its own diffraction pattern.since the slits are very large in number.only few maxima are seen whereas other maximas and minimas are suppressed.

To find resultant intensity all the secondary wave in each can be replaced by a single slit of amplitude $(E_m \sin \alpha) / \alpha$ starting from the midpoint of the slit and traveling at an angle θ with normal.
Let the path difference between the waves starting from midpoint of slit equal to λ

For path difference λ, phase difference 2π

For path difference $(a+b) \sin \theta$, phase difference $\Delta\phi = (2\pi/\lambda)(a+b)\sin\theta$

$\Delta\phi = 2\beta \quad \beta = (\pi/\lambda)(a+b)\sin\theta$ ………………….(1)

To find the resultant amplitude, we have to find the resultant of N vibration of amplitude $(E_m \sin \alpha) / \alpha$ and the phase difference is 2β. And it is found out by vector addition method

$$E_\theta = (E_m \sin\alpha / \alpha) \sin N\beta / \sin\beta \quad \text{………………………………….(2)}$$

We know that I a E^2

$$E_\theta^2 = [E_m^2 (\sin^2 \alpha) / \alpha^2] [(\sin^2 N\beta) / (\sin^2 \beta)]$$

$$I_\theta = I_m [(\sin^2 \alpha) / \alpha^2] [(\sin^2 N\beta) / (\sin^2 \beta)] \quad \text{…………………………..(3)}$$

The first factor $(\sin^2 \alpha) / \alpha^2$ in equation (3) gives the intensity distribution due to single slit and second factor
$(\sin^2 N\beta) / (\sin^2 \beta)$ gives the intensity pattern due to N slits
For I_θ to be maximum $\sin \beta = 0$

