Class XII Session 2025-26
Subject - Physics
Sample Question Paper - 10

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. If N is Avogadro number, M is atomic weight and ρ, the density, the number of free electrons per unit volume of a monovalent metallic crystal can be expressed as **[1]**

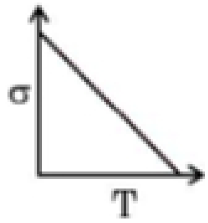
a) $\frac{N}{\mu M}$

b) $\frac{\rho N}{M}$

c) $\frac{MN}{\rho}$

d) $\frac{\rho M}{N}$

2. Which one of the following is the correct representation of variation of conductivity of a conductor with temperature? **[1]**

a)


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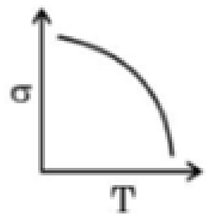

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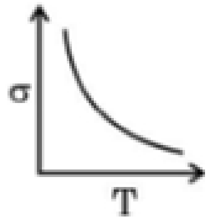

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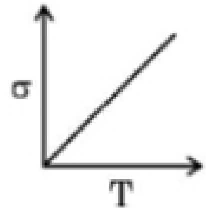


3. The principal behind optical fibre is: **[1]**

a) Total internal reflection

b) Both Total external reflection and Total internal reflection

c) Diffraction

d) Total external reflection

4. A bar magnet of pole strength (m) and magnetic moment (M) is cut perpendicular to its axis in two equal halves. The new pole strength (m') and magnetic moment (M') of each part are respectively: **[1]**

a) m and $\frac{M}{2}$

b) m and M

c) 2m and $\frac{M}{2}$

d) $\frac{m}{2}$ and 2M

5. Two charges $3 \times 10^{-8} C$ and $-2 \times 10^{-8} C$ are located 15 cm apart. At what point on the line joining them, the potential will be zero. **[1]**

a) 3 cm from first charge

b) 9 cm from first charge

c) None of these

d) 6 cm from first charge

6. The Magnetic Resonance Imaging (MRI) is based on the phenomenon of **[1]**

a) Nuclear magnetic resonance

b) Electron paramagnetic resonance

c) Electron spin resonance

d) Diamagnetism of human tissues

7. Two identical circular coaxial coils A and B, arranged in vertical planes parallel to each other, carry currents in the same direction. If the distance between the coils is decreased at a constant rate, the current: **[1]**

a) increases in both A and B.

b) increases in A and decreases in B.

c) decreases in both A and B.

d) remains same in both A and B.

8. At a point on the right bisector of a magnetic dipole, the magnetic: **[1]**

a) field is perpendicular to the axis of dipole

b) potential is zero at all points on the right bisector

c) potential varies as $\frac{1}{r^2}$

d) field varies as r^3

9. If two sources have a randomly varying phase different ϕ(t), the resultant intensity will be given by **[1]**

a) 2 I_0

b) $\frac{3}{2} I_0$

c) $\frac{I_0}{2}$

d) $\frac{I_0}{\sqrt{2}}$

10. The number of electric field lines crossing an area ΔS is n_1 when $\Delta \vec{S} || \vec{E}$, while number of field lines crossing same area is n_2 when $\Delta \vec{S}$ makes an angle of 30° with $\vec{E}$, then: **[1]**

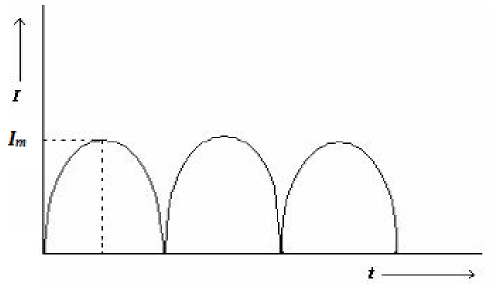
a) $n_1 < n_2$

b) $n_1 = n_2$

c) $n_1 > n_2$

d) cannot say anything.

