# END TERM EXAMINATION [DEC. 2015]
# FIRST SEMESTER [B. TECH]
# APPLIED PHYSICS-I [ETPH–103]

**Time: 3 Hrs.** **MM : 75**

*Note: Attempt any five questions including Q.no.1 which is compulsory. Select one question from each unit. Draw neat scientific diagrams wherever necessary. Work in SI units. Assume data wherever necessary.*

**Q.1. Answer any nine of the following:**

**Q.1. (a) Two coherent sources whose intensity ratio is 4:1 produce interference fringes, find the ratio of maximum to minimum intensity in the interferency pattern.** **(3)**

**Ans.**

$$I_{max} = (a_1 + a_2)^2$$

$$I_{min} = (a_1 - a_2)^2$$

$$\frac{I_{max}}{I_{min}} = \frac{(a_1 + a_2)^2}{(a_1 - a_2)^2}$$

Given

$$\frac{I_1}{I_2} = \frac{a_1^2}{a_2^2} = \frac{4}{1} = 2$$

$$\frac{a_1}{a_2} = \frac{2}{1} \text{ or } a_1 = 2a_2$$

$$\frac{I_{max}}{I_{min}} = \frac{(2a_2 + a_2)^2}{(2a_2 - a_2)^2} = \frac{9}{1}$$

$\therefore$

$$\boxed{I_{max} : I_{min} = 9 : 1}$$

**Q.1. (b) A slit is located ' at infinity' in front of lens of focal length 1m and is illuminated on either side of the central maximum of the diffraction pattern observed in the focal plane of the lens are separated by 6 *mm*. What is the width of the slit?** **(3)**

**Ans.** Width of central maximum

$$y = \frac{f\lambda}{a}$$

where

$y$ = linear half width of the central maximum

$f$ = focal length

$\lambda$ = wavelength of light

$\alpha$ = slit width

given

$y$ = 6 mm

$f$ = 1 m

$\lambda$ = 600 nm

$\therefore$

$$6\text{mm} = \frac{1m \times 600nm}{a}$$

$\Rightarrow$

$$a = \frac{1m \times 600 \times 10^{-9} m}{6 \times 10^{-3}}$$

$$a = 0.1\text{m}$$

**Q.1. (c) The axes of a polarizer and analyzer are oriented at 30° to each other. (1) if un-polarized light of intensity $I_0$ is incident on them, what is the intensity of the transmitted light.**

**(2) Polarized light of intensity $I_o$ is incident on this polarizer analyzer system. If the amplitude of the light makes an angle of 30° with the exis of the polarizer, what is the intensity of the transmitted light?** (3)

**Ans.** Given that $I_o$ is the unpolariged light incident on polarizer then after passing through it $I_1$ is the intensity of polarizer and $I_2$ is that of analyzer.

(1) The intensity of light after passing through polarizer

$$\boxed{I_1 = \frac{I_o}{2}} \quad ...(ii)$$

(2) If polarized light incident on polarizer at an angle of 30°

$$I_1 = I_o \cos^2(30°)$$

$$I_1 = I_o \frac{3}{4}$$

**Q.1. (d) What is the role of the core in an optical fibre.** (3)

**Ans.** The core is the innermost section of the fibre and has a remarkable property of conducting an optical beam. It is made of glass or plastic. The core the actual working structure of fibre is coverd with another layer of glass with slightly different chemical composition called cladding.

The refractive index of core is greater than refractive index of cladding. Light propagate through core in a fibre by total internal reflection phenomenon.

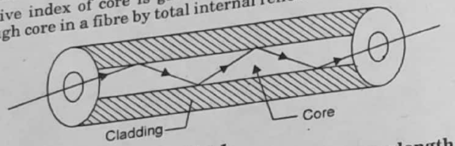



**Fig. 1.**

**Q.1. (e) A source is emitting 100W of green light at a wavelength of 500 nm. How many photons per second are emerging from the source.** (3)

**Ans.**

$$\text{Power} = \frac{\text{Energy}}{\text{time}}$$

$$\text{Energy of one photon} = h\nu$$

$$\text{Energy of 'n' photon} = nh\nu$$

$$\text{given} \Rightarrow \text{(p) power} = 100 \text{ W}$$

$$\lambda = 500\text{nm}$$

$$P = \frac{nh\nu}{t}$$

$$n = \frac{pt}{h\nu} = \frac{pt\lambda}{hc}$$

$$\frac{n}{t} = \frac{p\lambda}{hc} = \frac{100 \times 500 \times 10^{-9} m}{6.63 \times 10^{-34} \times 3 \times 10^{-18}} = \mathbf{2.5 \times 10^{20}}.$$

no. of photons per second

**Q.1. (f) A loudspeaker cannot be used for the production of ultrasonic waves. Justify.** (3)

**Ans.** The ultrasonic waves can not be produced by common method of diaphragm field with alternating current. This is due to the reason that at very high frequencies the inductive effect of the loudspeaker coil is so large that practically no current passes through it.



**Q.1. (g) A 1 kg object is lifted from the floor to a table 30 cm above the floor. By how much did the mass of the object increase because of its increased potential energy?** (3)

**Ans.** Relativistic point view increase in P.E. = mgh = 1 × 9.8 × 0.30

$$= 294\text{J}$$

It this energy is converted into mass then

$$E = mc^2$$

$$m = \frac{E}{c^2} = \frac{2.94}{(3 \times 10^8)^2} = 3.266 \times 10^{-17} \text{ kg}$$

**Q.1. (h) Explain the principle of the Magnetic Resonance Imaging (MRF) technique.** (3)

**Ans.** The principle of MRI is the directional magnetic field or moment associated with charged particle in motion. Nuclei containing an odd number of protons and /or neutrons have a characteristic motion or precession. Because nuclei are charged particles, this precession produces a small magnetic moment. When a human body is placed in a large magnetic field, many of the free hydrogen nuclei, present in water molecules, behave like compass needles and partially aligned by a strong magnetic field in the scanner. The nuclei can be rotated using radio waves and they subsequently oscillate in the magnetic field while returing to equilibrium. Simultaneously they emit a radio signal. This is detected using antennas (coils) and can be used for making detailed imaged of body tissues.

**Q.1. (i) Derive the definition of Curie as a unit of acitivity. Assume that the half-life of radium is 1620 years having an atomic weight of 226 kg/k mol.** (3)

**Ans.** In radio activity, the intensity is determined in terms of the rate of disintegration or number of particles emitted per second curie is a unit of radioactivity

$$1 \text{ curie} = 3.70 \times 10^{10} \text{ disintegrating second}$$

Curie is defined as that quantity of any radioactive substance that gives $3.7 \times 10^{10}$ disintegrating per second.

$$N = 1gm\left[\frac{1gm - mole}{226gm}\right]\left[6.023 \times 10^{23} \frac{\text{atoms}}{\text{gm-mole}}\right]$$

$$N = 2.26 \times 10^{21} \text{ atoms}$$

$$T_{1/2} = 1620 \text{ years}$$

$$\lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{1620 \times 365 \times 24 \times 60 \times 60}$$

$$\lambda = 1.355 \times 10^{-11} \text{ s}^{-1}$$

$$\text{Activity} = \lambda N$$

$$= 3.604 \times 10^{10} \frac{\text{disintegration}}{5}$$

$$= 0.974\ Ci = 1\ Ci \text{ (hence proved)}$$

**Q.1. (j) Find the frequency of rotation of a protion in a cyclotron whose magnetic fields is IT. Assume that the mass of the proton is $1.67 \times 10^{-27}$ kg.** (3 × 9 = 27)

**Ans.**

$$B = \frac{2\pi m\upsilon}{q}, \upsilon = \frac{B \times (q/m)}{2\pi}$$

$$= \frac{\dfrac{1 \times 1.6 \times 10^{-19}}{1.67 \times 10^{-27}}}{2 \times 3.14} = 15\text{MHz}$$

## UNIT-I

**Q.2. (a) Explain the terms temporal and spatial coherence in the context of the interfernce phenomenon. Explain why interference due to division of amplitude is observed in thin films.** (1+1+1)

**Ans. Temporal Coherence:** If the phase difference between the two field is constant during the period normally covered by observation, the wave has temporal coherence.

**Spatial Coherence:** If two fields, at two different points on a wave front of a given electromagnetic wave, have constant phase difference over any time, they possess spatial coherence.

When a thin film of oil spreads on the surface of water is exposed to white light beautiful colours are seen. These phenomena can be explain on the basis of interference between light reflected from the upper and lower surface of a film. Which is the interference due to division of amplitude in which the incident amplitude is alomost equally divided into two parts either by reflection of refraction. These divided parts reunite to produce interference pattern.

**Q.2. (b) Illustrate with a neat scientific, well-labeled diagram the formation of fringes due to a Fresnel's Bi-prism.** (1.5)

Ans.

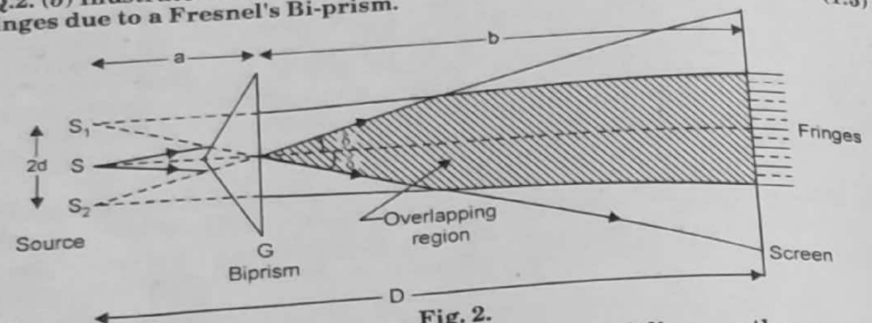



Fig. 2.

**Q.2. (c) Illustrate with a neat scientific, well labeled diagram the necessity of an extended sources to observe fringes in a thin film.** (1.5)

Ans.

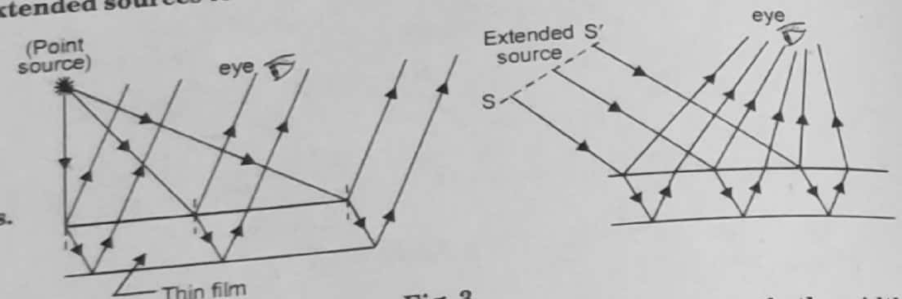



Fig. 3.

