PART – I

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

PART - II

16. Induced emf can be produced by changing the magnetic flux linked with a circuit.
The main ways are:
(i) Changing the magnetic field around the conductor or coil.
(ii) Changing the area of the coil placed in a magnetic field.
(iii) Changing the orientation (angle) of the coil with respect to the magnetic field.
(iv) Relative motion between the conductor (or coil) and the magnetic field (moving magnet or conductor).

17. $\tan\theta_p = \mu$
Given refractive index of glass, $\mu = 1.5$
$\theta_p = \tan^{-1}(1.5)$
$\theta_p \approx 56.3^\circ$
$\theta_p \approx 56^\circ$

18. Peltier effect: -
When an electric current is passed through a junction of two different conductors or semiconductors, heat is absorbed or liberated at the junction, depending on the direction of current. This phenomenon is called the Peltier effect.

19. The electrostatic potential at a point is defined as the work done per unit positive test charge in bringing it from infinity to that point in an electric field without any change in kinetic energy.
Mathematically,
$$V = \frac{W}{q}$$
where W is the work done and q is the test charge.

20. Threshold frequency:
The threshold frequency is the minimum frequency of incident radiation required to just eject electrons from a given metal surface.
Below this frequency, no photoelectric emission occurs, irrespective of the intensity of the incident light.

21. Ampere's Circuital Law: -
The line integral of the magnetic field around any closed path is equal to μ_0 times the total current enclosed by the path.
Mathematically,
$$\oint \vec{B}\cdot d\vec{l} = \mu_0 I_{\text{enc}}$$
where I_{enc} is the net current passing through the surface bounded by the closed path.

22. The sky appears blue due to Rayleigh scattering of sunlight by air molecules in the atmosphere.

Shorter wavelengths of light (blue and violet) are scattered much more than longer wavelengths (red). Since our eyes are more sensitive to blue light and violet is partly absorbed, the scattered light reaching our eyes is predominantly blue, making the sky appear blue.

23. Two uses of infrared (IR) radiation are: -

(i) Remote controls (TV, AC, etc.) for wireless signal transmission.
(ii) Thermal imaging / night vision to detect heat and temperature differences.

24. Dielectric strength of air

$E = 4 \times 10^6 \text{ V m}^{-1}$

Radius of sphere

$R = 0.4 \text{ m}$

For a Van de Graaff generator, the maximum potential is: -

$V_{\text{max}} = E \times R$

$V_{\text{max}} = 4 \times 10^6 \times 0.4 = 1.6 \times 10^6 \text{ V}$

$\boxed{V_{\text{max}} = 1.6 \times 10^6 \text{ V}(1.6\text{MV})}$

PART - III

25. (i) Kirchhoff's Current Law (KCL): -

At any junction in an electrical circuit, the algebraic sum of currents is zero.

$$\sum I = 0$$

i.e., total current entering a junction equals total current leaving the junction.

(ii) Kirchhoff's Voltage Law (KVL): -

Around any closed loop of a circuit, the algebraic sum of all potential differences (emfs and voltage drops) is zero.

$$\sum V = 0$$

26. Critical Angle: -

The critical angle is the angle of incidence in the denser medium for which the angle of refraction in the rarer medium becomes 90°.

Total Internal Reflection: -

When a ray of light travels from a denser to a rarer medium and the angle of incidence is greater than the critical angle, the ray is completely reflected back into the denser medium. This phenomenon is called total internal reflection.

27. Characteristics of photons: -

(i) Photons are quanta of electromagnetic radiation (light).
(ii) They have zero rest mass.
(iii) They always travel with the speed of light $\boldsymbol{c}$ in vacuum.
(iv) Each photon has energy

$E = h\nu$

(v) Photons carry momentum

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

(vii) They are electrically neutral.
(vii) They exhibit wave-particle duality.
(viii) Photon energy depends only on frequency, not on intensity.

28. Let charge on capacitor be Q and potential difference V.

$$dW = Vdq = \frac{q}{C}dq$$

$$W = \int_0^Q \frac{q}{C}dq = \frac{Q^2}{2C}$$

Using $Q = CV$,

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

For a parallel plate capacitor,

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

$W = \frac{1}{2}\frac{\varepsilon_0 A}{d} V^2$

29.

S.No.	Interference	Diffraction
(1).	Superposition of two waves	Bending of waves around edges
(2).	Superposition of waves from two coherent sources.	Superposition wavefronts emitted from various points of the same wavefront.
(3).	Equally spaced fringes.	Unequally spaced fringes.
(4).	Intensity of all the bright fringes is almost the same.	Intensity falls rapidly for higher orders.
(5).	Large number of fringes are obtained.	Less number of fringes are obtained.

