KENDRIYA VIDYALAYA GACHIBOWLI, GPRA CAMPUS, HYD – 32
SAMPLE PAPER TEST 04 (2020-21)
(SAMPLE ANSWERS)

SUBJECT: PHYSICS | **MAX. MARKS : 70**
CLASS : XII | **DURATION : 3 HRS**

General Instruction:

*(i) All questions are compulsory. There are **33** questions in all.*

(ii) This question paper has five sections: Section A, Section B, Section C, Section D and Section E.

*(iii) **Section A** contains ten very short answer questions and four assertion reasoning MCQs of 1 mark each, **Section B** has two case based questions of 4 marks each, **Section C** contains nine short answer questions of 2 marks each, **Section D** contains five short answer questions of 3 marks each and **Section E** contains three long answer questions of 5 marks each.*

(iv) There is no overall choice. However internal choice is provided. You have to attempt only one of the choices in such questions.

(v) You may use the following values of physical constants wherever necessary :

$c = 3\times10^{8} m/s$, $h = 6.63\times10^{-34} Js$, $e = 1.6\times10^{-19} C$, $\mu_0 = 4\pi\times10^{-7} TmA^{-1}$,

$\varepsilon_0 = 8.854\times10^{-12} C^2N^{-1}m^{-2}$, $m_e = 9.1\times10^{-31} kg$, $\frac{1}{4\pi\varepsilon_0} = 9\times10^{9} Nm^2C^{-2}$,

Mass of neutron $= 1.675\times10^{-27} kg$, Mass of proton $= 1.673\times10^{-27} kg$,

Avogadro's number $= 6.023\times10^{23}$ per gram mole, Boltzmann constant $= 1.38\times10^{-23} JK^{-1}$

SECTION – A
Questions 1 to 14 carry 1 mark each.

1. Which phenomena proves particle nature of light?
Ans: Photoelectric effect

OR

How does the maximum kinetic energy of electrons emitted vary with the work function of the metal?
Ans: The maximum kinetic energy of emitted electrons decreases, as the work function of the metal increases.

2. What happens during death due to electric shock?
Ans: Electric shock causes electrolysis of blood, which takes place even with small currents.

OR

A negligibly small current is passed through a wire of length 15 m and uniform cross-section 6 x 10^{-7} m^2 and its resistance is measured to be 5 Ω. What is the resistivity of the material at the temperature of the experiment?
Ans:

$$R = \rho\frac{l}{A} \Rightarrow \rho = \frac{RA}{l}$$

$$= \frac{5\times6\times10^{-7}}{15} = 2\times10^{-7}\,\Omega\,m$$

3. What will be the change in the phase if the wave undergoes reflection at an interface from rarer to denser medium?

Ans: When a light is reflected from denser to rarer medium there is no phase change in light. When a light is reflected from rarer to denser medium there is a phase change of R. Here air is rarer than glass so there is a phase change of it when light from air to glass undergo reflection.

4. Write the expression for the work done on an electric dipole of dipole moment p in turning it from its position of stable equilibrium to a position of unstable equilibrium in a uniform electric field E.

Ans:

Torque acting on the dipole, $\tau = PE \sin\theta$.

The work done can be calculated as $W = \int_{\theta_1}^{\theta_2} PE \sin\theta \cdot d\theta$

In stable equilibrium, the direction of electric field is parallel to the direction of the dipole moment *i.e.*, $\theta_1 = 0°$.

In unstable equilibrium, the direction of electric field is antiparallel to the direction of the dipole moment *i.e.*, $\theta_2 = 180°$.

$$W = \int_{\theta_1}^{\theta_2} PE \sin\theta \cdot d\theta = \left[-PE\cos\theta\right]_{0°}^{180°} = -PE\,[\cos 180° - \cos 0°]$$

$$= -PE\,[-1-1] = 2\,PE$$

OR

The dimensions of an atom are of the order of an Angstrom. Thus, there must be large electric fields between the protons and electrons. Why, then is the electrostatic field inside a conductor zero?

Ans: Electrostatic fields are caused by excess charges. However, there is no excess charge on the inner surface of an isolated conductor. Therefore, electrostatic field inside a conductor is zero.

5. What will be the potential at a point due to a charge of 4 x 10^{-7} C located 10 cm away is.

Ans:

$Q = 4 \times 10–7$ C, $K = 9 \times 109$, $x = 10\text{cm} = 0.01$ m

P = Potential = xKQ

$$P = 9 \times 10^9 \times 4 \times \frac{10^{-7}}{0.01} \Rightarrow P = 3.6 \times 10^4 \text{ V}$$

6. What is the value of mass and energy equivalent to 1 a.m.u.

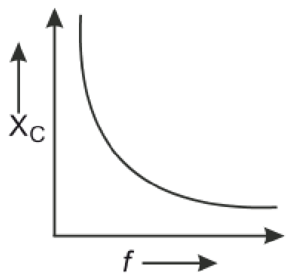
Ans: It is defined as one twelfth of the mass of an unbound neutral atom of carbon-12 in its nuclear and electronic ground state.

Mass of 1 mole C atoms = 12 gms, 1 amu = 12 / ($12 \times 6.023 \times 10^{23}$) = 1.67×10^{-27} kg

Energy equivalent, $E = mc^2 = 1.66{\times}10^{-27}$ kg $\times (3 \times 10^8)^2$ = 930 MeV

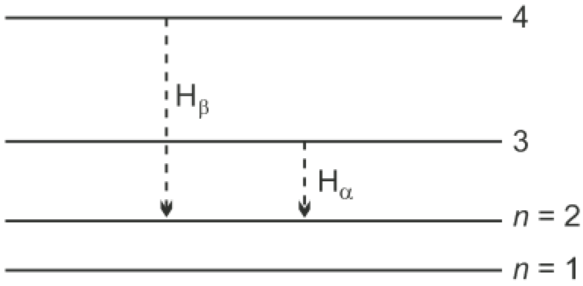
7. Draw the graph representing the variation of reactance 'Xc' of a capacitor with frequency 'f ' of an a.c. supply.

