PART - I

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

PART - II

16. Electric field: -

The electric field at a point is the force experienced per unit positive charge placed at that point.

$$\vec{E} = \frac{\vec{F}}{q}$$

17. Q-factor (Quality factor): -

The Q-factor of a resonant system is the ratio of stored energy to energy lost per cycle.

$$Q = 2\pi \frac{\text{Energy stored}}{\text{Energy lost per cycle}}$$

18. Ampere's Circuital Law:

The line integral of the magnetic field $\vec{B}$ around any closed path is equal to μ_0 times the total current I enclosed by the path:

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{\text{enclosed}}$$

19. Reason for the glittering of diamond: -

- Diamond has a high refractive index (~2.42), which causes strong bending (refraction) of light.
- It also has high dispersion, splitting white light into its component colors.
- Multiple internal reflections and dispersion make diamond sparkle or glitter.

20. Step (1): Recall the relation between intensity and amplitude

For a wave:

$I \propto A^2$

Where $I =$ intensity, $A =$ amplitude.

Step (2): Set up the ratio

Let the amplitudes of the two waves be A_1 and A_2.

$$\frac{I_1}{I_2} = \frac{A_1^2}{A_2^2} = 36:1$$

Step (3): Take square root

$$\frac{A_1}{A_2} = \sqrt{36}:\sqrt{1} = 6:1$$

Step (4): Answer

Ratio of amplitudes $A_1 : A_2 = 6:1$

21. Work function of a metal:

The work function is the minimum energy required to remove an electron from the surface of a metal.

Unit: Joule (J) or electronvolt (eV).

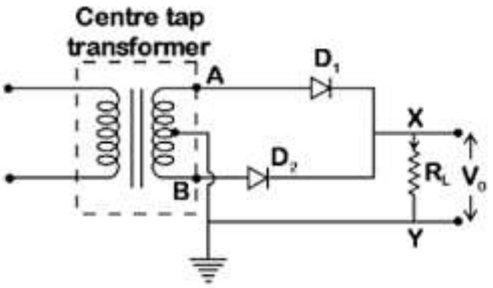
22. Activity (Decay rate):

The activity of a radioactive substance is the number of nuclei decaying per second.

$A = \dfrac{\text{Number of decays}}{\text{time}}$

Unit: Becquerel (Bq) = 1 decay per second, or Curie (Ci).

23. The full wave rectifier is a circuit which gives output rectified voltage corresponding to both cycles (positive and negative) of input signal. A centre tap full wave rectifier circuit is as shown in the figure.



Working: -

For Positive Cycle: In positive half cycle diode D_1 gets forward and D_2 gets reverse biased. Hence an output current across R_L will be from X to Y.

For negative half cycle

In negative cycle, D_1 gets reverse and D_2 gets forward biased. It gives an output current through load resistance R_L from X to Y.

24. $R_0 = 3\Omega = 100°C, T_0 = 20°C$

$\alpha = 0.004/°C, R_T = ?$

$Rr = R_0(1 + \alpha(T - T_0))$

$R_{100} = 3(1 + 0.004 \times 80)$

$\Rightarrow R_{100} = 3(1 + 0.32)$

$R_{100} = 3(1.32)$

$\Rightarrow R_{100} = 3.96\Omega$

PART - III

25. (i) Consider a positive charge ' q ' kept fixed at the origin. Let P be a point at distance r from the charge ' q '. Electrostatic potential at a point P

(ii) The electric potential at the point P is

$$V = \int_{\infty}^{r} (-\vec{E}) \cdot d\vec{r} = -\int_{\infty}^{r} \vec{E} \cdot \overrightarrow{dr}$$

(iii) Electric field due to positive point charge is

$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$$

$$V = -\frac{1}{4\pi\varepsilon_0}\int_{\infty}^{r}\frac{q}{r^2}\hat{r} \cdot d\vec{r}$$

(iv) The infinitesimal displacement vector, $d\vec{r} = d\hat{r}$ and using $\hat{r}\hat{r} = 1$, we have

$$V = -\frac{1}{4\pi\varepsilon_0}\int_{\infty}^{r}\frac{q}{r^2}\hat{r} \cdot d\hat{r} = -\frac{1}{4\pi\varepsilon_0}\int_{\infty}^{r}\frac{q}{r^2}dr$$

(v) After the integration,

$$V = -\frac{1}{4\pi\varepsilon_0}q\left\{-\frac{1}{r}\right\}_{\infty}^{r} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

(vi) Hence the electric potential due to a point charge q at a distance r is

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

26. Kirchhoff's Rules:

(i) First Rule (Junction Rule):

The total current entering a junction equals the total current leaving it.

