Code No. **042**

Roll No. ☐☐☐☐☐☐☐

- Please check that this question paper contains **6** 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 **34** 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.

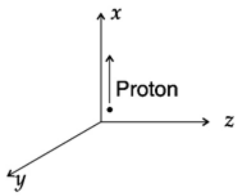
Q.1. Why do the electric field lines not form closed loops?

Q.2. A plane electromagnetic wave travels in vacuum along *z*-direction. What can you say about the direction of electric and magnetic field vectors?

Or

How are radio waves produced?

Q.3. A beam of protons projected along +*x*-axis, experiences a force due to a magnetic field along the –*y*-axis. What is the direction of the magnetic field?



Q.4. A long straight current carrying wire passes normally through the centre of a circular loop. If the current through the wire increases, will there be an induced emf in the loop? Justify.

Or

For an ideal inductor, connected across a sinusoidal ac voltage source, state which one of the following quantity is zero:

(*i*) Instantaneous power

(*ii*) Average power over full cycle of the ac voltage source

Q.5. Find the ratio of energies of photons produced due to transition of an electron of hydrogen atom from its:

(*i*) second permitted energy level to the first level, and

(*ii*) the highest permitted energy level to the first permitted level.

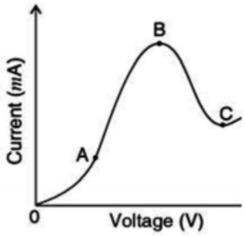
Q.6. Show graphically, the variation of the de-Broglie wavelength (λ) with the potential (V) through which an electron is accelerated from rest.

Q.7. Two nuclei have mass numbers in the ratio 1 : 2. What is the ratio of their nuclear densities?

Or

Two nuclei have mass numbers in the ratio 1 : 8. What is the ratio of their nuclear radii?

Q.8. 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 semiconductor has a negative resistance.



Or

Distinguish between 'intrinsic' and extrinsic' semiconductors.

Q.9. Write the special purpose *p-n* junction diodes.

Q.10. Define forward biasing and reverse biasing of *p-n* junction.

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):* When a body acquires negative charge, its mass decreases.
Reason (R): A body acquires negative charge, when its loses electrons.

Q.12. *Assertion (A):* If the distance between the parallel plates of a capacitor is halved, then the capacitance is doubled.
Reason (R): The capacitance depends on the introduced dielectric.

Q.13. *Assertion (A):* A convex lens of glass (μ = 1.5) behaves as a diverging lens, when immersed in carbon disulphide of higher refractive index (μ = 1.65).
Reason (R): A diverging lens is thinner in the middle and thicker at the edges.

Q.14. *Assertion (A):* When a plane wave passes through a thin prism, emerging wavefront gets tilted.
Reason (R): Speed of light is less in glass than in air.

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. **Electric Current & Resistance**

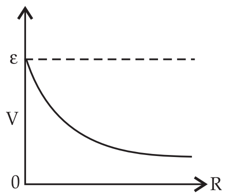
A simple device to maintain a steady current in an electrical circuit is the simple cell. When no current is drawn from the cell, the electrolyte has the same potential throughout, and the potential difference called electromotive force (emf) is denoted by e. It may be noted that emf is actually a potential difference, and **not** a force.

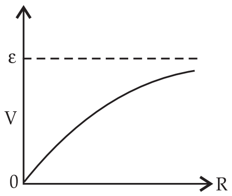
The electrolyte, through which current flows has a finite resistance '*r*' called the internal resistance. The actual value of internal resistance of cells vary from cell to cell. The resistances can be grouped in series and parallel combinations.

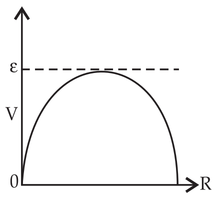
(*i*) The direction of the flow of current through electric circuit is

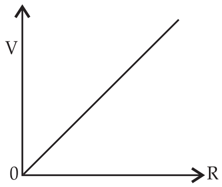
(*a*) from low potential to high potential. (*b*) from high potential to low potential.
(*c*) does not depend upon potential value. (*d*) current cannot flow through circuit.

(*ii*) A cell having an emf ε and internal resistance *r* is connected across a variable external resistance *R*. As the resistance *r* is increased, the plot of potential difference *V* across *R* is given by

(*a*)


(*b*)


(*c*)


(*d*)


(*iii*) **In a circuit, a cell with internal resistance r is connected to an external resistance R. The condition for the maximum current drawn from the cell is**

(*a*) $R = r$ (*b*) $R < r$ (*c*) $R > r$ (*d*) $R = 0$

(*iv*) **If n cells each of emf ε and internal resistance r are connected in parallel, the total emf and internal resistances will be**

(*a*) $\varepsilon, \frac{r}{n}$ (*b*) ε, nr (*c*) $n\varepsilon, \frac{r}{n}$ (*d*) $n\varepsilon, nr$

(*v*) **Given Figures (*a*) and (*b*) both show the variation of resistivity (ρ) with temperature (T) for some materials. Identify the type of the materials.**

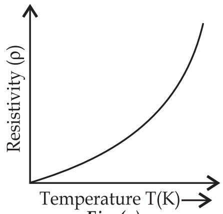


Fig. (a)

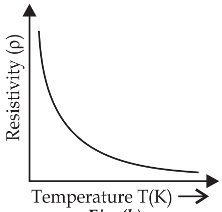


Fig. (b)

(*a*) Conductor and semiconductor (*b*) Conductor and Insulator
(*c*) Insulator and semiconductor (*d*) Both are conductors

Q.16. **Refraction of light**

When a beam of light encounters another transparent medium, a part of light gets reflected back into first medium, while the rest enters the other. A ray of light represents a beam. The direction of propagation of an obliquely incident ray of light that enters the other medium, changes at the interface of the two media. This phenomenon is called **Refraction of Light**.

Snell had experimentally obtained the **laws of refraction**. The refracted ray bends towards the normal, when it passes from rarer to denser medium. Also, the refracted ray moves away from the normal, when incident ray in a denser medium refracts into a rarer medium.

