MUMBAI UNIVERSITY

SEMESTER-2

APPLIED PHYSICS-2 SOLVED PAPER MAY 2017

Q.1 Attempt any five questions

Q.1(a) Why the Newton's rings are circular and fringes in wedge shaped film are straight? (3 marks)

Answer :

The Newton's rings are circular and the fringes in wedge shaped film are straight because :

1.The shape of the fringe depends on how the thickness of the air film enclosed varies.

2.In wedge shaped film the thickness of the air is constant over a straight line along the width of the wedge.

3.Hence the fringes are straight.

4.In a newtons ring set up the air film is enclosed below the convex lens. The thickness of the film is constant over a circle (or concentric circles) having center at the center of the lens.

5.Hence the fringes are circular.

Q.1(b) What is grating and grating element? (3 marks)

Answer :

1.A grating is an arrangement consisting of a large number of parallel slits of same width and separated by equal opaque spaces.

2.It is obtained by ruling equidistant parallel lines on a glass plate with the help of a diamond.

3.The lines act as opaque spaces and the incident light cannot pass through them.The space between the two lines is transparent to light and acts as a slit.

4.The spacing between the lines is of the order of wavelength of visible light.The number of a lines in a plane transmission grating is of the order of 15000 to 20000 per inch.

5. The width of each slit is **a** and opaque spacing between two consecutive slits is. **b.**

6.(a+b) is called grating element or grating constant.

7.It can be seen that distance between two consecutive slits is grating element.

Q.1(c) The core diameter of multimode step index fibre is 50 µm.The numerical aperture is 0.25.

Calculate the number of guided modes at an operating wavelength of 0.75 µm. (3 marks)

Answer:

$d = 50 \times 10^{-6}$ m

N.A = 0.25

$\lambda = 0.75 \times 10^{-6}$ m

$V = \frac{\pi d}{\lambda} \times N.A$

$= \frac{\pi \; x \; 50 \; x \; 10^{-6}}{0.75 \; x \; 10^{-6}}$

= 52.36

$\mathbf{N_m = \frac{V^2}{2}}$

= 1370.8

= 1370

Number of modes = 1370

Q.1(d) What is population inversion?

Explain it's significance in the operation of LASER. (3 marks)

Answer:

1.Normally atoms have the tendency to return to ground state releasing the absorbed energy. Hence, the population of atoms in ground state is greater than that of excited state.

2.For laser action, there should be more number of atoms in higher energy state.

3.Population inversion is the state in which the number of atoms in higher energy state is more than those in lower energy state.

4.Artificially creating more number of atoms in a higher energy states than the lower energy state is called population inversion. The chances of stimulated emission taking place increases when the state of population inversion is achieved in the medium.

Significance of population inversion in the operation of LASER :

(a) To increase the probability of stimulated emission,the number of atoms in the higher energy state must be greater than the number of atoms in the lower energy state.This is a precondition of LASER.

(b) It makes LASER possible with the help of metastable state.

(c) Amplification of light is ensured because of population inversion.

Q.1(e) What is a divergence of a vector field?

Express it in cartesian co-ordinate system. (3 marks)

Answer:

1.The divergence of a vector field simply measures how much the flow is expanding at a given point.

2.It does not indicate in which direction the expansion is occuring.

3.Divergence operates on a vector field ($\bar{F}$) and produces a scalar quantity that is a measure of how much the vectors are diverging.

4.Divergence is a scalar quantity.

5.Divergence in cartesian co-ordinate system is :

$$\overline{\nabla} \cdot \overline{A} = \frac{\partial A_x}{\partial x} + \frac{\partial A_y}{\partial y} + \frac{\partial A_z}{\partial z}$$

Q.1(f) What is meant by thin film?

Comment on the colours in thin film in sunlight. (3 marks)

Answer :

1.Thin film is the film whose thickness is of the order of wavelength of the light.It is used to expose it to light.

2.When a thin film is exposed to sunlight, it shows beautiful colours in the reflected system.

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

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

5.White light consists of a continuous range of wavelengths.

6.At a particular point of the film and for a particular position of the eye (with 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.

7.The colour seen will vary with the thickness of the film and inclination of the rays (with the position of the eye with respect to the film).

8.So, 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.

Q.1(g) An electron is accelerated through a potential difference of 18 kV in a colour TV cathode ray tube.

Calculate the kinetic energy and speed of electron. (3 marks)

Answer :

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

E = eV

= $1.6 \times 10^{-19} \times 18 \times 10^3$

= 28.8×10^{-16} J

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

v = $\sqrt{\frac{2E}{m}}$

= $\sqrt{\frac{2 \times 28.8 \times 10^{-16}}{9.1 \times 10^{-31}}}$

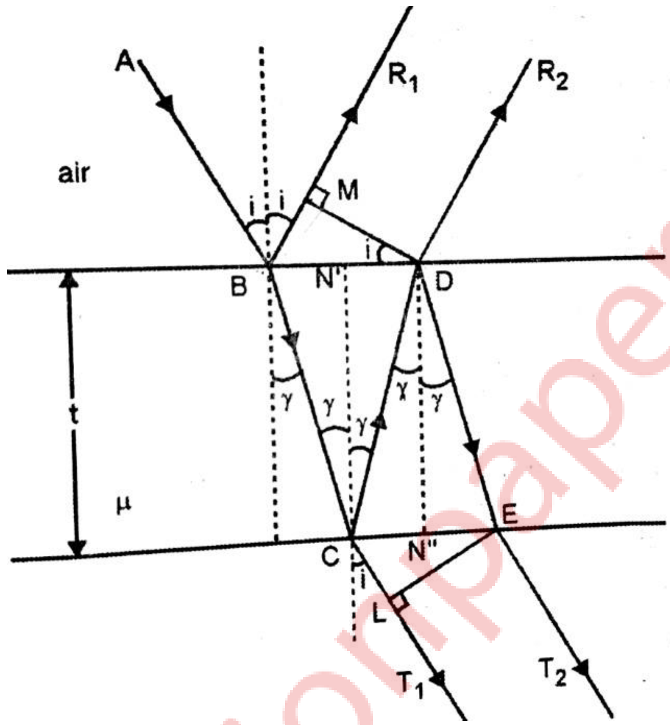
= 7.95×10^7 m/s

Kinetic energy of electron = 28.8 x 10-16 J

Speed of electron = 7.95×10^7 m/s

Q.2(a)Derive the conditions of maxima and minima due to interference of light transmitted from thin film of uniform thickness. (8 marks)

Answer:



Consider a thin film of uniform thickness (t) and R.I (μ)

On Reflected side,

The ray of light R_1 and R_2 will interfere.

The path difference between R_1 and R_2 is,

$\Delta = \mu(BC + CD) - BG$

BC = CD = t/cosr..........(1)

Now,

BD = (2t) tan r ....(2)

BM = BD sin i

BM = (2t) tan r sin i

BM = 2tμsinr(sinr / cosr)

BM = 2μt($\sin^2$r/cosr)..........(3)

Substituting (i) and (iii) in Δ :

$\Delta = \mu(t / \cos r + t / \cos r) - 2\mu t(\sin^2 r / \cos r)$

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

$\Delta = 2\mu t \cos r$

For transmitted system :

The transmitted rays CT1 and ET2 are also derived from the same incident ray AB and hence they are coherent.

Path difference = $\Delta = \mu(CD + DE) - CL$

For constructive interference :

$2\mu t \cos r = n\lambda$

For destructive interference :

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

Q.2(b) Difference between step index and graded index fibre.

An optical fibre has a numerical aperture of 0.20 and refractive index of cladding is 1.59.Determine the core refractive index and the acceptance angle for the fibre in water which has a refractive index of 1.33. (7 marks)

Answer :

Sr.no.	Step index fibre	Graded index fibre.
1.	The refractive index of the core of step index fiber is constant throughout the core.	The refractive index of the core of the graded index fiber is maximum at center,core and then it decreases towards core-cladding interface.
2.	Step index fiber is of two types viz; mono mode fiber and multi mode fiber.	Graded index fiber is of only one type,that is multi mode fiber.

3.	The light rays propagate in zig-zag manner inside the core.	The light rays,propagate in the form of skew rays or helical rays.
4.	The rays cross the fiber axis for every reflection.	The rays will not cross the,fiber axis.
5.	They can be manufactured easily.	They manufacturing process is complex.

Solution of problem :

N.A $= \frac{\sqrt{\mu_1^2 - \mu_2^2}}{\mu_0}$

In air μ_0 = 1

N.A = $\sqrt{\mu_1^2 - \mu_2^2}$ = 0.2

$\mu_1 = \sqrt{0.2^2 + 1.59^2}$

μ_1 = 1.6025

In water μ_0 = 1.33

N.A $= \frac{\sqrt{1.6025^2 - 1.59^2}}{1.33}$

= 0.15

$\sin \theta_{max}$ = N.A

$\theta_{max} = \sin^{-1}(0.15)$

θ_{max} = 8.6°

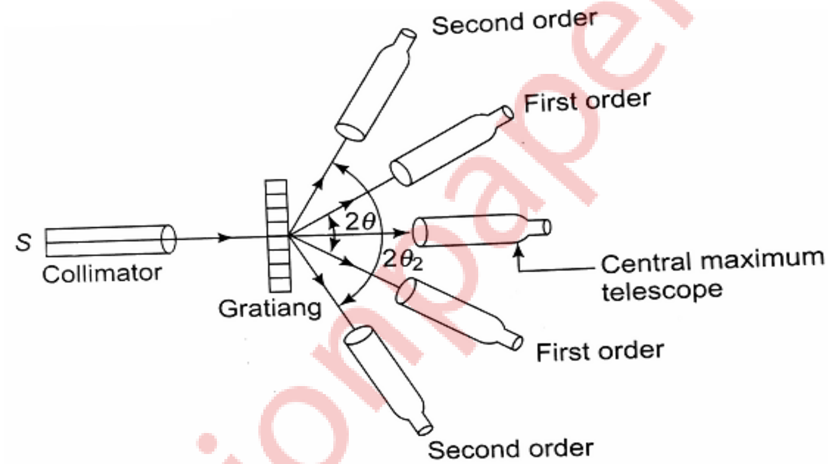
Core refractive index = 1.6025

Acceptance angle for the fibre in water = 8.6°

Q.3(a) Explain the experimental method to determine the wavelength of spectral line using diffraction grating.

What is the highest order spectrum which can be seen with monochromatic light of wavelength 6000 A° by means of a diffraction grating with 5000 lines/cm? (8 marks)

Answer :



1.The grating spectrum of the given source of monochromatic light is obtained by using a spectrometer.

2.The arrangement is as shown in Figure shown below.

3.The spectrometer is first adjusted for parallel rays.

4.The grating is then placed on the prism table and adjusted for normal incidence.

5.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.

6.On either side of this direct image a symmetrical diffraction pattern consisting of different orders can be seen.

7.The angle of diffraction θ for a particular order m of the spectrum is measured.

8.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.

9. The diffraction grating is often used in the laboratories for the determination of wavelength of light.

Solution of problem :

N = 5000 lines/cm

a + b = $\frac{1}{5000}$ cm

Using equation (a + b)sin θ = mλ

For m to be maximum sin θ should be equal to 1

n = $\frac{a+b}{\lambda}$

= $\frac{1}{5000 \times 6000 \times 10^{-8}}$

= 3.3

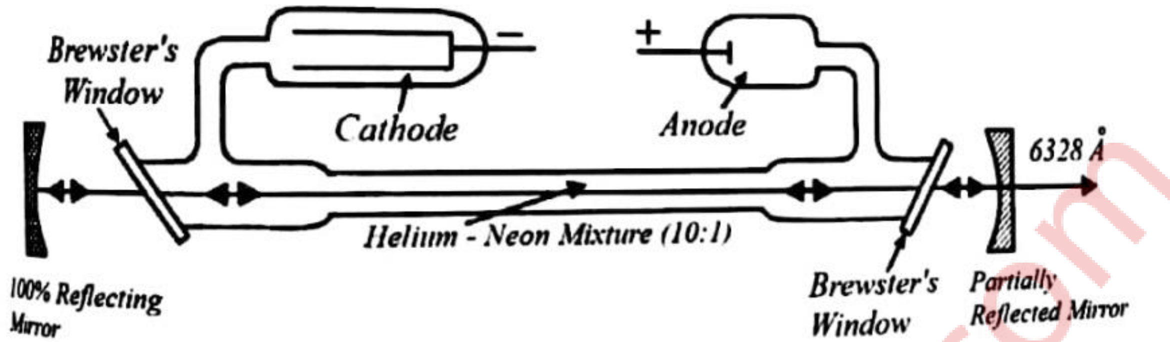
Maximum order of spectrum = 3

Q.3(b) Explain construction and working of He:Ne laser with neat label diagram. (7 marks)

Answer :

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 A°, in the red part of the visible spectrum.

CONSTRUCTION OF He-Ne LASER :



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

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 reflective mirror) are located at the opposite ends of the plasma tube.

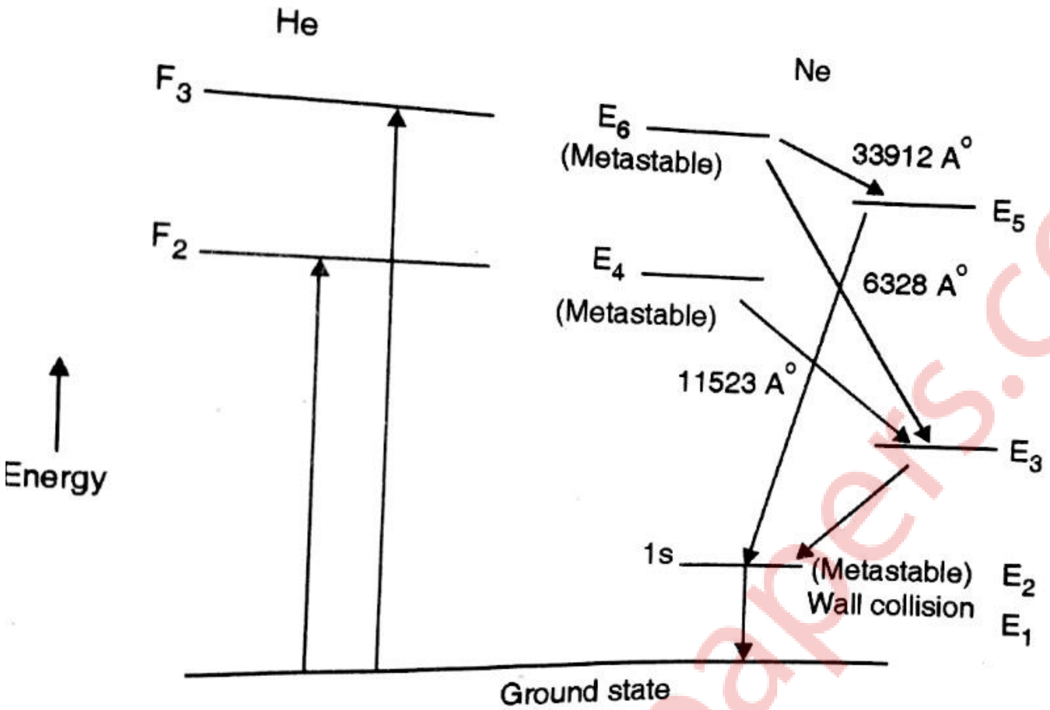
4.In order to make laser tubes more economical and durable manufacturers often attach the mirrors directly to the ends of the capillary tube.This is very common with small low power LASERS.

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 20 eV above the ground state. These are metastable states for helium.

2.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. E6 and E4 level of Ne atom nearly coincides with F3 and F2 of Helium.

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 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.

5.Consequently, three laser transitions take place.

E_6 to E_5 33900 A° (far IR region)

E_6 to E_3 6328 A° (visible)

E_4 to E_3 11500 A° (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.

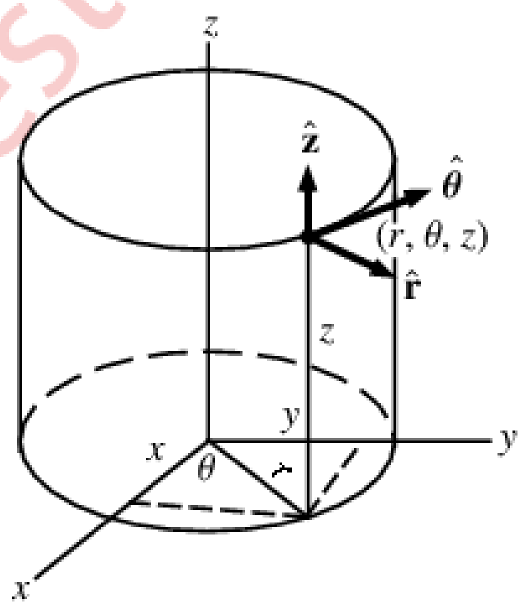
7.From E5 and E level neon atom can make downward transition to E2 level. Incoherent light is emitted due to spontaneous transition. As lower levels depopulate faster than upper levels it is easier to maintain population inversion throughout laser operation. E2 is again a metastable state.

8.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.

Q.4(a) Explain cylindrical co-ordinate system.

State the transformation relation between cartesian and cylindrical co-ordinates. (5 marks)

Answer:



1.A cylindrical coordinate system is a three-dimensional coordinate system that specifies point positions by the distance from a chosen reference axis, the direction from the axis relative to a chosen reference direction, and the distance from a chosen reference plane perpendicular to the axis.

2.The latter distance is given as a positive or negative number depending on which side of the reference plane faces the point.

3.The different co-ordinates of cylindrical co-ordinates is shown in the figure above.The angle θ is the angle made by r with X axis.

4.The origin of the system is the point where all three coordinates can be given as zero.

5.This is the intersection between the reference plane and the axis.

6.The distance from the axis may be called the radial distance or radius, while the angular coordinate is sometimes referred to as the angular position or as the azimuth.The radius and the azimuth are together called the polar coordinates, as they correspond to a two-dimensional polar coordinate system in the plane through the point, parallel to the reference plane.

7.The third co-ordinate is called the height or altitude if the reference plane is considered horizontal.

8.Cylindrical coordinates are useful in connection with objects and phenomena that have some rotational symmetry about the longitudinal axis, such as water flow in a straight pipe with round cross-section.

The transformation relation between cartesian and cylindrical co-ordinates are :

(A)Cartesian to cylindrical :

$r = \sqrt{x^2 + y^2}$

$\Phi = \tan^{-1}(\frac{y}{x})$

$z = z$

(B)Cylindrical to cartesian :

$x = r\cos\theta$

$y = r\sin\theta$

$z = z$

Q.4(b) Explain the concept of electrostatic focusing in electron impacts.

(5 marks)

Answer:

Electrostatic deflection is the method of aligning the path of charged particles by applying the electric field between the deflecting plates.

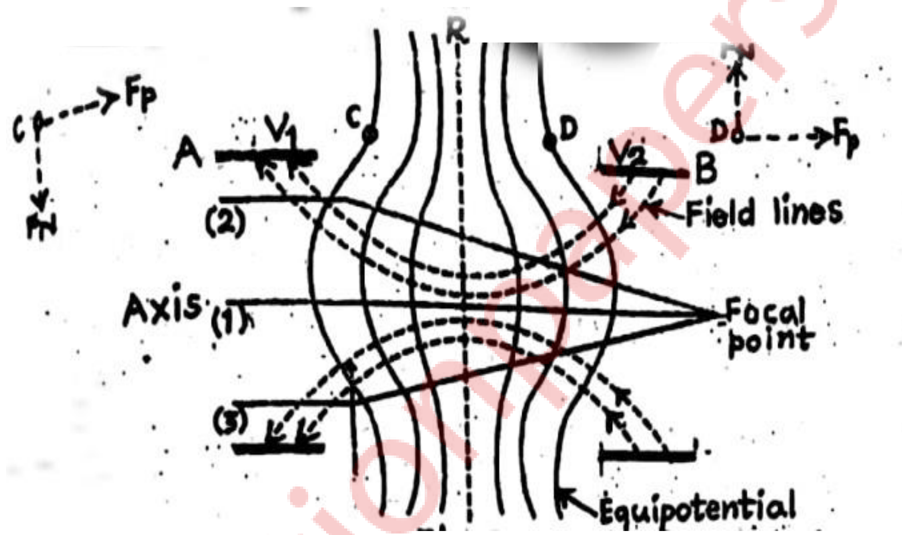


Diagram above represents the electrostatic focusing.A and B are two co-axial cylinders with potentials V1 and V2 such that V2>V1.R is the equipotential ring placed between A and B.

Working :

(1) Consider electron beam 1:

It will remain normal to all the equipotential surfaces and hence it is simply accelerated without any deviation of the path.

(2) Consider electron beam 2:

It will have following 2 effects:

(a) On the L.H.S off R: The parallel component of F_P will move the electron towards right while the normal component F_N will move the electron downwards by applying Fleming's left hand rule at point C.

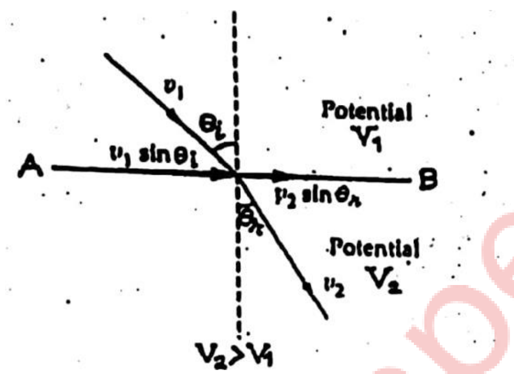
(b) On the R.H.S off R: F_P and F_N will move the electron towards right and towards up respectively by applying Fleming's left hand rule at point D.

(3) Consider electron beam 3:

It's path will be as shown with same case as case(2).

The focal length can be changed by varying V_1 and V_2

(4) Bethe's laws is also followed in electrostatic focusing :



$$\frac{v_2}{v_1} = \frac{\sin\theta_i}{\sin\theta_r}$$

(5)Electrostatic focusing is used for accelerating and focusing electron beams.

Q.4(c) Two optically plane glass strips of length 10 cm are placed one over the other.A thin foil of thickness 0.01 mm is introduced between them at one end to form an air film.

If the light used has wavelength 5900 A°,find the separation between consecutive bright fringes. (5 marks)

Answer :

$\tan\alpha = \frac{t}{l}$

$= \frac{0.01\ x\ 10^{-3}}{0.1}$

$= 10^{-4}$ radian

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

$= \frac{5.9\ x\ 10^{-7}}{2\ x\ 1\ x\ 10^{-4}}$

= 2.95 x 10-3 m

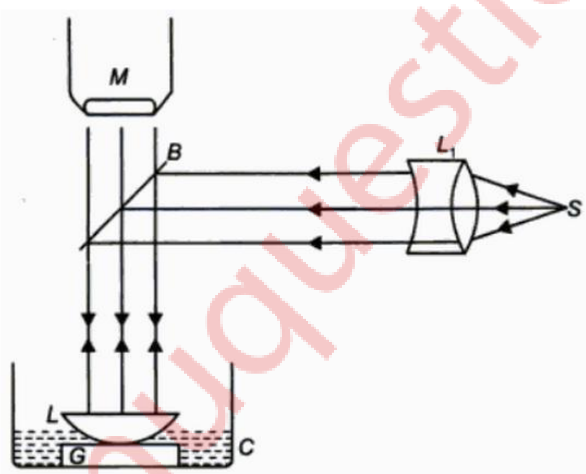
= 2.95 mm

The separation between consecutive bright fringes is 2.95 mm

Q.5(a) With Newton's ring experiment explain how to determine the refractive index of liquid. (5 marks)

Answer:

1.The experiment is performed when there is an air film between the plano-convex lens and the optically plane glass plate.



2.The diametre of the m^{th} and the $(m+p)^{th}$ dark rings are determined with the help of a travelling microscope.

For air :

$D_{m+p}^2 = 4(m+p)\lambda R$

$D_m^2 = 4m\lambda R$

$D_{m+p}^2 - D_m^2 = 4p\lambda R$

3.As shown in figure arrange the lens with glass plate. Pour one or two drops of liquid whose refractive index is to be determined without disturbing the arrangement. Now the air film between the lens and glass plate is replaced by the liquid. The diameters of m+pth and mth rings are determined.

For liquids,

$2\mu t\cos r = m\lambda$,for dark rings

For normal incidence cosr =1,so
$2\mu t = m\lambda$

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

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

Rearranging the above equation ,we get
$D_m^2 = \frac{4m\lambda R}{\mu}$

We have $D_{m+p}^2 - D_m^2 = 4p\lambda R$

For liquids,
$D_{m+p}^2 - D_m^2 = \frac{4p\lambda R}{\mu}$

From these two euations the refractive index of the given liquids is given by

$$\mu = \frac{D_{m+p}^2 - D_m^2}{D_{m+p}'^2 - D_m'^2}$$

4.In this way,refractive index of liquid is found using Newton's rings.

