Code No. 042

Roll No. ☐☐☐☐☐☐☐

- Please check that this question paper contains **5** printed pages.
- Code number given on the right hand side of the question paper should be written on the title page of the answer-book by the candidate.
- Please check that this question paper contains **33** questions.
- **Please write down the Serial Number of the question before attempting it.**
- 15 minutes time has been allotted to read this question paper. The question paper will be distributed at 10.15 a.m. From 10.15 a.m. to 10.30 a.m., the students will read the question paper only and will not write any answer on the answer-book during this period.

PHYSICS–XII

Sample Paper (Solved)

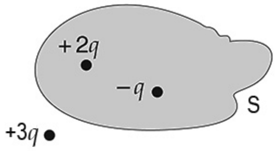
Time allowed : 3 hours *Maximum marks : 70*

General Instructions

SECTION-A

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

Q.1. Figure shows three point charges, + 2q, – q and +3q. Two charges +2q and –q are enclosed within a surface 'S'. What is the electric flux due to this configuration through the surface 'S'?



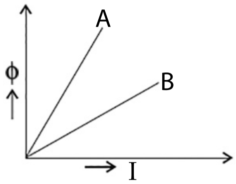
Q.2. Name the part of the electromagnetic spectrum of wavelength 10^{-2} m and mention its *one* application.

Or

Which part of electromagnetic spectrum has largest penetrating power?

Q.3. Using the concept of force between two infinitely long parallel current carrying conductors, define one ampere of current.

Q.4. A plot of magnetic flux (ϕ) versus current (I) is shown in the figure for two inductors A and B. Which of the two has larger value of self inductance?



Or

The instantaneous current and voltage of an a.c. circuit are given by

i = 10 sin 300 t A and V = 200 sin 300 t V.

What is the power dissipation in the circuit?

Q.5. Define ionisation energy. What is its value for a hydrogen atom?

Q.6. If the distance between the source of light and the cathode of a photo cell is doubled, how does it affect the stopping potential applied to the photo cell?

Q.7. Write any *two* characteristic properties of nuclear force.

Or

Two nuclei have mass numbers in the ratio 27 : 125. What is the ratio of their nuclear radii?

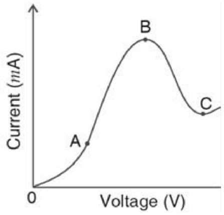
Q.8. What is the function of a photodiode?

Or

Why should a photodiode be operated at a reverse bias?

Q.9. Distinguish between 'intrinsic' and 'extrinsic' semiconductors.

Q.10. The graph shown in the figure represents a plot of current versus voltage for a given semiconductor. Identify the region, if any, over which the semi-conductor has negative resistance.



For questions number 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.

Q.11. *Assertion (A):* Total flux through a closed surface is zero, if no charge is enclosed by the surface.
Reason (R): Gauss law is true for any closed surface, no matter what its shape or size is?

Q.12. *Assertion (A):* The electric field inside a cavity is always zero.
Reason (R): charges reside only on the outer surface of a conductor with cavity.

Q.13. *Assertion (A):* The focal length of an equiconvex lens placed in air is equal to the radius of curvature of either face.
Reason (R): For an equiconvex lens, the radius of curvature of both the faces is the same.

Q.14. *Assertion (A):* Intensity pattern of interference and diffraction are not the same.
Reason (R): When there are few sources of light, then the result is called interference; but if there is a large number of them, the word diffraction is more often used.

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.

Q.15. **Electrostatic Potential & Potential Energy**

The electrostatic potential at a given point is defined as the "work done by an external force in bringing a unit positve charge from infinity to that point". A surface with a constant value of potential at all points is called **equipotential surface.**

The work done in bringing a charge 'q' from infinity to a given point in the external field is qv; and this work done is stored in the form of **potential energy,** which is denoted as P.E = $q\, v(r)$.

(*i*) Which of the following statement is true?

(*a*) Potential is the product of charge and work.
(*b*) Potential at a point is the work done per unit charge in bringing a charge from any point to infinity.
(*c*) Electrostatic force is non-conservative.
(*d*) Electrostatic force is a conservative force.

(*ii*) I volt is equivalent to

(*a*) $\frac{newton}{coulomb}$ (*b*) $\frac{newton}{second}$ (*c*) $\frac{joule}{coulomb}$ (*d*) $\frac{joule}{second}$

(*iii*) The work done in bringing a unit positive charge from infinite distance to a point at distance x from a positive charge Q is W. The potential ϕ at that point is

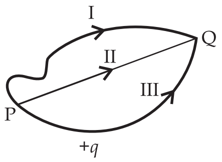
(*a*) W (*b*) $\frac{WQ}{x}$ (*c*) $\frac{W}{x}$ (*d*) WQ

(*iv*) **What is the angle between electric field and equipotential surface?**

(*a*) always 90° (*b*) always 0°

(*c*) 0° to 90° (*d*) 0° to 180°

(*v*) **Which among the following statements is true about the work done in bringing a unit positve charge from point P to Q in an electrostatic field?**



(*a*) Work done is same in all the three paths.

(*b*) Maximum work is done in case of path I.

(*c*) Minimum work is done is case of path II.

(*d*) Work done is zero in case of path II.

Q.16. **Phenomenon of Diffraction**

Diffraction is the general characteristic exhibited by all types of waves. Since the wavelength of light is much smaller than the dimensions of most obstacles, we do not encounter diffraction effects of light in everyday observations. Some scientists including Newton had noticed that the light spreads out from narrow holes and slits. It seems to turn around corners and enter regions, where we would expect a shadow. These effects known as **diffraction**, can only be properly understood using wave ideas.

At central point, central maximum is observed, while secondary maxima and minima can be observed on both sides of central point depending upon the phase difference.

(*i*) **A diffraction pattern is obtained using a beam of red light. What happens if the red light is replaced by blue light?**

(*a*) Bands disappear altogether.

(*b*) Diffraction bands become narrower and crowded together.

(*c*) Bands become broader and farther apart.

(*d*) No change.

