Class XII Session 2024-25
Subject - Physics
Sample Question Paper - 8

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

General Instructions:

1. There are 33 questions in all. All questions are compulsory.
2. This question paper has five sections: Section A, Section B, Section C, Section D and Section E.
3. All the sections are compulsory.
4. **Section A** contains sixteen questions, twelve MCQ and four Assertion Reasoning based of 1 mark each, **Section B** contains five questions of two marks each, **Section C** contains seven questions of three marks each, **Section D** contains two case study based questions of four marks each and **Section E** contains three long answer questions of five marks each.
5. There is no overall choice. However, an internal choice has been provided in one question in Section B, one question in Section C, one question in each CBQ in Section D and all three questions in Section E. You have to attempt only one of the choices in such questions.
6. Use of calculators is not allowed.

Section A

1. The formation of depletion region in a p-n junction diode is due to **[1]**

a) movement of dopant atoms b) drift of electrons only

c) diffusion of both electrons and holes d) drift of holes only

2. Inversion temperature of a thermocouple is the temperature of the hot junction at which the emf is: **[1]**

a) minimum b) Low

c) maximum d) zero

3. The graph drawn with object distance along abscissa & image as ordinate for a convex lens is **[1]**

a) straight b) circle

c) rectangular hyperbola d) parabola

4. The μ_0 is also known as : **[1]**

a) magnetic dipole b) Absolute Permittivity

c) Magnetic dipole moment d) Magnetic flux

5. Submarine cables act as **[1]**

a) spherical capacitor b) cylindrical capacitor with inner cylinder earthed

c) parallel plate capacitor

d) cylindrical capacitor with outer cylinder earthed

6. The magnetic moment of a current (l) carrying circular coil of radius (r) and number of turns (n) varies as **[1]**

a) $\frac{1}{r^2}$

b) r

c) $\frac{1}{r}$

d) r^2

7. A conducting circular loop is placed in a uniform magnetic field, B = 0.025 T with its plane perpendicular to the loop. The radius of the loop is made to shrink at a constant rate of 1 mm s^{-1}. The induced emf when the radius is 2 cm, is **[1]**

a) 2μV

b) $\pi\mu$V

c) $2\pi\mu V$

d) $\frac{\pi}{2}\mu$V

8. A paramagnetic sample shows a net magnetisation of 8 Am^{-1} when placed in an external magnetic field of 0.6T at a temperature of 4K. When the same sample is placed in an external magnetic field of 0.2 T at a temperature of 16K, the magnetisation will be **[1]**

a) 6 Am^{-1}

b) $\frac{2}{3}\text{Am}^{-1}$

c) 2.4 Am^{-1}

d) $\frac{32}{3}\text{Am}^{-1}$

9. Consider a ray of light incident from air onto a slab of glass (refractive index n) of width d, at an angle θ. The phase difference between the ray reflected by the top surface of the glass and the bottom surface is **[1]**

a) $\frac{4\pi d}{\lambda}\left(1-\frac{1}{n^2}\sin^2\theta\right)^{1/2}$

b) $\frac{4\pi d}{\lambda}\left(1-\frac{1}{n^2}\sin^2\theta\right)^{1/2}+2\pi$

c) $\frac{4\pi d}{\lambda}\left(1-\frac{1}{n^2}\sin^2\theta\right)^{1/2}+\frac{\pi}{2}$

d) $\frac{4\pi d}{\lambda}\left(1-\frac{1}{n^2}\sin^2\theta\right)^{1/2}+\pi$

10. Select the correct statements. Coulomb’s law correctly describes the electric force that: **[1]**

i. binds the electrons of an atom to its nucleus.
ii. binds the protons and neutrons in the nucleus of an atom.
iii. binds atoms together to form molecules.

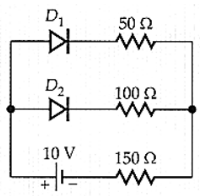
a) (i), (ii), and (iii)

b) (i) and (iii)

c) (ii) and (iii)

d) (i) and (ii)

11. Assume that each diode shown in the figure has a forward bias resistance of 50Ω and an infinite reverse bias resistance. The current through the 150Ω resistance is **[1]**



a) 0.04 A

b) zero

c) 0.05 A

d) 0.66 A

12. The radius of curvature of the curved surface of a plano-convex lens is 20 cm. If the refractive index of the material of the lens be 1.5, it will **[1]**

a) act as a concave lens irrespective of side on

b) act as a convex lens only for the objects that which the object lies

lie on its curved side

c) act as a concave lens for the objects that lie on its curved side

d) act as a convex lens irrespective of the side on which the object lies

13. **Assertion (A):** de-Broglie wavelength is significant for microscopic particles. **[1]**

Reason (R): de-Broglie wavelength is inversely proportional to the mass of a particle when velocity is kept constant.

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 but R is true.

14. **Assertion (A):** An applied electric field polarises a polar dielectric. **[1]**

Reason (R): The molecules of a polar dielectric possess a permanent dipole moment, but in the absence of electric field, these dipoles are randomly oriented and when electric field is applied these dipoles align along the direction of electric field.

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 but R is true.

15. **Assertion (A):** Light from two coherent sources is reaching the screen. If the path difference at a point on the screen for yellow light is $\frac{3\lambda}{2}$, then the fringe at that point will be coloured. **[1]**

Reason (R): Two coherent source always have constant phase relationship.

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 but R is true.

16. **Assertion (A):** At resonance, the inductive reactance is equal and opposite to the capacitive reactance. **[1]**

Reason (R): In series LCR-circuit, the inductive reactance is equal and opposite to the capacitive reactance.

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 but R is true.

Section B

17. Given: Wavelength of light in mercury is $5.5 \times 10^{-5} cm$. **[2]**

i. Calculate its frequency and period.

ii. What is the wavelength of the light in the glass, if the refractive index of glass is 1.5?

18. A ball of superconducting material is dipped in liquid nitrogen and placed near a bar magnet. **[2]**

i. In which direction will it move?

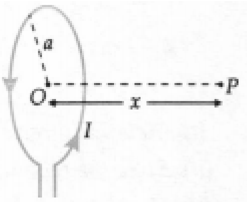
ii. What will be the direction of its magnetic moment?

19. Why do semiconductors obey Ohm's law for only low fields? **[2]**

20. i. Define the terms: **impact parameter** and distance of **closest approach** for an α-particle in the Geiger-Marsden scattering experiment. **[2]**

ii. What will be the value of the impact parameter for scattering angle (I) $\theta = 0^o$ and (II) $\theta = 180^o$?