11. The output current I versus time (t) curve of a full wave rectifier is shown in the figure. The average value of the output current in this case is **[1]**



a) I_m

b) Zero

c) $\frac{2I_m}{\pi}$

d) $\frac{I_m}{\pi}$

12. Which of the following pairs of media has the least value of critical angle? **[1]**

a) Glass to air

b) Glass to water

c) Diamond to water

d) Diamond to air

13. **Assertion (A):** In his study of photoelectric emission, Hallwachs connected a negatively charged zinc plate to an electroscope. He found that negatively charged particles were emitted from the zinc plate under the action of visible light. **[1]**

Reason (R): An uncharged zinc plate becomes positively charged when it is irradiated by visible light.

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:** If the distance between parallel plates a capacitor is halved and dielectric constant is made three times then the capacitance becomes six times. **[1]**

Reason: (R) Capacitance of the capacitor does not depend upon the nature of the material of the plates of the capacitor.

a) Assertion and reason both are correct statements and reason is correct explanation for assertion.

b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.

c) Assertion is correct statement but reason is wrong statement.

d) Assertion is wrong statement but reason is correct statement.

15. **Assertion (A):** Interference pattern is made by using yellow light instead of red light, the fringes becomes narrower. **[1]**

Reason (R): In Young's double slit experiment, fringe width is given by $\beta = \frac{\lambda D}{d}$.

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):** In alternating current, the direction of motion of free electrons changes periodically. **[1]**

Reason (R): Alternating current changes its direction after a certain is always 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.

Section B

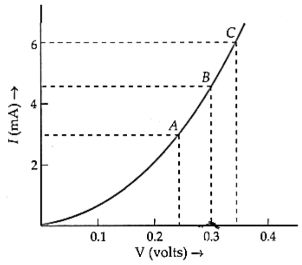
17. a. Which one of the following electromagnetic radiations has least frequency: **[2]**
UV radiations, X-rays, Microwaves?
b. How do you show that electromagnetic waves carry energy and momentum?
c. Write the expression for the energy density of an electromagnetic wave propagating in free space.

18. Two equal and unlike poles placed 5 cm apart in the air attract each other with a force of 14.4×10^{-4} N. How far from each other should they be placed so that the force of attraction will be 1.6×10^{-4} N? **[2]**

OR

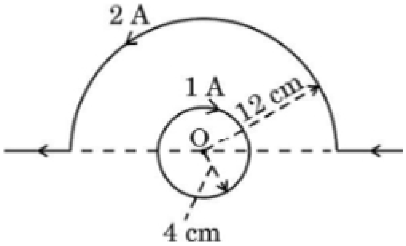
A short bar magnet placed in a horizontal plane has its axis aligned along the magnetic north-south direction. Null points are found on the axis of the magnet at 14 cm from the centre of the magnet. The earth's magnetic field at the place is 0.36 G and the angle of dip is zero. What is the total magnetic field on the normal bisector of the magnet at the same distance as the null–point (i.e., 14 cm) from the centre of the magnet? (At null points, field due to a magnet is equal and opposite to the horizontal component of earth's magnetic field.)

19. The figure shows the characteristic curve of a junction diode. Determine the d.c. and a.c. resistance of the diode, when it operates at 0.3 V. **[2]**



20. If Bohr's quantisation postulate (angular momentum = $\frac{nh}{2\pi}$) is a basic law of nature, it should be equally valid for the case of planetary motion also. Why then do we never speak of quantisation of orbits of planets around the sun? **[2]**

21. A current carrying circular loop and a straight wire bent partly in the form of a semicircle are placed as shown in the figure. Find the magnitude and direction of net magnetic field at point O. **[2]**



Section C

22. A conductor of length I is connected to a DC source of potential V. If the length of the conductor is tripled by gradually stretching it, keeping V constant, how will **[3]**
i. drift speed of electrons and
ii. resistance of the conductor be affected? Justify your answer

23. a. State briefly, with what purpose was Davisson and Germer experiment performed and what inference was drawn from this. **[3]**
b. Obtain an expression for the ratio of the accelerating potentials required to accelerate a proton and an α-particle to have the same de-Broglie wavelength associated with them.

