Class XII Session 2026-27
Subject - Physics
Sample Question Paper - 7

Time Allowed: 3 hours **Maximum Marks: 70**

General Instructions:

1. There are 33 questions in all. All questions are compulsory.
2. This question paper has five sections: Section A, Section B, Section C, Section D and Section E.
3. All the sections are compulsory.
4. **Section A** contains sixteen questions, twelve MCQ and four Assertion Reasoning based of 1 mark each, **Section B** contains five questions of two marks each, **Section C** contains seven questions of three marks each, **Section D** contains two case study based questions of four marks each and **Section E** contains three long answer questions of five marks each.
5. There is no overall choice. However, an internal choice has been provided in one question in Section B, one question in Section C, one question in each CBQ in Section D and all three questions in Section E. You have to attempt only one of the choices in such questions.
6. Use of calculators is not allowed.

Section A

1. In n-type semiconductor majority carriers and minority carriers are respectively **[1]**

   a) electrons and holes
   b) germanium and silicon
   c) holes and electrons
   d) aluminum and boron

2. A battery of emf E and internal resistance r is connected to an external circuit. The potential drop within the battery is proportional to: **[1]**

   a) power dissipated in the circuit
   b) total resistance of the circuit
   c) emf of the battery
   d) current in the circuit

3. The focal length of a concave mirror in air is f. When the mirror is immersed in a liquid of refractive index $\frac{5}{3}$, its focal length will become **[1]**

   a) $\frac{3}{5}f$
   b) $\frac{2}{3}f$
   c) $\frac{5}{3}f$
   d) f

4. A piece of a diamagnetic material, free to move when placed in a uniform magnetic field: **[1]**

   a) moves opposite to the field
   b) does not move at all
   c) moves along the field
   d) moves perpendicular to the field

5. When two charged conductors are connected by a wire, **[1]**

a) there will not be any change in energy

b) there is loss or gain of energy depending upon the potentials

c) there is always gain of energy

d) there is always loss of energy

6. An electron is shot into a liquid placed in a uniform magnetic field, in a plane perpendicular to magnetic field, then **[1]**

a) the kinetic energy of electron remains same

b) the trajectory of electron is circular

c) trajectory is an inward winding spiral

d) its revolution frequency decreases

7. The emf induced in a coil rotating in a magnetic field does **not** depend upon the following: **[1]**

a) Angular speed of rotation of the coil

b) Area of the coil

c) Number of turns in the coil

d) Resistance of the coil

8. A bar magnet is initially at right angles to a uniform magnetic field. The magnet is rotated till the torque acting on it becomes one-half of its initial value. The angle through which the bar magnet is rotated is: **[1]**

a) 75°

b) 60°

c) 45°

d) 30°

9. Wavefront generated from a line source is **[1]**

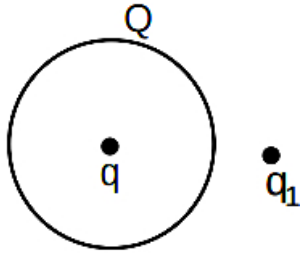
a) either cylindrical wavefront or spherical wavefront

b) cylindrical wavefront

c) spherical wavefront

d) plane wavefront

10. A thin, metallic spherical shell contains a charge Q on it. A point charge q is placed at the centre of the shell and another charge q_1 is placed outside it a shown in figure. All the three charges are positive. The force on the charge at the centre is: **[1]**



a) Towards left

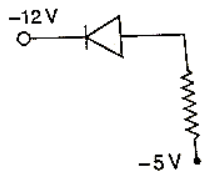
b) Towards right

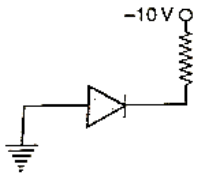
c) zero

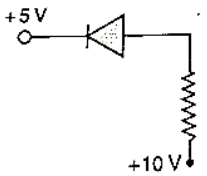
d) Upward

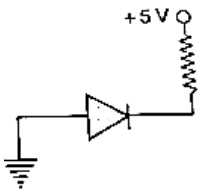
11. In the following figures, which one of the diodes is reverse biased? **[1]**

a)

b) 

b) 

c) 

d) 

12. Reflecting telescope utilizes **[1]**

a) Prism

b) Convex mirror

c) Both Convex mirror and Concave mirror

d) Concave mirror

13. **Assertion (A):** The de Broglie equation has significance for any microscopic or sub-microscopic particle. **[1]**

Reason (R): The de Broglie wavelength is inversely proportional to the mass of the object if velocity is constant.

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 but R is true.

14. **Assertion:** The value of electric potential and electric intensity at the middle point of the line joining an electron and a proton is zero. **[1]**

Reason: Electric potential is scalar and electric intensity is vector quantity.

a) Assertion and reason both are correct statements and reason is correct explanation for assertion.

b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.

c) Assertion is correct statement but reason is wrong statement.

d) Assertion is wrong statement but reason is correct statement.

15. **Assertion (A):** The phase difference between any two points on a wavefront is zero. **[1]**

Reason (R): Corresponding to a beam of parallel rays of light, the wavefronts are planes parallel to one another.

a) Both A and R are true and R is the

b) Both A and R are true but R is not

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 but R is true.

16. **Assertion (A):** It is advantageous to transmit electric power at high voltage. **[1]**
Reason (R): High voltage implies high current.

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 but R is true.

Section B

17. Light with an energy flux of 18 W/cm^2 falls on a non-reflecting surface at normal incidence. If the surface has an area of 20 cm^2, find the average force exerted on the surface during a 30-minute time span. **[2]**

18. A semiconductor is known to have an electron concentration of 8×10^{13} per cm^3 and a hole concentration of 5×10^{12} per cm^3, **[2]**

i. Is the semiconductor n-type or p-type?

ii. What is the resistivity of the sample if the electron mobility is 23,000 cm^2 / Vs and hole mobility is 100 cm^2/ Vs?