Q.5(b) Using spherical co-ordinate systems calculate the area of a disc of radius 2 cm. (5 marks)

Answer:

Consider the circular disc with centre at origin of X-Y plane.

Circular disc is a part of cylinder in cylindrical system.

z = 0

Differential area = ds = rdrd Φ

s = ∫ds

$s = \int_0^{2\pi} \int_0^2 r dr d\Phi$

s = 2 x 2$\boldsymbol{\pi}$

s = 4 $\boldsymbol{\pi}$ m^2

Area of disc = 4$\boldsymbol{\pi}$ m^2

Q.5(c) What are different techniques to synthesis nanomaterial?

Explain one of them in detail. (5 marks)

Answer:

The different techniques to synthesis nanomaterial are :

1.Ball milling

2.Sputtering

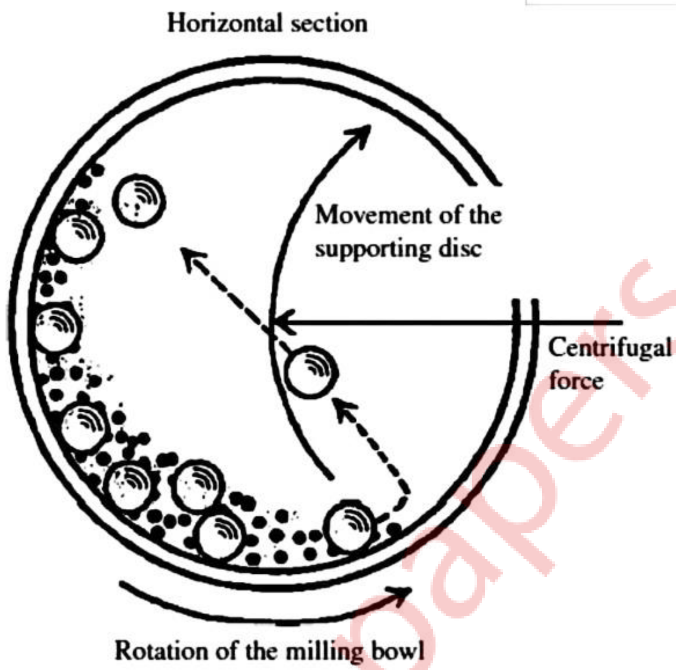
3.Vapour deposition

4.Sol gel technique

5.LASER synthesis

6.Inert gas condensation

BALL MILLING PROCESS :



1. As the name suggests, the ball milling method consists of balls and a mill chamber. Therefore over all a ball mill contains a stainless steel container and many small iron, hardened steel, silicon carbide, or tungsten carbide balls are made to rotate inside a mill (drum).

2. The powder of a material is taken inside the steel container. This powder will be made into nanosize using the ball milling technique. A magnet is placed outside the container to provide the pulling force to the material and this magnetic force increases the milling energy when milling container or chamber rotates the metal balls.

3. The ball to material mass ratio is normally maintained at 2 : 1.These silicon carbide balls provide very large amount of energy to the material powder and the powder then get crushed. This process of ball milling is done approximately 100 to 150 hrs to get uniform fine powder.

4. Ball milling is a mechanical process and thus all the structural and chemical changes are produced by mechanical energy.

Q.6(a) With neat diagram explain construction and working of scanning electron microscope. (5 marks)

Answer:

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

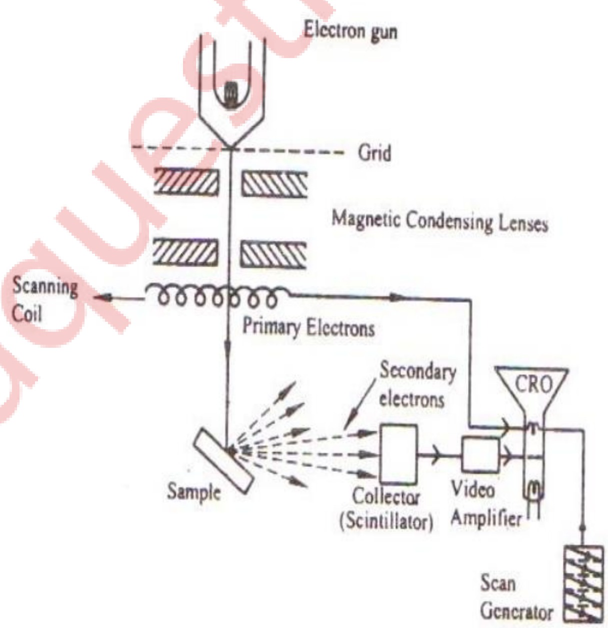
Principle:

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 :

1.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.

2.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.



Working :

1.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.

2.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.

3.By similar procedure the electron beam scans from left to right and the whole picture of the sample is obtained in the screen.

4.In this way,the scanning electron microscope works.

Q.6(b) Explain the construction and reconstruction of hologram with neat diagram. (5 marks)

Answer :

Holography technique to obtain 3D image of an object:

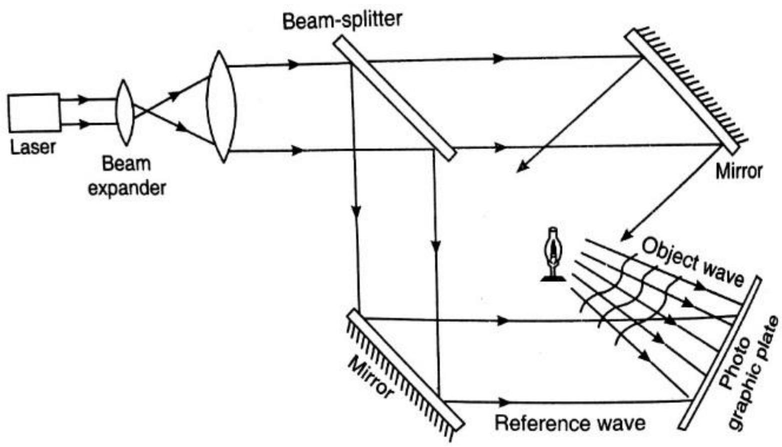
1. Holography is the science and practice of making holograms. Holography is actually a recording of interference pattern formed between two beams of coherent light coming from the same source.

2. In this process,both the amplitude and phase components of a light wave are recorded on a light sensitive medium such as a photographic plate. The recording is known as a hologram.

3. Holography requires an intense coherent light source.It became a practical proposition only after the invention of LASERS.

4. Holography is a two step process.In the first step,recording of hologram is done where the object is transformed into a photographic record and the second step is the reconstruction in which the hologram is transformed into image.

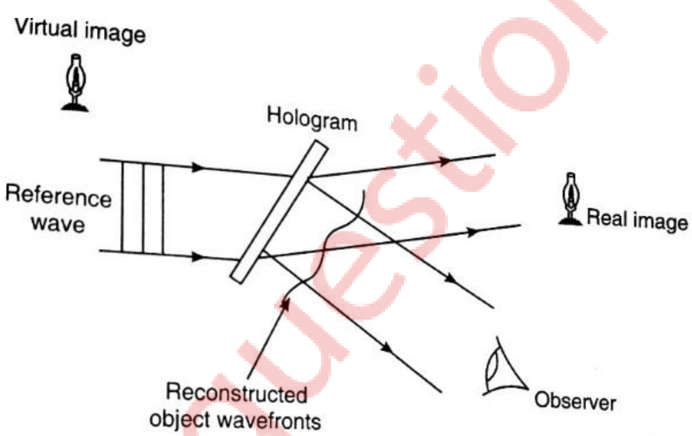
Construction process :



1.During the recording process we superimpose on the scattered wave emanating from the object,the another coherent wave(called as reference beam) of the same wavelength.

2.These 2 waves interfere in the plane of recording medium and produce interference fringes.This is the recording process of hologram.

Reconstruction process :



1.The reproduction of the image from the hologram is known as reconstruction of the hologram.

2.In this process,a wave identical to reference beam is used.

3.When the hologram is illuminated by the reconstruction wave,2waves are produced.

4.One wave appears to diverge from the object and provides the virtual image of the object.

5.The second wave converges to form the real image of the object.

Q.6(c) An electron is accelerated through a potential difference of 5 kV and enters a uniform magnetic field of 0.02 wb/m2 acting normal to the direction of electron motion.

Determine the radius of path. (5 marks)

Answer :

$$v = \sqrt{\frac{2qV}{m}} = \sqrt{\frac{2\ x\ 1.6\ x\ 10^{-19}\ x\ 5000}{9.1\ x\ 10^{-31}}} = 4193 \text{ x } 10^{4}$$

$$r = \frac{mv}{qB} = \frac{9.1\ x\ 10^{-31}\ x\ 4193\ x\ 10^{4}}{1.6\ x\ 10^{-19}\ x\ 0.02} = 0.0119 \text{ m}$$

Radius of path = 0.0119 m

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Q.1) Attempt any five of the following **(15 M)**

Q.1.A) Why the Newton's rings are circular and centre of interference pattern (reflected) is dark?

Ans:

i. In both air-wedge film and newton's ring experiments, each fringe is the locus of points of equal thickness of the film. In newton's ring experiment, the locus of points of equal thickness of air film lie on a circle with the point of contact of plano-convex lens and the glass plate as centre. So, the fringe are circular in nature and concentric..

ii. For wedge shaped air film, the locus of points of equal thickness are straight, lines parallel to the wedge so fringes appear straight and parallel.

Q.1.B) What is Rayleigh's criterion of resolution? Define resolving power of grating?

Ans:

i. According to the Rayleigh's criterion, two closely spaced point sources of light are said to be just resolved by an optical instrument only if the central maximum in the diffraction pattern of one Falls over the first minimum in the diffraction pattern of the other and vice versa.

ii. The resolving power of a grating is defined as the ratio of the wavelength of any spectral line to the difference in the wavelength between this line and a neighbouring lines such that two lines appear to be first resolved.

$$\therefore R.P = \lambda \,/\, \lambda + d\lambda$$

Where,
λ = wavelength of a line
$\lambda+d\lambda$ = wavelength of the next line that can just be seen s separate.

Q.1.C) Calculate the V number of an optical fibre having numerical aperture 0.25 and core diameter 20 μm, if its operating wavelength is 1.55 μm.

Ans:

$$NA = 0.25$$

$$\text{Core diameter} = 20\ \mu m$$

$$\lambda_0 = 1.55\ \mu m$$

Formula:

$$V = \pi d / \lambda_0 * NA$$

$$V = 3.14 * 20 * 10^{-6} / 1.55 * 10^{-6} * 0.25$$

$$V = 10.13$$

Q.1.D) What is pumping in LASER? Give the types of pumping.

Ans:

1. The process of raising large number of atoms from lower energy to a higher energy level is called pumping.
   Types of pumping:
   1. Optical pumping: which uses strong light source for excitation.
   2. Electrical pumping: which uses electron impact for excitation.
   3. Chemical pumping: which uses chemical reactions for excitation.
   4. Direct pumping: which uses direct conversion of electric energy into light energy.

Q.1.E) Show that the divergence of curl of a vector is zero.

Ans:

Let $\bar{F} = F_x \bar{a}_x + F_y \bar{a}_y + F_z \bar{a}_z$

$$\bar{F} = \nabla \times \bar{F} = \begin{bmatrix} a_x & a_y & a_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ F_x & F_y & F_z \end{bmatrix}$$

$$= \bar{a}_x \times \left(\frac{\partial F_z}{\partial y} - \frac{\partial F_y}{\partial z}\right) - \bar{a}_y \left(\frac{\partial F_z}{\partial x} - \frac{\partial F_x}{\partial z}\right) + \bar{a}_z \left(\frac{\partial F_y}{\partial x} - \frac{\partial F_x}{\partial y}\right)$$

Now div (curl $\bar{F}$) $= \nabla \cdot (\nabla \times \bar{F})$

$$= \frac{\partial}{\partial x}\left(\frac{\partial F_z}{\partial y} - \frac{\partial F_y}{\partial z}\right) - \frac{\partial}{\partial y}\left(\frac{\partial F_z}{\partial x} - \frac{\partial F_x}{\partial z}\right) + \frac{\partial}{\partial z}\left(\frac{\partial F_y}{\partial x} - \frac{\partial F_x}{\partial y}\right)$$

$$= \cancel{\frac{\partial^2 F_z}{\partial x \partial y}} - \cancel{\frac{\partial^2 F_y}{\partial x \partial z}} - \cancel{\frac{\partial^2 F_z}{\partial y \partial x}} + \cancel{\frac{\partial^2 F_x}{\partial y \partial z}} + \cancel{\frac{\partial^2 F_y}{\partial z \partial x}} - \cancel{\frac{\partial^2 F_x}{\partial z \cdot \partial y}} = 0$$

Q.1.F) Determine the magnetic field required to bend a beam consisting of electrons of speed 3 * 10^7 m/s in a circle of radius 5 cm.

Ans:

For the case of transverse field:

$$BeV = mv^2 / R$$

$$R = (m / e)(v / B)$$

For an electron with velocity 5 cm

$5 * 10^{-2} = (9.1 * 10^{-31} / 1.6 * 10^{-19}) * (3 * 10^7 / B)$

$B = (9.1 * 10^{-31} / 1.6 * 10^{-19}) * (3 * 10^7 / 5 * 10^{-2})$

$B = 3.413 * 10^{-3}$ wb/m^2

Q.1.G) What will be the fringe pattern if wedge shaped air film is illuminated with white light?

Ans:

At the thin edge, t=0 hence path difference between the rays is λ/2, a condition for darkness. Hence the edge of the film appears dark. It is called as zero order band. That is the reason extensively thin film appears dark in reflected light. Beyond the edge for a thickness t for which path difference is λ, we obtain the first bright band. As t increases to a value for which path difference is 3λ / 2 we obtain the first dark band.

For normal incidence and air film, r=0 and μ = 1

Total path difference = 2tcosθ + λ/2

2tcosθ = (2n-1) λ/2………………………… maxima

2tcosθ= nλ………………………………….....minima

For every small angle of wedge,

As θ=0, cosθ=1

2t= (2n-1) λ/2

2tcosθ= nλ

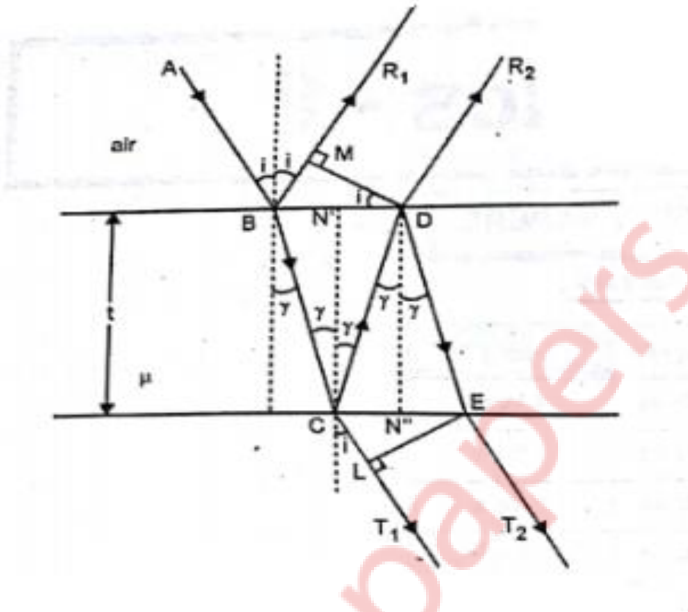
i.e. every next bright fringe will occur for thickness interval of λ/2 each

t=nλ/2, t=0, λ/2, 2λ/2, 3λ/2,…………….

i.e. every next dark fringe will occur for thickness interval of λ/2 each

Q.2.A) Obtain the condition for maxima and minima of the light reflected from a thin transparent film of uniform thickness. Why is the visibility of the fringe much higher in the reflected system than in the transmitted system. (8 M)

Ans:



i. The two rays will interfere consecutively if the path difference between them is an integral multiple of λ i.e.

$$2\mu t \cos r + \lambda/2 = n\lambda$$

Or

$$2\mu t \cos r = (2n-1)\lambda/2$$

Where,
n= 1, 2, 3, 4, ……….. (for maxima)
or

$$2\mu t \cos r = (2n-1)\lambda/2$$

Where n = 0, 1, 2, 3, 4, …………………

When this condition is satisfied the film will appear bright in the reflected system.

ii. The two rays will interfere destructively if the path difference between them is an odd multiple of λ/2 i.e.

$$2\mu t \cos r + \lambda/2 = (2n-1)\lambda/2$$

Or

$$2\mu t \cos r = n\lambda \qquad \text{(for minima)}$$

iii. The film which appears bright in reflected light appears dark in transmitted light and vice versa.

iv. For the transmitted light, the intensity of maxima is about 100% and the minima is about 85%. The result in poor contrast between bright and dark where in poor contrast between where as in reflected light, minima is having its intensity zero and maxima is nearly 15% of incident energy. This result in good contrast.

v. Hence visibility of fringe is much higher in reflected system.

Q.2.B) What is Numerical aperture? Explain the use of optical fibre in temperature sensor. The core diameter of a multimode step index fibre is 50 ⍰m. The numerical aperture is 0.25. Calculate the number of guided modes at an operating wavelength of 0.75 ⍰m. (7 M)

Ans:

1. Numerical aperture is the parameter which provides information about the acceptance angle i.e. the angle at which if the light ray enters the fibre it is sure to have total internal reflection experienced, that too in terms of parameters associated with fibre i.e. refractive index of core and cladding

   $NA = \sqrt{2\mu_1^2 . \frac{\mu_1-\mu_2}{\mu_1}}$

   ⍰$_1 = \sqrt{2\,\Delta}$
2. In optical fibre sensor particular applications the inherent physical property of the fibre material is utilised. The variations in refractive index of the fibre under the influences of external forces lead to the possibility of an optical fibre used as an transducer
3. Types of optical fibre:
   1. Extrinsic or hybrid or passive sensors.
   2. Intrinsic or active sensor

   Given:

   d= 50μm, NA = 0.25, λ_0 = 0.75⍰m

   To find: N= number of modes

   $N = V^2 / 2$

   $V = \pi d / \lambda_0 (NA)$

   $V = 52.36$

   ∴ Number of modes = $(52.36)^2 / 2 = 1371$

Q.3.A) Explain the experimental method to determine the wavelength of spectral lines using grating. A diffraction grating has 5000 lines / cm and the total ruled with is 5cm. Calculate dispersion for a wavelength of 5000 A^0 in the second order. (8 m)

Ans:

1. The grating spectrum of the given source of monochromatic light is obtained by using a spectrometer.

2. The spectrometer is first adjusted for parallel rays. The grating is then placed on the prism table and adjusted for normal incidence.
3. 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.
4. On either side of this direct image a symmetrical diffraction θ for a particular order m of the spectrum is measured.
5. The number of the lines per inch of grating are written it by manufacturers.

$$(a+b) = \frac{1}{number\ of\ lines/cm} = \frac{2.54}{number\ of\ lines/inch}$$

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

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

$$(a+b) = 1/5000$$

$$n = 2$$

using grating equation

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

$$2*5000*10^{-8} = 1/5000 *\sin\theta$$

$$\cos\theta = 0.866$$

Now dispersion power

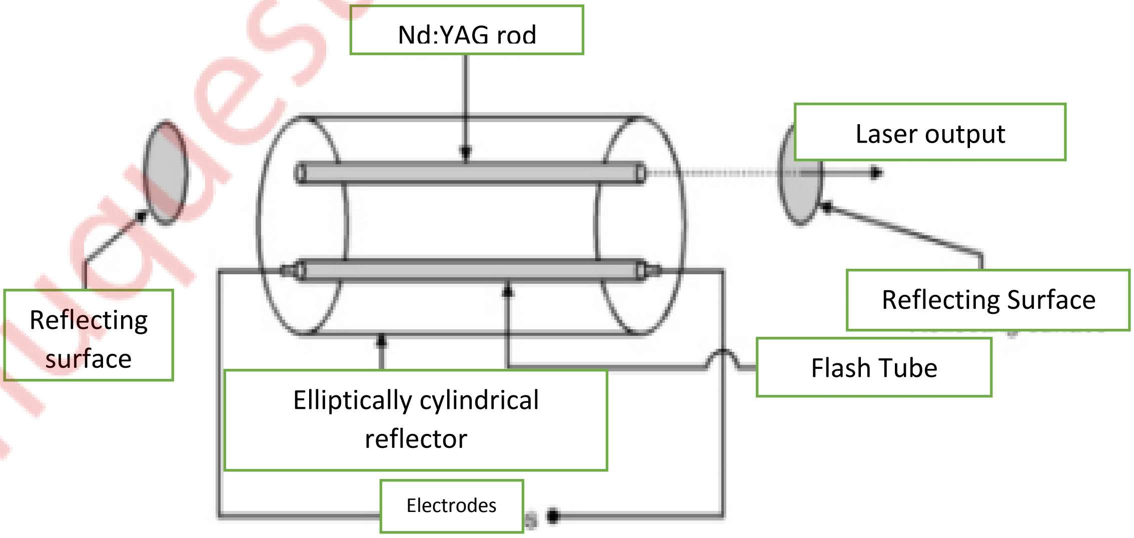
$$d\frac{d\theta}{d\lambda} = \frac{n}{(a+b)cos\theta} = \frac{2}{\frac{1}{5000}*0.866}$$

$= 11547$

Q.3.B) Explain construction and working of Nd: YAG laser. (7 M)

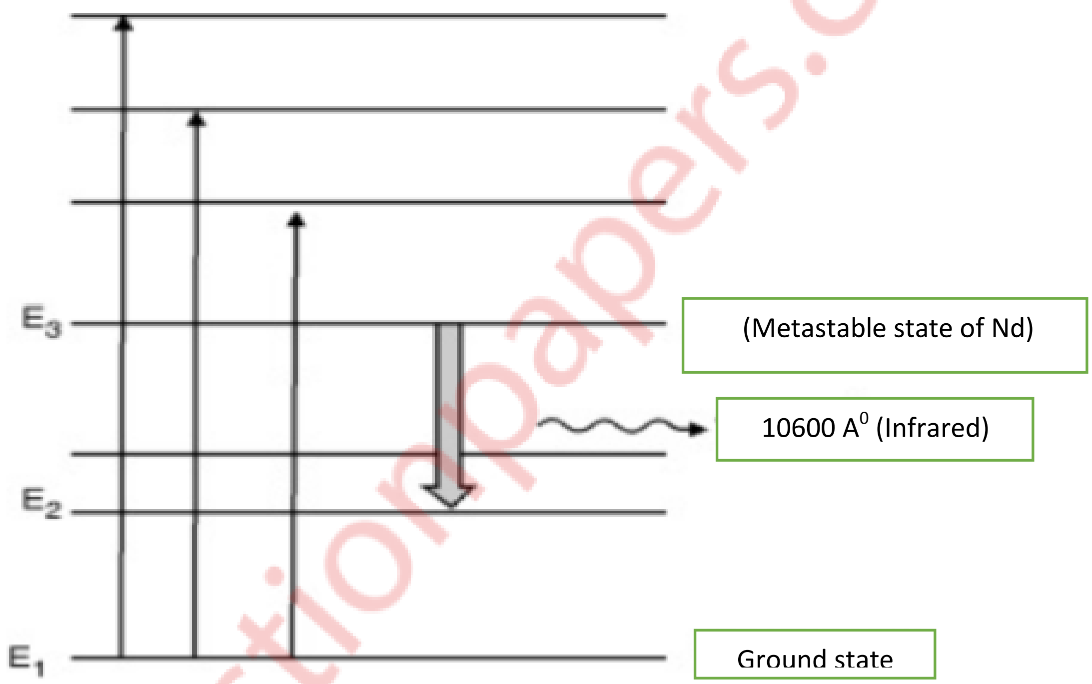
Ans:

1. It is solid state laser
2. Nd represents Neodymium
3. YAG represents yittrium Aluminium Garnet



1. As shown in figure, an elliptically cylinder reflector with both of its axis occupied by a flash lamp and Nd: YAG rod respectively. The light leaving one focus of the ellipse will certainly pass through the focus after reflection from reflecting surface. Hence after light generated by flash tube is focussed on the Nd: YAG rod.
2. Optical resonator is formed by highly silvered reflecting surface.

Working:



1. We have energy level E_1, E_2 and E_3 of Nd along with many other levels of YAG. E_1 is ground state and E_3 offers metastable state.
2. Pumping takes place with light of wavelength 5000A^0 to 8000A^0 which excites ND ions to higher state. The metastable state E_3 rapidly gets populated due to downward transitions from higher energy level as none of them is stable.
3. Population inversion takes place between E_3 and E_2. A continuous laser of 10600A^0 in infrared region is given out due to simulate emission taking place between E_3 and E_2.