30. Given: -

$F = 9 \times 10^{-3}$ N, $r = 10$ cm $= 0.1$ m

For two magnetic poles in air: -

$F = \frac{\mu_0}{4\pi}\frac{m^2}{r^2}$

where $\frac{\mu_0}{4\pi} = 10^{-7}$.

$9 \times 10^{-3} = 10^{-7}\frac{m^2}{(0.1)^2}$

$m^2 = \frac{9 \times 10^{-3} \times (0.1)^2}{10^{-7}} = \frac{9 \times 10^{-5}}{10^{-7}} = 900$

$m = \sqrt{900} = 30$

Pole strength of each pole $= 30$ A

31. Circuit Diagram (Bridge Rectifier): -

- Components: Four diodes (D1, D2, D3, D4) in a bridge, an AC source, and a load resistor (R_L).
- Connections: AC input connects across two opposite points of the bridge; the load resistor connects across the other two points.

Working: -

(i) Positive Half Cycle: Diodes D1 and D2 conduct, while D3 and D4 are reversebiased. Current flows through R_L from top to bottom.

(ii) Negative Half Cycle: Diodes D3 and D4 conduct, while D1 and D2 are reversebiased. Current flows through R_L in the same direction (top to bottom).

Input & Output Waveforms: -

- Input (AC): A symmetrical sine wave, alternating between positive and negative.
- Output (Pulsating DC): A series of positive pulses, with the negative parts of the input inverted to become positive, creating a more consistent, albeit still pulsating, DC signal.

32. Energy losses in a transformer (short): -

(i) Copper loss – due to resistance of primary and secondary windings.

(ii) Hysteresis loss – due to repeated magnetization of the core.

(iii) Eddy current loss – due to induced currents in the core.

(iv) Flux leakage loss – due to leakage of magnetic flux.

33. Given nucleus: -

$^{235}_{92}U$

Effect of emissions: -

- α-particle: $Z-2, A-4$

Emission of 2α :-

$Z = 92 - 4 = 88, A = 235 - 8 = 227$

- β-particle: $Z+1, A$ unchanged

Emission of 3β : -

$Z = 88 + 3 = 91, A = 227$

- γ-particle: No change in Z or A

Result: - Atomic number $= 91$, Mass number $= 227$

PART - IV

34. (a) Magnetic field due to an infinitely long straight current-carrying conductor

Using Ampere's circuital law:

$\oint \vec{B} \cdot d\vec{l} = \mu_0 I$

For a long straight conductor, choose a circular Amperian loop of radius r.

Magnetic field B is constant on the loop:

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

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

This is the required relation.

OR

(b) The rate of radioactive decay at any instant is directly proportional to the number of undecayed nuclei present.

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

Were

N = number of undecayed nuclei

$\lambda =$ decay constant

Separating and integrating:

$$\int \frac{dN}{N} = -\lambda \int dt$$

$\ln N = -\lambda t + \ln N_0$

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

This is the law of radioactivity.

35. (a) For a dipole of charges $+q$ and $-q$ separated by distance $2a$, dipole moment $p = 2aq$.

At a point on the axial line at distance r from the centre ($r \gg a$),

$$E = \frac{1}{4\pi\varepsilon_0}\left(\frac{2p}{r^3}\right)$$

$$E = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}$$

The direction of the field is along the dipole axis, from $-q$ to $+q$.

OR

(b) Frequency Modulation (FM): -

In frequency modulation, the frequency of the carrier wave is varied in accordance with the amplitude of the modulating (message) signal, while the carrier amplitude remains constant.

Advantages of FM: -

(i) Less noise and better signal quality.

(ii) Higher fidelity (better sound reproduction).

(iii) Signal amplitude remains constant, so power remains constant.

Limitations of FM: -

(i) Requires large bandwidth.

(ii) Complex and costly transmitters and receivers.

36. (a) (i) According to de Broglie hypothesis,

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

For an electron accelerated through potential V : -

$eV = \frac{1}{2}mv^2 \Rightarrow p = mv = \sqrt{2meV}$

Substitute in de Broglie relation: -

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

This is the required expression.