19. Suppose you are given a chance to repeat the alpha particle scattering experiment using a thin sheet of solid hydrogen in place of the gold foil. (Hydrogen is a solid at temperatures below 14 K). What results do you expect? **[2]**

20. Two magnets of magnetic moment M and $M\sqrt{3}$ are joined to form a cross. The combination is suspended in a uniform magnetic field B. The magnetic moment now makes an angle θ with the field direction. Find the value of the angle θ. **[2]**

OR

A short bar magnet of magnetic moment 0.9 JT^{-1} is placed with its axis at 30° to a uniform magnetic field. It experiences a torque of 0.063 J.

i. Calculate the magnitude of the magnetic field.

ii. In which orientation will the bar magnet be in stable equilibrium in the magnetic field?

21. a. It is not advisable to use a galvanometer as such to measure current directly. Why? **[2]**

b. Why should the value of resistance connected in parallel to a galvanometer be low?

c. Is the reading shown by an ammeter in a circuit less than or more than the actual value of current flowing in the circuit? Why?

OR

A charged particle of mass'm', charge 'q' moving at uniform velocity 'v', enters a uniform magnetic field 'B' acting normal to the plane of the paper. Deduce expression for the (t) radius of the circular path in which it travels, (ii) kinetic energy of the particle (assuming v << c).

Section C

22. a. Define Electrical conductivity. Obtain the expression of electrical conductivity of a **[3]**

conductor in terms of number density and relaxation time of free electrons.

b. Explain qualitative change in resistivity of a conductor with temperature using expression obtained in (a).

23. Red light, however bright it is, cannot produce the emission of electrons from a clean zinc surface. But even weak ultraviolet radiation can do so. Why? **[3]**

Electrons are emitted from the cathode of negligible work function, when photons of wavelength λ are incident on it. Derive the expression for the de Broglie wavelength of the electrons emitted in terms of the wavelength of the incident light.

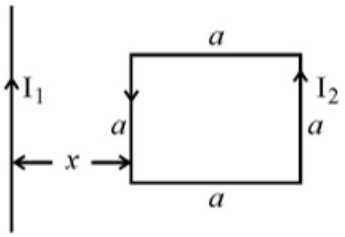
24. Define mobility of a charge carrier. Why is the mobility of an electron in the conduction band of a semiconductor is less than the mobility of a hole (or electron) in the valence band? **[3]**

25. The deuteron is bound by nuclear forces just as H-atom is made up of p and e bound by electrostatic forces. If we consider the force between neutron and proton in deuteron as given in the form of a Coulomb potential but with an effective charge e' $F = \frac{1}{4\pi\varepsilon_0}\frac{e'^2}{r}$ estimate the value of (e'/e) given that the binding energy of a deuteron is 2.2 MeV. **[3]**

26. Using Rydberg formula, calculate the wavelengths of the first four spectral lines in the Balmer series of hydrogen atom spectrum. **[3]**

27. a. Define mutual inductance and write its S.I. unit. **[3]**

b. A square loop of side **a** carrying a current I_2 is kept at distance x from an infinitely long straight wire carrying a current I_1 as shown in the figure. Obtain the expression for the resultant force acting on the loop.



OR

Derive the expression for the magnetic energy stored in a solenoid in terms of magnetic field B, area A and length l of the solenoid carrying a steady current I. How does this magnetic energy per unit volume compare with the electrostatic energy density stored in a parallel plate capacitor?

28. a. The interference pattern is not observed in Young's double slit experiment when the two sources S_1 and S_2 are far apart. Explain. **[3]**

b. Mention the conditions for the two sources to be coherent.

c. What is the effect on the interference pattern in a Young's double slit experiment, if the source of wavelength λ is replaced by another source of wavelength 1.5 λ, with the interference pattern still observable?

Section D

29. **Read the text carefully and answer the questions:** **[4]**

All the known radiations from a big family of electromagnetic waves which stretch over a large range of wavelengths. Electromagnetic wave include radio waves, microwaves, visible light waves, infrared rays, UV rays, X-rays and gamma rays. The orderly distribution of the electromagnetic waves in accordance with their wavelength or frequency into distinct groups having widely differing properties is electromagnetic spectrum.

(a) Which wavelength of the Sun is used finally as electric energy?
radio waves, infrared waves, visible light, microwaves

a) infrared waves b) radio waves

c) microwaves d) visible light

(b) Which of the following electromagnetic radiations have the longest wavelength?
X-rays, γ-rays, microwaves, radiowaves

a) γ-rays b) X-rays

c) microwaves d) radiowaves

(c) Which one of the following is not electromagnetic in nature?
X-rays, gamma rays, cathode rays, infrared rays

a) infrared rays b) gamma rays

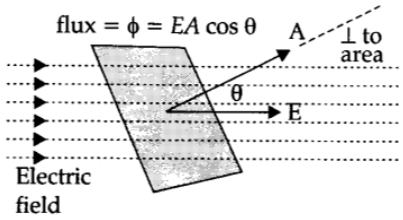
c) cathode rays d) X-rays

(d) Which of the following has minimum wavelength?
X-rays, ultraviolet rays, γ-rays, cosmic rays

a) ultraviolet rays b) X-rays

c) cosmic rays d) γ-rays

30. The total number of electric field lines passing a given area in a unit time is defined as the electric flux. **[4]**



If the plane is normal to the flow of the electric field, the total flux is given as:
ϕ = EA
When the same plane is tilted at an angle θ, the projected area is given as A cos θ and the total flux through this surface is given as:
ϕ = EA cos θ
where, E is the magnitude of the electric field. A is the area of the surface through which the electric flux is to be calculated.

i. If a unit positive charge is kept in the air, then what is the total flux coming out of unit charge? (1)

ii. What is the value of electric flux (φ) on a plane of area 1 m^2 on which an electric field of 2 V/m crosses with an angle of 30°. (2)

iii. When is the flux through a surface taken as positive? (1)

Section E

31. i. Draw a ray diagram for the formation of the image of a point object by a thin double convex lens having radii of curvatures R_1 and R_2 and hence, derive lens maker's formula. **[5]**

ii. Define power of a lens and give its SI unit. If a convex lens of length 50 cm is placed in contact coaxially with a concave lens of focal length 20 cm, what is the power of the combination?