(*ii*) **A parallel beam of light of wavelength 500 nm falls on a narrow slit and the resulting diffraction pattern is observed on a screen 1 m away. It is observed that the first minima is at a distance of 2.5 mm from the centre of the screen. The width of the slit is**

(*a*) 1 mm (*b*) 2 mm (*c*) 0.2 mm (*d*) 1.5 mm

(*iii*) **To observe diffraction, the size of the obstacle**

(*a*) should be much larger than the wavelength.

(*b*) should be $\lambda/2$, where λ is the wavelength.

(*c*) should be of the order wavelength.

(*d*) has no relation to wavelength.

(*iv*) **In a single slit diffraction experiment, the width of the slit is made double its original width. Then the central maximum of the diffraction pattern will become**

(*a*) narrower and brighter (*b*) narrower and fainter

(*c*) broader and fainter (*d*) broader and brighter

(*v*) **A slit of width *a* is illuminated by white light. The first minimum for red light (λ = 6500Å) will fall at θ = 30° when *a* will be**

(*a*) 6.5×10^{-4} mm (*b*) 3200 Å (*c*) 1.3 micron (*d*) 2.6×10^{-4} cm

SECTION-C

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

Q.17. Using Ampere's circuital law, obtain an expression for the magnetic field along the axis of a current carrying solenoid of length l and having N number of turns.

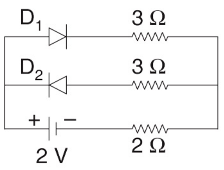
Q.18. State *one* feature by which the phenomenon of interference can be distinguished from that of diffraction. A parallel beam of light of wavelength 600 nm is incident normally on a slit of width '*a*'. If the distance between the slits and the screen is 0.8 m and the distance of 2nd order maximum from the centre of the screen is 15 mm, calculate the width of the slit.

Q.19. Two point charges q_1 and q_2 are located at $\vec{r_1}$ and $\vec{r_2}$ respectively in an external electric field $\vec{E}$. Obtained the expression for the total work done in assembling this configuration.

Or

Why does current in a steady state not flow in a capacitor connected across a battery? However momentary current does flow during charging or discharging of the capacitor. Explain.

Q.20. Assuming that the two diodes D1 and D2 used in the electric circuit shown in the figure are ideal, find out the value of the current flowing through 2 Ω resistor.



Q.21. Derive the expression for the self inductance of a long solenoid of cross sectional area A and length *l*, having *n* turns per unit length.

Q.22. (*a*) Why are coherent sources necessary to produce a sustained interference pattern?

(*b*) In Young's double slit experiment using mono-chromatic light of wavelength λ, the intensity of light at a point on the screen where path difference is λ, is K units.

Find out the intensity of light at a point where path difference is $\frac{2\lambda}{3}$.

Q.23. Explain, with the help of a circuit diagram, the working of a photo-diode. Write briefly how it is used to detect the opticals signals.

Q.24. Define the following using suitable diagrams: (*i*) magnetic declination and (*ii*) angle of dip. In which direction will a compass needle point when kept at the (*i*) poles and (*ii*) equator?

Or

A compass needle, free to turn in a vertical plane orients itself with its axis vertical at a certain place on the earth. Find out the values of (*i*) horizontal component of earth's magnetic field and (*ii*) angle of dip at the place.

Q.25. A ray of light is incident on a glass prism of refractive index and refractive angle A. If it just suffers total internal reflection at the other face, obtain an expression relating the angle of incidence, angle of prism and critical angle.

SECTION-D

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

Q.26. (*a*) Define self inductance. Write the S.I. units.

(*b*) Derive an expression for self inductance of a long solenoid of length *l*, cross-sectional area A having N number of turns.

Q.27. Prove that the current density of a metallic conductor is directly proportional to the drift speed of electrons.

Or

A number of identical cells *n*, each of emf ε, internal resistance *r* connected in series are charged by a d.c. source of emf ε_1, using a resistor R.

(*i*) Draw the circuit arrangement.

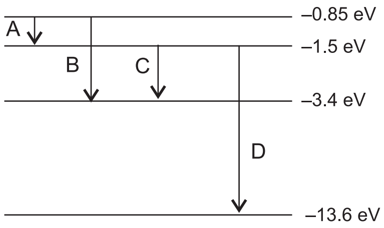
(*ii*) Deduce the expressions for (*a*) the charging current and (*b*) the potential difference across the combination of the cells.

Q.28. An electron and a photon each have a wavelength of 1.50 nm. find (*i*) their momenta, (*ii*) the energy of the photon and (*iii*) kinetic energy of the elctron.

Or

Draw a plot showing the variation of photoelectric current with collector plate potential for two different frequencies, $v_1 > v_2$, of incident radiation having the same intensity.
In which case will the stopping potential be higher? Justify your answer.

Q.29. The energy level diagram of an element is given. Identify, by doing necessary calculations, which transition corresponds to the emission of a spectral line of wavelength 102.7 nm.



Q.30. Distinguish between nuclear fission and fusion. Show how in both these processes energy is released. Calculate the energy release in MeV in the deuterium-tritium fusion reaction:

$${}_1^2\text{H} \rightarrow {}_1^3\text{H} \longrightarrow {}_2^4\text{H}e + n$$

Using the data:

$m\left({}_1^2\text{H}\right) = 2.014102\ u$ $\quad m\left({}_1^3\text{H}\right) = 3.016049\ u$

$m\left({}_2^4\text{He}\right) = 4.002603\ u$ $\quad m_n = 1.008665\ u$

$1u = 931.5\ \text{MeV}/c^2$

SECTION-E

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

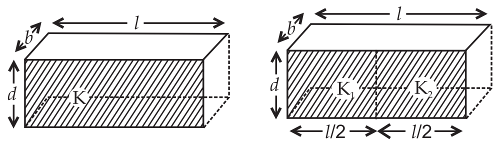
Q.31. Derive an expression for the energy stored in a parallel plate capacitor.

On charging a parallel plate capacitor to a potential V, the spacing between the plates is halved, and a dieletric medium of $\in_r = 10$ is introduced between the plates, without dis-connecting the d.c. source. Explain, using suitable expressions, how the (*i*) capacitance, (*ii*) electric field and (*iii*) energy density of the capacitor change.

