SAMPLE QUESTION PAPER

BLUE PRINT

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

S. No.	Chapter	VSA/ AR/ Case Based (1 mark)	SA-I (2 marks)	SA-II (3 marks)	LA (5 marks)	Total
1.	Electrostatics	2(5)	2(4)	1(3)	–	**7(16)**
2.	Current Electricity	1(4)	–	1(3)	–	
3.	Magnetic Effects of Current and Magnetism	3(3)	–	–	1(5)	**9(17)**
4.	Electromagnetic Induction and Alternating Current	2(2)	2(4)	1(3)	–	
5.	Electromagnetic Waves	3(3)	1(2)	–	–	**9(18)**
6.	Optics	1(1)	2(4)	1(3)	1(5)	
7.	Dual Nature of Radiation and Matter	1(1)	1(2)	–	–	**4(12)**
8.	Atoms and Nuclei	1(4)	–	–	1(5)	
9.	Electronic Devices	2(2)	1(2)	1(3)	–	**4(7)**
	Total	**16(22)**	**9(18)**	**5(15)**	**3(15)**	**33(70)**

Subject Code : **042**

PHYSICS

Time allowed : 3 hours ***Maximum marks : 70***

(i) *All questions are compulsory. There are 33 questions in all.*
(ii) *This question paper has five sections: Section A, Section B, Section C, Section D and Section E.*
(iii) *Section A contains ten very short answer questions and four assertion reasoning MCQs of 1 mark each. Section B has two case based questions of 4 marks each, Section C contains nine short answer questions of 2 marks each, Section D contains five short answer questions of 3 marks each and Section E contains three long answer questions of 5 marks each.*
(iv) *There is no overall choice. However internal choice is provided. You have to attempt only one of the choices in such questions.*

SECTION - A

All questions are compulsory. In case of internal choices, attempt any one of them.

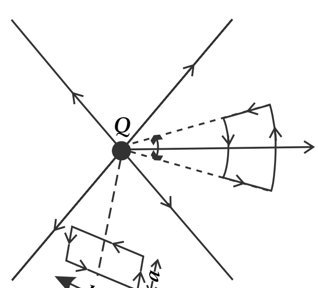
1. How does an increase in doping concentration affect the width of depletion layer of a *p-n* junction diode?

2. A resistance R is connected across a cell of emf ε and internal resistance r. A potentiometer now measures the potential difference between the terminals of the cell as V. Write the expression for r in terms of ε, V and R.

OR

Define electrical resistivity of a material.

3. A test charge q is made to move in the electric field of a point charge Q along two different closed paths. First path has sections along and perpendicular to lines of electric field. Second path is a rectangular loop of the same area as the first loop. How does the work done compare in the two cases ?

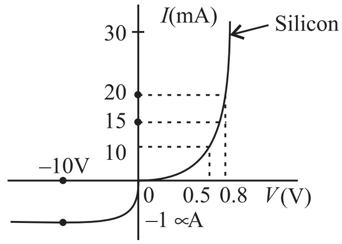


4. What will be the shape of the interference fringes in Young's double slit experiment when D (distance between slit and screen) is very large as compared to fringe width?

5. Draw a plot showing the variation of resistivity of a conductor with the increase in temperature.

OR

The V-I characteristic of a silicon diode is shown in figure. What is the resistance of the diode at $I_D = 15$ mA.



6. If the Earth did not have an atmosphere, would its average surface temperature be higher or lower than what it is now ?

7. A step down transformer converts transmission line voltage from 11000 V to 220 V. The primary of the transformer has 6000 turns and efficiency of the transformer is 60%. If the output power is 9 kW, then the value of input power?

8. What are the directions of electric and magnetic field vectors relative to each other and relative to the direction of propagation of electromagnetic waves?

OR

It is an electric field associated with an electromagnetic wave in vacuum is given by $\vec{E} = 40\cos(kz - 6\times10^{8}t)\hat{i}$, where E , z and t are in volt per meter, meter and second respectively. Find the value of wave vector k.

9. What is the impedance of a capacitor of capacitance C in an ac circuit using source of frequency n Hz?

10. In the magnetic meridian of a certain place the horizontal component of earth's magnetic field is 0.25 G and dip angle is 60°. What is the magnetic field of the earth at this location?

OR

What will be the nature of force, due to earth's horizontal magnetic field?

For question numbers 11, 12, 13 and 14, two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

(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 and R is also false

11. **Assertion (A):** An electric field is preferred in comparison to magnetic field for detecting the electron beam in a television picture tube.

    Reason (R): Electric field requires low voltage.

12. **Assertion (A) :** Work function of copper is greater than that of sodium. But both will have same value of threshold frequency and threshold wavelength.

    Reason (R) : The frequency is directly proportional to wavelength.

13. **Assertion (A) :** Magnetic force is always perpendicular to the magnetic field.

    Reason (R) : Electric force is along the direction of electric field.

14. **Assertion (A) :** Dipole oscillations produces electromagnetic waves.

    Reason (R) : Accelerated charge produces electromagnetic waves.

SECTION - B

Questions 15 and 16 are Case Study based questions and are compulsory. Attempt any 4 sub parts from each question. Each question carries 1 mark.

15. The capacity of a parallel plate air capacitor is $C_0 = \frac{\varepsilon_0 A}{d}$. When air is replaced fully by an insulating medium of dielectric constant K, its capacity becomes $C_m = \frac{\varepsilon A}{d} = K\frac{\varepsilon_0 A}{d} = KC_0$. When thickness of dielectric is $t\,(< d)$, then the capacity is $C_d = \frac{\varepsilon_0 A}{d - t\left(1 - \frac{1}{K}\right)}$. For metals, $K = \infty$. Therefore, when a metal plate of thickness $t < d$ is introduced, the capacity becomes $C' = \frac{\varepsilon_0 A}{d - t}$.