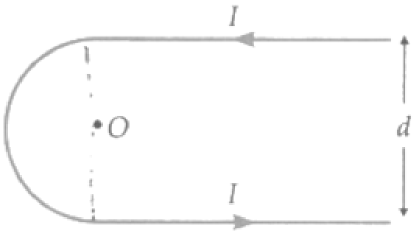
21. A student records the following data for the magnitudes (B) of the magnetic field at axial points at different distances x from the centre of a circular coil of radius a carrying a current I. Verify (for any two) that these observations are in good agreement with the expected theoretical variation of B with x. **[2]**



x →	x = 0	x - a	x = 2 a	x = 3a
y→	B_0	$0.25\sqrt{2}B_0$	$0.039\sqrt{5}B_0$	$0.010\sqrt{10}B_0$

OR

In the given figure, the curved portion is a semi-circle and the straight wires are long. Find the magnetic field at point O.

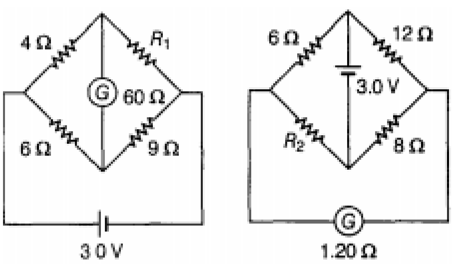


Section C

22. Define the current sensitivity of a galvanometer. Write its SI unit. **[3]**

Figure shows two circuits each having a galvanometer and a battery of 3 V.

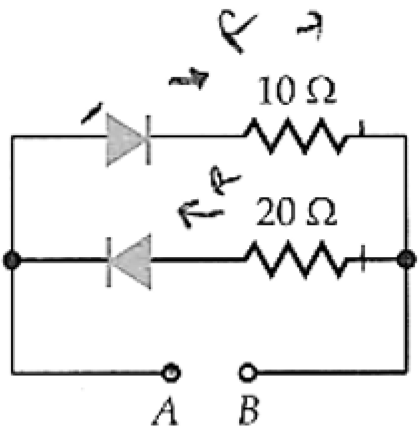
When the galvanometer in each arrangement do not show any deflection, obtain the ratio R_1/R_2.



23. A battery of V may be connected across points A and B, as shown in the figure. Find the current drawn from the battery if the positive terminal is connected to **[3]**

i. the point A and
ii. the point B

Assume that the resistance of each diode is zero in forward bias and infinity in reverse bias.



24. Consider a thin target (10^{-2}m square, 10^{-3}m thickness) of sodium, which produces a photocurrent of 100μA when a light of intensity 100W/m^2 (λ = 660nm) falls on it. Find the probability that a photoelectron is produced when a photon strikes a sodium atom. [Take density of Na = 0.97 kg/m^3]. **[3]**

25. The neutron separation energy is defined as the energy required to remove a neutron from the nucleus. Obtain the neutron separation energies of the nuclei $^{41}_{20}Ca$ and $^{27}_{13}Al$ from the following data: **[3]**

m($^{40}_{20}Ca$) = 39.962591 u

m($^{41}_{20}Ca$) = 40.962278 u

m($^{26}_{13}Al$) = 25.986895 u

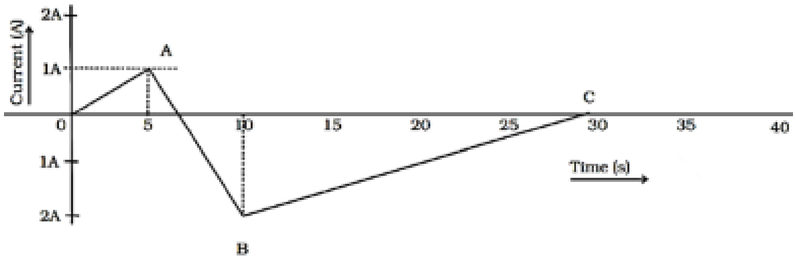
m($^{27}_{13}Al$) = 26.981541 u

26. Using Bohr's postulates, obtain the expression for the total energy of the electron in the stationary states of the hydrogen atom. Hence draw the energy level diagram showing how the line spectra corresponding to Balmer series occur due to transition between energy levels. **[3]**

27. A parallel beam of light of wavelength 600 nm is incident normally on a slit of width 0.2 mm. If the resulting diffraction pattern is observed on a screen 1 m away, find the distance of **[3]**

a. first minimum, and
b. second maximum, from the central maximum.

28. A (current vs time) graph of the current passing through a solenoid is shown in Figure. For which time is the back electromotive force (u) a maximum. If the back emf at t = 3s is e, find the back emf at t = 7 s, 15s, and 40s. OA, AB, and BC are straight line segments. **[3]**



OR

How is the mutual inductance of a pair of coils affected when:

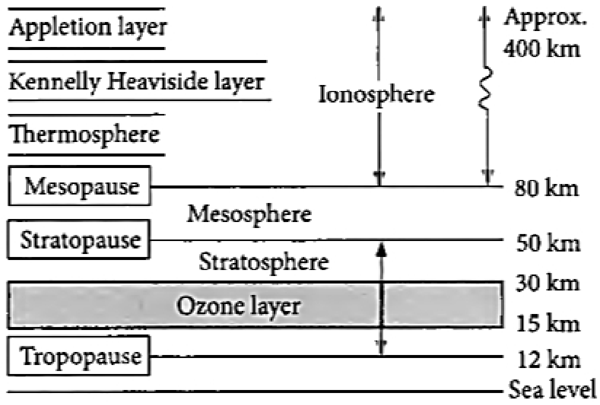
i. separation between the coils is increased?
ii. the number of turns of each coil is increased?
iii. A thin iron sheet is placed between the two coils, other factors remaining the same?

Section D

29. **Read the text carefully and answer the questions:** **[4]**

Radio waves are produced by the accelerated motion of charges in conducting wires. Microwaves are produced by special vacuum tubes. Infrared waves are produced by hot bodies and molecules also known as heat waves.

UV rays are produced by special lamps and very hot bodies like Sun.



(a) Solar radiation is

i. transverse electromagnetic wave
ii. longitudinal electromagnetic waves
iii. both longitudinal and transverse electromagnetic waves
iv. none of these.

a) Option (i)
b) Option (iv)
c) Option (iii)
d) Option (ii)

(b) What is the cause of greenhouse effect?

a) Ultraviolet rays
b) X-rays
c) Infrared rays
d) Radiowaves

(c) Biological importance of ozone layer is

a) it stops ultraviolet rays
b) none of these.
c) it reflects radiowaves
d) It layer reduces greenhouse effect

OR

Earth's atmosphere is richest in

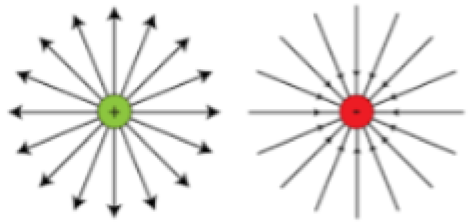
a) ultraviolet
b) infrared
c) X-rays
d) microwaves

(d) Ozone is found in

a) troposphere
b) mesosphere
c) ionosphere
d) stratosphere

30. **Read the text carefully and answer the questions:** **[4]**

A charge is a property associated with the matter due to which it experiences and produces an electric and magnetic field. Charges are scalar in nature and they add up like real numbers. Also, the total charge of an isolated system is always conserved. When the objects rub against each other charges acquired by them must be equal and opposite.