Or

(*a*) Obtain the expression for the potential due to an electric dipole moment p at a point 'x' on the axial line.

(*b*) Two identical capacitors of plate dimensions $l \times b$ and plate separation d have di-electric slabs filled in between the space of the plates as shown in the figure.



Obtain the relation between the dielectric constants K, K_1 and K_2.

Q.32. (*a*) Prove that the current flowing through an ideal inductor connected across a.c. source, lags the voltage in phase by $\frac{\pi}{2}$.

(*b*) An inductor of self inductance 100 mH, and a bulb are connected in series with a.c. source of rms voltage 10 V, 50 Hz. It is found that effective voltage of the circuit is $\frac{\pi}{4}$. Calculate the inductance of the inductor used and average power dissipated in the circuit, if a current of 1 A flows in the circuit.

Or

(*a*) Prove that an ideal capacitor in an ac circuit does not dissipate power.

(*b*) An inductor of 200 mH, capacitor of 400 f and a resistor of 10 Ω are connected in series to ac source of 50 V of variable frequency. Calculate the

(*i*) angular frequency at which maximum power dissipation occurs in the circuit and the corresponding value of the effective current, and

(*ii*) value of Q-factor in the circuit.

Q.33. Trace the rays of light showing the formation of an image due to a point object placed on the axis of a spherical surface separating the two media of refractive indices n_1 and n_2. Establish the relation between the distances of the object, the image and the radius of curvature from the central point of the spherical surface.

Hence derive the expression of the lens marker's formula.

Or

(*a*) Consider two coherent sources S_1 and S_2 producing monochromatic waves to produce interference pattern. Let the displacement of the wave produced by S_1 be given by $Y_1 = a \cos \omega t$ and the displacement by S_2 be $Y_2 = a \cos(\omega t + \phi)$

Find out the expression for the amplitude of the resultant displacement at a point and show that the intensity at that point will be $I = 4a^2 \cos^2 \frac{\phi}{2}$

Hence establish the conditions for constructive and destructive interference.

(*b*) What is the effect on the interference fringes in Young's double slit experiment when (*i*) the width of the source slit is increased (*ii*) the monochromatic source is replaced by a source of white light?

❒ ❒ ❒ ❒

Answer Sheet

S	A	M	P	L	E							P	A	P	E	R		

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PHYSICS

SECTION – A

1. Electric flux = $\oint_S \vec{E}.\vec{dS}$

According to *Gauss' law*, $\phi = \oint_S \vec{E}.\vec{dS} = \dfrac{q_1}{\varepsilon_0}$ ...where [q_1 is the total charge enclosed by the surface S

$\phi = \dfrac{2q - q}{\varepsilon_0} = \dfrac{q}{\varepsilon_0}$ $\therefore$ **Electric flux,** $\phi = \dfrac{q}{\varepsilon_0}$

2. ***Name of the part:*** Microwave

Applications:

(*i*) It is used in radar communication.

(*ii*) It is used in microwave ovens.

(*iii*) It is also used in analysis of fine details of molecular and atomic structure.

Or

γ-rays are the electromagnetic waves of frequency range 3×10^{18} Hz to 5×10^{22} Hz and have the highest penetrating power.

3. $F = \dfrac{\mu_0}{2\pi}\dfrac{I_2 I_2}{r}$

"One ampere of current is the value of steady current, which when maintained in each of the two very long, straight, parallel conductors of negligible cross-section; and placed one metre apart in vacumm, would produce on each of these conductors a force of equal to 2×10^{-7} newtons per metre (Nm^{-1}) of length."

4. Since $\phi = LI$ $\therefore$ $L = \dfrac{\phi}{I}$ = slope

Slope of A is greater than slope of B.

∴ **Inductor A** has larger value of self inductance than inductor B.

Or

$P = I_{rms}V_{rms} \cos \phi$

$\cos \phi = 1$ $\therefore$ $\phi = 0°$

$P = \dfrac{I_0}{\sqrt{2}} \times \dfrac{V_0}{\sqrt{2}} = \dfrac{1}{2} I_0 V_0$ $\therefore$ $\mathbf{P} = \dfrac{1}{2} \times 10 \times 200 = \mathbf{1{,}000W}$

5. ***Ionisation energy.*** The energy required to knock out an electron from an atom is called ionisation energy of the atom.

For hydrogen atom it is **13.6eV.**

6. Stopping potential remains ***unchanged***, if the distance between the light source and cathode is doubled.

7. (*i*) Nuclear forces are strongest forces in nature.
(*ii*) Nuclear forces are charge independent.

Or

$$\frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{27}{125}\right)^{1/3} = \frac{3}{5}$$

∴ Ratio of their nuclear radii = **3 : 5**

8. A photodiode is a special purpose p-n junction diode fabricated with a transparent window to allow light to fall on diode. It is operated under reverse bias.

Or

As fractional change in minority charge carriers is more than the fractional change in majority charge carriers, the variation in reverse saturation current is more prominent.

9.

'Intrinsic' semiconductors	*'Extrinsic' semiconductors*
1. Without any impurity atoms.	1. Doped with trivalent/pentavalent impurity atoms.
2. $n_e = n_h$	2. $n_e \neq n_h$

10. Between the region B and C, the semiconductor has a negative resistance.

11. (*b*) Both A and R are true but R is NOT the correct explanation of A.
[Hint: Gauss law implies that the total electric flux through a closed surface is zero, if no change is enclosed by the surface and it is true for any closed surface, independent its it shape and size.

12. (*a*) Both A and R are true and R is the correct explanation of A.

13. (*a*) Both A and R are true and R is the correct explanation of A.
[Hint: For an equiconvex lens, $R_1 = R_2 = R$. From $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$; for lens $\mu = 1.5$, $f = R$

14. (*b*) Both A and R are true but R is NOT the correct explanation of A.