But $\sin \beta = 0$ $\sin N\beta = 0$

Using L hospital rule

$\lim_{\beta \to \pm m\pi} \{d(\sin N\beta)/d(\sin\beta)\}$

$= N (\cos N\beta)/\cos\beta$

$= N (\cos Nm\pi)/(\cos m\pi)$

$= N$

Therefore $(\sin^2 N\beta) / (\sin^2 \beta) = N^2$
So equation (3) becomes

$$I_\theta = N^2 I_m (\sin^2 \alpha) / \alpha^2$$

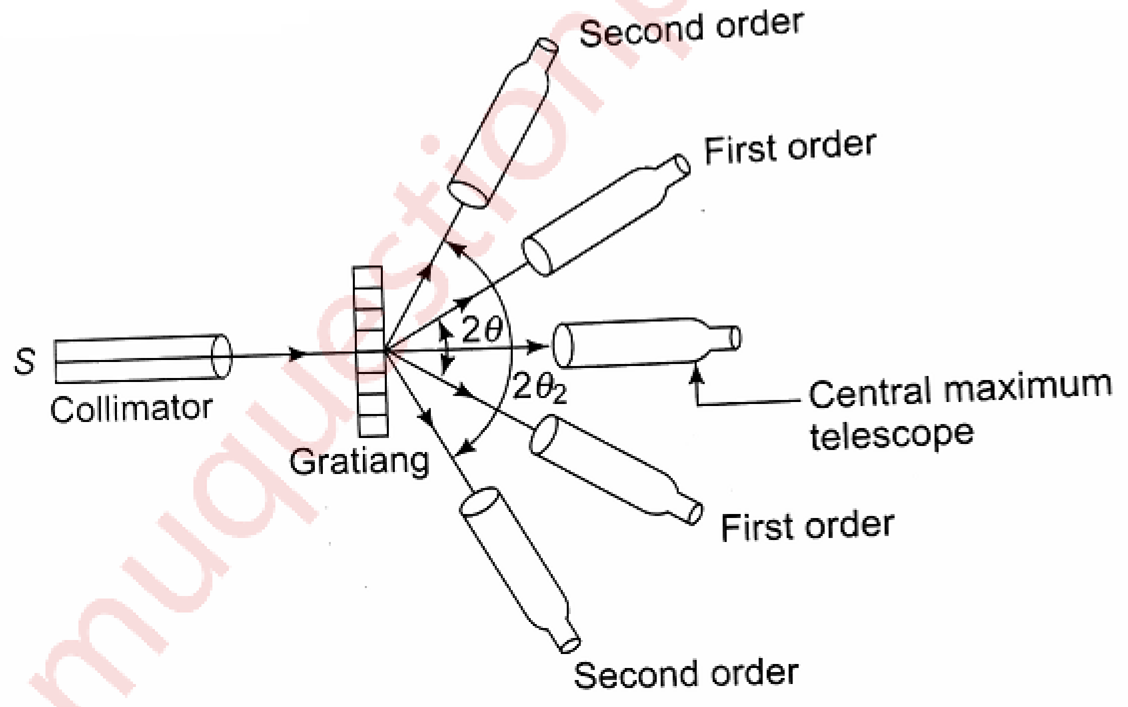
Condition for maxima $\beta = \pm m\pi$

$[\pi/\lambda (a+b)\sin\theta] = \pm m\pi$

$(a+b)\sin\theta = \pm m\lambda$ m = 1,2,3,4…………………

For minima $N\beta = \pm m\pi$ $N(\pi)/\lambda (a+b)\sin\theta = \pm m\pi$ $N(a+b)\sin\theta = \pm m\lambda$ m can be taken all the values except 0,N,2N,……………nN. Because for all the values condition for maxima will be satisfied therefore m can be (nN±1) values.

Determination of Wavelength of Light using Diffraction Grating



The diffraction grating is often used in the laboratories for the determination of wavelength of light. The grating spectrum of the given source of monochromatic light is obtained by using a spectrometer. The arrangement is as shown in Figure shown below The spectrometer is first adjusted for parallel rays. The grating is then placed on the prism table and adjusted for normal incidence. In the same direction as that of the incident light, the direct image of the slit or the zero-order spectrum can be seen in the telescope. On either side of this direct image a symmetrical diffraction pattern consisting of different orders can be seen. The angle of diffraction θ for a particular order m of the spectrum is measured.

The numbers of lines per inch of grating are written over it by the manufacturers.

Thus using the equation, $a + b) \sin \theta = m\lambda$

The unknown wavelength λ can be calculated by putting the values of the grating element $(a + b)$, the order m and the angle of diffraction θ.

Q.4.a) With a neat diagram explain the construction and working of scanning electron microscope.

Ans.

Scanning electron microscope is an improved model of an electron microscope. SEM is used to study the three dimensional image of the specimen.

Principle:

When the accelerated primary electrons strikes the sample , it produces secondary electrons . these secondary electrons are collected by a positive charged electron detector which in turn gives a 3- dimensional image of the sample.

Construction:

It consists of an electron gun to produce high energy electron beam. A magnetic condensing lens is used to condense the electron beam and a scanning coil is arranged in-between magnetic condensing lens and the sample.
The electron detector (Scintillator) is used to collect the secondary electrons and can be converted into electrical signal. These signals can be fed into CRO through video amplifier as shown.

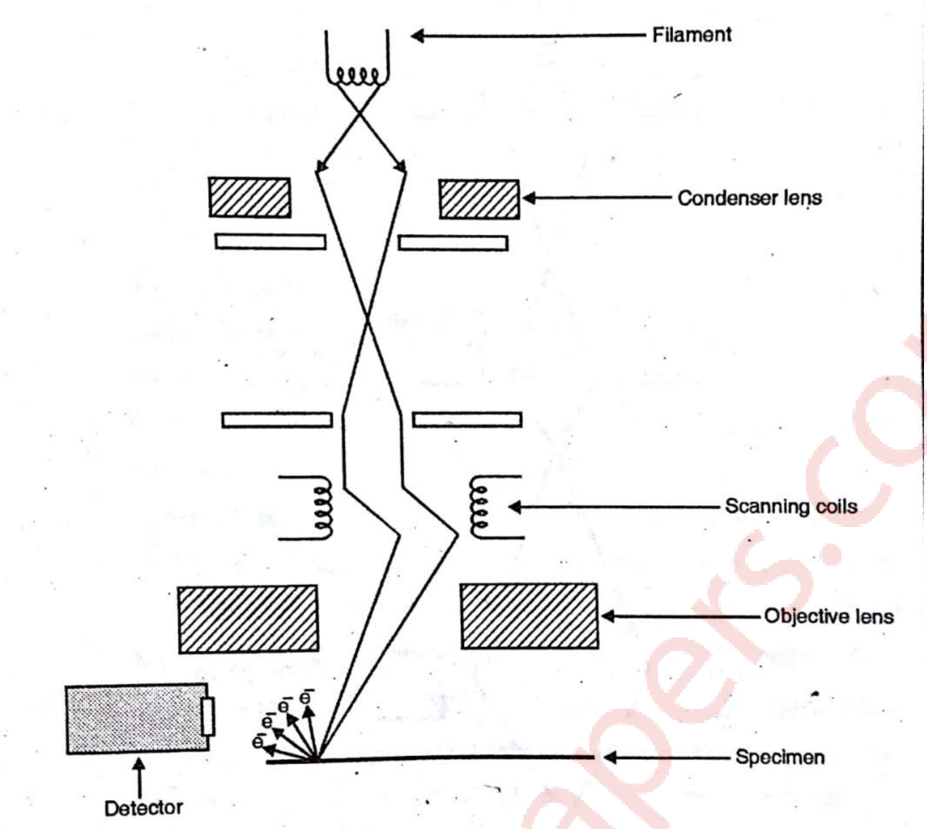
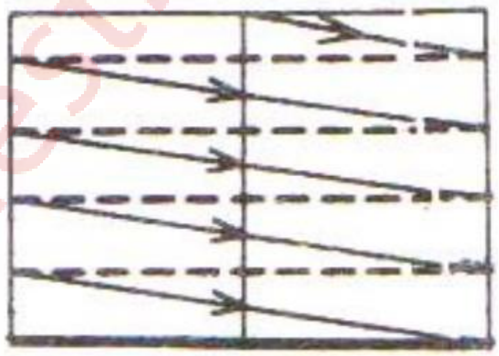


