MUMBAI UNIVERSITY
SEMESTER-2
APPLIED PHYSICS-2 SOLVED PAPER DEC 2017

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

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

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

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

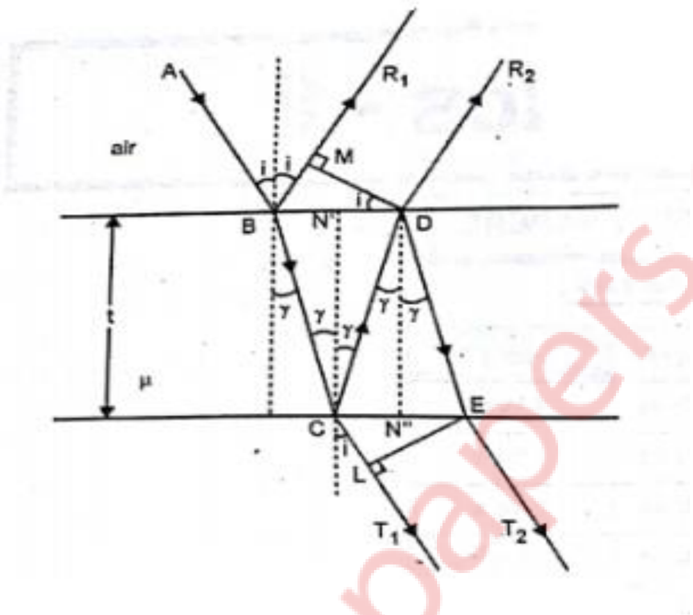
i.e. every next bright fringe will occur for thickness interval of λ/2 each

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

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

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)sinθ = mλ

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

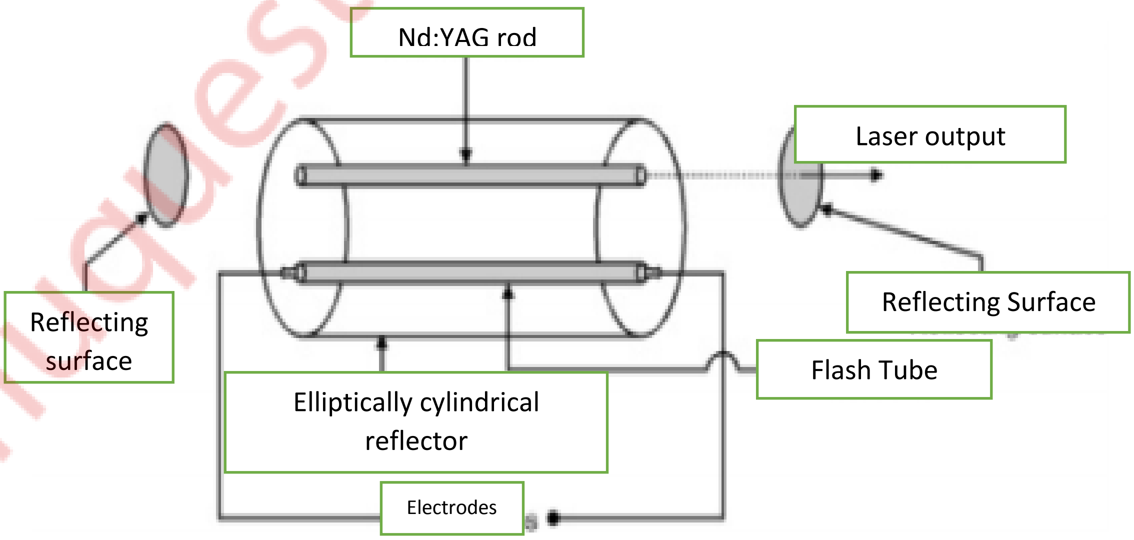
$$d\frac{d\theta}{d\lambda} = \frac{n}{(a+b)cos\theta} = \frac{2}{\frac{1}{5000}*0.866}$$

