Sample Question Paper- Physics

Time- 3 Hours **Max. Marks: 70**

General Instruction:

1. Candidates are allowed additional 15 minutes for only reading the paper. They must not start writing during this time.
2. All questions are compulsory. This question paper is divided into 4 Sections. A, B, C and D as follows:
   Section A: Question number 1 is of 12 marks. All parts of this section are compulsory.
   Section B: Question number 2 to 12 carry 2 marks each, with two questions having internal choice.
   Section C : Question numbers 13 to 19 carry 3 marks each, with two questions having internal choice.
   Section D: Question numbers 20 to 22 are long answer type questions and carry 5 marks each, with an internal choice.
3. All working, including rough work, should be done on the same sheet as, and adjacent to the rest of the answer.
4. The intended marks for questions or parts of questions are given in brackets [].
5. When solving numerical problems, all essential working must be shown.
6. In working our problems, use the following data:
   Gas constant R = 1.987 cal deg^{-1} mol^{-1} = 8.314 JK^{-1} mol^{-1} = 0.0821 dm^3 atm K^{-1} mol^{-1}
   1 l atm = 1 dm^3 atm = 101.3 J. 1 Faraday = 96500 Coulombs.
   Avogadro's number = 6.023×10^{23} mol^{-1}.

Question 1:

A. Choose the correct alternatives (a), (b), (c) or (d) for each of the following questions given below: [5]

(i) Ohm's law in vector form is

(a) $V = IR$

(b) $J = \sigma E$

(c) $J = \rho E$

(d) $E = \sigma J$

(ii) Current flowing through a long solenoid is varied. Then, magnetic flux density of the magnetic field inside it varies.

(a) Inversely with I

(b) Inversely with I^2

(c) Directly with I

(d) Directly with I^2

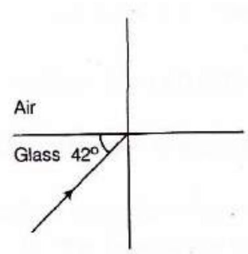
(iii) A convex lens, made of glass is immersed in water. As a result, its focal length will
(a) Increase
(b) Decreases
(c) Double
(d) remains same

(iv) de-Broglie wavelength of a moving particle is λ. Its momentum is given by
(a) $\frac{h\lambda}{c}$
(b) $\frac{h}{\lambda}$
(c) $\frac{hc}{\lambda}$
(d) zero

(v) Half- life of a certain radioactive substance is 69.3 days. Its distinguish constant is
(a) 0.010 day^{-1}
(b) 0.100 day^{-1}
(c) 0.001 day^{-1}
(d) 1.00 day^{-1}

(B) Answer the following questions briefly and to the point, [7]

(i) How will be the sensitivity of a potentiometer change with increase in current flowing through its wire?
(ii) Which of the two, an ammeter or a voltmeter has a greater resistance?
(iii) Why is soft iron preferred to steel in making the core of a transformer?
(iv) When would a moving charged particle travel undeviated in a uniform magnetic field?
(v) Complete the ray diagram shown in figure, given that the circular angle for air- glass pair is $i_c = 42^o$.



(vi) State the law of Malus.
(vii) Name any one material used as a moderator in a nuclear reactor.

Solution 1:
A.

(i) (b) As we know

$$l = Anev_d$$

$$\Rightarrow l = nAe\left(\frac{eE\tau}{m}\right)$$

$$\Rightarrow I = \frac{nAe^2\tau E}{m}$$

$$\Rightarrow \frac{l}{A} = \frac{ne^2\tau E}{m}$$

$$\Rightarrow J = \frac{ne^2\tau E}{m}$$

$$\Rightarrow J = \left(\frac{1}{\rho}\right)E$$

$$\Rightarrow J = \sigma E$$

(ii) (c) Let a rectangular amperian loop PQRS is taken in a solenoid. Now, applying Ampere's circuital law in this loop

$$\oint_{PQRS} B.dl = \int_P^Q B.dl + \int_Q^R B.dl + \int_R^S B.dl + \int_S^P B.dl = \mu_0 nU \text{ ---------------- (i)}$$

On remaining three sides, RQ, Sr and PQ, B.D*l* is zero as B is either zero or perpendicular to d*l*.

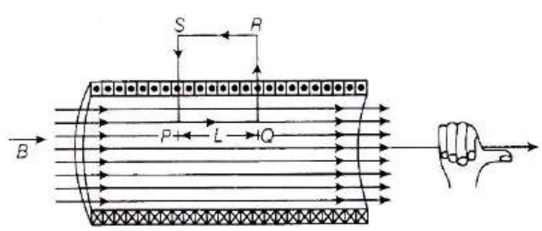
Thus, $\int_P^Q B.dl = BL$

Hence, Equation (i) becomes

$$BL = \mu nLI$$

$$\Rightarrow B = \mu_0 nl$$

$$\Rightarrow B\alpha l$$



(iii) (a) When a convex lens made up of glass is immersed in water, then due to change in refractive index, focal length of the lens changes. Since, water is less denser than glass, ie, refractive index of liquid is less than the refractive index of material of lens, so the focal length increase.

(iv) (b) According to de- Broglie, wavelength of moving particle is given by

$$\lambda = \frac{h}{mv} \Rightarrow \frac{h}{p}$$

$$\Rightarrow p = \frac{h}{\lambda}$$

(v) (a) We know that,
Half-life of radioactive substance is given by

$$T_{1/2} = \frac{0.693}{\lambda}$$

Where, λ = disintegration constant.

$$\lambda = \frac{0.693}{T_{1/2}}$$

Thus,

$$\lambda = \frac{0.693}{69.3} = 0.010 day^{-1}$$

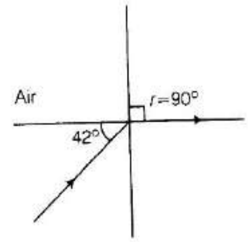
B. (i) Sensitivity of potentiometer means smallest potential difference that can be measured with the help of it. It can be increased by decreasing its potential gradient (K) ie, sensitivity is directly proportional to $\frac{1}{\kappa}$. Hence, by increasing the current through the wire sensitivity of the potentiometer decrease.