**Q.2. (d) Derive the relation for path difference and subsequently the width of a single band for a wedge shaped film.** (4)

**Ans.** If $t$ is the thickness of film at a distance $x$ from the edge the path difference between the two reflected rays producing interference will be $2\mu t \cos r \pm \lambda/2$ the condition for brightness is

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

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

or

and condition for darkness

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



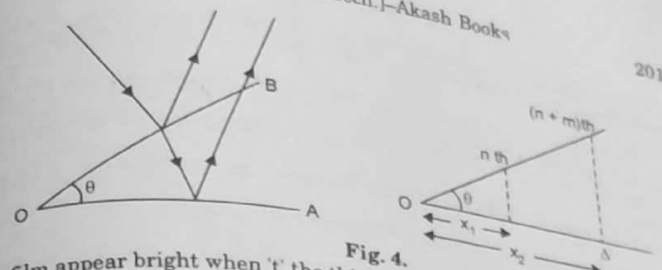



Fig. 4.

The film appear bright when 't' the thickness of film satisfies.

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

or

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

The film appear dark when 't' satisfies the condition.

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

or

$$t = \frac{n\lambda}{2\mu \cos r}$$

for small angle of incidence $\cos r = 1$ and $t = x\theta$

So condition for darkness reduces to

$$2\mu x\theta = n\lambda$$

if $x_1$ is the distance of the nth dark band from the edge of wedge $x_2$ that of the $(n+m)$th dark band then

$$x_1 = \frac{n\lambda}{2\mu\theta} \text{ and } x_2 = \frac{(n+m)\lambda}{2\mu\theta}$$

$$x_2 - x_1 = \frac{(n+m)\lambda}{2\mu\theta} - \frac{n\lambda}{2\mu\theta} = \frac{m\lambda}{2\mu\theta}$$

$$\beta = \frac{x_2 - x_1}{m} = \frac{\lambda}{2\mu\theta} \text{ so}$$

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

**Q.2. (e) An interference pattern is first obtained using a bi-prism set-up. When a thin sheet of glass ($\mu = 1.5$) of 5 μm thickness is introduced in the path of one of the interfering rays, the central fringes is shifted to a position normally occupied by the fifth fringes. Calculate the wavelength of light used.** (2)

**Ans.**

$$t = \frac{n\lambda}{\mu - 1}$$

where t = μm, $n = 5$, $\mu = 1.5$; $\lambda = ?$

$$\lambda = \frac{(\mu-1)t}{n} = \frac{(1.5-1)\times(5\times10^{-6})}{5}$$

$$= 5 \times 10^{-7}\text{m or } 500\text{nm}$$

**Q.3. (a) Distinguish between Fraunhoffer and Fresnel diffraction.** (2)

**Ans. (a) Fraunhoffer Diffraction:**

(i) The distance of the source and screen from the diffracting element (aperture or obstacle) are effectively infinite.

(ii) A convex lens is used to make the light from the source parallel before it falls on the aperture and another convex lens is used to focus the light after diffraction on the screen. This arrangement makes the source and screen at infinity from the obstacle.

(*iii*) The incident wave front is plane and the secondary waves originating from the exposed part of wavefront are in the same phase at every point in the plane of the aperture.

(*iv*) The diffraction is produced by interference between parallel rays which are brought to focus with a convex lens.

(*v*) In this class of diffraction, angular inclinations are important and not the distances.

(*vi*) This class of diffraction can be discussed with more accuracy in analytical terms.

(*vii*) It has number of important practical applications.

**(*b*) Fresnel Diffraction:**

(*i*) The source or the screen or both are at finite distances from the diffracting element *i.e.* aperture or obstacle.

(*ii*) No lenses are used to make the rays parallel or convergent.

(*iii*) The incident wave front is not plane but is either cylindrical or spherical.

(*iv*) The phase of secondary waves is not the same at all point in the plane of the aperture or the obstacle.

(*v*) The resultant amplitude at any instant on the screen is obtained by mutual interference of secondary waves from different elements of exposed part of wave front.

(*vi*) In this class of diffraction, distances are important rather the angular inclinations.

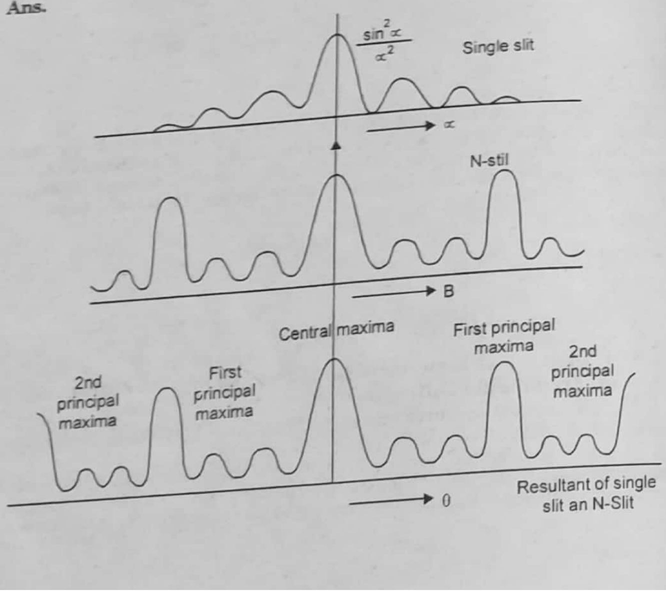
(*vii*) This type of diffraction is studied with approximations. Zone plate is an example of this type of diffraction.

**Q.3. (*b*) Derive the intensity pattern for a Fraunhoffer's diffraction due to a single slit using the analytical method.** (3)

**Ans.** Refer Q.3. (*a*) First Term Examination Sept. 2015.

**Q.3. (*c*) Show that the intensity pattern due to N slits is the product of two terms the diffraction pattern due to a single slit and the interference pattern due to N slits.** (5)

**Ans.**






**Q.3. (*d*) Transparency and opacity ratio in a grating having 5000 line in one cm is 1:2 which orders of the maxima will be missing the diffraction grating?** (2)

**Ans.**

$$\frac{a+b}{a} = \frac{n}{m} \quad \text{here } b = 2a$$

$$\frac{3a}{a} = \frac{n}{m}$$

$$n = m$$

for

$$m = 1, 2, 3....$$ so 3th, 6th, 9th order will be missing

$$n = 3.6, 9$$

## UNIT-II

**Q.4. (*a*) Explain the superposition of polarized light Hence, differentiale between plane polarized, circularly polarized and elliptically polarized lights.** (2+3)

**Ans.** When two plane polarised light waves superimposed the resultant wave rotate under certain condition.

**(*a*) Circularly Polarised light:** If the magnitude of the resultant wave remains constant and direction varies regularly so that the resultant vector traces a circle, the light is said to be circularly polarised

**(*b*) Elliptically polarised:** If the magnitude and direction of the resultant both vary and resultant vector traces an ellipse then light is said to be elliptically polarised.

**(*c*) Plane polarised light:** If the vibration of light are confined only to one direction and perpendicular to the direction of propagation of light, it is called plane polarized light.

**Q.4. (*b*) Differentiate between uniaxial and biaxial crystals.** (1.5+1.5)

**Ans. Uniaxial:** Uniaxial crystal has only one direction (optic axis) along which refracted ray travel with the same velocity *e.g.* calcute, tourmaline.

**Biaxial:** Biaxial crystal has two such direction (two optic axis) along which the velocities of refracled rays are same eg topaz, mica,, canesugar.

**Q.4. (*c*) Illustrate with a series of neat scientific well labeled diagrams the formation of a Nicol prism from a double refracting crystal.** (2)

**Ans.**

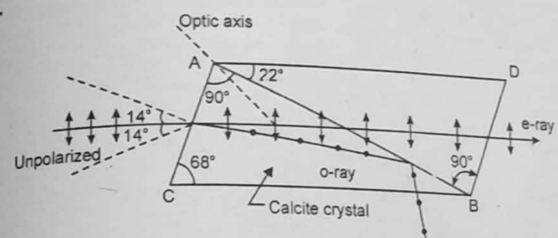



**Fig. 5.**

**Q.4. (*d*) A plane polarized light is incident on a quartz plate is cut parallel to the axis. Calculate the least thickness of the plate for which the o-and e-ray recombine to form a plane polarized light. Assume that $\mu_e = 1.5533$; $\mu_0 = 1.5442$ and $\lambda = 5.4 \times 10^{-5}$ cm.** (2)

**Ans.** Here the Quatz plate must act as half wave plate.

$$t = \frac{\lambda}{2[\mu_e - \mu_o]} = \frac{\lambda}{2(1.5533 - 1.5442)}$$

$$t = 0.0029 \text{ cm.}$$

**Q.5. (*a*) Illustrate with a schematic scientific diagram, the dependance of refractive index on the radial distance for a graded index optical fibre.** **(2.5)**

**Ans.** Refer Q.No. 4(*c*), First Term Examination September 2015.

**Q.5. (*b*) Define and explain numerical aperture for an optical fibre.** **(3)**

**Ans.** Refer Q.No. 4(*b*), First Term Examination September 2015.

**Q.5. (*c*) Show that fraction of atoms in the excited state in much smaller than that in the ground state at a temperature of 3000 K and an energy gap of 2eV.** **(2.5)**

**Ans.**

$$\frac{N_1}{N_2} = e^{-h\upsilon/kT}$$

Here

$$h\upsilon = 2\text{eV}$$
$$T = 3000\ k$$
$$K = (8.62 \times 10^{-5}\ \text{eV/k})$$
$$KT = .2586$$

$\therefore$

$$\boxed{\frac{N_2}{N_1} = 4 \times 10^{-10}}$$

**Q.5. (*d*) State the characteristics of the spontaneous emission using the concept of Einstein's A and B coefficient further derive that probability of radiation-Educed transitions per unit time equals the probability of stimulated emissions per unit time.** **(4)**

**Ans. Spontaneous Emission:**

1. It is a natural transition in which an atom is de-excited after the end of its lifetime in the higher energy level.

2. The photon can be moved in any direction.

3. The probability of spontaneous emission depends only on the properties of the two energy levels between which the transition occurs

**Einstein's Coefficients:** Consider an atomic system placed in a radiation field of energy E(*v*) under equilibrium conditions. Let $N_1$ and $N_2$ be the number of atoms in two energy levels of energies $E_1$ and $E_2$ respectively at any instant Fig. 6. The photons corresponding to transitions between these two levels must have an energy $h\upsilon = E_2 - E_1$. Atoms at level $E_2$ may jump spontaneously to level $E_1$ and $A_{21}$ be the corresponding spontaneous emission transition probability per unit time. In the presence of

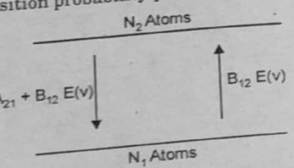



**Fig. 6. Induced absorption and spontaneous transitions**

external radiation of energy $E(\upsilon)$, absorption of energy $h\upsilon$ will take place causing atom being raised from $E_1$ to $E_2$. Let the induced absorption transition probability per unit time $B_{12}E(\upsilon)$ where $B_{12}$ is the transition probability per unit time per unit intensity of radiation. The interaction of radiations with excited atom at level $E_2$ produce stimulated emission. Let the probability of stimulated emission per unit time be $B_{21}E(\upsilon)$ where $B_{21}$ is the stimulated emission per unit time per unit energy density.