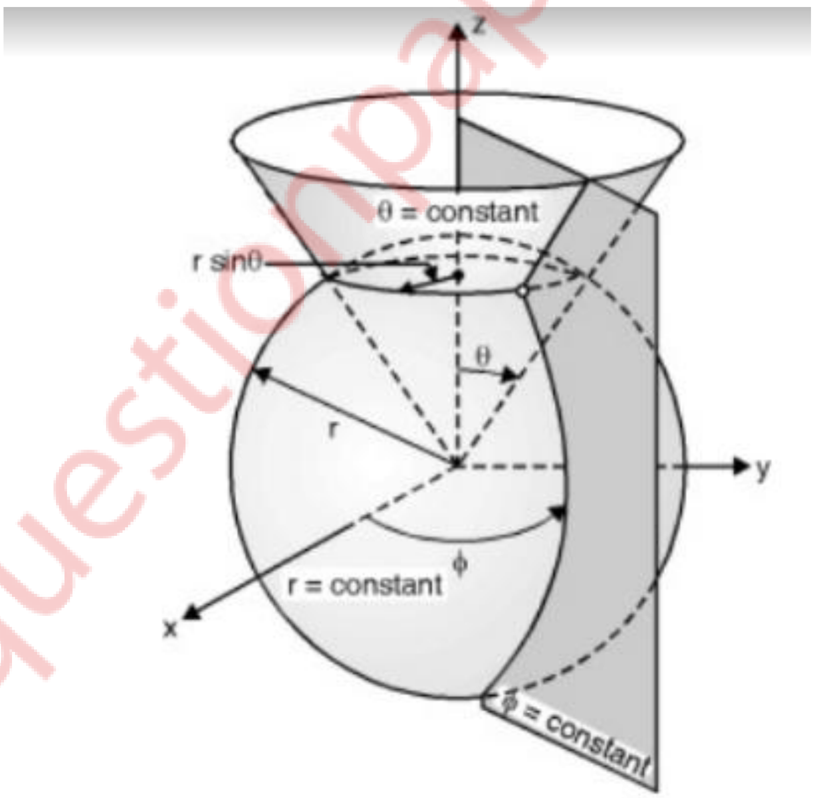
Q.4.A) Explain spherical co-ordinate system. State the transformation relation between Cartesian and spherical co-ordinates. (5 m)

Ans:

For spherical coordinates system also x, y, z axes are used for reference. Imagine a sphere of radius r with centre at origins. Any point on the sphere is ta the same distance r from origin, therefore the spherical surface is defined as r= constant surface.

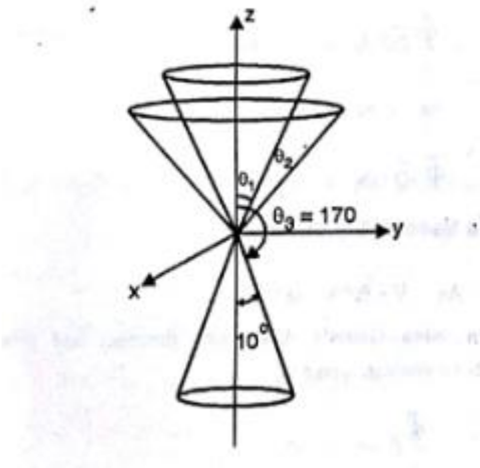
Now consider a line from origin making angle θ with z-axis. Rotate this line about z-axis fixing the end at the origin. This forms a cone with angle θ, this conical surface is defined as a θ = constant surface. When a sphere with centre at origin intersects with the vertical cone with vertex at origin, the intersection is a horizontal circle with radius equal to r sin θ. We want to locate a point in spherical coordinate system. Imagine a ∅ = constant plane similar to in cylindrical system. A horizontal circle with centre onz-axis, ∅=constant plane. The intersection is the point.

Because r=constant, θ=constant and ∅=constant surface intersects at a point, the point is defined as (r, ∅, θ). In spherical system varriations of angle θ is from 0 to 180^0 and variation of ∅ is from 0 to 360^0.



Conversion between cartesian and spherical coordinates:

The unit vector in spherical system are a_r, a_θ, $a_\emptyset$. These unit vectors are perpendicular to r= constant, θ=constant, ∅=constant surface respectively and in the increasing directions of the r, θ, ∅ respectivley.



When point is present in cartesian system, it must have corresponding cartesian coordinates. Here we are going to find relations between spherical coordinates. To find x and y corrsponding to point p, project point p in xy plane. The projection is OQ = rsinθ

Projection of OQ on x-axis is

$$OR=OQ\cos\emptyset=r\sin\theta\cos\emptyset$$

$$\therefore x= r\sin\theta\cos\emptyset$$

Projection of OQ on y-axis is

$$OS= OQ\sin\emptyset= r\sin\theta\sin\emptyset$$

$$y= r\sin\theta\sin\emptyset$$

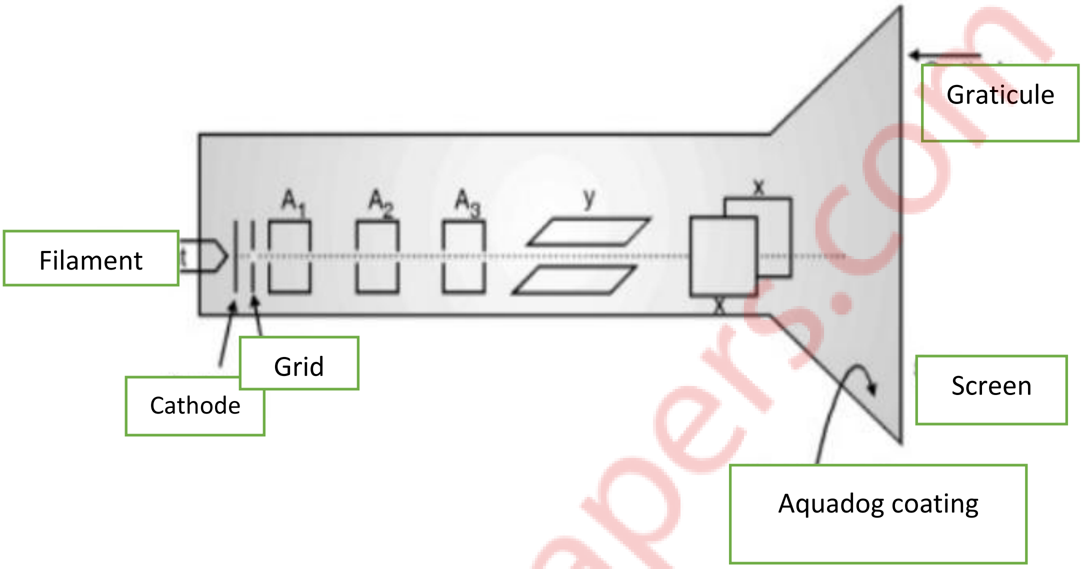
projection of OP on z-axisgives z-coordinats of p

projection of OP on z-axis = OT= OPcosθ

$$z=r\cos\theta$$

Q.4.B) Explain construction and working of cathode ray tube.(5 M)

Ans: A cathode ray tube is a specially designed vacuum tube in which an electron beam controlled by electric or magnetic fields are used to visual display of input electrical signal on the screen which is coated with fluorescent materials.



A CRT is a complex arrangement it is described by various parts like,

a) Electron gun
b) Deflective system
c) Fluorescent screen
d) Glass envelop

Electron gun:

1. The focused and accelerated electron beam is given out by the electron gun.
2. It consist of heater, a cathode, a grid, a pre-accelerating anode, a focussing anode and an accelerating anode.

Deflection system:

1. On reflecting particle "Pre requisites" and points 6,7 and 8 over there we get a general picture of electrostatic deflection.
2. There are two pairs of strictly parallel metal plates, two of them are parallel to X-axis called y plates as the causes deflection along X-axis.
3. The deflected beam generates as bright spot on the screen.

$$Y = D/2 * l/d * V/V_A$$

Fluorescent screen: The interior surface of circular front face of the CRT is coated with a thin translucent layer of phosphors.

Q.4.C) A wedge shaped air film having angle 40 seconds is illuminated by monochromatic light. Fringes are observed vertically through a microscope. The distance between 10

consecutive dark fringes is 1.2 cm. find the wavelength of monochromatic light used. (5 M)

Ans:

Given:

Θ = 40 seconds = 40 / 3600 degrees

= 40 / 3600 * π / 180 radians, β = 0.12 cm

Formula:

Spacing between the consecutive bright fringes is, $\beta = \lambda / 2\theta$ (for air film)

The wavelength is, $\lambda = 2\beta * \theta$

$$\Lambda = 2 * 0.12 * 40 * \pi / 3600 * 180$$

$$= 46.54 * 10^{-8} \text{ cm}$$

$$\lambda = 4654 \text{ A}^0$$

Q.5.A) With neat diagram explain construction and working of atomic force microscope. (5 M)

Ans:

1. 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.
2. Atomic force microscope is a modified TEM to overcome which woks as the probe in touch with sample using a microstable cantilever.
3. 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.
4. The force present 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.
5. 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 used for accuracy.
6. The information is later converted to visible one.
7. It overcomes the difficulty of TEM i.e. the problem associated with no-conducting material as AFM does not generate any current.
8. Depending on the situation forces that are measured in AFM include mechanical contact force, vander wall forces, capillary forces, electrostatic and magnetic forces.

Q.5.B) Derive Maxwell's two general equations in integral and differential form. (5 M)

Ans:

1. As the magnetic lines of forces are closed, the number of magnetic lines of flux entering any surface is exactly same as leaving.

$$\therefore \oint_v \bar{B} \cdot ds = 0$$

Using Gauss divergence theorem, convert surface integral to volume integral.

$$\therefore \oint_v \bar{B} \cdot ds = \oint_v \nabla \cdot \bar{B}\, dv = 0$$

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

This is point form of Maxwell's second equation.

Maxwell's second equation in integral form

$$\therefore \oint_v \bar{B} \cdot ds = 0$$

Q.5.C) an electron is accelerated through a potential difference of 5kv and enters a uniform magnetic field of 0.02 wb/m² acting normal to the direction of electron motion. Determine radius of the path. (5 M)

Ans:

for the case of acceleration due to electric field

$$1 / 2\ mv^2 = eV$$

$$V = \sqrt{\frac{2e}{m} * v}$$

And for the case of transverse field

$$BeV = mV^2 / R$$

$$R = (m/e)(V/B)$$

$$= (m/e)(V/B) \sqrt{\frac{2e}{m} * v}$$

$$= 1/B \sqrt{\frac{2*9.1*10^{-31}*5*10^3}{1.6*10^{-19}}}$$

$$= 0.012 \text{ m}$$

$$R = 12\text{mm}$$

Q.6.A) What are the different techniques to synthesise nanomaterial? Explain one of them in detail. (5 M)

Ans:

Various techniques are adopted for the synthesise of nanomaterial that too in various forms like nanoparticle, nanopowder, nanocrystals, nanofilms, nanowires, nanotubes, nanodots.

These methods include:

1. Ball milling
2. Sputtering
3. Vapour deposition
4. Sol gel technique
5. Electro deposition
6. Mechanical crushing or ball milling

7. Laser synthesis
8. Internal gas condensation.

Vapour deposition:

1. This method is used to prepare nanopowder.
2. In this technique initially the material is heated to form a solid surface under vacuum condition which forms nanopowder on the surface of the solid.

Q.6.B) What is holography? Differentiate between holography and photography. (5 M)

Ans:

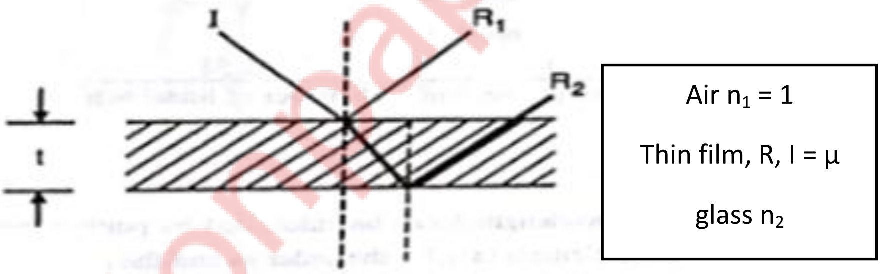
1. The advent of lasers has made the art of holography possible. Photography can be thought of as a new approach to the problem of generating images. An ordinary photography represents a two dimensional recording of three dimensional scene.
2. The emulsion of the photographic plate is sensitive to only intensity variations. In this process the phase information carried by the electromagnetic wave scattered from the object is lost. Since only the intensity pattern is recorded, the 3D character of the object is lost.
3. The principal behind holography is "During the recording process one superimposes on the scattered wave another coherent wave of same wavelength."
4. These two waves interfere in the plane of the recording medium and produce interference fringes. This is known s recording process. The interference fringes characteristic of light of object is formed. The recording medium records the intensity distribution in the interference pattern.
5. The interference pattern is recorded in it not only the amplitude distribution but also the phase of the electromagnetic waves scattered from the object. Since the recorded intensity pattern has both the amplitude and the phase recorded in it has been called "HOLOGRAM".
6. The hologram has little resemblance to the object. It has in it a coded form of a wavefront. The reproduction the image is known as reconstruction in which a wave identical to the one used as reference wave is used.
7. When hologram is illuminated by the reconstruction wave, two waves are produced. One wave appeared to diverge from the object and provides the virtual image of the object. The second wave converges to form a second image which is real.

Q.6.C) Describe in detail the concept of anti-reflecting film with a proper ray diagram.

(5 M)

Ans:

1. We are aware that compound microscope, telescope, camera lenses, etc. uses a combination of lenses.
2. 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. For advance telescopes that total loss comes out to be nearly 30% and cannot be tolerated if working under low intensity applications.
3. In order to reduce the reflection loss a transparent film of upper thickness is deposited on the surface. This film is known is "non reflecting film."
4. Popular material uses Mgf_2 because its refractive index is 1.38. cryolite is also used.
5. Thickness of the film may be obtained for given purpose as shown below:



6. Let ray I incident up on thin film at Mgf_2 coated on glass. This rays is reflected from upper surface as R_1 and from lower surfaces as R_2. The optical path difference between these two rays is $n_1(2t)$. as the incident ray enters from rarer to denser twice i.e at air to film and film to glass.
7. If both the rays R_1 and R_2 interfere with each other and path difference is $(2n+1)\lambda/2$, the destructive interference will take place.
   $\therefore 2n_1t=\lambda/2,\ n_1t=\lambda/4\mu \quad (n=0)$
   It means, in order to have destructive interference a layer of $n_1t=\lambda/4$ is coated on glass plate.

MUMBAI UNIVERSITY

SEMESTER-2

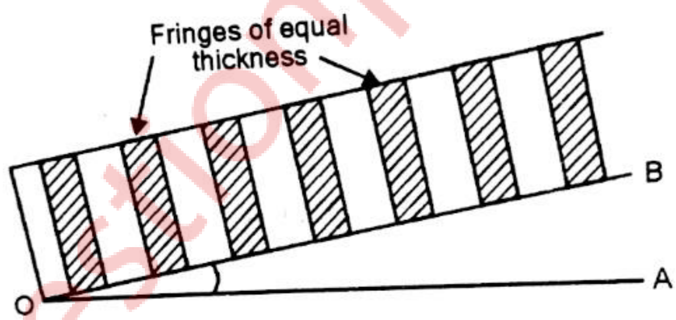
APPLIED PHYSICS-2 SOLVED PAPER MAY 2018

Q.1 Attempt any five questions

Q.1(a)Explain how interference in wedge shaped film is used to test optical flatness of given glass plate. (3 marks)

Answer :

1.The phenomenon of interference is used in testing the plainness of the surface of glass plate.



2.If two surfaces OA and OB are perfectly plane,the air film between them would gradually vary in thickness from O to A.The fringes are of equal thickness as each fringe is the locus of points at which the thickness of the film has a constant value.

3.To test the optical flatness of a surface,the specimen surface to be tested(OB) is placed over an optically plane surface (OA).

4.The fringes are observed in the field of view.

5.If the fringes are of equal thickness then surface is plane.

6.If the fringes are not of equal thickness then surface is not plane.

7.In this way interference in wedge shaped film is used to test optical flatness of given glass plate.

Q.1(b)What is diffraction grating?

What is the advantage of increasing the number of lines in the grating?

(3 marks)

Answer :

1.A diffraction grating is an arrangement consisting of a large number of parallel slits of same width and separated by equal opaque spaces.

2.It is obtained by ruling equidistant parallel lines on a glass plate with the help of a diamond.

3.The lines act as opaque spaces and the incident light cannot pass through them.The space between the two lines is transparent to light and acts as a slit.

4.The spacing between the lines is of the order of wavelength of visible light.The number of a lines in a plane transmission grating is of the order of 15000 to 20000 per inch.

Advantage of increasing the number of lines in the grating are :

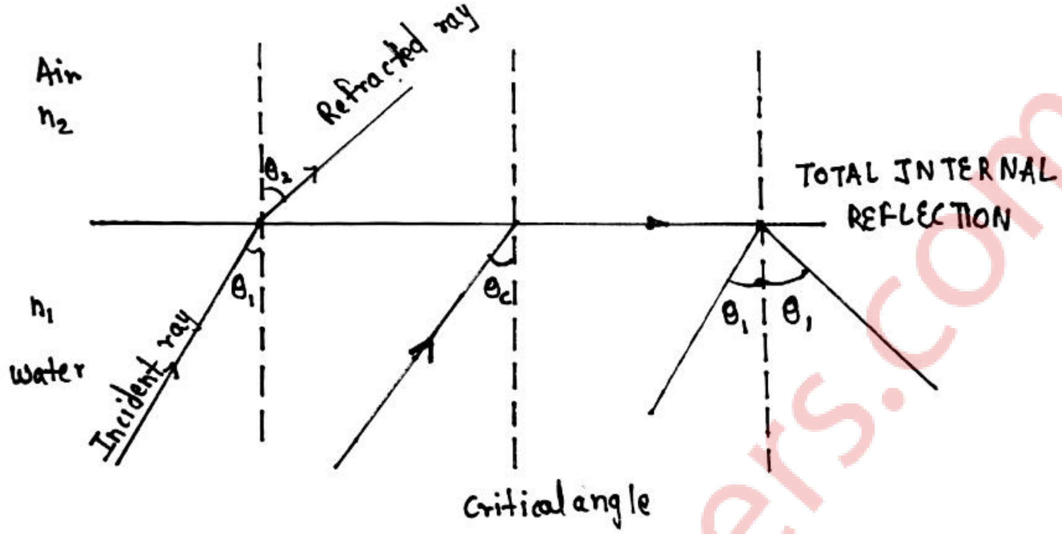
(a) The number of principal maxima that can be seen on a screen increases.
(b) The distance between two adjacent principal maxima increases.

Q.1(c)With neat ray diagram explain the concept of total internal reflection (TIR). (3 marks)

Answer:

1.Total internal reflection is the phenomenon which occurs when a propagated wave strikes a medium boundary at an angle larger than a particular critical angle with respect to the normal to the surface.

2.It refers to the complete reflection of a ray of light within a given medium from the surrounding surface. Here, the ray of light continues to be reflected within the medium (glass, water etc.) without being refracted.



3.When a ray of light is passing from a denser medium to rarer medium,if we increase the angle of incidence with normal,then at an angle known as critical angle(θ_c) a particular condition arrives in which the refracted ray becomes parallel to the boundary surface.

4.If any ray of light moving from denser medium to rarer medium strikes the boundary surface having incident angle greater than critical angle,then the ray of light continues to be reflected within the medium being refracted.

This is known as total internal reflection(TIR).

Q.1(d)Differentiate between spontaneous and stimulated emission. (3 marks)

Answer:

Sr.no.	**Spontaneous emission**	**Stimulated emission**
1.	When an atom in an excited state makes a transition into ground state by emission of photon, without any external stimulus, it’s called spontaneous emission.	When an atom in an higher energy state is forced by a photon to make a transition into ground state resulting into emission of another photon is called stimulated emission.
2.	It is not useful for LASER.	It is useful for LASER.
3.	Spontaneous emission does not require an external electromagnetic stimulus to release energy	Stimulated emission does require external electromagnetic stimuli to release energy.

4.	The probability of spontaneous emission to take place is higher than the probability for stimulated emission to take place	The probability of stimulated emission to take place is higher than the probability for spontaneous emission to take place

Q.1(e)Find cylindrical co-ordinates of a point ($3\bar{\imath} + 4\bar{\jmath} + \bar{\boldsymbol{k}}$) (3 marks)

Answer:

The point is (3,4,1)

r $=\sqrt{\boldsymbol{x}^2+\boldsymbol{y}^2}$

$=\sqrt{3^2+4^2}$

= 5

θ = $\tan^{-1}(\frac{y}{x})$

= $\tan^{-1}(\frac{4}{3})$

= 53.13°

= $0.2952\boldsymbol{\pi}$

z = z = 1

Point in cylindrical system is ($5, 0.2952\boldsymbol{\pi}, \mathbf{1}$)

Q.1(f)In Newtons's ring experiment,what will be the order of dark ring which will have double the diameter of 40th dark ring? (3 marks)

Answer :

For dark ring

$\mathbf{D^2_n = 4\, n\, \lambda\, R}$

$D^2_{40} = 4 \times 40 \times \lambda \times R$ …………(1)

Let n^{th} be the order of ring whose diameter is double the diameter of 40^{th} dark ring .
$(2D_{40})^2 = 4 \times n \times \lambda \times R$……………(2)

From equation 1 and 2

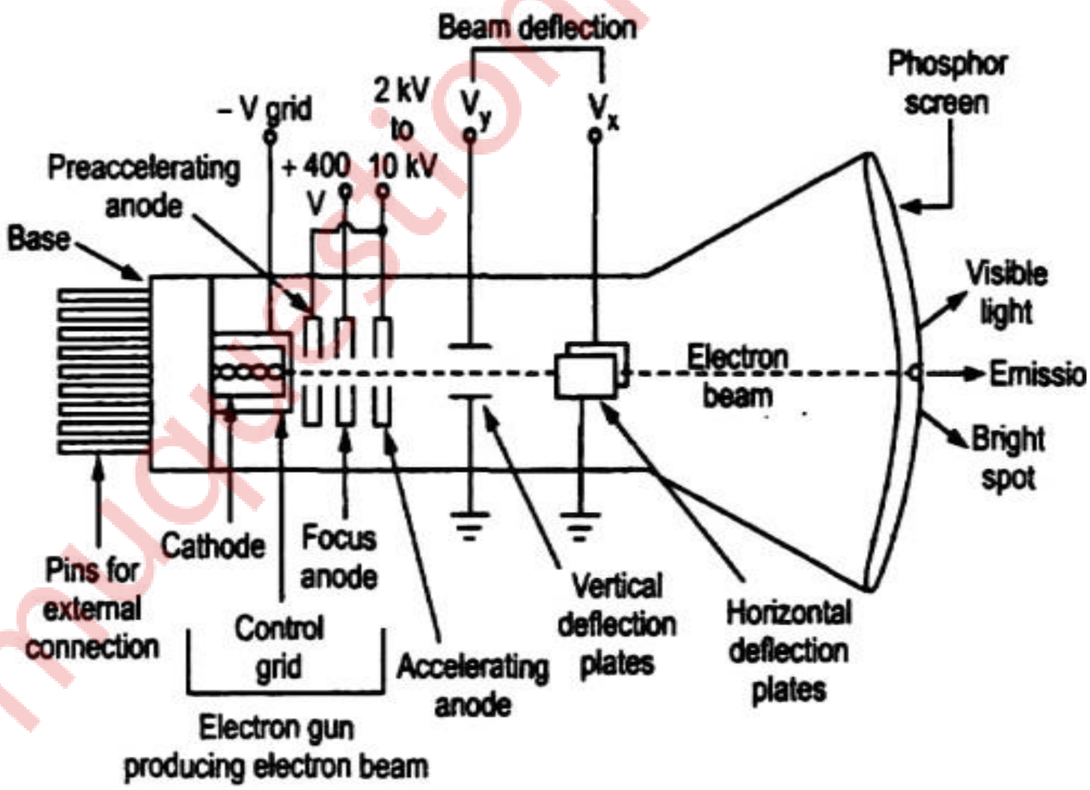
$\frac{D_{40}^2}{4D_{40}^2} = \frac{40}{n}$

n= 160

Value of n = 160

Q.1(g)Draw the block diagram of cathode ray tube and briefly explain its parts.

(3 marks)



Answer :

The main parts of the CRT are

i) Electron gun

ii) Deflection system

iii) Fluorescent screen

iv) Glass tube or envelope

v) Base

ELECTRON GUN

1.The electron gun section of the cathode ray tube provides a sharply focused, electron beam directed towards the fluorescent-coated screen.

2.This section starts from thermally heated cathode, emitting the electrons.

3.The control grid is given negative potential with respect to cathode.

4.This grid controls the number of electrons in t beam, going to the screen.

5.The light emitted is usually of the green colour.

Deflection System

When the electron beam is accelerated it passes through the deflection system, with which beam can be positioned anywhere on the screen.

Fluorescent Screen

1.The light produced by the screen does not disappear immediately when bombardment by electrons ceases, i.e., when the signal becomes zero.