The refraction of light through the atmosphere is responsible for many interesting phenomena such as advanced sunrise and delayed sunset is due to atmospheric refraction.

The refraction at spherical surfaces like lenses and prisms etc. have wide applications in our daily life.

(*i*) **Refraction of light from air to glass and from air to water are shown in Fig. (1) and Fig. (2) below. The value of the angle θ in the case of refraction as shown in Fig. (3) will be**

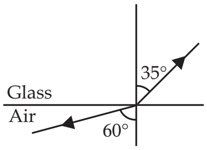


Fig. 1

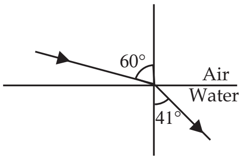


Fig. 2

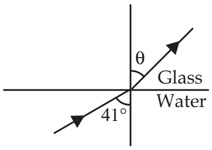


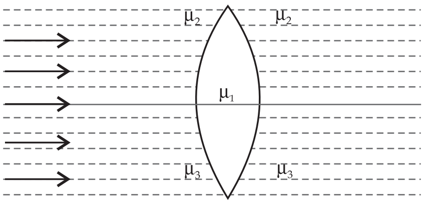
Fig. 3

(*a*) 30° (*b*) 35° (*c*) 60° (*d*) 41°

(*ii*) **A ray of light strikes a transparent rectangular slab of refractive index $\sqrt{2}$ at an angle of incidence of 45°. The angle between the reflected and refracted rays is**

(*a*) 75° (*b*) 90° (*c*) 105° (*d*) 120°

(*iii*) **A double convex lens, made of a material of refractive index μ_1, is placed inside two liquids of refractive indices μ_2 and μ_3 as shown. $\mu_1 > \mu_2 > \mu_3$. A wide, parallel beam of light is incident on the lens from the left. The lens will give rise to**



(*a*) a single convergent beam
(*b*) two different convergent beams
(*c*) two different divergent beams
(*d*) a convergent and a divergent beam.

(*iv*) **A convex lens is dipped in a liquid whose refractive index is equal to the refractive index of the lens. Then its focal length will**

(*a*) become zero
(*b*) become infinite
(*c*) become small, but non-zero
(*d*) remain unchanged

(*v*) **A converging lens is used to form an image on a screen. When the upper half of the lens is covered by an opaque screen,**

(*a*) half the image will disappear
(*b*) complete image will disappear
(*c*) intensity of image will decrease
(*d*) intensity of image will increase

SECTION-C

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

Q.17. (*a*) In what respect is a toroid different from a solenoid? Draw and compare the pattern of the magnetic field lines in the two cases.

(*b*) How is the magnetic field inside a given solenoid made strong?

Q.18. A parallel beam of light of 600 nm falls on a narrow slit and the resulting diffraction pattern is observed on a screen 1.2 m away. It is observed that the first minimum is at a distance of 3 mm from the centre of the screen. Calculate the width of the slit.

Q.19. Derive the expression for the electric potential at any point along the axial line of an electric dipole.

Or

An electric dipole of dipole moment $\vec{p}$, is placed in a uniform electric field $\vec{E}$. Deduce the expression for the torque $\vec{\tau}$ acting on it.

Q.20. Draw the circuit diagram of an illuminated photodiode in reverse bias. How is photodiode used to measure light intensity?

Q.21. Two identical loops, one of copper and the other of aluminium, are rotated with the same angular speed in the same magnetic field. Compare (*i*) the induced emf and (*ii*) the current produced in the two coils. Justify your answer.

Q.22. For a single slit of width "*a*", the first minimum of the interference pattern of a monochromatic light of wavelength λ occurs at an angle of $\frac{\lambda}{a}$. At the same angle of $\frac{\lambda}{a}$, we get a maximum for two narrow slits separated by a distance '*a*'. Explain.

Q.23. (*a*) Why are Si and GaAs preferred materials for fabrication in solar cells?

(*b*) Draw V–I characteristic of solar cell and mention its significance.

Q.24. Current flows through a circular loop. Depict the north and south pole of its equivalent magnetic dipole.

Or

Is the steady electric current the only source of magnetic field? Justify your answer.

Q.25. The radii of curvature of the faces of a double convex lens are 10 cm and 15 cm. If focal length of the lens is 12 cm, find the refractive index of the material of the lens.

SECTION-D

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

Q.26. (*a*) A rod of length l is moved horizontally with a uniform velocity 'v' in a direction perpendicular to its length through a region in which a uniform magnetic field is acting vertically downward. Derive the expression for the emf induced across the ends of the rod.

(*b*) How does one understand this motional emf by invoking the Lorentz force acting on the free charge carriers of the conductor? Explain.

Q.27. Write the principle of working of a potentiometer. Describe briefly, with the help of a circuit diagram, how a potentiometer is used to determine the internal resistance of a given cell.

Or

Answer the following:

(*a*) Why are the connections between the resistors in a meter bridge made of thick copper strips?

(*b*) Why is it generally preferred to obtain the balance point in the middle of the meter bridge wire?

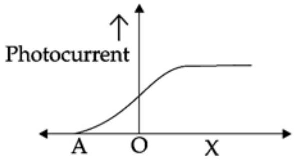
(*c*) Which material is used for the meter bridge wire and why?

Q.28. (*a*) Write the important properties of photons which are used to establish Einstein's photoelectric equation.

(*b*) Use this equation to explain the concept of (*i*) threshold frequency and (*ii*) stopping potential.

Or

The given graph shows the variation of photocurrent for a photo-sensitive metal:



(*a*) Identify the variable X on the horizontal axis.

(*b*) What does the point A on the horizontal axis represent?

(*c*) Draw this graph for three different values of frequencies of incident radiation υ_1, υ_2 and υ_3 ($\upsilon_1 > \upsilon_2 > \upsilon_3$) for same intensity.

(*d*) Draw this graph for three different values of intensities of incident radiation I_1, I_2 and I_3 ($I_1 > I_2 > I_3$) having same frequency.