The total emission probability per unit time from level $E_2$ to level $E_1$ (spontaneous +stimulated) is

$$A_{21} + B_{21}E(\upsilon)$$



The number of atoms that jump from $E_2$ to $E_1$ per unit time is $[A_{21} + B_{21}E(\upsilon)]N_2$ and the number of atoms that rise from level $E_1$ to $E_2$ per unit time is $B_{12}E(\upsilon)N_1$. Thus the net rate of change of atoms in level $E_2$ is

$$\frac{dN_2}{dt} = B_{12}E(\upsilon)N_1 - [A_{21} + B_{21}E(\upsilon)]N_2$$

at the equilibrium $dN_2/dt = 0$, we get

$$B_{12}E(\upsilon)N_1 = [A_{21} + B_{21}E(\upsilon)]N_2 \quad ...(1)$$

Thus the number of absorption and emission transitions per unit time between the two levels is the same. From eqn. (2) we get

$$E(\upsilon)[N_1B_{12} - N_2B_{21}] = N_2A_{21} \quad ...(2)$$

$$E(\upsilon) = \frac{A_{21}}{B_{21}} \cdot \frac{1}{\frac{N_1}{N_2}\left(\frac{B_{12}}{B_{21}}\right) - 1} \quad ...(3)$$

At thermal equilibrium, the atomic population $N_1$ and $N_2$ in energy levels $E_1$ and $E_2$ at temperature T is given by Maxwell-Boltzmann distribution as

$$N_1 = N_0 e^{-E_1/kT}$$
$$N_2 = N_0 e^{-E_2/kT}$$

where $N_0$ is the number of atoms present in the ground state and $k$ the Boltzman's constant. Dividing we get

$$\frac{N_2}{N_1} = e^{-(E_2 - E_1)/kT}$$

But $E_2 - E_1 = h\upsilon$, energy of emitted or absorbed photon, therefore

$$\frac{N_2}{N_1} = e^{-h\upsilon/kT} \text{ or } \frac{N_1}{N_2} = e^{h\upsilon/kT}$$

Putting this value in eqn. (3), we get

$$E(\upsilon) = \frac{A_{21}}{B_{21}} \cdot \frac{1}{e^{h\upsilon/kT}\left(\frac{B_{12}}{B_{21}}\right) - 1} \quad ...(4)$$

Comparing it with Planck's radiation law

$$E(\upsilon) = \frac{8\pi h\upsilon^3}{c^3} \frac{1}{e^{h\upsilon/kT} - 1}$$

We get

$$\frac{A_{21}}{B_{21}} = \frac{8\pi h\upsilon^3}{c^3} \quad ...(5)$$

$$\frac{B_{12}}{B_{21}} = 1 \quad ...(6)$$

The quantities $A_{21}, B_{12}, B_{21}$ are called Einstein's coefficients and eqns. (5) and (6) give relation between them. From eqn. (5) we note that

$$\frac{A_{21}}{B_{21}} \propto \upsilon^3$$

*i.e.* the ratio of spontaneous and stimulated emission probabilities is proportional to $\upsilon^3$. From eqn. (6) we get

$$B_{21} = B_{12}$$

*i.e.* the probability of stimulated emission is the same as that of absorption.

## UNIT-III

**Q.6. (a) At what speed will an object of length 100 cm be measured as 50 cm an observe at rest.** (2.5)

**Ans.**

$$l = lo\sqrt{\left(1-\frac{v^2}{c^2}\right)}$$

$$\frac{l_o}{2} = l_o\sqrt{1-\frac{v^2}{c^2}}$$

$$\frac{1}{4} = \left[1-\frac{v^2}{c^2}\right]$$

$$v^2/c^2 = 3/_4$$

$$v/_c = \sqrt{\frac{3}{2}}$$

$$\therefore \quad \boxed{v = \frac{\sqrt{3}}{2}c} = 0.866c$$

**Q.6. (b) The total energy of the particle is exactly twice its rest energy. Calculate the velocity of the particle.** (2.5)

**Ans.**

$$mc^2 = 2m.c^2$$

Where

$$m = 2m_0$$

$$m = \frac{m_o}{\sqrt{1-v^2/c^2}}$$

$$\therefore \quad \frac{m_o}{\sqrt{1-v^2/c^2}} = 2m_0$$

$$\frac{1}{2} = \sqrt{1-\frac{v^2}{c^2}}$$

$$\frac{v^2}{c^2} = 1-\frac{1}{4}$$

$$\frac{v^2}{c^2} = \frac{3}{4} \quad v = 0.886c$$

**Q.6. (c) Explain the Michelson-Morley experiment stating clearly its aim and result derived there in. How did the results of the experiments lead to the special theory of relativity?** (5)

**Ans.** In Michelson-Morley experiment the path difference give rise to frings shift ($\delta n$) or

$$\delta n = \frac{2d}{\lambda}\frac{v^2}{c^2}$$

The orbital velocity of the earth is about $3 \times 10^6$ cm/sec then $v^2/c^2 \sim 10^{-8}$ at least at some time of the year. The arrangement should be sensitive so as to detect effect of the order of $v^2/c^2$ *i.e.* one part in $10^8$. The expected shift for $d$ = 11 m (by repeated reflections) and $\lambda = 6\times10^{-5}$ cm is

$$\delta n = \frac{2\times1100\times(3\times10^6)^2}{6\times10^{-5}\times(3\times10^{10})^2} = 0.37$$

$$\delta n = 0.4$$

*or*

The experimental arrangement was capable of measuring one-hundredth of a fringe and as such the above shift was capable of accurate measurability. However, no effect was repeated after an other six months to elimnate the unseeming possibility that the



earth might be at rest relative to ether at the time of the experiment. The effect should have been observed at least at one of the two occassion. But experiment gave null effect on both occassions.

**Explanation of null result:** The null results of Michelson-Morely experiment are understandable if the postulate of ether is rejected . In other words, *the space or medium in which light propagates, is not moving relative to earth*. Lorentz proposed a hypothesis that the bodies are contracted in the direction of motion relative to stationary ether by a factor $\sqrt{1-v^2/c^2}$ . It can be seen that a contraction in the interferometer arm could make time $t_1$ and $t_2$ equal and thus no figure shift would be observed. But the contraction hypothesis was purely methematical without any experimental confirmation and could not be accepted.

It was Einstein who provided the theory of relativity in 1905 which was a major reconstruction of the description of physical phenomena. He concluded that the velocity of light is always the same in all directions and is independent of the relative *uniform motion of the observer, medium and source*. This statement is called the principle of *constancy of the speed of light*. This principle would lead to $\delta n = 0$, in Michelson-Morely experiment, since now the speed of light is $c$ rather than $(c + v)$ in any frame. Then $t_1 = t_2$ = 2d/c resulting in $\delta n = 0$. Thus according to principle of constancy of light no shift in fringes should be obseved. Hence postulate of constancy of speed of light is capable of explaining negative results of Michelson-Morely experiment.

**Conclusions or significance of null result:** The negative results of Michelson–Morley experiment has the following conclusion:

(*i*) Ether has no observable properties. Therefore, there is no such thing as absolute space or a fixed fundamental frame of reference with respect to which absolute motion of the bodies can be determined. Hence absolute motion is meaningless.

(*ii*) The velocity of light is same in all directions and does not depend upon the motion of the source or the observe or both.

**Q.6. (d) Explain the concept of time dilation citing experimental evidence.** (2)

**Ans. Experimental verification of Time-dilation.**

Time-dilation has been best verified in experiments on a nuclear particle, called meson. There are two types of mesons. The $\pi^+$ mesons decay (break into fragments) in such a way that in every $1.8\times10^{-8}$ *s*, half of them die out *i.e.* their flux decreases to $2^{-1}$ in every $1.8\times10^{-8}$s.

Now, in an experiment, in the laboratory, $\pi^+$ mesons were produced with speed 0.99c and their flux was measured at two places separated by 30 m. The laboratory time interval $\Delta t$ for travelling this distance was given by

$$\Delta t = \frac{30m}{0.99c} \cong \frac{30}{3\times10^8 m/s} = 10\times10^{-8} s.$$

This is about 5.6 times of $1.8\times10^{-8}$s. Hence, the flux of $\pi^+$ meason should decrease to $2^{-5.6}$ or less than 2% of the original flux in travelling 30 meters. But the actual flux at the second place was nearly 60% of that at the first place.

This discrepancy is explained by computing the proper time ($\Delta t$) given by relation

$$\Delta t' = \Delta t\left(1-\frac{v^2}{c^2}\right)^{1/2} = 10\times10^{-8}[1-(0.99)^2]^{1/2}$$

$$= 1.4\times10^{-8} \text{ s.}$$

This is 0.78 times of $1.8\times10^{-8}$. Hence, in this time the flux should fall to $2^{-0.78}$ (nearly 60%) of the original flux. This is exactly what is observed.

