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) As compared to ^{12}C atom, ^{14}C atom has
(a) Two extra protons and two extra electrons.
(b) Two extra protons but no extra electrons.
(c) Two extra neutrons but no extra electrons.
(d) Two extra neutrons and two extra electrons.

(ii) The current in a wire varies with time according to the equation i = 4 +2t, where t is in ampere and t is in second. The quantity of charge which passes through a cross- section the wire during the time t = 2s to t = 6s is
(a) 40 C
(b) 48 C
(c) 38 C
(d) 43 C

(iii) Two thin long parallel wires separated by a distance d carry a current of I ampere in same direction. They will:

(a) Attract each other with a force of $\frac{\mu_0 I^2}{2\pi d}$

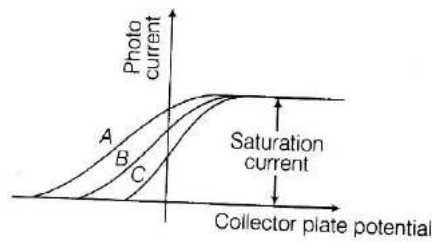
(b) Repel each other with a force of $\frac{\mu_0 I^2}{2\pi d}$

(c) Attract each other with a force of $\frac{\mu_0 I^2}{2\pi d^2}$

(d) Repel each other with a force of $\frac{\mu_0 I^2}{2\pi d^2}$

(iv) The near point of a hypermetropic person is 75cm from the eye. What is the power of the lens required to enable the person to read clearly a book held at 25 cm from the eye?
(a) 0+2.67 D (b) -3.42 D (c) 4.62 D (d) 5.42 D

(v) For the graph of collector plate potential versus photoelectric current shown below:



If I denotes intensity of incident radiation, then
(a) $I_A > I_B > I_C$ (b) $I_A < I_B < I_C$ (c) $I_A = I_B = I_C$ (d) $I_B > I_A$ and $I_B < I_C$

(B) Answer the following questions briefly and to the point, [7]
(i) An electrostatic field line is continuous curve, i.e. a field line cannot have sudden breaks. Why not?
(ii) A concave mirror is held in water. What should be the change in focal length of the mirror?
(iii) Do all the electrons that absorb a photon come out as photoelectrons?
(iV) Resonance frequency of a circuit is v. If the capacitance is made 4 times the initial value, find the change in the resonance frequency.
(v) Why is a coil wrapped on a conducting frame in a galvanometer?
(vi) A charged particle enters an environment of a strong and non- uniform magnetic field varying from point to point both in magnitude and direction, comes out of it following a complicated trajectory. Would its final speed equal to the initial speed, if it suffered no collisions with the environment?
(vii) Specific resisitacne of copper, silver and constantan are $1.75\times10^{-6}\Omega - cm$, $10^{-6}\Omega - cm$ and $48\times10^{-6}\Omega - cm$, respectively. Which is the best conductor and why?

Solution 1:

A. (i) (c) For ${}_{6}^{12}C$, A = 12 =N + Z, Z =6 ➔ N =6

For ${}_{6}^{14}C$, A = 14 =N + Z, Z =6 ➔ N =8

Also, number, of electrons in both atoms = number of protons = Z = 6

(ii) (b)

$$\int dq = \int idt = \int (4+2t)dt$$

$$\Rightarrow q = \int_{2}^{6} (4+2t)dt = \left[4t+t^2\right]_2^6$$
$$= 4\times6+6^2-4(4\times2+2^2) = 60-12 = 48C$$

(iii) (a) Current flows in same direction.

Thus, Wires attract each other and $\frac{F}{l} = \frac{\mu_0 I^2}{2\pi d}$

(iv) (a) Here, u = -25cm, v = -75cm

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{1}{(-75)} - \frac{1}{(-25)} = -\frac{1}{75} + \frac{1}{25}$$

Thus, f = 37.5cm

$$P = \frac{1}{f} = \frac{1}{37.5} = 2.67D$$

So, the corrective lens needs to have a converging power of +2.67D.

(v) (c) Intensities will be equal as the saturation current is same. To study the variation of photocurrent with collector plate potential at different frequencies the intensity is kept same.

B. (i) An electrostatic field line cannot be a discontinuous curve, that is, it cannot have breaks. If it has breaks, then it will indicate absence of electric field at the break points. But the electric filed vanishes only at infinity.

(ii) No change in focal length of the mirror f is independent of medium and depends only on radius of curvature R, I.e. $f = \frac{R}{2}$.

(iii) In photoelectric effect, we can observe that mmost electrons get scattered into the metal by absorbing a photon. Thus, all the electrons that absorb a photon does not come out as photoelectron. Only a few come out of metal whose energy becomes greater than the work function of metal.

(iv) As, resonance frequency,

$$v = \frac{1}{2\pi\sqrt{LC}}$$

$$\Rightarrow v\alpha \frac{1}{\sqrt{C}}$$

Thus,

$$v^{'}\alpha \frac{1}{\sqrt{C^{'}}} = \frac{1}{\sqrt{4C}} = \frac{1}{2\sqrt{C}} = \frac{1}{2}v$$

(v) Eddy currents in conducting frame help in stopping the coil soon, that is, in making the galvanometer deadbeat.