Q.29. In the ground state of hydrogen atom, its Bohr radius is given as 5.3×10^{-11} m. The atom is excited such that the radius becomes 21.2×10^{-11} m. Find

(*i*) the value of the principal quantum number and

(*ii*) the total energy of the atom in this excited state.

Q.30. (*a*) In a nuclear reaction ${}_2^3\text{He} + {}_2^3\text{He} \rightarrow {}_2^4\text{He} + {}_1^1\text{H} + {}_1^1\text{H} + 12.86\,\text{MeV}$, though the number of nucleons is con-served on both sides of the reaction, yet the energy is released. How? Explain.

(*b*) Draw a plot of potential energy between a pair of nucleons as a function of their separation. Mark the regions where potential energy is (*i*) positive and (*ii*) negative.

SECTION-E

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

Q.31. (*a*) When a parallel plate capacitor is connected across a dc battery, explain briefly how the capacitor gets charged.

(*b*) A parallel plate capacitor of capacitance 'C' is charged to 'V' volt by a battery. After some time the battery is disconnected and the distance between the plates is doubled. Now a slab of dielectric constant $1 < k < 2$ is introduced to fill the space between the plates.

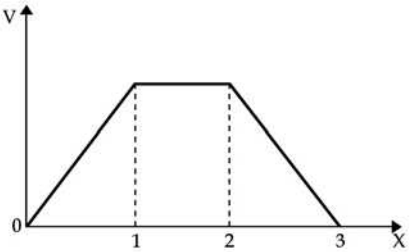
How will the following be affected?

(*i*) The electric field between the plates of the capacitor.

(*ii*) The energy stored in the capacitor.

Justify your answer in each case.

(*c*) The electric potential as a function of distance 'x' is shown in the figure. Draw a graph of the electric field E as a function of x.



Or

(*a*) Derive an expression for the potential energy of an electric dipole in a uniform electric field. Explain conditions for stable and unstable equilibrium.

(*b*) Is the electrostatic potential necessarily zero at a point where the electric field is zero? Give an example to support your answer.

Q.32. (*a*) Derive an expression for the average power consumed in a series LCR circuit connected to a.c. source in which the phase difference between the voltage and the current in the circuit is ϕ.

(*b*) Define the quality factor in an a.c. circuit. Why should the quality factor have high value in receiving circuits? Name the factors on which it depends.

Or

(*a*) Derive the relationship between the peak and the rms value of current in an a.c. circuit.

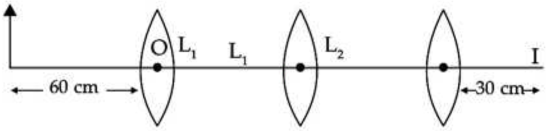
(*b*) Describe briefly, with the help of a labelled diagram, working of a step-up transformer. A step-up transformer converts a low voltage into high voltage. Does it not violate the principle of conservation of energy? Explain.

Q.33. (*a*) Explain with reason, how the power of a diverging lens changes when

(*i*) it is kept in a medium of refractive index greater than that of the lens,

(*ii*) incident red light is replaced by violet light.

(*b*) Three lenses L_1, L_2, L_3 each of focal length 30 cm are placed co-axially as shown in the figure. An object is held at 60 cm from the optic centre of Lens L_1. The final real image is formed at the focus of L_3. Calculate the separation between (*i*) (L_1 and L_2) and (*ii*) (L_2 and L_3).



Or

(*a*) State Huygen's principle. Using this principle explain how a diffraction pattern is obtained on a screen due to a narrow slit on which a narrow beam coming from a monochromatic source of light is incident normally.

(*b*) Show that the angular width of the first diffraction fringe is half of that of the central fringe.

(*c*) If a monochromatic source of light is replaced by white light, what change would you observe in the diffraction pattern?

❒ ❒ ❒ ❒

Answer Sheet

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PHYSICS

SECTION – A

1. Electric field lines do not form closed loops because the direction of an electric field is from positive to negative charge. So one can regard a line of force starting from a positive charge and ending on a negative charge. This indicates that electric field lines do not form closed loops.

2. The direction of electric field vector is along X-axis. Magnetic field vector is along Y-axis.

Or

Radio waves are produced by the accelerated motion of charges in conducting wires.

3. The direction of the magnetic field is towards positive direction of ***z-axis.***

4. ***No,*** As the magnetic field due to current carrying wire will be in the plane of the circular loop, so magnetic flux will remain zero.

Or

Average power over full cycle of the ac voltage source is ***zero***, when connected with an ideal inductor.

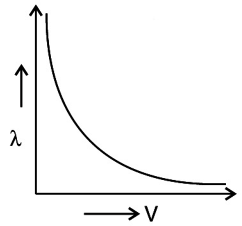
5. We have, $E_{2\to 1} = \text{const.}\left(\frac{1}{1^2}-\frac{1}{2^2}\right) = \text{const.}\ \frac{3}{4}$

and $E_{\infty\to 2} = \text{const.}\left(\frac{1}{2^2}-\frac{1}{\infty^2}\right) = \text{const.}\ \frac{1}{4}$

$\therefore$ Ratio = **3 : 1**

6. $\lambda = \frac{h}{mv} = \frac{h}{m\sqrt{\frac{2eV}{m}}}$

$= \frac{h}{\sqrt{2meV}} = \frac{\mathbf{12.27}}{\sqrt{\mathbf{V}}}\ \mathbf{\mathring{A}}$



7. Nuclear density, $f = \frac{\text{Mass of Nucleus}}{\text{Volume of Nucleus}}$

But, $R = R_0A^{1/3}$

$\therefore \quad f = \frac{mA}{\frac{4}{3}\pi R_0^3 A}$ **...where [*m* is mass of proton or neutron and A is number of nucleons**

$\therefore \quad f = \frac{m}{\frac{4}{3}\pi R_0^3}$

Thus, f is independent of A (mass number)

$\therefore$ The ratio of density will be **1 : 1**.

