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 x 10^{-6} m

N.A = 0.25

λ = 0.75 x 10^{-6} m

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

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

= 52.36

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 x 10^{-19} x 18 x 10^3

= 28.8 x 10^{-16} J

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

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

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

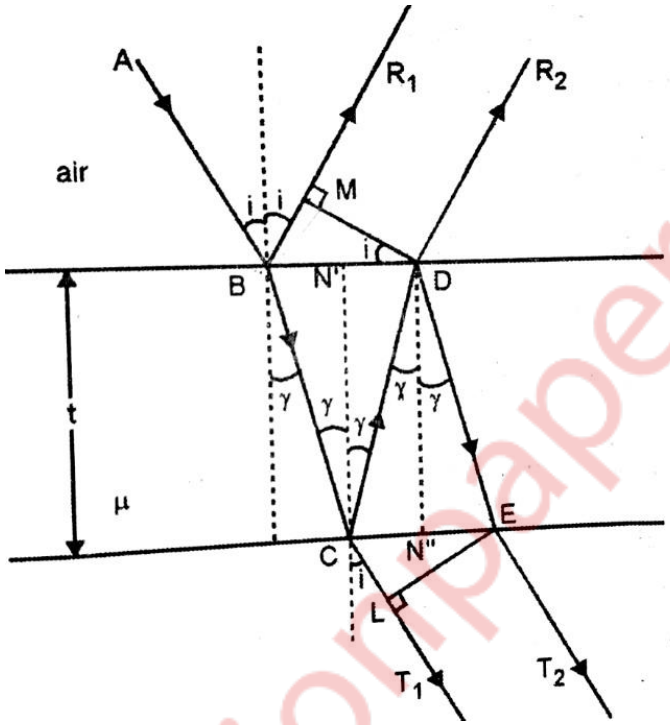
= 7.95 x 10^7 m/s

Kinetic energy of electron = 28.8 x 10-16 J

Speed of electron = 7.95 x 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,

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

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

Now,

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

$BM = BD \sin i$

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

$BM = 2t\mu \sin r(\sin r / \cos r)$

$BM = 2\mu t(\sin^2 r/\cos r)$.....(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°

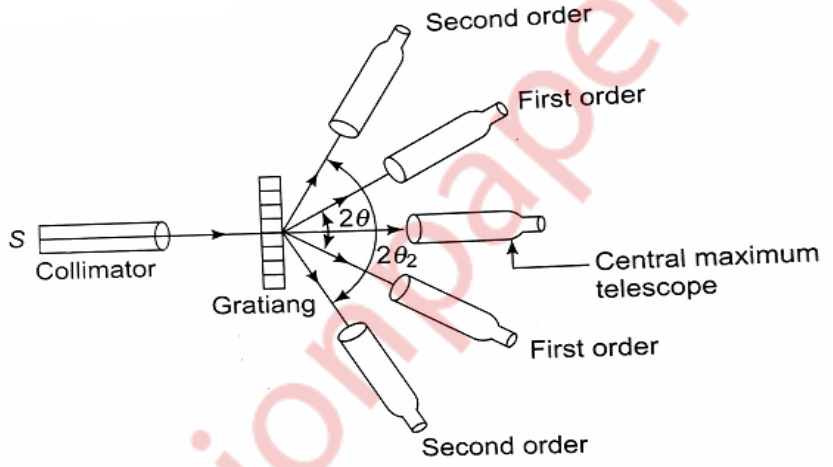
Core refractive index = 1.6025

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

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

= 3.3

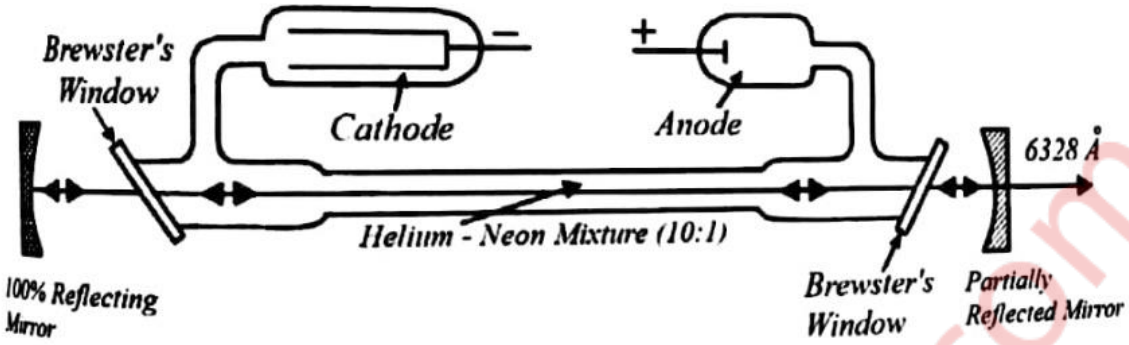
Maximum order of spectrum = 3

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.

