PART - I

1. (b)
2. (c)
3. (d)
4. (b)
5. (d)
6. (d)
7. (a)
8. (d)
9. (b)
10. (c)
11. (d)
12. (d)
13. (b)
14. (d)
15. (d)

PART - II

16. Step (1): Formula for parallel plate capacitor

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

Where:

$A =$ area of one plate

$d =$ separation between plates

$\varepsilon_0 = 8.854 \times 10^{-12}$ F/m

Step (2): Substitute values

Side of square plate: 5 cm = 0.05 m

$A = (0.05)^2 = 0.0025 \text{ m}^2$

Separation: $d = 1 \text{ mm} = 0.001 \text{ m}$

$C = 8.854 \times 10^{-12} \frac{0.0025}{0.001}$

$C = 8.854 \times 10^{-12} \cdot 2.5$

$C \approx 22.135 \times 10^{-12} \text{ F}$

$C \approx 22.1 \text{pF}$

17. Lenz's Law: The direction of induced current in a conductor is such that it opposes the change in magnetic flux that produces it.
18. Limitations of Cyclotron:

(i) Relativistic speeds: Cannot accelerate particles to speeds close to light, as mass increases.

(ii) Charge requirement: Only works for charged particles.

(iii) Magnetic field strength: Limited by the maximum achievable magnetic field.

(iv) Mass limitation: Heavy particles are difficult to accelerate.

19. Mass Defect: The difference between the total mass of individual nucleons and the actual mass of the nucleus.

$\Delta m = [Zm_p + Nm_n - m_{\text{nucleus}}]$

20. Optical Path: The product of the refractive index of a medium and the actual distance traveled by light in it.

Optical Path $= n \cdot d$

Where $n =$ refractive index, $d =$ actual distance.

21. (a) Source at infinity: Plane wavefront

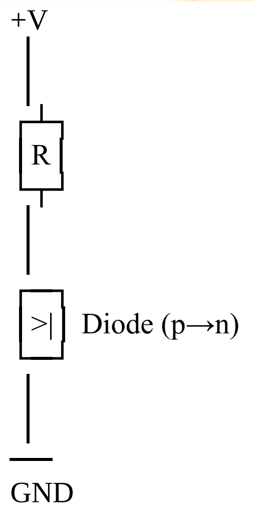
(b) Point source: Spherical wavefront

(c) Line source: Cylindrical wavefront

22. A forward-biased p-n junction diode circuit has:

- Diode with p-side connected to positive terminal of battery and n-side to negative terminal.
- Series resistor (optional) to limit current.

Circuit diagram:



Arrow in diode symbol points in the direction of conventional current.

23. Stopping Potential: The minimum negative potential applied to the collector (or plate) of a photoelectric cell to stop the most energetic emitted electrons, making the photoelectric current zero.

24. $I = \frac{E}{R+r}$

(i) For $R_1 = 2\Omega, I_1 = 0.9$ A :

$0.9 = \dfrac{E}{2+r} \Rightarrow E = 0.9(2+r) = 1.8 + 0.9r$

(ii) For $R_2 = 7\Omega, I_2 = 0.3$ A :

$0.3 = \dfrac{E}{7+r} \Rightarrow E = 0.3(7+r) = 2.1 + 0.3r$

Step (2): Equate E

$1.8 + 0.9r = 2.1 + 0.3r$

$0.9r - 0.3r = 2.1 - 1.8$

$0.6r = 0.3 \Rightarrow r = 0.5\Omega$

PART - III

25. (i) Kirchhoff's Current Law (KCL): The sum of currents entering a junction equals the sum of currents leaving the junction.

$$\sum I_{\text{in}} = \sum I_{\text{out}}$$

(ii) Kirchhoff's Voltage Law (KVL): The sum of all potential differences around a closed loop is zero.

$$\sum V = 0$$

26. Photon energy:

$$E = \frac{hc}{\lambda} = \frac{1240\text{eV cdot nm}}{300 \text{ nm}} \approx 4.13\text{eV}$$

Work function of calcium: $\phi = 3.20$eV

Since $E > \phi$, the photons have enough energy to eject electrons.