SECTION – B

15. (*i*) (*d*) Electrostatic force is a conservative force.
(*ii*) (*c*) $\frac{joule}{coulomb}$
(*iii*) (*a*) *W*
(*iv*) (*a*) always 90° ***[Hint: Electric field is always perpedicular to the equipotential surface at any point.***
(*v*) (*a*) Work done is same in all the three paths.
[Hint: Work done on a unit charge +q by the electrostatic field due to any given charge configuration is independent of the path.

16. (*i*) (*b*) Diffraction bands become narrower and crowded together.
[Hint: As $\lambda_{blue} < \lambda_{red}$, and width of diffraction bands is directly proportional to λ, hence diffraction bands become narrower and crowded.
(*ii*) (*a*) 0.2 mm
(*iii*) (*c*) should be of the order wavelength.
(*iv*) (*a*) narrower and brighter ***[Hint: Angular width of central maximum is given by $2\lambda/a$.***
(*v*) (*c*) 1.3 micron
[Hint: For first minimum; $a \sin\theta = 1$; $\lambda a = \frac{\lambda}{\sin\theta} = \frac{6.5 \times 10^{-7}}{\sin 30°} = 13 \times 10^{-7} = 1.3$ micron

SECTION – C

17. **Magnetic field due to Solenoid**
Let length of solenoid = L; Total number of turns in solenoid = N

No. of turns per unit length = $\frac{N}{L} = n$

ABCD is an Ampere's loop

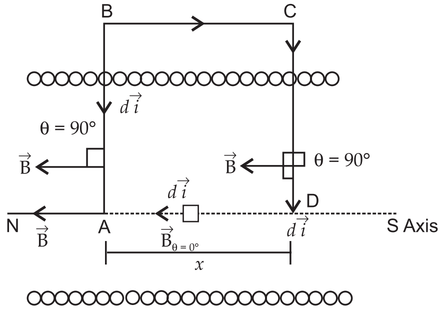
AB, DC are very large.

BC is in a region of $\vec{B} = 0$

AD is a long axis.

Length of AD = x

Current in one turn = I_0



Applying Ampere's circuital loop, $\oint \vec{B}.\vec{dl} = \mu_0 I$

$$\textbf{L.H.S.} = \int_A^B \vec{B}.\vec{dl} + \int_B^C \vec{B}.\vec{dl} + \int_C^D \vec{B}.\vec{dl} + \int_D^A \vec{B}.\vec{dl}$$

$$= 0 + 0 + 0 + \int_D^A \vec{B}.\vec{dl} \quad ...[\because (\theta = 90^o)\ (\because \vec{B} = 0)\ (\because \theta = 90^o)\ (\because \theta = 0^o)$$

$$= \vec{B}.\int_D^A \vec{dl} = B\int_D^A dl\cos\theta = B\int_D^A dl = B[l]_0^x = Bx$$

No. of turns in x length = nx, Current in turns nx, I = $nx\, I_0$

According to Ampere's circuital law, $Bx = \mu_0 I$

$\Rightarrow Bx = \mu_0\, nx\, I_0$ $\therefore$ $\mathbf{B = \mu_0\, nI_0}$

18. (*i*) In interference all the maxima are of equal intensity. In diffraction pattern central fringe is of maximum intensity while intensity of secondary maxima falls rapidly.

(*ii*) **Given:** $\lambda = 600$ nm $= 6 \times 10^{-7}$ m, D = 0.8 m, $\gamma_2 = 15 \times 10^{-3}$ m

To calculate: Width of the slit 'd'.

Calculations: $\gamma_2 = \frac{5}{2} \times \frac{\lambda D}{d}$

$\Rightarrow d = \frac{5}{2} \times \frac{6 \times 10^{-7} \times 0.8}{15 \times 10^{-3}}$ $\therefore$ Distance, $d = 8 \times 10^{-5} = \mathbf{80\ \mu m}$

19. Work done in bringing the charge q_1 from infinity to position r_1, $W_1 = q_1 V(r_1)$.

Work done in bringing charge q_2 to the position r_2, $W_2 = q_2 V(r_2) + \frac{q_1 q_2}{4\pi\varepsilon_0 r_{12}}$.

Hence, total work done in assembling the two charges,

$$W = W_1 + W_2 = \mathbf{q_1 V(r_1) + q_2 V(r_2) + \frac{q_1 q_2}{4\pi\varepsilon_0 r_{12}}}$$

Or

In the steady state, the displacement current and hence the conduction current, is zero as $|\vec{E}|$ between the plates, is constant.

During charging and discharging, the displacement current and hence the conduction current is non zero as $|\vec{E}|$ between the plates, is changing with time.

20. D_1 will conduct current while D_2 will not allow. Hence R = 3 Ω + 2 Ω = 5 Ω

As such, 2 Ω with D_1 and 2 Ω are in series, the net resistance of the circuit will be

3 Ω + 2Ω = 5 Ω $\therefore$ $I = \frac{2V}{5\Omega} = 0.4$ A

$\therefore$ **Value of the current flowing through 2 Ω resistor = 0.4 A**

21. ***Self-induction of a long solenoid:*** Consider a long solenoid of length l and radius r with $r << l$ and having n turns per unit length. If a current I flows through the coil, then the magnetic field inside the coil is almost constant and is given by $B = \mu_0 nI$.

Magnetic flux linked with each turn, $BA = \mu_0 nIA$

...where [n = number of turns per unit length, I = current flowing

When $A = \pi r^2$ = the cross-sectional area of the solenoid

$\therefore$ Magnetic flux linked with the entire solenoid is $\phi = \mu_0 nIA \times nl = \mu_0 n^2 IAl$. But $\phi = LI$.

$\therefore$ **Self inductance of the long solenoid is, $L = \mu_0 n^2 Al$**

22. (*a*) Coherent sources have a constant phase difference and, therefore, produce a sustained interference pattern. These sources are needed to ensure that the position of maxima and minima do not change with time.