(ii) Resistance of voltmeter is greater than ammeter, because in voltmeter, galvanometer is connected with a high resistance in series, while in ammeter small shunt resistance connected in parallel with galvanometer.

(iii) Soft iron is used to make core of transformer because hysteresis loop of soft iron is narrow then steel, therefore energy loss is small.

(iv) When a charged particle is moving parallel to the magnetic field force exerted by the field on the particle is $F = qv\sin\theta = 0$. Hence, the path of charged particle, remains unchanged, that is, straight line.

(v) When incident angle is greater than or equal to the critical angle, only then total internal takes place.
Here, $\angle i = \angle c \Rightarrow \angle r = 90^o$



(vi) According to law of Malus, when a beam of completely plane polarized light is passed through analyser, the intensity l of transmitted light varies directly as the square of the cosine of angle 'θ' between the transmission directions of the polarizer and analyser, i.e., $l \alpha \cos^2 \theta$ or $l = l_0 \cos^2 \theta$ where, l_0 = maximum intensity of transmitted light.

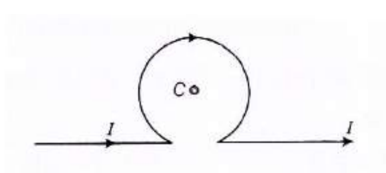
(vii) Heavy water (D_2O)

Section- B

Question 2: Define drift velocity and relaxation time, with reference to the free electron theory of conductors. [**2**]

Solution 2:
Drift velocity: It is defined as the average velocity with which the free electron get drifted towards the positive end of the conductor under the influence of an eternal electric field applied.
Relaxation time: The average time that has been elapsed since each electron suffered its last collision with ion/atom of conductor is called relaxation time.

Question 3: **[2]**
A long straight wire is bent as shown in the adjacent figure. Find the resultant magnetic field B at the centre C of the circular path of radius 2 cm if a current I of 5 A is passed through the wire as shown.



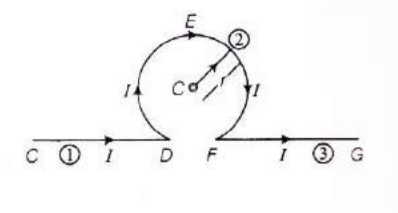
Solution 3:
Here,

$B_1 = \frac{\mu_0 l}{4\pi r}, \odot \Rightarrow B_2 = \frac{\mu_0 l}{2R}, \otimes \Rightarrow B_2 = \frac{\mu_0 l}{4\pi R}, \odot$

$\Rightarrow B_c = B_2 - \left(B_1 + B_3\right) = \frac{\mu_0 l}{2R} - \frac{\mu_0 l}{2\pi R}$

$= \frac{\mu_0 l}{2R}\left[\frac{1}{\pi} - 1\right]\hat{n}$

$\Rightarrow B_c = \frac{\mu_0 l}{2R}\left[\frac{1}{\pi} - 1\right] n, upward$



Using, $l = 5A, r = 2cm = 2\times10^{-2} m,$

Then

$B_c = \frac{4\pi\times10^{-7}\times5}{2\times2\times10^{-2}}\left[\frac{1-\pi}{\pi}\right]$

$= 5\times10^{-5}\left[1-\pi\right]$

$= 107\times10^{-5}$

Upward direction.

Question 4: **[2]**

(i) Explain the meaning of the statement: "Angle of dip at a certain place on earth is 60^o."

(ii) If the horizontal component of earth's magnetic field at this place is $3\times10^{-5} T$, calculate the earth's total magnetic field at that place.

Solution 4:

(i) If there is angle of dip 60^o at certain place on earth, it means at that place direction of total strength of earth's magnetic field at 60^o, with the horizontal line in a magnetic meridian.

(ii) We know that, $H = r\cos G\delta$

Where, H- Horizontal component of magnetic field and R- total magnetic field

$R = \frac{H}{\cos\delta} = \frac{3\times10^{-5}T}{\cos 60^o} = \frac{3\times10^{-5}T}{\frac{1}{2}}$

$\Rightarrow R = 6\times10^{-5} T$

Question 5:

(i) Briefly explain the following terms (a) Curie temperature (b) Self- induction

OR

(ii) Name any two types of energy losses in a transformer. State how any one of them can be minimized. **[2]**

Solution 5:

(i) (a) When a ferromagnetic material is heated, its magnetization decreases gradually with rise in temperature. At a particular temperature, ferromagnetic material changes over to paramagnetic material. This is because the domain structure disintegrates with rise in temperature. The particular temperature at which of transition from ferromagnetism to paramagnetism takes place is called Curie temperature.

(b) Self – induction is the property of a coil by virtue of which, the coil opposes any change in the strength of current flowing through it by inducing an emf in itself. It is also called inertia of electricity due to this property.

OR

(ii) Iron loss: It is the energy loss in the form of heat in the iron core of the transformer. This occurs because of the presence of eddy current in iron core.

Hysteresis loss: This is the loss of energy due to repeated magnetization and demagnetization of the iron core when AC is fed to it. The loss can be minimized by using a magnetic material which has low hysteresis loss.

Question 6: (i) What is displacement current?
(ii) Which electromagnetic radiation is used to study the crystal structure? **[2]**

Solution 6:

(i) Displacement current: It is a current which is produced due to the rate of change of electric flux with respect to time. It is given by

$$I_d = \varepsilon_o \frac{d}{dt}(\phi_E)$$

(ii) X- rays can be reflected and diffracted by the crystals. Hence it is used to study the crystal.