Or

Since $R = R_0 A^{1/3}$

$$\Rightarrow \quad R_1 : R_2 = (1^{1/3} : 8^{1/3}) = \left(\frac{1}{8}\right)^{1/3} = \mathbf{1:2}$$

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

Or

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

9. There are some special purposes diodes, which are developed for different applications.
Example: (*i*) zener diode (*ii*) photodiode (*iii*) Light emitting diodes (LED) (*iv*) Solar cell

10. **Forward biasing and reverse biasing of *p-n* junction.** A *p-n* junction is said to be forward biased if *p* region is maintained at higher potential with respect to *n* regions. A *p-n* junction is said to be reverse biased if *p* region is maintained at lower potential with respect to *n* region.

11. (*d*) A is false and R is also false.

12. (*b*) Both A and R are true but R is NOT the correct explanation of A. *[Hint: The capacitance of a parallel plate capacitor is given by* $C = \frac{K \epsilon_0 A}{d}$, *hence* $C \propto \frac{1}{d}$ *and* $C \propto K$.

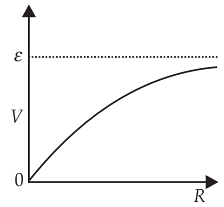
13. (*b*) Both A and R are true but R is NOT the correct explanation of A.

$\left[\textbf{Hint: } \mu = \frac{\mu_g}{\mu_c} = \frac{1.5}{1.65} < 1, \frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right);\right.$ ***f* becomes negative and hence diverging lens**

14. (*a*) Both A and R are true and R is the correct explanation of A.
[Hint: The lower portion of wavefront, which travels through the maximum thickness of the glass gets delayed.

15. **(*i*)** (*b*); from high potential to low potential.

(*ii*) (*b*);



(*iii*) (*d*); $R = 0$

(*iv*) (*a*); $\varepsilon, \frac{r}{n}$ ...**[In parallel combination, total emf is equal to one cell, while internal resistance is** $\frac{r}{n}$.

(*v*) (*a*); Conductor and semiconductor *[Hint: In conductors due to increase in temperature, the resistivity increases and in semiconductors it decreases exponentially*

16. **(*i*)** (*b*); $\theta = 35°$ $\left[\textbf{Hint : } {}^a\mu_g = \frac{\sin 60°}{\sin 35°}; {}^a\mu_w = \frac{\sin 60°}{\sin 41°} \therefore {}^a\mu_w \times {}^w\mu_g = {}^a\mu_g\right.$

(*ii*) (*c*); 105° *[Hint:* $\mu = \frac{\sin i}{\sin r}$; $\because \angle r = 30°; \theta = [180° - (i + r)] = [180° - (45° + 30°)] = (180° - 75°) = 105°$

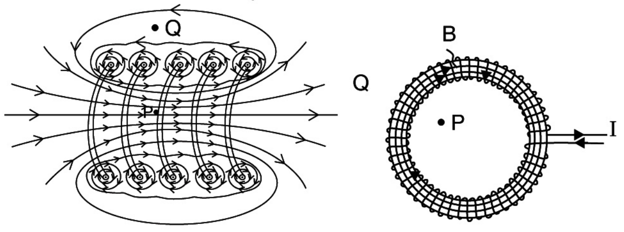
(*iii*) (*d*); a convergent and a divergent beam. *[Hint: As* $\mu_2 > \mu_1$; *the upper half of the lens will become diverging; And* $\mu_1 > \mu_3$, *the lower half of the lens will become converging.*

(*iv*) (*b*); become infinite *[Hint: When refractive index of lens is equal to the refractive index of liquid, the lens behaves like a plane surface with focal length equal to infinity.*

(*v*) (*c*); intensity of image will decrease *[Hint: Image formed is complete, but has decreased intensity*

17. (*a*) ***Solenoid*** consists of a long wire wound in the form of a helix where the neighbouring turns are closely spaced, whereas, the ***toroid*** is a hollow circular ring on which a large number of turns of a wire is closely wound.

(*b*) Magnetic field inside a given solenoid is made strong by putting a soft iron core inside it. It is strengthened by increasing the amount of current through it.



(a) Solenoid ***(b) Toroid***

18. $\lambda = 600 \text{ nm} = 600 \times 10^{-9}$ m, D = 1.2 m

First minima at $x_1 = 3 \text{ mm} = 3 \times 10^{-3}$ m

Diffraction angle for first minima:

$$\theta_1 = \frac{x_1}{D}$$

$$\theta_1 = \frac{3 \times 10^{-3} \times 10}{12} = 2.5 \times 10^{-3} \text{ rad}$$

We know, $a \sin \theta_1 = n\lambda$, $n = 1$

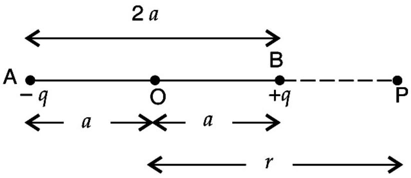
$a \sin \theta_1 = n\lambda$

Since angle is very small so $\sin \theta_1 \sim \theta$

$$a = \frac{\lambda}{\theta_1} = \frac{600 \times 10^{-9}}{2.5 \times 10^{-3}} = \frac{6}{2.5} \times 10^{-4} \text{ m} = 2.4 \times 10^{-4} \text{ m} = 0.24 \text{ mm}$$

$\therefore$ **a = 0.24 mm**

19. Consider an electric dipole consisting of two points charged $-q$ and $+q$ and separated by distance $2a$. Let P be a point on the axis of the dipole at a distance r from its centre O.