(*b*) $I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$

Let I_0 be the intensity of either source, then

$$I_1 = I_2 = I_0 \text{ and } I = 2I_0(1 + \cos\phi) = 4I_0\cos^2\frac{\phi}{2}$$

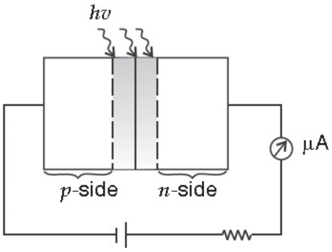
When $p = \lambda$, $\phi = 2\pi$, then $I = 4I_0 \cos^2\phi/2 = 4I_0\cos^2\pi = 4I_0 = K$

When $P = \frac{2\pi}{3}$, $\phi = \frac{4\pi}{3}$

$$I = 4I_0\cos^2\frac{2\pi}{3} = 4I_0\left(\cos\left(\pi - \frac{\pi}{3}\right)\right)^2$$

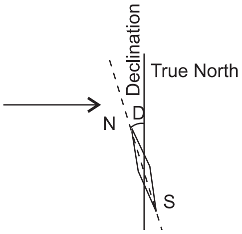
$$\Rightarrow \quad I = 4I_0\left(-\cos\frac{\pi}{3}\right)^2 = I_0 \qquad \therefore \quad \mathbf{I = \frac{K}{4}} \qquad ...[\because 4I_0 = K$$

23. ***Working of a photo-diode:*** Its working is based on photo conduction from light. The conductivity of *p-n* junction photodiode increases with the increase in intensity of light falling in it. When visible light of energy greater than forbidden energy gap (*i.e.* $h\nu > E_g$) is incident on a reverse biased *p-n* junction photodiode, additional electron-hole pairs are created in the depletion layer (or near the junction) due to the absorption of photons. The charge carriers will be separated by the junction field and made to flow across the junction, creating reverse current across the junction. The value of reverse saturation current increases with increase in the intensity of incident light. It is found that the reverse saturation current through the photodiode varies almost linearly with the light flux.



When the photodiode is reverse biased then a certain current exists in the circuit even when no light is incident on the *p-n* junction of photodiode. This current is called dark current. A photodiode can turn its current ON and OFF in nanoseconds. Hence it can be used to detect the optical signals.

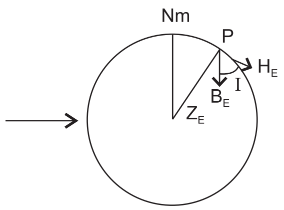
24. **Magnetic declination:** Angle between magnetic meridian and geographical meridian.



Angle of dip. It is the angle which the magnetic needle makes with the horizontal in the magnetic merdian.

(*i*) Direction of compass needle is **vertical** to the earth's surface **at poles.**

(*ii*) **Parallel** to the earth's surface **at equator**.



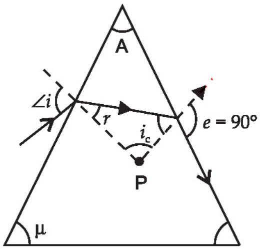
Or

Since, the compass needle is oriented vertically—

(*i*) Horizontal component of earth's magnetic field will be zero.

(*ii*) The value of angle of dip at that place will be 90°.

25. $\mu = \dfrac{\sin i}{\sin r}$ $\quad\ldots\left[\begin{array}{l}\because \angle i = \angle i_c \\ \angle r = \angle i_e \\ \angle e = 90^\circ;\ \sin 90^\circ = 1\end{array}\right.$



and $\dfrac{1}{\mu} = \dfrac{\sin i_c}{\sin r_e}$

$\angle A + \angle P = 180^\circ$ and $\angle r + \angle i_c = 180^\circ - \angle P = \angle A$

$\Rightarrow \angle r = \angle A - \angle i_c \qquad \Rightarrow \mu = \dfrac{\sin i}{\sin(A - i_c)} \qquad \therefore \qquad \dfrac{1}{\sin i_c} = \dfrac{\sin i}{\sin(A - i_c)}$

SECTION – D

26. (*a*) **Self-inductance of a coil**

Since flux $\phi = LI$

emf induced $\varepsilon = -\dfrac{d\phi}{dt} = -L\dfrac{dI}{dt}$ **...where[L is coefficient of self-induction or self inductance**

Self inductance is numercially equal to the magnetic flux linked with the coil when unit current passes through it. Its S.I. unit is **henry.**

(*b*) Consider a long solenoid of length l and radius r with $r << l$ and having n turns per unit length. If a current I flows through the coil, then the magnetic field inside the coil is almost constant and is given by $B = \mu_0 nI$.

Magnetic flux linked with each turn $BA = \mu_0 nIA$

...where[$A = \pi r^2$ = cross-sectional area of the solenoid

∴ Magnetic flux linked with the entire solenoid is

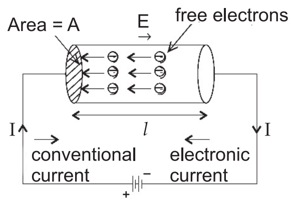
ϕ = Flux linked with turn × Total number of turns $= \mu_0 nIA \times nl = \mu_0 n^2 IAl$

But $\phi = LI$

∴ Self-inductance of the long solenoid is $L = \mu_0 n^2 lA$

If N is the total number of turns in the solenoid then $n = \dfrac{N}{l}$. $\qquad \therefore\ L = \dfrac{\mu_0 N^2 A}{l}$

27. Suppose a potential difference V is applied across a conductor of length l and of uniform cross-section A. The electric field E set up inside the conductor is given by



$E = \dfrac{V}{l}$

Under the influence of field $\vec{E}$, the free electrons begin to drift in the opposite direction $\vec{E}$ with an average drift velocity v_d.

Let the number of electrons per unit volume or electron density = n

Charge on an electron = e

No. of electrons in length l of the conductor = n × volume of the conductor = $n \times Al$

Total charge contained in length l of the conductor, $q = enAl$ ...(*i*)

All the electrons which enter the conductor at the right end will pass through the conductor at the left end is time, $t = \dfrac{distance}{velocity} = \dfrac{l}{v_d}$ ...(*ii*)

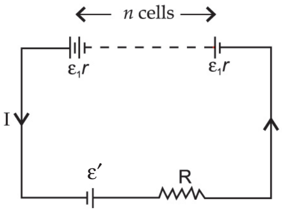
Current $I = \dfrac{q}{t} = \dfrac{lneA}{l/v_d} = neAv_d$ **...[From (*i*) & (*ii*)**

Current density, $J = \dfrac{I}{A} = \dfrac{neAv_d}{A} = nev_d \qquad \therefore \qquad \mathbf{J} \propto v_d$

Hence current density of a metallic conductor is directly proportional to the drift speed of electrons.

