PART - A

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

PART - B

16. Loop Rule (Kirchhoff's Voltage Law)

Statement: -

The algebraic sum of all emfs and voltage drops in any closed loop of an electric circuit is zero.

$$\sum (\text{emf}) - \sum (IR) = 0$$

Meaning: -The total energy gained by charges in a loop equals the total energy lost across resistances.

17. - Electric field: $E = 3 \times 10^4$ N/C

- Dipole moment: $p = 3.4 \times 10^{-30}$
- Maximum torque on a dipole is given by:

$\tau_{\max} = pE$

Maximum torque occurs when the dipole is perpendicular to the field.

Step (1): Substitute values

$\tau_{\max} = (3.4 \times 10^{-30}) \times (3 \times 10^4)$

$\tau_{\max} = 10.2 \times 10^{-26}$

$\tau_{\max} \approx 1.02 \times 10^{-25}$

18. Power Factor (PF)

Definition: -

The power factor of an AC circuit is the ratio of real power (P) to apparent power (S).

$$\text{Power Factor } = \frac{P}{S} = \cos\phi$$

Where: -

P = Real (active) power in watts (W)

S = Apparent power in volt-amperes (VA)

ϕ = Phase difference between voltage and current

Meaning: Indicates how effectively the current is being converted into useful work.

19. Modified Ampère's Circuital Law (Integral Form)

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 \left(I_{\text{enclosed}} + \varepsilon_0 \frac{d\Phi_E}{dt} \right)$$

Where:

$\vec{B}$ = Magnetic field

$d\vec{l}$ = Element of the closed loop

I_{enclosed} = Current enclosed by the loop

$\frac{d\Phi_E}{dt}$ = Rate of change of electric flux (displacement current)

μ_0 = Permeability of free space

20.

Aspect	Interference	Diffraction
Definition	Superposition of light from two or more coherent sources.	Bending of light around edges or apertures.
Source	Requires coherent sources.	Can occur with a single source.
Fringe Width	Fringes are equally spaced.	Fringes are unequally spaced.
Cause	Due to path difference between waves.	Due to wavefront bending and superposition.
Example	Young's double slit experiment.	Single slit diffraction.

21. Characteristics of Photons: -

(i) Particle of light: Photon is a quantum of electromagnetic radiation.
(ii) Energy: $E = h\nu$ (proportional to frequency).
(iii) Momentum: $p = \frac{E}{c} = \frac{h\nu}{c}$.
(iv) No rest mass: Photons have zero rest mass.
(v) No electric charge: Photons are electrically neutral.
(vi) Speed: Travel at speed of light c in vacuum.
(vii) Wave-particle duality: Exhibit both wave and particle properties.

22. Reason for Stars Twinkling: -

- Stars twinkle because their light passes through Earth’s atmosphere, which has layers of varying density and temperature.
- This causes refraction of light in different directions, making the apparent brightness and position fluctuate.

23. De Morgan's Theorems

(1). $\overline{A \cdot B} = \bar{A} + \bar{B}$
(2). $\overline{A + B} = \bar{A} \cdot \bar{B}$
Proof (Using Truth Table)
First Theorem: $\overline{A \cdot B} = \bar{A} + \bar{B}$

A	B	A-B	$(\overline{A \cdot B})$	$\bar{A}$	$\bar{B}$	$\bar{A} + \bar{B}$
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

Second Theorem: $\overline{A + B} = \bar{A} \cdot \bar{B}$

A	B	$A + B$	$(\overline{A + B})$	$\bar{A}$	$\bar{A}$	$(\overline{A \cdot B})$
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

Both theorems are proved.

24. Robotics

Definition: -

Robotics is the branch of science and engineering that deals with the design, construction, operation, and application of robots.

Key point: -

Robots are programmable machines capable of performing tasks automatically.

PART -C

25.

Aspect	Coulomb Force	Gravitational Force
Nature	Electrical force between charges	Attractive force between masses
Formula	$F = k\frac{q_1q_2}{r^2}$	$F = G\frac{m_1m_2}{r^2}$
Sign	Can be attractive or repulsive	Always attractive
Magnitude	Much stronger than gravity	Much weaker than electrical force
Constant	$\boldsymbol{k}$ (Coulomb constant)	G (Gravitational constant)
Dependence	Depends on charge	Depends on mass

26. Equivalent Resistance in Parallel

- For resistors R_1, R_2, R_3, ... connected in parallel, the voltage across each resistor is the same, but the current divides.

$$\frac{1}{R_{\text{eq}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$$

- Special case (two resistors):

$$R_{\text{eq}} = \frac{R_1R_2}{R_1 + R_2}$$

27. Properties of Cathode Rays: -

(i) Negatively charged particles – deflected by electric and magnetic fields.
(ii) Travel in straight lines in vacuum.
(iii) Cause fluorescence when striking a phosphorescent screen.
(iv) Possess momentum and kinetic energy – can move small objects.
(v) Independent of the material of the cathode – properties are same for all metals.
(vi) Produce heat on striking a solid surface.