Ans:



8. What is the fundamental particle in an electromagnetic wave?
Ans: Photon

9. When is H_α line of the Balmer series in the emission spectrum of hydrogen atom obtained?
Ans: Balmer series is obtained when an electron jumps to the second orbit ($n_2 = 2$) from any orbit greater than 2 ($n_1 > 2$). In particular H_α is obtained when $n_1 = 3$ i.e., when an electron jumps from orbit $n_1 = 3$ to orbit $n_2 = 2$.



OR

What is the significance of negative sign in the expression, $E = -13.6/n^2$ eV ?
Ans: The negative sign shows that electron is bound with the nucleus. Energy will be required to remove the electron from hydrogen atom.

10. The work function of tungsten is 5.4 eV. Find the wavelength of radiation which can eject photoelectrons of maximum energy 1.5 eV from tungsten.
Ans:

$$\frac{hc}{\lambda} = W + E_{max}$$
$$= 5\cdot4\times1\cdot6\times10^{-19} + 1\cdot5\times1\cdot6\times10^{-19} = 11\cdot04\times10^{-19}\,J$$
$$\therefore \quad \lambda = \frac{hc}{11\cdot04\times10^{-19}} = 1\cdot799\times10^{-7}\,m = 1799\,\text{Å}$$

OR

What happens to the wavelength of a photon after it collides with an electron?
Ans: When a photon collides with an electron, some part of its (photon) energy is transferred to electron and its energy decreases and wavelength increases as

$$E = \frac{hc}{\lambda} \Rightarrow E \propto \frac{1}{\lambda}$$

For question numbers 11, 12, 13 and 14, two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.
(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false and R is also false

11. Assertion: A convex mirror is preferred over a plane mirror in vehicles to observe traffic coming from behind.
Reason: Images formed by convex mirrors are erect and diminished in size.

Ans: (a) A convex mirror produces smaller images which increases the field of view as compared to a plane mirror of the same size. Also in case of convex mirror the image is erect like in plane mirror.

12. Assertion: The size of the mirror does not affect the nature of the image.
Reason: Small mirrors always form a virtual image.
Ans: (c) The size of the mirror does not affect the nature of the image except that a bigger mirror forms a brighter image as it gathers more light rays due to wider aperture.

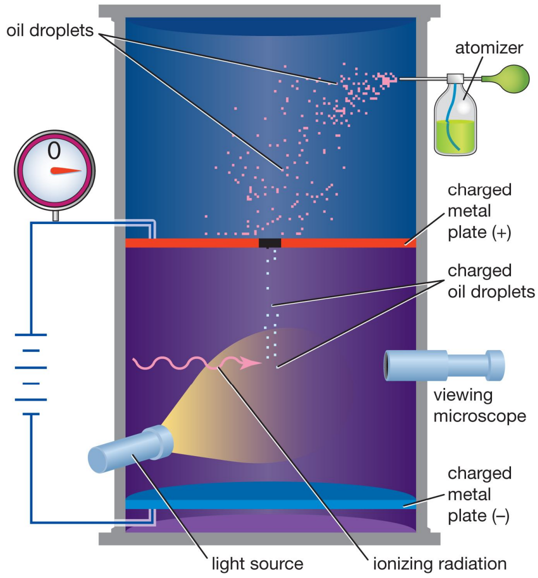
13. Assertion: Hydrogen atom consists of only one electron but its emission spectrum has many lines.
Reason: Only Lyman series is found in the absorption spectrum of hydrogen atom whereas in the emission spectrum, all the series are found.
Ans: (b) Every atom has certain definite energy level. In the normal state, the electron in the hydrogen atom stays in lowest energy level. When the atom gets appropriate energy from outside, then this electron rises to some higher energy level i.e., atom is excited. Within nearly 10-8 s, the electron leaves the higher energy level. Now, it can return either directly to the lowest energy level (or the ground state) or come to the ground state after passing through other lower energy levels. Since there are a large number of atoms in a light source (hydrogen lamp), all possible transitions take place in the source and many lines are seen in the spectrum. The slit gives the shape of the spectrum and large number of lines are obtained because a large number of atoms are getting excited and de-excited to different energy levels.

14. Assertion: Amongst alpha, beta and gamma rays, a-particle has maximum penetrating power.
Reason: The alpha particle is heavier than beta and gamma rays.
Ans: (d) The penetrating power is maximum in case of gamma rays because gamma rays are an electromagnetic radiation of very small wavelength.

SECTION - B

Questions 15 and 16 are Case Study based questions and are compulsory.
Attempt any 4 sub parts from each question. Each question carries 1 mark.

15. The famous oil-drop experiment was conducted by Robert Millikan to measure the charge of an electron. An electric field is set up by means of a horizontal pair of oppositely charge plates kept at a small distance apart. Tiny oil drops are sprayed into this electric field. A fine magnifying eyepiece is used to observe these drops. The electric field can be adjusted so that the upward force on negatively charged oil droplets balances their weight. When no net force acts on the tiny oil particles, $qE = mg$. By his experiment, Millikan could measure that the charge on the oil droplets appear as the integral multiples of certain fundamental value of charge. Magnitude of this fundamental charge was measured to be 1.6×10^{-19} C, the charge of an electron (because, charge arises due to transfer of electrons and the least number of electrons that can be transferred is one and also, only integer values are possible).