Fig. 8.3.2 : Schematic diagram of SEM

Working:

Stream of electrons are produced by the electron gun and these primary electrons are accelerated by the grid and anode. These accelerated primary electrons are made to be incident on the sample through condensing lenses and scanning coil.



These high speed primary electrons on falling over the sample produces low energy secondary electrons. The collection of secondary electrons are very difficult and hence a high voltage is applied to the collector.
These collected electrons produce scintillations on to the photo multiplier tube are converted into electrical signals. These signals are amplified by the video amplifier and is fed to the CRO.
By similar procedure the electron beam scans from left to right and the whole picture of the sample is obtained in the CRO screen.

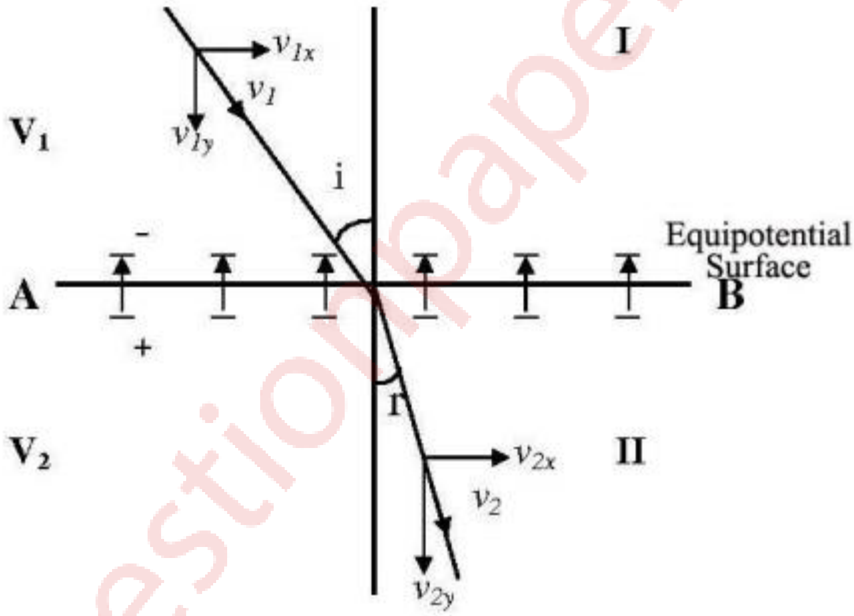
Q.4.b) Derive Bethe's Law for electron refraction.

Ans.

Region I has potential V1 and region II has potential V2. The plane surface AB constitutes one of the equipotential surfaces. Let an electron with velocity v1 enter region I making an angle I with the normal. As the electron passes through the equipotential surface AB, it experiences a force which alters its velocity. Because the electric field exists only in the y-direction, the vertical component (y-component) of electron changes while the tangential component (x-component) remains constant.

$$v_{1x} = v_{2x}$$
$$v_1 \sin i = v_2 \sin r$$
$$\frac{\sin i}{\sin r} = \frac{v_2}{v_1}$$

If V1>V2, v_{1y} increases while if V2>V1, v_{2y} increases.