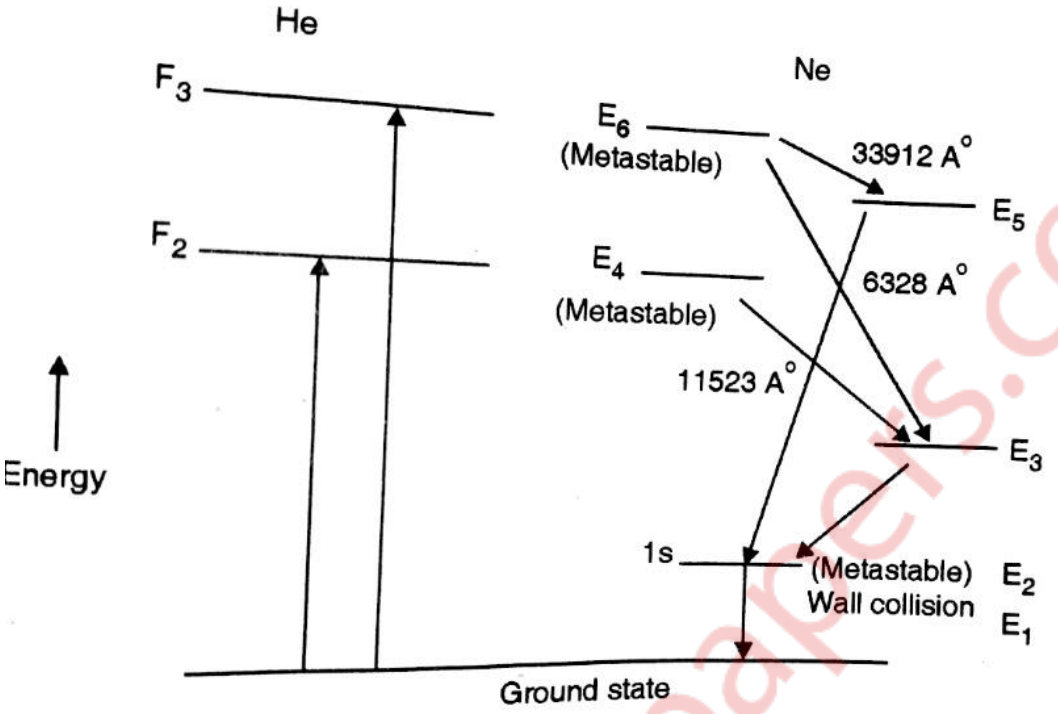
4.In order to make laser tubes more economical and durable manufacturers often attach the mirrors directly to the ends of the capillary tube.This is very common with small low power LASERS.

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.

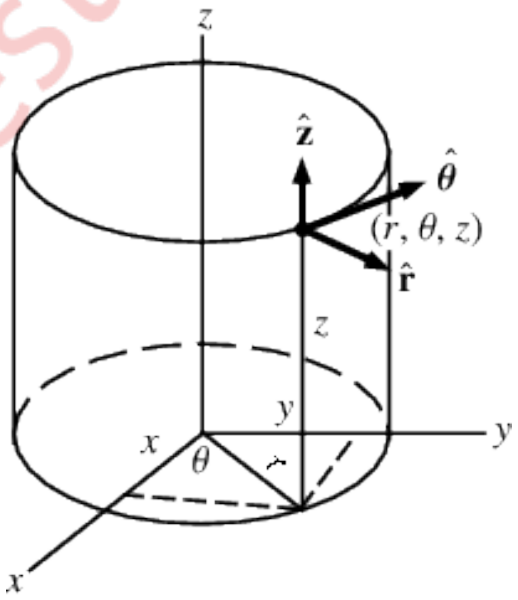
7.From E5 and E level neon atom can make downward transition to E2 level. Incoherent light is emitted due to spontaneous transition. As lower levels depopulate faster than upper levels it is easier to maintain population inversion throughout laser operation. E2 is again a metastable state.

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.