24. How is a light emitting diode fabricated? Briefly explain the basic processes involved in the emission of spontaneous radiation from it. Write two advantages of LED lamps over the incandescent low power lamps. **[3]**

25. Plot a graph showing the variation of binding energy per nucleon as a function of mass number. Which property of nuclear force explains the approximate constancy of binding energy in the range $30 < A < 170$? **[3]**
How does one explain the release of energy in both processes of nuclear fission and fusion from the graph?

26. An electron in a hydrogen atom makes transitions from orbits of higher energies to orbits of lower energies. **[3]**
a. When will such transitions result in (a) Lyman (b) Balmer series?
b. Find the ratio of the longest wavelength in Lyman series to the shortest wavelength in Balmer series.

27. A plane wavefront is propagating from a rarer into a denser medium. Use Huygens principle to show the refracted wavefront and verify Snell's law. **[3]**

28. Define the term self-inductance of a solenoid. Obtain the expression for the magnetic energy stored in an inductor of self-inductance L to build up a current I through it. **[3]**

OR

Define mutual inductance between a pair of coils. Derive an expression for the mutual inductance of two long coaxial solenoids of the same length wound one over the other.

Section D

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

Microwave oven: The spectrum of electromagnetic radiation contains a part known as microwaves. These waves have frequency and energy smaller than visible light and wavelength larger than it. What is the principle of a microwave oven and how does it work? Our objective is to cook food or warm it up. All food items such as fruit, vegetables, meat, cereals, etc., contain water as a constituent. Now, what does it mean when we say that a certain object has become warmer? When the temperature of a body rises, the energy of the random motion of atoms and molecules increases and the molecules travel or vibrate or rotate with higher energies. The frequency of rotation of water molecules is about 2.45 gigahertz (GHz). If water receives microwaves of this frequency, its molecules absorb this radiation, which is equivalent to heating up water. These molecules share this energy with neighbouring food molecules, heating up the food. One should use porcelain vessels and non-metal containers in a microwave oven because of the danger of getting a shock from accumulated electric charges. Metals may also melt from heating. The porcelain container remains unaffected and cool, because its large molecules vibrate and rotate with much smaller frequencies, and thus cannot absorb microwaves. Hence, they do not get eaten up. Thus, the basic principle of a microwave oven is to generate microwave radiation of appropriate frequency in the working space of the oven where we keep food. This way energy is not wasted in heating up the vessel. In the conventional heating method, the vessel on the burner gets heated first and then the food inside gets heated because of transfer of energy from the vessel. In the microwave oven, on the other hand, energy is directly delivered to water molecules which is shared by the entire food.

(a) As compared to visible light microwave has frequency and energy

a) Frequency is less but energy is more
b) more than visible light
c) less than visible light
d) equal to visible light

(b) When the temperature of a body rises

a) the energy of the random motion of atoms and molecules remains same.
b) the energy of the random motion of atoms and molecules decreases.
c) the random motion of atoms and molecules becomes streamlined.
d) the energy of the random motion of atoms and molecules increases

(c) The frequency of rotation of water molecules is about

a) 2.45 kHz

b) 2.45 GHz

c) 2.45 MHz

d) 2.45 THz

OR

In the microwave oven

a) The vessel gets heated first, and then the food grains inside

b) The vessel gets heated first and then the water molecules collect heat from the body of the vessel

c) Energy is directly delivered to the food grains.

d) Energy is directly delivered to water molecules which is shared by the entire food

(d) Why should one use porcelain vessels and non-metal containers in a microwave oven?

a) Because it will prevent the food items to become hot

b) Because it may crack due to high frequency

c) Because of the danger of getting a shock from accumulated electric charges

d) Because it will get too much hot

30. The smallest charge that can exist in nature is the charge of an electron. During friction, it is only the transfer of electrons that makes the body charged. Hence net charge on anybody is an integral multiple of the charge of an electron [1.6×10^{-19} C] i.e. **[4]**

$q = \pm ne$

where n = 1, 2, 3, 4,...