27. Magnetic Lorentz Force: A charged particle of charge q moving with velocity $\vec{v}$ in a magnetic field $\vec{B}$ experiences a force given by:

$\vec{F} = q(\vec{v} \times \vec{B})$

Direction: Perpendicular to both $\vec{v}$ and $\vec{B}$ (given by right-hand rule)

Magnitude: $F = qvB\sin\theta$, where θ is the angle between $\vec{v}$ and $\vec{B}$

28. Advantages of AC over DC: -

(i) Easy to transform voltages using transformers.

(ii) Less power loss in transmission over long distances.

(iii) Simple generation and distribution.

Disadvantages of AC: -

(i) More dangerous due to alternating nature (can cause severe shocks).

(ii) Inductive and capacitive losses may occur in circuits.

29. Properties of Electromagnetic Waves (6 points): -

(i) Transverse in nature: Electric and magnetic fields are perpendicular to each other and to the direction of wave propagation.
(ii) Travel in vacuum: Do not require a medium; can propagate through empty space.
(iii) Speed in vacuum: Travel at speed of light, $c = 3 \times 10^8$ m/s.
(iv) Mutually perpendicular fields: $\vec{E} \perp \vec{B} \perp$ direction of propagation.
(v) Carry energy and momentum: Can exert pressure (radiation pressure).
(vi) Obey superposition principle: Two or more EM waves can overlap without disturbing each other.

30. Step (1): Phase difference and path difference

For a wave of wavelength λ, if two points on a wave have a path difference Δx, then the phase difference ϕ between them is proportional to the path difference:

$\phi \propto \Delta x$

Step (2): Relation using wavelength

A complete wavelength λ corresponds to a phase change of 2π radians.

Path difference $\Delta x = \lambda \Rightarrow \phi = 2\pi$

So, in general:

$$\phi = \frac{2\pi}{\lambda} \cdot \Delta x$$

Step (3): Final Relation

$$\phi = \frac{2\pi}{\lambda} \Delta x$$

31. (i) The gravitational force between two masses is always attractive but Coulomb's force between two charges can be attractive or repulsive, depending on the nature of charges.

(ii) The value of the gravitational constant $G = 6.626 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$. The value of the constant k in Coulomb law is $k = 9 \times 10^9\ \text{N m}^2\text{C}^{-2}$.

(iii) The gravitational force between two masses is independent of the medium. The electrostatic force between the two charges depends on the nature of the medium in which the two charges are kept at rest.

(iv) The gravitational force between two-point masses is the same whether two masses are at rest or in motion. If the charges are in motion, yet another force (Lorentz force) comes into play in addition to Coulomb force.

32. Short Solution - Difference between Intrinsic and Extrinsic Semiconductors: -

Aspect	Intrinsic Semiconductor	Extrinsic Semiconductor
Definition	Pure semiconductor with no impurity	Semiconductor doped with impurity atoms
Charge carriers	Equal number of electrons and holes	Either electrons (n-type) or holes (p-type) dominate
Conductivity	Lower, depends on temperature	Higher, depends on type and amount of dopant
Examples	Pure Si, Ge	Si doped with P (n-type) or B (p-type)
Control over properties	Difficult	Can be controlled by doping

33. Given: $n = 5, r = 13.25\text{Å} = 13.25 \times 10^{-10}$ m

(i) Angular momentum: -

$$L = n\frac{h}{2\pi} = 5 \cdot \frac{6.626 \times 10^{-34}}{2\pi} \approx 5.27 \times 10^{-34}\text{Js}$$

(ii) Velocity: -

$$v=\sqrt{\frac{ke^2}{mr}}=\sqrt{\frac{(9\times10^9)(1.6\times10^{-19})^2}{9.11\times10^{-31}\cdot13.25\times10^{-10}}}\approx4.37\times10^5\ \mathrm{m/s}$$

PART - IV

34. (a) Short Solution - Electric Field of an Infinitely Long Wire:

- Consider a line charge with linear charge density $\lambda(\mathrm{C/m})$.
- Using Gauss's law with a cylindrical Gaussian surface of radius r and length L :

$$\oint\ \vec{E}\cdot d\vec{A}=\frac{q_{\text{enclosed}}}{\varepsilon_0}$$

- Charge enclosed: $q_{\text{enclosed}}=\lambda L$
- Surface area of cylinder: $A=2\pi rL$

$$E\cdot(2\pi rL)=\frac{\lambda L}{\varepsilon_0}\Rightarrow E=\frac{\lambda}{2\pi\varepsilon_0 r}$$

Electric field:

$$\boxed{E=\frac{\lambda}{2\pi\varepsilon_0 r}}$$

OR

(b) (i) First Theorem: -

The complement of the sum is equal to the product of its complements.