Question 7: A thin convex lens of focal length 20 cm is kept in contact with a thin concave lens of focal length 15 cm. Find the focal length and the nature of the combination**.** **[2]**

Solution 7:

Let f_1 and $-f_2$ be the focal length of convex lens and concave lens, respectively. Then total focal length of the combination is

$$\Rightarrow \frac{1}{f} = \frac{1}{f_1} + \frac{1}{-f_2}$$

Here, f_1 = 20cm

f_2 = -15 cm

$$\Rightarrow \frac{1}{f} = \frac{1}{20} - \frac{1}{15} = \frac{3-4}{60} = -\frac{1}{60}$$

Total focal length, f = -60cm

Question 8: What is meant by dispersive power? Write an expression of dispersive power in terms of refractive indices. **[2]**

Solution 8:

Dispersive Power: It is the ability of the prism material to cause dispersion. It is defined as the ratio of angular dispersion to the mean deviation when a white light of beam is passed through prism.

So, dispersive power $(\omega) = \frac{\mu_V - \mu_R}{(\mu - 1)}$

Where, μ_V = refractive index for violet colour.

μ_R = refractive index for red colour.

Question 9: **[2]**

(i) For each of the following, state one phenomenon in which

(a) Particles behave like waves.

(b) Waves behave like particles.

OR

(ii) Plot a labelled graph of maximum kinetic energy of photoelectrons versus frequency of incident radiation. State how you will obtain the value of Plank's constant from the graph.

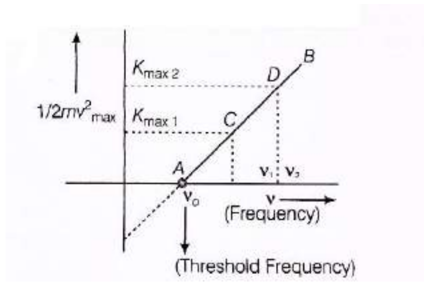
Solution 9:

(i) (a) Interference of light is the phenomena in which particles behave like waves. In this phenomena, when two or more waves of the same frequency and having zero or constant phase difference are travelling in same direction superimpose on each other.

(b) Photoelectric effect, is the phenomena is which waves behaves like particles. In this phenomena, when a suitable frequency of light, falls on the metal surface, electrons are emitted from metal surface.

OR

(ii) The variation of the maximum kinetic energy with the frequency of radiation, incident on a metal plate is a straight line AB as shown below.



Take two points on the graph C and D. The corresponding frequency of radiation is v_1, v_2 and maximum kinetic energy is K_{max1}, K_{max2}.
Now, according to Einstein's photoelectric equation

$$K_{max} = \frac{1}{2} m v_{max}^2 = hv - W_0$$

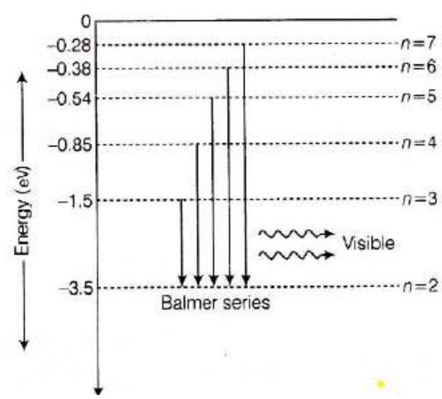
$\Rightarrow K_{max1} = hv_1 - W_0$ and $K_{max2} = hv_2 - W_0$

Thus,

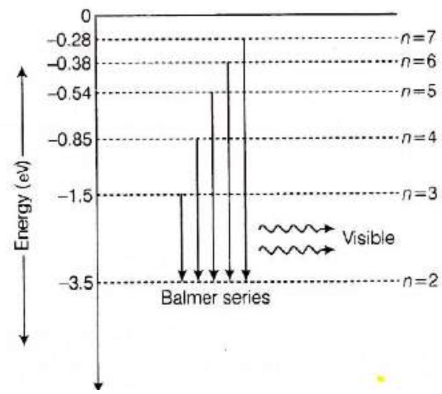
$$K_{max2} - K_{max1} = h(v_2 - v_1)$$

$$h = \frac{(K_{max2} - K_{max1})}{v_2 - v_1}$$

Question 10: Draw energy level diagram for hydrogen atom showing at least four lowest energy levels. Show the transition responsible for emission of Balmer series. **[2]**



Solution 10:



For Balmer series $\vec{v} = \frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{n^2}\right]$

n = 3, 4, 5, …..

Clearly, when an electron goes from higher energy level to lower energy level, it loses some energy which is released in the form of photons.

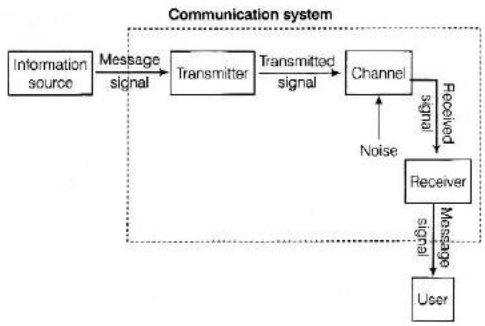
Question 11:
What is mean by 'binding energy per nucleon' of a nucleus? State its physical significance. **[2]**

Solution 11:
Binding energy per nucleon is the average energy required to extract one nucleon from the nucleus. It is obtained by dividing the binding energy of the nucleus by the mass number;
Mathematically,
B.E. per nucleon = $\left[Zm_p + (A-Z)m_n - M\right]C^2 / A$
Where, M is the mass of nuclevs, M_p is the mass of proton and M_n is mass of neutron.
Physical Significance
Binding energy per nucleon is directly proportional to stability of the nuclevs.

Question 12: **[2]**

Name essential components of a communication system. Draw its block diagram.

Solution 12:
There are three essential components of communication system.
(i) Transmitter (ii) Channel (iii) Receiver



Section- C

Question 13: **[3]**

Using Gauss' theorem, obtain an expression for intensity of electric' field 'E' at a point, which is at a distance r (r > R) from the centre C of a thin spherical shell (of radius R) carrying charge Q.