(i) The capacitance of a capacitor will decrease if we introduce a slab of

(a) copper (b) aluminium (c) zinc (d) none of these.

(ii) When area of parallel plate air capacitor is halved and distance between the plates is doubled, its capacity becomes n times, where n is

(a) 1 (b) 2 (c) 4 (d) 1/4

(iii) A metal plate of thickness $t = d/2$ is introduced in between the plates of an air capacitor. The increase in its capacity is

(a) 1% (b) 100% (c) 50% (d) 200%

(iv) Very thin metal foil is introduced in between the plates of an air capacitor of capacitance C. The new capacity is

(a) $C/2$ (b) $2\,C$ (c) C (d) $3\,C$

(v) Potential drop in a dielectric is equal to ________

(a) electric field strength × thickness
(b) electric field strength × area of a cross-section
(c) electric field strength
(d) zero.

16. A town has a population of 1 million. The average electric power needed per person is 300 W. A reactor is to be designed to supply power to this town. The efficiency with which thermal power is converted into electric power is aimed at 25%.

(i) The release in energy in nuclear fission is consistent with the fact that uranium has

(a) more mass per nucleon than either of the two fragments
(b) has more mass per nucleon as the two fragment
(c) has exactly the same mass per nucleon as the two fragments
(d) less mass per nucleon than either of the two fragments.

(ii) Assuming 200 MeV of thermal energy to come from each fission event on an average, find the number of events on an place every day.

(a) 3.24×10^{24} (b) 3.24×10^{21} (c) 3.24×10^{22} (d) 3.24×10^{20}

(iii) Assuming the fission to take place largely through U^{235}, at what rate will the amount of U^{235} decrease?

(a) 1.2643 kg (b) 1.367 kg (c) 3.0 kg (d) 4.56 kg

(iv) If uranium enriched to 3% in U^{235} will be used, how much uranium is needed per month (30 days)?

(a) 1000 kg (b) 1264 kg (c) 3000 kg (d) 1462 kg

(v) If the number of fissions are 2.375×10^{24}, what is the mass of U^{235} isotope used?

(a) 789.23 g (b) 879.32 g (c) 926.65 g (d) 980.74 g

SECTION - C

All questions are compulsory. In case of internal choices, attempt anyone.

17. When a capacitor is connected in series with a series *LR* circuit, the alternating current flowing in the circuit increases. Explain why ?

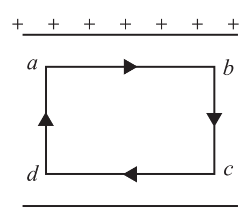
18. An α-particle and a proton are accelerated from rest by the same potential. Find the ratio of their de Broglie wavelengths.

OR

The photoelectric threshold wavelength for silver is λ_0. Find the energy of the electron ejected from the surface of silver by an incident wavelength $\lambda(\lambda < \lambda_0)$.

19. State the underlying principle of a transformer and obtain the expression for the ratio of secondary to primary voltage in terms of the number of secondary and primary windings and primary and secondary currents.

20. The electric field inside a parallel plate capacitor is E. Find the amount of work done in moving a charge q over a closed rectangular loop $a\ b\ c\ d\ a$.



21. A 80 μF capacitor is charged by a 50 V battery. The capacitor is disconnected from the battery and then connected across another uncharged 320 μF capacitor. Calculate the charge on second capacitor.

22. When viewing through a compound microscope, our eyes should be positioned not on the eye-piece but a short distance away from it for best viewing. Why? How much should be that short distance between the eye and eyepiece?

OR

When monochromatic light is incident on a surface separating two media, the reflected and refracted light both have the same frequency as the incident frequency. Given reason.

23. The following table provides the set of values, of *V* and *I*, obtained for a given diode:

	V	*I*
Forward biasing	2.0 V	60 mA
	2.4 V	80 mA
Reverse biasing	0 V	0 μA
	– 2V	– 0.25 μA

Assuming the characteristics to be nearly linear, over this range, calculate the forward and reverse bias resistance of the given diode.

OR

Energy gap in a $p-n$ photodiode is 2.8 eV. Can it detect a wavelength of 600 nm? Justify your answer.

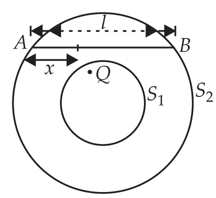
24. Why should the objective of a telescope have large focal length and large aperture? Justify your answer.

25. Even though an electric field $\vec{E}$ exerts a force $q\vec{E}$ on a charged particle yet the electric field of an EM wave does not contribute to the radiation pressure (but transfers energy). Explain.

SECTION - D

All questions are compulsory. In case of internal choices, attempt any one.

26. In the figure shown, calculate the total flux of the electrostatic field through the spheres S_1 and S_2. The wire AB, shown here, has a linear charge density, λ, given by $\lambda = kx$ where x is the distance measured along the wire, from the end A.



27. **(a)** State the law that gives the polarity of the induced emf.

(b) A 15 μF capacitor is connected to 220 V, 50 Hz source. Find the capacitive reactance and the rms current.

OR

The current flowing through an inductor of self inductance L is continuously increasing. Plot a graph showing the variation of

(i) Magnetic flux versus the current

(ii) Induced emf versus dI/dt

(iii) Magnetic potential energy stored versus the current.