$\overline{A+B}=\bar{A}\cdot\bar{B}$

A	B	A + B	$\overline{A+B}$	$\bar{A}$	$\bar{B}$	$\bar{A}.\bar{B}$
0	0	0	1	1	1	1
0	1	1	0	1	0	0
1	0	1	0	0	1	0
1	1	1	0	0	0	0

(ii) Second Theorem: -

The complement of the product of two inputs is equal to the sum of its complements.

$\overline{A\cdot B}=\bar{A}+\bar{B}$

A	B	A. B	$\overline{A.B}$	$\bar{A}$	$\bar{B}$	$\bar{A}+\bar{B}$
0	0	0	1	1	1	1
0	1	0	1	1	0	1
1	0	0	1	0	1	1
1	1	1	0	0	0	0

35. Comparing EMFs using Potentiometer: -

- Setup: Connect standard cell (EMF E_1) and test cell (EMF E_2) in series with a long wire of uniform resistance.
- Adjust jockey along the potentiometer wire to find null point (no current in galvanometer) for each cell.
- Measure balancing lengths: l_1 for standard cell, l_2 for test cell.
- Relation: EMFs are proportional to lengths:

$$\frac{E_1}{E_2}=\frac{l_1}{l_2}\ \Rightarrow\ E_2=E_1\frac{l_2}{l_1}$$

36. (a) Torque on a Current-Carrying Coil: -

(i) Consider a rectangular coil of N turns, area A, carrying current I in a uniform magnetic field B.

(ii) Force on each side: -

For side of length l perpendicular to $\vec{B}$, magnetic force:

$F=IlB$

(iii) Torque on coil: -

$\tau = F \cdot \frac{w}{2} \cdot 2 = IBlw = IBA$ (for 1 turn)

For N turns and angle θ between normal to coil and $\vec{B}$:

$\tau = NIAB\sin\theta$

Torque is maximum when $\theta = 90^\circ$.

OR

(b) Photoemissive Cell: -

Construction: Vacuum tube with photoemissive cathode and anode.

Working: Light falls on cathode → electrons emitted → current flows to anode (photoelectric effect).

Applications:

(i) Automatic streetlights

(ii) Light sensors

37. (a) (i) By Faraday's law: -

$\mathcal{E} = B\cos\theta \frac{dA}{dt}$ (change area induces EMF)

(ii) Rotating disc:

$R^2 = \frac{A}{\pi} = \frac{0.03}{3.1416} \approx 0.00955 \text{ m}^2$

$\mathcal{E} = \frac{1}{2}B\omega R^2 = 0.5 \cdot 0.4 \cdot (2\pi \cdot 20) \cdot 0.00955 \approx 0.24 \text{ V}$

OR

(b) (i) Brewster's Law: -

Statement: When unpolarised light is incident on a surface at an angle θ_B (Brewster's angle), the reflected light is completely plane polarised with its electric vector perpendicular to the plane of incidence.

$\tan\theta_B = n$

Where n = refractive index of the medium.

(ii) Calculation of Brewster's Angle

Given: $n = 1.65$

$\tan\theta_B = n = 1.65$

$\theta_B = \arctan(1.65) \approx 58.2^\circ$

38. (a) Let N = number of undecayed nuclei at time t, λ = decay constant.

(i) Rate of decay:

$\frac{dN}{dt} \propto -N \Rightarrow \frac{dN}{dt} = -\lambda N$

(ii) Integrate:

$\int \frac{dN}{N} = -\int \lambda dt \Rightarrow \ln N = -\lambda t + C$

(iii) Solve for N :

$N = N_0 e^{-\lambda t}$

Radioactive Decay Law:

$N = N_0 e^{-\lambda t}$

OR

(b) Absorption Spectrum: -

Definition: The absorption spectrum is a spectrum obtained when white light passes through a substance, showing dark lines or bands at specific wavelengths where light is absorbed.

Types of Absorption Spectrum: -

(i) Continuous absorption spectrum: Absorption occurs over a continuous range of wavelengths.

(ii) Line absorption spectrum: Shows dark lines at discrete wavelengths, corresponding to specific energy transitions of atoms or molecules.

(iii) Band absorption spectrum: Shows dark bands due to absorption by molecules with closely spaced energy levels.