In our case we have taken V2>V1. As the electrons move through the electric field their kinetic energy is provided by the respective potential energy of the electric fields.

Hence$mv_1^2/2=qV_1$

And $mv_2^2/2=qV_2$

Dividing the above equation we get,

$v_1^2/ v_2^2= V_1/ V_2$

$v_1/ v_2=\sqrt{V1/V2}$

Hence we get, $\frac{\sin i}{\sin r} = \frac{v_2}{v_1} = \sqrt{\frac{V2}{V1}}$

This is known as ***Bethe's law of electron refraction***.

Q.4.c) Derive the condition for absent spectra in grating.

Ans.

Absent Spectra with a Diffraction Grating

- It may be possible that while the first order spectra is clearly visible, second order may be not be visible at all and the third order may again be visible. It happen when for again angle of diffraction 0, the path difference between the diffracted ray from the two extreme ends of one slit is equal to an integral multiple of A if the path difference between the secondary waves from the corresponding point in the two halves will be A/2 and they will can all one another effect resulting is zero intensity. Thus the mining of single slit pattern are obtained in the direction given by.

$a \sin \theta = m\lambda$ ____ (1)
where m = 1, 2, 3, …… excluding zero but the condition for nth order principles maximum in the grating spectrum is
$(a + b) \sin \theta = n\lambda$ … ___ (2)

- If the two conditions given by equation (2) are simultaneously satisfied then the direction in which the grating spectrum should give us a maximum every slit by itself will produce darkness in that direction and hence the most favourable phase for reinforcement will not be able to produce an illumination i.e., the resultant intensity will be zero and hence the absent spectrum. Therefore dividing equation (2) by equation (1)

$((a+ b) \sin \theta)/a \sin \theta = n/ m$
$(a+ b) /a = n/m$

- This is the condition for the absent spectra in the diffraction pattern If a= b i.e., the width of transparent portion is equal to the width of opaque portion then from equation (3) n = 2m i.e., 2nd, 4th, 6th etc., orders of the spectra will be absent corresponds to the minima due to single slit given by m = 1, 2, 3 etc.

b = 2a
n=3m
i.e., 3rd, 6th, 9th etc., order of the spectra will be absent corresponding to a minima due to a
single slit given by m = 1, 2, 3 etc.

Q.5.a) Draw the block diagram of an optical fibre communication system and explain function of each block.

Ans.