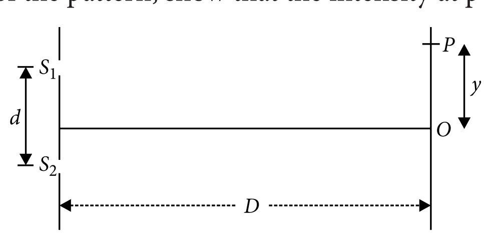
28. The current in the forward bias is known to be more (~mA) than the current in the reverse bias (~ μA) What is the reason, then, to operate the photodiode in reverse bias ?

29. **(a)** In a single slit diffraction experiment, the width of the slit is made double the original width. How does this affect the size and intensity of the central diffraction band? Explain.

(b) When a tiny circular obstacle is placed in the path of light from a distant source, a bright spot in seen at the centre of the obstacle. Explain why.

OR

The intensity at the central maxima (O) in Young's double slit experiment is I_0. If the distance OP equals one-third of the fringe width of the pattern, show that the intensity at point P would be $\frac{I_0}{4}$.



30. A cell of emf E and internal resistance r is connected to two external resistances R_1 and R_2 and a perfect ammeter. The current in the circuit is measured in four different situations :

(i) without any external resistance in the circuit

(ii) with resistance R_1 only

(iii) with R_1 and R_2 in series combination

(iv) with R_1 and R_2 in parallel combination

The currents measured in the four cases are 0.42 A, 1.05 A, 1.4 A and 4.2 A, but not necessarily in that order. Identify the currents corresponding to the four cases mentioned above.

SECTION - E

Directions (Q. No. 31-33) : All questions are compulsory. In case of internal choices, attempt any one.

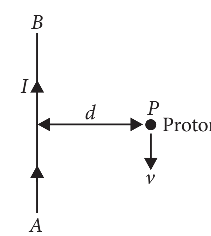
31. Derive the expression for the torque on a rectangular current carrying loop suspended in a uniform magnetic field.

OR

(a) State Biot-Savart law, and write its mathematical expression

Use this law to derive an expression for the magnetic field due to a circular coil carrying current at a point along its axis.

(b) A long straight wire AB carries a current I. A proton P travels with a speed v, parallel to the wire, at a distance d from it in a direction opposite to the current as shown in the figure. What is the force experienced by the proton and what is its direction?



32. Write the basic assumptions used in the derivation of lens maker's formula and hence derive this expression.

OR

(a) Draw a ray diagram for final image formed at least distance of distinct vision (D) by a compound microscope and write expression for its magnifying power.

(b) An angular magnification (magnifying power) of 30 is desined for a compound microscope using as objective of focal length 1.25 cm and eyepiece of focal length 5 cm. How will you set up the compound microscope?

33. **(a)** Using de Broglie's hypothesis, explain with the help of a suitable diagram, Bohr's second postulate of quantization of energy levels in a hydrogen atom.

(b) The ground state energy of hydrogen atom is –13.6 eV. What are the kinetic and potential energies of the electron in this state?

OR

Using Bohr's postulates, derive the expression for the frequency of radiation emitted when electron in hydrogen atom undergoes transition from higher energy state (quantum number n_i) to the lower state, (n_f). When electron in hydrogen atom jumps from energy state $n_i = 4$ to $n_f = 3, 2, 1$. Identify the spectral series to which the emission lines belong.

SOLUTIONS

1. When there is an increase in doping concentration, the applied potential difference causes an electric field which acts opposite to the potential barrier. This results in reducing the potential barrier and hence the width of depletion layer decreases.

2. $\varepsilon = I(R + r)$ and $V = IR$

$$\therefore \quad \frac{\varepsilon}{V} = \frac{R+r}{R}$$

We get, $r = \left(\dfrac{\varepsilon}{V} - 1\right)R$

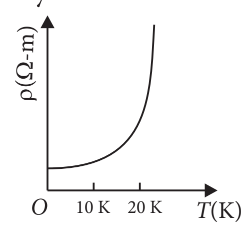
OR

It is defined as the resistance offered by a unit length and unit area of cross-section of the wire.

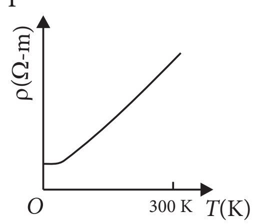
3. Since the electric field is conservative in nature, work done in both the cases is zero.

4. Straight line.

5. The resistivity of a conductor increases non-linearly with increase in temperature.



(For low temperature)



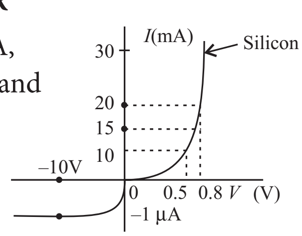
(For high temperature)

OR

From diagram, At $I = 20$ mA, $V = 0.8$ V and

At $I = 10$ mA, $V = 0.5$ V

$$r_{fb} = \frac{\Delta V}{\Delta I} = \frac{0.3\ \text{V}}{10\ \text{mA}} = 30\ \Omega$$



6. Lower because of absence of green house effect.

7. Here, $V_p = 11000$ V, $V_s = 220$ V

$N_p = 6000$, $\eta = 60\%$

$P_o = 9$ kW $= 9 \times 10^3$ W

Efficiency, $\eta = \dfrac{\text{Output power}}{\text{Input power}} = \dfrac{P_o}{P_i}$

$$\therefore \quad P_i = \frac{P_o}{\eta} = \frac{9\times10^3}{60/100} = 1.5 \times 10^4 = 15\ \text{kW}$$

8. In an electromagnetic wave $\vec{E}, \vec{B}$ and direction of propagation are mutually perpendicular.

OR

Compare the given equation with

$E = E_0\cos(kz - \omega t)$

We get, $\omega = 6 \times 10^8\ \text{s}^{-1}$

Wave vector, $k = \dfrac{\omega}{c} = \dfrac{6\times10^8\ \text{s}^{-1}}{3\times10^8\ \text{m s}^{-1}} = 2\ \text{m}^{-1}$

9. Impedance of a capacitor, $Z = X_C$

$= \dfrac{1}{\omega C} = \dfrac{1}{2\pi n C}$, where n is the frequency of source.