(i) If a tiny oil droplet of mass 9.8 x 10^{-15} kg is suspended between the plates when the electric field applied is 105 N/C, the magnitude of charge on the oil droplet is:
(a) 9.6 x 10^{-19} C (b) 6.4 x 10^{-19} C (c) 7.8 x 10^{-19} C (d) 1.08 x 10^{-18} C

(ii) How many electrons are present in excess on the above mentioned droplet?
(a) 4 (b) 6 (c) 8 (d) 5

(iii) If mass of the oil droplet were more, which of the following may not be an option to get the desired result (suspension of oil droplet)?
(a) Charge on the oil droplet is also more (b) Increase the electric field strength
(c) Decrease the electric field strength (d) None of these

(iv) Which of the following cannot be a charge on the oil droplet?
(a) 1.6 x 10^{-19} C (b) 6.4 x 10^{-19} C (c) 7.8 x 10^{-19} C (d) 8.4 x 10^{-19} C

(v) If the electrons were positively charged, what change would you suggest in the experimental set up shown here?
(a) Interchange the polarity of the plates (b) Use a different oil
(c) Make the plates vertical (d) All of these

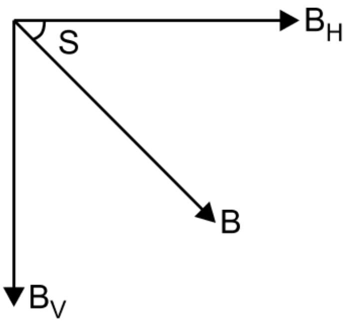
Ans: (i) (a) 9.6 x 10^{-19} C (ii) (b) 6 (iii) (c) Decrease the electric field strength
(iv) (c) 7.8 x 10^{-19} C (v) (a) Interchange the polarity of the plates

16. A suspended magnet gets aligned with the earth's magnetic field at that place. Along the equator, a suspended magnet will align horizontally. The orientation of the magnet depends on the dip angle at that place. Angle of dip is the angle between the net magnetic field of earth and the horizontal. At equator, angle of dip is 0 (zero) and at poles its value is 90°. This means, at equator, the earth's magnetic field is completely horizontal and at poles. The Earth's magnetic field is vertical.

If S is the angle of dip at a place and B is the Earth's magnetic field, then the horizontal component of Earth's magnetic field $B_H = B \cos \delta$ the vertical component $B_V = B \sin \delta$

$\Rightarrow B = \sqrt{B_H{}^2 + B_V{}^2}$

$Also, \tan\delta = \dfrac{B_V}{B_H}$



Based on the above information, answer the following questions.

(i) A magnet stands vertical at a place when suspended that place will be:
(a) At equator (b) At poles (c) At 30° latitude (d) At 60° latitude

(ii) The angle of dip of a face where the magnet gets aligned completely horizontal is:
(a) 0° (b) 90° (c) 30° (d) 45°

(iii) The horizontal and vertical components of the magnetic field at a place are $\frac{\sqrt{3}}{2}$R and B/2 respectively. When a magnet is left free at that place, the angle made by its magnetic axis with the horizontal is:
(a) 45° (b) 30° (c) 60° (d) 15°

(iv) Earth's magnetic field always has a vertical component except at:
(a) Poles (b) Equator (c) 30° latitude (d) 75° latitude

(v) The magnetic field due to earth has a horizontal component of 26μT at a place where the dip is 60°. Vertical component of the field at that point is:
(a) 25 μT (b) 30 μT (c) 45 μT (d) 54 μT

Ans: (i) (b) At poles (ii) (a) 0° (iii) (b) 30° (iv) (b) Equator (v) (c) 45 μT

SECTION – C

Questions 17 to 25 carry 2 marks each.

17. Write the expression for average power of an LCR circuit. What happens to the average power, when phase angle is 0 and π/2?

Ans:

Let, the alternating e.m.f. applied to an LCR circuit, is $E = E_0 \sin\omega t$

When alternating current lags behind the applied e.m.f. by a phase angle ϕ. $I = I_0 \sin(\omega t - \phi)$

Total work done over a complete cycle is given by $W = \frac{E_0 I_0}{2}\cos\phi \times T$

∴ Average power in the LCR or inductive circuit over a complete cycle.

$$P = \frac{W}{T} \Rightarrow P = \frac{E_0 I_0 \cos\phi}{T}\cdot\frac{T}{2} \Rightarrow P = \frac{E_0}{\sqrt{2}}\frac{I_0}{\sqrt{2}}\cos\phi \Rightarrow P = E_v I_v \cos\phi$$

Hence, average power over a complete cycle in an inductive circuit is the product of virtual e.m.f., virtual current and cosine of the phase angle between the voltage and current.

When phase angle is 0, the circuit is resistive. Therefore, $P = E_v I_v$

When phase angle is π/2, the circuit is purely inductive or capacitive. Therefore, P = 0.

OR

How much current is drawn by the primary coil of a transformer connected to 220 V supply, when it delivers power to a 110 V and 550 W refrigerator?

Ans:

Here, $V_p = 220$ V, $V_s = 110$ V, $P_{out} = 550$ W, $I_p = ?$

Now, $P_{out} = V_s I_s$

$$\Rightarrow 550 = 110\, I_s \Rightarrow I_s = \frac{550}{110} = 5\text{ A}$$

Now, $$\frac{I_p}{I_s} = \frac{V_s}{V_p} \Rightarrow I_p = \frac{V_s I_s}{V_p} = \frac{110 \times 5}{220} = 2{\cdot}5\text{ A}$$

18. Find the wavelength of electromagnetic waves of frequency 5 x 10^{19} Hz in free space. Give its two applications.

Ans:

Given : $\nu = 5 \times 1019$ Hz, $c = 3 \times 10^8$ ms^{-1}.

$\therefore$ Wavelength in free space is given by $\lambda = \dfrac{c}{\nu} = \dfrac{3\times10^8}{5\times10^{19}} = 0{\cdot}6 \times 10^{-11}$ m

$= 0{\cdot}06$ Å

The wavelength lies in the Gamma rays region. Gamma rays are used for: (i) Treatment of cancer and tumors. (ii) Certain nuclear reactions.

19. The photoelectric cut-off voltage in a certain photoelectric experiment is 2.5 V. What is the maximum kinetic energy of photoelectrons emitted?

Ans:

Given: Cut-off voltage, $V_o = 2{\cdot}5$ V

Maximum kinetic energy of photoelectrons, $E_k = eV_o = 1{\cdot}6 \times 10^{-19} \times 2{\cdot}5 = 4 \times 10^{-19}$ J.

20. C, Si and Ge have same lattice structure. Why is C insulator while Si and Ge intrinsic semiconductors?

Ans: The 4 bonding electrons of C, Si or Ge lie, respectively, in the second, third and fourth orbit. Hence, energy required to take out an electron from these atoms (i.e., ionisation energy Eg) will be least for Ge, followed by Si and highest for C. Hence, number of free electrons for conduction in Ge and Si are significant but negligibly small for C.