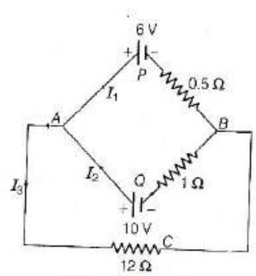
(vi) Yes, its final speed equal to the initial speed as the magnetic force acting on the charged particle only changes the direction of velocity of changed particle but cannot change the magnitude of velocity of charged particles.

(vii) The best conductor is silver because electrical conductivity is inversely proportional to the resistivity and resistivity of silver is least.

Section- B

Question 2: Account for the following: **[2]**

Apply Kirchhoff's laws to the loops ACBPA and ACBQA to write the expressions for the current I_1, I_2 and I_3 in the network.



Circuit diagram of loops

Solution 2: Applying Kirchhoff's first law, $I_3 = I_1 + I_2$

Applying Kirchhoff's second law to the loop ACBPA,

$$-12I_3 - 0.5I_1 + 6 = 0$$

$$\Rightarrow 0.5I_1 + 12I_3 = 6$$

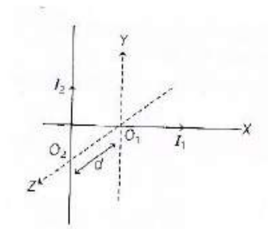
Now, applying Kirchhoff's second law to the loop ACBQA,

$$-12I_3 - 1I_2 + 10 = 0$$

$$\Rightarrow I_2 + 12I_3 = 10$$

Question 3: **[2]**

Two long wires carrying currents I_1 and I_2 are arranged as shown in the figure. One carrying current I_1 is along the X- axis. The other carrying current I_2 is along a line parallel to Y – axis, given by x = 0 and z = d. Find the force exerted at point O_2 because of the wire along the X- axis.



A Rowland ring of mean radius 15 cm has 3500 turns of wire wound on a ferromagnetic core of

Solution 3:

Here, first we have to find the direction of magnitude field at point O2 due to the wire carrying current I_0. Use Maxwell's right hand grip rule, the direction of magnetic field at point O_2 due to current I_1 is along Y – axis.

Here, the wire at point O_2 is placed along Y – axis. Now, by the formula, $F = I_2(L \times B)$

Angle between L And B is O^0, both are at Y- axis, ie, $F = ILBSinO^0 = 0$

So, the force exerted at point O_2 because of wire along X-axis is zero.

OR

Given, radius of Rowland ring, r = 15 cm = 0.15m

Number of turns, N = 3500

Relative permeability of ferromagnetic core, μ ,= 800

Current, $I = 1.2A$

Magnetic filed due to the toroid,

$$B = \mu n I$$

$$B = \mu n I$$

$$B = \mu_0 \mu_t \frac{N}{2\pi r}.l$$

$$= 4 \times 3.14 \times 10^{-7} \times 800 \times \frac{3500 \times 1.2}{2 \times 3.14 \times 0.15}$$

$$= 4.48T$$

Question 4: **[2]**

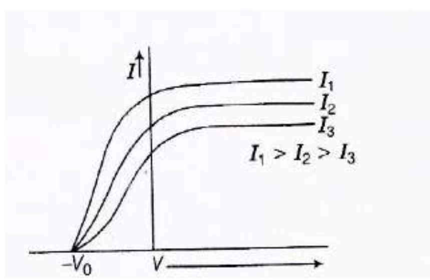
(i) The angle of dip at a location in southern India is about 18°. Would you expect a greater or smaller dip angle in Britain?

(ii) Geologists claim that besides the main magnetic North – South Pole, there are several local poles in the earth's surface oriented in different directions. How is such a thing possible at all?

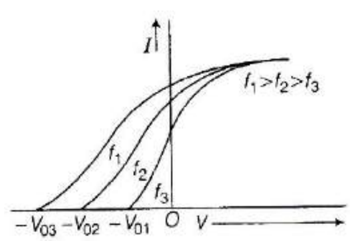
Solution 4:
(i) We can expect a greater value of angle of dip in Britain because Britain is located close to North Pole. (The value of angle of dip in Britain is about 70°).

(ii) The earth's magnetic field is only due to the dipole field. As there are several local north-south poles that may exist oriented in different directions, so they may nullify the effect of each other. These local north-south poles mat occur due to the deposition of magnetized minerals.

Question 5: Draw suitable graphs to show the variation of photoelectric current I with collector plate potential V for
(i) a fixed frequency but different intensities $I_1 > I_2 > I_3$ of radiation.
(ii) a fixed intensity but different frequencies $f_1 > f_2 > f_3$. **[2]**
Solution 5:
Graphs showing variation if photoelectric current I with collector plate potential V.
(i) A fixed frequency but different intensities of radiations.



(ii) fixed intensity but different frequencies of radiations.



Question 6: The frequency of oscillation of the electric field vector of a certain electromagnetic wave is $5\times10^4 Hz$. What is the frequency of oscillation of the corresponding magnetic field vector and to which part of the electromagnetic spectrum does it belong?

OR

Show that linear magnification of an image formed by a curved mirror may be expressed as,

$$m = \frac{f}{f-u} = \frac{f-v}{f}$$

Where, letters have their usual meanings. **[2]**

Solution 6:
For electromagnetic waves, frequency of electric field vector and magnetic field vector is same.
Thus, Frequency, $v = 5\times10^4 Hz$
The part of the electromagnetic spectrum to which this wave belongs to is radio waves.