10. Here, $H_E = 0.25$ G and $\delta = 60°$

$$\because \quad \cos\delta = \frac{H_E}{B_E}$$

$\therefore$ The magnetic field of earth at the given location is

$$B_E = \frac{H_E}{\cos 60°} = \frac{0.25}{1/2} = 0.50\ \text{G}$$

OR

Earth's horizontal magnetic field is uniform. The lines of force due to the field are parallel and straight.

11. **(d) :** If electric field is used for detecting the electron beam, then very high voltage will have to be applied and very long tube will have to be taken.

12. **(d) :** $W_{Cu} > W_{Na}$ or $(h\upsilon_0)_{Cu} > (h\upsilon_0)_{Na}$

or $(\upsilon_0)_{Cu} > (\upsilon_0)_{Na}$

Thus, the threshold frequency of copper is greater than sodium.

Also, $\dfrac{hc}{(\lambda_0)_{Cu}} > \dfrac{hc}{(\lambda_0)_{Na}}$ or $(\lambda_0)_{Na} > (\lambda_0)_{Cu}$.

13. **(b)**

14. **(a) :** Assertion is true. The reason is also true according to the classical theory of Maxwell. The dipole oscillation gives radiation because the charges are accelerated. (Any oscillation has acceleration).

15. **(i) (d)**

(ii) (d) : As $C_0 = \dfrac{\varepsilon_0 A}{d}$

$$\therefore \quad C_0' = \frac{\varepsilon_0 A/2}{2d} = \frac{\varepsilon_0 A}{4d} = \frac{1}{4}C_0 = nC_0$$

$$\Rightarrow \quad n = \frac{1}{4}$$

(iii) (b) : $C_0' = \dfrac{\varepsilon_0 A}{d-t} = \dfrac{\varepsilon_0 A}{d - d/2} = \dfrac{2\varepsilon_0 A}{d} = 2C_0$

Increase in capacity $= C' - C_0 = 2\,C_0 - C_0 = C_0$

Percentage increase in capacity $= \dfrac{C_0}{C_0} \times 100 = 100\%$

(iv) (c): When a thin metal foil is introduced in between the plates, we have two capacitors, each of capacity 2 C joined in series. As

$$\frac{1}{C_s}=\frac{1}{C_1}+\frac{1}{C_2}=\frac{1}{2C}+\frac{1}{2C}=\frac{2}{2C}=\frac{1}{C}$$

$C_s = C$

(v) (a) : When a dielectric is introduced between the two plates of a parallel plate capacitor, the potential difference decreases by the value of the product of electric field strength × thickness, which is the potential difference of the dielectric.

16. (i) (a)

(ii) (a) : Total population of town = 10^6

Average power consumed by per person = 300 W

Total power consumed per day = $300 \times 10^6 \times 60 \times 60 \times 24$

= $300 \times 86400 \times 10^6$ J

Energy generated in one fission

= $200 \times 10^6 \times 1.6 \times 10^{-19}$ J

= 3.2×10^{-11} J

Efficiency = 25%

$\therefore$ Electrical energy, $E = 3.2 \times 10^{-11} \times \dfrac{25}{100}$

= 8×10^{-12} J

Let the number of fission be N,

Total energy of N fission = $N \times 8 \times 10^{-12}$

Given,

$N \times 8 \times 10^{-12} = 300 \times 86400 \times 10^6$

$\Rightarrow$ $N = 3.24 \times 10^{24}$

(iii) (a): Number of moles required per day,

$$n=\frac{N}{6.023\times10^{23}}$$

$$\Rightarrow\ n=\frac{3.24\times10^{24}}{6.023\times10^{23}}=5.38\text{ mol}$$

$\therefore$ Amount of uranium required per day = 5.38×235

= 1264.3 g = 1.2643 kg.

(iv) (b) : Total uranium needed per month = 1.264×30

Let x kg of uranium enriched to 3% in U^{235} be used

$$\therefore\ x\times\frac{3}{100}=1.264\times30=1264\text{ kg}$$

(v) (c): Mass of uranium used,

$$m=\frac{\text{Mass number}}{\text{Avagadro's number}}$$

$$=235\times2.375\times\frac{10}{6.023}=926{\cdot}65\text{ g}$$

17. Impedance offered by series LR circuit is $Z=\sqrt{R^2+X_L^2}$, but when capacitor is connected in series with LR circuit, its impedance decreases to $Z'=\sqrt{R^2+(X_L-X_C)^2}$ and hence alternating current flowing in the circuit increases.