Hence nobody can have a charge represented as 1.1e, 2.7e, $\frac{3}{5}$e, etc.

Recently, it has been discovered that elementary particles such as protons or neutrons are composed of more elemental units called quarks.

i. Find the number of electrons if the body has 3.2×10^{-18} C of charge.

ii. If a charge on a body is 1 nC, then how many electrons are present on the body?

iii. If a body gives out 10^9 electrons every second, how much time is required to get a total charge of 1 C from it?

iv. A polythene piece rubbed with wool is found to have a negative charge of 3.2×10^{-7} C. Calculate the number of electrons transferred.

Section E

31. a. Draw a ray diagram for formation of a real and diminished image of an object kept in front of a concave mirror. Hence derive the mirror equation. **[5]**

b. A concave mirror of focal length 10 cm produces a real image which is 3 times the size of the object. Find the distance of the object from the mirror.

OR

i. Describe briefly how a diffraction pattern is obtained on a screen due to a single narrow slit illuminated by a monochromatic source of light. Hence, obtain the conditions for the angular width of secondary maxima and secondary minima.

ii. Two wavelengths of sodium light of 590 nm and 596 nm are used in turn to study the diffraction taking place at a single slit of aperture $2 \times 10^{-6} m$. The distance between the slit and the screen is 1.5m. Calculate the separation between the positions of first maxima of the diffraction pattern obtained in the two cases.

32. A capacitor of capacitance C_1 is charged to a potential V_1 while another capacitor of capacitance C_2 is charged to a potential difference V_2. The capacitors are now disconnected from their respective charging batteries and connected in parallel to each other. **[5]**

i. Find the total energy stored in the two capacitors before they are connected.
ii. Find the total energy stored in the parallel combination of two capacitors.
iii. Explain the reason for the difference of energy in parallel combination in comparison to the total energy before they are connected

OR

a. If two similar large plates, each of area A having surface charge densities $+\sigma$ and **-** σ are separated by a distance d in air, then find the expression for

   i. the field at points between the two plates and on the outer side of the plates. Specify the direction of the field in each case.
   ii. the potential difference between the plates.
   iii. the capacitance of the capacitor so formed.

b. Two metallic spheres of radii R and 2R are charged so that both of these have the same surface charge density σ. If they are connected to each other with a conducting wire, in which direction will the charge flow and why?

33. An emf ε = 100 sin 314 t is applied across a pure capacitor of 637 μF. Find **[5]**

i. the instantaneous current I
ii. instantaneous power P
iii. the frequency of power and
iv. the maximum energy stored in the capacitor.

OR

i. An ac source of voltage V = V_0sin ωt is connected to a series combination of L, C, and R. Use the phasor diagram to obtain expressions for impedance of the circuit and phase angle between voltage and current. Find the condition when the current will be in phase with the voltage. What is the circuit in this condition called?

ii. In a series, LR circuit X_L = R and power factor of the circuit is P_1. When capacitor with capacitance C such that X_L = X_C is put in series, the power factor becomes P_2. Calculate $\frac{P_1}{P_2}$.

Solution

Section A

1.