Solution 13:

Consider a shell of radius R with centre C. Let +Q charge in uniformly distributed over the surface of shell, now electric field intensity at point r can be calculated by Gauss' theorem.
So, according to Gauss theorem

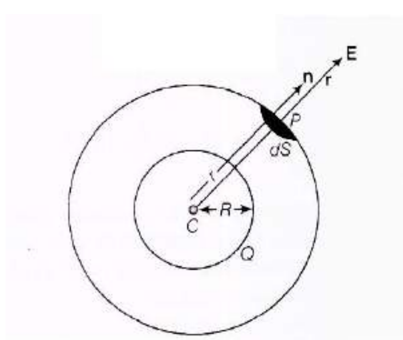
$$\oint_S E.dS = \oint E.\hat{n}dS = \frac{q}{\varepsilon_0}$$

$$\Rightarrow \oint EdS\cos 0^o = \frac{q}{\varepsilon_0}$$

$$\Rightarrow E\oint dS = \frac{q}{\varepsilon_0}$$

$$\Rightarrow E(4\pi r^2) = \frac{q}{\varepsilon_0}$$

$$\Rightarrow E = \frac{q}{4\pi\varepsilon_0 r^2}$$



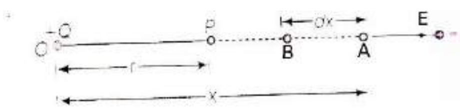
Question 14: **[3]**

(i) Obtain an expression for electric potential 'V' due to a point 'Q' at a distance r.

OR

(ii) A parallel plate capacitor is charged by a battery, which is then disconnected. A dielectric slab is now introduced between the two plates to occupy the space completely. State the effect on the following:
(a) the capacitance of the capacitor.
(b) potential difference between the plates
(c) the energy stored in the capacitor

Solution 14:
(i) Let P be the point at a distance r from the origin at which electric potential due to charge +Q is required.



Suppose a test charge Q_0 is placed at point A at distance x from o the electrostatic force acting on charge Q is,

$$F = \frac{1}{4\pi\varepsilon x^2} Q_0, \text{ along OA}$$

Now, small amount of work done in moving a positive charge A to B, where AB =dx is

$$dW = F.dx + Fdx\cos 180^o = -Fdx$$

Total work done in moving a positive charge from ∞ to point P is,

$$W = \int_{\infty}^{r} -Fdx = -\frac{1}{4\pi\varepsilon_0}\int_{+\infty}^{r}\frac{QQ_0}{X^2}dx$$

$$= -\frac{QQ_0}{4\pi\varepsilon_0}\left[-\frac{1}{X}\right]_{\infty}^{r}$$

So,

$$W = -\frac{QQ_0}{4\pi\varepsilon_0}\left[\frac{1}{r}-\frac{1}{\infty}\right] = \frac{QQ_0}{4\pi\varepsilon_0}$$

So, by definition, electrostatic potential at point P due to charge q.

Thus, $V = \dfrac{W}{Q_0} = \dfrac{Q}{4\pi\varepsilon_0 r}$

(ii) (a) When capacitor is fully charged, then capacitance of capacitor can be given as

$$C_0 = \frac{\varepsilon_0 A}{d}$$

Let a dielectric slab having dielectric constant (K) inserted in the capacitor, then we know that

$K = \varepsilon_0 = \frac{\varepsilon_m}{\varepsilon_0} \Rightarrow \varepsilon_m = \varepsilon_0 \varepsilon_r = K\varepsilon_0$

Then capacitance of new capacitor with dielectric slab is

$C_m = K\frac{\varepsilon_0 A}{d}$

$C_m = KC_0$

(b) $V = \frac{Q}{C_m} = \frac{Q}{KC_0}$

Hence, potential difference decreases by factor of $\left(\frac{1}{K}\right)$.

(c) Energy of capacitor = $\frac{1}{2}C_0V^2$

For dielectric medium

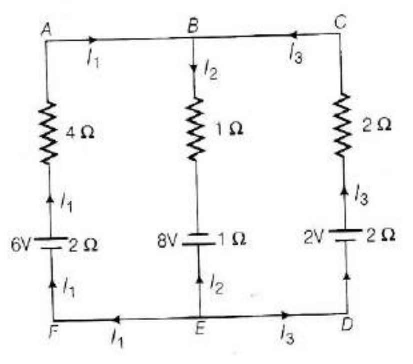
$E = \frac{1}{2}C_mV^2 = \frac{KC_0V^2}{2}$

$E = k\left(\frac{1}{2}C_0V^2\right)$

Here, energy increases by the factor k times.

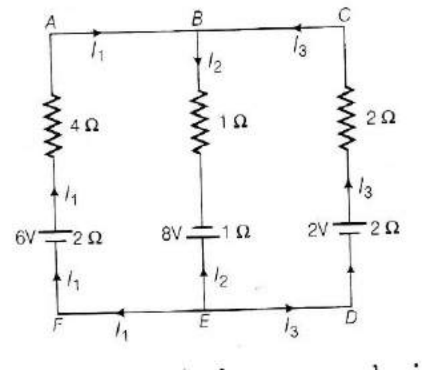
Question 15:

Using Kirchhoff's law of electrical networks, calculate the current I_1, I_2, and I_3 in the circuit shown below: **[3]**



Solution 15:

According to the question:



Applying Kirchhoff's law in loop 1(AB E FA),

$-6l_1 + 2l_2 - 8 + 6 = 0$

$\Rightarrow -6l_1 + 2l_2 - 2 = 0$

$\Rightarrow -6l_1 + 2l_2 = 2$

$\Rightarrow -3l_1 + l_2 = 1$

Applying Kirchhoff's law in loop 1(B C DEB),

$4l_3 - 2 + 8 - 2l_2 = 0$

$\Rightarrow 4l_3 - 2l_2 + 6 = 0$

$\Rightarrow 2l_2 - 4l_3 = 6$

$\Rightarrow l_2 - 2l_3 = 3$

Applying KCI,

$l_1 + l_2 + l_3 = 0 \Rightarrow l_1 + l_2 = -l_3$

Substituting l_3 in equation (ii), we get,.