= 11547

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

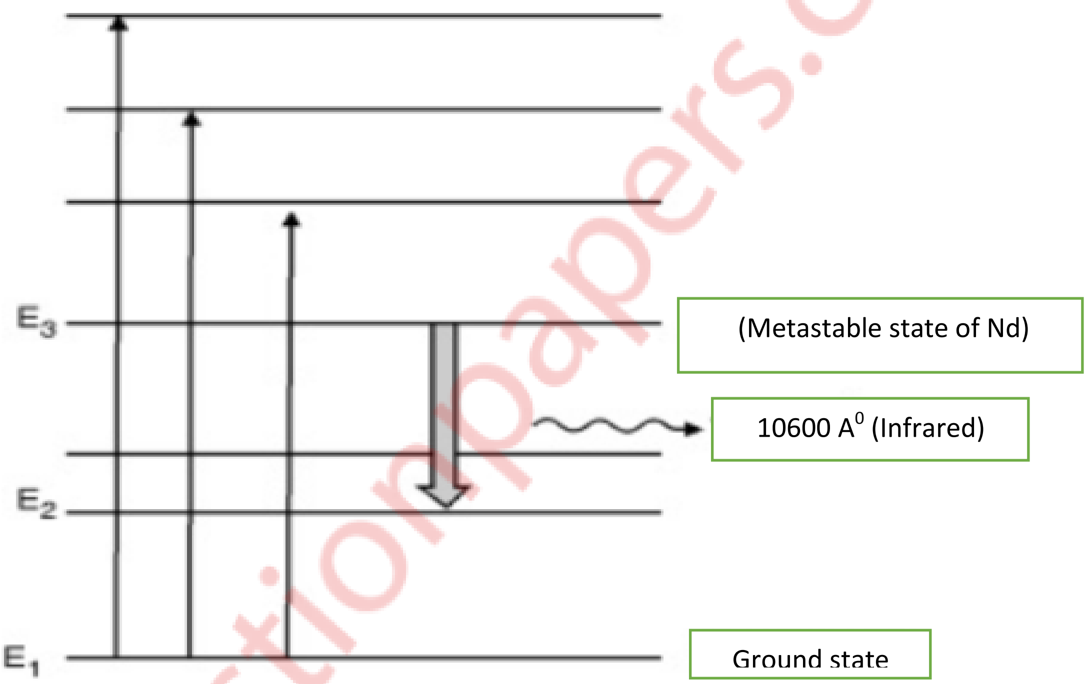
Ans:

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.

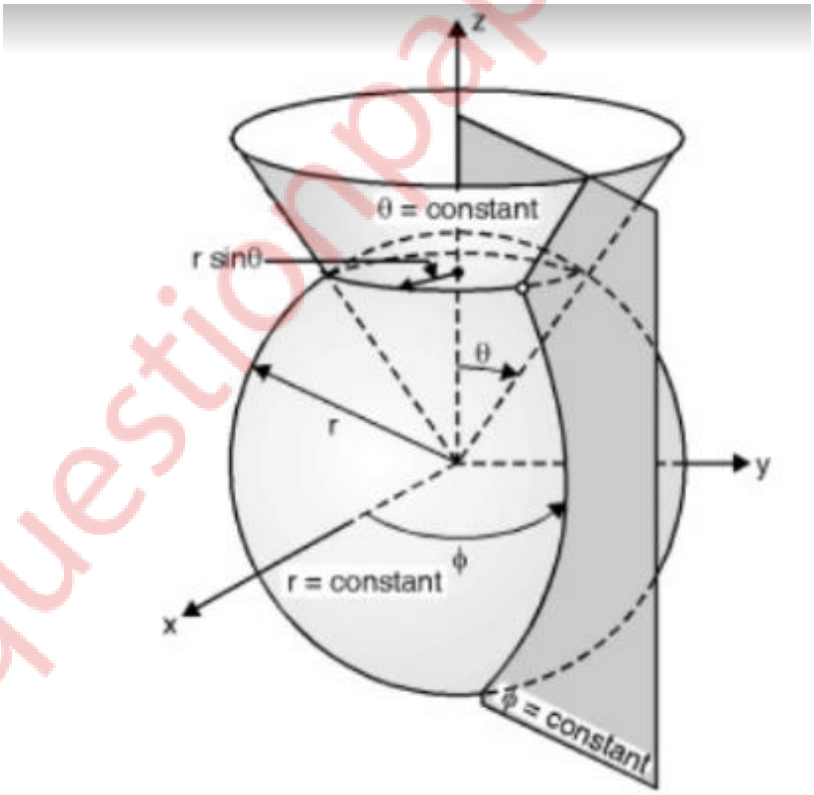
Q.4.A) Explain spherical co-ordinate system. State the transformation relation between Cartesian and spherical co-ordinates. (5 m)

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.