Or

(*i*) The circuit arrangement for charging n cells is shown here.



(*ii*) (*a*) Net emf = $\varepsilon' - n\varepsilon$

Total resistance = $R + nr$

Charging current, $I = \dfrac{Net\ emf}{Total\ Resistance} = \dfrac{\varepsilon' - n\varepsilon}{R + nr}$

(*b*) P.D. across each cell = $\varepsilon + Ir$

$$= \varepsilon + \frac{\varepsilon' - n\varepsilon}{R + nr}.r = \frac{\varepsilon R + \varepsilon nr + \varepsilon' r - \varepsilon nr}{R + nr} = \frac{\varepsilon R + \varepsilon' r}{R + nr}$$

∴ **P.D.** across the series combination of n cells, $\mathbf{V = n(\varepsilon + Ir)}$.

28. (*i*) ***Momenta,*** $p = \dfrac{h}{\lambda} = \dfrac{6.63 \times 10^{-34}}{1.5 \times 10^{-9}}$ = $\mathbf{4.42 \times 10^{-25}\ kg\ ms^{-1}}$

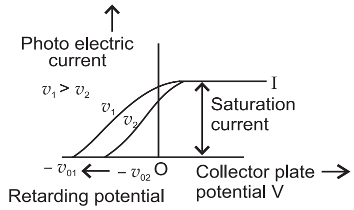
(*ii*) ***Energy,*** $E = \dfrac{hc}{\lambda} = \dfrac{(6.63 \times 10^{-34}) \times (3 \times 10^{8})}{(1.5 \times 10^{-9}) \times (1.6 \times 10^{-19})} = \dfrac{19.89 \times 10^{-26}}{2.40 \times 10^{-28}} = 8.2875 \times 10^{2} = \mathbf{828.75\ eV}$

(*iii*) ***Kinetic energy,*** $E_K = \dfrac{1}{2}\dfrac{p^2}{m} = \dfrac{1}{2} \times \dfrac{(4.42 \times 10^{-25})^2}{(9 \times 10^{-31}) \times (1.6 \times 10^{-19})}$

$$= \frac{1}{2} \times \frac{19.54 \times 10^{-50}}{14.4 \times 10^{-50}} = \frac{19.54 \times 10^{-50}}{28.8 \times 10^{-50}} = \mathbf{0.678 = 0.68\ eV}$$

Or

Stopping potential is directly proportional to the frequency of incident radiation. The stopping potential is more negative for higher frequencies of incident radiation. Therefore, stopping potential is higher in υ_1.



29. Here λ = 102.7 nm = 102.7×10^{-9}m

The energy of the emitted photon is,

$$E = \frac{hC}{\lambda} = \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{102.7 \times 10^{-9}} = \frac{19.878 \times 10^{-26}}{102.7 \times 10^{-9}} = 1.9355 \times 10^{-18}\,J$$

∴ Energy corresponds = $\dfrac{1.9355 \times 10^{-18}}{1.6 \times 10^{-19}}$eV = 12.097 eV ≈ **12.1 eV**

This energy corresponds to the transition D for which the energy change

= –1.5 – (–13.6) = **12.1 eV**

30. (*a*) The breaking of heavy nucleus into smaller fragments is called **nuclear fission**; while the joining of lighter nuclei to form a heavy nucleus is called **nuclear fusion**.

(*b*) Binding energy per nucleon of the daugher nuclei, in both processess, is more than that of the parent nuclei. The difference in binding energy is released in the form of energy. In both processes some mass gets converted into energy.

(*c*) **Energy released:** $Q = \left[m\left({}^2_1H\right) + m\left({}^3_1H\right) - m\left({}^4_2He\right) - m(n)\right] \times 931.5$ MeV

= [2.014102 + 3.016049 – 4.002603] – 1.008665] × 931.5 MeV

= 0.018883 × 931.5 MeV = **17.59 MeV**

SECTION – E

31. (*a*) Consider a parallel plate capacitor with plate area '*A*' and separation between the plates equal to '*d*'. Suppose at any instant of time charge on the capacitor plate is '*q*' and potential difference due to this charge is '*v*'. To supply a charge '*dq*' further to the capacitor amount of work required is

$dW = Vdq$ or $dW = \frac{q}{c}\,dq$ ...[$\because$ $q = Cv$

In order to supply a charge 'Q',

Work required, $W = \frac{1}{C}\int_0^Q q\,dq$ $\Rightarrow$ $W = \frac{1Q^2}{2C}$

Thus energy stored by capacitor is, $U = \frac{1Q^2}{2C}$

(*b*) (*i*) $C_f = \frac{K\varepsilon_0 A}{d'} = \frac{K\varepsilon_0 A}{d/2}$ ...[$\because$ $d' = d/2$

$C_f = \frac{20\varepsilon_0 A}{d} = 20C_i$ ...[$\because$ $C_i = \frac{\varepsilon_0 A}{d}$

$\therefore$ ***Capacitance becomes 20 times.***

(*ii*) $E_f = \frac{V}{d'} = \frac{V}{d/2}$ ...[$\because$ $d' = d/2$

$E_f = 2\frac{v}{d} = 2E_i$ ...[$\because$ $E_i = V/d$

$\therefore$ ***Electric field is doubled.***

(*iii*) Energy density,

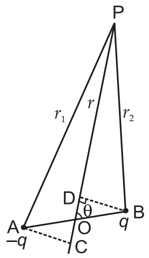
$$U_f = \frac{1}{2}\frac{\sigma^2}{\varepsilon_0} = \frac{1}{2}\varepsilon_0\left(\frac{\sigma}{\varepsilon_0}\right)^2 = \frac{1}{2}\varepsilon_0(E_i)^2$$

$U_f = \frac{1}{2}\varepsilon_r\varepsilon_0 E_f{}^2$ or $U_f = \frac{10}{2}\varepsilon_0(2E_i)^2$ ...[$\because$ $E_i = \sigma/\varepsilon_0$

$$\therefore \quad U_f = 40\left(\frac{1}{2}\varepsilon_0 E_i{}^2\right) = \mathbf{40\ Ui}$$

So energy density is 40 times.