OR

We know that, the linear magnification of an image formed by a curved mirror is given by

$$m = \frac{h'}{h} = \frac{-v}{u} \text{ ----------------------------(i)}$$

However, from mirror formula,

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{u-f}{uf}$$

$$\Rightarrow v = \frac{uf}{u-f}$$

Thus, $m = \frac{-v}{u} = -\frac{1}{u}\left(\frac{uf}{u-f}\right) = \frac{f}{f-u}$ --------------------- (ii)

Again, as per mirror formula,

$$\frac{1}{u} = \frac{1}{f} - \frac{1}{v} = \frac{v-f}{fv}$$

Thus,

$$m = \frac{-v}{u} = -v\left(\frac{v-f}{fv}\right) = \frac{f-v}{f} \text{ -------------------------- (iii)}$$

From Equations (ii) and (iii), we get,

$$m = \frac{f}{f-u} = \frac{f-v}{f}$$

Question 7: What kinetic energy of a neutron will be associated by the de – Broglie wavelength $1.32\times10^{-10} m$? Given that, mass ,of a neutron = $1.675\times10^{-27} kg$. **[2]**

Solution 7:
Given: $\lambda = 1.32\times10^{-10} m$ and $m_n = 1.675\times10^{-27} kg$

Since,

$$\lambda = \frac{h}{\sqrt{2m_n K}}$$

Thus,

$$K = \frac{h^2}{2m_n\lambda^2}$$

$$= \frac{\left(6.63\times10^{-34}\right)^2}{2\times1.675\times10^{-27}\times\left(1.32\times10^{-10}\right)^2}$$

$$= 7.53\times10^{-21}$$

Question 8: A carrier wave of a peak voltage 12 V is used to transmit a message signal. What should be the peak voltage of the modulating signal in order to have a modulation index 75%? **[2]**

Solution 8: Modulation index (m) is the ratio of amplitude of modulating wave (A_m) to the amplitude of carrier wave

(A_c), ie, $m = \frac{A_m}{A_c}$

Given: $m = 75\% = \frac{75}{100}$ and $A_c = 12V$

As, $m = \frac{A_m}{A_c}$

Thus,

$$\frac{75}{100} = \frac{A_m}{12}$$

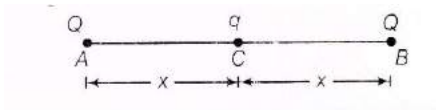
$$\Rightarrow A_m = 9V$$

Question 9: **[2]**

A charge q is placed at the centre of the line joining two equal charges Q. Show that the system of three charges will be in equilibrium, if $q = -\frac{Q}{4}$.

Solution 9:

Suppose the three charges be placed as shown in the figure.



As, the net force on q is zero, so it is already in equilibrium. For equilibrium of other two charges, the net force on each charge must be zero.
Total force on charge Q at B is

$$\frac{1}{4\pi\varepsilon_0}\cdot\frac{Qq}{x^2}+\frac{1}{4\pi\varepsilon_0}\cdot\frac{Q\cdot Q}{(2x)^2}=0$$

$$\Rightarrow \frac{1}{4\pi\varepsilon_0}\cdot\frac{Qq}{x^2}=-\frac{1}{4\pi\varepsilon_0}\cdot\frac{Q^2}{4x^2}$$

$$\Rightarrow q=-\frac{Q}{4}$$

Question 10: (i) A power transmission line feed input power at 2300V to a step- down transformer with its primary windings having 4000 turns. What should be the number of turns in the secondary in order to get output power at 230V?
(ii) Self- induction is called the inertia of electricity. Why? **[2]**

Solution 10:
(i) Given, primary voltage, $V_p = 2300V$

Secondary voltage, $V_s = 230V$

Primary turns, $N_p = 4000$ turns

Here, we assume that the transformer is ideal. No power loss in the form of heat, etc.
Using the formula,

$$\frac{V_s}{V_p}=\frac{N_s}{N_p} \text{ or } \frac{230}{2300}=\frac{N_s}{4000}$$

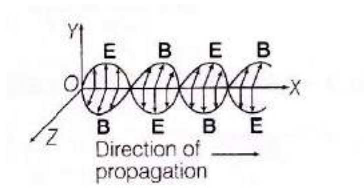
$$\Rightarrow N_s = 400$$

(ii) Self – induction of coil is the property by virtue of which it tends to maintain the magnetic flux linked with it and opposes any change in the flux by inducing current in it. This property of a coil is analogous to mechanical inertia. That is why self- induction is called the inertia of electricity.

Question 11:
(i) An electromagnetic wave is travelling in a medium with a velocity $v = v\hat{i}$. Draw a sketch showing the propagation of the electromagnetic wave indicating the direction of the oscillation electric and magnetic fields.
(ii) How are the magnitudes of the electric and magnetic fields related to velocity of the electromagnetic wave? **[2]**

Solution 11:

(i) Given that velocity, $v = v\hat{i}$, i.e. the wave is propagating along X-axis and electric field E is along Y- axis and magnetic field B is along Z –axis. The propagation of electromagnetic wave is shown in the figure.



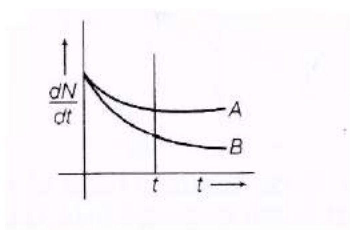
(ii) Speed of electromagnetic wave can be given as

$$c = \frac{E_0}{B_0} = \frac{E}{B}$$

Where, E_0 and B_0 are peak values of E and b or instantaneous values of E and B.