$l_2 - 2(l_1 + l_3) = 3$

$\Rightarrow l_2 - 2l_1 - 2l_2 = 3$

$-2l_1 - l_2 = 3$

Solving equation (i) and (iv), we get,

$-3l_1 + l_2 = 1$

$-2l_1 - l_2 = 3$

$\Rightarrow -5l_2 = 4$

$\Rightarrow l_1 = -4/5A$

$l_2 = 2l_1 - 3$

$= 2(-4/5) - 3 = \frac{-8}{5} - 3 = \frac{-23A}{5}$

And

$l_3 = -(l_1 + l_2) = \frac{+23}{5} + 4/5 = 27/5^A$

Negative sign implies l_1 and l_2 are in opposite direction of what we have assumed.

Question 16: **[5]**

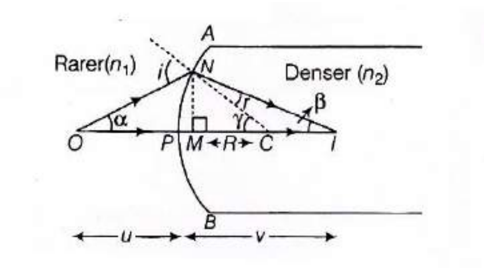
(i) Obtain an expression for refraction at a single convex spherical surface separating the two media having refractive indices n_1 (rarer medium) and n_2 (denser medium) ie, a relation between u, v, n_1, n_2 and R.

OR

(ii) Derive R = 2f for a spherical mirror, where the symbol have their usual meaning.

Solution 16:

(i) Let APB is a convex refracting surface which separates a rarer and a denser medium having refractive indices n_1 and n_2.



Where, i = angle of incidence

And r = angle of refraction

Now, in ΔNOC

$i = \alpha + \gamma$

Similarly, in ΔNIC

$\gamma = r + \beta$ or $r = \gamma - \beta$

Suppose all rays are paraxial, then the angles i,r, α , β and γ are small.

$$\Rightarrow \alpha = \tan\alpha = \frac{NM}{OM} = \frac{NP}{OP}$$

$$\beta = \tan\beta = \frac{NM}{MI} = \frac{NM}{PI}$$

$$\gamma = \tan\gamma = \frac{NM}{MC} = \frac{NM}{PC}$$

From Snell's law, $\frac{\sin i}{\sin r} = \frac{n_1}{n_2}$

If I and r are small, then

$\frac{i}{r} = \frac{n_1}{n_2}$ or $n_1 i = n_2 r$

or

$$n_1\left[\alpha+\gamma\right]=n_2\left[\gamma-\beta\right]$$

$$n_1\left[\frac{NM}{OP}+\frac{NM}{PC}\right]=n_2\left[\frac{NM}{PC}-\frac{NM}{PI}\right]$$

$$n_1\left[\frac{1}{OP}+\frac{1}{PC}\right]=n_2\left[\frac{1}{PC}-\frac{1}{PI}\right]$$

$$\frac{n_1}{OP}+\frac{n_2}{PI}=\frac{n_2-n_1}{PC}$$

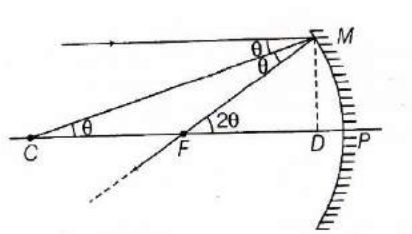
Using sign convection,

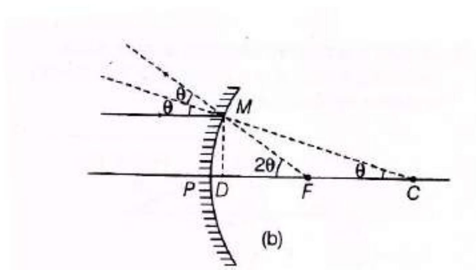
$$-\frac{n_1}{u}+\frac{n_2}{v}=\frac{n_2-n_1}{R}$$

$$\Rightarrow\frac{n_2}{v}-\frac{n_1}{u}=\frac{n_2-n_1}{R}$$

OR

Consider a ray parallel to the principal axis striking the mirror at point M. Let θ be the angle of incident and MD be perpendicular to the principal axis. Then,





Geometry of reflection of an incident ray on
(a) concave spherical mirror and
(b) convex spherical mirror

$\angle MCP=\theta$ and $\angle MFP=2\theta$

Now, $\tan\theta=\dfrac{MD}{CD}$

$\tan 2\theta = \frac{MD}{fD}$ -----------------------(i)

For small θ (condition true for paraxial rays), $\tan\theta = \theta$ and $\tan 2\theta = 2\theta$

Therefore, from equation (i) , we get,

$\frac{MD}{FD} = 2\frac{MD}{CD}$ or $FD = \frac{CD}{2}$ ------------------------ (ii)

Again, for small θ, we can observe that the point D is very close to the point P. Therefore,, $FD = f$ and $CD = R$.

From Equation (ii), we get,

$$f = \frac{R}{2}$$

Question 17: **[3]**

When a ray of ordinary light is incident on the surface of separation of two media at polarizing angle, show the help of a labelled diagram that reflected ray and the refracted ray the mutually perpendicular to each other.