Electric field lines of a positive point charge   Electric field lines of a negative point charge

(a) The cause of charging is:

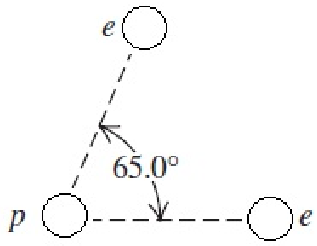
a) the actual transfer of atoms
b) the actual transfer of protons
c) the actual transfer of electrons
d) the actual transfer of neutrons

(b) Pick the correct statement.

i. The glass rod gives protons to silk when they are rubbed against each other.
ii. The glass rod gives electrons to silk when they are rubbed against each other.
iii. The glass rod gains protons from silk when they are rubbed against each other.
iv. The glass rod gains electrons when they are rubbed against each other.

a) Option (i)
b) Option (iv)
c) Option (iii)
d) Option (ii)

(c) If two electrons are each 1.5×10^{-10}m from a proton, as shown in Figure, magnitude of the net electric force they will exert on the proton is



a) 1.97×10^{-8} N
b) 3.83×10^{-8} N
c) 4.63×10^{-8} N
d) 2.73×10^{-8} N

(d) A charge is a property associated with the matter due to which it produces and experiences:

a) electric effects only
b) magnetic effects only
c) both electric and magnetic effects
d) non magnetic effects only

OR

The cause of quantization of electric charges is:

a) transfer of an integral number of electrons
b) transfer of an integral number of neutrons
c) transfer of an integral number of protons
d) transfer of an integral number of Atom

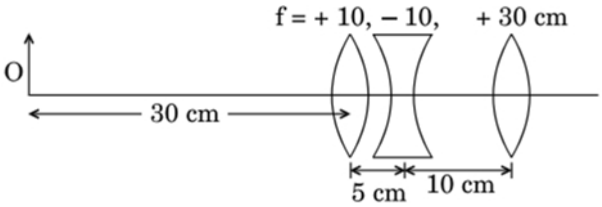
Section E

31. a. Using the ray diagram for a system of two lenses of focal lengths f_1 and f_2 in contact with each other, show that the two lens system can be regarded as equivalent to a single lens of focal length f, where **[5]**

$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$.

Also write the relation for the equivalent power of the lens combination.

b. Determine the position of the image formed by the lens combination given in the figure.



OR

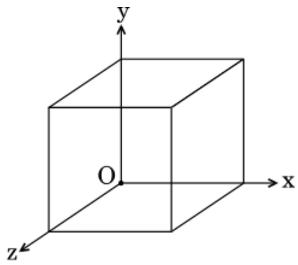
What is interference of light? Write two essential conditions for sustained interference pattern to be produced on the screen. Draw a graph showing the variation of intensity versus the position on the screen in Young's experiment when (a) both the slits are opened and (b) one of the slit is closed. What is the effect on the interference pattern in Young's double-slit experiment when:

i. Screen is moved closer to the plane of slits?

ii. Separation between two slits is increased. Explain.

32. a. Two-point charges q_1 and q_2 are kept r distance apart in a uniform external electric field $\vec{E}$. Find the amount of work done in assembling this system of charges. **[5]**

b. A cube of side 20 cm is kept in a region as shown in the figure. An electric field $\vec{E}$ exists in the region such that the potential at a point is given by V = 10x + 5, where V is in volt and x is in m.



Find the

i. electric field $\vec{E}$, and

ii. total electric flux through the cube.

OR

a. Derive the expression for the electric potential due to an electric dipole at a point on its axial line.

b. Depict the equipotential surfaces due to an electric dipole.

33. An ac voltage V = $V_m$sin ωt is applied to a series LCR circuit. Obtain an expression for the current in the circuit and the phase angle between the current and voltage. What is resonance frequency? **[5]**

OR

A resistor of 400 Ω, an inductor of $\frac{5}{\pi}$ H and a capacitor of $\frac{50}{\pi}\mu F$ are connected in series across a source of alternating voltage of 140 sin $100\pi t\,V$. Find the voltage (rms) across the resistor, the inductor and the capacitor. Is the algebraic sum of these voltages more than the source voltage? If yes, resolve the paradox.

(Given, $\sqrt{2} = 1.414$).

Solution

Section A

1.

(c) diffusion of both electrons and holes

Explanation: diffusion of both electrons and holes

2.

(d) zero

Explanation: At the temperature of inversion, thermo emf is zero.

3.

(c) rectangular hyperbola

Explanation:

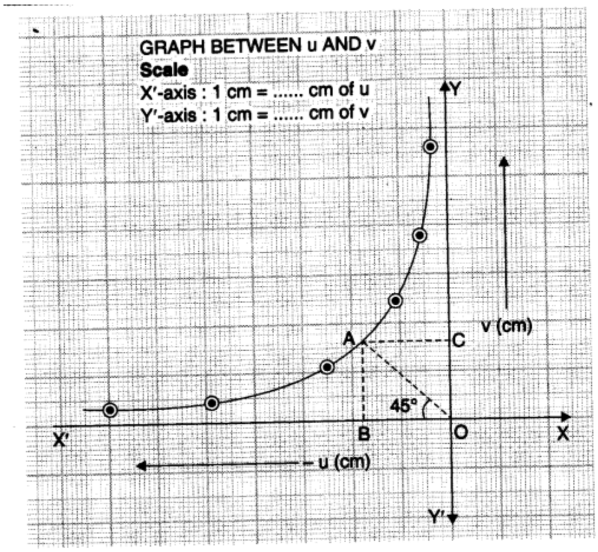


Fig. Graph between u and v. It is a rectangular hyperbola.

4.

(b) Absolute Permittivity

Explanation: Absolute Permittivity

5.

(d) cylindrical capacitor with outer cylinder earthed

Explanation: A submarine cable consists of an inner conductor which carries power. This conductor is covered by an insulator, which acts as a dielectric. The dielectric material is covered by a metal coating called shield, which is connected to ground. The cable acts as a cylindrical capacitor, with the conductor acting as the inner cylinder, and the metal shield as the outer cylinder which is connected to earth.

6.

(d) r^2

Explanation: M = IA = I $\times$ πr^2 i.e., $M \propto r^2$

7.

(b) $\pi \mu V$

Explanation: $\phi = B\pi r^2 \cos 0^\circ = B\pi r^2$

$|\varepsilon| = \frac{d\phi}{dt} = \frac{d}{dt}\left(\pi r^2 B\right) = 2\pi r B \frac{dr}{dt}$

When r = 2cm $= 2 \times 10^{-2}$ m

$\frac{dr}{dt} = 1 \text{ mm s}^{-1} = 10^{-3} ms^{-1}$

$|\varepsilon| = 0.025 \times \pi \times 2 \times 2 \times 10^{-2} \times 10^{-3}$

$= 0.100 \times \pi \times 10^{-5} = \pi \mu V$

8.