Electric potential at point P due to the dipole is,

$$V = V_1 + V_2$$

or $V = \frac{1}{4\pi\varepsilon_0}\frac{-q}{AP} + \frac{1}{4\pi\varepsilon_0}.\frac{q}{BP}$ or $V = -\frac{1}{4\pi\varepsilon_0}.\frac{q}{r+a} + \frac{1}{4\pi\varepsilon_0}.\frac{q}{r-a}$

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

or $V = \frac{1}{4\pi\varepsilon_0}.\frac{q \times 2a}{r^2 - a^2}$

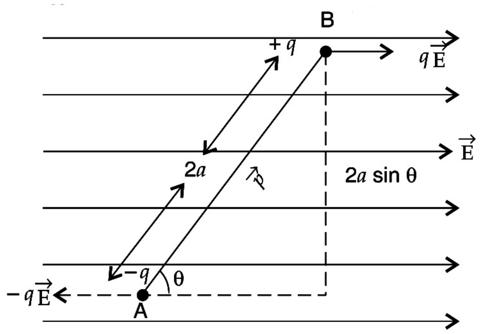
or $V = \frac{1}{4\pi\varepsilon_0}.\frac{p}{r^2 - a^2}$ **...where** [p is dipole moment [$p = q \times 2a$

For ideal dipole : $a << r$

So $a^2 << r^2$ $\therefore$ $\mathbf{V = \frac{1}{4\pi\varepsilon_0}.\frac{p}{r^2}}$

Or

Consider a dipole with charges + q and – q placed in a uniform electric field $\vec{E}$ such that AB = $2a$ as shown in the figure.



Since the dipole experiences no net force in a uniform electric field but experiences a torque (τ) is given by

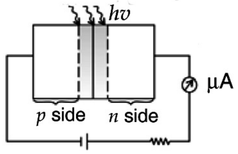
$\vec{\tau} = \vec{p} \times \vec{E}$ $\therefore$ $\tau = pE \sin\theta$

It tends to rotate the dipole in clockwise direction. To rotate the dipole anti-clockwise work has to be done on the dipole.

$$W = \int_{\theta_1}^{\theta_2} \tau d\theta \quad \text{or} \quad W = \int_{\theta_1}^{\theta_2} pE\sin\theta d\theta$$

or $W = pE\,[-\cos\theta]_{\theta_1}^{\theta_2}$ $\therefore$ $\mathbf{W = -pE\,[\cos\theta_2 - \cos\theta_1]}$

20. A measurement of the change in the reverse saturation current on illumination can give the values of light intensity because photocurrent is proportional to incident light intensity.



A reverse biased photodiode illuminated with light.

21. (*i*) Induced emf in a coil is ε = NBAω sin ω*t*. As the angular speed is same, induced emf will also be same in both the loops.

(*ii*) Current induced in a loop is $I = \frac{\varepsilon}{R} = \frac{\varepsilon A}{\rho l}$

As the resistivity of copper is lesser, more amount of current is induced in it.

22. For a single slit of width 'a', the n^{th} minimum, $\sin\theta_n = \frac{n\lambda}{a}$

or $\theta_n = \frac{n\lambda}{a}$ (when θ is small)

$\theta_n = \frac{\lambda}{a}$ (when n = 1 for the first minimum)

Now, the maximum of two narrow slits separated by a distance 'a'

Path difference, $(x) = \frac{\lambda D}{d}$

angle (θ) $= \frac{x}{D} = \frac{\lambda}{d}$ or $\frac{\lambda}{a}$ ...[$\because d = a$]

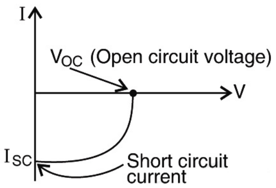
This is why, at the same angle $\frac{\lambda}{a}$, we get a maximum for two narrow slits separated by a distance 'a'.

23. (*a*) **The important criteria for a material for solar cell fabrication are:**

(*i*) Band gap of the order of 1.0 eV to 1.8 eV

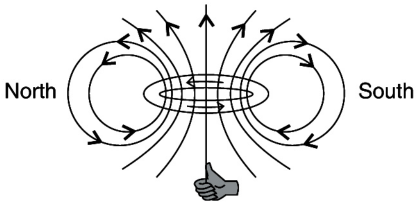
(*ii*) High optical absorption ($\sim 10^4$ cm^{-1})

Silicon (band gap ≅ 1.1eV) and GaAs (band gap 1.43eV) satisfy these criterion better than other materials.



(*b*) It does not draw current but supplies the same to the load.

24. Direction of the magnetic field lines is given by right hand *thumb rule.*



Magnetic field lines

Or

No. Steady current is not the only source of magnetic field. Magnets are also source of magnetic field. Unsteady current will also be source of varying magnetic field.

25. **Given :** R_1 = 10 cm, R_2 = – 15 cm, f = 12 cm

Using *lens maker's formula*, we have

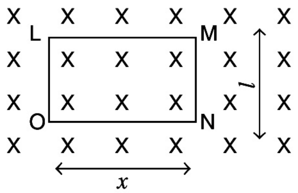
$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\Rightarrow \quad \frac{1}{12} = (n-1)\left(\frac{1}{10} - \frac{1}{-15}\right) \qquad \Rightarrow \quad \frac{1}{12} = (n-1)\left(\frac{3+2}{30}\right)$$

$$\Rightarrow \quad (n-1) = \frac{30}{5} \times \frac{1}{12} = \frac{1}{2} \qquad \therefore \quad n = 1 + \frac{1}{2} = \frac{3}{2} = 1.5$$

∴ **Refractive index of the material of the lens = 1.5**

26. (*a*) **Induced emf in rotating metallic rod:** Suppose a rectangular loop LMNO is placed in a uniform magnetic field B.



Suppose at any instant, length ON = x

Area of the loop LMNO = $l\,x$

Flux through the loop, $\phi = Bl\,x$ **...[∵ Max flux, ϕ = BA**

Induced emf, $E = -\frac{d\phi}{dt} = \frac{d}{dt} Blx$

$$= -Bl\frac{dx}{dt} = Blv \qquad \text{...where } \left[\frac{dx}{dt} = -v, \text{ that is the velocity of conductor MN.}\right.$$

(*b*) The induced emf produced in a rod (l) moved with velocity (v) kept in a magnetic field (perpendicular to the plane of length of the rod) is given by $e = Blv$. ...(*i*)

This induced emf is called motional emf, by moving a conductor instead of varying the magnetic field; that is by changing the magnetic flux enclosed by the circuit.

We can explain motional emf by invoking the Lorentz force acting on the free charge carriers of the conductor.