Solution 17:

From Snell's law

$\frac{\sin i_p}{\sin r_p} = \mu$ --------------------------- (i)

From Brewster law,

$\tan i_p = \frac{\sin i_p}{\cos i_p} = \mu$ ---------------------(ii)

Equating the equations (i) and (ii),

$$\frac{\sin i_p}{\sin r_p} = \frac{\sin i_p}{\cos i_p}$$

$\Rightarrow \sin r_p = \cos i_p$

$\Rightarrow \sin r_p = \sin(90^o - i_p)$

$\Rightarrow i_p + r_p = 90^o$

Hence, the reflected and transmitted rays are perpendicular to each other.

Question 18:

Explain the working principle and construction of Meter Bridge. How resistance of a wire is measured using meter bridge? **[3]**

Solution 18:

According to radioactive decay law, the rate of decay of radioactive atoms at any instant is proportional to the number of atoms present at that instant.

Let N be the number of atoms present in a radioactive substance at any instant t.

Let dN be the number of atoms that disintegration in a short interval dt.

Then, the rate of disintegration $-\frac{dN}{dt}$ is proportional to N,

$-\frac{dN}{dt}\alpha N$ or $-\frac{dN}{dt}=\lambda N$

Where, λ is a constant for the given substance and is called decay constant. For a given element, the value of λ is constant but for different elements, it is different.

From the above equation, we have,

$$\frac{dN}{dt}=-\lambda dt$$

Integration above equation, we get,

$\log_e N=-\lambda t+C$ --------------- (i)

Where, C is the integration constant. To determine C, we apply the intial conditions. Suppose there were N_o atoms in the beginning, ie, $N = N_o$ at $t = 0$.

Then, $\log_e N_o = C$

Substituting this value of C in Equation (i), we have,

$$\log_e N=-\lambda t+\log_e N_o$$

$$\Rightarrow \log_e N-\log_e N_o=-\lambda t$$

$$\Rightarrow \frac{\log_e N}{\log_e N_o}=-\lambda t$$

$$\Rightarrow \frac{N}{N_o}=e^{-\lambda t}$$

$$\Rightarrow N=N_o e^{-\lambda t}$$

Question 19:

For reference to a semiconductor diode, define the terms ‘depletion region’ and ‘potential barrier’. How will the width of depletion region change during reverse biasing? **[3]**

Solution 19:

Depletion region: The small region on either side of the junction which is depleted of mobile (free) charge carries and has only immobile ions is called depletion region.

Potential barrier: The accumulation of negative charges in p- region and positive charges in the n-region set up a potential barrier, ie, the potential difference across the depletion region. It opposes the diffusion of electron and holes across the junction.

Effect on depletion region during reverse biasing

During reverse biasing, the positive terminal of the external battery attracts electrons from n – region and its negative terminal attracts holes from p- region.
Due to which, holes in the p- region and electrons in the n- region are pushed away from the function. Hence, potential barrier and with of the depletion layer increase.

Section –D
(Answer all questions)

Question 20: **[5]**

(i) An 8 H inductor, a $2\mu F$ capacitor and a 100Ω resistor are connected in series to an AC supply of 220V and 50 Hz. Calculate
(a) Impedance of the circuit.
(b) Current flowing through the circuit.
(c) Phase difference between the current and the supply voltage.
(d) Average power consumed by the circuit.

OR

(ii) An AC generator generating an emf E given by E = 311sin(10t) is connected to a 44 Ω resistor. Calculate
(a) rms value of AC flowing through the resistor
(b) Frequency of the current
(c) Mean value of emf generated by the generator in time interval 0.06s to 0.08s

Solution 20:

(i) Given, $\alpha = 8H, C = 2\mu F = 2\times10^{-6} F, R = 100\Omega, v = 50Hz, E_{rms} = 220v$

(a)

$$X_L = \omega L = 2\pi v \times L$$
$$= 2\times3.14\times50\times8 = 2512\Omega$$
$$X_c = \frac{1}{\omega C} = \frac{1}{2\times3.14\times50\times2\times10^{-6}} = 1592\Omega$$

Impendence,

$$Z = \sqrt{R^2 + \left(X_L - X_C\right)^2}$$
$$= \sqrt{(100)^2 + (2512 - 1592)^2}$$
$$= 925.41\Omega \approx 925\Omega$$

(b) $l_{rms} = \frac{E_{rms}}{Z} = \frac{220}{925} = 0.238A$

(c) Phase difference,

$$\phi = \tan^{-1}\frac{(X_L - X_C)}{R}$$
$$= \tan^{-1}\frac{(2512-1592)}{100}$$
$$= \tan^{-1}(92) = 83^o 7^{'}$$

(d) Average power(P) =
$$l_{rms} E_{rms} \cos\phi$$
$$= 0.238 \times 220 \times \cos 83^o 7^{'}$$
$$= 0.23 \times 220 \times 0.119 = 623W$$

(ii) Given,
$$E_0 = 311V, R = 44\Omega, \omega = 10$$
(a)
$$E_{rms} = \frac{E_0}{\sqrt{2}}$$
$$= \frac{311}{\sqrt{2}} = \frac{311}{1.41} = 220V$$
$$I_{rms} = \frac{E_{rms}}{R}$$
$$= \frac{220}{44} = 5A$$

(b) $\omega = 2\pi v \Rightarrow 2\pi v = 10$
$$v = \frac{10}{2\pi} = \frac{10\times 7}{2\times 22} = 1.59hz$$

(c)

$$T = \frac{2\pi}{\omega} = \frac{2 \times 3.14}{10} = \frac{628}{10} = 0.628$$

$$E_{avg} = \frac{1}{T}\int_{t_1}^{t_2} E(t)dt = \frac{1}{T}\int_{t_1}^{t_2} 311\sin(10t)dt$$

$$= \frac{1}{0.628}\int_{0.06}^{0.08} 311\sin(10t)dt$$

$$= \frac{311}{0.628\times}\left[\cos\omega t_2 - \cos\omega t_1\right]$$

$$= -\frac{311}{628}\left[\cos 10\times 0.08 - \cos 10\times 0.06\right]$$

$$= 49.5\left[0.696 - 0.825\right] = 6.38V$$

Question 21: **[5]**

(i) Draw a labelled ray diagram of an image formed by a compound microscope with final image formed at the least distance of distinct vision (D). Derive an expression for its magnifying power (in terms v_0, u_0, f_e and D).