18. de Broglie wavelength, $\lambda=\dfrac{h}{\sqrt{2mE}}$

$$=\frac{h}{\sqrt{2mqV}}\quad[\because\ \text{kinetic energy } E=qV]$$

$$\therefore\ \frac{\lambda_\alpha}{\lambda_p}=\frac{h}{\sqrt{2m_\alpha q_\alpha V}}\times\frac{\sqrt{2m_p q_p V}}{h}$$

$$\Rightarrow\ \frac{\lambda_\alpha}{\lambda_p}=\sqrt{\frac{m_p q_p}{m_\alpha q_\alpha}}=\sqrt{\frac{m_p q_p}{(4m_p)\cdot(2q_p)}}=\sqrt{\frac{1}{8}}=\frac{1}{2\sqrt{2}}$$

$$\Rightarrow\ \lambda_\alpha:\lambda_p=1:2\sqrt{2}$$

OR

According to Einstein's photoelectric equation,

$$K=\frac{hc}{\lambda}-\frac{hc}{\lambda_0}=hc\left(\frac{1}{\lambda}-\frac{1}{\lambda_0}\right)=hc\left(\frac{\lambda_0-\lambda}{\lambda\lambda_0}\right)$$

19. Step-up transformer (or transformer) is based on the principle of mutual induction.

An alternating potential (V_p) when applied to the primary coil induced emf in it.

$$\varepsilon_p=-N_p\frac{d\phi}{dt}$$

If resistance of primary coil is low $V_p = \varepsilon_p$.

$$i.e.,\ V_p=-N_p\frac{d\phi}{dt}$$

As same flux is linked with the secondary coil with the help of soft iron core due to mutual induction emf is induced in it.

$$\varepsilon_s=-N_s\frac{d\phi}{dt}$$

If output circuit is open $V_s = \varepsilon_s$

$$V_s=-N_s\frac{d\phi}{dt}$$

Thus $\dfrac{V_s}{V_p}=\dfrac{N_s}{N_p}$

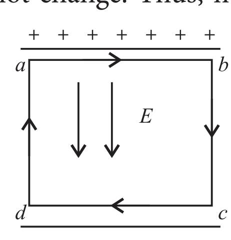
For an ideal transformer, $P_{out} = P_{in}$

$$\Rightarrow\ I_sV_s=I_pV_p\quad\therefore\ \frac{V_s}{V_p}=\frac{I_p}{I_s}=\frac{N_s}{N_p}$$

For step-up transformer $\dfrac{N_s}{N_p}>1$

In case of dc voltage flux does not change. Thus, no emf is induced in the circuit.

20. Electric field inside a parallel plate capacitor = E



Here, electric field is conservative. Work done by the conservative force in closed loop is zero.

So, required work done = 0.

21. Common potential after connection is

$$V = \frac{C_1V_1 + C_2V_2}{C_1 + C_2} = \frac{80\times10^{-6}\times50+0}{(80+320)\times10^{-6}} = 10\text{ V}$$

Now charge on second capacitor after connection is

$q_2 = C_2V = 320 \times 10^{-6} \times 10$

$q_2 = 3.2 \times 10^{-3}$C.

22. The eye-piece makes a real image of the objective aperture at a short distance on the outer (eye) side. This is called "exit-pupil" or "eye-ring". Therefore, the eye must have its pupil on this exit-pupil for best viewing. It is only a few millimeters from the eye-piece.

OR

Reflection and refraction arise through interaction of incident light with atomic constituents of matter which vibrate with the same frequency as that of the incident light. Hence frequency remains unchanged.

23. Forward resistance $R_f = \frac{\Delta V_f}{\Delta I_f} = \frac{(2.4-2.0)\text{ V}}{(80-60)\text{ mA}}$

or $R_f = \frac{0.4\text{ V}}{20\times10^{-3}\text{ A}} = \frac{400}{20} = 20\ \Omega$

Reverse resistance $R_r = \frac{\Delta V_r}{\Delta I_r} = \frac{(-2-0)\text{ V}}{(-0.25-0)\ \mu\text{A}}$

or $R_r = \frac{2\text{ V}}{0.25\times10^{-6}\text{ A}} = 8\times10^{6}\ \Omega$

OR

Energy of photon, $E = \frac{hc}{\lambda}$

$= \frac{6.62\times10^{-34}\times3\times10^{8}}{600\times10^{-9}\times1.6\times10^{-19}}$ eV = 2.07 eV

As $E < E_g$ (2.8 eV), so photodiode cannot detect this photon.

24. Objective of a telescope is a convex lens of large focal length and a large aperture. It faces the distant object and forms bright image of the distant objects. The aperture of the objective is taken large so that it can gather sufficient amount of light from the distant objects.

25. Electric force on a charged particle is oscillating because electric field of an electromagnetic wave is an oscillating field. Since direction changes every half cycle, so electric force averaged over an integral number of cycles is zero. That is why electric field is not responsible for radiation pressure.

26. Total flux through the sphere S_1

$$\phi_1 = \frac{Q}{\varepsilon_0}$$

Charge on the line enclosed by the sphere S_2

$$q = \int_0^l \lambda dx = \int_0^l kx dx \Rightarrow q = k\frac{l^2}{2}$$

Total charge enclosed by the sphere S_2

$$Q' = Q + k\frac{l^2}{2}$$

Total flux through the sphere S_2

$$\phi_2 = \frac{Q + k\frac{l^2}{2}}{\varepsilon_0}$$

27. (a) Lenz's law gives the polarity of induced emf. The induced emf (or current) always opposes the cause that produces it.