Lorentz force acting on charge q is

$|F| = |qvB|$ ...(*ii*)

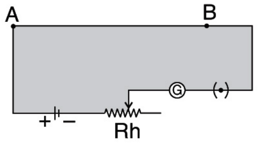
The work done in moving the charge through a distance 'l' is : $W = qvBl$

Since the emf is the work done per unit charge, $e = \frac{W}{q} = \frac{qvBl}{q} = Blv$ ...(*iii*)

This expression is the same as given in (*i*).

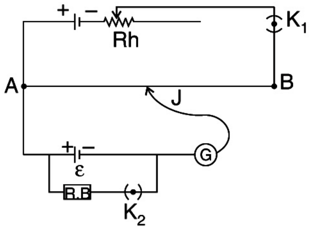
27. ***Potentiometer :*** A potentiometer is a device used to measure potential difference.

Principle : The basic principle of a potentiometer is that when a constant current flows through a wire of uniform cross-sectional area and composition, the potential drop across any length of the wire is directly proportional to that length.



$V \propto l$ or $V = Kl$ ...where [K is called potential gradient

Close the key K_1. A constant current flows through the potentiometer wire. With key K_2 kept open, move the jockey along AB till it balances the emf ε of the cell. Let l_1 be the balancing length of the wire. If K is the potential gradient, then emf of the cell will be



$\varepsilon = Kl_1$ ...(*i*)

With the help of resistance box R.B, introduce a resistance R and close key K_2. Find the balance point for the terminal potential difference V of the cell. If l_2 is the balancing length, then

$V = Kl_2$ ...(*ii*)

Dividing (*ii*) by (*i*), we have $\frac{\varepsilon}{V} = \frac{Kl_1}{Kl_2} = \frac{l_1}{l_2}$

Let r be the internal resistance of the cell

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

$$\frac{\varepsilon}{V} = \frac{R+r}{R} = \frac{l_1}{l_2}$$

$$\frac{R}{R} + \frac{r}{R} = \frac{l_1}{l_2} \quad \Rightarrow 1 + \frac{r}{R} = \frac{l_1}{l_2}$$

$$\Rightarrow \frac{r}{R} = \frac{l_1}{l_2} - 1 = \frac{l_1 - l_2}{l_2}$$

∴ **Internal resistance, $r = R\left[\frac{l_1 - l_2}{l_2}\right]$**

Or

(*a*) The connections between the resistors in a meter bridge are made of thick copper strip, so as to have the minimum possible resistances.

(*b*) It is generally preferred to obtain the balance point in the middle of the meter bridge, so as to minimise the error of balance.

(*c*) The material used for meter bridge is an alloy 'constant' or 'manganin' because of (*i*) high resistivity and (*ii*) low temperature coefficient of resistivity.

28. (*a*) **Important properties of Photons:**

(*i*) In interaction of radiation with matter, radiation behaves as if it is made up of particles called photons.

(*ii*) Each photon has energy E (= $h\nu$) and momentum p (= $h\nu/c$), and speed c, the speed of light.

(*iii*) All photons of light of a particular frequency ν, or wavelength λ, have the same energy E (= $h\nu = hc/\lambda$) and momentum p (= $h\nu/c = h/\lambda$), whatever the intensity of radiation may be. By increasing the intensity of light of given wavelength, there is only an increase in the number of photons per second crossing a given area, with each photon having the same energy. Thus, photon energy is independent of intensity of radiation.

(*iv*) Photons are electrically neutral and are not deflected by electric and magnetic fields.

(*v*) In a photon-particle collision (such as photon-electron collision), the total energy and total momentum are conserved. However, the number of photons may not be conserved in a collision. The photon may be absorbed or a new photon may be created.

(*b*) **Einstein's photoelectric equation is**

$K_{max} = h\nu - \phi_0$ ...(*i*)

(*i*) **Threshold frequency.** Since K_{max} must be non-negative, equation (*i*) implies that photoelectric emission is possible only if

$$h\nu > \phi_0 \quad \text{or} \quad \nu > \nu_0, \text{ where } \nu_0 = \frac{\phi_0}{h}$$

This equation shows that the greater the work function ϕ_0, higher the threshold frequency ν_0 needed to emit photoelectrons.

Thus, there exists a **threshold frequency** ν_0 $(= \phi_0/h)$ for the metal surface, below which no photoelectric emission is possible, no matter how intense the incident radiation may be or how long it falls on the surface.

(*ii*) **Stopping potential.** The minimum value of negative potential ν_0, which should be applied to the anode in a photocell, so that the photoelectric current becomes zero, is called **Stopping potential.**

$$\therefore \quad K_{max} = \frac{1}{2}mv^2{}_{max} = eV_0$$

$$eV_0 = h\nu - \phi_0; \text{ for } \nu \geq \nu_0$$

$$\text{or} \quad V_0 = \left(\frac{h}{e}\right)V - \frac{\phi_0}{e}$$

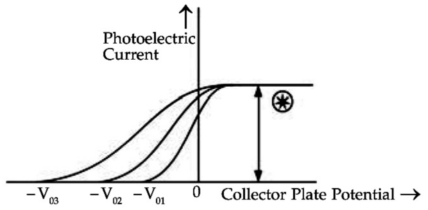
V_0 is the stopping potential.

Or

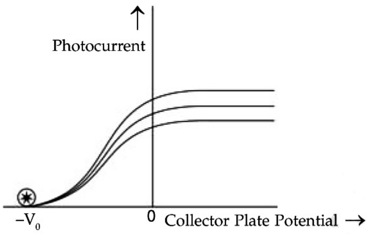
(*a*) 'X' is a collector plate potential.

(*b*) 'A' represents the **stopping potential**.