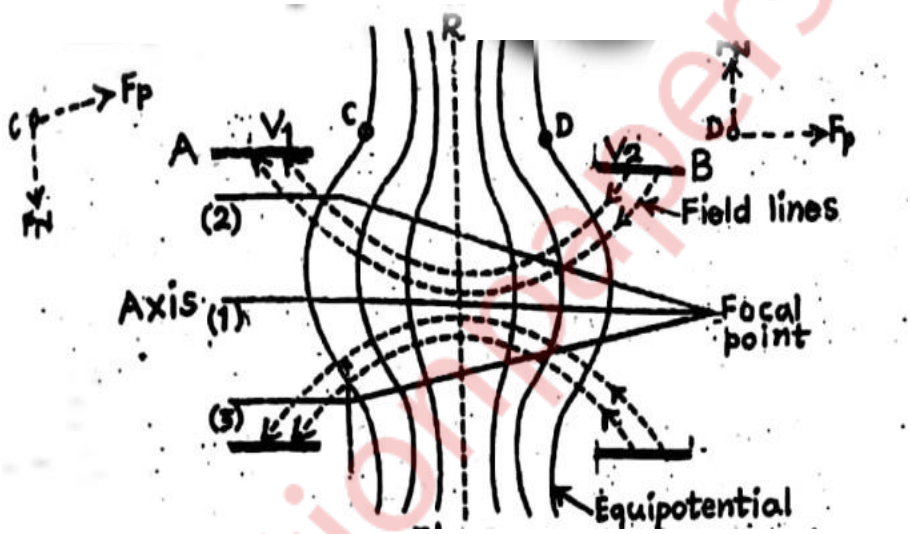


Diagram above represents the electrostatic focusing.A and B are two co-axial cylinders with potentials V1 and V2 such that V2>V1.R is the equipotential ring placed between A and B.

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.

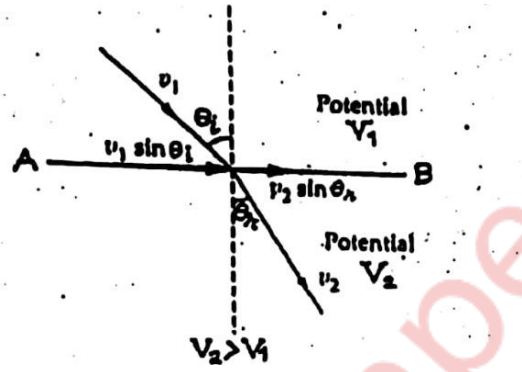
(b) On the R.H.S off R: F_P and F_N will move the electron towards right and towards up respectively by applying Fleming's left hand rule at point D.