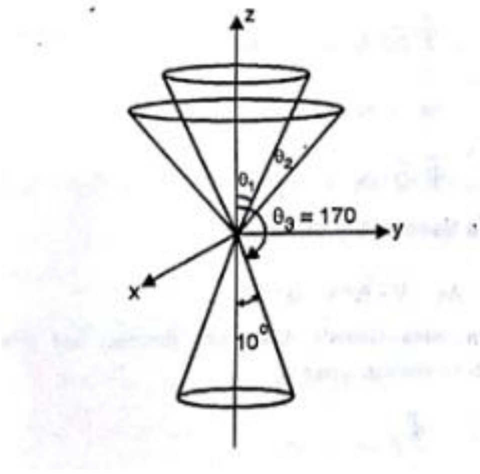
Now consider a line from origin making angle θ with z-axis. Rotate this line about z-axis fixing the end at the origin. This forms a cone with angle θ, this conical surface is defined as a θ = constant surface. When a sphere with centre at origin intersects with the vertical cone with vertex at origin, 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 $OQ = r\sin\theta$

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

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

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

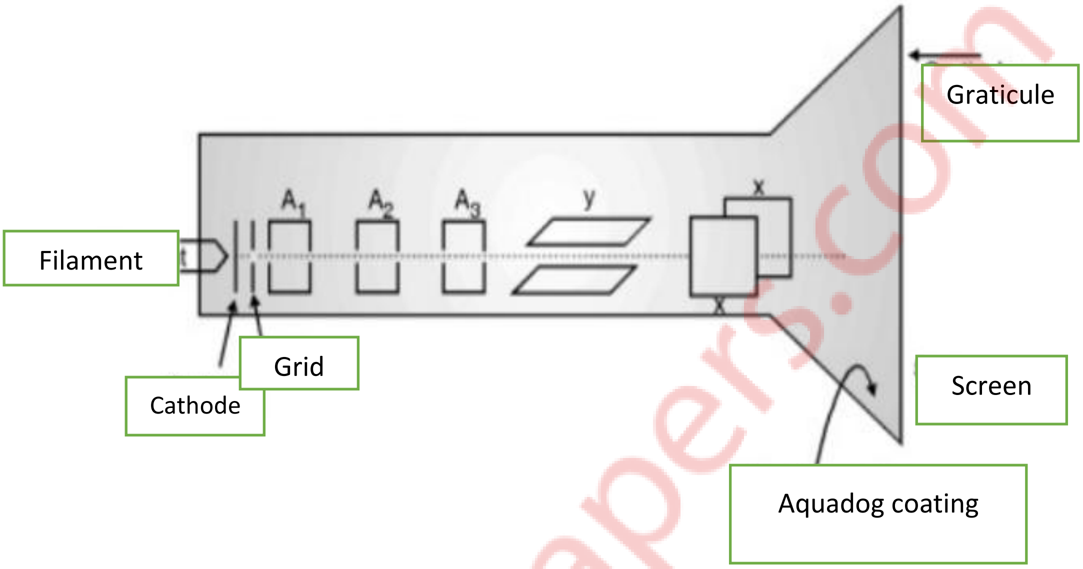
projection of OP on z-axisgives z-coordinats of p

projection of OP on z-axis = $OT = OP\cos\theta$

$$z = r\cos\theta$$

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, $\lambda = 2\beta * \theta$

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

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

$\lambda = 4654\ A^0$

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/m^2 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:

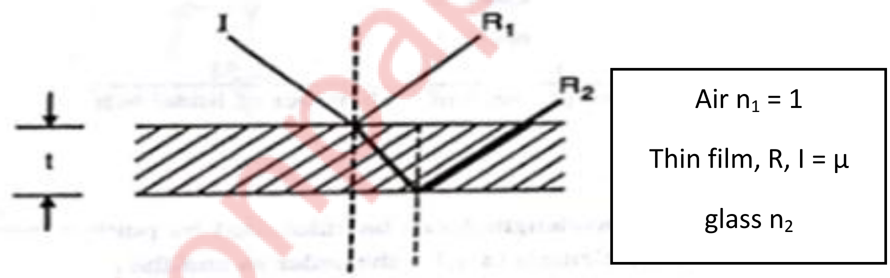
1. The advent of lasers has made the art of holography possible. Photography can be thought of as a new approach to the problem of generating images. An ordinary photography represents a two dimensional recording of three dimensional scene.
2. The emulsion of the photographic plate is sensitive to only 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.