2.The time period for which the trace remains on the screen after the signal becomes zero is known as "persistence or fluorescence" .

3.The persistence may be as short as a few microsecond, or as long as tens of seconds or even minutes.

4.Medium persistence traces are mostly used for general purpose applications. Ø Long persistence traces are used in the study of transients.Long persistence helps in the study of transients since the trace is still seen on the screen after the transient has disappeared.

Glass Tube

1.All the components of a CRT are enclosed in an evacuated glass tube called envelope.

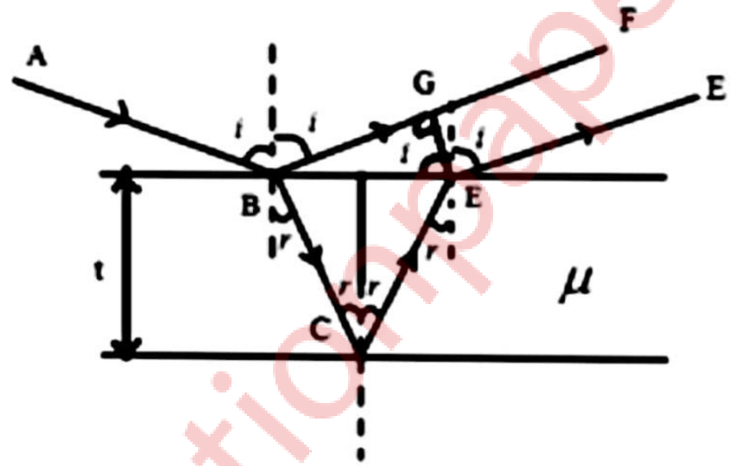
2.This allows the emitted electrons to move about freely from one end of the tube to the other end.

Base

The base is provided to the CRT through which the connections are made to the various parts.

Q.2(a)Derive the conditions of maxima and minima due to interference of light reflected from thin film of uniform thickness. (8 marks)

Answer:



Consider a thin film of uniform thickness (t) and R.I (μ)

On Reflected side,

The ray of light BF and DE will interfere.

The path difference between BF and DE is,

$\Delta = \mu(BC + CD) - BG$

$BC = CD = t/\cos r$..........(1)

Now,

$BD = (2t) \tan r$ ....(2)

$BG = BD \sin i$

$BG = (2t) \tan r \sin i$

BG = 2tμsinr(sinr / cosr)
BG = 2μt(sin^2r/cosr)..........(3)

Substituting (i) and (iii) in Δ :

Δ = μ(t / cosr + t / cosr)−2μt(sin^2r / cosr)

= 2μtcosr(1−sin^2r)

Δ = 2μtcosr

This is a geometric path difference. However, there is a phase change of π, as ray BF is reflected from a denser medium. Hence we need to add ±λ2 to path difference

Δ = 2μtcosr ± λ2

For Destructive Interference:

Δ = nλ

2μtcosr±λ2=nλ

2μtcosr=(2n±1)λ2.....(n=0,1,2,...)

This is the required expression for constructive Interference or Maxima.

For Destructive interference:

Δ = (2n±1)λ/2

2μtcosr ± λ/2 = nλ

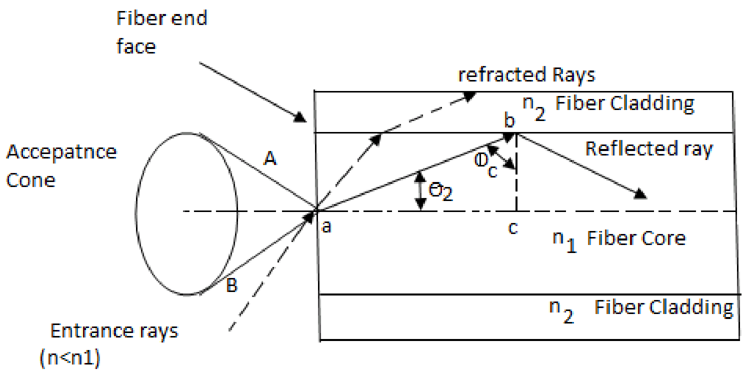
2μtcosr = nλ

This is the required expression for destructive interference.

Q.2(b)Derive the formula for numerical aperture of step index fibre and give it's physical significance.The N.A of of an optical fibre is 0.5 and the core refractive index is 1.54.Find the refractive index of cladding. (7 marks)

Answer:

Numerical Aperture is the ability of fiber to collect the light from the source and save the light inside it by maintaining the condition of total internal reflection.



Consider a light ray entering from a medium air of refractive index n_0 into the fiber with a core of refractive index n_1 which is slightly greater than that of the cladding n_2.

Applying Snell's law of reflection at point A,

$\sin\Theta_1 / \sin\Theta_2 = n_1 / n_o = n_1$ as $n_0 = 1$

In right angled Δabc

$\theta_2 = \pi / 2 - \varnothing_c$

$\sin\theta_1 = n_1 \sin(\pi / 2 - \varnothing_c)$

$= n_1 \cos\varnothing_c$

$\cos\varnothing_c = (1 - \sin\varnothing_c{}^2)^{1/2}$

From the above equation

$\sin\theta_1 = n_1(1 - \sin\varnothing^2{}_c)^{1/2}$

When the TIR takes place, $\phi_c = \theta_c$ and $\theta_1 = \theta_a$

$\sin\theta_a = n_1(1 - \sin\theta_c{}^2)^{1/2}$

$\sin\theta_c = n_2 / n_1$

$\sin\theta_a = n_1[1 - (n2/n1)^2]^{1/2}$

N.A.$= \sin\theta_a$

N.A. $= \sin\theta_a = \sqrt{n_1^2 - n_2^2}$

Thus,the formula for numerical aperture of step index fibre has been derived.

PHYSICAL SIGNIFICANCE OF NUMERICAL APERTURE :

1.It is the parameter which provides information about the acceptance angle.

2.Smaller N.A is not an advantage because it makes it harder to launch power into fibre.

SOLUTION OF PROBLEM :

N.A. = $\sqrt{n_1^2 - n_2^2}$

$0.5^2 = 1.54^2 - n_2^2$ $\qquad$ $n_2 = 1.4566$

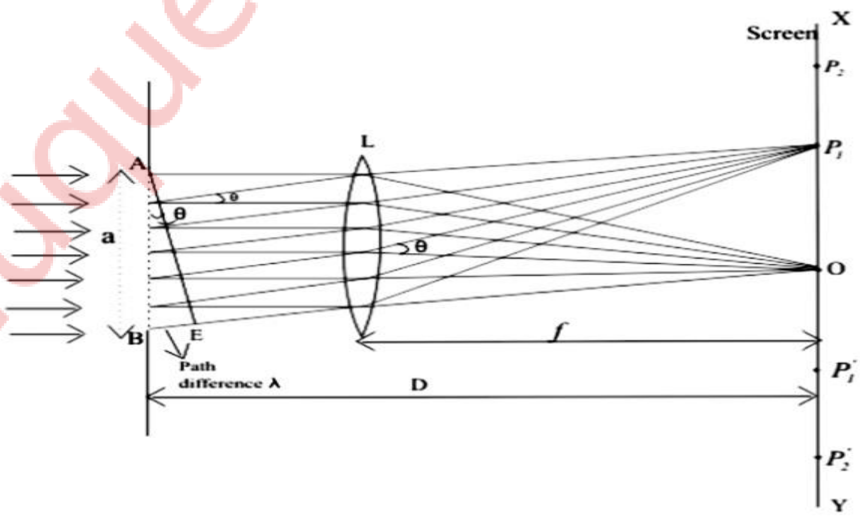
Refractive index of cladding = 1.4566

Q.3(a)Discuss the Fraunhoffer diffraction at single slit and obtain the condition for minima.   In plane transmission grating the angle of diffraction for second order principal maxima for wavelength 5×10^{-5} is 35^o.Calculate number of lines/cm for this diffraction grating. (8 marks)

Answer:

Fraunhofer diffraction at single slit :

1.Let us first consider a parallel beam of light incident normally on a slit AB of width 'a' which is of order of the wavelength of light.



2.A real image of diffraction pattern is formed on the screen with the help of converging lens placed in the path of the diffracted beam

3.All the rays that starts from slit AB in the same phase reinforce each other and produce brightness at point O on the axis of slit as they arrive there in the same phase

4.The intensity of diffracted beam will be different in different directions and there are some directories where there is no light

5.Thus diffraction pattern on screen consists of a central bright band and alternate dark and bright bands of decreasing intensity on both sides

6.Now consider a plane wave front PQ incident on the narrow slit AB. According to Huygens principle each point t on unblocked portion of wavefront PQ sends out secondary wavelets in all directions

7.Their combined effect at any distant point can be found y summing the numerous waves arriving there from the principle of superposition

8.Let C be the center of the slit AB.The secondary waves, from points equidistant from center C of the clit lying on portion CA and CB of wave front travel the same distance in reaching O and hence the path difference between them is zero

9.These waves reinforce each other and give rise to the central maximum at point O

i) Condition for minima :

1.We now consider the intensity at point P1 above O on the screen where another set of rays diffracted at a angle θ have been bought to focus by the lens and contributions from different elements of the slits do not arise in phase at P1

2.If we drop a perpendicular from point A to the diffracted ray from B,then AE as shown in figure constitutes the diffracted wavefront and BE is the path difference between the rays from the two edges A and B of the slit.

3.Let us imagine this path difference to be equal to one wavelength.

4.The wavelets from different parts of the slit do not reach point P1 in the phase because they cover unequal distance in reaching P1.Thus they would interfere and cancel out each other effect. For this to occur

$BE = \lambda$

Since $BE = AB\sin\theta$

$a\sin\theta = \lambda$

or $\sin\theta = \lambda/a$

or $\boldsymbol{\theta = \lambda/a}$ ---(1)

As angle of diffraction is usually very small so that $\sin\theta = \theta$

5.Such a point on screen as given by the equation (1) would be point of secondary minimum

6.It is because we have assume the slit to be divided into two parts, then wavelets from the corresponding points of the two halves of the slit will have path difference of $\lambda/2$ and wavelets from two halves will reach point P_1 on the screen in a opposite phase to produce minima

7.Again consider the point P_2 in the figure and if for this point path difference BE = 2λ ,then we can imagine slit to be divided into four equal parts

8.The wavelets from the corresponding points of the two adjacent parts of the slit will have a path difference of $\lambda/2$ and will mutually interfere to cancel out each other

9.Thus a second minimum occurs at P_2 in direction of θ given by
$\theta = 2\theta/a$

10. Similarly nth minimum at point P_n occurs in direction of θ given by
$\boldsymbol{\theta_n = n\theta/a}$ ---(2)

$(a+b)\sin\theta = m\,\lambda$
$(a+b)\sin 35 = 2 \times 5 \times 10^{-5}$

$a+b = 1.7434 \times 10^{-4}$

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

$= 5735$ lines/cm

Number of lines/cm = 5735

Q.3(b)What is the difference between photography and holography?

Explain holography technique to obtain 3D image of an object. (7 marks)

Answer:

Holography	Photography
1. The light from the object is scattered directly onto the recording medium in the recording of holography.	**1.** A lens is required in photography to record the image
2. A laser is required to record a hologram.	**2.** A photograph can be recorded using normal light sources e.g.sunlight,etc.
3. In photography,only intensity is recorded so photography produces 2-D picture of the object.	**3.** In holography, both intensity as well as phase of light wave is recorded,thus holography gives 3-D picture of object.
5.There is a need of vibration less table for holography.	**5.**There is no need of vibration less table for photography.
6. When a hologram is cut in half, the whole scene can still be seen in each piece.	**6.**When a photograph is cut in half, each piece shows half of the scene.

Holography technique to obtain 3D image of an object:

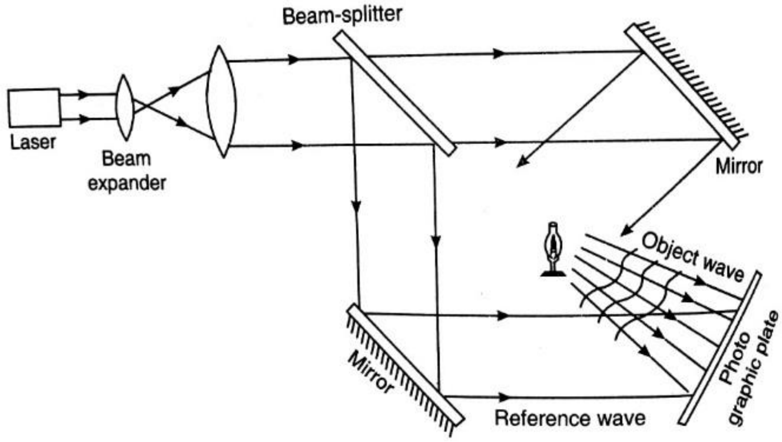
1. Holography is the science and practice of making holograms. Holography is actually a recording of interference pattern formed between two beams of coherent light coming from the same source.

2. In this process,both the amplitude and phase components of a light wave are recorded on a light sensitive medium such as a photographic plate. The recording is known as a hologram.

3. Holography requires an intense coherent light source.It became a practical proposition only after the invention of LASERS.

4. Holography is a two step process.In the first step,recording of hologram is done where the object is transformed into a photographic record and the second step is the reconstruction in which the hologram is transformed into image.

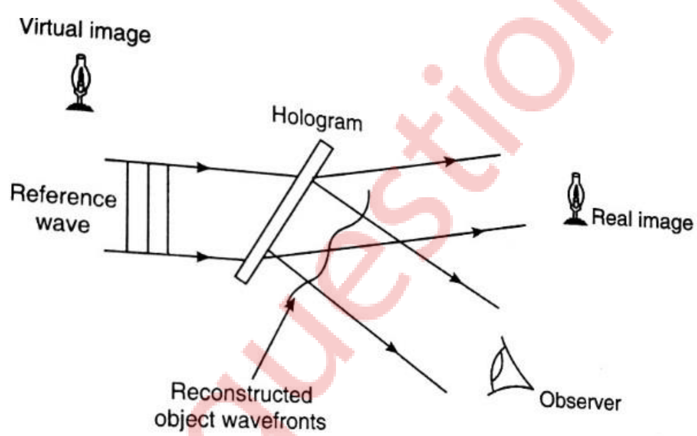
Construction process :



1.During the recording process we superimpose on the scattered wave emanating from the object,the another coherent wave(called as reference beam) of the same wavelength.

2.These 2 waves interfere in the plane of recording medium and produce interference fringes.This is the recording process of hologram.

Reconstruction process :



1.The reproduction of the image from the hologram is known as reconstruction of the hologram.

2.In this process,a wave identical to reference beam is used.

3.When the hologram is illuminated by the reconstruction wave,2waves are produced.

4.One wave appears to diverge from the object and provides the virtual image of the object.

5.The second wave converges to form the real image of the object.

Q.4(a)Find the divergence of vector field F=$x^2yz\bar{\imath} + xz\bar{\jmath}$ (5 marks)

Answer:

Divergence = $\frac{d(x^2yz)}{dx} + \frac{d(xz)}{dy}$ = 2xyz

Divergence = 2xyz

Q.4(b)Explain how A.C voltage and its frequency is measured using CRO.

(5 marks)

Answer:

Method to Measure Voltage :

1.The simplest way to measure signal is to set the trigger button to auto that means oscilloscope start to measure the voltage signal by identifying the zero voltage point or peak voltage by itself. As any of these two points identified the oscilloscope triggers and measure the range of the voltage signal.

2.Vertical and horizontal controls are adjusted so that the displayed image of the sine wave is clear and stable. Now take measurements along the center vertical line which has the smallest divisions. Reading of the voltage signal will be given by vertical control.

Method to Measure Frequency :

1.Increase the vertical sensitivity to get the clear picture of the wave on the screen without chopping any of its amplitude off.

2.Now adjust the sweep rate in such a way that screen displays a more than one but less than two complete cycles of the wave.

3.Now count the number of divisions of one complete cycle on the graticule from start to end.

4.Now take horizontal sweep rate and multiply it with the number of units that you counted for a cycle. It will give the period of the wave. The period is the number of seconds each repeating waveform takes. With the help of period, you can simply calculate the frequency in cycles per second (Hertz).

Q.4(c)A wedged shaped air film having an angle of 40 seconds is illuminated by monochromatic light and fringes are observed vertically through a microscope.

The distance measured between consecutive fringes is 0.12 cm.

Calculate wavelength of light used. (5 marks)

Answer :

β = 0.12 cm

θ = 40 seconds = 1.9392 x 10^{-4} radians

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

$\lambda = \beta \times 2\theta$

= 0.12 x 2 x 1.9392 x 10^{-4}

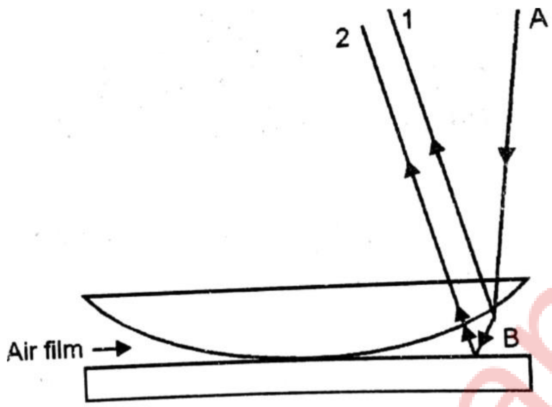
= 4654 A^o

Wavelength of light used = 4654 A^o

Q.5(a)Explain Newton's ring experiment and show that diameters of n^{th} dark rings are proportional to square root of natural numbers. (5 marks)

Answer:

Newton's ring experiment:



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.

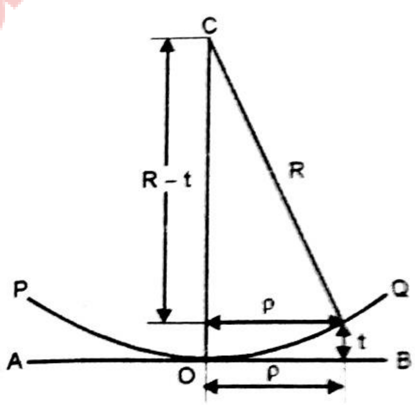
2.The thickness of the film gradually increases from the point of contact outwards.

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 ρ be the radius of a Newton's ring corresponding to the constant film thickness t.

Path difference between two interfering rays = 2μtcos(r+ θ) + λ/2

$R^2 = \rho^2 + (R-t)^2$

$\rho^2 = 2Rt - t$

t<<R

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

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

For dark rings :

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

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

If D is the diameter of Newton's ring

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

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

D_n α $\sqrt{n}$

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

Q.5(b)Write Maxwell's equation and give its physical significance. (5 marks)

Answer:

The Maxwell's equation and their physical significances are :

1. Maxwell's first equation is ∇. D = ρ

Integrating this over an arbitrary volume V we get

$\int_V \nabla.D\, dV = \int_V \rho\, dV$.

But from Gauss Theorem, we get

$\int_s D.dS = \int_v \rho \, dV = q$

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 equations is $\nabla.B = 0$

Integrating this over an arbitrary volume V, we get

$\int_v \nabla.B = 0.$

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

$\Phi c\ E.\ dl = -\int_s \partial B/\partial t.\ dS.$

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 $\Phi = \int_s B.dS$).

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

$\int_s \nabla \times H.\ dS = \int_s (J + \partial D/\partial t)\ dS$

Using Stoke's theorem to convert surface integral on L.H.S. of above equation into line integral, we get

$\Phi c\ H.dl = \int_s (J + \partial D/\partial t).dS$

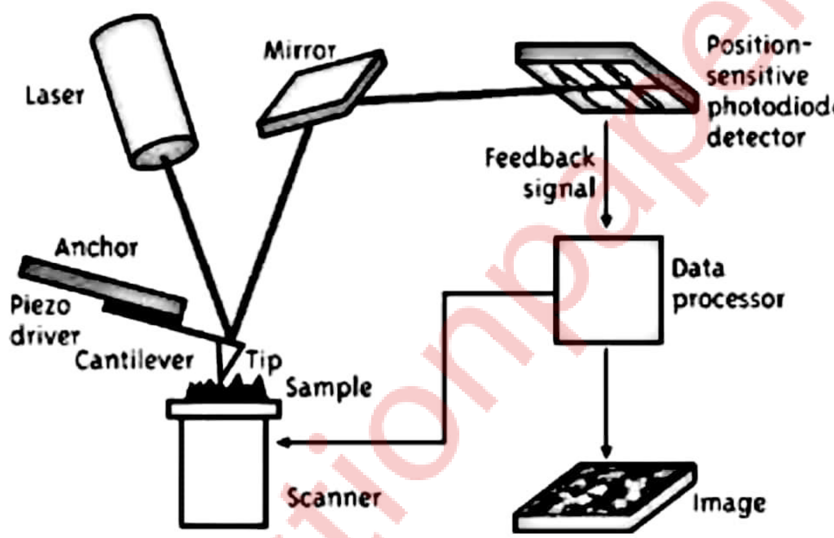
Maxwell's fourth equation signifies that:

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

Q.5(c)Explain construction and working of atomic force microscope.

(5 marks)

Answer:



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 present 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 o 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 force, mechanical contact force etc.

Q.6(a)Explain different types of carbon nanotubes and give its applications.

(5 marks)

Answer:

1.A carbon nanotube is a small cylindrical carbon structure made out of graphene. The tube comprises hexagonal structures.

2.There are many different types of carbon nanotubes, but they are normally categorized as either single-walled (SWNT) or multi-walled nanotubes (MWNT).

The different types of carbon nanotubes are :

Single-walled nanotubes (SWNT) :

(i) Single-walled nanotubes (SWNT) consists of a graphene sheet rolled on leading to a single cylinder.Two halves of a Fullerene molecule closes the structure at both ends.

(ii) They have diameters ranging from 1nm to 5nm and are usually well over 1 mm in length.

(iii) The length to diameter ratio is generally about 1000 so that they can be considered as nearly one-dimensional structures.

Multi-walled nanotubes (MWNT) :

(i)MWNT is arrangement of several coaxial tubes of graphene sheets forming a tube like structure.Each MWNT has from 2 to 50 such tubes.

(ii) The separation between neighbouring tubes is roughly about 0.34-0.36 mm.

(iii) They have inner diameters from 1.5 to 15 nm and outer diameters from 2.5 to 30 nm.They are usually over 1 mm in length

APPLICATIONS OF CNT:

1.Improving Structural Properties

2.Enhancing electrical and thermal conductivity

3.Energy harvesting/storage

4.Electromagnetic interference (EMI) shielding

5.Construction of nanoscale electronic devices.

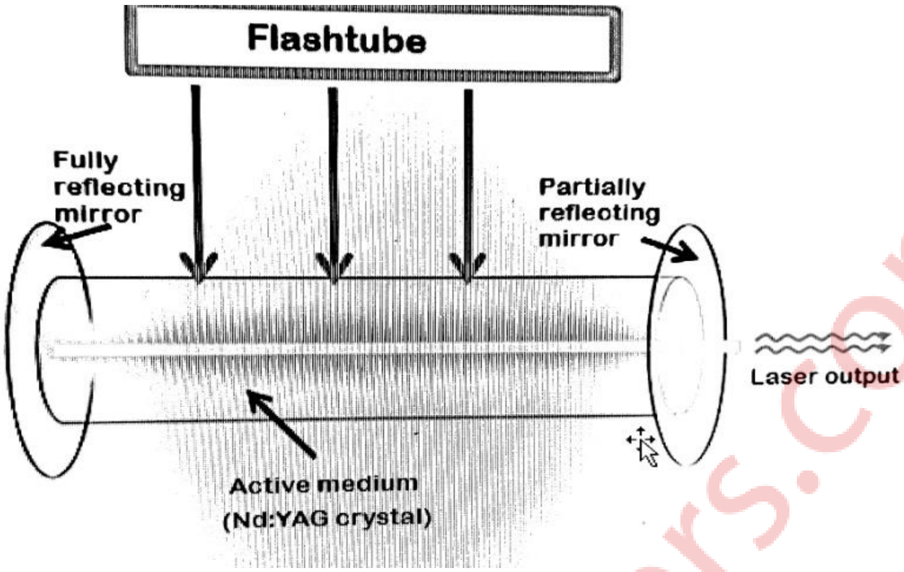
6.The electron emission concept of CNTs is used in developing a flat-panel display.

Q.6(b)Explain construction and working of Nd:YAG LASER. (5 marks)

Answer:

Neodymium-doped Yttrium Aluminum Garnet (Nd: YAG) laser is a solid state laser in which Nd:YAG is used as a laser medium.

Construction of Nd:YAG LASER :



Nd:YAG laser consists of three important elements: an energy source, active medium, and optical resonator.

Energy source :

The energy source or pump source supplies energy to the active medium to achieve population inversion. In Nd: YAG laser, light energy sources such as flashtube or laser diodes are used as energy source to supply energy to the active medium.