(b) $\frac{2}{3}\mathrm{Am}^{-1}$

Explanation: On increasing the temperature magnetic susceptibility of paramagnetic material decreases or vice versa . According to Curie law, we can deduce a formula for the relation between magnetic field induction, temperature and magnetisation.

i.e., I (magnetization) $\propto \frac{B(\text{ magnetic field induction })}{t(\text{ temperature in kelvin })} \Rightarrow \frac{I_2}{I_1} = \frac{B_2}{B_1} \times \frac{t_1}{t_2}$

Let us suppose, here I_1 = 8 Am^{-1}

B_1 = 0.6 T, t_1 = 4 K

B_2 = 0.2 T, t_2 = 16 K

$\Rightarrow \frac{0.2}{0.6} \times \frac{4}{16} = \frac{I_2}{8}$

$\Rightarrow I_2 = 8 \times \frac{1}{12} = \frac{2}{3}\mathrm{Am}^{-1}$

9.

(d) $\frac{4\pi d}{\lambda}\left(1 - \frac{1}{n^2}\sin^2\theta\right)^{1/2} + \pi$

Explanation: The ray reflected by the top surface of the glass and the bottom surface is:-

$\frac{4\pi d}{\lambda}\left(1 - \frac{1}{n^2}\sin^2\theta\right)^{1/2} + \pi$

10.

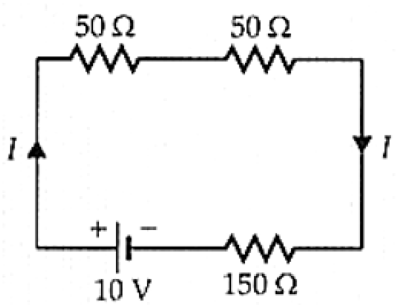
(b) (i) and (iii)

Explanation: According to Coulomb’s law, electric force binds the electrons of an atom to its nucleus and atoms together to form molecules.

11. **(a)** 0.04 A

Explanation:

Diode D_1 is forward biased and offers 50 Ω resistance. Diode D_2 is reverse biased and offers infinite resistance. The equivalent circuit is



Current through the 150Ω resistance,

I = $\frac{10}{50+50+150}$

= $\frac{10}{250}$ = 0.04 A

12.

(d) act as a convex lens irrespective of the side on which the object lies

Explanation:

The relation between focal length f, the refractive index of the given material μ, R_1 and R_2 is known as lens maker's formula and it is $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$R_1 = \infty, R_2 = -R$

$f = \frac{R}{(\mu-1)}$

Here, R = 20 cm, μ = 1.5. On substituting the values, we get

$f=\frac{R}{\mu-1}=\frac{20}{1.5-1}=40\text{cm}$

As f > 0 means converging nature. Therefore, the lens act as a convex lens irrespective of the side on which the object lies.

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

Explanation: de-Broglie wavelength, $\lambda = \frac{h}{mv}$

h and v remaining constant, $\lambda \propto \frac{1}{m}$

So, as the mass of the particle becomes smaller and smaller the de-Broglie wavelength of the particle becomes more and more significant.

Hence, assertion and reason both are true and reason explains the assertion properly.

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

Explanation: Both A and R are true and R is the correct explanation of A.

15.

(d) A is false but R is true.

Explanation: When the source is emitting yellow light, then there will be a dark fringe at a point where path difference is $\frac{3\lambda}{2}$ [from condition for dark fringe $x=(2n+1)\frac{\lambda}{2}$] . If the light is white then the fringe will be coloured, the yellow and neighbouring colours being absent.

16.

(c) A is true but R is false.

Explanation: In a series LCR-circuit, only at resonance, the inductive reactance is equal and opposite to the capacitive reactance.

Section B

17. Given: Wavelength, λ = 5.5×10^{-5} cm = 5.5×10^{-7} m

1. Frequency, $\nu=\frac{c}{\lambda}=\frac{3\times10^{8}m/s}{5.5\times10^{-7}m}$ = 5.45×10^{14} Hz $=5.45\times10^{8}MHz$
   Time period, $T=\frac{1}{\nu}$ = $\frac{1}{5.45\times10^{8}}=1.83\times10^{-9}\mu s$
2. Wavelength of the light in the glass, λ_g = $\frac{\lambda}{\mu}$ = $\frac{5.5\times10^{-7}}{1.5}$ = 3.67×10^{-7} m

18. i) Away from the magnet

ii) The direction of the magnetic moment is opposite to that of the magnetic field applied.

Explanation:

Now considering both superconducting material and liquid nitrogen are diamagnetic in nature, thereby after dipping the ball in liquid nitrogen it will come out as a diamagnetic material. The ball has acquired diamagnetic properties, when in contact with a magnet will form magnetic poles in opposite direction of the magnet kept thereby, repelling the ball away.

As the ball is repelled away it can be said that the magnetic moment will form opposite in direction to the magnetic field applied.

19. The drift velocity of a charge carrier is proportional to electric field E.

$v=\frac{eE}{m}\tau$ i.e., $v\propto E$

But v cannot be increased indefinitely by increasing E. At high speeds, relaxation time τ begins to decrease due to the increase in collision frequency. So drift velocity saturates at the thermal velocity (v_{th} = 10^5ms^{-1}) and becomes independent of the electric field at higher values of E. At 300 K,

$v_{th}=\left(\frac{3k_BT}{m}\right)^{1/2}$ = 10^5 ms^{-1}

τ = 10^{-12} s

An electric field of 10^6 Vm^{-1} causes saturation of drift velocity. Hence semiconductors obey Ohm's law for low electric fields (E < 10^6 Vm^{-1}) and above this field, I become independent of V.

20. i. IMPACT PARAMETER: It is the perpendicular distance from the centre of the nucleus of the initial velocity vector of the alpha particle.
Distance of closest approach: It is the distance of the alpha particle from the nucleus when the kinetic energy of alpha particle becomes equal to electrical potential energy between nucleus and alpha particle.

ii. Impact parameter $b=\frac{z_1z_2e^2}{8\pi\varepsilon_0k}\cot\frac{\theta}{2}$.

I. if θ = 0^o [b = 0]

II. if $\theta = 180^o$ [b = ∞]

21. The magnetic field at an axial point at distance x from the centre of the circular current loop is given by

$$B = \frac{\mu_0 I a^2}{2(a^2+x^2)^{3/2}} = \frac{\mu_0 I}{2a(1+x^2/a^2)^{3/2}}$$

i. At x = 0 $B = \frac{\mu_0 I}{2a} = B_0$

ii. At x = a

$$B = \frac{\mu_0 I}{2a\left(1+\frac{a^2}{a^2}\right)^{3/2}} = \frac{\mu_0 I}{2a(2)^{3/2}}$$

$$= \frac{B_0}{2\sqrt{2}} = \frac{\sqrt{2}}{4}B_0 = 0.25\sqrt{2}B_0$$

iii. At x =2a, $B = \frac{\mu_0 I}{2a\left(1+\frac{4a^2}{a^2}\right)^{3/2}}$

$$= \frac{B_0}{5^{3/2}} = \frac{\sqrt{5}}{25}B_0 = 0.04\sqrt{5}B_0$$

iv. At x =3 a, $B = \frac{\mu_0 I}{3a\left(1+\frac{9a^2}{a^2}\right)^{3/2}}$

$$= \frac{B_0}{10^{3/2}} = \frac{\sqrt{10}}{100}B_0 = 0.01\sqrt{10}B_0$$

OR

Magnetic field at point O due to any current element is perpendicular to and points out of the plane of paper.