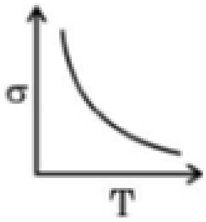
(b) $\frac{\rho N}{M}$

Explanation:

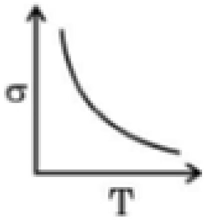
As the crystal is monovalent, it has one free electron per atom. If V is the volume of M mass of the crystal, it will contain N atoms or N free electrons. Therefore, the number of free electrons per unit volume,

n = $\frac{N}{V} = \frac{N}{M/\rho} = \frac{\rho N}{M}$ $[\because \rho = \frac{M}{V}]$

2.

(c) 

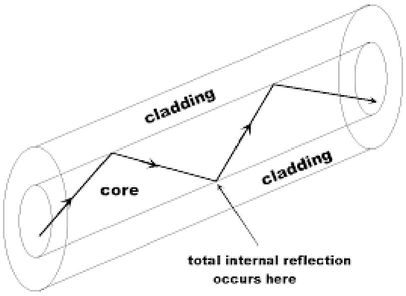
Explanation:



3. **(a)** Total internal reflection

Explanation:

Optical fibres are fabricated with high-quality composite glass/quartz fibres. Each fibre consists of a core and cladding. The refractive index of the material of the core is higher than that of the cladding. When a signal in the form of light is directed at one end of the fibre at a suitable angle, it undergoes repeated total internal reflections along the length of the fibre and finally comes out at the other end as shown in figure.



4. **(a)** m and $\frac{M}{2}$

Explanation:

M = m(2l)

M' = ml

M' = $\frac{M}{2}$

So, pole strength will be m and $\frac{M}{2}$.

5.

(b) 9 cm from first charge

Explanation:

To find the point where the electric potential is zero, we need to consider the contributions of both charges. The potential due to a point charge is given by the formula $V = \frac{kQ}{r}$, where k is Coulomb's constant, Q is the charge, and r is the distance from the charge. Let's denote the first charge $Q_1 = 3 \times 10^{-8}\,C$ and the second charge $Q_2 = -2 \times 10^{-8}\,C$. The distance between the charges is 15 cm. To find the point where the potential is zero, we can set up the equation for the potential due to both charges at a point x cm from the first charge:

i. The distance from the first charge to the point is x.
ii. The distance from the second charge to the point is $15 - x$. The total potential at that point is:
$V = \frac{k \cdot 3 \times 10^{-8}}{x} + \frac{k \cdot (-2 \times 10^{-8})}{15 - x}$ Setting $V = 0$: $\frac{3 \times 10^{-8}}{x} - \frac{2 \times 10^{-8}}{15 - x} = 0$ This simplifies to: $\frac{3}{x} = \frac{2}{15 - x}$

Cross-multiplying gives: $3(15 - x) = 2x$
Expanding and rearranging leads to: $45 - 3x = 2x \implies 45 = 5x \implies x = 9\,\text{cm}$
Thus, the point where the potential is zero is indeed 9 cm from the first charge.

6. **(a)** Nuclear magnetic resonance
Explanation:
The Magnetic Resonance Imaging (MRI) is based on the phenomenon of nuclear magnetic resonance.

7.
(c) decreases in both A and B.
Explanation:
decreases in both A and B.

8.
(b) potential is zero at all points on the right bisector
Explanation:
The magnetic potential at any point is the amount of work done in bringing a unit north pole from infinity to that point. At any point on the right bisector, the potentials due to the two poles are equal and opposite.

9. **(a)** 2 I_0
Explanation:
For two incoherent sources, the resultant intensity at every point is just twice of the two individual intensities.

10.
(c) $n_1 > n_2$
Explanation:
The solution is correct because the number of electric field lines crossing an area is directly related to the component of the electric field that is perpendicular to that area. When the area vector $\Delta\vec{S}$ is aligned with the electric field $\vec{E}$, all the field lines pass through, resulting in the maximum number n_1. When the area vector makes an angle of 30° with the electric field, only a portion of the electric field contributes to the number of lines crossing the area. This is given by the formula $n_2 = n_1 \cos(30^\circ)$, where $\cos(30^\circ) < 1$. Therefore, n_2 will be less than n_1, confirming that n_1 is greater than n_2.