OR

i. State Huygen's principle. With the help of a diagram, show how a plane wave is reflected from a surface. Hence verify the law of reflection.

ii. A concave mirror of focal length 12 cm forms a three times magnified virtual image of an object. Find the distance of the object from the mirror.

32. Derive an expression for the electric potential at a point due to an electric dipole. Mention the contrasting features of electric potential of a dipole at a point as compared to that due to a single charge. **[5]**

OR

Derive an expression for equivalent capacitance of three capacitors when connected

i. in series and

ii. in parallel.

33. i. With the help of a labelled diagram, describe the principle and working of an ac generator. Hence, obtain an expression for the instantaneous value of the emf generated. **[5]**

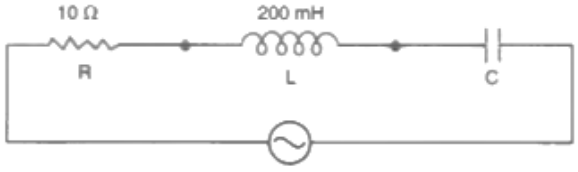
ii. The coil of an ac generator consists of 100 turns of wire, each of area 0.5 m^2. The resistance of the wire is 100 Ω. The coil is rotating in a magnetic field of 0.8 T perpendicular to its axis of rotation, at a constant angular speed of 60 radian per second. Calculate the maximum emf generated and power dissipated in the coil.

OR

In the following circuit, calculate:

i. the capacitance of the capacitor, if the power factor of the circuit is unity,

ii. the Q-factor of this circuit. What is the significance of the Q-factor in ac circuit? Given the angular frequency of the ac source to be 100 rad/s. Calculate the average power dissipated in the circuit.



Solution

Section A

1. **(a)** electrons and holes
   Explanation:
   N-type semiconductors have a larger electron concentration than hole concentration. The term n-type comes from the negative charge of the electron.
   In n-type semiconductors, electrons are the majority carriers and holes are the minority carriers.
   N-type semiconductors are created by doping an intrinsic semiconductor with donor impurities (or doping a p-type semiconductor as done in the making of CMOS chips). A common dopant for n-type silicon is phosphorus.

2. **(d)** current in the circuit
   Explanation:
   current in the circuit

3. **(d)** f
   Explanation:
   f

4. **(b)** does not move at all
   Explanation:
   does not move at all

5. **(d)** there is always loss of energy
   Explanation:
   Let the two conductors have capacitances C_1 and C_2 and let their potentials be V_1 and V_2.
   Total initial energy of the conductors $U_i = \frac{1}{2}C_1V_1^2 + \frac{1}{2}C_2V_2^2$.
   When two charged conductors are connected by a wire, the flow of charge stops when the potentials are equalized.
   Let V be the common potential and Q_1 and Q_2 be the charges on the conductors after the common potential is attained.
   $V = \frac{\text{Total charge}}{\text{Total capacitance}} = \frac{Q_1+Q_2}{C_1+C_2} = \frac{C_1V_1+C_2V_2}{C_1+C_2}$
   The final energy
   $U_f = \frac{1}{2}(C_1 + C_2)\,V^2 = \frac{1}{2}(C_1 + C_2)\left(\frac{C_1V_1+C_2V_2}{C_1+C_2}\right)^2 = \frac{1}{2}\frac{(C_1V_1+C_2V_2)^2}{C_1+C_2}$
   $U_f - U_i = \frac{1}{2}\left[\frac{(C_1V_1+C_2V_2)^2}{C_1+C_2} - \left(C_1V_1^2 + C_2V_2^2\right)\right] = -\frac{1}{2}\frac{C_1C_2(V_1-V_2)^2}{C_1+C_2}$

6. **(c)** trajectory is an inward winding spiral
   Explanation:

When the electron is shot into a magnetic field it describes a circular path due to magnetic Lorentz force. $Bev = \frac{mv^2}{r}; v = \frac{Ber}{m}; v \propto r$
When the electron passes into a liquid, its velocity reduces progressively due to the frictional forces experienced in the liquid. As the velocity decreases, the radius also decreases and the path of the electron deviates from being circular and becomes an inward spiral, The kinetic energy of the electron also decreases. The revolution frequency $\nu = \frac{Be}{2\pi m}$ remains constant as it is independent of the velocity of the particle.

7.

(d) Resistance of the coil
Explanation:
The emf induced in a coil rotating in a magnetic field does not depend on Resistance of the coil. The induced emf is influenced by the area of the coil, the number of turns, and the angular speed of rotation.

8.

(b) 60°
Explanation:
60°

9.

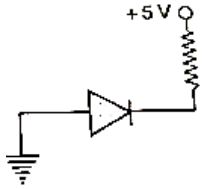
(b) cylindrical wavefront
Explanation:
cylindrical wavefront

10.

(c) zero
Explanation:
The force on the charge at the center of the spherical shell is zero because of the properties of electrostatics. According to Gauss's law, the electric field inside a conductor in electrostatic equilibrium is zero. Since the charge at the center induces a charge distribution on the inner surface of the shell, the shell's outer surface will have a charge that balances the inner charge. As a result, the electric field at the center due to the shell and the induced charges cancels out, leading to no net force acting on the central charge.

11.

(d)



Explanation:
The p-n junction is said to be reverse biased, when the positive terminal of the external battery in the circuit is connected to n-section and the negative terminal to p-section of the junction diode.

12.

(d) Concave mirror
Explanation:
Concave mirror

13. **(a)** Both A and R are true and R is the correct explanation of A.
Explanation:
$\lambda = \frac{h}{mv}$
For constant v, $\lambda \propto \frac{1}{m}$
λ is significantly measurable only in case of microscopic or sub-microscopic particles.