It amounts to this: In laboratory measurements the elapsed time for 30 $m$ travel is $10\times10^{-8}$s, while the $\pi^+$ meson themselves measure the time as $1.4\times10^{-8}$ s only. A seven fold dilation has occurred in this case.

**Q.7. (a) An ultrasonic interferometer-based is used to measure the velocity of ultrasonic waves in sea water. The distance between two consecutive antinodes is found to be 0.4 *mm*. Calculate the velocity of waves in sea water. Frequency of the waves generated by the crystal is 1.5 MHz.** (3)

**Ans.** $d = \lambda/2 \Rightarrow \lambda = 2d$

and $\quad v = \lambda f \Rightarrow = 2df = 2\times0.4 \text{ mm} \times 1.5\times10^6 \text{ Hz} = 1.2\times10^3 \text{ m/s}$

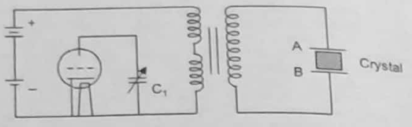
$\lambda = 0.8 \text{ mm}$

**Q.7. (*b*) Enumerate the different methods for the production of ultrasonic waves and describe one of them in detail. How will you determine the wavelength of these waves?** (3+3)

**Ans.** Two populsr methods for the production of ultrasonic waves are

(1) Magnetostriction method (2) Piezoelectric Method

According to the Piezoelectric effect, if a certain crystal like quartz or tourmaline is compressed along mechanical axis potential defference is obtained along a electric axis, similarly it is also found that if these crystals are subjected to potential difference along electric axis, the crystal is set into vibrations along mechanical axis the two frequencies coincide , the resonance occurss and vibration will be of large amplitude Figure shows a piezoelectric generator.




Crystal is placed between H.T. metal plate. The plates are connected to the primary of a transformer which is coupled inductively to the oscillatory circuit of a valve as shown is the figure. if the natural frequency of oscllations of the value circuit is equal to the natural freq. of crystal resonance occurs and vibration of large freq. is obtained.

**To find Wavlength of Ultrasonic waves:** In this case a liquid or solid trough in which ultrasonic travel, act like an acoustic grating. The grating element is equal to the wavelenght of ultrasonic waves. Let this wavelength be $\lambda_L$. Then using the phenomenon of diffration from optics we have the relations

$$\lambda_L \sin\theta = n\lambda$$

$\lambda_L \rightarrow$ represent the distance between consecutive nodal point

$\theta$ – angle of diffraction

$n$ – order of spectrum

$\lambda$ – wavelength of light used

**Q.7. (*c*) We want to generate an ultrasonic wave of frequency 'f' by both the popular methods i.e. magneto-striction and piezo-electric methods. What sould be the length of the nickel rod for the magneto-striction method and the thickness of the quartz crystal for the pizoelectric method. Assume the Young's modulus of nickle = $2.14 \times 10^{11}$ N/m$^2$; Density of nickel = $8908 \frac{kg}{m^3}$; Young's smodulus for quartz = $7.9 \times 10^{10}$ $N/m^2$; Density ofequarts = $\frac{2650 kg}{m^3}$.** (3)

**Ans.** Let n is the required frequency.

$$\lambda = 7.9\times10^{10} \text{ N/m}^2$$

$$\rho = 2650 \text{ kg/m}^3$$

$$v = \sqrt{\frac{7.9\times10^{10}}{2650}} = 25450 \text{ m/s}$$

If t be the thickness of quartz slab in meter then

$$v = n\lambda = n(2t)$$

$n$ is the frequency

$$\therefore \quad n = \frac{v}{2t} = \frac{2725}{t} Hz$$

or

$$\boxed{t = \frac{2725}{n} m}$$

(*ii*)

$$\eta = \frac{1}{2t}\sqrt{\frac{y}{\rho}} = \frac{1}{2t}\sqrt{\frac{2.14\times10^{11}}{8908}}$$



$$t = \frac{1}{2n}\sqrt{\frac{2.14\times10^{11}}{8908}} = \sqrt{\frac{2.14\times10^{11}}{17816}}$$

$$\boxed{t = \frac{3465}{n} m}$$

## UNIT-IV

**Q.8. (*a*) A cyclotron is used to accelerate protons having a mass half that of the deuterons.**

**(*i*) If the megnetic field has an intensity of 2.0T, what is the change in the frequency of the oscillating electric field.** (2)

**Ans.** (*i*) $1.67\times10^{-27}$ kg, $q = 1.6\times10^{-19}$C, $B = 2.0$T

$$v = \frac{Bq}{2\pi m} = \frac{2\times1.6\times10^{-19}}{2\times3.14\times1.67\times10^{-27}} = 3.05\times10^7 Hz$$

**(*ii*) What is the maximum energy acquired by the protons if the potential applied across the does of the cyclotron are 25kV?** (2)

**Ans.** (*ii*) $\quad E = qV = 1.6\times10^{-19} \times 25\times10^3 \text{ J} = 4.0\times10^{-15} \text{ J}$

**Q.8. (*b*) Explain how the credibility of the laws of energy and momentum led to the concept of endoergic and exoergic nuclear reactions.** (2+2)

**Ans.** The energy balance in typical nuclear reaction may be written as

$$m_0c^2 + M_0c^2 + E_0 = m_1c^2 + M_1c^2 + E_1 + E_2$$

where $\quad M_0 \rightarrow$ rest mass of target particle

$m_0$ – rest mass of bombarding particle

$m_1$ – rest mass of ejected particle

$M_1$ – Mass of the recoiling nucleus

$E_0$, $E_1$ and $E_2$ are the corresponding kenetic energies. The difference between the sum of initial and sum of the final rest mass energy is called Q-value of the reaction

$$Q = [M_0 + m_0 - m_1 - M_1]\, c^2$$

or

$$Q = E_1 + E_2 - E_0$$

when Q is + ve reaction is said to be exothermic and energy is released in the process. When Q is –ve reaction is said to be endothermic and the energy is obsorbed.

**Q.8. (c) The binding energy per nucleus were split into two equal-size nuclei, about how much enery would be released in the process?** (2)

**Ans.** There as 238 nucleus involved. Each nucleen will release about

$$8.5 - 7.5 = 1\text{MeV}$$

Total energy released

$$= 238\times1\text{MeV} = 238 \text{ MeV}$$

**Q.8. (*d*) If the magnetic field is directed upwards and the particles are moving counterclockwise in a cyclotron, what is the charge on the particles?** (2)

**Ans.** Charge on the particle is negative and force must be directed to centre of circle.

**Q.9. (*a*) The half-life of $^{60}$Co is nearly 5.25 years. Find the duration it will take for the activity of the sample to decreases to (*i*) (1/2) of its original value, (*ii*) (1/4) of its original value.** (1+1)

**Ans.** As we know

$$\frac{N}{N_0} = \left[\frac{1}{2}\right]^n$$

there fore

(*i*) $\frac{N}{N_0} = \left[\frac{1}{2}\right]^1 \Rightarrow$ Time duration for half of the sample is 5.25 years

(ii) $\frac{N}{N_0} = \left[\frac{1}{2}\right]^2$ $\Rightarrow$ Time duration for one fourth of sample is 10.5 years

**Q.9. (b) The temperature at the core the sun is 2 × 10⁷ K. The hudrogen atoms present, in the presence of protons, converts into deuterium atoms, which further converts into helium atoms. Wrtie the Stellar-thermo nuclear reactions. Further using the concept of energy-mass equivalence, calculate the energy relased in this process in watt-hourse.** **(3+2)**

**Ans.** The source of steller energy is fusion. A large amount of energy can be obtained by fusion but it is not easy to fuse light nuclei due to the force of repulsion between the positively charged nuclei. Fusion is possible only when the kinetic energy of each nuclie is large enough to overcome the repulsion which may happen at very high temperature of the order of $1C^7 + 10^9\,k$. At very high temperature the nuclie are able to overcome their mutual coulomp repulsion and fuse together. This reaction is called thermonuclear reaction.

Carbon-nitrogen cycle as one of the most important nuclear reaction for release of energy by fusion of energy by fusion.

$$^{12}_{6}C + ^{1}_{1}H \rightarrow ^{13}_{7}N + \gamma$$

$$^{13}_{7}N \rightarrow ^{13}_{6}C + ^{13}_{6}C + ^{0}_{1}e + \nu$$

$$^{13}_{6}C + ^{1}_{1}H \rightarrow ^{14}_{7}N + \gamma$$

$$^{14}_{7}N + ^{1}_{1}H \rightarrow ^{15}_{8}O + \gamma$$

$$^{15}_{8}0 \rightarrow ^{15}_{7}N + ^{0}_{1}e + \nu$$

$$^{15}_{7}N + ^{1}_{1}H \rightarrow ^{12}_{6}C + ^{4}_{2}He$$

The amount of energy released in this reaction is 27.5 MeV. Another main source of stellar - energy is proton-proton cycle.

$$^{1}_{1}H + ^{1}_{1}H \rightarrow ^{2}_{1}He + ^{0}_{1}e + 0.42\,MeV + \nu$$

$$^{2}_{1}H + ^{1}_{1}H \rightarrow ^{3}_{2}He + \gamma + 5.5\,MeV$$

$$^{3}_{2}He + ^{3}_{2}He \rightarrow ^{4}_{2}He + 2^{1}_{1}H + 12.8\,MeV$$

$$4^{1}_{1}H \rightarrow ^{4}_{2}He + 2^{0}_{1}e + 2\gamma + 2\nu + 24.64\,MeV$$

The total energy released in one cycle of reaction is

$$2\,(0.42 + 5.5) + 12.8 = 24.64 \text{ MeV}$$

**Q.9. (c) Enunicate the phenomenon of nuclear fission and fusion giving atleat two equations each as an example.** **(2+3)**

**Ans. Nuclear Fission:** Fission is the splitting of a massive atom into two or more smaller ones.

When a heavy nucleus undergoes a fission process, a large amount of energy is released together with the emission of neutrons which further produce fission. This energy is known as nuclear energy or atomic energy

$$^{238}_{91}U + ^{1}_{0}n \rightarrow ^{148}_{56}Ba + ^{88}_{36}Kr + 3^{1}_{0}n + \text{energy}$$

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{95}_{42}M_o + ^{139}_{57}La + 7\left(^{0}_{-1}e\right) + 2\left(^{1}_{0}n\right) + Q$$