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

(ii) Second Rule (Loop Rule):

The algebraic sum of EMFs and potential drops around any closed loop is zero.

$\sum \text{EMF} - \sum IR = 0$

27. Conversion of Galvanometer into an Ammeter: -

A galvanometer measures small currents. To measure large currents, it is converted into an ammeter.
Method: Connect a low resistance (called shunt) in parallel with the galvanometer.
$I = I_g + I_{\text{shunt}}$
Where: -
- I = total current
- I_g = current through galvanometer
- Most of the current bypasses the galvanometer through the shunt, protecting it and allowing measurement of large currents.

28. Inducing EMF by changing the area of a coil: -

- According to Faraday's law, EMF is induced when the magnetic flux through a coil changes:

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

- Magnetic flux: $\Phi_B = B \cdot A \cdot \cos\theta$
- If the area A of the coil changes with time (while B and θ remain constant), the flux changes.
- This change in flux induces an EMF in the coil.

29. Fraunhofer Lines: -

- They are dark lines in the solar spectrum where specific wavelengths of light are absorbed by elements in the Sun's atmosphere.

Use in identifying elements: -
- Each element absorbs light at characteristic wavelengths.
- By matching Fraunhofer lines with known absorption lines of elements, we can identify the elements present in the Sun.

30. Step (1): Determine which diodes conduct

- An ideal diode conducts only if forward biased.
- Both diodes have their anode connected to the positive terminal, so both will conduct.

Step (2): Simplify the circuit
- Both diodes conduct → they act as short circuits.
- So, resistors R_2 and R_3 are now in parallel, as each is in series with a conducting diode:

$$R_2 \| R_3 = \frac{R_2 R_3}{R_2 + R_3} = \frac{3 \cdot 2}{3 + 2} = \frac{6}{5} = 1.2\Omega$$

This combination is in series with $R_1 = 2\Omega$.
Step (3): Total resistance
$R_{\text{total}} = R_1 + R_{23} = 2 + 1.2 = 3.2\Omega$
Step (4): Total current from the source

$$I_{\text{total}} = \frac{V}{R_{\text{total}}} = \frac{10}{3.2} \approx 3.125 \text{ A}$$

Step (5): Current through R_1
- Since R_1 is in series with the parallel combination, current through R_1 is the same as total current:

$I_{R_1} = I_{\text{total}} \approx 3.125 \text{ A}$

31. Optical Path (OP): -

The optical path is the product of the refractive index of a medium and the physical distance traveled by light in that medium. It represents the distance light would travel in vacuum to experience the same phase change.
Equation: -
Optical Path $(\text{OP}) = n \cdot l$
Where:

n = Refractive index of the medium
l = Physical distance traveled by light in the medium

32. Three Laws of Photoelectric Effect:

(i) Threshold Frequency Law: -

Photoelectric emission occurs only if the incident light has a frequency greater than the threshold frequency ν_0 of the metal. Light with $\nu < \nu_0$ cannot emit electrons, no matter how intense it is.
(ii) Instantaneous Emission Law: -
Electrons are emitted immediately when light of frequency $\nu \geq \nu_0$ falls on the metal. There is no time lag.
(iii) Proportionality Law: -
The photoelectric current is directly proportional to the intensity of incident light, provided the frequency is above the threshold.

33. Step (1): Energy released per fission
For $^{235}_{92}U$, the energy released per fission is approximately:
$E_{\text{per flesion}} \approx 200\text{MeV}$
Convert MeV to joules:
$1\text{MeV} = 1.602 \times 10^{-13}$ J
$E_{\text{per fisilon}} = 200 \times 1.602 \times 10^{-13} \approx 3.204 \times 10^{-11}$ J
Step (2): Number of Uranium nuclei in 1 kg
Molar mass of $^{235}U \approx 235$ g/mol $= 0.235$ kg/mol
Number of moles:
$$n = \frac{\text{mass}}{\text{molar mass}} = \frac{1}{0.235} \approx 4.255 \text{ mol}$$
Number of nuclei:
$N = n \cdot N_A = 4.255 \times 6.022 \times 10^{23} \approx 2.56 \times 10^{24}$ nuclei
Step (3): Total energy released
$E_{\text{total}} = N \cdot E_{\text{per flasion}} = 2.56 \times 10^{24} \times 3.204 \times 10^{-11}$
Multiply carefully:
$2.56 \times 3.204 \approx 8.2$
$E_{\text{total}} \approx 8.2 \times 10^{13}$ J