21. A proton and a deuteron having equal moments enter in a region of uniform magnetic field at right angle to the direction of the field. Find the ratio of the radii of curvature of the path of the particle.

Ans:

If a charge particle enters right angle to the direction of magnetic field, it follows a circular trajectory motion and radius can be given as,

$$qvB = \frac{mv^2}{r} \Rightarrow r = \frac{mv}{qB} = \frac{p}{qB} \quad [\because p = mv]$$

Since, momentums are equal and they have equal charges.

So, $r_p : r_d = 1 : 1$

OR

The velocities of two a-particles A and B entering a uniform magnetic field are in the ratio 5 : 1. On entering the field they move in different circular paths. Give the ratio of the radii of curvature of the paths of the particles.

Ans:

Radius of circular path $r = \frac{mv}{qB}$ *i.e.,* $r \propto v$

$$\therefore \quad \frac{r_A}{r_B} = v\frac{\nu_A}{\nu_B} = \frac{5}{1}$$

22. Two point charges of +4 μC and +6 μC repel each other with a force of 12 N. If each is given an additional charge of - 5 μC, what will be the new force?

Ans:

Given: $q_1 = +4\ \mu C$, $q_2 = +6\ \mu C$, F = 12 N.

$q'_1 = +4 - 5 = -1\ \mu C$, $q'_2 = +6 - 5 = 1\ \mu C$, $F' = ?$

$$\frac{F'}{F} = \frac{(q_1')(q_2')}{q_1q_2} = \frac{(-1)(1)}{(4)(6)} = \frac{-1}{24} \Rightarrow F' = \frac{-F}{24} = \frac{-12}{24} = \frac{-1}{2} = -0{\cdot}5\text{ N} \qquad \text{(Attractive)}$$

23. Two wires A and B are formed from the same material with same mass. Diameter of wire A is half of diameter of wire B. If the resistance of wire A is 36 Ω, find resistance of wire B.

Ans:

Volume of A = Volume of B

[∵ Mass is same and made of same material]

$$\Rightarrow \pi\left(\frac{D_A}{2}\right)^2 lA = \pi\left(\frac{D_B}{2}\right)^2 lB$$

$$\Rightarrow \frac{l_A}{l_B} = \frac{D_B^2}{D_A^2} = 4 \left[\because D_A = \frac{1}{2}D_B\right]$$

Now, Resistance, $R = \frac{\rho l}{A} = \frac{\rho l}{\pi\left(\frac{D^2}{4}\right)} \Rightarrow R \propto \frac{l}{D^2}$

$$\Rightarrow \frac{R_B}{R_A} = \frac{l_B}{l_A} \times \frac{D_A^2}{D_B^2} = \frac{1}{4} \times \frac{1}{4} = \frac{1}{16} \Rightarrow RB = \frac{R_A}{16} = \frac{36}{16} = 2{\cdot}25\ \Omega$$

24. Define one coulomb, what is SI-CGS unit of charge? Give dimensional formula of Coulomb as well.

Ans:

One coulomb is the charge transferred in one second across a section of wire carrying current of one ampere.

As $i = \frac{dq}{dt} \Rightarrow \int dq = \int i\,dt \Rightarrow q = it$

When $i = IA \Rightarrow t = IS$

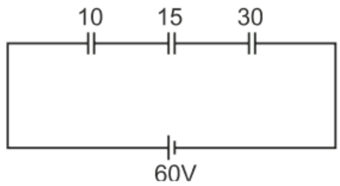
Then $q = IC$

Coulomb is SI unit of charge. In CGS, charge is measured in terms of stat coulomb (esu). 1 coulomb = 3 × 10^9 stat coulomb. Dimensional formula for coulomb is [AT].

25. Three capacitors of 10 μF, 15 μF and 30 μF are connected in series to a voltage source of 60 V. Calculate the charge, potential difference and energy stored in each capacitor.

Ans:

Let the equivalent capacitance of the series combination be C. Then,



$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} = \frac{1}{10} + \frac{1}{15} + \frac{1}{30} = \frac{3+2+1}{30} = \frac{6}{30}$$

$$\Rightarrow \quad C = 5\,\mu F$$

Charge stored on the combination, $q = C \times V = 5 \times 60 = 300\,\mu C$

Since the capacitors are in series, the charge on each capacitor is $300\,\mu C$.

The potential difference across the capacitors, $V_1 = \frac{q}{C_1} = \frac{300}{10} = 30\text{ V}$

$$V_2 = \frac{q}{C_2} = \frac{300}{15} = 20\text{ V}$$

$$V_3 = \frac{q}{C_3} = \frac{300}{30} = 10\text{ V}$$

Energy of the capacitors are, $U_1 = \frac{1}{2}qV_1 = \frac{1}{2} \times 300 \times 30 = 4500\,\mu J$

$$U_2 = \frac{1}{2}qV_2 = \frac{1}{2} \times 300 \times 20 = 3000\,\mu J$$

$$U_3 = \frac{1}{2}qV_3 = \frac{1}{2} \times 300 \times 10 = 1500\,\mu J$$

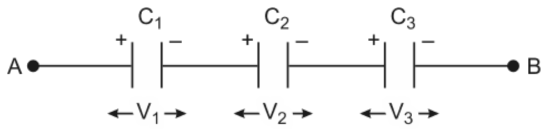
OR

Derive equivalent capacitances for (i) Combination of capacitors in Series. (ii) Combination of capacitors in Parallel.

Ans:

(i) When capacitors are connected in series, the voltage drop across them will be as follows:

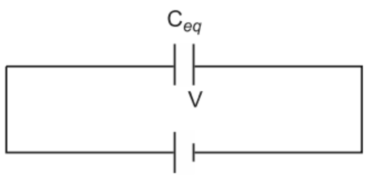
$$V = V_1 + V_2 + V_3 = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$$



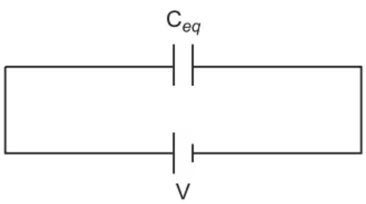
As same charge will flow in series connections.