28. (i) Instantaneous Current

$i = I_0 \sin\theta$
$i = 20 \times \sin 60°$
$i = 20 \times 0.866 \approx 17.32$ A

(ii) Average Value (over half cycle)

$$I_{\text{avg}} = \frac{2I_0}{\pi}$$

$$I_{\text{avg}} = \frac{2 \times 20}{3.1416} \approx 12.73 \text{ A}$$

(iii) RMS Value

$$I_{\text{RMS}} = \frac{I_0}{\sqrt{2}}$$

$$I_{\text{RMS}} = \frac{20}{1.414} \approx 14.14 \text{ A}$$

29. Relation Between f and R

(i) Consider a concave mirror:

- Center of curvature: C
- Pole: P
- Radius of curvature: $R = CP$
- Focal point: F
- Focal length: $f = PF$

(ii) Using geometry and paraxial approximation:

For a ray parallel to principal axis, after reflection it passes through focal point F. Using angle of incidence = angle of reflection and small-angle approximation:

$\angle CPF \approx \angle FCP$

From the mirror geometry:

$$PF = \frac{1}{2} CP$$

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

Relation:

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

Relation Between f and R

(i) Consider a concave mirror:

- Center of curvature: C
- Pole: P
- Radius of curvature: $R = CP$
- Focal point: F
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From the mirror geometry:

$$PF = \frac{1}{2} CP$$

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

Relation:

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

30. Given:

Electron accelerated through a potential difference V.

Charge of electron: e

Mass of electron: m

Step (1): Kinetic energy of electron

$$\text{K.E.} = eV = \frac{1}{2} m v^2$$

$$v = \sqrt{\frac{2eV}{m}}$$

Step (2): de Broglie wavelength formula

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

Substitute $v = \sqrt{2\mathrm{eV/m}}$:

$$\lambda = \frac{h}{m\sqrt{2eV/m}} = \frac{h}{\sqrt{2meV}}$$

de Broglie wavelength of electron:

$$\lambda = \frac{h}{\sqrt{2meV}}$$

31. Conversion of Galvanometer into Voltmeter

- A galvanometer measures current.
- To measure voltage, a high resistance R_v is connected in series with the galvanometer.

$$V = I_g\left(R_g + R_v\right)$$

Where:

- I_g = Full-scale deflection current of galvanometer
- R_g = Internal resistance of galvanometer
- R_v = Series resistance added
- Purpose: The series resistance limits current so that the galvanometer deflects fully at a specific voltage.

32. Transistor as a Switch

A transistor can operate in two modes for switching:

(i) Cut-off region: -

- Base current $I_B = 0$ → no collector current $I_C = 0$
- Transistor is OFF ⟶ behaves like an open switch

(ii) Saturation region: -

- Base current I_B is sufficient → collector current flows
- Transistor is ON ⟶ behaves like a closed switch
- Application: Used in digital circuits and relay drivers to turn devices ON/OFF.

33. Pile of Plates

Definition: A pile of plates is an early form of a capacitor (condenser) used to store electric charge.

Construction: -

- Alternate layers of metallic plates and insulating material (dielectric) are stacked together.
- Metal plates act as conductors, dielectric prevents direct contact.

Working: -

- When connected to a battery, opposite charges accumulate on adjacent plates.
- Increases total capacitance due to series/parallel combination of plates.

PART - D

34. (a) Step (1): Choose Amperian loop

- Circle of radius r around wire (magnetic field is tangential and same at every point).
- Length of loop: $2\pi r$

$$\oint Bdl = B(2\pi r)$$

Step (2): Apply Ampère's law

$$B(2\pi r) = \mu_0 I$$

$$B = \frac{\mu_0 I}{2\pi r}$$

Magnetic field at distance r from a long straight conductor:

$$B = \frac{\mu_0 I}{2\pi r}$$

OR

(b) Wheatstone Bridge Balance Condition

- Bridge setup: Four resistances R_1, R_2, R_3, R_4 in a diamond shape, galvanometer between middle points.
- Condition for balance: No current flows through the galvanometer.

At balance: $\frac{R_1}{R_2} = \frac{R_3}{R_4}$

Derivation (using Kirchhoff's law):

Let $I_1R_1 = I_2R_3$ and $I_1R_2 = I_2R_4$

$\Rightarrow \frac{R_1}{R_2} = \frac{R_3}{R_4}$

35. (a) Spectral Series of Hydrogen Atom

Definition: -When an electron in a hydrogen atom jumps from a higher energy level $(n > m)$ to a lower level $(n = m)$, it emits light of specific wavelength. The set of such lines is called a spectral series.