(b) Here, $C = 15\ \mu\text{F} = 15 \times 10^{-6}$ F

$\upsilon = 50$ Hz

$V = 220$ V

$\therefore$ Capacitive reactance,

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi\upsilon C}$$

$$X_C = \frac{1}{2\times\pi\times50\times15\times10^{-6}} = 212\ \Omega$$

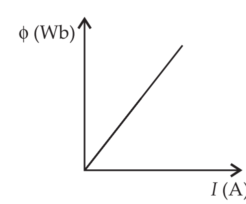
$$\therefore\ I_{\text{rms}} = \frac{V}{X_C}$$

$$= \frac{220}{212} = 1.04\text{ A}$$

OR

(i) Suppose current I is flowing through an inductor of self inductance L. Then magnetic flux linked with the inductor is given by

$\phi = LI$



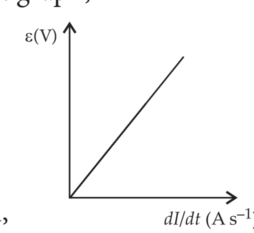
Magnetic flux versus the current graph,

(ii) Induced emf is given by,

$$\varepsilon = -\frac{d\phi}{dt} = -\frac{d}{dt}(LI) = -L\frac{dI}{dt}$$

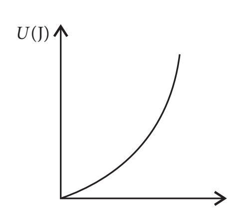
$$|\varepsilon| = L\frac{dI}{dt}$$

Induced emf versus dI/dt graph,



(iii) Magnetic potential energy stored versus the current graph,

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

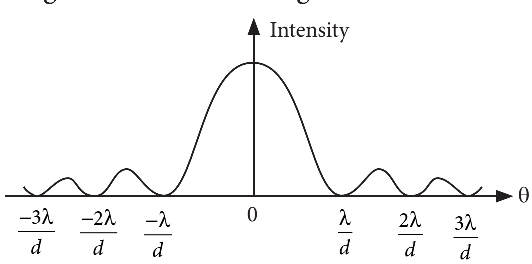


28. Consider the case of an n-type semiconductor. The majority carrier density (n) is considerably larger than the minority hole density p (*i.e.*, $n >> p$). On illumination, let the excess electrons and holes generated be Δn and Δp, respectively

$$n' = n + \Delta n$$
$$p' = p + \Delta p$$

Here n' and p' are the electron and hole concentrations at any particular illumination and n and p are carriers concentration when there is no illumination. Remember $\Delta n = \Delta p$ and $n >> p$. Hence, the fractional change in the majority carriers (*i.e.*, $\Delta n/n$) would be much less than that in the minority carriers (*i.e.*, $\Delta p/p$). In general, we can state that the fractional change due to the photoeffect on the minority carrier dominated reverse bias current is more easily measurable than the fractional change in the forward bias current. Hence, photodiodes are preferably used in the reverse bias condition for measuring light intensity.

29. (a) Intensity distribution of light in diffraction at a signal slit is shown in figure.



Width of central maximum is given by

$$\beta_0 = \frac{2D\lambda}{d}$$

When width (d) of the slit is increased, the width of central maximum decreases and the intensity increases.

(b) The bright spot is produced due to constructive interference of waves diffracted from the edge of the circular obstacle.

OR

$$\text{Fringe width } (\beta) = \frac{\lambda D}{d}$$

$$y = \frac{\beta}{3} = \frac{\lambda D}{3d}$$

$$\text{Path difference, } (\Delta p) = \frac{yd}{D} \Rightarrow \Delta p = \frac{\lambda D}{3d} \cdot \frac{d}{D} = \frac{\lambda}{3}$$

$$\Delta\phi = \frac{2\pi}{\lambda} \cdot \Delta p = \frac{2\pi}{\lambda} \cdot \frac{\lambda}{3} = \frac{2\pi}{3}$$

Intensity at point $P = I_0 \cos^2 \Delta\phi$

$$= I_0 \left[\cos \frac{2\pi}{3}\right]^2 = I_0 \left(\frac{1}{2}\right)^2 = \frac{I_0}{4}$$

30. The current relating to corresponding situations are as follows :

(i) Without any external resistance $I_1 = \frac{E}{r}$

In this case, effective resistance of circuit is minimum so current is maximum.

Hence $I_1 = 4.2$ A.

(ii) With resistance R_1 only $I_2 = \frac{E}{r + R}$

In this case, effective resistance of circuit is more than situations (i) and (iv) but less than (iii). So $I_2 = 1.05$ A.

(iii) With R_1 and R_2 in series combination

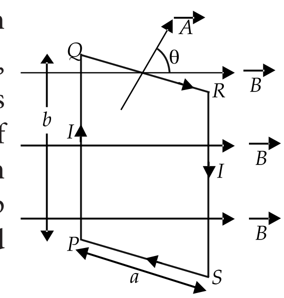
$$I_3 = \frac{E}{r + R_1 + R_2}$$

In this case, effective resistance of circuit is maximum so current is minimum. Hence $I_3 = 0.42$ A.

(iv) $I_4 = \dfrac{E}{r + \dfrac{R_1 R_2}{R_1 + R_2}}$

In this case, the effective resistance is more than (i) but less than (ii) and (iii). So $I_4 = 1.4$ A.

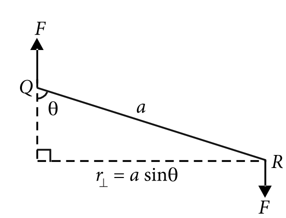
31. When a rectangular loop $PQRS$ of sides 'a' and 'b' carrying current I is placed in uniform magnetic field $\vec{B}$, such that area vector $\vec{A}$ makes an angle θ with direction of magnetic field, then forces on the arms QR and SP of loop are equal, opposite and collinear, thereby perfectly cancel each other, whereas forces on the arms PQ and RS of loop are equal and opposite but not collinear, so they give rise to torque on the loop.