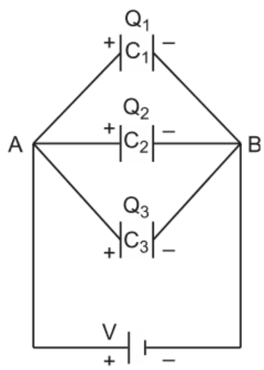
$$\frac{1}{C_{eq}} = Q\left[\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right]$$

$$\frac{1}{C_{eq}} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3} \text{ Farad.}$$



(ii) In parallel configuration, voltage across capacitors are same but total charge gets distributed among all parallel capacitors.





$$\therefore \quad Q = Q_1 + Q_2 + Q_3 = C_1V + C_2V + C_3V$$

$$C_{eq}V = V(C_1 + C_2 + C_3)$$

$$C_{eq} = (C_1 + C_2 + C_3) \text{ Farad.}$$

SECTION – D

Questions 26 to 30 carry 3 marks each.

26. Name the constituent radiation of electromagnetic spectrum which:
(i) is used in satellite communication.
(ii) is used for studying crystal structure.
(iii) is similar to radiation emitted during decay of radioactive nuclei.
(iv) has its wavelength range 390 tun to 770 nm.
(v) is absorbed from sunlight by ozone layer.
(vi) produces intense heating effect.

Ans:

(i) Microwaves	**(ii)** X-rays	**(iii)** Gamma rays
(iv) Visible light	**(v)** Ultraviolet radiation	**(vi)** Infrared rays

OR

The magnetic field in a plane electromagnetic wave is given by
$B_y = (2 \times 10^{-7}\ T) \sin(0.5 \times 10^3 x + 1.5 \times 10^{11} t)$
(i) What is the wavelength and frequency of the wave?
(ii) Write an expression for the electric field.
Ans:

(i) Comparing the given equation with the standard equation of electromagnetic wave,

$$B = B_0 \sin(kx + \omega t)$$

We have, $k = \dfrac{2\pi}{\lambda} = 0{\cdot}5 \times 10^3$

$$\therefore\ \lambda = \frac{2\pi}{0\cdot5\times10^3}\ \text{m} = 1{\cdot}26\ \text{cm}$$

$$\omega = 2\pi\nu = 1{\cdot}5 \times 10^{11} \Rightarrow \nu = \frac{1\cdot5\times10^{11}}{2\pi}\ \text{Hz} = 2{\cdot}38 \times 10^{10}\ \text{Hz}$$

(ii) Given, $B_0 = 2 \times 10^{-7}$ T

$$\therefore\ E_0 = B_0 c = 2 \times 10^{-7} \times 3 \times 10^8 = 60\ \text{NC}^{-1}$$

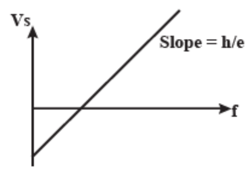
The electric field is perpendicular to both, the magnetic field and the direction of propagation of wave.
Thus, $E_z = (60\ \text{NC}^{-1}) \sin(0{\cdot}5 \times 10^3 x + 1{\cdot}5 \times 10^{11} t)$

27. Plot a labelled graph of stopping potential of photoelectrons (V_s) versus frequency (v) of incident radiation. How will you use this graph to determine the value of Planck's constant? Explain.
Ans:

The graph for V_s and ν is as follows:

Determination of Planck's constant: As from the graph it is clear that slope of the graph is given by

$$\text{Slope} = \frac{h}{e}$$



where, h = Planck's constant

e = Charge on an electron

Now, from Einstein's photoelectric equation

$$K_{max.} = h\nu - \phi \qquad \text{[Multiple sign]}$$

$$\Rightarrow\ eV_0 = h\nu - \phi$$

$$\Rightarrow\ V_0 = \left(\frac{h}{e}\right)\nu - \frac{\phi}{e}$$

Comparing this equation with $y = mx + c$.

Slope of (V_0, ν) graph $= \frac{h}{e}$.

So, Planck's constant h = Slope (V_0, ν) graph.

28. A galvanometer with a coil of resistance 12.0 Ω shows full scale deflection for a current of 2.5 mA. How will you convert the galvanometer into: (i) an ammeter of range 0 to 7.5 A, (ii) a voltmeter of range 0 to 10.0 V?

Ans:

(i) Given: $R_g = 12\ \Omega$, $I_g = 2{\cdot}5$ mA $= 2{\cdot}5 \times 10^{-3}$ A, $I = 7{\cdot}5$ A

Value of shunt resistance, $Rs = \frac{I_g}{I - I_g} \cdot R_g = \frac{2\cdot5\times10^{-3}}{7\cdot5-(2\cdot5\times10^{-3})} \times 12 = 4{\cdot}0 \times 10^{-3}\ \Omega$

Thus, by connecting a resistance of 4 mΩ in parallel with galvanometer it can be converted into an ammeter of range 0 to 7·5 A.

(ii) Given: V = 10 V

∴ Value of resistance to be put in series can be calculated as,

$$R = \frac{V}{I_g} - R_g = \frac{10}{2\cdot5\times10^{-3}} - 12 = 3988\ \Omega$$

Therefore, by connecting a resistance of 3988 Ω in series with the galvanometer, it can be converted into a voltmeter of range of 0 to 10 V.

29. The core of a transformer is made of a material whose hysteresis loop is narrow. Why?

Ans: A transformer works on a.c. supply. Therefore, during its operation, the iron core of the transformer is taken over the complete cycle of magnetisation and demagnetisation again and again. In taking the core over a complete cycle of magnetisation, the energy spent per unit volume of the core is equal to area of the hysteresis loop. Therefore, to minimise the loss of energy, the core of the transformer is made of a material, whose hysteresis loop is narrow.