14. **(d)** Assertion is wrong statement but reason is correct statement.
Explanation:
Electric potential V is a scalar quantity, therefore, the electrical potential at the middle point will be the algebraic sum of potentials due to electron and proton, i.e.
V = $\frac{K\Sigma q}{r}$ = 0, as Σq = -q + q = 0
But if a unit positive charge held at the center will be repelled by a proton and attracted by an electron with the same force, the net force on unit positive charge will not be zero. Therefore, electric field intensity E cannot be zero at the middle point.

15. **(b)** Both A and R are true but R is not the correct explanation of A.
Explanation:
Both A and R are true but R is not the correct explanation of A.

16. **(c)** A is true but R is false.
Explanation:
As P = VI, so for the transmission of same power, high voltage implies low current. At high voltages, heat losses ($H = I^2Rt$) are substantially reduced.

Section B

17. t = 30 minute = 30×60 = 1800 sec = 0.18×10^4 sec.
The total energy falling on the surface is
U = (18 W/cm^2) $\times$ (20 cm^2) $\times$ (30 $\times$ 60 s)
= 6.48×10^5 J
Therefore, the total momentum delivered (for complete absorption) is
$p = \frac{U}{c} = \frac{6.48 \times 10^5 \text{J}}{3 \times 10^8 \text{m/s}}$ = 2.16×10^{-3} kg m/s
The average force exerted on the surface is
$F = \frac{p}{t} = \frac{2.16 \times 10^{-3}}{0.18 \times 10^4}$ = 1.2×10^{-6} N

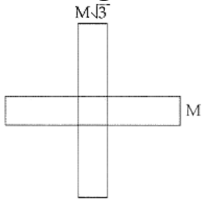
18. Here $n_e = 8 \times 10^{13}$ cm^{-3}, n_h = 5 x 10^{12} cm^3, μ_e = 23,000 cm^2 V^{-1} s^{-1}, μ_h = 100 cm^2 V^{-1} s^{-1}

i. As $n_e > n_h$, the semiconductor must be n-type.

ii. Resistivity,
$\rho = \frac{1}{e(n_e\mu_e + n_h\mu_h)}$
$= \frac{1}{1.6 \times 10^{-19}\left(8 \times 10^{13} \times 23 \times 10^3 + 5 \times 10^{12} \times 10^2\right)} \Omega$ cm
$= \frac{1}{1.6 \times 10^{-19}\left(184 \times 10^{16} + 5 \times 10^{14}\right)} \Omega$ cm
$= \frac{1}{1.6 \times 10^{-5} \times 18405} \Omega$ cm = 3.395 Ω cm

19. The nucleus of a hydrogen atom is a proton (mass $1.67 \times 10^{-27} kg$) which has only about one-fourth of the mass of an alpha particle $\left(6.64 \times 10^{-27} kg\right)$. Because the alpha particle is more massive, it won't bounce back in even a head on collision with a proton. It is like a bowling ball

colliding with a ping pong ball at rest. Thus, there would be no large angle scattering in this case. In Rutherford's experiment, by contrast, there was large angle scattering because a gold nucleus is more massive than an alpha particle. The analogy there is a ping pong ball hitting a bowling ball at rest.

20. 

In equilibrium condition, torque on both magnets are equal and opposite. Hence,

MB sin θ = $\sqrt{3}$ M sin (90° - θ)

MB sin θ = $\sqrt{3}$ M cos θ ,by rearranging the equation we get,

$\frac{\sin\theta}{\cos\theta} = \frac{\sqrt{3}M}{M}$

tan θ = $\sqrt{3}$ or θ = 60°

OR

i. Magnetic moment M = 0.9 J/T

τ = 0.063 J, $\theta = 30^o$

We know $\tau = M \times B$

= MB sin θ

$0.063 = 0.9 \times B \times \sin 30^o$

B = $\frac{2\times0.063}{0.9}$ = 0.14 T

ii. Stable equilibrium is position of minimum energy. Since $U = -\vec{M}\cdot\vec{B}$

U = - MB cos θ

Where U is the energy stored or P.E. of the magnet inside magnetic field B.

So, when θ = 0, U = -MB is the minimum energy.

Thus, when $\vec{M}$ and $\vec{B}$ are parallel to each other bar magnet is in stable equilibrium.

21. a. It will not measure accurate value of current because its high resistance will affect the current in the circuit.

b. To reduce the galvanometer resistance a small resistance is connected in parallel.

c. It is less than the actual value of current because it has some resistance which consume some energy and hence the reading shown by an ammeter in a circuit less than the actual value of current flowing in the circuit.

OR

i. Force exerted by the magnetic field

= Centripetal force on the charge

or $qvB\sin 90^\circ = \frac{mv^2}{r}$

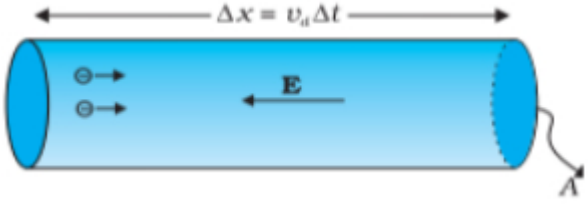
$\therefore$ Radius $r = \frac{mv}{qB}$

ii. Velocity,$v = \frac{qBr}{m}$

$\therefore \text{K. E.} = \frac{1}{2}mv^2 = \frac{1}{2}m\left(\frac{qBr}{m}\right)^2 = \frac{B^2q^2r^2}{2m}$

Section C

22. a. **Electrical conductivity:-** It is the reciprocal of the resistivity.