(ii) Kinetic energy of electron $E = 2\text{eV} = 2 \times 1.6 \times 10^{-19} = 3.2 \times 10^{-19}$ J

For a non-relativistic electron,

$E = \frac{p^2}{2m} \Rightarrow p = \sqrt{2mE}$

$p = \sqrt{2(9.1 \times 10^{-31})(3.2 \times 10^{-19})}$

$p \approx 7.6 \times 10^{-25}$ kg m s^{-1}

$p \approx 7.6 \times 10^{-25}$ kg m s^{-1}

OR

(b) Maxwell's Equations (Integral Form): -

(1) Gauss's law (electric field):

$\oint \vec{E} \cdot d\vec{A} = \frac{Q_{\text{enc}}}{\varepsilon_0}$

(2) Gauss's law (magnetism):

$\oint \vec{B} \cdot d\vec{A} = 0$

(3) Faraday's law of electromagnetic induction:

$\oint \vec{E} \cdot d\vec{l} = -\frac{d\Phi_B}{dt}$

(4) Ampere-Maxwell law:

$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{\text{enc}} + \mu_0 \varepsilon_0 \frac{d\Phi_E}{dt}$

These are the Maxwell equations in integral form.

37. (a) Astronomical Telescope (short): -

An astronomical telescope is used to observe distant celestial objects.

It consists of two convex lenses:

Objective: large focal length and large aperture (forms a real, inverted image)

Eyepiece: small focal length (acts as a magnifying glass)

Magnifying Power (Angular Magnification)

Magnifying power M is defined as:

$M = \frac{\text{angle subtended at eye with telescope}}{\text{angle subtended at eye without telescope}}$

(i) Telescope in normal adjustment (final image at infinity)

$M = \frac{f_o}{f_e}$

where

f_o = focal length of objective

f_e = focal length of eyepiece

(ii) Final image at least distance of distinct vision (D)

$\boxed{M = \frac{f_0}{f_e}\left(1 + \frac{f_e}{D}\right)}$

OR

(b)(i) When resistors are connected in series, the same current flows through each resistor.

Total potential difference:

$V = V_1 + V_2 + V_3$

Using Ohm's law $V = IR$:

$IR = IR_1 + IR_2 + IR_3$

$R = R_1 + R_2 + R_3$
$R_{eq} = R_1 + R_2 + R_3$
Thus, the equivalent resistance of a series network is the sum of individual resistances.
(ii) Free electron number density
$n = 8.5 \times 10^{28}\ \mathrm{m^{-3}}$
Given: -
$A = 0.5\ \mathrm{mm^2} = 0.5 \times 10^{-6}\ \mathrm{m^2}$
$I = 0.2\ \mathrm{A}, e = 1.6 \times 10^{-19}\mathrm{C}$
Drift velocity formula: -

$$v_d = \frac{I}{neA}$$

Substitute: -

$$v_d = \frac{0.2}{(8.5 \times 10^{28})(1.6 \times 10^{-19})(0.5 \times 10^{-6})}$$

$v_d \approx 2.9 \times 10^{-5}\ \mathrm{m\ s^{-1}}$
$\boxed{v_d \approx 3 \times 10^{-5}\ \mathrm{m\ s^{-1}}}$

38. **(a)** Step (1): Refraction at first surface
Using refraction formula at a spherical surface: -

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

For first surface: $\mu_1 = 1$ (air), $\mu_2 = \mu$ (lens), object at infinity $u = \infty$, image distance $v = v_1$:

$$\frac{\mu}{v_1} - 0 = \frac{\mu - 1}{R_1} \Rightarrow v_1 = \frac{\mu}{\mu - 1} R_1$$

Step (2): Refraction at second surface
Second surface: $\mu_1 = \mu_1 \mu_2 = 1$, image at infinity, lens thickness ≈ 0 (thin lens), so $v_2 = f$.

$$\frac{1}{v_2} - \frac{\mu}{v_1} = \frac{1 - \mu}{R_2}$$

Substitute v_1 from Step 1 and simplify: -

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

Lens Maker's Formula: -

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

OR

(b) Step (1): Impedance
$Z = \sqrt{R^2 + (X_L - X_C)^2}$
were

$$X_L = \omega L, X_C = \frac{1}{\omega C}$$

Step (2): Phase angle
The phase angle ϕ between applied voltage and current is:

$$\tan \phi = \frac{\text{Reactance}}{\text{Resistance}} = \frac{X_L - X_C}{R} = \frac{\omega L - \frac{1}{\omega C}}{R}$$

Final Expression:

$$\phi = \tan^{-1}\left(\frac{\omega L - 1/(\omega C)}{R}\right)$$

- $\phi > 0$: voltage leads current (inductive)
- $\phi < 0$: current leads voltage (capacitive)