Main spectral series of hydrogen: -

Series	Transition ($n \rightarrow m$)	Region of Spectrum
Lyman	$n \rightarrow 1$	Ultraviolet (UV)
Balmer	$n \rightarrow 2$	Visible light
Paschen	$n \rightarrow 3$	Infrared
Brackett	$n \rightarrow 4$	Infrared
Pfund	$n \rightarrow 5$	Infrared

Formula (Rydberg formula): -

$$\frac{1}{\lambda} = R_H\left(\frac{1}{m^2} - \frac{1}{n^2}\right), n > m$$

OR

(b) Step (1): Refraction at first surface

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R_1}$$

For lens in air: $n_1 = 1, n_2 = n$

$$\frac{n}{v} - \frac{1}{u} = \frac{n-1}{R_1}$$

Step (2): Refraction at second surface

Object inside lens at distance u' (from second surface)

$$\frac{1}{v} - \frac{n}{u'} = \frac{1-n}{R_2}$$

Combine both using thin lens approximation $(u' \approx v_1)$

Step (3): Lens maker formula

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

- Sign convention:
- Convex surface $\rightarrow R > 0$
- Concave surface $\rightarrow R < 0$

Lens maker's formula:

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

36. (a) Continuous Spectrum: -

- Produced by hot solids, liquids, or dense gases.
- Shows all wavelengths without gaps.
- Example: Sunlight.

Line Spectrum: -

- Produced by excited atoms in gas phase.
- Appears as discrete bright lines at specific wavelengths.
- Example: Hydrogen emission lines (Lyman, Balmer series).

Band Spectrum: -

- Produced by molecules.
- Shows closely spaced lines forming bands.
- Example: Emission from diatomic molecules like N_2 or CO.

OR

(b) Circuit Diagram of Half-Wave Rectifier

AC
~

D Diode

Load Resistor R_L

GND

Working

(i) Positive half-cycle:
- Diode is forward biased → current flows through load RLR_LRL.
- Output voltage follows the input.

(ii) Negative half-cycle:
- Diode is reverse biased → current cannot flow.
- Output voltage is zero.
- Result: Only positive half-cycles appear across the load.
- Purpose: Converts AC to pulsating DC.

37. (a) Step (1): Electric field due to each charge
- Charges: $+q$ and $-q$ separated by distance $2a$
- Axial point is far away ($r \gg a$)

$$E = E_{+} + E_{-}$$
$$E = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{(r-a)^2} + \frac{q}{(r+a)^2}\right]$$

Step (2): Approximation ($r \gg a$)
$$\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2} \approx \frac{4a}{r^3}$$
$$E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2ga}{r^3}$$

Step (3): Use dipole moment
$$p = q \cdot 2a$$
$$\mathrm{E} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2p}{r^3}$$

Electric field on the axial line of a dipole:
$$E_{\text{axial}} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2p}{r^3}$$

OR

(b) Photo-Emissive Cell

Construction:

Consists of a vacuum tube with: -

(i) Cathode: Thin metal plate (photoemissive material, e.g., cesium)

(ii) Anode: Metal plate to collect emitted electrons
(iii) Vacuum: Ensures free movement of electrons
External circuit connected to measure current
Working: -
(i) Illumination: When light of sufficient frequency strikes the cathode:
$h\nu \geq \phi$
Electrons are emitted (photoelectric effect)
(ii) Electron flow: Emitted electrons move toward the anode, producing photoelectric current in the external circuit.
(iii) Control: By varying light intensity or potential difference, the photo current can be measured.

38. **(a)** Step (1): Potential due to each charge

$$V = \frac{1}{4\pi\varepsilon_0}\left(\frac{q}{r_+} - \frac{q}{r_-}\right)$$

- r_+ =distance from $+q$
- $r-$= distance from $-q$

Step (2): Approximation ($r \gg a$)

$r_\pm \approx r \mp a\cos\theta$

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

$$V \approx \frac{q}{4\pi\varepsilon_0} \cdot \frac{2a\cos\theta}{r^2}$$

Step (3): Express in terms of dipole moment

$p = 2qa$

$$V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{p\cos\theta}{r^2}$$

OR

(b) AC Emf by Changing Coil Orientation
Principle: Faraday's law of electromagnetic induction

$$\mathcal{E} = -\frac{d\Phi_B}{dt}$$

where $\Phi_B = BA\cos\theta$ is the magnetic flux.
Working:
(i) A coil of area A is placed in a uniform magnetic field B.
(ii) If the coil is rotated with angular velocity ω :
$\theta = \omega t$
(iii) Magnetic flux through coil:
$\Phi_B = BA\cos(\omega t)$
(iv) Induced emf:

$$\mathcal{E} = -\frac{d\Phi_B}{dt} = BA\omega\sin(\omega t)$$

Result: The emf varies sinusoidally → produces alternating current.