$I\Delta t = +neA\left|\vec{v}_d\right|\Delta t$

Substituting $\left|\vec{v}_d\right| = \frac{e|\vec{E}|}{m}\tau$

$I\Delta t = \frac{e^2\ A}{m}\tau\ n\ \Delta t|\vec{E}|$

$I = |\vec{j}|A$

$\Rightarrow |\vec{j}| = \frac{ne^2}{m}\tau|\vec{E}|\ \ldots(1)$

$\vec{j} = \sigma\vec{E}\ \ldots(2)$

Comparing eq. (1) & (2):-

$\sigma = \frac{ne^2}{m}\tau$

b. On increasing the temperature, the value of τ decreases as a consequence conductivity decreases and hence resistivity increases.

23. The frequency of ultraviolet radiations is more while that of red light is less than the threshold frequency for a zinc surface, so ultraviolet radiations can cause the emission of electrons and red light cannot.

From Einstein's photoelectric equation, K.E. of a photoelectron is

$\frac{1}{2}mv^2 = h\nu - W_0 = h\nu - 0 = \frac{hc}{\lambda}$

or $v = \sqrt{\frac{2hc}{m\lambda}}$

de Broglie wavelength of electrons,

$\lambda_e = \frac{h}{mv}$

$= \frac{h}{m}\sqrt{\frac{m\lambda}{2hc}} = \sqrt{\frac{h\lambda}{2mc}}$

24. **Electrical mobility:** The drift velocity acquired by a charge carrier in a unit electric field is called its electrical mobility and is denoted by μ. In a semiconductor,

Drift velocity of a charge carrier α Applied electric field

$\mu = \frac{v}{E}$

Hence, the electrical mobility μ is the drift velocity per unit electric field.

The mobility of an electron in the conduction band of a semiconductor is greater than the mobility of a hole in the valence band. The electrons in the conduction band are almost free. They get easily accelerated by an electric field. But the electrons in the valence band are bound between the atoms of a semiconductor. They are less accelerated by an electric field and so acquire drift velocity smaller than that of electrons in the conduction band. The mobility of electrons in the valence band is less than the mobility of electrons in the conduction band. As the motion of an electron in the valence band is equivalent to the motion of a hole in the opposite direction, hence the mobility of a hole in the valence band is smaller than the mobility of an electron in the conduction band.

25. The binding energy of H atom in ground state

$E = \frac{me^4}{8\pi\varepsilon_0^2h^2} = 13.6eV$ ...(i)

If proton and neutron had charge e' each and governed by the same electrostatic force, then in the above equation we would need to replace electronic mass m by the reduced mass m' of proton-neutron (as some mass of proton and neutron is used by binding energy) and electronic charge e is replaced by e'

$\frac{1}{m'} = \frac{1}{M} + \frac{1}{N}$ (M = mass of proton, mass of neutron)

$m' = \frac{MN}{M+N}$ (take M = N)

= $\frac{M}{2}$ (If m = mass of proton)

m' = $\frac{1836m}{2}$ = 918 m

$\therefore$ Binding energy $(E) = \frac{918me^{t^4}}{8\pi\varepsilon_0^2 h^2}$ ....(ii)

Dividing (ii) by (i) we get,

$\frac{E'}{E} = \frac{918e'4}{e^4} = \frac{2.2MeV}{13.6eV}$

$\left(\frac{e'}{e}\right)^4 = \frac{2.2\times10^6 eV}{918\times13.6eV}$

$\frac{e'}{e} = \frac{2200000}{1248.48} = (176.21)^{14}$

Required ratio $\frac{e'}{e} = 3.64.$

26. The Rydberg formula is $E = E_0 Z^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

$\frac{hc}{\lambda} = E_0 Z^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

E_0 = -13.6 eV = $-13.6 \times 1.6 \times 10^{-19} J = -21.76 \times 10^{-19} J$

$\frac{hc}{\lambda_{n_{12}}} = 21.76 \times 10^{-19} \left[\frac{1}{2^2} - \frac{1}{n_1^2}\right]$

$\therefore \lambda_{n_{12}} = \frac{hc}{21.76\times10^{-19}\times\left(\frac{1}{4} - \frac{1}{n_1^2}\right)}$

$\lambda_{n_{12}} = \frac{6.63\times10^{-34}\times3\times10^8\times4n_1^2}{21.76\times10^{-19}\times(n_1^2-4)}$

$\lambda_{n_{12}} = \frac{3.653n_1^2}{(n_1^2-4)} \times 10^{-7} m = \frac{3653n_1^2}{(n_1^2-4)} \overset{o}{A}$

The wavelengths of the first four lines in the Balmer series correspond to transitions from n_1 = 3, 4, 5, 6, to n_2 = 2.

Substituting n_1 = 3, 4, 5, and 6, we get

$\lambda_{32} = 6575\overset{o}{A}$, $\lambda_{42} = 4870\overset{o}{A}$

$\lambda_{52} = 4348\overset{o}{A}$ and $\lambda_{62} = 4109\overset{o}{A}$

27. a. **<u>Mutual inductance</u>**: It is the property of the coils that enables it to oppose the changes in the current in another coil. Its S.I unit is Henry (H).

b. Force on the part of the loop which is parallel to infinite straight wire and at a distance x from it.