Force on side PQ or RS of loop is

$F = IbB \sin 90° = Ib\, B$

and perpendicular distance between two non-collinear forces is $r_\perp = a \sin\theta$



So, torque on the loop is

$\tau = Fr_\perp = IbB\, a \sin\theta = I\, ba\, B \sin\theta$

or $\tau = IAB \sin\theta$

and if loop has N turns, then $\tau = NIAB \sin\theta$

In vector form, $\vec{\tau} = \vec{M} \times \vec{B}$

where $\vec{M} = NI\vec{A}$ is called magnetic dipole moment of current loop and is directed in direction of area vector $\vec{A}$ *i.e.*, normal to the plane of loop.

(a) If the plane of loop is normal to the direction of magnetic field *i.e.*, $\theta = 0°$ between $\vec{B}$ and $\vec{A}$, then the loop does not experience any torque *i.e.*, $\tau_{\min} = 0$

(b) If the plane of loop is parallel to the direction of magnetic field *i.e.*, $\theta = 90°$ between $\vec{B}$ and $\vec{A}$, then the loop experiences maximum torque *i.e.*,

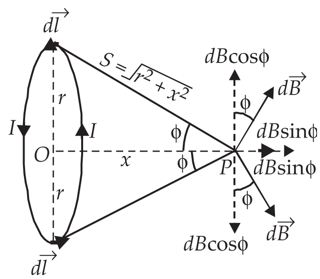
$$\tau_{\max} = NIAB$$

OR

(a) Biot-Savart law states that magnitude of intensity of small magnetic field $d\vec{B}$ due to a current carrying element $d\vec{l}$ at any point P at distance r from it is given by

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$$

Magnetic field on the axis of circular coil



Small magnetic field due to current element of circular coil of radius r at point P at distance x from its centre is

$$dB = \frac{\mu_0}{4\pi}\frac{Idl\sin 90°}{S^2} = \frac{\mu_0}{4\pi}\frac{Idl}{(r^2 + x^2)}$$

Component $dB\cos\phi$ due to current element at point P is cancelled by equal and opposite component $dB\cos\phi$ of another diametrically opposite current element, whereas the sine components $dB\sin\phi$ add up to give net magnetic field along the axis. So, net magnetic field at point P due to entire loop is

$$B = \oint dB\sin\phi = \int_0^{2\pi r}\frac{\mu_0}{4\pi}\frac{Idl}{(r^2 + x^2)}\cdot\frac{r}{(r^2 + x^2)^{1/2}}$$

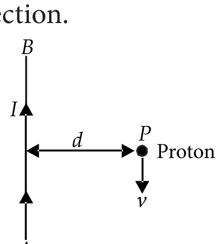
$$B = \frac{\mu_0 Ir}{4\pi(r^2 + x^2)^{3/2}}\int_0^{2\pi r} dl \quad \text{or} \quad B = \frac{\mu_0 Ir}{4\pi(r^2 + x^2)^{3/2}}\,2\pi r$$

or $\quad B = \dfrac{\mu_0 Ir^2}{2(r^2 + x^2)^{3/2}}$ directed along the axis,

(i) towards the coil if current in it is in clockwise direction.

(ii) away from the coil if current in it is in anticlockwise direction.

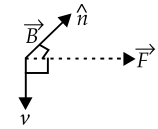
(b)



Magnetic field due to I at P

$\vec{B} = \dfrac{\mu_0 I}{2\pi d}$ into the plane of the paper.

Expression for Lorentz magnetic force



$$\vec{F} = q(\vec{v}\times\vec{B}) = e\left(\vec{v}\times\frac{\mu_0 I}{2\pi d}\hat{n}\right)$$

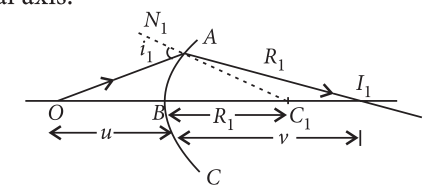
$\vec{F} = \dfrac{\mu_0 Ie\vec{v}}{2\pi d}$ away from the wire

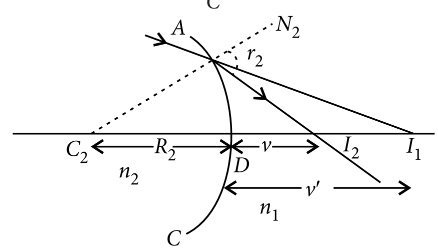
32. Basic assumptions in derivation of lens maker's formula:

(i) Aperture of lens should be small

(ii) Lenses should be thin

(iii) Object should be point sized and placed on principal axis.





Suppose we have a thin lens of material of refractive index n_2, placed in a medium of refractive index n_1, let O be a point object placed on principle axis then for refraction at surface ABC we get image at I_1.

$$\therefore \quad \frac{n_2}{v_1} - \frac{n_1}{u} = \frac{n_2 - n_1}{R_1} \quad \text{...(i)}$$

But the refracted ray before goes to meet at I_1 falls on surface ADC and refracts at I_2

finally; hence I_1 works as a virtual object for second refracting surface.

$$\therefore \quad \frac{n_1}{v} - \frac{n_2}{v_1} = \frac{n_1 - n_2}{R_2} \quad \text{...(ii)}$$

Equation (i) + (ii),

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

$$\therefore \quad \frac{1}{v} - \frac{1}{u} = (n_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \text{...(iii)}$$

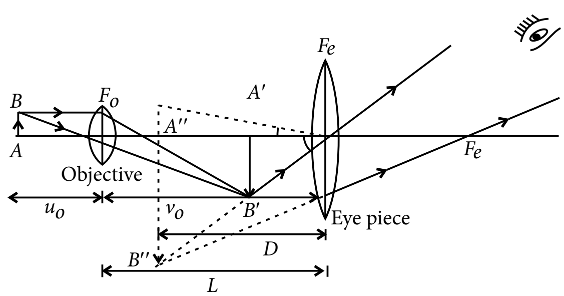
If $u = \infty$, $v = f$,

$$\frac{1}{f} = (n_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

which is lens maker's formula.