**Nuclear Fusion:** Fusion is the fusing of two or more lighter atoms into a larger one High energy is requred to bring two nuclei so close that nuclear forces become important and glue the nuclei together

$$^{2}_{1}H + ^{2}_{1}H = ^{4}_{2}He + Q$$

$$^{3}_{2}He + ^{3}_{2}He \rightarrow ^{4}_{2}He + 2^{1}_{1}H + Q$$

# END TERM EXAMINATION [DEC. 2016]
## FIRST SEMESTER [B.TECH]
## APPLIED PHYSICS–I [ETPH–103]

Time : 3 hrs. M.M. : 75

**Q.1. (a) Two wavelength of light $\lambda_2$ are sent through a young's Double slit expreimental set up simultaneously. What must be true concerning $\lambda_1$ and $\lambda_2$ if the third order bright fringe is to coincide with the fourth-order $\lambda_2$ fringe. (2.5)**

**Ans.** Path difference = $n\lambda$

$$n_1\lambda_1 = n_2\lambda_2$$

$$3\lambda_1 = 4\lambda_2$$

$$\frac{\lambda_1}{\lambda_2} = \frac{4}{3}$$

**Q.1. (b) A slit is located at infinity in front of a lens of focal length in 1m and is illumenated normally with light of wavelength. The first minima on either side of the central maximum of the diffraction pattern observed in the focal plane of the lens are separated by 7 mm what is the width of the slit. (2.5)**

**Ans.**

$$\frac{x}{f} = \frac{\lambda}{d}$$

$$d = \frac{\lambda f}{x} = \frac{\overset{100\,mm}{\cancel{7}00}\ mm \times 1m}{\cancel{7}m}$$

$$= 100\times10^{-3}m\times1\times10^{-3}$$

$$\frac{10\cancel{0}\ mm}{10\cancel{0}\cancel{0}} = .1\text{ mm} \quad ...(1)$$

**Q.1. (c) The velocity of light in water is $2.2 \times 10^8$m/s. What is the polarising angle of incidence for water surface. (2.5)**

**Ans.**

$$\mu = \tan ip$$

$$\mu = \frac{\mu_{water}}{\mu_{air}} = \frac{v_{air}}{v_{water}} = \tan ip = \frac{3\times10^8}{2.2\times10^8} = 1.36$$

$$ip = \tan^{-1}(1.36)$$

$$= 53.7°$$

**Q.1. (d) In the coherence time for an ordinary light $\tau_c = 10^{-10}$ sec, obtain the degree of monochromaticly for $\lambda_0 = 5893$ Å. (2.5)**

**Ans.**

$$\Delta\lambda = \frac{\lambda^2}{\tau\times c} = \frac{5893\times5893\times10^{-20}m}{10^{-10}\times3\times10^8}$$

$$= 1\text{Å}$$

**Q.1. (e) Explain the statement Amplification of the incident light were required that the stimulated emission is dominant compared to absorption.** **(2.5)**

**Ans.** Stimulated emission emits coherent light having same phase, intensity and amplitude. In order to increase the number of coherent photons it should domainte over the spontaneous emission and absorption so that population inversion condition may be achieved.

**Q.1. (f) Opera singer are able to shatter crystal glasses with their voices. How is it possible.** **(2.5)**

**Ans.** Every object has a resonant frequency or the natural frequency at which something vibrates. Crystal glassess because of their hollow shape, are particularly resonant.

The vibration of glass, through are easier to hear since the bowl amplifie the sound. Whenever we sing, the air molecules around us wiggle as the sound waves ripple. To break-the glass you need to sing the same pitch you hear after tapping the glass. If you sing loud & loud enough, the glass can vibrate so much it shatters.

**Q.1. (g) How much energy must be given to an electron to accelerate it 0.98 C**

**Ans.**

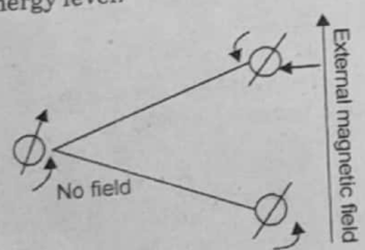
$$KE = (m - m_0)c^2$$

$$m = \frac{m_0}{\sqrt{1-v^2/c^2}} = \frac{m_0}{\sqrt{1-\left[\frac{0.98C}{c}\right]^2}} = 5.02m_0$$

$$K.E = [5.02m_0 - m_0]\,c^2$$
$$= 4.02\,m_0c^2$$
$$= 4.02 \times 9.1 \times 10^{-31} \times (3 \times 10^8)^2$$
$$= 3.296 \times 10^{-13}\,J$$

**Q.1. (h) Explain the principle of the Nuclear magnetic Resonance. Illustrate with diagram.** **(2.5)**

**Ans.** Nuclear magnetic resonance is defined as a condition when the frequency of the rotating magnetic field becomes equal to the frequency of the processing nucleus. The magnetic principle of nuclear magnetic resonance is based on the spin of atomic nuclei. The magnetic measurement depend upon the spin of unpaired electron whereas nuclear magnetic resonance measures magnetic effect caused by the spin of protons & neutrons. Both these nucleons have intrinsic angular momenta or spins and hence act as elementary magnet. The existence of nuclear magnetism was revealed in the hyper fine structure of spectral lines. If the nucleus with a certain magnetic moment is placed in the magnetic field, we can abserve the phenomenon of space quantization and for each allowed direction there will be a slightly different energy level.






**Q.1. (i) Which of the fundamental interaction has the least significance in nuclear physics. Justify your answer.** **(2.5)**

**Ans.** The fundamental interaction that has least significance in nuclear physics is gravitational force as its is the weakest of the four interaction. If you take two protons and hold them very close together, they will exert several forces on each other. Because they both have mass, the two protons exert gravitational aftraction on each other. Because they both have a positive electric charge, they both exert electromagnetic sepulsion on each other. Also they both have internal color charge and thus exert attraction via the strong nuclear forces.

Gravity is so weak at the atomic scale that scientists can typically ignore it without incurring significant errors in their calculations.

**Q.1. (j) Light is passing from air into a liquid and is deviated 20° when the angle of incidence is 60°. Under what conditions will total interal reflection occurs at this interface.**

**Ans.**

$$\sin 20 = 0.34$$
$$\sin 60° = 0.866$$

$$\mu = \frac{\sin i}{\sin r} = 3.03$$

$$\mu = \frac{\sin 60}{\sin 20} = \frac{0.866}{0.340} = 2.54$$

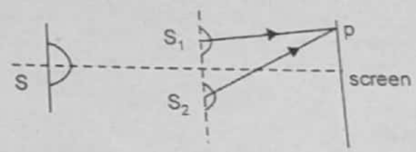
$$C = \sin^{-1}\left[\frac{1}{\mu}\right] = 19.2°$$

$$\theta_C = \sin^{-1}\left[\frac{1}{2.54}\right] = \sin^{-1}(0.3937)$$

UNIT -I

**Q.2. (a) Derive the mathematical expression for the intensity distribution when two sinusoidal coherent waves with amplitudes $A_1$ and $A_2$ and a phase difference of $\phi$ superpose to produce interference.** **(4)**

**Ans.**




Let $A_1$ and $A_2$ be the amplitudes of the two waves from $S_1$ and $S_2$ respectively. Then the displacement $Y_1$ due to one wave from $S_1$ is represented as

$$Y_1 = A_1 \sin \omega t \qquad ...(1)$$

The displacement $Y_2$ due to other wave from $S_2$ is represented as

$$Y_2 = A_2 \sin (\omega t + \phi) \qquad ...(2)$$

According to the principle of superposition, the resultant displacement Y at P is given as

$$
\begin{aligned}
Y &= Y_1 + Y_2 \\
&= A_1 (\sin \omega t) + A_2 \sin (\omega t + \phi) \\
&= A_1 \sin \omega t + A_2 [\sin \omega t \cos \phi + \cos \omega t \sin \phi] \\
&= (A_1 + A_2 \cos \phi) \sin \omega t + (A_2 \sin \phi) \cos \omega t \quad ...(3)
\end{aligned}
$$

suppose $A_1 + A_2 \cos \phi = A \cos \delta$ ...(4)

$A_2 \sin \phi = A \sin \delta$ ...(5)

Substituting equations (4) & (5) in eq (3) we get

$$Y = A \cos \delta \sin \omega t + A \sin \delta \cos \omega t$$

or $$Y = A \sin (\omega t + \delta)$$

Squaring & adding (4) & (5) we get

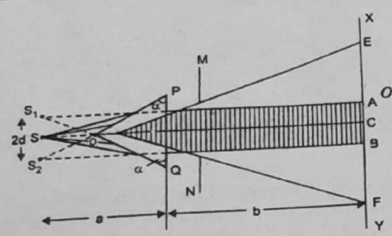
$$A^2 = A_1^2 + A_2^2 \cos^2\phi + 2A_1 A_2 \cos\phi + A_2^2 \sin^2\phi$$

or $$A^2 = A_1^2 + A_2^2 + 2A_1 A_2 \cos\phi$$

or $$\boxed{I = A_1^2 + A_2^2 + 2A_1 A_2 \cos\phi}$$

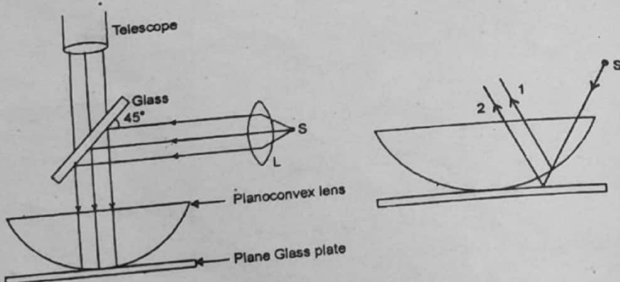
**Q.2. (*b*) Illustrate with neat scientific well labeled diagrams the classification of interference in two classes, that is, one due to division of waveform & another due to division of amplitude.**

**Ans. (1) Due to division of wavefront**




*OPQ* – Fresnel Biprism
*XY* – Screen
*S* – Narrow vertical Slit illuminated by a monochromatic light

**(2) Due to division of Amplitude**






**Q.2. (*c*) Explain using mathematical derivation the formation of the nth bright ring in a Newton's ring set up in the reflected light with a diameter given by the expression D = $\sqrt{(2\lambda R)(2n-1)}$.** (4)

**Ans.**

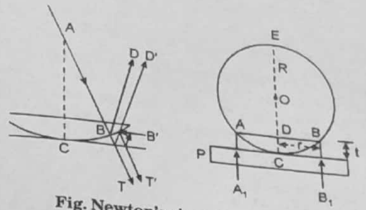



**Fig. Newton's rings by reflected light**

From the geometry of the circle we have

$$ED \times DC = AD \times DB$$

or $$(CE - CD)\, CD = AD \times DB$$

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

or $$2Rt - t^2 = r^2$$

where r is the radius of the ring.