$F_1 = \frac{\mu_0}{2\pi}\frac{I_1 I_2 a}{x}$ (away from the infinite straight wire)

Force on the part of the loop which is at a distance (x + a) from it

$F_2 = \frac{\mu_0}{2\pi}\frac{I_1 I_2 a}{(x+a)}$ (towards the infinite straight wire)

Net force $F = F_1 - F_2$

$F = \frac{\mu_0 I_1 I_2 a}{2\pi}\left[\frac{1}{x} - \frac{1}{x+a}\right]$

$F = \frac{\mu_0}{2\pi}\frac{I_1 I_2 a^2}{x(x+a)}$

OR

Rate of work done,

$\frac{dW}{dt} = |\varepsilon| i$

$dW = \left(LI\frac{dI}{dt}\right) dt$

dW = LI dI

Total amount of work done,

$\int dW = \int LI dI$

$W = \frac{1}{2} LI^2$

For the solenoid:

Inductance, L = $\mu_0 n^2 AE$; B = $\mu_0 nI$

$\therefore$ W = $U_B = \frac{1}{2}LI^2$

$= \frac{1}{2}\left(\mu_0 n^2 Al\right)\left(\frac{B}{\mu_0 n}\right)^2$

$= \frac{B^2 Al}{2\mu_0}$

Magnetic energy per unit volume

Electrostatic Energy Stored Per Unit Volume stored in parallel plate capacitor = $\frac{1}{2}\varepsilon_0 E^2$

28. a. fringe width $\beta = \frac{D\lambda}{d}$

so as d increases β decrease so fringes will not be resolved and observable. (they do not appear separate)

b. Conditions:-

- Two sources produce waves of same frequency.
- Two sources produce waves of constant phase difference.

c. $\beta = \frac{D\lambda}{d}$

so if λ changes by 1.5λ

β, fringe width increases, so more brighter will be the fringes.

Section D

29. **Read the text carefully and answer the questions:**

All the known radiations from a big family of electromagnetic waves which stretch over a large range of wavelengths. Electromagnetic wave include radio waves, microwaves, visible light waves, infrared rays, UV rays, X-rays and gamma rays. The orderly distribution of the electromagnetic waves in accordance with their wavelength or frequency into distinct groups having widely differing properties is electromagnetic spectrum.

(a) **(a)** infrared waves

Explanation:

Infrared rays can be converted into electric energy as in solar cell.

(b) **(d)** radiowaves

Explanation:

Radiowaves have longest wavelength.

(c) **(c)** cathode rays

Explanation:

Cathode rays are invisible fast moving streams of electrons emitted by the cathode of a discharge tube which is maintained at a pressure of about 0.01 mm of mercury.

(d) **(d)** γ-rays

Explanation:

γ-rays have minimum wavelength.

30. i. The total flux corning out is ε_0^{-1}.

ii. ϕ = EA cos θ

= (2)(1)(cos 90° - 30°)

= (2)(1) (cos 60°)

= (2)(1)($\frac{1}{2}$)

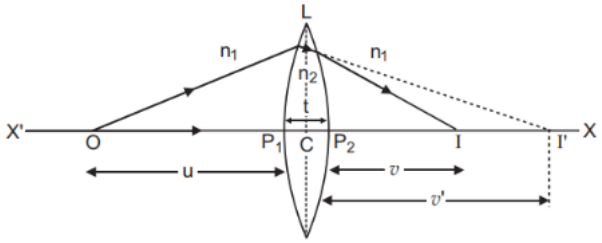
= 1 Vm

iii. It will be positive when the flux lines are directed outwards.

Section E

31. i. Consider the figure. Suppose L is a thin lens. The thickness of lens is t, which is very small. O is a point object on the principal axis of the lens. The distance of O from pole P_1 is u. The first

refracting surface forms the image of O at I' at a distance v' from P_1.



From the refraction formula at spherical surface:

$\frac{n_2}{v'} - \frac{n_1}{u} = \frac{n_2 - n_1}{R_1}$ ....(i)

The image I' acts as a virtual object for second surface and after refraction at second surface, the final image is formed at I. The distance of I from pole P_2 of second surface is v. The distance of virtual object (I') from pole P_2 is (v' - t).

For refraction at second surface, the ray is going from second medium (refractive index n_2) to first medium (refractive index n_1), therefore from refraction formula at spherical surface

$\frac{n_1}{v} - \frac{n_2}{(v'-t)} = \frac{n_1 - n_2}{R_2}$ .....(ii)

For a thin lens, t is negligible as compared to v', therefore from (ii),

$\frac{n_1}{v} - \frac{n_2}{(v')} = -\frac{n_2 - n_1}{R_2}$ .....(iii)

Adding equations (i) and (iii), we get

$\frac{n_1}{v} - \frac{n_1}{u} = (n_2 - n_1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

or $\frac{1}{v} - \frac{1}{u} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ .....(iv)

If the object O is at infinity, the image will be formed at second focus i.e. if $u = \infty$, $v = f_2 = f$

Therefore from equation (iv)

$\frac{1}{f} - \frac{1}{\infty} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

i.e. $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ ....(v)

This is the formula of refraction for a thin lens. This formula is called Lens-Maker's Formula.

ii. **Power of a Lens:** The power of a lens is its ability to deviate the rays towards its principal axis. It is defined as the reciprocal of focal length in metres.

Power of a lens, $P = \frac{1}{f(\text{ in metres })}$ diopters $= \frac{100}{f(\text{ in cm})}$ diopters

The SI unit for power of a lens is dioptre (D).

Power of convex lens, $P_1 = \frac{1}{F_1} D = \frac{1}{0{\cdot}50} = 2$ D

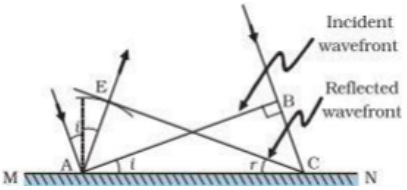
Power of concave lens, $P_2 = \frac{1}{F_2} D = \frac{1}{-0{\cdot}20} = -5$ D

$\therefore$ Power of combination of lenses in contact

$P = P_1 + P_2 = 2 - 5 = -3$ D

OR

i. **Huygen's principle** Each point of the wavefront is the source of a secondary disturbance and the wavelets emanating from these points spread out in all directions with the speed of the wave. These wavelets emanating from the wavefront are usually referred to as secondary wavelets, a common tangent to all these spheres gives the new position of the wavefront at a later time.