Magnetic field at O due to the upper straight wire is

$B_1 = \frac{1}{2} \times \frac{\mu_0 I}{2\pi(\frac{d}{2})} = \frac{\mu_0 I}{2\pi d}$

Similarly, field at O due to lower straight wire is

$B_2 = \frac{\mu_0 I}{2\pi d}$

Field at O due to the semicircle of radius $\frac{d}{2}$ is

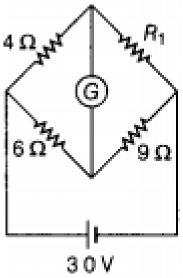
$B_3 = \frac{1}{2} \times \frac{\mu_0 I}{2(\frac{d}{2})} = \frac{\mu_0 I}{2d}$

Resultant field at O,

$B = B_1 + B_2 + B_3 = \frac{\mu_0 I}{2d}\left[1 + \frac{2}{\pi}\right]$

Section C

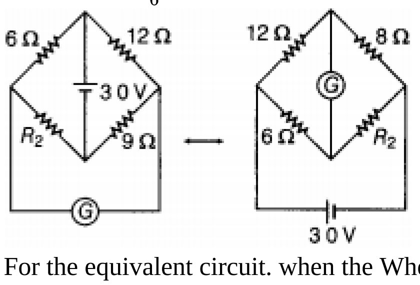
22. Current sensitivity of a galvanometer is defined as the deflection produced in the galvanometer when a unit current flows through it. The SI unit of current sensitivity is rad. A^{-1}. Current sensitivity is expressed as $\frac{\theta}{I} = \frac{NAB}{K}$ where N, A, B and K are number of turns, cross-sectional area, magnetic field intensity and galvanometer's constant respectively.



For balanced Wheatstone bridge, there will be no deflection in the galvanometer.

$\therefore \frac{4}{R_1} = \frac{6}{9}$

$\Rightarrow \quad R_1 = \frac{4\times 9}{6} = 6\Omega$



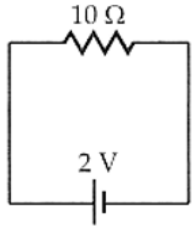
For the equivalent circuit. when the Wheatstone bridge is balanced, there will be no deflection in the galvanometer.

$\therefore \quad \frac{12}{8} = \frac{6}{R_2}$

$\Rightarrow \quad R_2 = \frac{6\times8}{12} = 4\Omega$

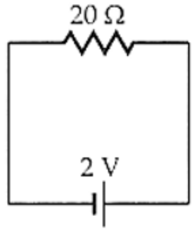
$\therefore \quad \frac{R_1}{R_2} = \frac{6}{4} = \frac{3}{2}$

23. i. When the positive terminal of the battery is connected to point A, diode D_1 gets forward biased and offers zero resistance and diode D_2 gets reverse biased and offers infinite resistance. The given circuit reduces to the equivalent circuit shown in the figure.



$\therefore$ Current drawn from the battery,

ii. When the positive terminal of the battery is connected to point B, the diode D_1 gets reverse biased and offers infinite resistance, and diode D_2 gets forward biased and offers zero resistance. The given circuit reduces to the equivalent circuit shown in the figure.



$\therefore$ Current drawn from the battery,

I = $\frac{2\text{ V}}{20\Omega}$ = 0.1 A

24. 6×10^{26} Na atoms weights 23 kg.

Volume of target = $(10^{-4} \times 10^{-3}) = 10^{-7}$ m^3

Density of sodium = (d) = 0.97 kg/m^3

Volume of 6×10^{26} Na atoms = $\frac{23}{0.97}$m^3 = 23.7m^3

Volume occupied of 1 Na atom

$= \frac{23}{0.97\times6\times10^{26}}\text{m}^3 = 3.95 \times 10^{-26}\text{m}^3$

No. of sodium atoms in the target

$= \frac{10^{-7}}{3.95\times10^{-26}} = 2.53 \times 10^{18}$

Energy per s nhν = 10^{-4}J $\times$ 100 = 10^{-2} W

hν (for λ = 660 nm) $= \frac{1234.5}{600}$

= 2.05eV = $2.05 \times 1.6 \times 10^{-19} = 3.28 \times 10^{-19}$J

$n = \frac{10^{-2}}{3.28\times10^{-19}} = 3.05 \times 10^{16}/\text{s}$

$n = \frac{1}{3.2} \times 10^{17} = 3.1 \times 10^{16}$

If P is the probability of emission per atom, per photon, the number of photoelectrons emitted/second

$= P \times 3.1 \times 10^{16} \times 2.53 \times 10^{18}$

Current is given by $= P \times 3.1 \times 10^{+16} \times 2.53 \times 10^{18} \times 1.6 \times 10^{-19}\text{A}$

$= P \times 1.25 \times 10^{+16}\text{A}$

This must equal $100\ \mu\text{A}$

$P = \frac{100\times10^{-6}}{1.25\times10^{+16}}$

$\therefore P = 8 \times 10^{-21}$

Thus the probability of photoemission by a single photon on a single atom is very much less than 1. It is due to the reason the absorption of two photons by an atom is negligible.

25. Given that,

Mass m($^{40}_{20}$Ca) = 39.962591 u

Mass m($^{41}_{20}$Ca) = 40.962278 u

Mass m($^{26}_{13}Al$) = 25.986895 u

Mass m($^{27}_{13}Al$) = 26.981541 u

We know that,

Removal of one neutron ($^{1}_{0}n$) from $^{41}_{20}\mathrm{Ca}$ leads to the formation of $^{40}_{20}\mathrm{Ca}$,

$^{41}_{20}\mathrm{Ca} \rightarrow ^{40}_{20}\mathrm{Ca} + ^{1}_{0}\mathrm{n}$

The mass defect of this reaction is given by,

$\Delta \mathrm{m} = \mathrm{m}\left(^{40}_{20}\mathrm{Ca}\right)\mathrm{u} + \mathrm{m}\left(^{1}_{0}\mathrm{n}\right)\mathrm{u} - \mathrm{m}\left(^{41}_{20}\mathrm{Ca}\right)\mathrm{u}$