Question 12: **[2]**

Which sample A or B shown in the figure, has shorter mean- life?



Solution 12:

From the given figure, we can say that at t = Q

$$\left(\frac{dN}{dt}\right)_A = \left(\frac{dN}{dt}\right)_B \Rightarrow (N_o)_A = (N_o)_B$$

Considering any instant t by drawing a line perpendicular to time- axis, we find that

$$\left(\frac{dN}{dt}\right)_A > \left(\frac{dN}{dt}\right)_B$$

$$\Rightarrow \lambda_A N_A > \lambda_B N_B$$

Since,

$$N_A > N_B$$

Thus,

$$\lambda_A > \lambda_B$$

$$\Rightarrow \tau_A > \tau_B$$

Section- C

Question 13: **[3]**

Give the circuit diagram of a common emitter amplifier, using an n-p-n transistor. Draw the input and output waveforms of the signals. Write the expression for is voltage gain.

Solution 13:
Circuit diagram of a common emitter amplifier

Voltage gain: It is equal to the ratio of small change in output voltage at the collector to that change in input voltage, i.e.,

$$A_v = \frac{\text{Output voltage}}{\text{Input voltage}}$$

$$= \frac{\Delta V_{CE}}{\Delta V_{BE}} = \frac{(\Delta I_C) R_{out}}{(\Delta I_B) R_{in}}$$

$$= \beta_{AC} \times \frac{R_{out}}{R_{in}}$$

Where, β_{AC} is AC current gain.

Question 14: **[3]**

(i) Two slits are made 1 mm apart and the screen is placed 1 m away. What is the fringe sepration, when blue- green light of wavelength 500nm is used?
(ii) What should be the width of each slit to obtaib 10 maxima of the double slit pattern within the central maxima of the single slit pattern?

OR

A beam of light consisting of two wavelengths 560 nm and 420nm, is used to obtain interference fringes in a Yong's double slit experiment. Find the least distance from the central maxima, where the bright fringes due to both the wavelengths coincide. The distance between the two slits is 4 mm and the screen is at a distance of 1 m from the slits.

Solution 14:
(i) Given,

$$d = 1mm = 10^{-3} m, D = 1m,$$

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

Thus, Fringe separation,

$$\beta = \frac{\lambda D}{d} = \frac{5 \times 10^{-7} \times 1}{10^{-3}}$$

$$= 5 \times 10^{-4} = 0.5mm$$

(ii) Let width of each slit be a, then the width central maxima of single slit diffraction is given by

$x = \frac{2\lambda D}{a}$

And as per condition given,

$x = 10\beta = \frac{10\lambda D}{d}$

$\Rightarrow \frac{2\lambda D}{a} = \frac{10\lambda D}{d}$

$\Rightarrow a = \frac{d}{5} = \frac{1}{5} = 0.2mm$

OR

To find the point of coincidence of bright fringes, we can equate the distance of bright fringes from the central maxima, made by both the wavelength of light.

Given, D = 1m, d =4mm = $4 \times 10^{-3} m$,

$\lambda_1 = 560nm, \lambda_2 = 420nm$

Let nth order bright fringe of λ_1 coincides with (n + 1) the order bright fringe of λ_2.

Thus,

$\frac{Dn\lambda_1}{d} = \frac{D(n+1)\lambda_2}{d}$

$\Rightarrow n\lambda_1 = (n+1)\lambda_2$

$\Rightarrow n560 = (n+1)420$

$\Rightarrow n = 3$

So, for wavelength λ_1, the distance of 3rd bright fringe from central maxima,

$x_3 = \frac{3\lambda_1}{d} = \frac{3 \times 560 \times 10^{-9} \times 1}{4 \times 10^{-3}}$

$= 420 \times 10^{-6} m$

$= 420 \mu m$

Question 15: Calculate the binding energy per nucleon of $^{20}Ca_{40}$ nucleus.

Given, $m\left({}_{20}Ca^{40}\right) = 39.962589u, m_n = 1.008665u, m_p = 1.007825u(take, 1amu = 931MeV)$.

OR

The electron in a given Bohr orbit has a total energy of -15eV. Find

(i) Its kinetic energy. (ii) Potential energy.

(iii) Wavelength of light emitted, when the electron makes a transition to the ground state. (Take - $E_g = -13.6eV$) **[3]**

Solution 15:

In a nucleus of ${}_{20}Ca^{40}$, number of protons = 20

Number of neutrons = 40 – 20 = 20

Total mass of 2 protons and 20 neutrons

$= 20m_p + 20m_n$

$= 20\left(m_p + m_n\right)$

$= 20(1.007825 + 1.008665)$

$= 40.3298u$

Mass defect,

$\Delta m = 40.3298 - 39.962589$

$= 0.367211u$

Total $BE = 0.367211 \times 931 = 341.873441V$

Be/nucleon $= \dfrac{341.873441}{40} = 8.547 MeV / nucleon$

OR

(i) In Bohr's model, total energy is given by

$E_n = -1.5eV$

Thus, Kinetic energy of electron, $K_n = -E_n = 1.5eV$

(ii) Potential energy of electron,

$U_n = 2E_n$

$= 2 \times -1.5$

$= -3eV$

(iii) If an electron makes a transition from 1.5eV state to ground state having energy -13.6eV, the energy of radiated photon

$E = -1.5 - (-13.6)$

$= 12.1eV$

$= 12.1 \times 1.6 \times 10^{-19} J$

As,

$E = hv = \dfrac{hc}{\lambda}$

$\Rightarrow \lambda = \dfrac{hc}{E}$

$= \dfrac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{12.1 \times 1.6 \times 10^{-19}}$

$\lambda = 1.027 \times 10^{-7} m = 102.7 nm$

Question 16: **[5]**

When two charged capacitors are connected to each other, then show that there is always some loss of energy due to sharing of charges.