OR

In a series LCR circuit with an a.c. source of effective voltage 50 V, frequency v = -50/π Hz, R = 300 Ω, C = 20 μF and L =1.0 H. Find the r.m.s. current in the circuit. It

Ans:

Given, $L = 1{\cdot}0$ H, $C = 20\ \mu F = 20 \times 10^{-6}$ F, $R = 300\ \Omega$, $V_{rms} = 50$ V, $\nu = \frac{50}{\pi}$ Hz

Inductive reactance, $X_L = \omega L = 2\pi\nu L$

$$= 2 \times \pi \times \frac{50}{\pi} \times 1 = 100\ \Omega$$

Capacitive reactance, $XC = \frac{1}{\omega C} = \frac{1}{2\pi\nu C} = \frac{1}{2\times\pi\times\frac{50}{\pi}\times20\times10^{-6}} = 500\ \Omega$

Impedance of circuit, $Z = \sqrt{R^2 + (X_C - X_L)^2} = \sqrt{(300)^2 + (500-100)^2}$

$$= \sqrt{90000 + 160000} = \sqrt{250000} = 500\ \Omega$$

$$I_{rms} = \frac{V_{rms}}{Z} = \frac{50}{500} = 0{\cdot}1\ A$$

30. What is the effect on the interference pattern observed in a Young's double slit experiment in the following cases when:

(i) separation between the slits is decreased.

(ii) screen is moved away from the plane of slits.

(iii) width of the slits are doubled.

Ans:

Fringe width is given by, $\beta = \frac{D\lambda}{d}$

Where, D is distance of screen from the slit, d is width of slit, λ is wavelength of light.

(i) As the separation between the slits d decrease, the fringe width increases and intensity of light decreases.

(ii) In this case, as D increases fringe width increases and intensity of light decreases.

(iii) When width of the slits are doubled the fringe width would be halved and the intensity of light is doubled. Hence, the resultant intensity of maxima is given by

$$I_{max} = I1 + I2 + 2\sqrt{I_1 I_2} = 2I + 2I + 2\sqrt{2I \times 2I} = 4I + 4I = 8I$$

Hence, the intensity at maxima is increased.

SECTION – E

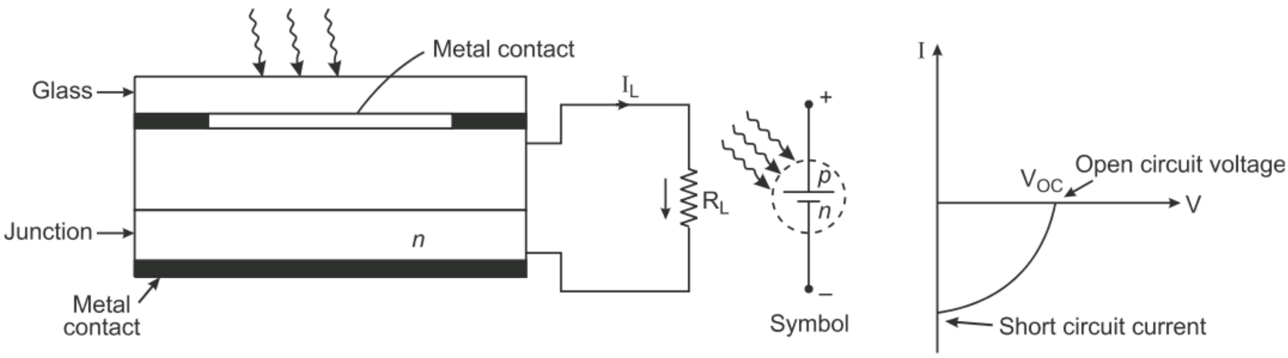
Questions 31 to 33 carry 5 marks each.

31. Explain solar cell in brief. Give some uses of solar cells.

Ans: A solar cell is a junction diode which converts light energy into electrical energy. It is based on photovoltaic effect. The surface layer of p-region is made very thin so that the incident photons may easily penetrate to reach the junction which is the active region. In an operation in the photovoltaic mode (i.e., generation of voltage due to bombardment of optical photons); the materials suitable for photocells are silicon (Si), gallium arsenide (GaAs), cadmium sulphide (CdS) and cadmium selenide (CdSe).

Working:

When photons of energy greater than energy band gap of (hv > Eg) are made to incident on the junction, electron-hole pairs are created which moves in opposite directions due to junction field. These are collected at two sides of junction, thus producing photovoltage giving rise to photocurrent. The characteristic curve of solar cell is shown above.

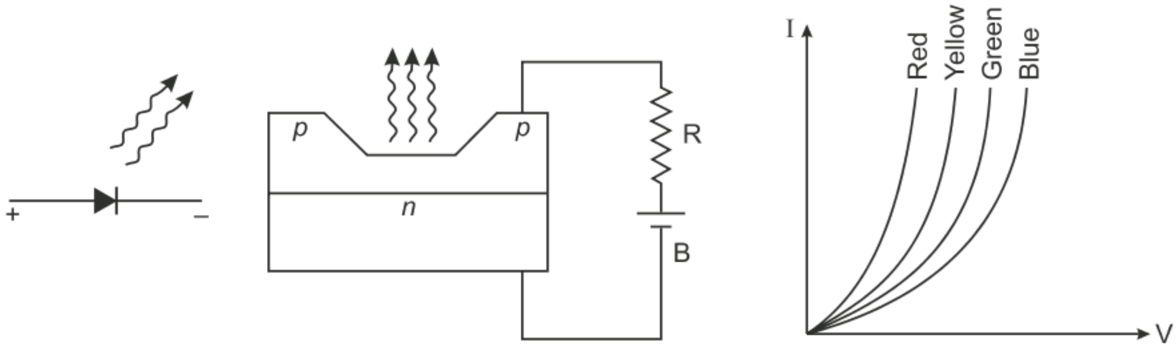


Uses of solar cells: (i) Solar cells are used for charging storage batteries in day time, which can supply the power during night times. (ii) The solar cells are also used in artificial satellite to operate the various electrical instruments kept inside the satellite. (iii) They are used for generating electrical energy for cooking food and pumping water. (iv) Solar cells are used in calculators, wrist watches and light meters (in photography). (v) Solar cells are used to produce electric power in remote areas, where electric power supply is not available. (vi) Solar cells are used in traffic signals. (vii) Solar cells are used in remote radiotelephones.

OR

What do you mean by light emitting diode. Explain its working in detail.