As $R$ the radius of curvature of the lens is very large as compared to thickness $t$ of the film, so that $t_2$ can be neglected as compared to 2Rt.

$$2Rt = r^2 = \left(\frac{AB}{2}\right)^2 = \left(\frac{d}{2}\right)^2 = \frac{d^2}{4}$$

or $$\frac{d^2}{4R} = 2t$$

where d is the diameter of the ring. The path difference between the two rays, one reflceted from A and other $A_1 = 2\mu t \cos r$. Since one of the rays is reflected from the denser medium (at $A_1$ or $B_1$), a further path difference of $\lambda/2$ is introduced because of reflection under different conditions. Thus the point A and B will lie on a bright ring of diameter AB if the total difference is

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

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

where $$n = 1,2,3,...\text{etc.}$$

Here r is angle of refraction. Since the rays are incident practically normal, so that angle r is nearly zero i.e. cos r = 1.

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

or $$2t = \frac{(2n-1)\lambda/2}{\mu}$$

Putting the value of 2t from above eqn., we get the condition for nth bright ring

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

Scanned by CamScanner

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

or

$$d_n = \sqrt{\frac{(2n-1)2R\lambda}{\mu}}$$

or

$$D = \sqrt{(2\lambda R)(2n-1)} \text{ for } \mu = 1$$

**Q.2. (*d*) Sodium light ($\lambda$ = 5893 A) is used in a fresnel's Bi-prism set up. A total of 60 fringes are observed in the field of view of the eye-piece calculate the number of fringes that would be observed in the same field of view if the sodium light is replaced by a mercurry vapour lamp with ($\lambda$ = 5461A°)** **(2)**

**Ans.**

$$n_1\lambda_1 = n_2\lambda_2$$

$$\frac{60 \times 5893}{5461} = n_2 = 64$$

**Q.3. (*a*) List five differences between interference and diffraction fringes.** **(2.5)**

**Ans.**

| Interference | Diffraction |
|---|---|
| 1. The interference occurs between two separate wave fronts originating from coherent sources. | 1. Diffraction occurs between the secondary wavelets originating from the exposed part of same wave front. |
| 2. In an interference pattern the pringes are are normally of the same width. | 2. In diffraction pattern the fringes never of the same width and go on decreasing in width as we move away from the edge of the shadow. |
| 3. In an interference pattern the regions of minimum intensity are perfectly dark. (zero intensity) | 3. In diffraction pattern the intensity of minima is never perfectly dark. |
| 4. In an interfence pattern all the bright fringes (maxima) are of uniform intensity. | 4. The intensity of the central maxima is maximum and decreases on either side as the order of maxima increases. |
| 5. There is requirement of two coherent sources. | 5. Only one source of light is required. |

**Q.3. (*b*) What is meant by a diffraction grating. How is it useful for the determination on of wavelength of a monochromatics source of light? What is the advantages of increasing the number of lines on the grating? What is the fundamental difference in the spectra obtained by a prism to that of a diffraction grating for a white light source.**

**Ans.** (1) An arrangement consisting of a large number of equidistant parallel rectangular slits of equal width separated by equal obaque portion is known as a diffraction grating.



(2) By using the diffraction grating formula

$$(e + d) \sin\theta = n\lambda$$

and observing the diffraction pattern the wavelength of light can be determined

where $(e + d)$ = grating elment

$n$ – order of spectrum

$\lambda$ – wavelength of light

(3) If we increase the numer of lines of the grating, the principal maxima will become intense and sharp, while secondary maxima become weaker.

(4) The fundamental difference in the spectra obtained by prism & grating is in the sequence of colour

In prism the sequence of colours is VIBGYOR

In grating the sequence of colours is ROYGBIV

**Q. 3. (*c*) In a Fraunhofer diffraction pattern experiment using two slits, the third, sixth and ninth interference maxima are found to be missing if the slit width is 0.05 ×10$^{-3}$m, Calculate the inter-slit separation.** **(2)**

**Ans.**

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

if

if

$$a = b\frac{n}{m} = 2$$

$$2a = b\,n = 3\,m \text{ third six ninth spectram are mission}$$

$$a = 0.05 \times 10^{-3}\text{ m}$$

$$b = 0.1 \times 10^{-3}\text{ m}$$

**Q.3. (*d*) Determine the minimum number of lines in a grating that are just able to resolve the sodium lines of wavelength 5890A & 5896 Å in the first order spectrum.** **(2)**

$$\frac{\lambda}{d\lambda} = nN$$

for n = 1

$\lambda$ = 5893 (mean of 5890 & 5896 A°)

$d\lambda$ = 6 A° (difference of 5890 & 5896 A°)

N = 986

**Ans.**

$$\frac{5890 + 5896/2}{5893 - 5890} = \frac{5893}{6} = 982$$

**Q.3. (*e*) A diffraction pattern is observed using a beam of red light. What happens if the red light is replaced by the blue light.** **(2)**

**Ans.** Diffraction formula for grating.

$$(e + d) \sin\theta = n\lambda$$

if $\lambda_{red}$ is replaced by $\lambda_{blue}$

as $\lambda_{red} > \lambda_{blue}$

therefore the number of maxima formed on the screan increases

## UNIT-II

**Q.4. (a) Explain the phenomenon of double refraction. Describe the working principle of a Nicol prism. How is a Nicol prism used to produce circularly polarised light.**

**Ans.** (1) The phenomenon of splitting of unpolarised light into two polarised refracted rays is known as double refraction.

(2) **Working Principal of Nicol prism:-** When unpolarised bean of light enters the calcite crystal, it splits up into two plane polarised says as o-ray & e-ray, with vibration in two mutually perpendicular plane. If by some optical means, we eliminate one of the two beams, the we would obtain only one plane polarised beam. The nicol prism is designed in such a way so as to eleminate the ordinary ray by total internal reflection. Hence only the extraordinary ray is transmitted through the prism.

(3) Circularly polarised light is produced by recombining two waves of equal amplitude and vibrations in mutually perpendicular directions and having a phase difference of $\pi/2$ or path diff. of $\lambda/4$ between them. For this the plane polarised light must fall normally on quarter wave plate in such a way that plane of vibration of incident light makes an angle of 45° with the direction of optic axis & For obtaining elliptically polarised light the plane polarised light must fall normally on quarter wave plate in such a way that plane of vibrations of incident light makes an angle other that 45° with direction of optic axis.

**Q.4. (b) The plane of polarization get rotated through 23.8° as light travels through an 18 cm long column of 20% sugar solution. Determine the specific rotation of solution.**

**Ans.**

$$\theta = 23.8^\circ \frac{20}{100} - S_1$$

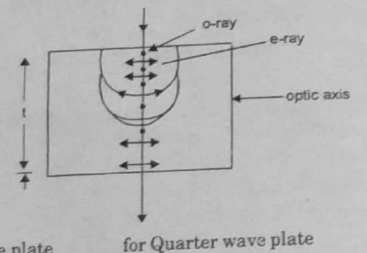
$$l = 18$$

$$S = \frac{100}{lc} = \frac{10\times 23.8}{10\times .20} = \frac{2.38}{3.6}$$

$$S = 66^\circ \deg\, dm^{-1} (g/c.c)^{-1}$$

**Q.4. (c) Explain with a neat scientific well labeled Diagram the functioning of the retarding plates (1) Half wave plate (ii) Quarter wave plate.**

**Ans.**




for Halfwave plate

$$t = \frac{\lambda}{2(\mu_0 - \mu_e)}$$

for Quarter wave plate

$$t = \frac{\lambda}{u(\mu_0 - \mu_e)}$$



where

$\mu_0$ – refractive index of 0–ray

$\mu_e$ – refractive index of e-ray

**Q.5. (a) Illustrate Fiber communication system with a detailed block diagram.** (2)

**Ans.**

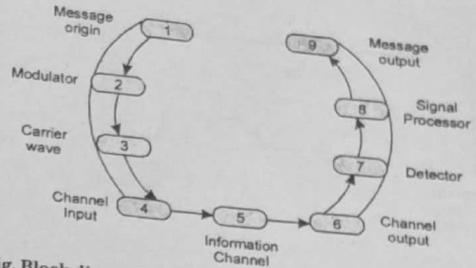



**Fig. Block diagram of an optical fiber communication system**

**Q.5. (b) A step index fibre has a core of refractive index 1.5. If the NA of the fibre of 0.26, calculate the refractive index of the cladding material.** (2.5)

**Ans.**

$$N_A = \sqrt{(\mu_1^2 - \mu_2^2)}$$

$$\mu_1 = 1.5$$

$$N_A = \sqrt{\mu_1^2 - \mu_2^2}$$

$$N_A = \sqrt{\mu_1^2 - (1.5)^2}$$

$$0.26 \times 0.26 = n_f^2 - (1.5)^2 \Rightarrow 1.48$$

$$\mu_2 = 1.48$$

$$0.26 \times 0.26 + (1.5)(1.5)$$

$$.0598 + 2.25\ \mu^2 = 1.48$$

$$= 2.3098$$

$$= 1.52$$

**Q.5. (c) Explain the construction & working of a He-Ne laser. What are the merits of laser.** (4)

**Ans.** He-Ne laser is a four level laser, which was first successfully built by Ali Javan, W. Bennett and D. Herriott in 1961.

**Construction:**

The He-Ne laser consists of a mixture of He and Ne in a ratio of about 10 : 1, placed inside a long narrow discharge tube. The pressure inside the tube is about 1 mm of Hg. The gas system is enclosed between a pair of plane mirrors or a pain of concave mirrio so that a resonator system is formed. One of the mirror is of very high reflectivity whil the other is partially transparent so that energy may be coupled out of the system. This shown in fig. (a).