Verification of law of reflection

In $\triangle$AEC & $\triangle$CBA

EC = AB (c x t each)

$\angle$AEC = $\angle$CBA (90° each)

AC = AC (common side)

By RHS congruency $\triangle AEC \cong \Delta CBA$

$\Rightarrow \angle i = \angle r$

Hence the law of reflection is verified.

ii. m = +3, f = -12 cm, u = ?

m = $-\frac{v}{u} = 3 \Rightarrow$ v = -3u

using mirror formula

$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

$\frac{1}{-3u} + \frac{1}{u} = \frac{1}{-12}$

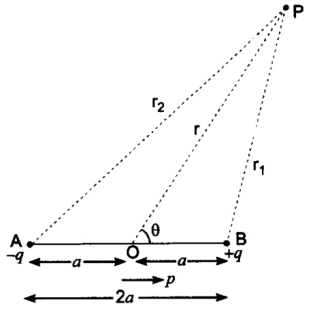
u = -8 cm

Hence the distance of the object from the mirror is 8 cm

32. Consider an electric dipole having charges -q and +q at separation '2a'. The dipole moment of dipole is $\vec{p} = q(\overrightarrow{2\ a})$, directed from -q to +q.

The electric potential due to dipole is the algebraic sum of potentials due to charges +q to -q

If r_1 and r_2 are distances of any point P from charge +q to -q respectively as shown in the figure, then the potential due to electric dipole at point P, is



$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r_1} - \frac{1}{4\pi\varepsilon_0}\frac{q}{r_2} = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$ ...(i)

If (r, θ) are polar coordinates of point P with respect to mid-point O of dipole, then

By geometry,

$r_1^2 = r^2 + a^2 - 2ar\cos\theta$ ...(ii)

and, $r_2^2 = r^2 + a^2 - 2ar\cos\theta$ ...(iii)

From (ii), $r_1^2 = r^2\left[1 - \frac{2a\cos\theta}{r} + \frac{a^2}{r^2}\right]$

If r >> a i e.,$\frac{a}{r}$ <<1, then it is sufficient to retain terms only upto first order in $\left(\frac{a}{r}\right)$.

$\therefore r_1^2 = r^2\left[1 - \frac{2a\cos\theta}{r}\right] \Rightarrow r_1 = r\left[1 - \frac{2a\cos\theta}{r}\right]^{\frac{1}{2}}$ ...(iv)

Similarly from (iii), ${r_2}^2 = r^2\left[1 + \frac{2a\cos\theta}{r}\right] \Rightarrow r_2 = r\left[1 + \frac{2a\cos\theta}{r}\right]^{\frac{1}{2}}$ ...(v)

From (iv) and (v), $\frac{1}{r_1} = \frac{1}{r}\left[1 - \frac{2a\cos\theta}{r}\right]^{\frac{-1}{2}}$ and, $\frac{1}{r_2} = \frac{1}{r}\left[1 + \frac{2a\cos\theta}{r}\right]^{\frac{-1}{2}}$

Using binomial theorem and retaining terms upto first order in $\left(\frac{a}{r}\right)$ only, we have

$\frac{1}{r_1} = \frac{1}{r}\left[1 - \left(-\frac{1}{2}\right)\frac{2a\cos\theta}{r}\right] = \frac{1}{r}\left[1 + \frac{a}{r}\cos\theta\right]$ ...(vi)

and, $\frac{1}{r_2} = \frac{1}{r}\left[1 - \frac{a}{r}\cos\theta\right]$ ...(vii)

Substituting these values in (i), we get

$V = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r}\left(1 + \frac{a}{r}\cos\theta\right) - \frac{1}{r}\left(1 - \frac{a}{r}\cos\theta\right)\right]$

$= \frac{1}{4\pi\varepsilon_0}\frac{q}{r}\left[1 + \frac{a}{r}\cos\theta - 1 + \frac{a}{r}\cos\theta\right]$

$= \frac{1}{4\pi\varepsilon_0}\frac{q}{r}\left[\frac{2a}{r}\cos\theta\right] = \frac{1}{4\pi\varepsilon_0}\frac{(q\cdot 2a)\cos\theta}{r^2}$

or, $V = \frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{r^2}$ ...(viii)

But, $p\cos\theta = \vec{p}\cdot\hat{r}$ where, $\hat{r}$ is unit vector along position vector $\vec{OP} = \vec{r}$.

Electric potential due to an electric dipole is

$V = \frac{1}{4\pi\epsilon_0}\frac{\vec{p}\cdot\hat{r}}{r^2}$ (for r >> a) $= \frac{1}{4\pi\epsilon_0}\frac{\vec{p}\cdot\vec{r}}{r^3}$ ...(ix)

Contrasting features: The electric potential due to a dipole depends on distance r and also on the angle between position vector $\vec{r}$ and dipole moment $\vec{p}$. The electrostatic potential at large distances falls off, as $\frac{1}{r^2}$ and not as $\frac{1}{r}$ which is the characteristic of potential due to a single charge.

Special Cases:

i. When point P lies on the axis of dipole, then $\theta = 0^o$

$\therefore \cos\theta = \cos 0 = 1$

$\therefore V = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^2}$

ii. When point P lies on the equatorial plane of the dipole, then

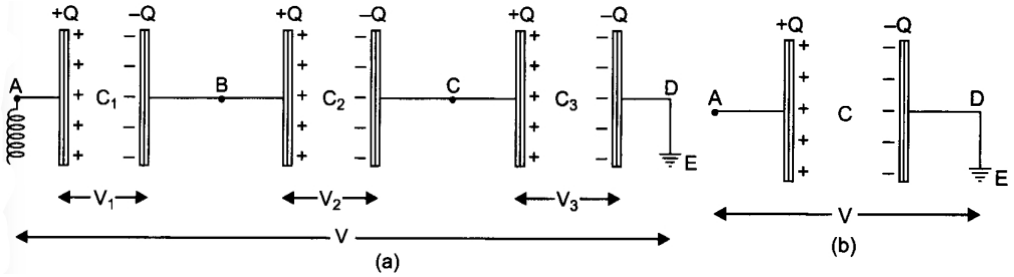
$\therefore \cos\theta = \cos 90^o = 0$

$\therefore V = 0$

It may be noted that the electric potential at any point on the equitorial line of a dipole is zero.