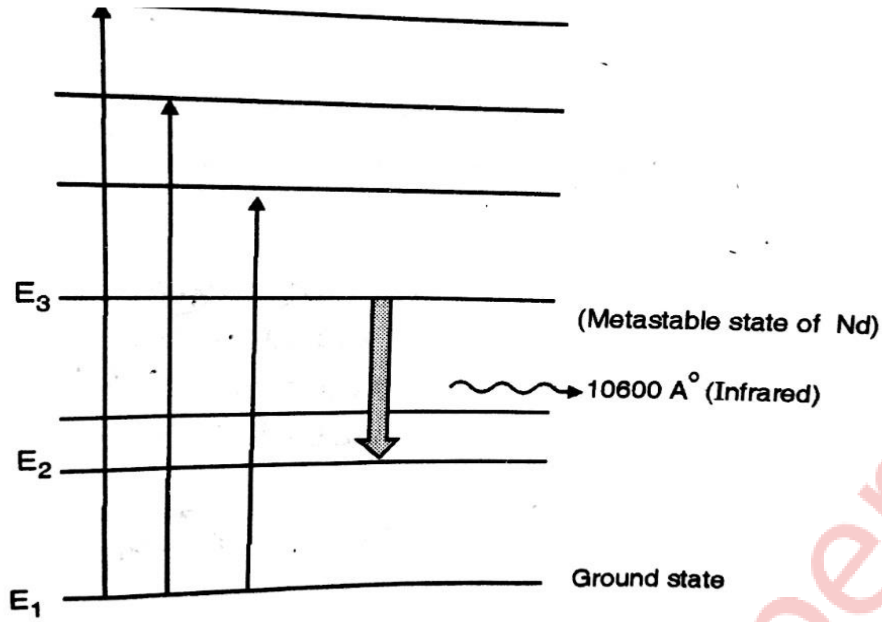
Active medium :

The active medium or laser medium of the Nd:YAG laser is made up of a synthetic crystalline material (Yttrium Aluminum Garnet (YAG)) doped with a chemical element (neodymium (Nd)). The lower energy state electrons of the neodymium ions are excited to the higher energy state to provide lasing action in the active medium.

Optical resonator :

The Nd:YAG crystal is placed between two mirrors. These two mirrors are optically coated or silvered.One mirror is fully silvered whereas, another mirror is partially silvered. The mirror, which is fully silvered, will completely reflect the light.The mirror which is partially silvered will reflect most part of the light but allows a small portion of light through it to produce the laser beam. This mirror is known as a partially reflecting mirror.

WORKING OF Nd:YAG LASER :



1.Energy levels E_1,E_2 and E_3 are of Nd and other levels belong to YAG.E_1 is ground state and E_3 offers metastable state.

2.Pumping takes place with light of 5000 A° to 8000A° which excites Nd^{+3} ions to higher states.

3.The metastable state E_3 rapidly gets populated due to downward transitions from higher energy levels as none of them is metastable.

4.Population inversion takes place between E_3 and E_2.

5.A continuous LASER of 10600 A° in infrared region is given out due to stimulated smission between E_3 and E_2.

Q.6(c)Write a note on electrostatic focusing.	(5 marks)

Answer:

Electrostatic deflection is the method of aligning the path of charged particles by applying the electric field between the deflecting plates.

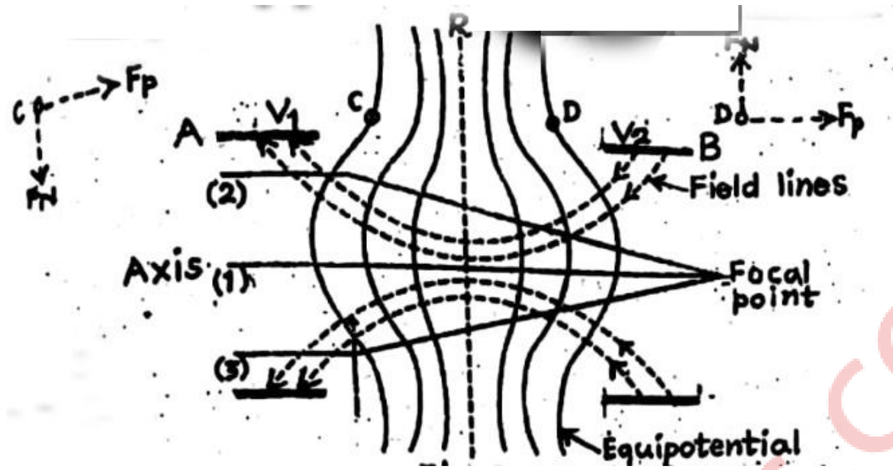


Diagram above represents the electrostatic focusing.A and B are two co-axial cylinders with potentials V1 and V2 such that V2>V1.R is the equipotential ring placed between A and B.

Working :

(1) Consider electron beam 1:

It will remain normal to all the equipotential surfaces and hence it is simply accelerated without any deviation of the path.

(2) Consider electron beam 2:

It will have following 2 effects:

(a) On the L.H.S off R: The parallel component of F_P will move the electron towards right while the normal component F_N will move the electron downwards by applying Fleming's left hand rule at point C.

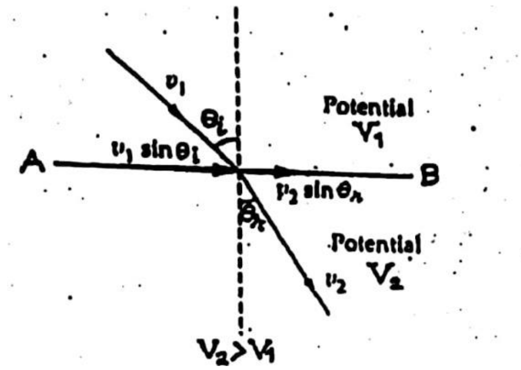
(b) On the R.H.S off R:F_P and F_N will move the electron towards right and towards up respectively by applying Fleming's left hand rule at point D.

(3) Consider electron beam 3:

It's path will be as shown with same case as case(2).

The focal length can be changed by varying V_1 and V_2

(4) Bethe's laws is also followed in electrostatic focusing :



$\frac{v_2}{v_1} = \frac{sin\ \theta_i}{\sin\theta_r}$

(5)Electrostatic focusing is used for accelerating and focusing electron beams.

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

$$\nabla . F=\left(\frac{\partial}{\partial x}, \frac{\partial}{\partial y}, \frac{\partial}{\partial z}\right) .(f 1 . f 2 . f 3)=\frac{\partial f 1}{\partial x}, \frac{\partial f 2}{\partial y}, \frac{\partial f 3}{\partial z}$$

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

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

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

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,

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

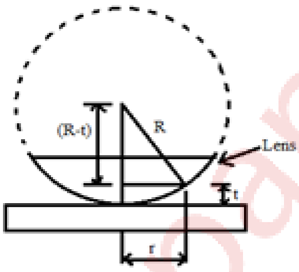
$$t = \frac{5890 \times 10^{-8}}{2 \times 1.5 \times 0.5}$$

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

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

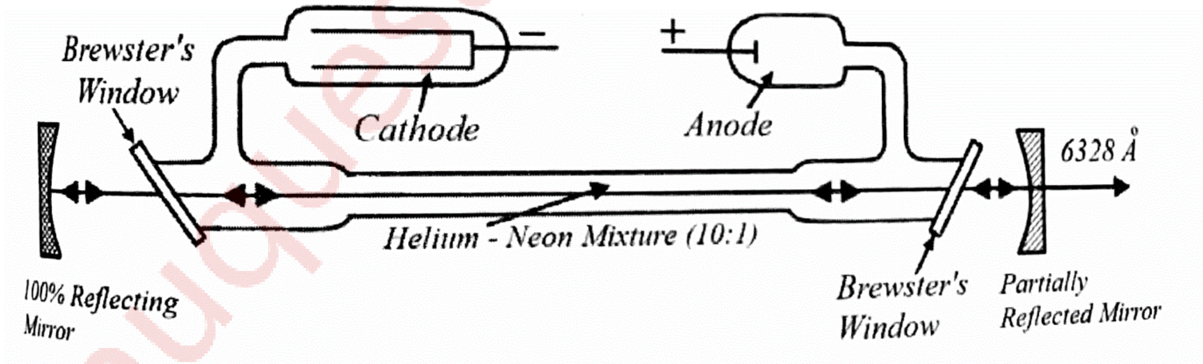
$$M=\frac{1}{2}\left(\frac{\pi\times 40\times 10^{-6}}{1.5\times 10^{-6}}\times 0.344\right)^2$$

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.



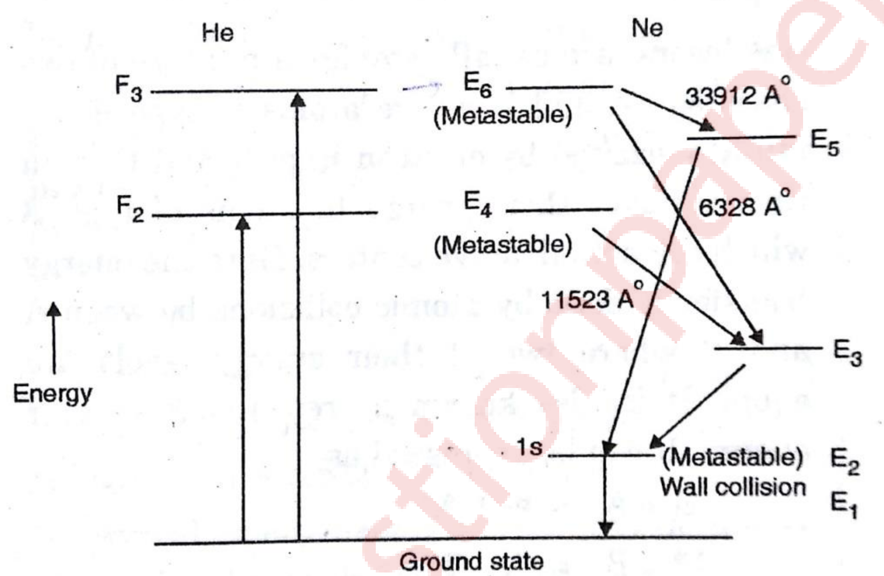
He Ne gas laser employ four level pumping schemes. When the power is switched on the electric field ionizes some of the atoms in the mixture of He and Ne gases. Due to electric field, the electrons and ions will be accelerated towards anode and cathode. Since electron have smaller mass they acquire higher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

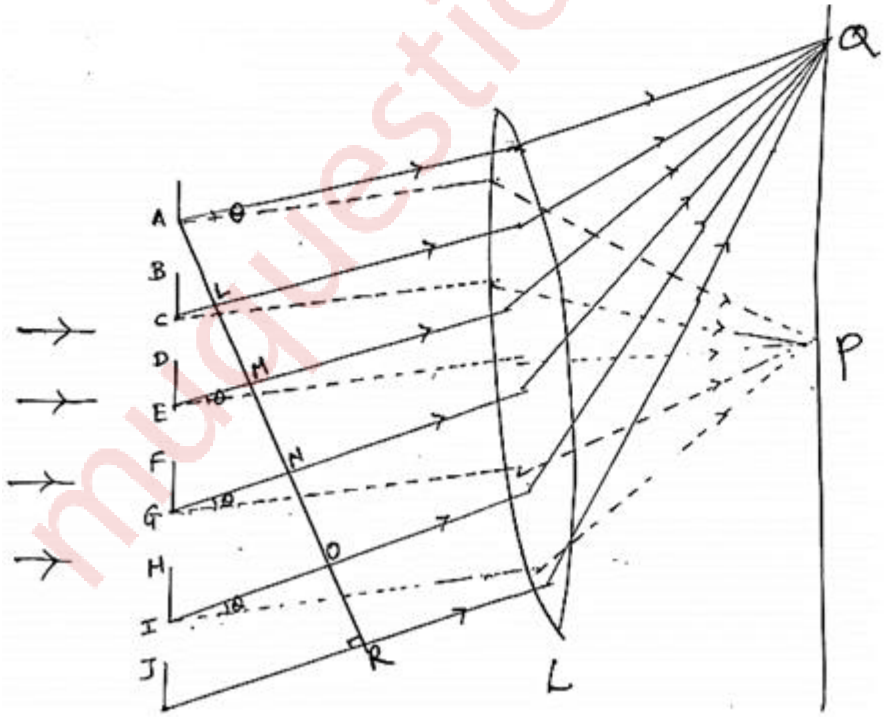
Q.3.b) What is diffraction grating and grating element? Explain experimental method to determine the wavelength of the spectral line using diffraction grating?

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

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

We know that I a E^2

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

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

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 β = 0 sin Nβ = 0

Using L hospital rule

$\lim_{\top}(\beta \to \pm m\pi)$ {d(sinNβ)/d(sinβ)}

=N (cosNβ)/cosβ

=N (cosNmπ)/(cosmπ)

=N

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

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

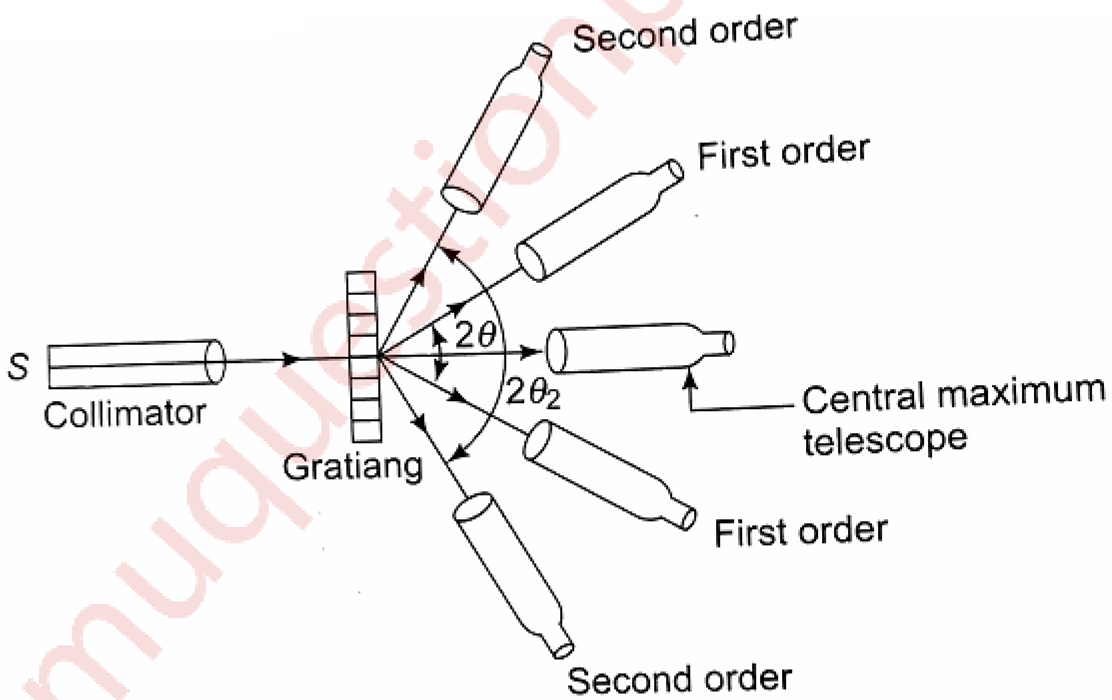
Condition for maxima β = ±mπ

[π/λ (a+b)sinθ] = ±mπ

(a+b)sinθ= ±mλ m = 1,2,3,4…………………

For minima Nβ = ±mπ N (π)/λ (a+b)sinθ= ±mπ N(a+b)sinθ= ±mλ 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.

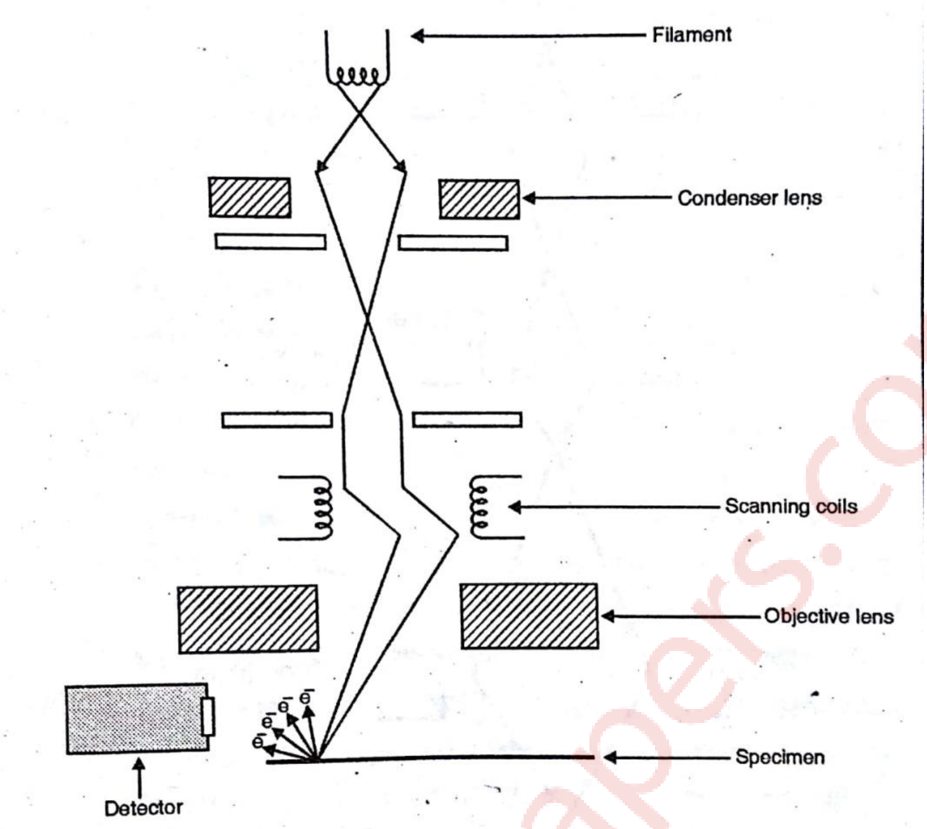
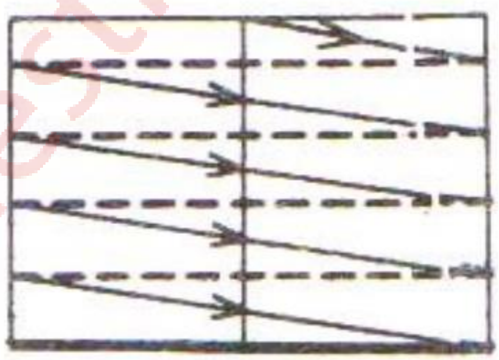


Fig. 8.3.2 : Schematic diagram of SEM

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.

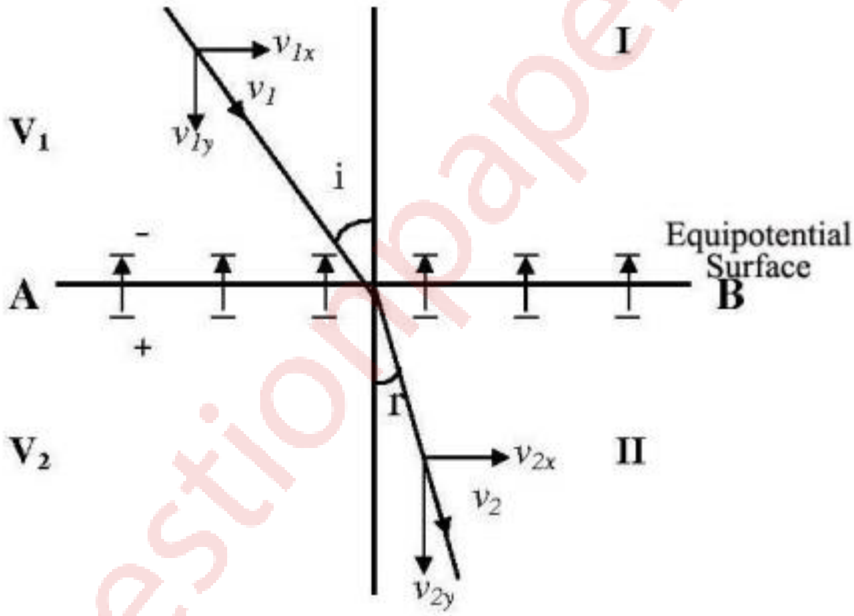
Q.4.b) Derive Bethe's Law for electron refraction.

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, $\boldsymbol{\frac{\sin i}{\sin r} = \frac{v_2}{v_1} = \sqrt{\frac{V2}{V1}}}$

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.

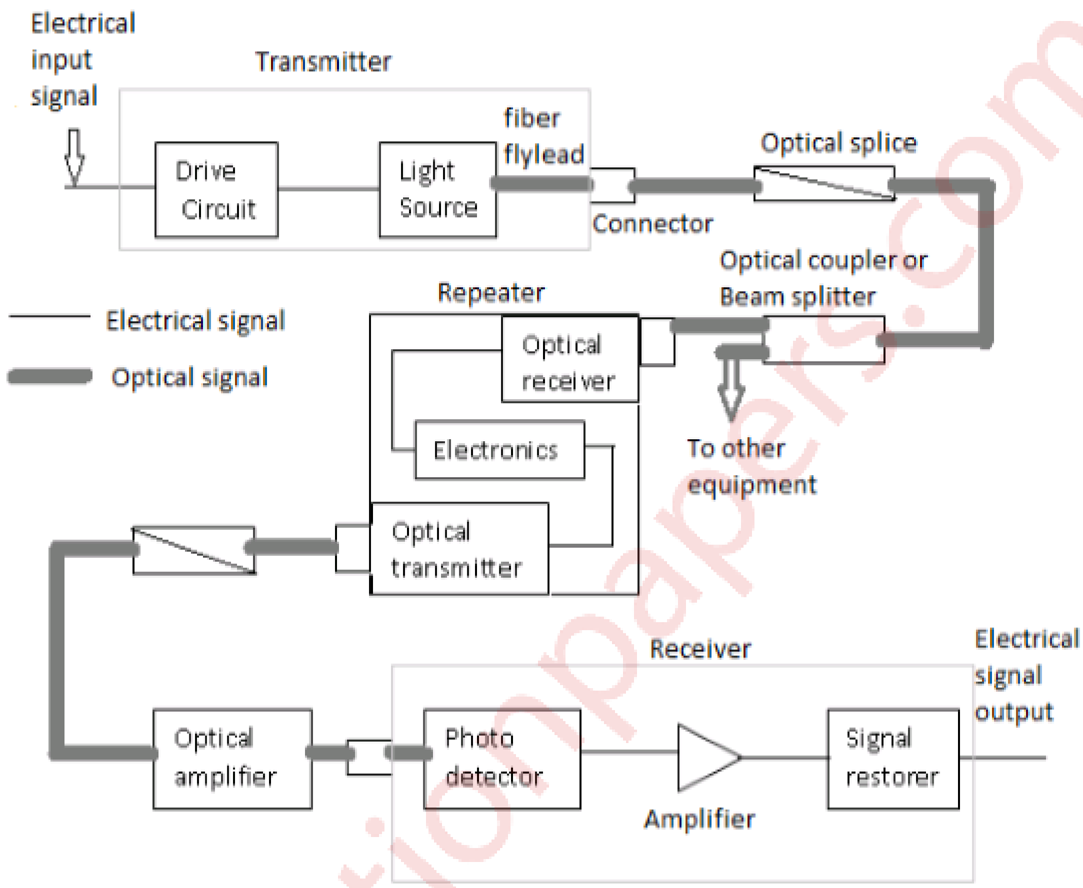


Figure 1

- 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

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

And for (n+1)th dark ring λ2

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

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

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

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

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

$$\boldsymbol{n = 6}$$

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

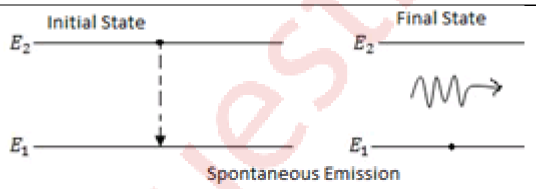
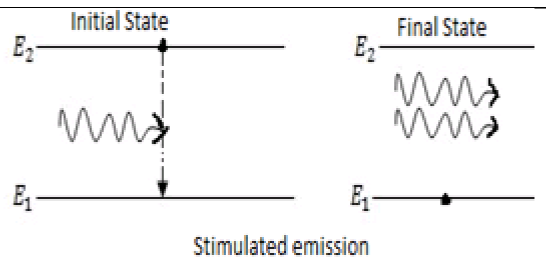
$$D_6^2 = 4 \times 6 \times 90 \times 6 \times 10^{-5}$$

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

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

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**

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 : $\Delta = 1.2\% = 0.012$, $\mu_1 = 1$

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 ,

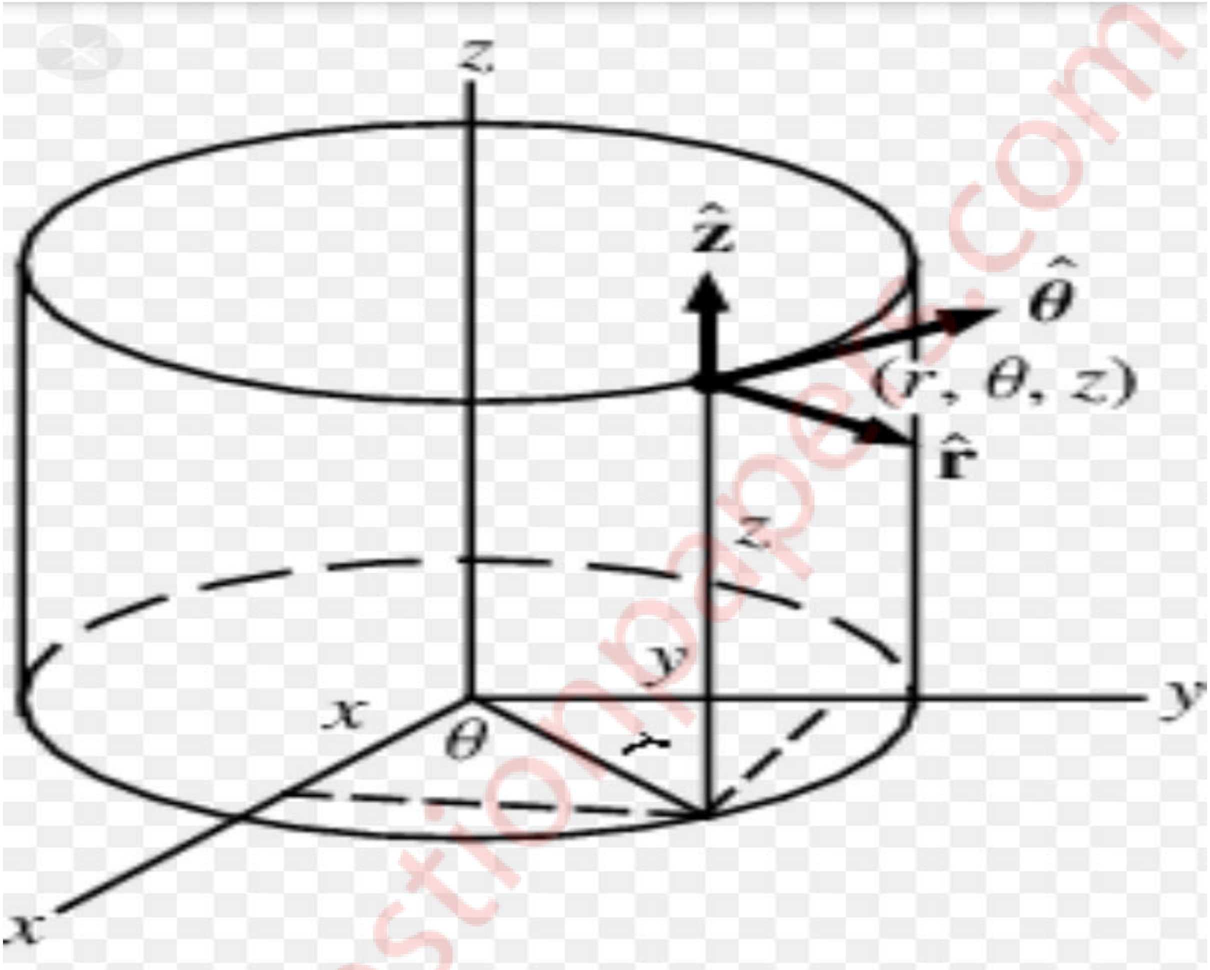
$$V = \iiint_E dV \ .$$

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.