= 39.962591 u + 1.008665 u - 40.962278 u = 0.008978 u

We have, 1 a.m.u = 913.5 MeV/c^2

Hence the energy required to remove neutron removal is given by,

E = Δ mc^2 = 0.008978 $\frac{\mathrm{MeV}}{\mathrm{c}^2} \times 31.5\ c^2$ = 8.363007 MeV

We know that,

Removal of one neutron $^{1}_{0}n$ from $^{27}_{13}Al$ leads to the formation of $^{26}_{13}Al$,

$^{27}_{13}\mathrm{Al} \rightarrow ^{26}_{13}\mathrm{Al} + \frac{1}{0}\mathrm{n}$

The mass defect of this reaction is given by,

$\Delta m = m\left(^{26}_{13}Al\right) + m\left(^{1}_{0}n\right)u - m\left(^{27}_{13}Al\right)u$

= 25.986895 u + 1.008665 u - 26.981541 u = 0.014019 u

We have, 1 a.m.u = 913.5 MeV/c^2

Hence the energy required to remove neutron removal,

E = Δmc^2 = 0.014019 $\frac{MeV}{c^2} \times$ 931.5 c^2 = 13.059 MeV

Hence, Energy required for removal of neutron is given by,

$^{41}_{20}\mathrm{Ca}$ = 8.363007 MeV

$^{26}_{13}Al$ = 13.059 MeV

26. Suppose m be the mass of an electron and v be its speed in nth orbit of radius r. The centripetal force for revolution is produced by electrostatic attraction between electron and nucleus.

or,

$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(e)}{r^2}$ ...(i)

$mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r}$

So, Kinetic energy [K] = $\frac{1}{2}mv^2$

$K = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{2r}$

Potential energy = $\frac{1}{4\pi\varepsilon_0}\frac{(Ze)(-e)}{r} = -\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r}$

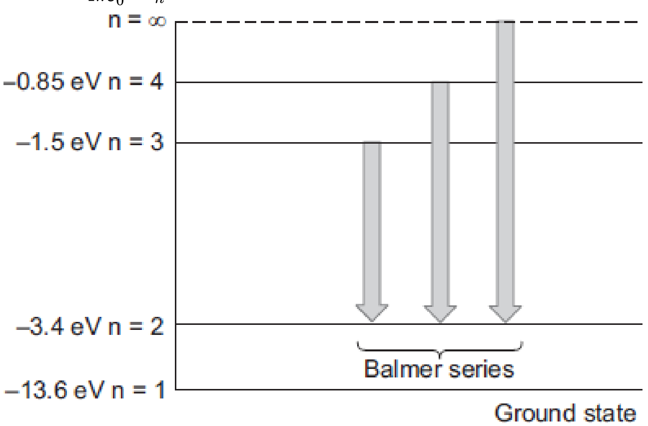
total energy

E = KE + PE = $\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{2r} + \left(-\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r}\right)$

$E = -\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{2r}$

For n^{th} orbit, E can be written as E_n

$E_n = -\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{2r_n}$ ...(ii)



Energy level diagram of Balmer series

27. a. Using the theory of diffraction fringes $\sin\theta = \frac{n\lambda}{a}$

$\frac{x}{D} = \frac{n\lambda}{a}$

n = 1

a = 0.2×10^{-3} m

D = 1 m

λ = 600×10^{-9} m

x = $\frac{1\times600\times10^{-9}\times1}{0.2\times10^{-3}}$

= 3 mm ; so the distance of first minima is 3 mm.

b. $\sin\theta = \left(n - \frac{1}{2}\right)\frac{\lambda}{a}$

$\frac{x}{D} = \left(n - \frac{1}{2}\right)\frac{\lambda}{a}$

n = 2

x = $\frac{3\lambda D}{2a}$

= $\frac{3\times600\times10^{-9}\times1}{2\times0.2\times10^{-3}}$

= 4.5 mm

28. The maximum back electromotive force (u) will be maximum when there is a maximum rate of change of magnetic flux which is directly proportional to the rate of change of current.

Maximum change or rate of current will be where (t - I) graph for the solenoid makes a maximum angle with time axis which is in part AB

So the maximum back e.m.f. will occur between 5 s to 10 s. As the back e.m.f. at t = 3 s it is e (given)

Rate of change of current at t = 3 s-slope of OA graph with time axis So the rate of change of current at 3s = $\frac{1}{5}A/s$

So back electromotive force at t = 3s $= L \times \frac{1}{5} = \frac{L}{5} = e$ (given)

$\because e = L \cdot \frac{dI}{dt}$ and L = constant for the solenoid.

Similarly back e.m.f. u between 5 to 10 sec.

$u_1 = L\left(\frac{-3}{5}\right) = -3\frac{L}{5} = -3e$

back e.m.f. between 10 to 30 sec

$u_2 = L\frac{[0-(-2)]}{(30-10)} = \frac{+2L}{20} = \frac{+1}{2}\frac{L}{5}$

$u_2 = +\frac{1}{2}e$

So back e.m.f. at 7 sec = -3 e

Back e.m.f. at 15 sec $= +\frac{1}{2}e$

At 40 sec graph is along the time axis, i.e. its slope with time axis is zero.

So, $\frac{dI}{dt} = 0$

Or back e.m.f. at 40 sec = 0

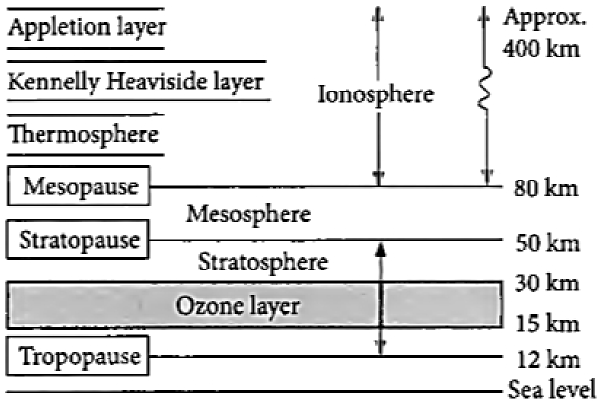
OR

i. Mutual inductance (M) decreases because the quantity of flux linking to a coil due to the other one will decrease.
ii. M increases because as the number of turns increase, the overall flux density also increases and hence the mutual inductance will also increase.
iii. M increases because iron is ferromagnetic in nature hence, it will increase the flux density.

Section D

29. **Read the text carefully and answer the questions:**

Radio waves are produced by the accelerated motion of charges in conducting wires. Microwaves are produced by special vacuum tubes. Infrared waves are produced by hot bodies and molecules also known as heat waves. UV rays are produced by special lamps and very hot bodies like Sun.



(i) **(a)** Option (i)

Explanation: transverse electromagnetic wave

(ii) **(c)** Infrared rays

Explanation: Greenhouse effect is due to infrared rays.

(iii) **(a)** it stops ultraviolet rays

Explanation: Ozone layer absorbs the harmful ultraviolet radiations coming from the sun.