Or



(*a*) ***Potential at a point due to an electric dipole:*** Let us consider an electric dipole consisting of two equal and opposite charges – q at A and + q at B, separated by a distance 2 l with centre at O. We have to calculate potential at a point P, whose polar co-ordinates are (r, θ), *i.e.*, OP = r and ∠BOP = θ, as shown in the figure.

Here AP = r_1 and BP = r_2, we can easily calculate potential as P due to point charges at A and B using $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$.

$$V_1 = \frac{1}{4\pi\varepsilon_0}\times\frac{(-q)}{r_1} \text{ and } V_2 = \frac{1}{4\pi\varepsilon_0}\times\frac{q}{r_2}$$

Total potential at P due to both the charges of the dipole is given by

$$V = V_1 + V_2$$

That is, $V = \frac{q}{4\pi\varepsilon_0}\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$ ...(*i*)

To put this result in a more convenient form, we draw normals from A and B on the line joining O and P. From ΔBOD, we note that OD = l cos θ and from ΔOAC we note that OC = l cos θ. For a small dipole (AB << OP), from the figure, we can take PB = PD and PA = PC.

Hence $r_1 = r + l\cos\theta$, $r_2 = r - l\cos\theta$

Using these results in equation (*i*), we get

$$V = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{(r - l\cos\theta)} - \frac{1}{(r + l\cos\theta)}\right] = \frac{q}{4\pi\varepsilon_0}\left[\frac{2(l\cos\theta)}{(r^2 - l^2\cos^2\theta)}\right] = \frac{q\times 2(l\cos\theta)}{4\pi\varepsilon_0 r^2}$$

where we have neglected the term containing second power of l since $l << r$.

In terms of dipole ($p = q \times 2l$), we can express this result as $V = \frac{p\cos\theta}{4\pi\varepsilon_0 r^2}$ ...(*ii*)

This result shows that unlike the potential due to a point charge, the potential due to a dipole is inversely proportional to the square of the distance.

Let us now consider its special cases.

Special Cases:

Case I: When point P lies on the axial line of the dipole on the side of positive charge,

$\theta = 0$ and $\cos\theta = 1$

Then equation (*ii*) reduces to

$$V_{AXIS} = \frac{p}{4\pi\varepsilon_0 r^2} \quad ...(iii)$$

Case II: When point P lies on the axial line of the dipole but on the side of negative charge,

$\theta = 180^o$ and $\cos\theta = 1$

Then $V_{AXIS} = -\frac{p}{4\pi\varepsilon_0 r^2}$ ...(*iv*)

Case III: When point P lies on the equatorial line of the dipole (perpendicular bisector of AB), $\theta = 90^o$ and $\cos\theta = 0$

Then $V_{equatorial} = 0$

Thus, electric potential due to a dipole is zero at every point on the equatorial line of the dipole.

(*b*) In first case , $C_1 = \frac{\varepsilon_0 K \times (l \times b)}{d}$ ...(*i*)

In second case, these two apartments are in parallel, their net capacity would be the sum of two individual capacitances

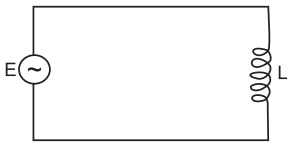
$$C_2 = C_2' + C_2'' = \frac{\varepsilon_0 K_1\left(\frac{l}{2}\times b\right)}{d} + \frac{\varepsilon_0 K_2\left(\frac{l}{2}\times b\right)}{d} \quad ...(ii)$$

Since these are identical capacitors, comparing (*i*) and (*ii*),

We have $C_1 = C_2$

$$\frac{\varepsilon_0 K(l\times b)}{d} = \varepsilon_0\frac{(l\times b)}{d}\left(\frac{K_1+K_2}{2}\right) \quad \therefore \quad K = \mathbf{\frac{K_1+K_2}{2}}$$

32. (*a*) induced emf, $e = -L\frac{dI}{dt}$



Hence net voltage in the circuit $= \left(V - L\frac{dI}{dt}\right)$

According to Kirchhoff's Rule, $V - L\frac{dI}{dt} = 0$

$$V_m \sin\omega t = L\frac{dI}{dt}$$

$$\int_0^l dI = \int_0^\omega \frac{V_m}{L}\sin\omega t\, dt$$

$$I = -\frac{V_m}{\omega L}\cos\omega t = \left(\frac{V_m}{\omega L}\right)\sin\left(\omega t - \frac{\pi}{2}\right) \quad ...\left[\because \frac{V_m}{\omega L} = I_m\right.$$

$$\therefore \quad I = I_m \sin\left(\omega t - \frac{\pi}{2}\right)$$

(*b*) **Given:** L = 100 mH = 100 × 10^{-3} H, V_{rms} = 10 V, Frequency = 50 Hz, $\phi = \frac{\pi}{4}$, I = 1 A

Average power dissipation,

$$P = V_{rms} I_{rms} \cos\phi = 10 \times 1 \times \cos\frac{\pi}{4}$$

$$= \frac{10}{\sqrt{2}} W = \mathbf{5\sqrt{2} Watts} \qquad ...\left[\because \cos\frac{\pi}{4} = \frac{1}{\sqrt{2}}\right.$$

Or

(*a*) Power dissipated in AC circuit is given by (P) = $V_{rms} I_{rms} \cos\phi$ **...where [cos** $\phi = \frac{R}{Z}$

For an ideal capacitor, R = 0, $\cos\phi = \frac{R}{Z} = 0$

$P = V_{rms} I_{rms} \times (0) = 0$ (zero)

i.e., power dissipated in an ideal capacitor is zero.