Solution 16:

When two charged capacitors are connected to each other, they share charges, till they acquire a common potential. On sharing charges, there is always some loss of energy. However, total charge of the system remains conserved. Consider two capacitors having capacitances C_1, C_2 and potentials V_1, V_2, respectively.

Then before the two capacitors are connected together, the total energy stored in the two capacitors,

$$U = U_1 + U_2 = \frac{1}{2}C_1V_1^2 + \frac{1}{2}C_2V_2^2 \text{ --------------------- (i)}$$

When the two capacitors are connected together, total charge on the capacitor,

$$q = q_1 + q_2 = C_1V_1 + C_2V_2$$

Total capacitance of the two capacitors,

$$C = C_1 + C_2$$

Therefore, total energy of the two capacitors, after they are connected

$$U' = \frac{1}{2}\cdot\frac{q^2}{C} = \frac{1}{2}\cdot\frac{\left(C_1V_1 + C_2V_2\right)^2}{C_1 + C_2} \text{ -------------------- (ii)}$$

Subtracting Eq (ii) from Eq. (i), we get,

$$U - U' = \left(\frac{1}{2}C_1V_1^2 + \cdot\frac{1}{2}C_1V_2^2\right) - \frac{1}{2}\frac{\left(C_1V_1 + C_2V_2\right)^2}{C_1 + C_2}$$

$$= \frac{C_1^2V_1^2 + C_1C_2V_1^2 + C_1C_2V_2^2 + C_2^2V_2^2 - \left(C_1V_1 + C_2V_2\right)^2}{2\left(C_1 + C_2\right)}$$

$$= \frac{C_1C_2\left(V_1^2 + V_2^2 - 2V_1V_2\right)}{2\left(C_1 + C_2\right)}$$

$\Delta U = \dfrac{C_1C_2(V_1 - V_2)^2}{2(C_1 + C_2)}$ is a positive quantity.

Since, $U - U'$ is positive, there is always a loss of energy, when two charged capacitors are connected together in the form of heat radiation due to electric current while charging.

Question 17: **[3]**

Careful measurement of the electric field at the surface of a black box indicates that the net outward flux through the surface of the box is 8.0×10^3 N-m^{2}C^{-1}.

(i) What is the net charge inside the box?

(ii) If the net outward flux through the surface of the box was zero, could you conclude that there was no charges inside the box. Why or why not?

Solution 17:

Here, $\phi = 8.0 \times 10^3 N - m^2 C^{-1}$

(i) Suppose that the net charge inside the box is q, then according to Gauss theorem,

$\phi = \frac{q}{\varepsilon_0}$ or $q = \varepsilon_0 \phi$

Since, $\varepsilon_0 = 8.854 \times 10^{-12} C^2 N^{-1} m^{-2}$

Thus,

$\varepsilon_0 = 8.854 \times 10^{-12} \times 8.0 \times 10^3 = 70.832 \times 10^{-9} C$

$q = 0.07 \mu C$

(ii) If the net outward flux through the surface of the box is zero, then it cannot be conducted that there is no charge inside the box. There may be equal amount of positive and negative charges inside the box. So, the net charge inside the box is zero.

Question 18:

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

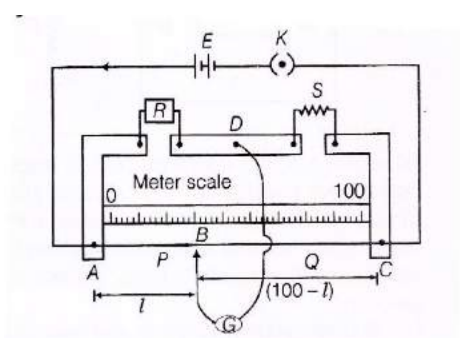
Solution 18:

A meter bridge is also known as slide Wire Bridge. It is a practical from of Wheatstone bridge.

Principle:

It si constructed on the principle of balanced Wheatstone bridge, that is, when a Wheatstone bride is balanced,

$\frac{P}{Q} = \frac{R}{S}$, where the initials have usual meanings.



A meter bridge

At balancing situation of bridge,

$$\frac{P}{Q}=\frac{R}{S}$$

$$\Rightarrow \frac{l}{100-l}=\frac{R}{S}$$

$$\Rightarrow S=\frac{100-l}{l}\times R$$

Application

(a) To measure an unknown resistance. The unknown resistance can be found by

$$S=R\times\frac{(100-l)}{l}$$

(b) To compare the two unknown resistances.

$$\frac{R}{S}=\frac{l}{100-l}$$

The meter bridge cannot be used to measure very low or very high resistance.