(*c*) Graph for different frequencies:



(*d*) Graph for different intensities:



29. (*i*) **Given :**

$r_1 = 5.3 \times 10^{-11}$ m, $r_2 = 21.2 \times 10^{-11}$ m,

$$\frac{r_2}{r_1} = \frac{21.1 \times 10^{-11}}{5.3 \times 10^{-11}} = 4$$

Since $r \propto n^2$

$$\left(\frac{n_2}{n_1}\right)^2 = \frac{r_2}{r_1} = 4 \qquad \Rightarrow \frac{n_2}{n_1} = \sqrt{4} = 2$$

$\therefore\ n_2 = 2n_1$

Therefore, Value of principal quantum number in this excited state is **2**.

(*ii*) Energy of electron in ground state = –13.6 eV

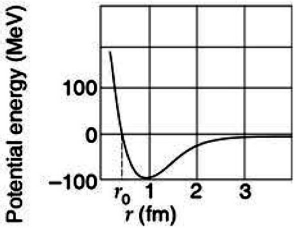
$$E_n = \frac{-13.6}{n^2}$$

$$\therefore\ E_n = \frac{-13.6}{(2)^2} = \frac{-13.6}{4} = -3.4 \text{ eV}$$

$\therefore$ Total energy of the atom in this excited state = **–3.4 eV**

30. **(*a*)** Since the total binding energy of nuclei on the left side of the reaction is not the same as the total binding energy of nucleus on the right hand side, this difference of binding energy appears as the energy released.

(*b*) Since the total binding energy of nuclei on the left side of the reaction is not the same as the total binding energy of nucleus on the right hand side, this difference of binding energy appears as the energy released.



For separation (r) ≤ 0.8 fermi

Force is repulsive

For r > 0.8 fermi force will be attractive.

31. **(*a*)** **Charging of capacitor with dc battery.** Whenever parallel plate capacitor is connected with dc source, plates start acquiring charge in accordance with the terminals of the battery till potential difference across the plates becomes equal to terminal potential of dc battery.

(*b*) (*i*) The electric field between the plates of parallel plate capacitor, $E_0 = \frac{\sigma}{\varepsilon_0} = \frac{Q}{\varepsilon_0 A}$

If dielectric is inserted, $E' = \frac{Q}{\varepsilon_0 A.K} = \frac{\varepsilon_0}{K}$

So, the electric field intensity decreases to 1/K times.

(*ii*) Since Energy stored in the capacitor

$$U = \frac{Q^2}{2C} = \left(\frac{Q^2}{2}\right) \times \left(\frac{d}{\varepsilon_0 A}\right) = \frac{Q^2 d}{2\varepsilon_0 A} \quad ...(i) \qquad ...\left[\because C = \frac{\varepsilon_0 A}{d}\right.$$

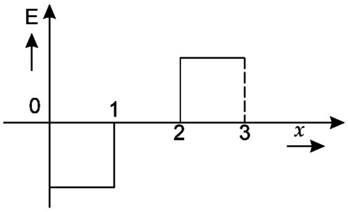
Similarly, $$U' = \frac{Q^2}{2C'} = \left(\frac{Q^2}{2}\right) \times \left(\frac{d_1}{2K\varepsilon_0 A}\right) = \frac{Q^2 d_1}{2K\varepsilon_0 A} \quad ...(ii)$$

$$= \frac{2}{K}\left(\frac{Q^2 d}{2\varepsilon_0 A}\right) \qquad [\because d_1 = 2d]$$

$$= \frac{2}{K}[U] \qquad [\because 1 < K < 2]$$

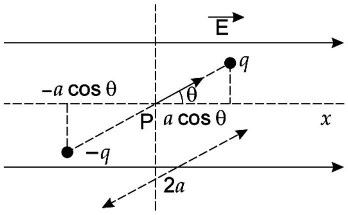
Therefore, energy stored between the plates increases.

(*c*) Graph of Electric field E as a function of x:



Or

(*a*) (*i*) **Potential Energy of an Electric dipole:**



Torque acting on dipole $\vec{\tau} = \vec{p} \times \vec{E} \Rightarrow \vec{\tau} = pE \sin\theta\, \hat{n}$

$\therefore$ Work done, $dw = \tau.d\theta = pE \sin\theta.d\theta$

$[\because w = pE \sin\theta]$

$$w = \int_{\theta_1}^{\theta_2} dw = pE\int_{\theta_1}^{\theta_2} \sin\theta\, d\theta$$

$\Rightarrow \quad w = pE[-\cos\theta]_{\theta_1}^{\theta_2}$ $\quad\Rightarrow\quad w = pE[\cos\theta_1 - \cos\theta_2]$

If $\theta_1 = 0, \theta_2 = \theta$ $\quad\therefore\quad$ $\boldsymbol{w = pE\,(1 - \cos\theta)}$

(*ii*) **Conditions:**

For stable equilibrium: When electric dipole is parallel to electric field.

For unstable equilibrium: Anti Parallel to electric field.

(*b*) (*i*) It is **NOT** necessary that the electrostatic potential be zero at a point, where the electric field is zero.

(*ii*) Inside **Equipotential surface** is such example.

32. (*a*) Let an alternating current $I = I_m \sin \omega t$ be passing through a network of L, C and R creating a potential difference of $V = V_m \sin(\omega t \pm \phi)$ where ϕ is the phase difference. Then the power consumed is

$$P = VI = V_m I_m \sin(\omega t \pm \phi) \sin \omega t$$

$$= V_m I_m (\sin \omega t \cos\phi \pm \cos \omega t \sin\phi) \sin \omega t$$

$$= V_m I_m \left(\sin^2 \omega t \cos\phi \pm \frac{1}{2} \sin 2\omega t \sin\phi\right)$$

$$P_{av} = \frac{\int_0^T P\,dt}{\int_0^T dt} = \frac{V_m I_m}{T} \qquad \ldots\left[\because \int \sin^2 \omega t \cos\phi\, dt + \frac{1}{2}\int \sin\phi \sin 2\omega t\; dt\right]$$

$$P_{av} = \frac{V_m I_m}{T}\left[\frac{T}{2}\cos\phi + 0\right] \qquad \ldots\left[\because \int_0^T \sin^2 \omega t\; dt = \frac{T}{2} \text{ and} \int_0^T \sin 2\omega t\; dt = 0\right]$$

$$P_{av} = \frac{V_m I_m}{2}\cos\phi \qquad \Rightarrow \qquad \mathbf{P_{av} = V_{rms}\, I_{rms} \cos\phi}$$

(*b*) Quality factor should be high to have the current corresponding to a particular frequency

to be more and to avoid the other unwanted frequencies. Q-factor depends on *f*, L, R and C.
Sharpness of resonance is determined by quality factor (Q) of the circuit *i.e.*,

$$Q = \frac{\omega_0 L}{R} = \frac{1}{\omega_0 CR} = \frac{1}{R}\sqrt{\frac{L}{C}}$$

Larger the value of Q, Sharper is the resonance *i.e.* sharper peak in the current.