OR

(a) Ray Diagram : (with proper labeling)



Magnifying power, $m = \dfrac{v_o}{u_o}\left(1+\dfrac{D}{f_e}\right)$

$$m = \frac{L}{f_0}\left(1+\frac{D}{f_e}\right)$$

(b) $\because$ $m = m_o m_e = -30$ (virtual, inverted)

$\therefore$ $f_o = 1.25$ cm, $f_e = 5$ cm

Let us setup a compound microscope such that the final image be formed at D, then

$$m_e = 1+\frac{v}{f_e} = 1+\frac{25}{5} = 6$$

and position of object for this image formation can be calculated.

$$\frac{1}{v_e}-\frac{1}{u_e}=\frac{1}{f_e} \quad \text{(Using lens formula for eye-piece)}$$

$$\frac{1}{-25}-\frac{1}{u_e}=\frac{1}{5} \Rightarrow -\frac{1}{u_e}=\frac{1}{5}+\frac{1}{25}=\frac{6}{25}$$

$$u_e = \frac{-25}{6} = -4.17 \text{ cm}$$

$\because$ $m = m_o\, m_e \Rightarrow m_0 = \dfrac{m}{m_e} = \dfrac{-30}{6}$

$\therefore$ $m_o = \dfrac{+v_o}{u_o} = \dfrac{-30}{6} = -5$

$\therefore$ $v_o = -5u_o$

$$\frac{1}{v_o}-\frac{1}{u_o}=\frac{1}{f_o} \quad \text{(Using lens formula for objective)}$$

$$\Rightarrow \frac{1}{-5u_o}-\frac{1}{u_o}=\frac{1}{1.25} \Rightarrow \frac{-6}{5u_o}=\frac{1}{1.25} \Rightarrow u_o = -1.5 \text{ cm}$$

$\because$ $v_0 = -5u_0$ so, $v_o = 7.5$ cm

Tube length $= v_o + |u_e| = 7.5$ cm $+ 4.17$ cm

$L = 11.67$ cm

Object should be placed at 1.5 cm distance from the objective lens.

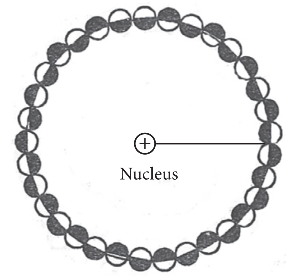
33. **(a)** According to de Broglie, a stationary orbit is that which contains an integral number of de Broglie waves associated with the revolving electron.

For an electron revolving in n^{th} circular orbit of radius r_n,

Total distance covered = Circumference of the orbit $= 2\pi r_n$

$\therefore$ For the permissible orbit, $2\pi r_n = n\lambda$

According to de-Broglie,



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

where v_n is speed of electron revolving in n^{th} orbit.

$\therefore$ $2\pi r_n = \dfrac{nh}{mv_n}$

or $mv_n r_n = \dfrac{nh}{2\pi} = n\left(\dfrac{h}{2\pi}\right)$

(b) For ground state, $n = 1$

$$E = \frac{-13.6}{n^2} = \frac{-13.6}{1^2} = -13.6 \text{ eV}$$

$\therefore$ K.E. $= -E = -(-13.6) = 13.6$ eV

$\because$ P.E. $= 2E$ $\therefore$ P.E. $= 2(-13.6) = -27.2$ eV

OR

$$\because \frac{mv^2}{r_n} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r_n^2} \quad \ldots\text{(i)}$$

$$\text{and } mvr_n = \frac{nh}{2\pi} \quad \ldots\text{(ii)}$$

From eqn. (i) and (ii)

$$\therefore r_n = \frac{\varepsilon_0 h^2 n^2}{\pi m e^2}$$

Total energy

$$E_n = \frac{1}{2}mv_n^2 - \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r_n} = \frac{1}{8\pi\varepsilon_0}\frac{e^2}{r_n} - \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r_n}$$

$$E_n = -\frac{1}{8\pi\varepsilon_0}\frac{e^2}{r_n} = -\frac{1}{8\varepsilon_0^2}\frac{me^4}{h^2n^2}$$

$$E_n = \frac{-Rhc}{n^2}$$

where Rydberg constant $R = \dfrac{me^4}{8\varepsilon_0^2 h^3 c}$

Energy emitted $\Delta E = E_i - E_f$

$$\Delta E = Rhc\left[\frac{1}{n_f^2}-\frac{1}{n_i^2}\right]$$

But $\Delta E = h\upsilon$

$$\upsilon = Rc\left[\frac{1}{n_f^2}-\frac{1}{n_i^2}\right] \text{ or } \upsilon = \frac{me^4}{8\varepsilon_0^2h^3}\left(\frac{1}{n_f^2}-\frac{1}{n_i^2}\right)$$

When electron in hydrogen atom jumps from energy state $n_i = 4$ to $n_f = 3, 2, 1$, the Paschen, Balmer and Lyman spectral series are found.

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