Question 19:

A compound microscope has an objective of focal length 1 cm and an eyepiece of focal length 2.5 cm. An object has to be placed at a distance of 1.2cm away from the objective for the normal adjustment. Determine the angular magnification and length of microscope tube. **[3]**

Solution 19:

Given, focal length of objective, $f_0=1cm$

Focal length of eyepiece, $f_0=2.5cm$

Object distance, $u_0=-1.2cm$

Since,

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

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

$$\Rightarrow \frac{1}{v_o}=1-\frac{1}{1.2}=\frac{0.2}{1.2}$$

$$\Rightarrow v_o=\frac{1.2}{0.2}$$

$$\Rightarrow v_o=6cm$$

Since, Angular magnification,

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

$$\Rightarrow m = \frac{6}{|-1.2|}\left(1 + \frac{25}{2.5}\right) = 55$$

Thus, Length of microscope tube,

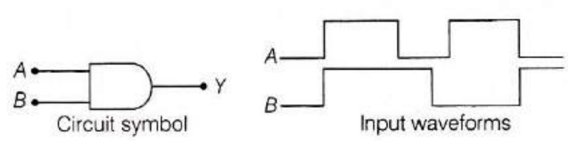
$$L = v_o + f_o = (6 + 2.5) = 8.5cm$$

Section –D
(Answer all questions)

Question 20: **[5]**

(i) What is LED (light emitting diode)? How it works? How LEDs advantages over incandescent low power lamps? **[2]**

(ii) In the figure given below, circuit symbol of a logic gate and two input waveforms A and B are shown below:



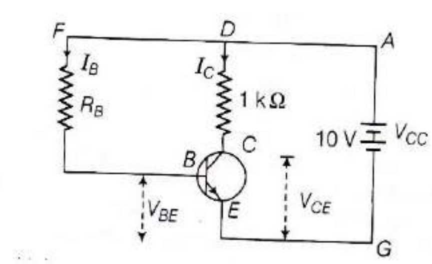
(a) Name the logic gate (b) Write its truth table.

(c) Give the output waveform. **[3]**

OR

(i) Derive the relation between α and β. (Where, α and β are current gain in common base and common emitter connection of transistor.)

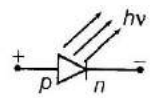
(ii) In the circuit given, the transistor used has a current gain $\beta = 100$. If the bias resistance $R_B = a \times 10^5 \Omega$, then $V_{CE} = 5V$. Neglecting V_{BE}, find the integer value of a.



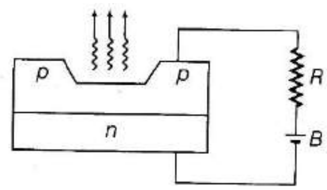
Solution 20:

(i) Light Emitting Diode (LED)

It is a heavily doped p-n junction diode which converts electrical energy into light energy. This diode emits spontaneous radiation, under forward biasing. The diode is covered with a transparent cover, so that the emitted light may come out. Its symbol is



Working



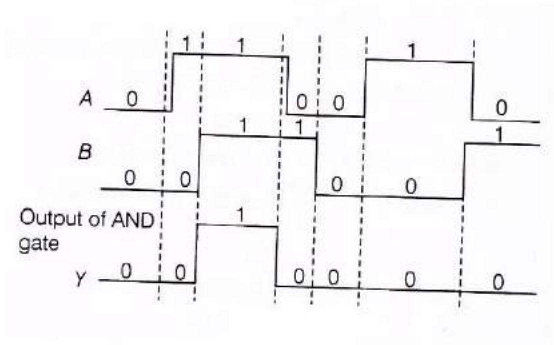
When p-n junction is forward biased, electrons and holes move towards opposite sides of junction through it. Therefore, there are excess minority carries on the recombines with majority carries near the junction.
On recombination of electron and holes, the energy is given out in the form of heat and light.

LEDs Advantage over Incandescent Low Power Lamps

It has the following advantages over conventional incandescent low power lamps.
(a) Fast action and no warm up time required.

(b) The bandwidth of emitted light is form 100 $\overset{o}{A}$ to 500 $\overset{o}{A}$. So, it is nearly (not exactly) monochromatic.
(c) Long life and ruggedness.
(d) Low operational voltage and less power consumed.
(e) Fast ON-OFF switching capability.

(ii) (a) AND gate.
(b)
(c) Output waveform



OR

(i) We know that,
Change in emitter current = Sum of change in collector current and base current
That is, $\Delta I_E = \Delta I_C + \Delta I_B$
Dividing ΔI_C both side, we get,

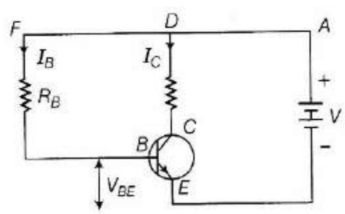
$$\frac{\Delta I_E}{\Delta I_C} = 1 + \frac{\Delta I_B}{\Delta I_C}$$