(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

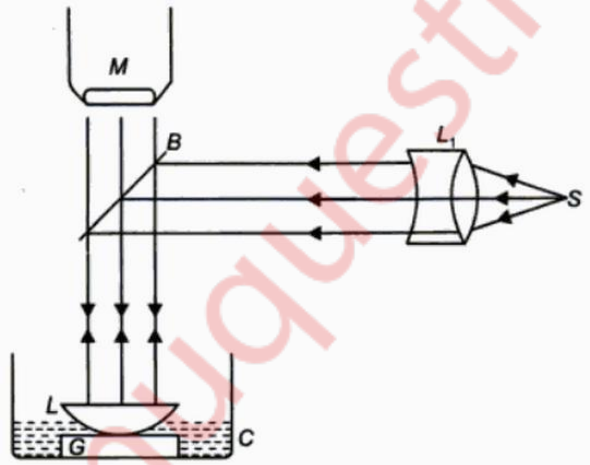
= 2.95 mm

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

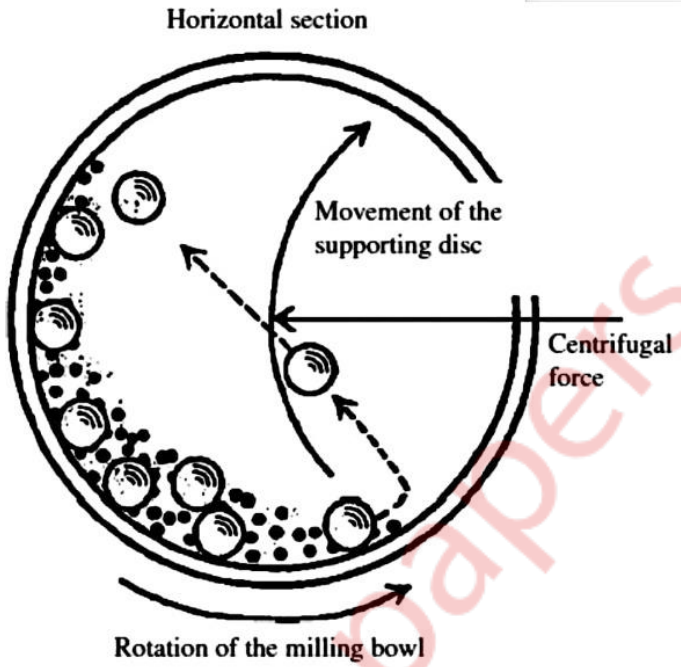
3.Vapour deposition

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.

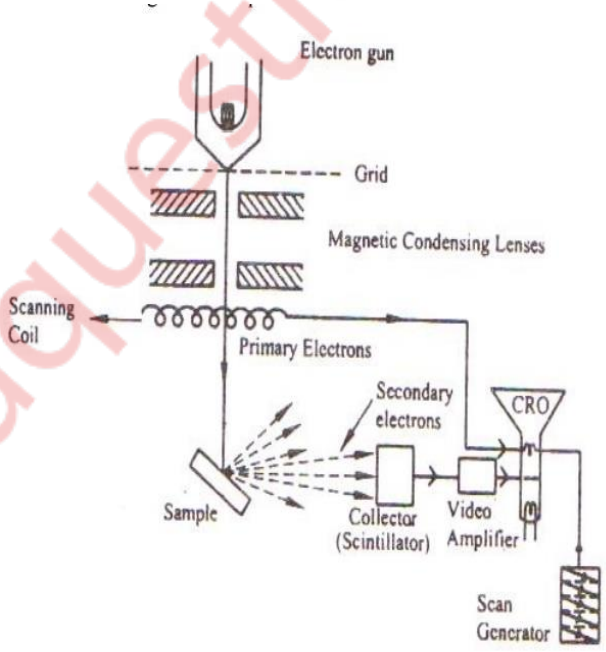
Principle:

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:

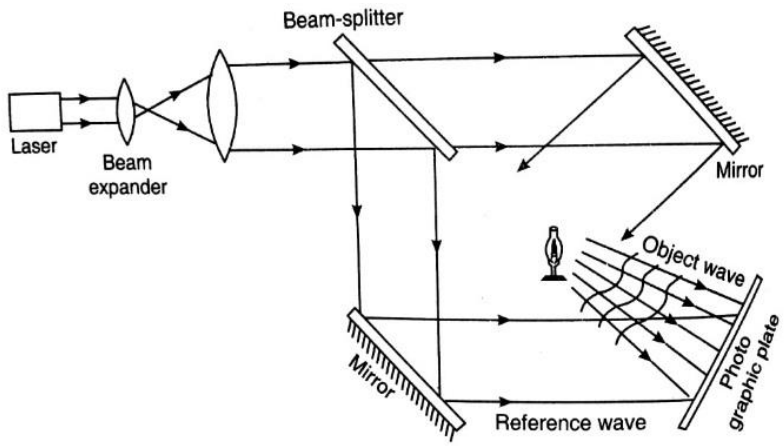
1. Holography is the science and practice of making holograms. Holography is actually a recording of interference pattern formed between two beams of coherent light coming from the same source.

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.

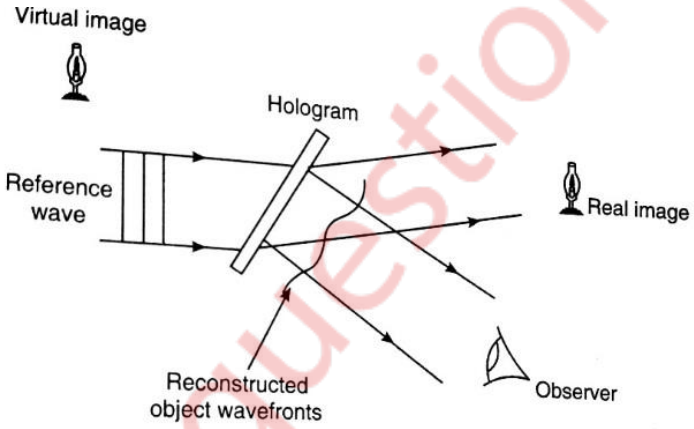
Construction process :



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 :

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

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

Radius of path = 0.0119 m