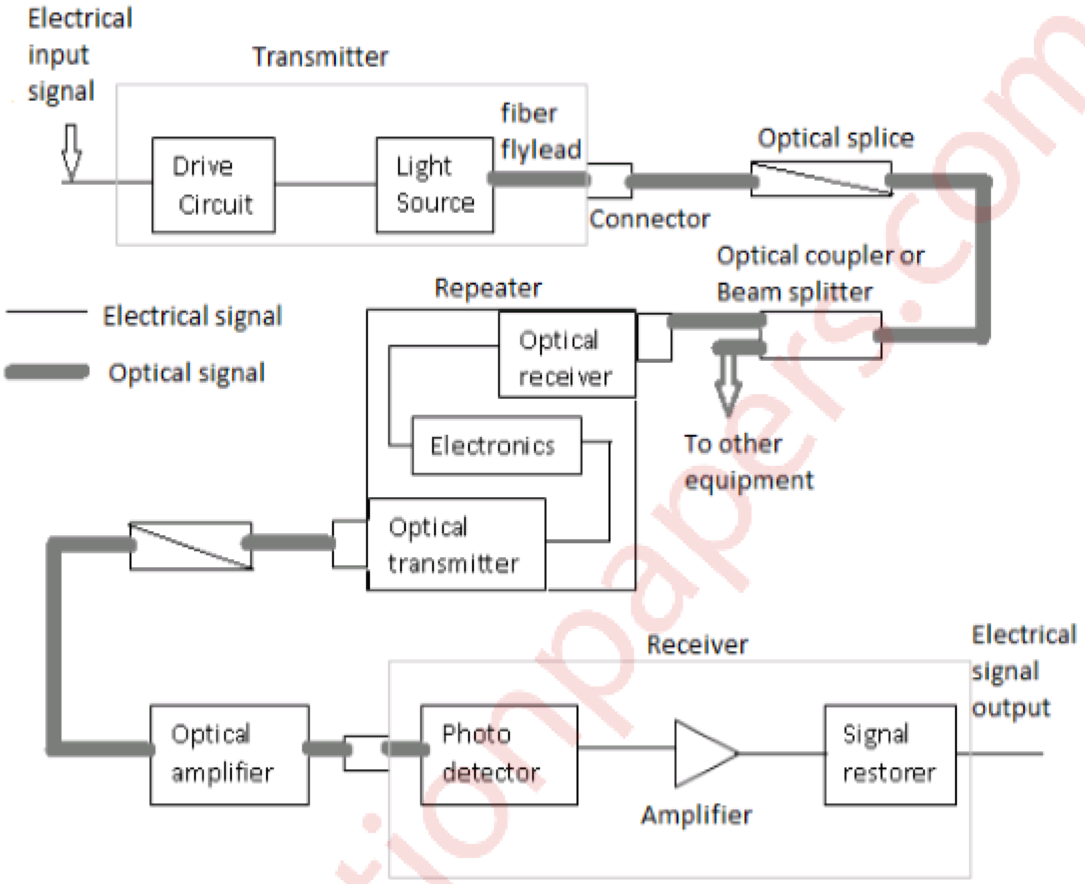


Figure 1

- The optical fiber consists of three main elements:

1. ***Transmitter:*** An electric signal is applied to the optical transmitter. The optical transmitter consists of driver circuit, light source and fiber flylead.
    - Driver circuit drives the light source.
    - Light source converts electrical signal to optical signal.
    - Fiber flylead is used to connect optical signal to optical fiber.
2. ***Transmission channel:*** It consists of a cable that provides mechanical and environmental protection to the optical fibers contained inside. Each optical fiber acts as an individual channel.
    - Optical splice is used to permanently join two individual optical fibers.

- Optical connector is for temporary non-fixed joints between two individual optical fibers.
- Optical coupler or splitter provides signal to other devices.
- Repeater converts the optical signal into electrical signal using optical receiver and passes it to electronic circuit where it is reshaped and amplified as it gets attenuated and distorted with increasing distance because of scattering, absorption and dispersion in waveguides, and this signal is then again converted into optical signal by the optical transmitter.

3. ***Receiver:*** Optical signal is applied to the optical receiver. It consists of photo detector, amplifier and signal restorer.
    - Photo detector converts the optical signal to electrical signal.
    - Signal restorers and amplifiers are used to improve signal to noise ratio of the signal as there are chances of noise to be introduced in the signal due to the use of photo detectors.

- For short distance communication only main elements are required.

  Source- LED

  Fiber- Multimode step index fiber

  Detector- PIN detector

- For long distance communication along with the main elements there is need for couplers, beam splitters, repeaters, optical amplifiers.

  Source- LASER diode

  Fiber- single mode fiber

  Detector- Avalanche photo diode (APD)

Q.5.b) Derive Maxwell's Third Equation.

Ans.

According to Faraday's Law, electromagnetic force induced in a closed loop is negative rate of charge of magnetic flux.

$$e = -\frac{d\emptyset}{dt}$$

Total magnetic flux on any arbitrary surface S

$$\emptyset = \oint B.ds$$

$$e = -\frac{d}{dt}\left[\oint B.ds\right] = -\oint \left[\frac{dB}{dt}\right].ds$$

The electromotive force is the work done in carrying a unit charge around the closed loop.

$$e = \oint E.dl$$

$$\oint E.dl = -\oint \left[\frac{dB}{dt}\right].ds$$

By using Stokes theorem contour integration can be converted to surface integration as

$$\oint E.dl = \oint [\nabla \times E].ds$$

$$\oint [\nabla \times E].ds = -\oint \frac{dB}{dt}.ds$$

$$\oint \left[\nabla \times E + \frac{dB}{dt}\right].ds = 0$$

$$\boldsymbol{\nabla \times E = -\frac{dB}{dt}}$$

This is ***Maxwell's third equation.***

Q.5.c) An electron enters a uniform magnetic field B=0.23x10^{-2} Wb/m^2 at 45^0 angle to B. Determine the radius and pitch of helical path. Assume electron speed to be 3x10^7 m/s.

Ans.