$$\frac{1}{\alpha} = 1 + \frac{1}{\beta}$$

$$\Rightarrow \frac{1}{\alpha} = \frac{\beta + 1}{\beta}$$

$$\Rightarrow \alpha = \frac{\beta}{\beta + 1}$$

(ii) We redraw the above circuit as,



Using Kirchhoff's second law in loop ADCEGA, we have,

$$-V_{cc} + I_C \times 10^3 + V_{CE} = 0$$

$$V_{cc} = I_C \times 10^3 + V_{CE}$$

$$10 = I_C \times 10^3 + 5$$

$$\Rightarrow I_C = 5 \times 10^3 A$$

Again using Kirchhoff's second law in loop AFBEGA,
We have,

$$I_B R_B + V_{BE} - V_{CC} = 0$$

$$\Rightarrow \frac{I_c}{\beta} \times R_B + 0 = V_{cc}$$

$$\Rightarrow \frac{5 \times 10^{-3}}{100} \times R_B = 10$$

$$\Rightarrow R_B = 2 \times 10^5 \Omega$$

But $R_B = a \times 10^5 \Omega$

Thus,

$$a \times 10^5 \Omega = 2 \times 10^5 \Omega$$

$$\Rightarrow a = 2$$

Question 21: **[5]**

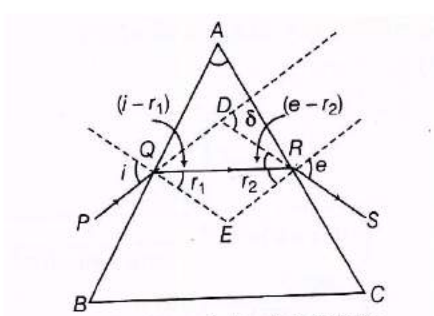
Show that the refractive index of the material of a prism is given by $\mu = \dfrac{\sin\left(\dfrac{A + \delta m}{2}\right)}{\sin\left(\dfrac{A}{2}\right)}$

Where, the symbols have their usual meanings.

OR

Define the term resolving power of an astronomical telescope. How does, it get affected on
(i) Increasing the aperture of the objective lens?
(ii) Increasing the wavelength of light used?
(iii) Increasing the focal length of the objective lens?

Solution 21:
Consider a prism ABC of refractive index μ. A light ray PQ is incident on face AB at an angle of incidence i and refracted at an angle r_1. It strikes on face AC at an angle r_2 and emerges at an angle e. The angle of deviation is δ.



A prism of refractive index μ

Thus, $\angle DQR = (i - r_1)$ and $\angle DQR = (e - r_2)$

For ΔDQR, δ is exterior angle,

Thus,

$\delta = (i - r_1) + (e - r_2)$

$\Rightarrow \delta = (i + e) - (r_1 + r_2)$ -----------------------------(i)

In cyclic quadrilateral AQER,

$\angle A + \angle E = 180^o$ ----------------- (ii)

In ΔQER,

$r_1 + r_2 + \angle E = 180^o$ -------------(iii)

From equations (ii) and (iii), we get,

$\angle A = r_1 + r_2$ ----------------- (iv)

Substituting the value in equation (i), we get,

$\delta = (i + e) - \angle A$ -------------------(v)

For minimum angle of deviation (δ_m), $\delta = \delta_m$ and i =e, $r_1 = r_2$ =r (assume)

From equation (iv), we get,

$\angle A = r + r$

$\Rightarrow r = \frac{\angle A}{2}$ ------------------(vi)

Form equation (v), we get,

$\delta_m = i + i - \angle A$

$\Rightarrow i = \frac{\angle A + \delta_m}{2}$ ----------------------(vii)

If μ is refractive index of the material of the prism, then according to the Snell's law,

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

Substituting the values of I and r, we get,

$$\mu = \frac{\sin\left(\frac{\angle A + \delta_m}{2}\right)}{\sin\left(\frac{\angle A}{2}\right)}$$

OR

Resolving power of an astronomical telescope ($N\mu$)

The ability of an astronomical telescope to form separate images of two neighboring astronomical objects, is called its resolving power.

The least distance between two neighboring objects for which telescope can form separate images is called the limit of resolution. The angular limit of resolution of a telescope is given by

$$\theta = \frac{1.22\lambda}{d}$$

Where, λ =wavelength f light used and d = diameter of aperture of objective lens.
Resolving power id the reciprocal of limit of resolution.

Hence, Resolving power = $\frac{d}{1.22\lambda}$

(i) As, resolving power is directly proportional to d, therefore, resolving power of the telescope increase on increasing diameter of the aperture of the objective lens.
(ii) As, resolving power is inversely proportional to λ, therefore, resolving power of the telescope decreases on increasing the wavelength of the light used.
(iii) Resolving power of a telescope is independent of the focal length of the objective lens. Hence, on increasing the focal length of the objective lens, resolving power remains unchanged.

Question 22: **[5]**
(i) Derive the formula for power associated in AC circuit.
(ii) State the principle and construction of AC generator.

OR

A circuit containing 80 mH inductor and a 60 μF capacitor in series is connected to a 230V, 50 Hz supply. The resistance in the circuit is negligible.
(i) Obtain the current amplitude and rms value.
(ii) Obtain the rms vale of potential drop across each element.
(iii) What is average power transferred to inductor?
(iv) What is the average power transferred to capacitor?
(v) What is the total average power absorbed by the circuit?