OR

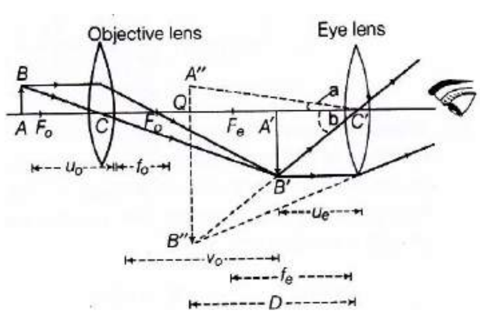
Draw a neat and labelled diagram of an experimental set up of Young's double slit experiment to study the interference of light and show that $\beta = \frac{\lambda D}{d}$

Where, the terms have their usual meaning. Show intensity variation in the interference.

Solution 21:

(i) A compound microscope consists of two convex lenses coaxially separated by some distance. The lens coaxially separated by some distance. The lens nearer to the object is called the objective. The lens through which the final image is viewed is called the eyepiece.

Ray diagram of an image formed by compound microscope is shown below:



Angular magnification or magnifying power of a compound microscope is defined as the ratio of the angle β subtended by the final image at the eye to the angle α subteneted by the object seen directly, when both are placed at least distance of distinct vision.

Thus, angular magnification, $m = \frac{\beta}{\alpha}$

Since, the angles are small, then

$\alpha = \tan\alpha$ or $\beta = \tan\beta$

Thus, $m = \frac{\tan\beta}{\tan\alpha}$

From right angled $\Delta C^{'}QB^{''}$, we have,

$$\tan\beta = \frac{B^{''}Q}{C'Q} = \frac{B''Q}{D} = \frac{A''B''}{D}$$

Also, from right angled $\Delta C^{'}A''Q$, we have,

$$\tan\alpha = \frac{A^{''}Q}{C'Q} = \frac{AB}{D}$$

$$\Rightarrow m = \frac{B''Q}{A'B'} \times \frac{A'B'}{AB}$$

Thus, the magnification produced by the compound microscope is the product of the magnification produced by the eyepiece and objective.

Thus, $m = m_e \times m_o$

Where, m_e and m_o are the magnifying powers of the eyepiece and objective, respectively.

Case I: When the final image is formed at near point.

Linear magnification is given by

$$m_e = 1 + \frac{D}{f_e} \text{------------------- (ii)}$$

Where, f_e is local length of the eyepiece.

$\frac{A'B'}{AB}$ is the linear magnification of the object produced by the objective.

$$m_o = \frac{v_o}{u_o} \text{-------------------- (iv)}$$

We know that,

$$\frac{1}{v_o} - \frac{1}{u_o} = \frac{1}{f_o}$$

Multiplying both sides by v_o, we have,

$$\frac{v_o}{v_o} - \frac{v_o}{u_o} = \frac{v_o}{f_o}$$

$$\Rightarrow -\frac{v_o}{u_o} = -1 + \frac{v_o}{f_o}$$

$$\Rightarrow \frac{v_o}{u_o} = 1 - \frac{v_o}{f_o}$$

Substituting the value of $\frac{v_o}{u_o}$ in Equation (v), we have,

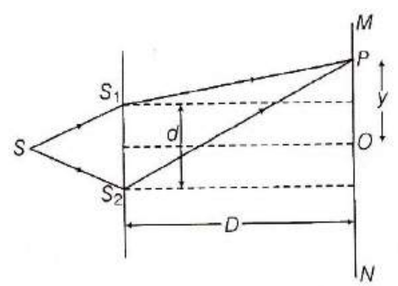
$$m = \left(1 - \frac{v_o}{f_o}\right)\left(1 + \frac{D}{f_o}\right)$$

OR

Young's Double Slit Experiment

Suppose S_1 and S_2 are two line slits, a small distance d apart. They are illuminated by a strong source S of monochromatic light of wavelength λ.

MN is a screen at a distance D from the slits.



Consider a point P at a distance y from O, the centre of screen.

The path difference between two waves arriving at point P is equal to $S_2P - S_1P$.

Now,

$$(S_2P)^2 - (S_1P)^2$$

$$= \left[D^2 + \left(y + \frac{d}{2}\right)^2\right] - \left[D^2 + \left(y - \frac{d}{2}\right)^2\right] = 2yd$$

Thus,

$$(S_2P)^2 - (S_1P)^2 = \frac{2yd}{S_2P + S_1P}$$

But, $S_2P + S_1P = 2D$

Thus,

$$S_2P - S_1P = \frac{dy}{D}$$

For constructive interference
(Bright images)

Path difference, $= \frac{dy}{D} = n\lambda$

Where, n = 0, 1, 2, 3, …..

Thus, $y = \frac{nd\lambda}{d}$

Hence, for n = 0, $y_o = 0$ at O central bright fringe.

The separation between two consecutive bright fringes is

$$\beta = \frac{nD\lambda}{d} - \frac{(n-1)D\lambda}{d} = \frac{D\lambda}{d}$$

For destructive interference (Dark fringes)

Path difference $= \frac{dy}{D} = (2n-1)\frac{\lambda}{2}$

Or $y = (2n-1)\frac{D\lambda}{2d}$

n = 0, 1, 2, 3, …..

The separation between two consecutive bright fringes is

$$\beta = \frac{(2n-1)D\lambda}{2d} - \frac{\{2(n-1)-1\}D\lambda}{2d} = \frac{D\lambda}{d}$$

The distance between two consecutive bright or dark fringes is called fringe width β.