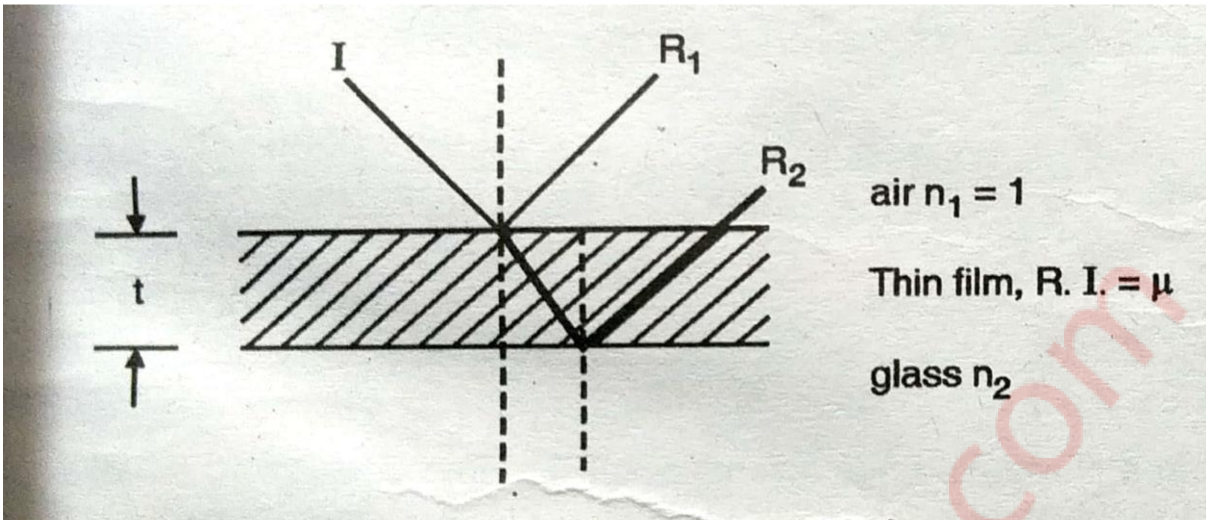


Fig. 2.6.1 : Thin film coating

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.

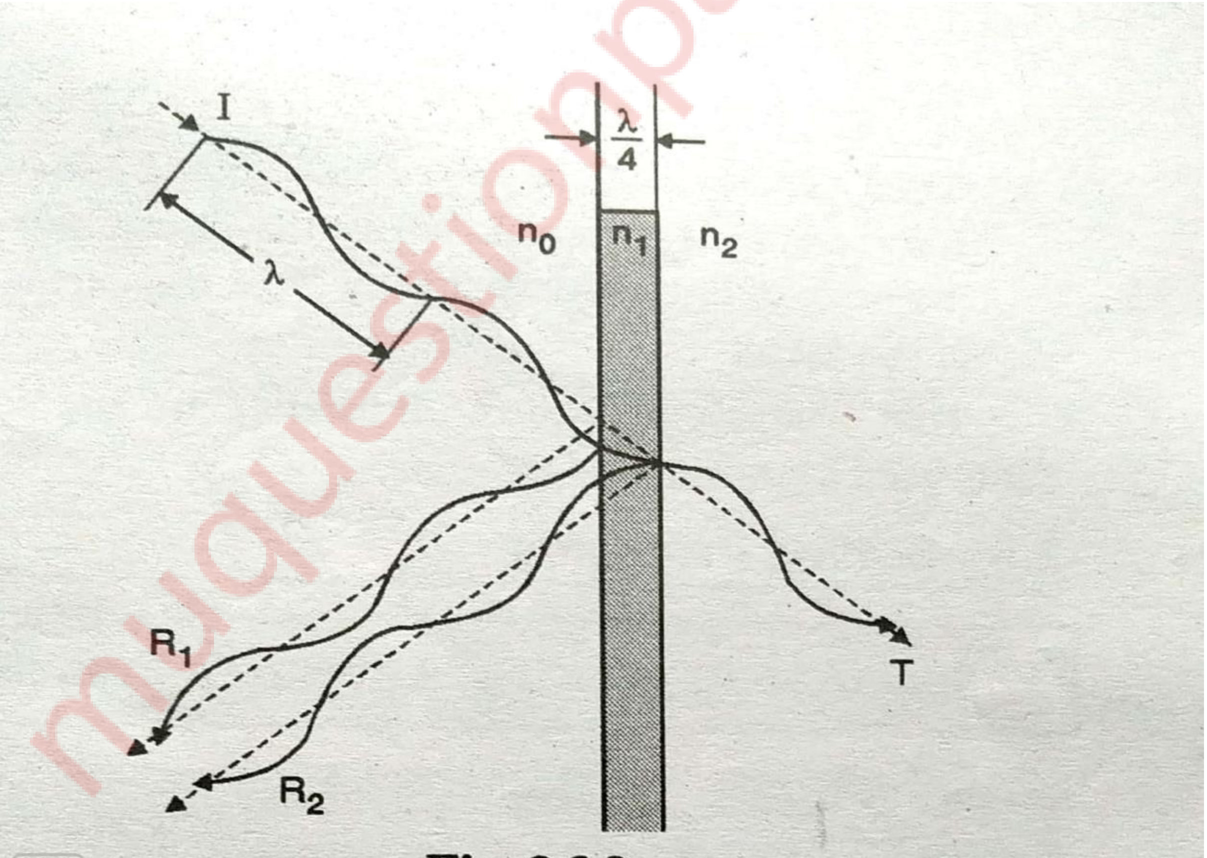


Fig. 2.6.2

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 $\mu = \frac{\mu_1 + \mu_2 + \mu_3}{3}$.

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

μ = 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,

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

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

Putting n=3

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

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

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 .

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

∴ NA = 0.121

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

∴ V = 584523.077r .

∴ V < 2.405 .

∴ 584523.077r < 2.405

∴ 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.

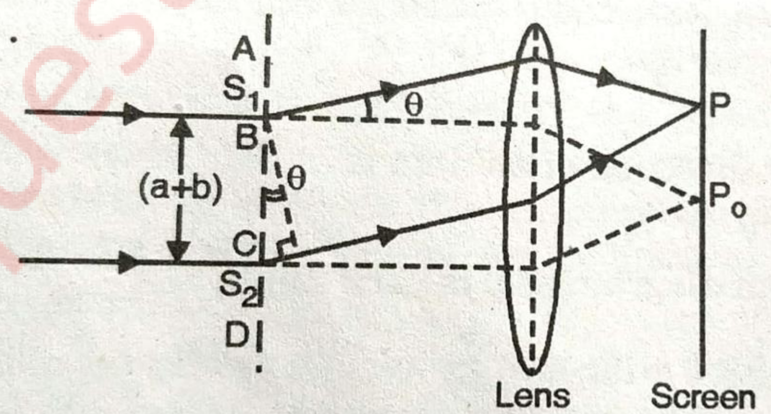


Fig. 3.5.1 : Fraunhoffer diffraction at double slit

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

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

The corresponding phase difference

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

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

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 $\frac{A_2D}{A_1A_2} = \sin\theta$ 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

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

$= \ 4 I_0 \dfrac{\sin^2\alpha}{\alpha^2}\cos^2\beta$ 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 $\dfrac{\sin^2\alpha}{\alpha^2}$ 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 $\dfrac{\lambda}{2}$ i.e.

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

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 $e\sin\theta_n = m\lambda$

$\therefore \dfrac{n}{m} = 2$ 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 $e\sin\theta_n = m\lambda$

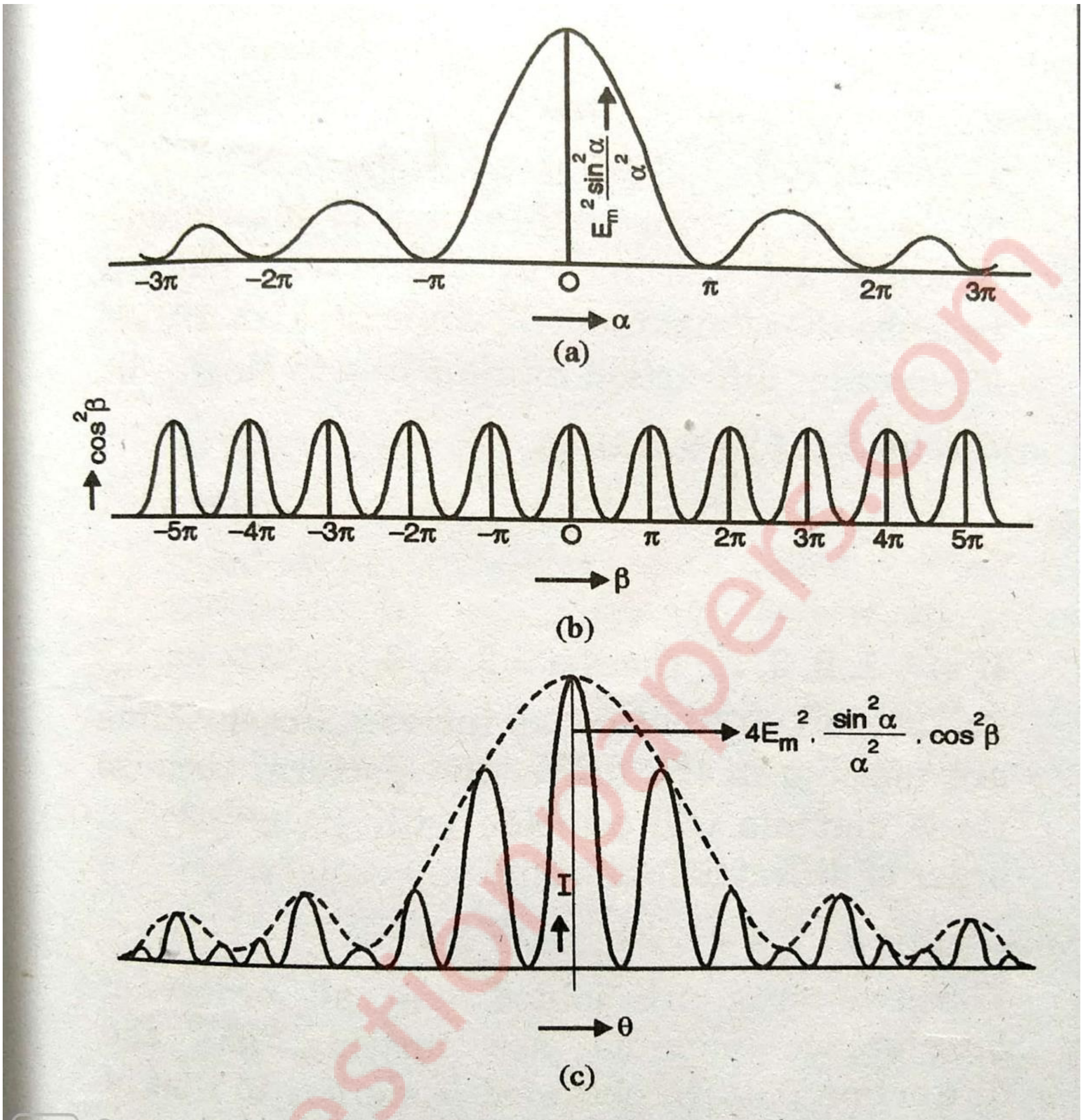


Fig. 3.5.3

$\therefore \frac{n}{m} = 3$ 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.

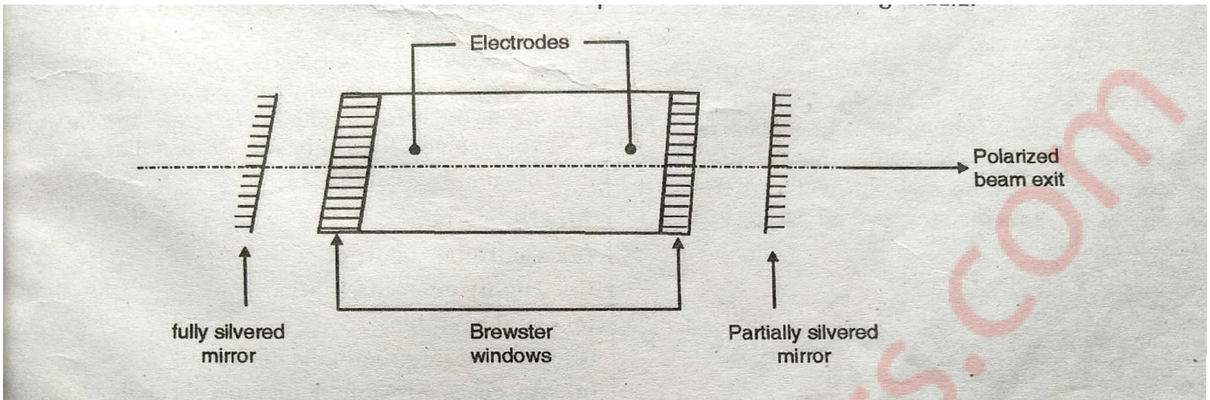


Fig. 4.11.1 : He-Ne laser tube (schematic presentation)

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.

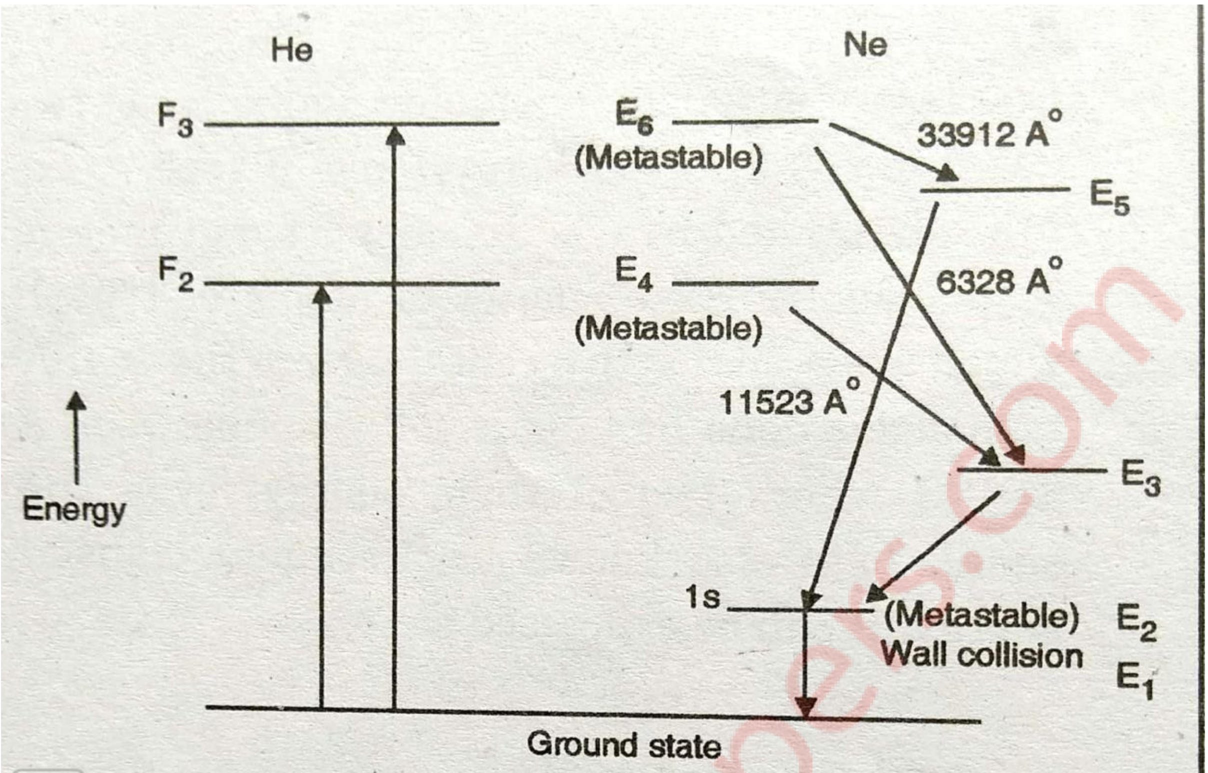


Fig. 4.11.2 : Energy level diagram of He-Ne

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 $\vec{F} = x^2y\vec{\imath} - (z^3 - 3x)\vec{\jmath} + 4y^2\vec{k}$. **(5M)**

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

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

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) .

$$\vec{v}\,.\vec{F} = 2xy\,.$$

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

Ans :

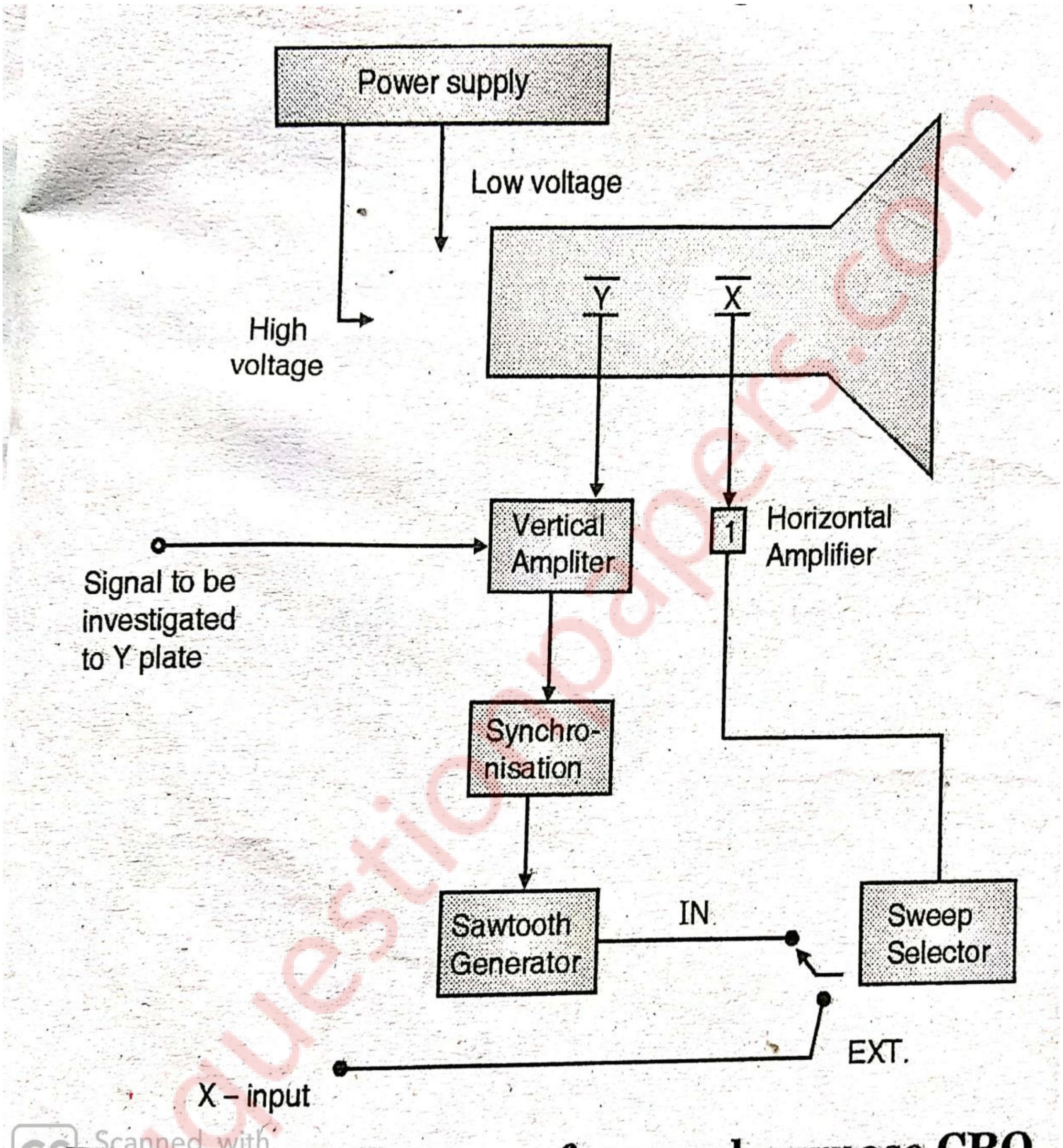


Fig. 7.14.1 : A diagram of general purpose CRO

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

To find : λ

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

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

Solution : λ = 2 X 1.4 X 96.96 X 10^{-6} X 25 X 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 : $\Delta E = 1.8\ eV = 1.8 \times 1.6 \times 10^{-19}\ J = 2.88 \times 10^{-19}$, 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, $\Delta E = \frac{hc}{\lambda}$.