PART - IV

34. (a) (i) Coulomb's Law (Electrostatics):
The force of interaction between two stationary point charges is directly proportional to the product of the magnitudes of the charges and inversely proportional to the square of the distance between them. The force acts along the line joining the two charges.
Mathematical form:
$$F = k\frac{q_1 q_2}{r^2}$$
where
- F = magnitude of electrostatic force,
- $\boldsymbol{q}_1, \boldsymbol{q}_2$ = charges,
- r = distance between the charges,
- $k = \frac{1}{4\pi\varepsilon_0}$ in vacuum.

Nature of force:
- Like charges repel, unlike charges attract.

(ii) Differences between Coulomb force and Gravitational force (short):
(i) Nature of force: -
Coulomb force: Can be attractive or repulsive.
Gravitational force: Always attractive.
(ii) Acting entities: -
- Coulomb force: Acts between electric charges.
- Gravitational force: Acts between masses.

(iii) Medium dependence: -
- Coulomb force: Depends on the medium (permittivity).
- Gravitational force: Independent of medium.

(iv) Relative strength: -
- Coulomb force: Very strong.
- Gravitational force: Very weak.

(v) Shielding: -

- Coulomb force: Can be shielded.
- Gravitational force: Cannot be shielded.

OR

(b) Fizeau used a rotating toothed wheel placed between a light source and a distant plane mirror. Light passes through a gap between the teeth, travels to the mirror, and returns.
When the wheel rotates slowly, the reflected light passes back through the same gap and is seen. At a particular speed of rotation, the returning light is blocked by the next tooth, causing darkness.
Knowing:
- distance between the wheel and mirror,
- number of teeth on the wheel,
- speed of rotation at which extinction occurs,

the time taken by light for the round trip is calculated, and hence the speed of light is determined using $c = \frac{\text{distance}}{\text{time}}$.

35. **(a)** A cyclotron is a device used to accelerate charged particles (like protons) to very high energies using a constant magnetic field and a high frequency alternating electric field.
Construction (brief):
It consists of two hollow semicircular metal chambers called Dees (D_1 and D_2) placed in a uniform magnetic field perpendicular to their plane. An alternating voltage source is connected across the Dees.
Working:
- A charged particle released at the center enters one Dee and moves in a circular path due to the magnetic field.
- On crossing the gap between the Dees, the particle is accelerated by the electric field.
- The electric field reverses direction just as the particle crosses the gap, so it gains energy every time.
- As the particle's speed increases, the radius of its circular path increases, producing a spiral trajectory.
- When the particle reaches the outer edge, it is extracted and directed to a target.

Principle:
The time period of revolution of a charged particle in a magnetic field is independent of its speed, allowing repeated acceleration at a fixed frequency.

OR

(b) Explanation: -
According to Huygens' principle, every point inside the slit acts as a source of secondary wavelets. These wavelets interfere with each other. At certain angles, destructive interference occurs, giving dark bands (minima).
Condition for n^{th} minimum: -
For complete destructive interference, the path difference between extreme rays from the slit equals $n\lambda$.
$a \sin\theta = n\lambda$ where $n = 1,2,3,\ldots$

36. **(a)** In a series RLC circuit connected to an AC source, the total impedance Z is the vector sum of resistance and reactance.
- Inductive reactance: $X_L = \omega L$
- Capacitive reactance: $X_C = \frac{1}{\omega C}$

The net reactance is:
$X = X_L - X_C$
The impedance of the circuit is:
$Z = \sqrt{R^2 + (X_L - X_C)^2}$
Let ϕ be the phase angle between the applied voltage V and current I. Then,
$\tan\phi = \frac{X_L - X_C}{R}$

OR

(b) Arrangement: -
A beam of electrons emitted from an electron gun was accelerated by a known potential and directed onto a nickel crystal. The scattered electrons were detected using a movable detector.
Observation: -
At certain angles and accelerating voltages, the intensity of scattered electrons showed sharp maxima, similar to diffraction patterns of waves.