Thus, Fringe width, $\beta = \frac{D\lambda}{d}$

Intensity of the Fringes,

$$I_R = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$$

For a bright fringe = 4*l* and for a dark fringe

$\phi = (2n-1)\pi$

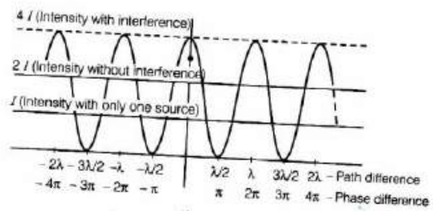
$\Rightarrow cos\phi = -1$

So, $l_R = l_{\min} = l_1 + l_2 - 2\sqrt{l_1 l_2} = 0$

Thus, Intensity of a dark fringe = 0.

Distribution of Intensity

The distribution of intensity in Young’s double slit experiment is shown below.



Question 22: **[5]**

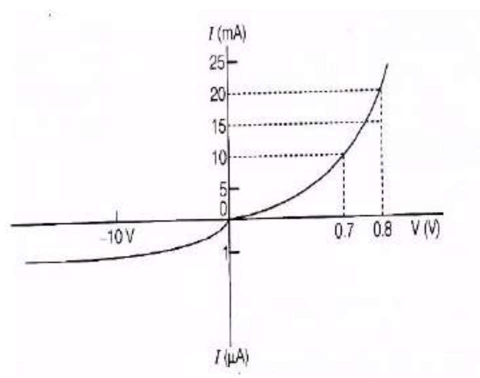
(i)For a transistor in a common emitter mode, draw labelled graph to show

(a) Input characteristic curve.

(b) Output characteristic curve.

(c) Transfer characteristic curve. (Circuit diagram of the arrangement is not required)

(ii) The characteristic curve of a silicon diode is shown below



Calculate the resistance of the diode at

(a) I = 15mA and (b) V = -10V

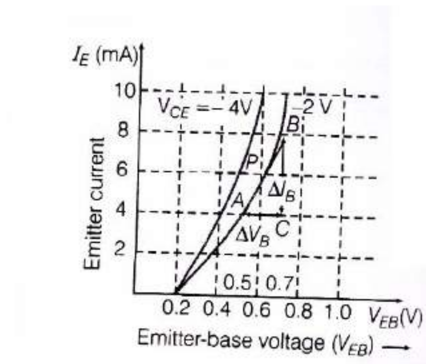
OR

(ii) (a) Show how you will obtain an AND gate using NOR gates. Draw the truth table for this arrangement of gates.

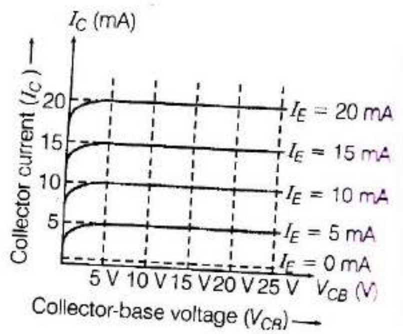
(b) For a common emitter transistor amplifier, the audio signal voltage across the collector resistance (r_c) of $2kg\Omega$ is 2V. If the current amplification factor (β) of the transistor is 100, calculate the input signal voltage (V_{BE}) and base current (I_B) for base resistance of $1kg\Omega$.

Solution 22:

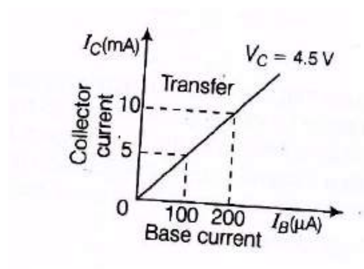
(i) Input characteristic: A graph showing the variation of base current I_B with base-emitter voltage V_{BE} at constant collector–emitter voltage V_{CE} is called the input characteristic of the transistor. Two such curves for two different collector-emitter voltages have been plotted in the below figure.



(ii) Output characteristic: A graph showing the variation of collector current I_C with collector-emitter voltage V_{CE} at constant base-current I_B is called the output characteristic of the transistor, figure shows such curves for different values or I_B.



(iii) Transfer characteristic: It is a graph showing the variation of collector current I_C witrh base current I_B at constant collector-emitter voltage V_{CE}. As shown in figure, the transfer characrteristic of a transistor is almost a straight line.



OR

(a) From the graph, at

$I = 15mA = 15\times10^{-3} A, V = 0.75V$

Thus,

$$R = \frac{V}{I} = \frac{0.75}{15\times10^{-3}} = 0.05\times10^{3}\Omega$$

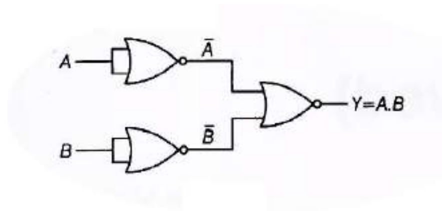
$$= 50\Omega$$

(b) From the graph, at

$V = -10V, I = 1mA = 10^{-3} A$

$\Rightarrow R = \left|\frac{V}{I}\right| = \left|\frac{-10}{-10^{-3}}\right| = 100\Omega$

(ii) (a) To obtain AND gate from NOR gate, two NOT gates obtained from NOR gates are connected to a NOR gate.
Logic symbol



(b) Given,

$V_o = 2V, R_o = 2k\Omega = 2000\Omega, R_i = 1k\Omega = 1000\Omega, \beta = 100$

Voltage again,

$$\frac{V_o}{V_i} = \beta \frac{R_o}{R_i}$$
$$\Rightarrow \frac{2}{V_i} = 100 \times \frac{2000}{1000}$$
$$\Rightarrow V_i = 0.01V$$

Since, $\beta = \frac{I_C}{I_B} = \frac{V_0 / RC}{I_B}$

Base current,

$$I_B = \frac{V_o}{\beta R_C} = \frac{2}{100 \times 2000} = 10^{-5} A = 10\mu A$$