Given:- B=0.23x10^{-2} Wb/m^2

v=3x10^7 m/s

e=1.6x10^{-19} C

m=9.1x10^{-31} kg

Formula: R=mv/eB

$$R = \frac{9.1 \times 10^{-31} \times 3 \times 10^{7}}{1.6 \times 10^{-19} \times 0.23 \times 10^{-2}}$$

R=0.074 m

Thus the radius of helical path is **0.074m.**

Q.6.a) If $A = x^2z\,i - 2y^2z^2 j + xy^2zk$. Find $\nabla.A$ at point (1,-1,1).

Ans.

$$\nabla.A = \frac{\partial}{\partial x}(x^2z)i - \frac{\partial}{\partial y}(2y^2z^2)j + \frac{\partial}{\partial z}(xy^2z)k$$

$$\nabla.A = 2xz - 4yz^2 + xy^2$$

At(1,-1,1),

$$\nabla.A = 2(1)(1) - 4(-1)(1^2) + (1)(-1^2)$$

$$\nabla.A = 7$$

Q.6.b) A newtons rings setup is used with a source emitting two wavelength λ_1=6000A^0 and λ_2=4500 A^0. It is found that nth dark ring due to 6000A^0 coincides with (n+2)th dark ring due to 4500 A^0. If the radius of curvature of the lens is 90 cm, find the diameter of nth dark ring of 6000A^0.

Ans.

Given:- λ1=6000A^0

λ2=4500 A^0

R=90 cm

$(D_n)_{\lambda 1} = (D_{n+2})_{\lambda 2}$

Formula:- $D_n^2 = 4nR\lambda$

For nth dark ring λ1

$$\boldsymbol{(D_n^2)_{\lambda 1} = 4nR\lambda 1} \text{-------------(1)}$$

And for (n+1)th dark ring λ2

$$\boldsymbol{\left(D_{n+2}^2\right)_{\lambda 2} = 4(n+2)R\lambda 2} \text{----------------(2)}$$

$$4nR\lambda 1 = 4(n+2)R\lambda 2$$

$$n\lambda 1 = (n+2)\lambda 2$$

$$n = \frac{2\lambda 2}{\lambda 1 - \lambda 2}$$

$$n = \frac{2 \times 4500}{6000 - 4500}$$

$$\boldsymbol{n = 6}$$

Using Equation 1, the diameter of 6th dark ring for λ1 is

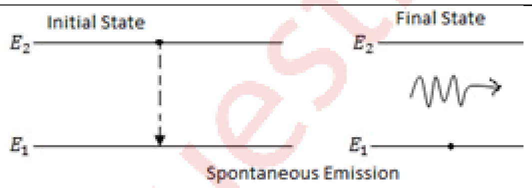
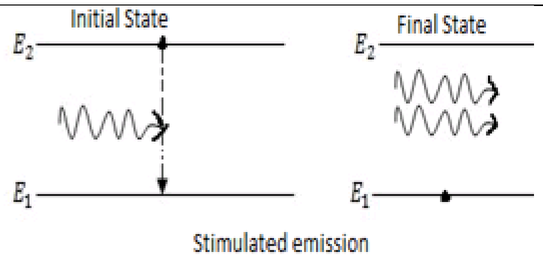
$$D_6^2 = 4 \times 6 \times 90 \times 6 \times 10^{-5}$$

$$D_6 = \sqrt{4 \times 6 \times 90 \times 6 \times 10^{-5}}$$

$$\boldsymbol{D_6 = 0.36\ cm}$$

Q.6.c) Differentiate between spontaneous and stimulated emission.

Ans.

Sr. No.	Spontaneous emission	Stimulated emission
1	The transition of an electron from the excited state to the ground state happens as a result of the natural tendency of the electron without the action of any external agent. The radiation produced as a result of such transitions is called as spontaneous radiation.	Stimulated emission of radiation is the process whereby photons are used to generate other photons that have exact phase and wavelength as that of parent photon.
2	This phenomenon is found in LEDs, Fluorescent tubes.	This is the key process of formation of laser beam.
3	There is no population inversion of electrons in LEDs.	Population inversion is achieved by various 'pumping' techniques to get amplification giving the LASER its name "Light amplification by stimulated emission of radiation."
4	No external stimuli required.	Thus stimulated emission is caused by external stimuli.
5	 **Figure 3.5: Spontaneous Emission**	 **Figure 3.6: Stimulated Emission**