OR

(b) infrared

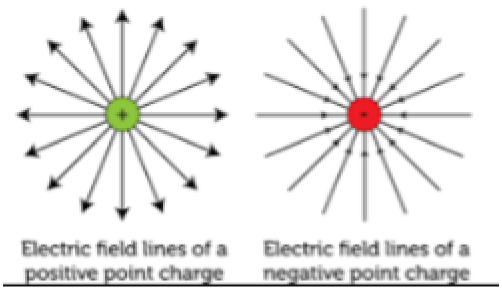
Explanation: The atmosphere of earth is richest in infrared radiation.

(iv) **(d)** stratosphere

Explanation: Ozone layer lies in stratosphere.

30. **Read the text carefully and answer the questions:**

A charge is a property associated with the matter due to which it experiences and produces an electric and magnetic field. Charges are scalar in nature and they add up like real numbers. Also, the total charge of an isolated system is always conserved. When the objects rub against each other charges acquired by them must be equal and opposite.



(i) **(c)** the actual transfer of electrons

Explanation: the actual transfer of electrons

(ii) **(d)** Option (ii)

Explanation: The glass rod gives electrons to silk when they are rubbed against each other.

(iii) **(a)** 1.97×10^{-8} N

Explanation: 1.97×10^{-8} N

(iv) **(c)** both electric and magnetic effects

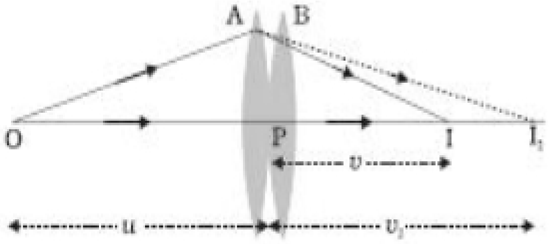
Explanation: both electric and magnetic effects

OR

(a) transfer of an integral number of electrons

Explanation: transfer of an integral number of electrons

Section E

31. a. 

For less A

$\frac{1}{f_1} = \frac{1}{v_1} - \frac{1}{u}$ eg. (I)

For less B

$\frac{1}{f_2} = \frac{1}{v} - \frac{1}{v_1}$ eg.(II)

Adding eqn. (i) & eqn. (ii)

$\frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{v_1} - \frac{1}{u} + \frac{1}{v} - \frac{1}{v_1}$

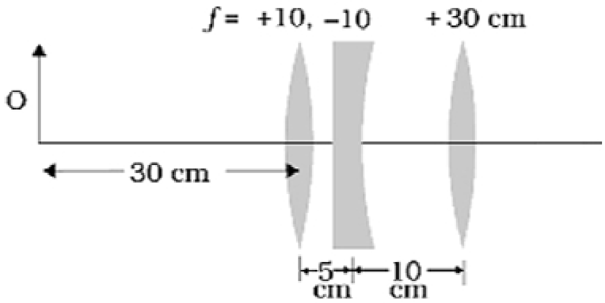
$\frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{v} - \frac{1}{u}$

$\frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{F}$

∴ equivalent power

$P = P_2 + P_2$

b. Image formed by lense of f = +10 cm



$\frac{1}{v_1} - \frac{1}{u_1} = \frac{1}{f_1}$

$\frac{1}{v_1} - \frac{1}{30} = \frac{1}{10}$

∴ v_1 = 15 cm

This image formed by the lens act as object from concave lens

∴ u_2 = 15 - 5 = 10 cm

$\frac{1}{f_2} + \frac{1}{v_2} = \frac{1}{u_2}$

$\frac{1}{-10} = \frac{1}{v} - \frac{1}{10}$

$v = \infty$

Therefore virtual image forms at right of concave lens at $v = \infty$ and act as convex lens. (f = +30 cm)

∴ u_2 = 15 - 5 = 10 cm

$\frac{1}{v_3} = \frac{1}{4} - \frac{1}{f_3}$

$\frac{1}{v_3} = \frac{1}{\infty} = \frac{1}{30}$

v_3 = 30 cm

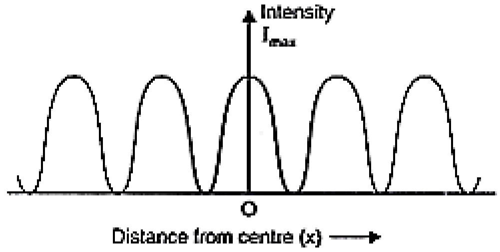
OR

Interference of light: Phenomenon of redistribution of light energy in a medium on account of superposition of light waves from two coherent sources is called interference of light.

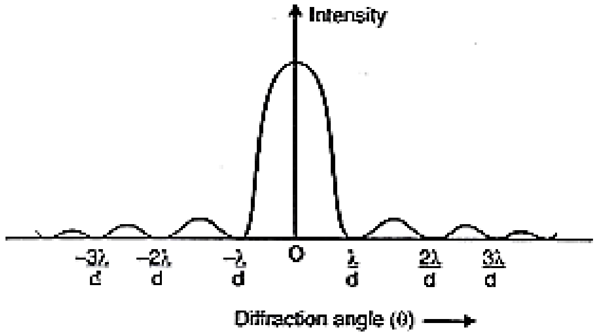
Conditions for sustained interference: The two essential conditions of sustained interference are as follows:

i. The two sources of light should emit light continuously.
ii. The light waves should be of same wavelength (Monochromatic).

(a) When both the slits are open, we get an interference pattern on the screen. Then the following intensity distribution curve is obtained.



(b) When one of the slits is closed, diffraction pattern is obtained on the screen. The following intensity curve is obtained.



Also we know that, Fringe width, $\beta = \frac{D\lambda}{d}$, therefore

i. The distance D decreases, the fringe width β also decreases if screen is moved closer to the plane of the slits.
ii. Fringe width β decreases if separation d between two slits is increased.

32. i. Let the charge q_1 travels r_1 distance.

The work done in bringing the charge q1 in the field is:-

$W_1 = F_1 \times r_1$

$= q_1E \times r_1$

the work done in bringing the second charge

$W_2 = F_2 \times r_2$

$= q_2E \times r_2$

and the work is also done to overcome the force of the charge on one-another.

$W_3 = \frac{1}{4\pi\epsilon_0} \cdot \frac{q_1q_2}{r^2}$

So, total work = $q_1Er_1 + q_2Er_2 + \frac{1}{4\pi\epsilon_0} \cdot \frac{q_1q_2}{r^2}$

ii. a. Given that, V = 10x + 5

We know

$E = -\frac{dv}{dx}$

v = 10x + 5

$\frac{dv}{dx} = \frac{d}{dx}(10x + 5)$

$= 10\frac{d}{dx}x + 0$

= 10

electric field is given by E = -10 N/C

b. Since electric field is constant in negative x-direction

as the flux enter in the cube will be same as flux come out through the cube so flux

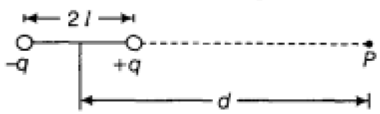
$\phi_{in} = \phi_{out}$ hence,

Net flux from the cube = 0, so total electric flux is given by:

$\phi_{net} = 0$

OR

a. Let electric potential is to be determined at a point P lying on the axis of an electric dipole of dipole length 2l at a distance d from the centre of the dipole as shown in the figure.