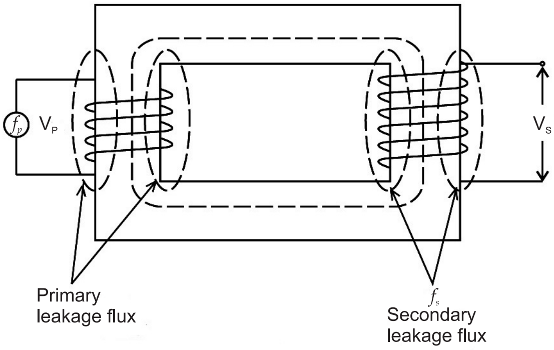
Or

(*a*) R.M.S. value of current say $I = I_m \sin \omega t$ is given by

$$I_{rms} = \sqrt{\frac{\int_0^T I_m^2 \sin^2 \omega t\, dt}{\int_0^T dt}} = \frac{I_m}{\sqrt{T}}\sqrt{\int_0^T \sin^2 \omega t\, dt}$$

$$= \frac{I_m}{\sqrt{T}} = \sqrt{\int_0^T \left(\frac{1-\cos 2\omega t}{2}\right) dt} = \frac{I_m}{\sqrt{T}}\left[\sqrt{\frac{T}{2}}\right] = \frac{I_m}{\sqrt{2}}$$ ...where [I_m is the peak value of current

(*b*) The supply of ac to the primary will bring a varying flux in the secondary causing emf. Since $f_S \propto N_S$ and $\varepsilon_S = \frac{d\phi_s}{dt}$ the emf induced in the secondary flux will be more than the primary as the condition $N_S > N_P$ is satisfied. Production of high voltage does not violate the law of conservation of energy as the current will be reduced in the process.



As $V_S > V_P$ with $N_S > N_P$. Hence I_S will become less than I_P.

33. (*a*) The power of a lens is the reciprocal of its focal length.

$$P = \frac{1}{f}$$ ...[when '*f*' is taken in meters

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

$$= \frac{n_2 - n_1}{n_1}\left(-\frac{2}{R}\right)$$ ...$\left[\because \frac{1}{R_1} = \frac{1}{R_2} = \frac{1}{R}\right.$

= **negative** ...[$\because$ R_1 is negative for diverging lens

(*i*) If $n_1 > n_2$ (given)

$\frac{n_2 - n_1}{n_1}$ becomes negative

$\therefore$ P = $\frac{1}{f}$ becomes positive

or **lens becomes converging**

(*ii*) $\because (n_2)_{violet} > (n_2)_{red}$

which means that the power of lens ***increases*** on changing to violet light from red light.

(*b*) **Given :** $f_1 = f_2 = f_3 = 30$ cm

$u_1 = 60$ cm, I_3 is formed at the focus of L_3.

$L_1L_2 = ?;\quad L_2L_3 = ?$

Since final image (I_3) is formed at the focus of L_3, the rays emerging from L_2 and incident on L_3 have to be parallel to principal axis.

Since the object is placed at a distance of 60 cm from L_1, *i.e.*, at 2F; the image will be formed at 2F on the other side of L_1 (60 cm).

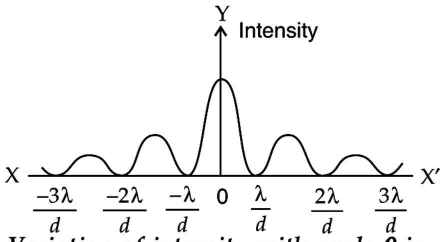
This image I_1 will be at the focus of L_2, because rays emerging out from L_2 are parallel to principal axis.

(*i*) $\because$ $\mathbf{L_1L_2} = 2f_1 + f_2 = (2 \times 30) + 30 =$ **90 cm**

(*ii*) **L_2L_3 can be any distance.**

Or

(*a*) **Huygen's principle:** "(*i*) Each point on a wavefront acts as a fresh source of new disturbance called secondary waves or wavelets; (*ii*) The secondary wavelets spread out in all directions with the speed of wave in the given medium; (*iii*) The new wavefront at any later time is given by the forward envelope (tangential surface in the forward direction) of the secondary wavelets at that time."



Variation of intensity with angle θ in single slit diffraction

The reason is that the intensity of the central maxima is due to the constructive interference of wavelets from all parts of the slit, the first secondary maxima is due to the contribution of wavelets from one third part of the slit (wavelets from remaining two parts interfere destructively), the second secondary maxima is due to the contribution of wavelets from the one fifth part only (the remaining four parts interfere destructively) and so on. Hence, the intensity of secondary maxima decreases with the increase in the order *n* of the maxima.

(*b*) Central bright lies between, $\theta = \frac{+\lambda}{a}$ and $\theta = \frac{-\lambda}{a}$. Therefore, Angular width of central bright fringe = $2\theta = \frac{2\lambda}{a}$. So, 1st diffraction fringe, lies between $\theta_1 = \frac{\lambda}{a}$ and $\theta_2 = \frac{2\lambda}{a}$. Therefore,

Angular width of first diffraction fringe is $\left(\frac{2\lambda}{a} - \frac{\lambda}{a}\right) = \frac{\lambda}{a}$ **Hence proved.**

(*c*) If monochromatic source of light is replaced by a source of white light, instead of white fringes we obtain few coloured fringes and then uniform illumination.

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