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:

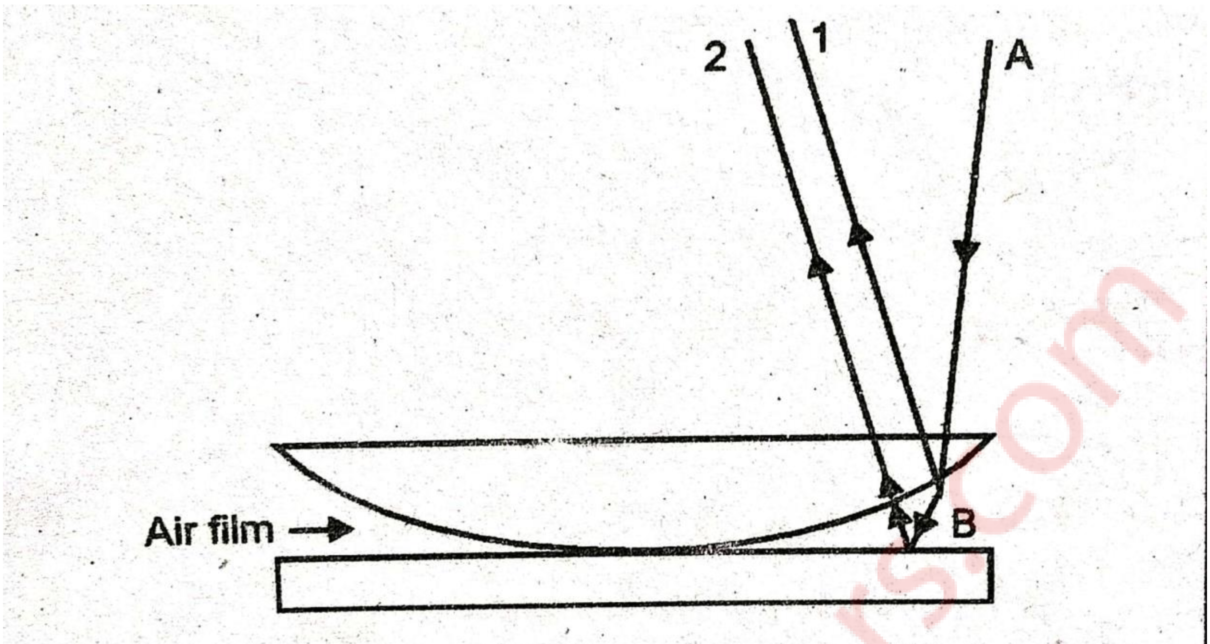


Fig. 1.9.1 : Formation of Newton's rings

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.

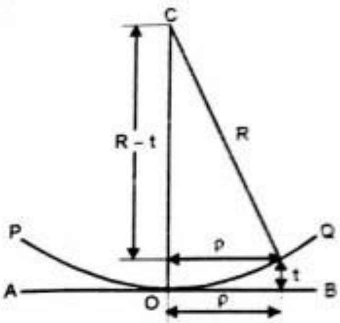
3.If monochromatic light is allowed to fall normally on this film, a system of alternate bright and dark concentric rings, with centre dark is formed in the air film.

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=$\frac{D}{2}$

$\frac{D^2 n}{4R}$ =nλ

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

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^{7}m/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 .

MUMBAI UNIVERSITY CBCGS SEM II

Q.P Code: 29702

APPLIED PHYSICS II DEC 2019 PAPER SOLUTIONS

Q1)a) Why does an excessively thin film appear to be perfectly dark when illuminated by white light. (3M)

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

5) The coloration will vary with the thickness of the film and 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) In a plane transmission grating the angle of diffraction for the first order principal maximum is 20° for a wavelength of 6500^0A. Calculate the number of lines in 1 cm of the grating surface. (3M)

Ans : m=1 , $\lambda = 6500 \times 10^{-10}$m , $\theta = 20^\circ$,

We know that

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

Hence, $(a+b) = m\lambda / \sin\theta = 1 \times 6500/\sin(20) = 7119.81 \times 10^{-8}$ cm .

Number of lines per cm = $1/(a+b) = 1/7119.81 \times 10^{-8} = 14000$

Number of lines per cm is 14000 .

Q1)c) Explain the term V-number of an optical fibre. **(3M)**

Ans : 1) In optical fibre, the light propagates in the same way as the electromagnetic wave propagates.

2) When confined to a duct or guide, it propagates like electromagnetic wave, but at a much higher frequency.

3) The number of modes supported by a fibre is determined by an important parameter called "cut off parameter " or "V-Number ".

4) The mathematical expression for V-number is

$$V = \pi \frac{d}{\lambda_0} \sqrt{\mu_1^2 - \mu_2^2}$$

Where λ_0 =free space wavelength

d=2a= diameter of the core (a = radius of the core)

$$\therefore V = \frac{\pi d}{\lambda} (NA)$$

$$= \frac{\pi d}{\lambda} \mu_1 \sqrt{2\Delta}$$

5) The maximum number of modes N_m supported by SI fibre is given by

$N_m \approx \frac{1}{2} V^2$ (provided V-number is considerably larger than unity)

Q1)d) Differentiate between Spontaneous Emission and Stimulated Emission. **(3M)**

Ans :

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.	1) 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) It cannot be controlled .	2)It can be controlled effectively .
3) Here, no multiplication of photons takes place .	3)Here, multiplication of photons takes place.
4) This phenomenon is found in LEDs, Fluorescent tubes.	4) This is the key process of formation of laser beam.
5) There is no population inversion of electrons in LEDs.	6) Population inversion is achieved by various 'pumping' techniques to get amplification .

Q1)e) Show that divergence of curl of a vector is zero. (3M)

Ans :

$$\text{Let } \bar{F} = F_x \bar{a}_x + F_y \bar{a}_y + F_z \bar{a}_z$$

$$\bar{F} = \nabla \times \bar{F} = \begin{bmatrix} a_x & a_y & a_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ F_x & F_y & F_z \end{bmatrix}$$

$$= \bar{a}_x \times \left(\frac{\partial F_z}{\partial y} - \frac{\partial F_y}{\partial z}\right) - \bar{a}_y \left(\frac{\partial F_z}{\partial x} - \frac{\partial F_x}{\partial z}\right) + \bar{a}_z \left(\frac{\partial F_y}{\partial x} - \frac{\partial F_x}{\partial y}\right)$$

$$\text{Now} \quad \text{div} (\text{curl } \bar{F}) = \nabla \cdot (\nabla \times \bar{F})$$

$$= \frac{\partial}{\partial x}\left(\frac{\partial F_z}{\partial y} - \frac{\partial F_y}{\partial z}\right) - \frac{\partial}{\partial y}\left(\frac{\partial F_z}{\partial x} - \frac{\partial F_x}{\partial z}\right) + \frac{\partial}{\partial z}\left(\frac{\partial F_y}{\partial x} - \frac{\partial F_x}{\partial y}\right)$$

$$= \cancel{\frac{\partial^2 F_z}{\partial x \, \partial y}} - \cancel{\frac{\partial^2 F_y}{\partial x \, \partial z}} - \cancel{\frac{\partial^2 F_z}{\partial y \, \partial x}} + \cancel{\frac{\partial^2 F_x}{\partial y \, \partial z}} + \cancel{\frac{\partial^2 F_y}{\partial z \, \partial x}} - \cancel{\frac{\partial^2 F_x}{\partial z \cdot \partial y}} = 0$$

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

Ans : $eV = ½(mv^2)$

Kinetic Energy = $1.6 \text{ X } 10^{-19} \text{ X } 18 \text{ X } 10^3$

$= 28.8 \text{ X } 10^{-16}$ Joules .

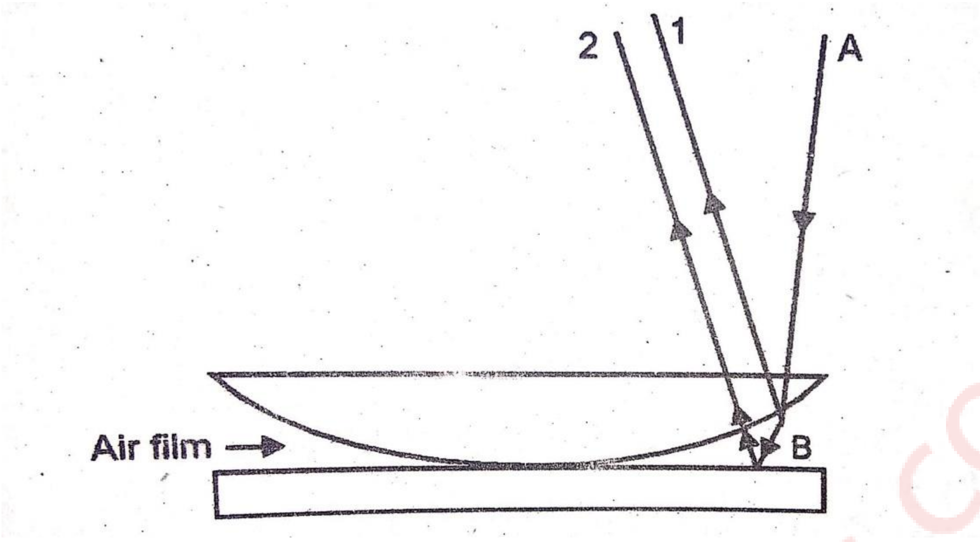
$v = (2eV/m)^{1/2} = (2\text{X}1.6 \text{ X}10^{-19} \text{ X}18 \text{ X}10^3 /9.1 \text{ X } 10^{-27})^{1/2}$

$= 795.5 \text{ X } 10^3$ m/sec .

The Kinetic Energy of the electron is $28.8 \text{ X } 10^{-16}$ Joules and its speed is $795.5 \text{ X } 10^3$ m/sec .

Q1)g) What will happen when a liquid is introduced between the plano convex lens and glass plate in Newton's rings experiment. (3M)

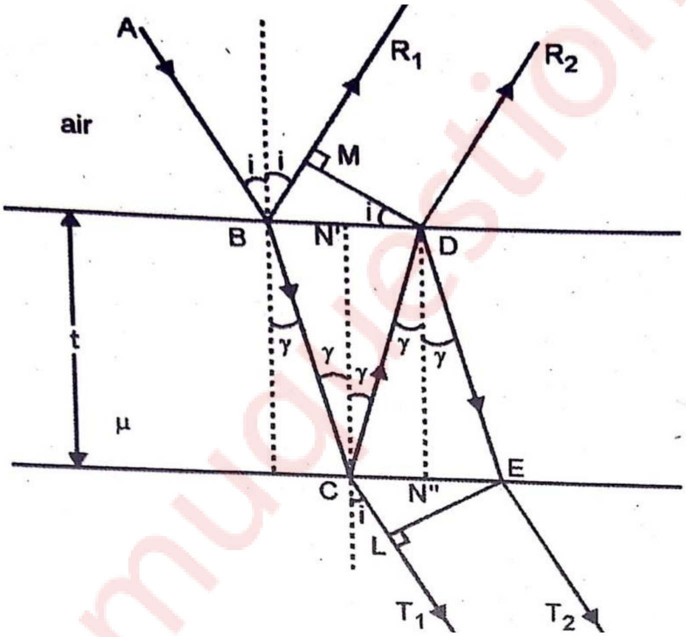
Ans : When a plano-convex lens with large radius of curvature is placed on a plane glass plate such that its curved surface faces the glass plate, a wedge air film (of gradually increasing thickness) is formed between the lens and the glass plate. The thickness of the air film is zero at the point of contact and gradually increases away from the point of contact .



Q2)a) What do you mean by thin film? Obtain the conditions for the maxima and minima of the light reflected from a thin transparent film of uniform darkness. (8M)

Ans :

A thin film is a layer of material with thickness in the sub- nanometer to micron range. As light strikes the surface of a film it is either transmitted or reflected at the upper surface. Light that is transmitted reaches the bottom surface and may once again be transmitted or reflected. Thin films can be engineered to control the amount of light reflected or transmitted at a surface for a given wavelength.



i) The two rays will interfere consecutively if the path difference between them

is an integral multiple of λ i.e.

$2\mu t \cos r + \lambda/2 = n\lambda$

Or

$2\mu t \cos r = (2n-1)\lambda/2$

Where,

n= 1, 2, 3, 4, ……….. (for maxima)

or

$2\mu t \cos r = (2n-1)\lambda/2$

Where n = 0, 1, 2, 3, 4, ………………….

When this condition is satisfied the film will appear bright in the reflected system.

ii) The two rays will interfere destructively if the path difference between them is an odd multiple of λ/2 i.e.

$$2\mu t \cos r + \lambda/2 = (2n-1)\,\lambda/2$$

Or

$$2\mu t \cos r = n\lambda \qquad \text{(for minima)}$$

iii. The film which appears bright in reflected light appears dark in transmitted light and vice versa.

iv. For the transmitted light, the intensity of maxima is about 100% and the minima is about 85%. The result in poor contrast between bright and dark where in poor contrast between where as in reflected light, minima is having its intensity zero and maxima is nearly 15% of incident energy. This result in good contrast.

Q2)b) Explain Step index and Graded index fibre. A Step Index Fibre has a core diameter of $2.9*10^{-6}$ m , the refractive indices of core and cladding are 1.52 and 1.5189 respectively .If the light of wavelength 1.3 µm is transmitted through the fibre determine the normalized frequency and number of modes supported by the fibre. (7M)

Ans :

Step Index Fibre is the simplest type of an optical fibre. It consists of a thin cylindrical structure of transparent glossy material of uniform refractive index μ_1 surrounded by cladding of another material of uniform but slightly lower refractive index μ_2 .These fibres are called as the step index fibres due to the discontinuity of the index profile at the core cladding surface.

The graded index fibre has its core refractive index gradually decreasing in a nearly parabolic manner from a maximum value at the center of the core to a content value at the core-cladding interface. The variation in refractive index is achieved by using concentric layers of different refractive indices. Such a profile causes a periodic focusing of the light propagating through the fibre.

Numerical : For an optical fibre

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

Where V is V-Number or normalized frequency , d is diameter of the core ,NA is the numerical aperture and λ is the wavelength of light used .

$$V = \frac{3.14\ X\ 2.9\ X10^{-6}}{1.3X10^{-6}} X\sqrt{1.52^2 + 1.5189^2}$$

V =15.05 .

For Step Index fibre, the number of modes is

$$N = V^2/2 = 113 \ .$$

The normalized frequency is 15.05 Hz and the number of modes is 113, i.e it is a multimode fibre .

Q3)a) With neat energy level diagram describe the construction and working of Nd-YAG laser (8M)

Ans : Neodymium-doped Yttrium Aluminum Garnet (Nd: YAG) laser is a solid state laser in which Nd: YAG is used as a laser medium. Nd: YAG laser is a four-level laser system, which means that the four energy levels are involved in laser action. These lasers operate in both pulsed and continuous mode. Nd: YAG laser generates laser light commonly in the near-infrared region of the spectrum at 1064 nanometers (nm).

Construction :

Nd : YAG laser consists of three important elements: an energy source, active medium, and optical resonator. The laser is an elliptically cylinder reflector with both of its axis occupied by a flash lamp and Nd : YAG rod respectively. The light leaving one focus of the ellipse will certainly pass through the other focus after reflection from reflecting surface. Hence, entire light generated by flash tube is focussed on the Nd:YAG rod. The optical resonator is formed by highly silvered reflecting surfaces. Each mirror is silvered or coated differently. One mirror is fully silvered whereas, another mirror is partially silvered.

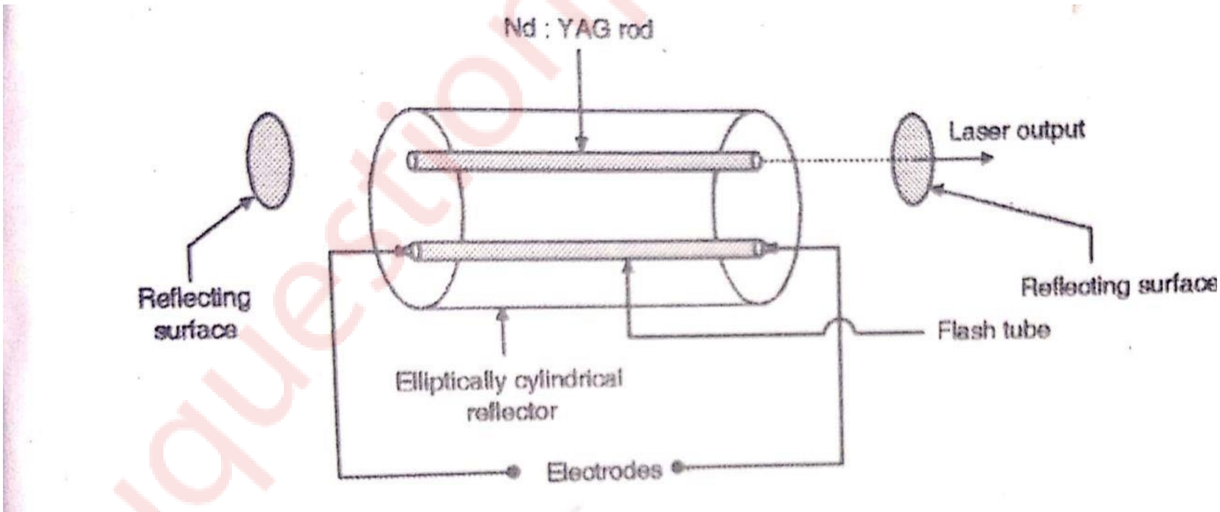


Fig. 4.12.1 : Nd : YAG laser

Working :

1) Nd: YAG laser is a four-level laser system, which means that the four energy levels are involved in laser action. The light energy sources such as flashtubes or laser diodes are used to supply energy to the active medium. In Nd:YAG laser, the lower energy state electrons in the neodymium ions are excited to the higher energy state to achieve population inversion.

2) Consider a Nd:YAG crystal active medium consisting of four energy levels E_1, E_2, E_3, and E_4 with N number of electrons. The number of electrons in the energy states E1, E_2, E_3, and E_4 will be N_1, N_2, N_3, and N_4. Let us assume that the energy levels will be $E_1 < E_2 < E_3 < E_4$. The energy level E_1 is known as ground state, E_2 is the next higher energy state or excited state, E_3 is the metastable state or excited state and E_4 is the pump state or excited state. Let us assume that initially, the population will be $N_1 > N_2 > N_3 > N_4$.

3) When flashtube or laser diode supplies light energy to the active medium (Nd:YAG crystal), the lower energy state (E_1) electrons in the neodymium ions gains enough energy and moves to the pump state or higher energy state E_4.

4) The lifetime of pump state or higher energy state E_4 is very small (230 microseconds (Âµs)) so the electrons in the energy state E_4 do not stay for long period. After a short period, the electrons will fall into the next lower energy state or metastable state E_3 by releasing non-radiation energy (releasing energy without emitting photons).

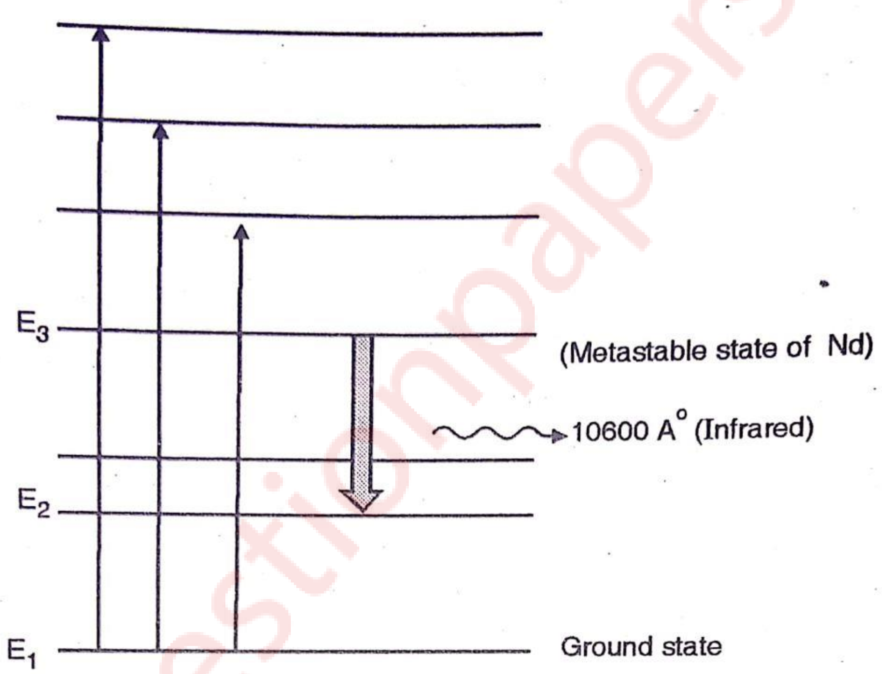


Fig. 4.12.2 : Energy levels of Nd along with YAG

5) The lifetime of metastable state E_3 is high as compared to the lifetime of pump state E_4. Therefore, the electrons reach E_3 much faster than they leave E_3. This results in an increase in the number of electrons in the metastable E_3 and hence population inversion is achieved.

6) After some period, the electrons in the metastable state E_3 will fall into the next lower energy state E_2 by releasing photons or light. The emission of photons in this manner is called spontaneous emission. Population Inversion takes place between E_3 and E_2 .A continuous laser of 10600 Å in infrared region is given out due to stimulate emission taking place between E_3 and E_2 .

Q3)b) What is grating element. The visible spectrum ranges from 4000 ̊A to 5000 ̊A .Find the angular breadth of the first order visible spectrum produced by a plane grating having 6000 lines/cm when light is incident normally on the grating. (7M)

Ans : A grating element is a diffraction grating. These can take many forms but the most basic is a repeated array of lines where the spacing from line to line is on the order of the wavelength. When the period of the grating is less than the wavelength, the grating acts like an effective medium and exhibits anisotropy and an average refractive index. Gratings can be used beam splitters.

The angles of the diffraction orders depend on wavelength so gratings can also be used to separate colors of light for spectroscopy, multiplexing, and more.

Numerical :

Given : 11 = 4000 Å = 4000 x 10-10 m,

12 = 7000 Å = 7000 x 10-10 m,

a + b = 6000 cm; m=1

Formula : (a + b) sin 0 = mλ

Hence, for λ, we have

$\sin\Theta_1 = 1 \times 4000 \times 10^{-10} \times 6000 \times 10^{-2} = 0.24$

$\Theta_1 = \sin^{-1}(0.24) = 13° 53'$ ·

For λ_2 we have

$\sin\Theta_1 = 1 \times 7000 \times 10^{-10} \times 6000 \times 10^{-2} = 0.42$

$\Theta_2 = \sin^{-1}(0.42) = 24° 50'$

Angular breadth of the first order visible spectrum

$= \Theta_2 - \Theta_1 = 24° 50' - 13° 53' = 10° 57'$

Ans : The angular breadth is 10° 57' .

Q4)a) Explain with neat diagram, construction and working of SEM. (5M)

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

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.

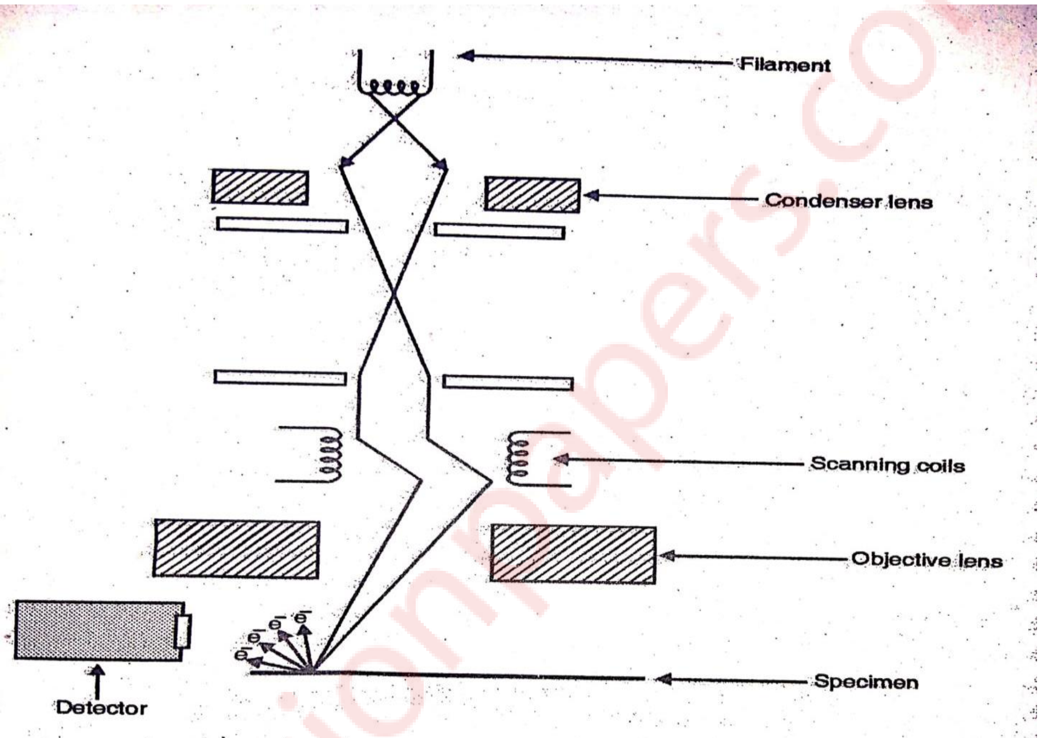


Fig. 8.3.2 : Schematic diagram of SEM

Q4)b) Explain spherical co-ordinate system. State the transformation relation between Cartesian and spherical co-ordinates. (5M)

Ans : Spherical coordinates determine the position of a point in three-dimensional space based on the distance ρ from the origin and two angles θ and φ. If one is familiar with polar coordinates, then the angle is essentially the same as the angle θ from polar coordinates.