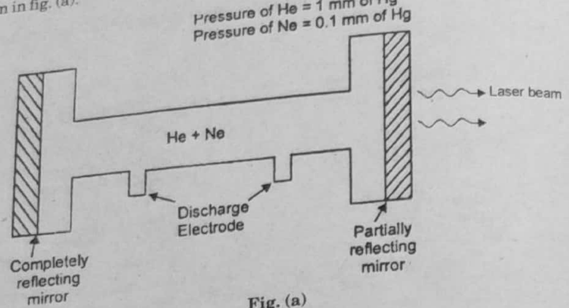



**Fig. (a)**

**Working:**

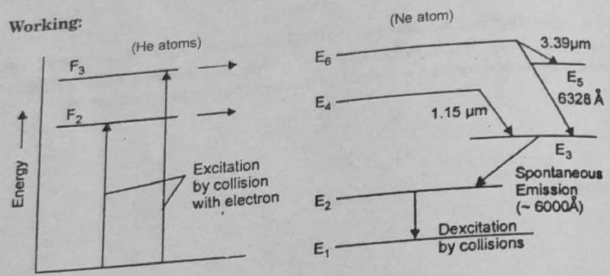



**Fig. (b)**

When an electric discharge is passed through the gas, the electron travelling down the tube collide with the He-Ne atom and excite them to level marked $F_2$ and $F_3$. These levels are metastable, *i.e.,* He atoms excite to this state stay there for sufficiently long time before losing energy through collisions. Through this collision, the Ne atoms are excited to the levels marked $E_4$ and $E_6$ which have nearly the same energy as levels $F_2$ and $F_3$ of He. The population in these levels are more than $E_3$ and $E_5$. Thus, a state of population inversion triggers lasing action. The Ne atoms then drop down from the lower laser level to the level $E_2$ through spontaneous emission. From the level $E_2$, the Ne atoms are brought to the ground state through collisions with the wall. The transition from $E_6$ to $E_5$, $E_4$ to $E_3$ and $E_6$ to $E_3$ result in emission of radiation, 3.39 μm, 1.15 um and 6328 Å, respectively. The transition corresponding to 3.39 μm and 1.15 μm are not visible but 6328 Å corresponds to the red light of He-Ne laser. The pressure of two gases must be so chosen that the condition of population inversion is not quenched. Thus, the condition must be such that there is an efficient transfer of energy from He to Ne atoms.

**Merits of laser:**

Laser is highly coherent, intense, monochromatic & directional beam.



**Q.5. (*d*) The light output of a typical laser is 10.6 μm. What is the energy difference between the enrgy levels of the exciled slate and the meta stable state. What is the energy of the photon emitted. What is the frequency associated with photon. If two moles of photons are emitted per second. What is the power of the laser output.**

**Ans.** (i)

$$\lambda = 10.6\ \mu m$$

$$10.6 \times 10^{-6}\ m$$

$$E = hv = \frac{h \times c}{\lambda} = \frac{19.89 \times 10^{-26}}{10.6 \times 10^{-6}} = 1.87 \times 10^{-20}\ J$$

(ii) ∴

$$\Delta E = \frac{20 \times 1.6 \times 10^{-19} \times 10^{6}}{50 \times 10^{-3} \times 1.6 \times 10^{-19}} \begin{bmatrix} 1.87 \times 10^{-20} \\ \times 6.25 \times 10^{18} ev \end{bmatrix}$$

$$\Delta E = 1.8 \times 10^{-20} \times 6.25 \times 10^{18}\ ev$$

$$= 1.172\ ev$$

(iii)

$$V = \frac{c}{\lambda} = \frac{3 \times 10^{8}}{10.6 \times 10^{-6}}\ V = .28 \times 10^{14}\ Hz$$

(iv)

$$1 \text{ mol photons} = 6.023 \times 10^{-23}$$

$$E = \frac{\frac{hc}{\lambda} 6.626 \times 10^{-34} \times 6.023 \times 10^{-23} \times 3 \times 10^{8}}{10.6\ \mu m}$$

$$\frac{119}{10.6} = 11.29 \times 10^{-5}$$

$$11.29 \times 10^{-5}\ J \times 2$$

$$= 22.58 \times 10^{-5}$$

$$V = 22.58\ KW$$

## UNIT-III

**Q.6. (*a*) Length of a moving spaceship is found to be 80% of its actual length to an observer at rest. Calculate the speed of the spaceship.** (2)

**Ans.**

$$l' = l\sqrt{1 - \frac{v^2}{c^2}}$$

$$80\% = l\sqrt{1 - \frac{v^2}{c^2}}$$

let

$$l = 100$$

$$\frac{80}{100} = \sqrt{1 - \frac{-v^2}{c^2}}$$

$$v = 0.6\ c$$

**Q.6. (b) The ratio of the proper life to the mean life of moving fundamental particle is 1/5 calculate the speed of the fundamental particle.** **(2)**

**Ans.**

$$\Delta t' = \frac{\Delta t}{\sqrt{1-\frac{v^2}{c^2}}}$$

$$\frac{\Delta t}{\Delta t'} = \sqrt{1-\frac{v^2}{c^2}}$$

$$\left(\frac{1}{5}\right) = \sqrt{1-\frac{v^2}{c^2}}$$

$$\frac{1}{25} = 1-\frac{v^2}{c^2}$$

$$\frac{v^2}{c^2} = 1-\frac{1}{25}$$

$$= \frac{25-1}{25}$$

$$\frac{v}{c^2} = \frac{24}{25}$$

$$v = .97c$$

**Q.6. (c) Justify the statement of universal equivalence between mass & energy.** **(4)**

**Ans.** $E = mc^2$

In the process of annihilation of matter, an electron and a positron, may give up all of its mass in producing two photons or radiant energy. Hence the entire mass is converted into energy due to universal equivalence of mass and energy. This variafies mass – energy relation

$$E = mc^2$$

which shows that an amount of enrgy $mc^2$ is always associated with a mass m, or conversely, a mass m $\left(=\frac{E}{c^2}\right)$ always corresponds to an energy.

Sommerfeld was able to explain the fine structure of $H_\alpha$ line only by introducing relativistic correction on the basis of relativistiic variation of mass with velocity. The good agreement of his theory with experimental results provide verification of mass-energy relation.

**Q.6. (d) A flash of light has component of $v_x$, $v_y$, $v_z$ in the unprimed co-ordinate system i.e. $v_x^2 + v_y^2 + v_z^2 = c^2$. Using the Lorentz velocity tranformation, calculate the speed of light.** **(4.5)**

**Ans. Addition of Velocities**

Very high velocities cannot be added directly in classical mechanics because velocities must be added in a manner consistent with the Lorentz transformation. Let a frame S' be



moving with a uniform velocity $v$ relative to S in the direction of positive X-axis. Let velocities u and u′ of a particle as observed in S and S′ respectively be defined as

$$\mu \approx u_x\hat{i} + u_y\hat{j} + u_z\hat{k} \text{ and } u'_x\hat{i} - u'_y\hat{j} + u'_z\hat{k}$$

Inverse Lorentz transformations are given as

$$x \approx \gamma(x' + vt'), y = y', z = z' \text{ and } t = \gamma\left(r^2 + \frac{v}{c^2}x'\right)$$

Differentiating above relations we obtain

$$dx = \gamma(dx' + vdt'), dy = dy' dz = dz' \text{ and } dt = \gamma\left(dt' + \frac{v}{c^2}dx'\right)$$

Let a body moves a distance $dx$ in a time-interval dt in the frame S. Then, the velocity of the body measured by an observer in S is

$$u_x = \frac{dx}{dt} = \frac{dx' + vdt'}{dt' + \frac{v}{c^2}dx'} = \frac{\frac{dx'}{dt'} + v}{1 + \frac{v}{c^2}\cdot\frac{dx'}{dt'}} = \frac{\mu'_x + v}{1 + \frac{v}{c^2}u'_x}$$

Similarly one can obtain, $\mu_y = \dfrac{u'_y}{\gamma\left(1+\frac{v}{c^2}u'_x\right)}$ and $u_z = \dfrac{u'_z}{\gamma\left(1+\frac{v}{c^2}u'_x\right)}$

The inverse Lorentz transformations are obtained by replacing v by –v and by interchanging the primes. Thus the inverse equations for addition of velocities may be written as

$$u'_x = \frac{u_x - v}{1 - \frac{v}{c^2}u_x}, \quad u'_y = \frac{u_y}{\gamma\left(1-\frac{v}{c^2}u_x\right)} \text{ and } u'_z = \frac{\mu_2}{\gamma\left(1-\frac{v}{c^2}\mu_x\right)}$$

Now if a photon moves with velocity c in frame S′ and frame S′ moves with velocity v w.r.t frame S along positive X-axis then the velocity of photon as observed from frame S may calculated using,

$$u_x = \frac{u_x + v}{1 + \frac{v}{c^2}u_x} = \frac{c+v}{1+\frac{v}{c^2}c} = c.$$

Hence the speed of light is same for all inertial frames i.e. the velocity of light in vacuum is thus an absolute constant independent of the frame of reference. This is one of the postulates of relativity.

Now consider three frames of reference S, S′ and S″. If S′ moves with a velocity $v_1$ relative to S and S″ with velocity $v_2$ relative to S′ then the velocity v of S″ with respect to S is given by

$$v = \frac{v_1 + v_2}{1 + \frac{v_1 v_2}{c^2}}$$

When $v_1 = c$ and $v_2 = c$,

$$v = \frac{c+c}{1+c.\frac{c}{c^2}} = c$$

*i.e*, when the velocity of light is added to the velocity of light, we obtain velocity of light. It means the velocity of light in vacuum is the maximum attainable velocity in nature.

**Q.7. (*a*) Enumerate the different properties possessed by the ultrasonic waves. Elaborate three properties to give the applications associated with them. (5)**

**Ans.** (i) Ultrasonic waves have a large energy content & is used to create heat by way of friction between material to be joined.

(ii) Because of the small wavelength, the ultrasonics show negligible diffraction and can be transmitted over long distances without appreciable loss of energy. For this reasion ultrasonic waves have been used in determining the depth of ocean by echo-sounding.

Wave length is related to velocity and frequency by the relation $\lambda = {}^{v}/_{n}$.

(iii) Their speed of propagation increases with increasing frequency.

(iv) Intense ultrasonic radiations have a disruptive effect on liquid by causing bubbles to be formed. Therefore these radiation used for removing dust and soot from chimney gases.

(v) When a plane stationary ultrasonic wave is set up in a liquid, a structure is produced in which the density of the liquid varies from layer to layer along the direction of propagation of the waves. This structure can diffract light in the same way as the structure of a crystal diffracts x-rays.