Solution 22:
(i) **Average Power Associated in AC Circuit**

Power is defined as the product of voltage and current. In AC circuit, both emf and current change continuously with respect to time, so in AC circuit, we have to calculate average power in complete cycle (O to T).
Instantaneous power, P =EI---------------(i)
Here, E and I are instantaneous voltage and current, respectively. If the instantaneous power remains constant for a small time dt, then small amount of work done in maintaining the current for a small dt is $\frac{dW}{dt} = Ei$

Or $dW = EIdt$ --------------------(ii)

Integrating equation (ii) on both sides, we get, $\int dW = \int_0^T EIdt$

Total work done or energy spent in maintaining current over one full cycle,

$$W = \int_0^T E_0 \sin \omega t \cdot l_0 \sin\left(\omega t + \phi\right) dt$$
$$= E_0 l_0 \int_0^T \sin \omega t (\sin \omega t \cos \phi + \cos \omega t \sin \phi dt$$
$$= E_0 l_0 \left[\cos \phi \int_0^T \sin^2 \omega t dt + \sin \phi \int_0^T \sin \omega t \cos \omega t dt \right]$$
$$= E_0 l_0 \left[\cos \phi \int_0^T \left(\frac{1 - \cos 2\omega t}{2} \right) dt + \frac{\sin \phi}{2} \int_0^T 2 \sin \omega t \cos \omega t dt \right]$$
$$= E_0 l_0 \left[\frac{\cos \phi}{2} \int_0^T (1 - \cos 2\omega t) dt + \frac{\sin \phi}{2} \int_0^T \sin 2\omega t dt \right]$$
$$= E_0 l_0 \left[\cos \phi \left(\int_0^T dt - \int_0^T \cos 2\omega t dt \right) + \sin \phi \int_0^T \sin 2\omega t dt \right]$$
$$= E_0 l_0 \left[\left(\cos \phi [t]_0^T - \int_0^T \cos 2\omega t dt \right) + \sin \phi \int_0^T \sin 2\omega t dt \right]$$

Since,

$$\int_0^T \cos 2\omega t dt = 0$$

And $\int_0^T \sin 2\omega t dt = 0$

So, $W = \frac{E_0 l_0}{2} \cos \phi$

Average power associated in AC circuit,

$$P_{av} = \frac{W}{T} = \frac{E_0 l_0 T \cos \phi}{2T} = \frac{E_0 l_0 \cos \phi}{2}$$
$$P_{av} = \frac{E_0}{\sqrt{2}} \cdot \frac{l_0}{\sqrt{2}} \cos \phi$$
$$P_{av} = E_{rms} l_{rms} \cos \phi = E_V l_V \cos \phi$$

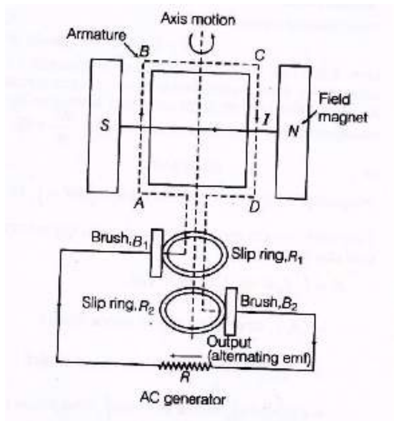
Here, $\cos \phi$ is power factor.

(ii) **AC Generator**

A generator produces electrical energy from mechanical work, just the opposite of what a motor does. In a generator, the shaft is rotated by some mechanical means, such as an engine or a turbine starts working and an emf is induced in the coil.

Principle

An AC generator is based on the phenomenon of electromagnetic induction which states that whenever magnetic flux linked with a conductor (or coil) changes, an emf is induced in the coil.



Main Parts of an Ac Generator
Armature: A rectangular coil ABCD consisting of a large number of turns of copper wire wound over a soft iron core is called armature. The soft iron core is used to increase the magnetic flux.

Field magnet: Two pole pieces of a strong electromagnet.

Slip rings: The ends of the coil ABCD are connected to two hollow metallic rings R_1 and R_2.

OR

Given:

$L = 80mH = 80\times10^{-3}H,$

$R = 0$

$v = 50Hz$

$C = 60\mu F = 60\times10^{-6}F,$

$\omega = 2\pi v = 100\pi ras/s$

$V_{rms} = 230V, V_o = \sqrt{2}V_{rms} = \sqrt{2}\times230V$

(i) $l_o = ?$ and $l_{rms} = ?$

$$l_o = \frac{V_o}{Z} = \frac{V_o}{\left(\omega L - \frac{1}{\omega C}\right)}$$

$$= \frac{230\sqrt{2}}{\left(100\pi \times 8010^{-3} - \frac{1}{100\pi \times 60 \times 10^{-6}}\right)}$$

$$= \frac{230\sqrt{2}}{\left(8\pi - \frac{1000}{6\pi}\right)} = -11.63A$$

$$I_{rms} = \frac{I_o}{\sqrt{2}} = \frac{-11.63}{\sqrt{2}} = -8.23A$$

Hence, emf lags behind the current bu 90^o.

(ii) For L,

$$V_L = I_{rms} \omega L$$

$$= 8.23 \times 100\pi \times 80 \times 10^{-3}$$

$$= 206.84V$$

For C,

$$V_C = I_{rms} \frac{1}{\omega C}$$

$$= 8.23 \times \frac{1}{100\pi \times 60 \times 10^{-6}}$$

$$= 436.84V$$

Since, voltage across L and C are 180^o out of phase, therefore they are subtracted.
Thus, applied rms voltage= 436.84-206.84
=230.0 V

(iii) Average power transferred per cycle by source to inductor is always zero because of phase difference of $\pi / 2$ between voltage and current through L.

(iv) Average power transferred per cycle by the source to capacitor is always zero because of phase difference of $\pi / 2$ between voltage and current through C (power factor, $\cos\phi = 0$).

(v) Hence, total power absorbed by the circuit is also zero.