OR

i. In fig. (a) three capacitors of capacitances C_1, C_2, C_3 are connected in series between points A and D.



In series first plate of each capacitor has charge +Q and second plate of each capacitor has charge -Q i.e., charge on each capacitor is Q.

Let the potential differences across the capacitors C_1, C_2, C_3 be V_1, V_2, V_3 respectively. As the second plate of first capacitor C_1 and first plate of second capacitor C_2 are connected together, their potentials are equal. Let this common potential be V_B. Similarly the common potential of second plate of C_2 and first plate of C_3 is V_C. The second plate of capacitor C_3 is connected to earth, therefore its potential $V_D = 0$. As charge flows from higher potential to lower potential, therefore $V_A > V_B > V_C > V_D$.

For the first capacitor, $V_1 = V_A - V_B = \frac{Q}{C_1}$ ...(i)

For the second capacitor, $V_2 = V_B - V_C = \frac{Q}{C_2}$ ...(ii)

For the third capacitor, $V_3 = V_C - V_D = \frac{Q}{C_3}$ ...(iii)

Adding (i), (ii) and (iii), we get

$V_1 + V_2 + V_3 = V_A - V_D = Q\left[\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right]$ ...(iv)

If V be the potential difference between A and D, then

$V_A - V_D = V$

$\therefore$ From (iv), we get

$V = (V_1 + V_2 + V_3) = Q\left[\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right]$ ...(v)

If in place of all the three capacitors, only one capacitor is placed between A and D such that on giving it charge Q, the potential difference between its plates become V, then it will be called **equivalent capacitor**. If its capacitance is C, then

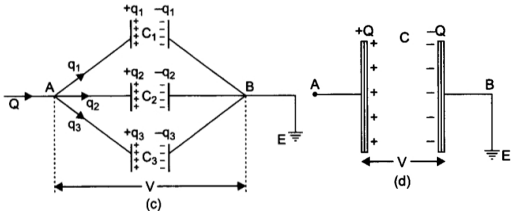
$V = \frac{Q}{C}$ ...(vi)

Comparing (v) and (vi), we get

$\frac{Q}{C} = Q\left[\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right]$ or $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$ ...(vii)

Thus in series arrangement, "The reciprocal of equivalent capacitance is equal to the sum of the reciprocals of the individual capacitors."

ii. **Parallel Arrangement:** In fig. (c) three capacitors of capacitance C_1, C_2, C_3 are connected in parallel.



In parallel the potential difference across each capacitor is same V (say). Clearly the potential difference between plates of each capacitor

$V_A - V_B = V$ (say)

The charge Q given to capacitors is divided on capacitors C_1, C_2, C_3.

Let q_1, q_2, q_3 be the charges on capacitors C_1, C_2, C_3 respectively.

Then $Q = q_1 + q_2 + q_3$ ...(I)

and $q_1 = C_1V, q_2 = C_2V, q_3 = C_3V$

Substituting these values in (i), we get

$Q = C_1V + C_2V + C_3V$ or $Q = (C_1 + C_2 + C_3)V$ ...(ii)

If, in place of all the three capacitors, only one capacitor of capacitance C be connected between A and B; such that on giving it charge Q the potential difference between its plates be V, then it will be called equivalent capacitor. If C be the capacitance of equivalent capacitor, then

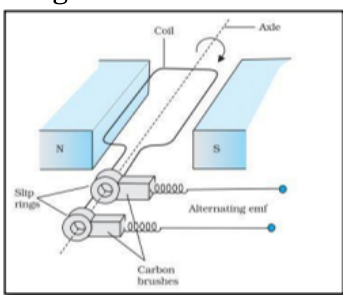
$Q = CV$ ...(iii)

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

$CV = (C_1 + C_2 + C_3)V$ or $C = (C_1 + C_2 + C_3)$

Important Note: It may be noted carefully that the formula for the total capacitance in series and parallel combination of capacitors is the reverse of corresponding formula for combination of resistors in current electricity.

33. i. Diagram



Principle - It is based on the principle of electromagnetic induction. Whenever there is a change in magnetic flux linked with a coil , an emf is induced in the coil.

Working - When a rectangular coil is rotated in a magnetic field, the magnetic flux changes continuously which induces an emf and the direction of current changes periodically.

$\varepsilon = \frac{-Nd\phi}{dt}$

$= -NBA\frac{d}{dt}(\cos\omega t)$

$\varepsilon = NBA\omega\sin\omega t$

ii. $\varepsilon = NBA\omega$

= 100 × 0.8 × 0.5 × 60

= 2400 V

hence, the maximum emf generated will be 2400 V.

Power dissipated, P = $\frac{\varepsilon_{rms}^2}{R}$

$= \frac{\left(\frac{2400}{\sqrt{2}}\right)^2}{100}$

= 28.8 kW

OR

i. Calculation of Capacitance

As power factor is unity,

$\therefore X_L = X_C$ also L=200mH and R= 10 Ω

$\Rightarrow \omega = \frac{1}{\sqrt{LC}}$

$100 = \frac{1}{\sqrt{200\times10^{-3}\times C}}$

$10^4 \times 2 \times 10^2 \times 10^{-3} \times C = 1$

hence ca[pacitance is given by ,C = $\frac{1}{2\times10^3}$ F

= 0.5×10^{-3} F

= 0.5mF

ii. Q-factor of circuit and its importance Calculation of average power dissipated

Quality factor, $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$

$= \frac{1}{10}\sqrt{\frac{200\times10^{-3}}{0.5\times10^{-3}}}$

$= \frac{1}{10}\times 20 = 2$

Significance: It measures the sharpness of resnance.

Average Power dissipated,

$P = V_{rms}\, I_{rms}\cos\phi$

$= 50 \times \frac{50}{10} \times 1$ W

= 250 watts