(vi) Velocity of ultrasonic waves depends on the temperature of the medium through which it propagated. It decreases with increase of temperature but for water the effect is reverse. It depends upon the elastic properties and density of the medium. Thus v = $\sqrt{E/\rho}$, where E is elastic constant and $\rho$ the density of the medium.

**Q.7. (*b*) The velocity of the ultrasonic waves in sea water is equal to 1440m/s. Find the depth of a submerged submarine if an ultrasonic pulsed reflected from the submarine is received 0.5 sec after being sent out. (2.5)**

**Ans.**
$$v = \frac{2d}{t}$$
$$t = 0.55$$
$$f = 1.45 \text{ MHz}$$
$$1440 = \frac{2d}{.5}$$
$$d = \frac{1440 \times .5}{2} = 360\ m$$

**Q.7. (c) The distance between two consecutive antinodes produces by an ultrasonic interferometer based system is found to be 0.55mm. Calculate the velocity of the waves in sea water. Frequency of the waves generated by the crystal is 1.45 MHz.**

**Ans.** d–distance between any two alternate compression and rerefaction in liquid



$$\frac{\lambda u}{2} = d \quad \text{so } 2d = \lambda u$$

also velocity of ultrasonic wave is

$$v = \lambda \mu V$$
$$\lambda\mu = 1.1 \text{ mm } 1.1 \times 10^{-3}$$
$$v = 1.45 = 1.45 \times 10^{6}$$
$$V = 1.59 \times 10^{3} \text{ m/sec.}$$

**Q.7. (*d*) We want to generate an ultrasonic wave of 'F' by both the popular methods i.e. magnetiostriction and piezoelectric methods what should be the length of the ferromagnetic rod for the magnetiostriction method and the thickness of the quartz crystal for the piezoelectric method. Assume the Young's modulus of nickel = $2.14 \times 10^{11}$ N/m$^2$, Density of ferromagnetic rod = 8908 kg/m$^3$. Young's modulus for quartz = $7.9 \times 10^{10}$ N/m$^2$; Density of quartz = $\frac{2650}{m^3}$kg.**

**Ans.** Let n is the required frequency.

$$\lambda = 7.9 \times 10^{10} \text{N/m}^2$$
$$\rho = 2650 \text{ kg/m}^3$$
$$v = \sqrt{\frac{7.9\times 10^{10}}{2650}} = 25450 m/s$$

It t be the thickness of quartz slab in meter then

$$v = n\lambda = n\,(2t)$$

n is the frequency

$$\therefore \quad n = \frac{v}{2t} = \frac{2725}{t} Hz$$

or
$$\boxed{t = \frac{2725}{n} m}$$

$$\eta = \frac{1}{2t}\sqrt{\frac{y}{\rho}} = \frac{1}{2t}\sqrt{\frac{2.14\times 10^{11}}{8908}}$$

$$t = \frac{1}{2n}\sqrt{\frac{2.14\times 10^{11}}{8908}} = \sqrt{\frac{2.14\times 10^{11}}{17816}}$$

$$\boxed{t = \frac{3465}{n} m}$$

## UNIT-IV

**Q.8. (*a*) Define one Becquerel. How manly Bacquerel are there in one curie of a luminous watch dial contain 5μci of the radium isotape $^{226}_{88}R_a$. How many decays per second occur in it.**

**Ans. Becquerel:** One Becquerel (Bq) is defined as the decay rate of one disintegration per second.

$$1\,Bq = 1 \text{ decay per second}$$

$$1\,C_i = 3.7 \times 10^{10} \text{ decay per second}$$

$$\therefore \quad 1\mu C_i = 10^{-6}\,C_i$$

$$\therefore \quad 5\mu C_i = \left[3.7\times10^{10}\,\frac{\text{decays/sec}}{C_i}\right]\left[5\times10^{-6}\,Ci\right]$$

$$= 1.85 \times 10^5 \text{ decays/s}$$

**Q.8. (*b*) Evaluate the natural unit of the magnetic moment i.e. the Bohr magneton. Hence show that the ratio of the Bohr magneton to the nuclear magneton is 1836**

**Ans.** Nuclear magneton $= \dfrac{e\hbar}{2m_p}$, where $m_p$ – rest mass of proton

Bohr magneton $\quad \mu_B = \dfrac{e\hbar}{m_e}$, where $m_e$ = rest mass of electron

The ratio of $\dfrac{\text{nuclear magneton}}{\text{Bohr magneton}} = \dfrac{m_e}{m_p} = \dfrac{1}{1836}$

So nuclear magneton is about 2000 time smaller than Bohr magneton

**Q.8. (*c*) How many time does a deutron need to be accelerated to acquire 20 MeV of kinetie energy if the potential across the cyclotron dees are 50 kV**

**Ans.**

$$n = \frac{E_{max}}{U.e}$$

$$E_{max} = 20 \text{ Mev} = 20 \times 10^6 \text{ eV}$$

$$= 20 \times 10^6 \times 1.6 \times 10^{-19}\text{J}$$

$$U = 50 \text{ kv} = 50 \times 10^{-3} \text{ V}$$

$$e = 1.6 \times 10^{-19}$$

$$n = \frac{20\times1.6\times10^{-19}\times10^6}{50\times10^{-3}\times1.6\times10^{-19}}$$

$$= \boxed{400 = n}$$

**Q.8. (*d*) Explain the phenomenon of radioactivity. Further enuciate whether endoergic or an exoergic reaction.** **(4)**

**Ans.** The phenomenon of spontaneous emission of powerful radiation exhibited by heavy elements is called radioactivity.



There are three naturally occurring radioactive series among the elements in the periodic table. These are known as uranium series, the actinuim series and the thorium series. Each series decays through a number of unstable nuclei by means of alpha & beta emission. Radioactive phenomenon is spontaneous and an irreversible self disintegrating activity because the element break itself up for good.

The natural radioactivity is exoergic reaction as the energy is released during the reaction.

**Q.9. (*a*) The sun acts as a big fusion reactor. How do the fusion reaction remain confined within the sun in this case?** (4.5)

**Ans.** Hydrogen gas in the core of the sun gets squeeze together so tightly that four hydrogen nuclei combine to form one helium atom. This is called nuclear fusion.

In the process some of the mass of the hydrogen atoms is converted into energy in the form of light. The same process occurs in thermonuclear bombs. In the sun the process occurs in a controled manner. In a bomb it happerr all at once in a big chain-reaction explosion. In the sun's core the same amount of energy as 15 billion of these bombs is produced each second. The son does't blow to pieces because of the tremendous weight of the gas above. It just exactly balances the pressure from all the energy produced. If the fusion rate would go down so that less energy was produced in the sun's core, then gravity would cause the sun to start collapsing. This would in turn squeeze the hydrogen atoms closer together until the amount of fusion went up by just enough to produce the energy needed to hold it up again.

If the fusion rate in the sun's core goes up to much, then the pressure makes the sun expand a little so that the hydrogen isn't quite so closely packed. The night balance is again reached when the weight from the mass above the core exactly balances the pressure from all the energy being produced.

**Q.9. (*b*) Explain how the concept of liquid drop model explains the binding together of nucleons in a nucleus. Hence, give the semi-empirical mass formula.** (4)

**Ans.** Nucleus is like a spherical drop of an uncompressible liquid, which is held in equilibrium by a balance between the short range attraction among the nucleons and the repulsive electrostatic forces among the protons. The inter nucleon forces also give rise to surface tension forces, which maintain the spherical shape of the drop.

Semi empirical energy formula for the nucleus

$$E_B = a_1A - a_2A^{2/3} - a_3z\,(z-1)\,A^{-1/3}$$

It can be witten as the following –

$$zM^A = Zm_p + \frac{(A-z)}{M_n} - [a_1A - a_2A^{2/3} - a_3z(z-1)A^{-1/3}]$$

The Average binding energy per nucleon is

$$\frac{E_B}{A} = a_1 - a_2A^{-1/3} - a_3\,z(z-1)\,A^{-4/3} \qquad (1)$$

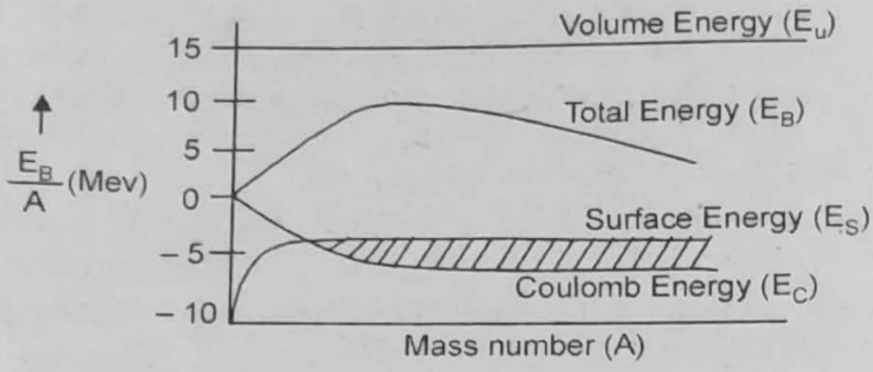
where $E_B$ – Total binding energy $M_n$ – Mass of neutron

$a_1 + a_2$, $a_3$ – constants $M_p$ – Mass of proton

Z – Atomic mass

A – Atomic Number

In Fig. each term on right is plotted against A, together with their $\dfrac{E_B}{A}$




Also,
$$E_B = E_V + E_S + E_C$$
and
$$E_V = a_1 A$$
$$E_S = -a_2 A^{2/3}$$
$$E_C = -a_3 \frac{Z(z-1)}{A^{1/3}}$$

**Q.9. (*c*) How many counts per minute are detected by a GM counter if the counter wire collect $10^6$ electrons per discharge with an average current in the circuit of about $1.6 \times 10^{-12}$ A.**

**Ans.**
$$I = \frac{q}{t} = \frac{Nne}{60}$$
$$N = 600 \text{ count/min}$$

**Q.9. (*d*) In an ionization chamber, about $10 \times 10^4$ pion pairs are produced, resulting in the loss of about 40 ev of energy. Estimate the amount of charge collected by each plate what is the kinetic energy of alpha particle.**

**Ans.**
$$Q = ne = (10 \times 10^4) \times (1.6 \times 10^{-19})$$
$$= 6 \times 10^{-14} \text{ C}$$
$$K.E = nE = (10 \times 10^4) \times 40$$
$$= 4 \text{ MeV}$$