Conclusion: -
The diffraction of electrons by the crystal confirmed that electrons behave like waves, in agreement with de Broglie's hypothesis:
$$\lambda = \frac{h}{p}$$

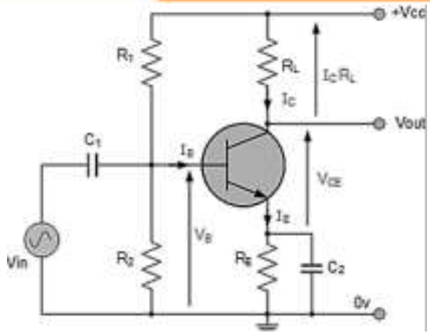
37. **(a)** $v_d = \frac{eE\tau}{m}$
where
$e =$ charge of electron,
$m =$ mass of electron,
$\tau =$ mean relaxation time.
Current density:
If n is the number of free electrons per unit volume, then
$J = nev_d$
Substituting v_d
$$J = \frac{ne^2\tau}{m}E$$
Microscopic form of Ohm's law:
$J = \sigma E$
where
$$\sigma = \frac{ne^2\tau}{m}$$
is the electrical conductivity of the material.

OR

(b) (i) Radius of n^{th} orbit
Centripetal force = Electrostatic force:
$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$$
Using angular momentum condition and solving, we get:
$$r_n = \frac{\varepsilon_0 h^2}{\pi m e^2}n^2 = a_0 n^2$$
where $a_0 = 0.529$Å is the Bohr radius (for hydrogen).
(ii) Velocity of electron in n^{th} orbit
From Bohr's postulates:
$$v_n = \frac{e^2}{2\varepsilon_0 h}\frac{1}{n}$$

38. **(a)** **(i)** Properties of Electromagnetic Waves (short solution):
(i) Electromagnetic waves are transverse waves.
(ii) They consist of oscillating electric and magnetic fields, mutually perpendicular and perpendicular to the direction of propagation.
(iii) They do not require a material medium and can propagate through vacuum.
(iv) In vacuum, they travel with the speed of light $c = 3 \times 10^8$ m s^{-1}.
(v) The electric and magnetic fields are in phase.
(vi) They carry energy and momentum and exert radiation pressure.
(vii) They obey the principle of superposition.
(ii) Given:
Relative permeability, $\mu_r = 2.5$
Relative permittivity, $\varepsilon_r = 2.25$
Refractive index n :
$$n = \sqrt{\mu_r \varepsilon_r}$$
$$n = \sqrt{2.5 \times 2.25} = \sqrt{5.625} \approx 2.37$$
$$n \approx 2.37$$

OR



(b)

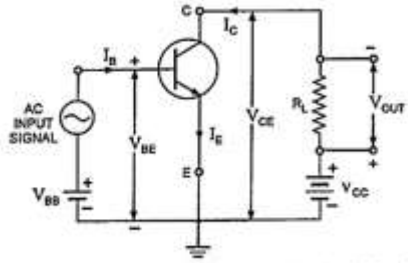
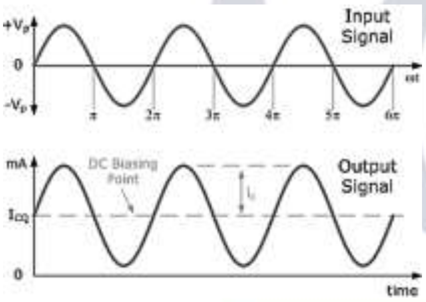
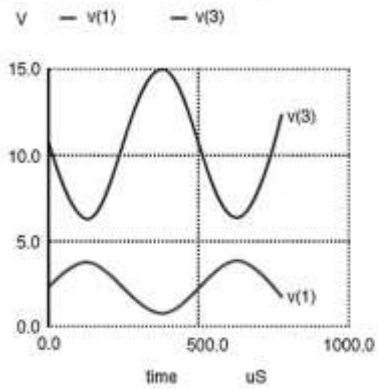


Fig. 10.32 *Common Emitter NPN Transistor Amplifier Circuit*

Principle:
A transistor amplifies weak AC signals by using a small change in base current to produce a large change in collector current.
Working (Common Emitter mode):
- The transistor is biased so that the base-emitter junction is forward biased, and the collector-base junction is reverse biased.
- A small AC input signal is applied at the base.
- This causes a small change in base current, which produces a much larger change in collector current.
- The varying collector current produces a large voltage variation across the load resistance, giving an amplified output.





Waveforms:
- Input waveform: Small-amplitude AC signal at th-hase.
- Output waveform: Large-amplitude AC signal at une collector, 180° out of phase with the input.