Ans: Light Emitting Diode: Light emitting diode is a photoelectronic device which converts electrical energy into light energy, under forward bias condition. It is a heavily doped p-n junction diode which under forward bias emits spontaneous radiation. The diode is covered with a transparent cover so that the emitted light may come out. Symbolically LED is shown in fig. (i). The construction and circuit used for working with LED is shown in fig. (ii). In an LED, the upper layer of p-type semiconductor is deposited by diffusion on n-type layer of semiconductor. The metallised contacts are provided for applying the forward bias voltage to the p-n junction diode from battery B through a resistance R which controls the brightness of light emitted.



(i) (ii) (iii)

Working of LED: When a p-n junction is forward biased, the size of depletion layer decreases. The movement of majority carrier takes places across the junction. The electrons move from n-side to p-side through the junction and holes move from p-side to n-side through the junction. As a result of it, the concentration of the minority carriers increases rapidly on the two sides of the junction boundary. These excess minority carriers on carriers side of the junction boundary recombine with majority carriers there. In each recombination of electron and hole the electron will fall from higher energy state to ground state. As a result of it, a photon is released whose energy is nearly equal to the energy gap Eg. If A, is the wavelength of photon emitted, then

$$E_g = \frac{hc}{\lambda} \text{ or } \lambda = \frac{hc}{E_g}$$

For a p-n junction of Ge and Si, the larger percentage of this energy released is mainly transferred into thermal energy of the vibrating lattice. As a result of it, no light is emitted. However, some other p-n junction semiconductor diodes made of materials like gallium arsenide (GaAs), gallium phosphide (GaP) and gallium-arsenide phosphide (GaAsP) a greater percentage of energy released is in the form of visible light. Due to it, the junction becomes a light source, i.e., a light emitting diode (LED). The colour of light emitting diode depends upon the type of material used in making the semiconductor diodes as given below:

(i) Gallium-arsenide (GaAs) - infrared radiation.

(ii) Gallium-phosphide (GaP) - red or green light.

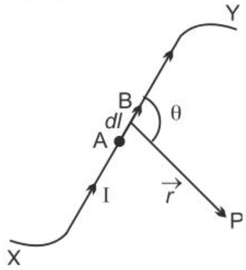
(iii) Gallium-arsenide-phosphide (GaAsP) - red or yellow light.

LEDs emit no light when reverse-biased. Rather, the LEDs will be destroyed when reverse biased. As the forward current increases, intensity of light also increases and reaches a maximum value. Beyond this stage if forward current is further increased, the intensity of light starts decreasing. During working LEDs are forward biased such that the light emitting efficiency is maximum. V-I characteristics of LED is similar to that of junction diode. For LEDs, the threshold voltages are much higher and slightly different for different colours, fig. (iii).

32. State Biot-Savart's law, giving the mathematical expression for it. Use this law to derive the expression for the magnetic field due to a circular coil carrying current at a point along its axis. How does a circular loop carrying current behave as a magnet?

Ans:

It states that the magnetic field strength (dB) produced due to a current element (carrying current I and length dl) at a point having position vector $\vec{r}$ relative to current element is,



$$d\vec{B} = \frac{\mu_0}{4\pi} \times \frac{I\vec{dl} \sin \vec{r}}{r^3}$$

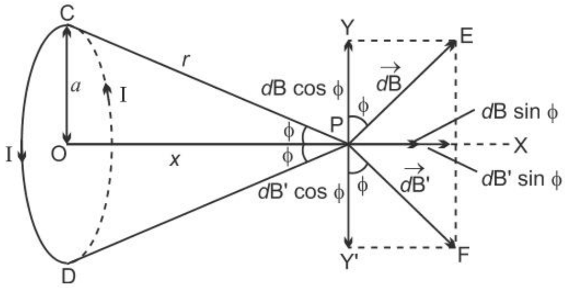
Where, μ_0 is permeability of free space. Its value is $\mu_0 = 4\pi \times 10^{-7}$ Wb A^{-1} m^{-1}.

or $$dB = \frac{\mu_0}{4\pi} \times \frac{Idl \sin \theta}{r^2}$$

Where, θ is the angle between current element $I\vec{dl}$ and position vector $\vec{r}$ as shown in the figure. The direction of magnetic field $d\vec{B}$ is perpendicular to the plane containing $I\vec{dl}$ and $\vec{r}$.

Magnetic field on the axis of circular current loop:

Consider a circular loop of radius a carrying current I, with its plane perpendicular to the plane of paper. Let P be a point of observation on the axis of this circular loop at a distance x from its centre O. Consider a small element of length dl of the coil at point C. The magnitude of the magnetic induction $d\vec{B}$ at point P due to this element is given by



$$d\vec{B} = \frac{\mu_0}{4\pi} \times \frac{I\vec{dl} \times \vec{r}}{r^3}$$

or $$dB = \frac{\mu_0}{4\pi} \times \frac{Idl \times \sin \phi}{r^2}$$

The direction of $d\vec{B}$ is perpendicular to the plane containing $\vec{dl}$ and $\vec{r}$ and is given by right hand screw rule. As the angle between $I\vec{dl}$ and $\vec{r}$ is 90°, the magnitude of the magnetic induction $d\vec{B}$ is given by

$$dB = \frac{\mu_0}{4\pi} \times \frac{Idl}{(a^2 + x^2)} \qquad [\because\ r^2 = a^2 + x^2]$$

Since the components of the magnetic field induction along PY′ and PY are equal and opposite and cancel each other. The components in X-direction are added up.

∴ Total magnetic field induction,

$$B = \int d B \sin \phi = \int \frac{\mu_0 I\, dl \sin \phi}{4\pi (a^2 + x^2)} = \frac{\mu_0 I}{4\pi(a^2 + x^2)} \sin \phi \int dl$$

$$\sin \phi = \frac{a}{\sqrt{a^2 + x^2}} \text{ and } \int dl = 2\pi a$$

$$B = \frac{\mu_0 I\, a}{4\pi(a^2 + x^2)\sqrt{a^2 + x^2}} 2\pi a = \frac{\mu_0}{4\pi} \frac{2\pi a^2 I}{(a^2 + x^2)^{3/2}} \text{ along PX}$$

Special cases:

(i) When point P lies at the centre of the circular coil, then $x = 0$

∴ $$B = \frac{\mu_0 I}{4\pi} \frac{2\pi I}{a}$$

(ii) When point P lies far away from the centre of coil, then $x >> a$. As $x >> a$, then a^2 can be neglected in comparison to x^2.