Relationship between spherical and Cartesian coordinates :

Spherical coordinates are defined as indicated in the following figure, which illustrates the spherical coordinates of the point P. For spherical coordinates system also x, y, z axes are used for reference. Imagine a sphere of radius r with centre at origins. Any point on the sphere is at the same distance r from origin, therefore the spherical surface is defined as r= constant surface.

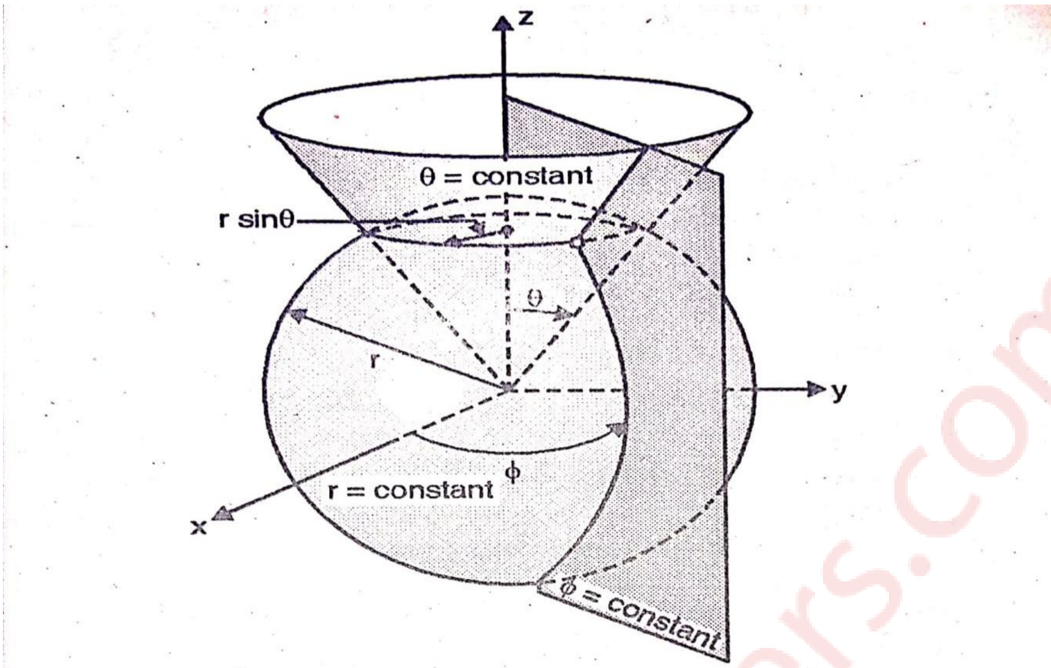


Fig. 6.1.8 : Spherical Coordinates

Now consider a line from origin making angle θ with z-axis. Rotate this line about z-axis fixing the end at the origin. This forms a cone with angle θ, this conical surface is defined as a θ = constant surface. When a sphere with centre at origin intersects with the vertical cone with vertex at origin, the intersection is a horizontal circle with radius equal to r sin θ. We want to locate a point in spherical coordinate system. Imagine a Ø = constant plane similar to in cylindrical system. A horizontal circle with centre onz-axis, Ø=constant plane. The intersection is the point.

Because r=constant, θ=constant and Ø=constant surface intersects at a point, the point is defined as (r, Ø, θ). In spherical system varriations of angle θ is

from 0 to 180 and variation of Ø is from 0 to 360 .

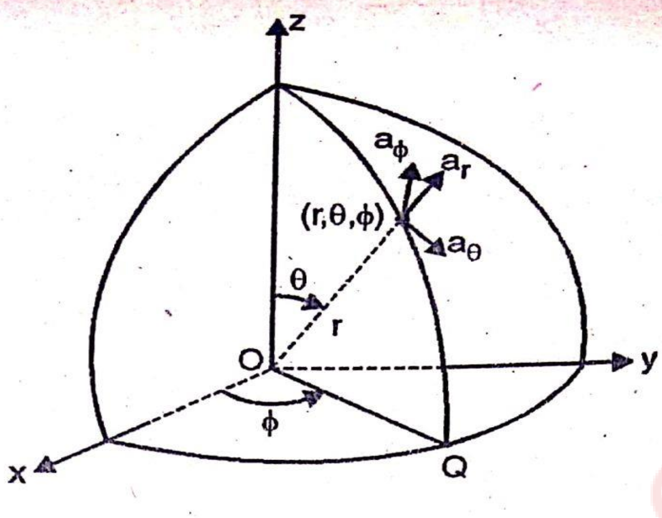


Fig. 6.1.10 : Unit vectors in spherical System

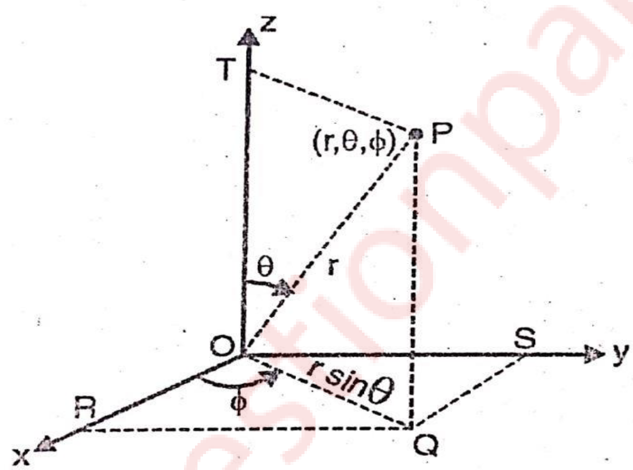


Fig. 6.1.11 : Relation between Spherical and Cartesian coordinates

Q4)c) What is holography? Distinguish between holography and ordinary photography. (5M)

Ans : Holography is a photographic technique that records the light scattered from an object, and then presents it in a way that appears three-dimensional. The principle behind holography is that during the recording process one superimposes on the scattered wave (emanating from the object) another coherent wave (called reference beam) of the same wavelength .

Holography	Photography
1)) In holography, both intensity as well as phase of light wave is recorded, thus holography gives three dimensional picture of the object.	1) In photography, only intensity is recorded so photography produces two dimensional picture of the object .
2) If the hologram is broken into parts, each part is capable of reconstructing the entire object.	2) In photography the destruction of even very small portion of negative or photography results in a irrepareable loss of information.
3) Holography has high information capacity as compared to photography.	3) Photography has low information capacity.
4) A photograph can be recorded using normal light sources (sunlight or electric lighting) e.g. lens .	4) In holography, the light from the object is scattered directly onto the recording medium e.g. laser .

Q5)a) Show that diameter of Newton's dark ring is directly proportional to square root of natural number. (5M)

Ans : 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.

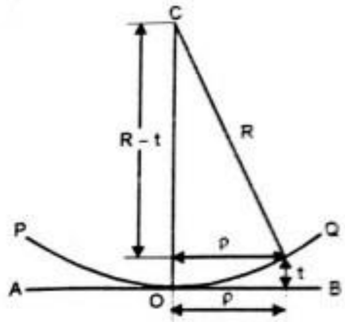
3.If monochromatic light is allowed to fall normally on this film, a system of alternate bright and dark concentric rings, with centre dark is formed in the air film.

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= 2µtcos(r+Ɵ)+λ/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=$\frac{D}{2}$

$\frac{D^2 n}{4R}$ =nλ

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

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

Q5)b) What are the different techniques to synthesize nanomaterial and explain any one of them in detail. (5M)

Ans : The different techniques to synthesize nanomaterials are :

1) Ball Milling
2) Sputtering

2) Vapour Deposition
3) Sol Gel Technique
4) Electro Deposition
5) Mechanical Crushing
6) Laser Synthesis
7) Inert gas condensation

i) Ball Milling is a process where a powder mixture placed in the ball mill is subjected to high energy collision from the balls.
ii) Planetary ball mill is frequently used system for mechanical alloying since only a very few amount of powder is required. In simple language, a ball mill consists of a hollow cylindrical shell rotating about its axis.
iii) The axis of the shell may be either horizontally or at a small angle to the horizontal. It is partially filled with balls which makes grinding media and made up of steel, stainless steel or ceramic .
iv) The inner surface of the shell is made up of an abrasion resistant material. When continuously operated, the shell rotates and lifts the ball up and drops them from near the top of the shell which causes the grinding of the particles inside .
v) It has been used in size comminutions of ore, mineral dressing, preparing talc powders and many other applications.
vi) Ball milling is a grinding method that grinds nanotubes into extremely fine powders. During the ball milling process, the collision between the tiny rigid balls in a concealed container will generate localized high pressure. Usually, ceramic, flint pebbles and stainless steel are used.

Q5)c) In a Newton's ring experiment,the diameter of nth and (n+12)th rings are 4.3 mm and 6.8 mm respectively. Radius of curvature of plano-convex lens is 1m.Find the wavelength of light. (5M)

Given : D^2_n=4.3X4.3=18.49 mm^2 , D^2_{n+2}=6.8x6.8=46.24 mm^2 ,R=1000mm

To find : λ

Solution :

Diameter of nth dark ring is given by

$$D^2_n = 4nR\lambda$$

$$\frac{D_n^2}{D_{n+2}^2} = \frac{18.49}{46.24} = \frac{4nR\lambda}{4(n+2)R\lambda} \quad .$$

$$\frac{18.49}{46.24} = \frac{n}{n+2} \quad .$$

18.49(n+2) = 46.24n .

18.49n +36.98 = 46.24n .

27.75n = 36.

n = 1.297 ≈ 1

Now, 18.49 = 4nRλ =4x1x1xλ .

λ = 18.49/4 = 4.622 m

Ans : The wavelength of light used is 4.622 m .

Q6)a) Explain the physical significance of divergence and curl of a vector field. (5M)

Ans : The divergence of a vector field $\mathbf{F}$, denoted $\mathrm{div}(\mathbf{F})$ or $\nabla\cdot\mathbf{F}$ (the notation used in this work), is defined by a limit of the surface integral

$$\nabla\cdot\mathbf{F}\equiv\lim_{V\to 0}\frac{\oint_S \mathbf{F}\cdot d\,\mathbf{a}}{V}$$

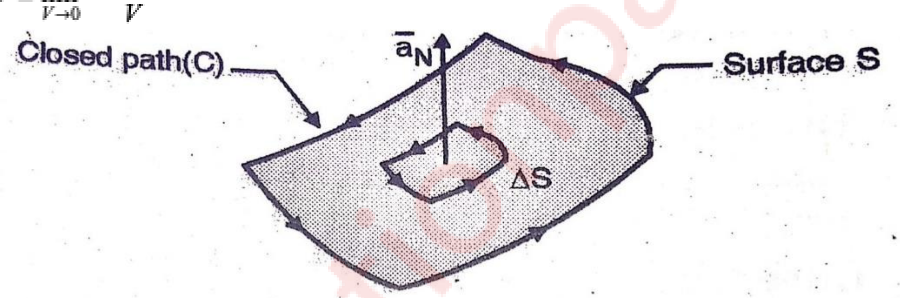


Fig. 6.3.6 : Curl of a vector

where the surface integral gives the value of F integrated over a closed infinitesimal boundary surface $S=\partial V$ surrounding a volume element V, which is taken to size zero using a limiting process. The divergence of a vector field is therefore a scalar field. If $\nabla\cdot\mathbf{F}=0$, then the field is said to be a divergenceless field. The symbol ∇ is variously known as "nabla" or "del."

The physical significance of the divergence of a vector field is the rate at which "density" exits a given region of space. The definition of the divergence therefore follows naturally by noting that, in the absence of the creation or destruction of matter, the density within a region of space can change only by having it flow into or out of the region. By measuring the net flux of content passing through a surface surrounding the region of space, it is therefore immediately possible to say how the density of the interior has changed. This property is fundamental in physics, where it goes by the name "principle of continuity." When stated as a formal theorem, it is called the divergence theorem, also known as Gauss's theorem. In fact, the definition in equation (1) is in effect a statement of the divergence theorem.

For example, the continuity equation of fluid mechanics states that the rate at which density ρ decreases in each infinitesimal volume element of fluid is proportional to the mass flux of fluid parcels flowing away from the element, written symbolically as

$$\nabla\cdot(\rho\,\mathbf{u}) = -\frac{\partial\rho}{\partial t}, \qquad (2)$$

where u is the vector field of fluid velocity. In the common case that the density of the fluid is constant, this reduces to the elegant and concise statement

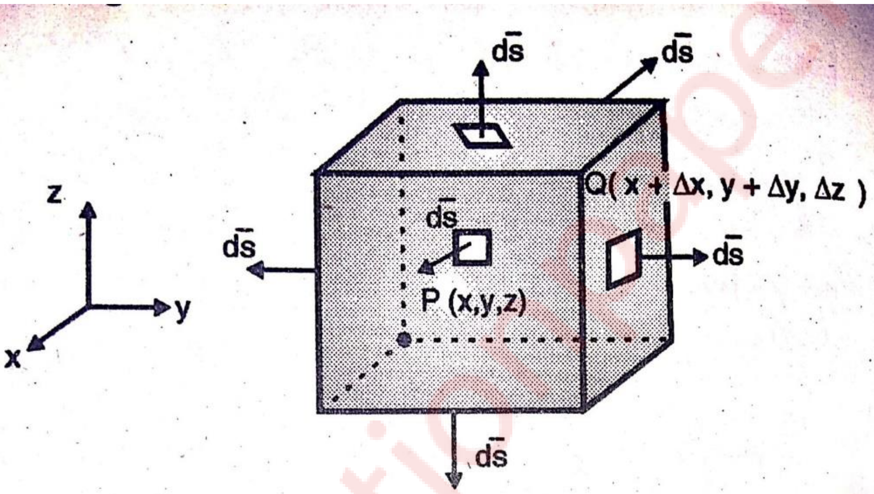
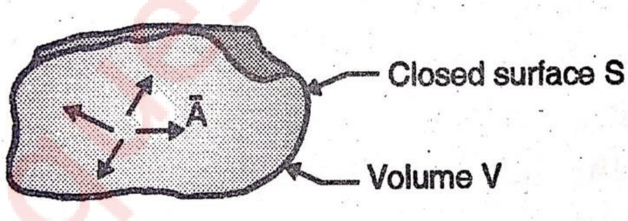


Fig. 6.3.3 : Divergence in Cartesian

(3)



$$\nabla\cdot\mathbf{u} = 0,$$

which simply says that in order for density to remain constant throughout the fluid, parcels of fluid may not "bunch up" in any place, and so the vector field of fluid parcel velocities for any physical system must be a divergenceless field.

Divergence is equally fundamental in the theory of electromagnetism, where it arises in two of the four Maxwell equations,

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon_0} \tag{4}$$

$$\nabla \cdot \mathbf{B} = 0, \tag{5}$$

where MKS units have been used here, E denotes the electric field, ρ is now the electric charge density, ϵ_0 is a constant of proportionality known as the permittivity of free space, and B is the magnetic field. Together with the two other of the Maxwell equations, these formulas describe virtually all classical and relativistic properties of electromagnetism.

A formula for the divergence of a vector field can immediately be written down in Cartesian coordinates by constructing a hypothetical infinitesimal cubical box oriented along the coordinate axes around an infinitesimal region of space. There are six sides to this box, and the net "content" leaving the box is therefore simply the sum of differences in the values of the vector field along the three sets of parallel sides of the box. Writing $\mathbf{F} = (F_x, F_y, F_z)$, it therefore following immediately that

$$\nabla \cdot \mathbf{F} = \frac{\partial F_x}{\partial x} + \frac{\partial F_y}{\partial y} + \frac{\partial F_z}{\partial z}. \tag{6}$$

This formula also provides the motivation behind the adoption of the symbol $\nabla \cdot$ for the divergence. Interpreting ∇ as the gradient operator $\nabla = (\partial / \partial x, \partial / \partial y, \partial / \partial z)$, the "dot product" of this vector operator with the original vector field $\mathbf{F} = (F_x, F_y, F_z)$ is precisely equation (6).

While this derivative seems to in some way favor Cartesian coordinates, the general definition is completely free of the coordinates chosen. In fact, defining

$$\mathbf{F} \equiv F_1 \, \hat{\mathbf{u}}_1 + F_2 \, \hat{\mathbf{u}}_2 + F_3 \, \hat{\mathbf{u}}_3, \tag{7}$$

the divergence in arbitrary orthogonal curvilinear coordinates is simply given by

$$\nabla \cdot \mathbf{F} \equiv \frac{1}{h_1 \, h_2 \, h_3} \left[\frac{\partial}{\partial u_1} (h_2 \, h_3 \, F_1) + \frac{\partial}{\partial u_2} (h_3 \, h_1 \, F_2) + \frac{\partial}{\partial u_3} (h_1 \, h_2 \, F_3) \right]. \tag{8}$$

The divergence of a linear transformation of a unit vector represented by a matrix A is given by the elegant formula

$$\nabla \cdot \frac{\mathbf{A}\,\mathbf{x}}{|\mathbf{x}|} = \frac{\mathrm{Tr}\,(\mathbf{A})}{|\mathbf{x}|} - \frac{\mathbf{x}^{\mathrm{T}}\,(\mathbf{A}\,\mathbf{x})}{|\mathbf{x}|^3}, \tag{9}$$

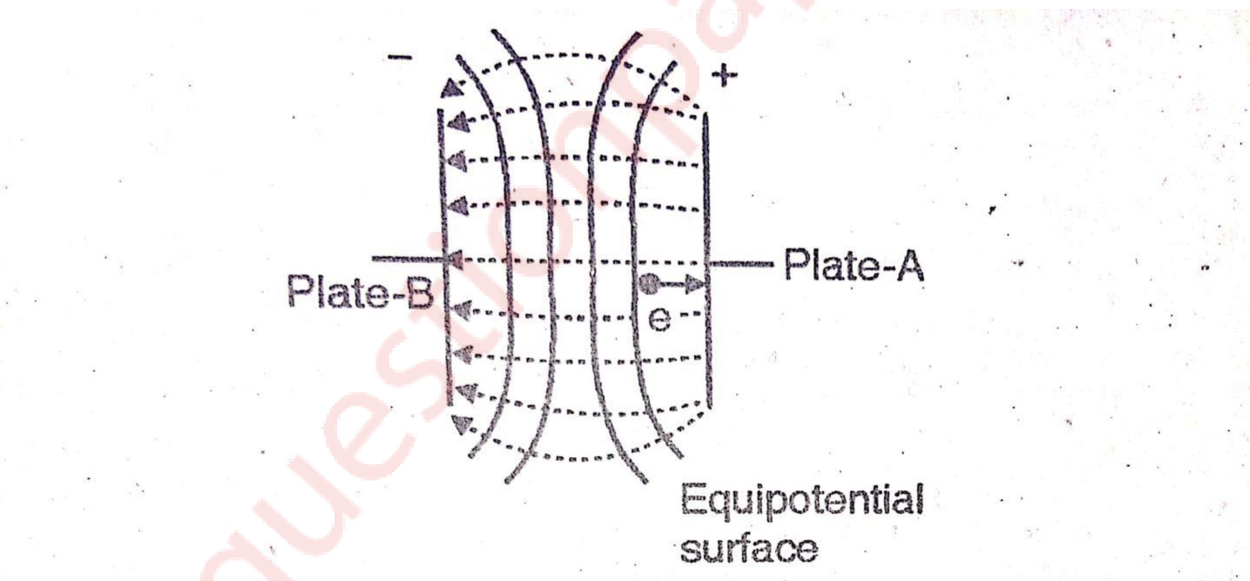
where $\mathrm{Tr}\,(\mathbf{A})$ is the matrix trace and $\mathbf{x}^{\mathrm{T}}$ denotes the transpose.

The concept of divergence can be generalized to tensor fields, where it is a contraction of what is known as the covariant derivative, written

$$\nabla \cdot A \equiv A^{\alpha}_{;\alpha}. \tag{10}$$

Q6)b) State Bethe's Law and explain electrostatic focusing of electron beam. (5M)

Ans : Diagram above represents the electrostatic focusing. A and B are two co-axial cylinders with potentials V1 and V2 such that V2>V1.R is the equipotential ring placed between A and B.



Working :

(1) Consider electron beam 1:

It will remain normal to all the equipotential surfaces and hence it is simply accelerated without any deviation of the path.

(2) Consider electron beam 2:

It will have following 2 effects:

i) On the Left Hand Side of R : The parallel component of F will move the electrons towards right while the normal component of F will move the electron downward by applying Fleming's Left Hand Rule at point C .

ii) On the Right Hand Side of R : The horizontal and vertical component of F will move the elctrons towards right and towards left respectively by applying Fleming's Left Hand Rule at point D .

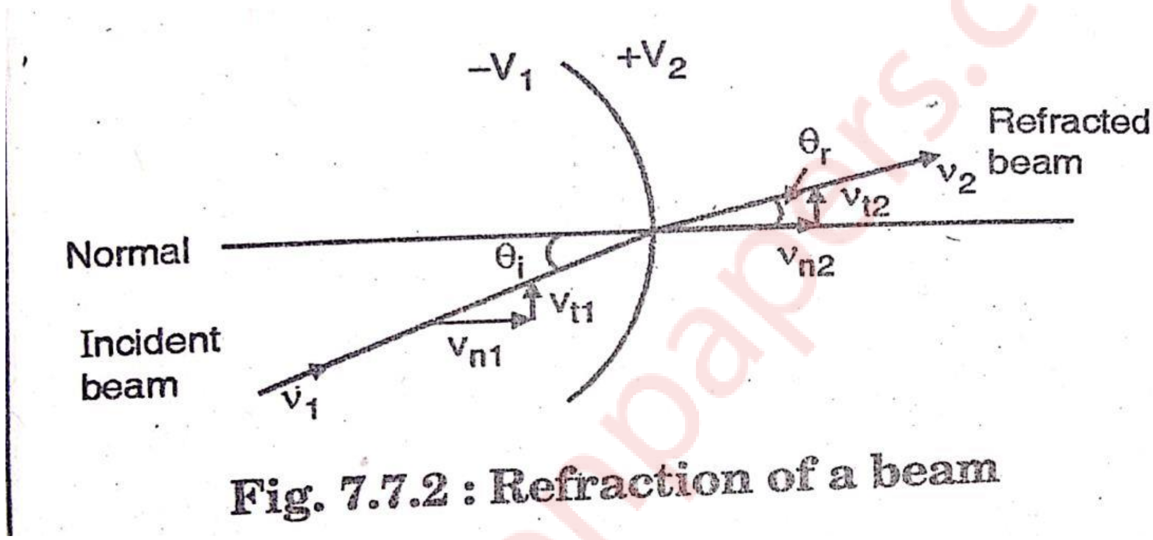


Fig. 7.7.2 : Refraction of a beam

(3) Consider electron beam 3:

It's path will be as shown with same case as case(2).

The focal length can be changed by varying V1 and V2

(4) Bethe's laws is also followed in electrostatic focusing .

(5) Electrostatic focusing is used for accelerating and focusing electron beams.

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. If V1>V2, v_{1y} increases while if V2 > V1, v_{2y} increases. This is known as **Bethe's law** of electron refraction.

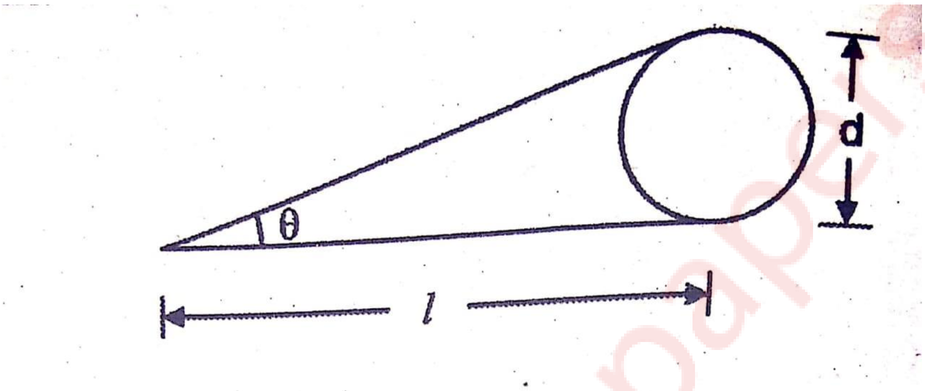
Q6)c) Two glass plates enclose a wedge-shaped air film touching at one end are separated by wire of 0.03mm diameter at distance 15 cm from the edge. Monochromatic light of wavelength λ=6000 Å from a broad source falls normally on the film. Calculate the fringe width. (5M)

Given :

l = 15 cm , r = 0.03 mm = 0.003 cm ,d = 0.006 cm , λ = 6000 Å

To find : fringe width (β)

Solution : Assuming that (i)wedge angle is very small , (ii) the medium is air , (iii) Incident of light in normal



tanϴ = d/l =ϴ . (for very small ϴ)

and $\beta = \lambda/2\Theta$

$\beta = 15 \times 6000 \times 10^{-8}/2 \times 0.006$

$\beta = 0.075$ cm

Ans : The value of fringe width is 0.075 cm .