(*b*) **Given.** L = 200 mH, C = 400 μF, R = 10 Ω, V = 50 V

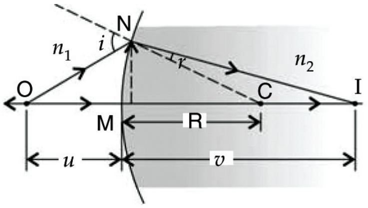
(*i*) angular frequency $(W_0) = \frac{1}{\sqrt{LC}}$

$$= \frac{1}{\sqrt{(200\times10^{-3})\times(400\times10^{-6})}} = \frac{1}{\sqrt{8\times10^{-5}}} = \frac{10^3}{\sqrt{80}} = \frac{1000}{8.9} = \mathbf{112\ s^{-1}}$$

Corresponding value of current (I) = $\frac{V}{R} = \frac{50}{10}$ = **5A**

(*ii*) Q factor (Q) = $\frac{1}{R}\sqrt{\frac{L}{C}} = \frac{1}{10}\frac{\sqrt{200\times10^{-3}}}{\sqrt{400\times10^{-6}}} = \sqrt{\mathbf{5}}$

33. For small angles,



$\tan\angle NOM = \frac{MN}{OM}$ $\tan\angle NCM = \frac{MN}{MC}$

$\tan\angle NIM = \frac{MN}{MI}$

Now, for ΔNOC, *i* is exterior angle

∴ $i = \angle NOM + \angle NCM$

$$i = \frac{MN}{OM} + \frac{MN}{OM} \qquad ...(i)$$

Similarly, $r = \angle NCM - \angle NIM$

$$i.e., \ r = \frac{MN}{MC} - \frac{MN}{MI} \qquad ...(ii)$$

Now by Snell's law,

$n_1 \sin i = n_2 \sin r$ or for small angles $n_1 i = n_2 r$

Substituting the values of *i* and *r* from equations (*i*) and (*ii*), we get $\frac{n_1}{OM} + \frac{n_2}{MI} = \frac{n_2 - n_1}{MC}$ ...(*iii*)

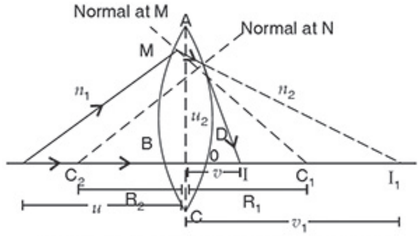
By applying Cartesian sign convention,

OM = –*u*, MI = –*v*, MC = +R

Substituting these values in (*iii*), we get $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$

This equation gives us a relation between object and image distance in terms of refractive index of the medium and the radius of the curvature of the curved spherical surface. It holds for any curved spherical surface.

Lens maker's formula: Consider a thin double convex lens of refractive index n_2 placed in a medium of



Refraction through a double convex lens refractive index n_1. Here, $n_1 < n_2$. Let B and D be the poles, C_1 and C_2 be the centres of curvature and R_1 and R_2 be the radii of curvature of the two lens surfaces ABC and ADC, respectively.

For ***refraction at surface ABC,*** we can write the relation between the object distance u, image distance v_1 and radius of curvature R_1 as

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

For ***refraction at surface ADC,*** we can write the relation between the object distance v_1, image distance v and radius of curvature R_2, as

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

Adding equations (i) and (ii), we get

$$\frac{n_1}{v} - \frac{n_1}{u} = (n_2 - n_1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \Rightarrow \frac{1}{v} - \frac{1}{u} = \left[\frac{n_2 - n_1}{n_1}\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \quad \text{...}(iii)$$

If the object is placed at infinity ($u = \infty$), the image will be formed at the focus *i.e.*, $v = f$,

$$\therefore \quad \frac{1}{f} = \left[\frac{n_2}{n_1} - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \quad \text{...}(iv)$$

$$\frac{1}{f} = [n_{2i} - 1]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

This is lens maker's formula.

Or

(a) The resultant displacement will be $\vec{y} = \vec{y_1} + \vec{y_2}$.

$y_1 = a \cos \omega t$ and $y_2 = a \cos(\omega t + \phi)$

$$y = y_1 + y_2 = a[\cos \omega t + \cos(\omega t + \phi)] = 2a \cos\left(\frac{\phi}{2}\right) \cos\left(\omega t + \frac{\phi}{2}\right)$$

The resultant amplitude is $A = 2a \cos\left(\frac{\phi}{2}\right)$ and hence intensity (I) = $\mathbf{4a^2 \cos^2}\left(\frac{\phi}{2}\right)$

Conditions:

For constructive interference—

$\phi = 0, \pm 2\pi, \pm 4\pi$ .... the intensity will be maximum, *i.e.*, $\phi = 2n\pi$ **...where [n = 1, 2, ...**

For destructive interference—

$\phi = \pm \pi, \pm 3\pi, \pm 5\pi$ .... the intensity will be zero, *i.e.*, $\phi = (2n + 1)\pi$ **...where [n = 1, 2,....**

(b) (i) **When width of the source slit is increased,** then the angular fringe width remains unchanged, but fringes become less and less sharp, so visibility of fringes decreases. If the condition $\frac{s}{S} < \frac{\lambda}{d}$ is not satisfied, the interference pattern disappears.

(ii) **When the monochromatic source is replaced by a source of white light**, the interference pattern due to different component colours of white light overlap (incoherently). The central bright fringes for different colours are at the same position. Therefore, the central fringe is white. For a point P for which $S_2P - S_1Q = \lambda_b/2$, where λ_b ($\approx$ 4000 Å) represents the wavelength for the blue colour, the blue component will be asbent and the fringe will appear red in colour. Slightly farther away where $S_2Q - S_1Q = \lambda_b = \lambda_r/2$ where λ_r ($\approx$ 8000 Å) is the wavelength for the red colour, the fringe will be predominantly blue.

Thus, the fringe closest on either side of the central white fringe is red and the farthest will appear blue. After a few fringes, no clear fringe pattern is seen.

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