∴ $$B = \frac{\mu_0}{4\pi} \frac{2\pi I a^2}{x^3}$$

In a current loop, both the opposite faces behave as opposite poles, making it a magnetic dipole.

OR

(i) An electron is projected with a velocity of 105 ms^{-1} at right angles to a magnetic field of 0.019G. Calculate the radius of the circular path described by electron. [Given e =1.6 x 10^{-19} C, m = 9.1 x 10^{-31} kg].
(ii) Calculate the force per unit length on a long straight wire carrying current of 4 A due to a parallel wire carrying current of 6 A. The distance between the wires is 3 cm.
Ans:

(i) Given: $v = 105\ \text{ms}^{-1}$, $B = 0{\cdot}019\ \text{G} = 0{\cdot}019 \times 10^{-4}\ \text{T}$

Now, $evB = \dfrac{mv^2}{r}$

$$\therefore \quad r = \frac{mv}{Be} = \frac{9\cdot1\times10^{-31}\times10^{5}}{0\cdot019\times10^{-4}\times1\cdot6\times10^{-19}} = \frac{9\cdot1\times10^{-26}}{0\cdot019\times1\cdot6\times10^{-23}} = 299{\cdot}34\times10^{-3} = 0{\cdot}299\ \text{m}$$

(ii) Given: $I_1 = 4$ A, $I_2 = 6$ A, $r = 3$ cm $= 0{\cdot}03$ m

Now, force per unit length is $F = \dfrac{\mu_0}{4\pi}\dfrac{2I_1I_2}{r} = 10^{-7}\times\dfrac{2\times4\times6}{0\cdot03} = 1{\cdot}6\times10^{-4}\ \text{Nm}^{-1}$.

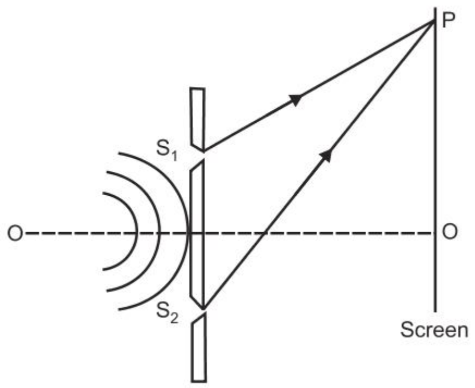
33. (i) "Two independent monochromatic sources of light cannot produce a sustained interference pattern". Give reason.
(ii) Light wave each of amplitude 'a' and frequency 'ω', emanating from two coherent light sources superpose at a point. If the displacements due to these waves is given by $y_1 = a\cos\omega t$ and $y_2 = a\cos(\omega t + \phi)$ where ϕ is the phase difference between the two, obtain the expression for the resultant intensity at the point.
Ans: (i) The condition for the sustained interference is that both the sources must be coherent (i.e., they must have the same wavelength and the same frequency, and they must have the same phase or constant phase difference). Two sources are monochromatic if they have the same frequency and wavelength. Since they are independent, i.e., they have different phases with irregular difference, they are not coherent sources.
(ii) Let the displacement of the waves form the sources Si and S2 at point P on the screen at any time t be given by:

$$y_1 = a\cos\omega t \quad \text{and} \quad y_2 = a\cos(\omega t + \phi)$$

Where, ϕ is the constant phase difference between the two waves.

By the superposition principle, the resultant displacement at point P is given by:

$$y = y_1 + y_2$$
$$y = a\cos\omega t + a\cos(\omega t + f)$$
$$y = 2a\left[\cos\left(\frac{\omega t + \omega t + \phi}{2}\right)\cos\left(\frac{\omega t - \omega t - \phi}{2}\right)\right]$$
$$y = 2a\cos\left(\omega t + \frac{\phi}{2}\right)\cos\left(\frac{\phi}{2}\right) \quad \text{...(i)}$$



Let $\quad 2a\cos(\phi/2) = A \quad$ ...(ii)

Then, equation (i) becomes

$$y = A\cos(\omega t + \phi/2)$$

Now, we have $A^2 = 4a^2\cos^2\dfrac{\phi}{2}$ ...(iii)

The intensity of light is directly proportional to the square of the amplitude of the wave. The intensity of light at point on the screen is given by

$$I = 4a^2\cos^2\frac{\phi}{2}$$

OR

Derive Snell's law of refraction using Huygens' principle.

Ans: Laws of refraction: Consider a plane wavefront AB incident on a surface PQ separating two media (1) and (2). The medium (1) is rarer, having refractive index n1, in which the light travels with a velocity ci. The medium (2) is denser, having refractive index n2, in which the light travels with a velocity c2. At time t = 0, the incident wavefront AB touches the boundary separating two medium at A. The secondary wavelets from point B advance forward with a velocity c1, and after time t seconds touches at D, thus covering a distance BD = c1t. In the same time interval oft seconds, the secondary wavelets from A, advance forward in the second medium, and travels with a speed of c2. With the point A as the centre and a distance AC = c2t, an envelope is drawn to obtain a new refracted wave front as CD.

Consider triangles BAD and ACD,

$$\sin i = \sin(\angle BAD) = \frac{BD}{AD} = \frac{c_1 t}{AD}$$

$$\sin r = \sin(\angle ADC) = \frac{AC}{AD} = \frac{c_2 t}{AD}$$

$$\Rightarrow \frac{\sin i}{\sin r} = \frac{c_1 t}{c_2 t} = \frac{c_1}{c_2} \quad \Rightarrow \frac{\sin i}{\sin r} = \frac{c_1}{c_2} = \text{constant}$$

This constant is called the refractive index of the second medium with respect to the first medium.

$$\frac{c_1}{c_2} = \frac{n_2}{n_1} = {}_1n_2$$

$$\therefore \quad \frac{\sin i}{\sin r} = \frac{c_1}{c_2} = \frac{n_2}{n_1} = {}_1n_2$$

This is known as the snell's law.