Potential at P due to +q charge of the dipole $= \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{(d-l)}$

Potential at P due to -q charge of the dipole

$= \frac{1}{4\pi\varepsilon_0}\frac{-q}{(d+l)}$

Total potential at P due to both the charges of the dipole

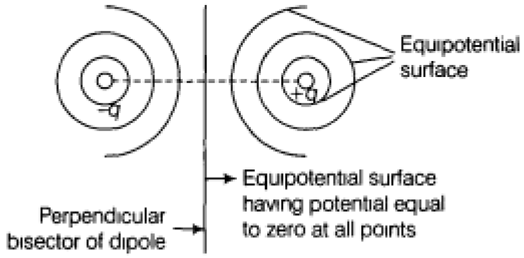
$= \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{(d-l)} - \frac{1}{(d+l)}\right]$

$= q \times \frac{2l}{4\pi\varepsilon_0} \times \frac{1}{\left(d^2-l^2\right)} = \frac{p}{4\pi\varepsilon_0} \times \frac{1}{\left(d^2-l^2\right)}$

where, the scalar value of dipole moment (p) = q × 2l

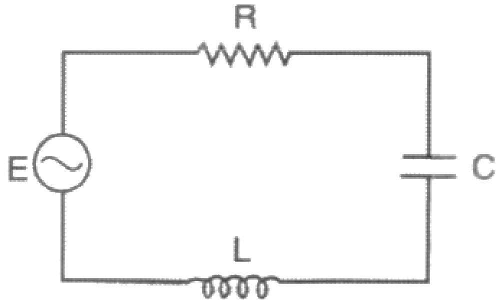
If l << d, then neglecting l^2 we get, the final value of the electric potential to be, $V = \frac{1}{4\pi\varepsilon_0}\frac{p}{d^2}$

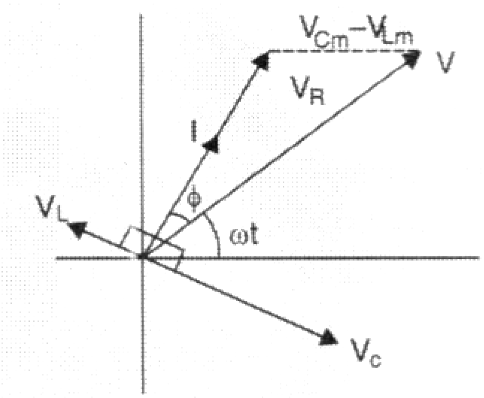
b. An electric dipole consists of two equal and opposite charges separated by some distance. Equipotential lines and electric field are always perpendicular to each other. Equipotential surfaces of a dipole are as shown below:



Potential of points lying on the perpendicular bisector surface will be zero.

33. i. In a series LCR circuit shown,





From the phasor relation, voltages $V_L + V_R + V_C = V$, as V_C and V_L are along the same line and in opposite directions, so they will combine in single phasor $(V_C + V_L)$ having magnitude $|V_{Cm}$ - VLm|. Since voltage V is shown as the hypotenuse of a right-angled triangle with sides as V_R and $(V_C + V_L)$, So the Pythagoras Theorem results as :

$V_m^2 = V_R^2 + (V_{Cm} - V_{Lm})^2$

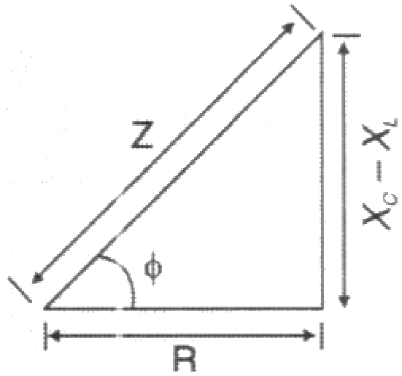
$V_m^2 = (I_m R)^2 + (I_m X_C - I_m X_L)^2$

$V_m^2 = I_m{}^2(R^2 + (X_C - X_L)^2)$

Now current in tire circuit :

$I_m = \frac{V_m}{\sqrt{\left(R^2+(X_C-X_L)^2\right.}}$

$I_m = \frac{V_m}{Z}$ as $Z = \sqrt{\left[R^2 + (X_C - X_L)^2\right]}$



As phasor 1 is always parallel to phasor V_R, the phase angle ϕ is the angle between V_R and V and can be determined from figure.

$\tan\phi = \frac{V_{Cm} - V_{Lm}}{V_{Rm}}$

$\tan\phi = \frac{X_C - X_L}{R}$

ii. **Resonance frequency** is defined as the **frequency** at which the impedance of the **LCR circuit** becomes minimum or current in the **circuit** becomes maximum. It is shown as: $V_{Cm} = V_{Lm}$ and $X_L = X_C$

$f_0 = \frac{1}{2\pi\sqrt{LC}}$

OR

$C = \frac{50}{\pi}\mu F, L = \frac{5}{\pi}H, R = 400\Omega$

As applied voltage, $V = 140\sin 100\pi t$

Comparing it with $V = V_0 \sin\omega t$,

$V_0 = 140\text{V}, \omega = 100\pi$

Inductive reactance, $X_L = \omega L$

$X_L = 100\pi \times 5/\pi = 500\Omega$

Capacitive reactance, $X_C = \frac{1}{\omega C}$

$X_c = \frac{1}{100\pi \times \frac{50}{\pi} \times 10^{-6}} = 200\Omega$

Impedance of the AC circuit,

$Z = \sqrt{R^2 + (X_L - X_C)^2}$

$= \sqrt{1409^2 + (500 - 200)^2}$

$Z = \sqrt{1600 + 900} = 500\Omega$

Maximum current in the circuit,

$I_0 = \frac{V_0}{Z} = \frac{140}{500}$

$I_{\text{rms}} = \frac{I_0}{\sqrt{2}} = \frac{140}{500 \times \sqrt{2}} = 0.2\text{A}$

V_{rms} across resistor R, $V_{rms} = I_{rms}R$

$V_{rms} = 0.2 \times 400 = 80\text{V}$

V_{rms} across inductor, $V_L = I_{\text{rms}}X_L$

$V_L = 0.2 \times 500 = 100\text{V}$

V_{rms} across capacitor, $V_C = I_{\text{rms}}X_C$

$V_C = 0.2 \times 200 = 40\text{V}$

Now, V

Here, $V \neq V_R + V_L + V_C$

Because V_C, V_L and V_R are not in same phase,

$\therefore V = \sqrt{V_R^2 + (V_L - V_C)^2}$

V = $\sqrt{80^2 + (100 - 40)^2} = 100\ V$

which is same as the applied rms voltage.