11.
(c) $\frac{2I_m}{\pi}$
Explanation:
Current waveform can be represented as, $I = I_m sin\omega t$ for $0 \leq \omega t \leq 2\pi$, where I_m = max load current
Average current, $I_{DC} = \frac{I_m}{\pi} \int_0^{\pi} \sin(\omega t)\,\mathrm{d}(\omega t)$
$= \frac{I_m}{\pi}[-cos(\omega t)]_0^{\pi} = \frac{2I_m}{\pi}$

12.
(d) Diamond to air
Explanation:
Diamond to air

13.

(d) A is false but R is true.

Explanation:

A is false but R is true.

14.

(b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.

Explanation:

Assertion and reason both are correct statements but reason is not correct explanation for assertion.

15. **(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.

16. **(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.

Section B

17. a. Microwave

b. When a charge oscillates with some frequency. It produces an oscillating electric field and magnetic field in space. So, an electromagnetic wave is produced. The frequency of the em wave is equal to the frequency of oscillation of the charge. Hence energy associated with the em wave comes at the expense of the energy of the source. If the em wave of energy U strikes on a surface and gets completely absorbed, total momentum delivery to the surface is p = $\frac{U}{E}$.

Hence em wave also carry momentum.

c. The em wave consists of oscillating electric and magnetic fields, So net energy density of em wave is

U = $U_E + U_B$

U = $\frac{1}{2}\varepsilon_0 E^2 + \frac{1}{2}\frac{B^2}{\mu_0}$

18. Distance between the poles = 5 cm

Force of attraction = 14.4×10^{-4} N

The force of attraction between two magnetic poles is given by the formula

F = $\frac{\mu_0}{4\pi}\frac{q_{m_1}q_{m_2}}{r^2}$ i.e., $F \propto \frac{1}{r^2}$

$\therefore \frac{F_1}{F_2} = \frac{r_2^2}{r_1^2}$

$r^2 = \sqrt{\frac{F_1}{F_2}} \cdot r_1 = \sqrt{\frac{14.4\times10^{-4}}{1.6\times10^{-4}}} \times 5 \times 10^{-2}$

= 0.15 m

OR

Earth's magnetic field at the given place, H = 0.36G

The magnetic field at a distance d, on the axis of the magnetic is given as:

$B_1 = \frac{\mu_0}{4\pi}\frac{2M}{d^3} = H$ .... (i)

where,

μ_0 = Permeability of free space

M = Magnetic moment

The magnetic field at the same distance d, on the equatorial line of the magnet is given as:

$B_2 = \frac{\mu_0 M}{4\pi d^3} = \frac{H}{2}$ [Using equation (i)]

Total magnetic field on the normal bisector is given by, B = $B_1 + B_2$

$= H + \frac{H}{2}$

= 0.36 + 0.18 = 0.54G

Hence, the magnetic field is 0.54 G in the direction of earth's magnetic field.

19. The d.c. resistance is just equal to the voltage divided by current.

$\therefore r_{dc} = \frac{V_B}{I_B} = \frac{0.3\text{ V}}{4.5\times10^{-3}A}$ = 66.67 Ω

Consider two points A and C around the point of operation B. Then,

$r_{ac} = \frac{\Delta V}{\Delta I} = \frac{V_C - V_A}{I_C - I_A} = \frac{0.35-0.25}{(6-3)\times 10^{-3}} = 33.33\ \Omega$

20. The angular momentum associated with planetary motion is large relative to the Planck's constant. As the angular momentum of Earth in its orbit is of order of 10^{70} h which results in a higher value of the quantum level of order of 10^{70}. The more is the value of n, successive energies and angular momenta are relatively very small. So, the quantum levels of planetary motion are considered as continuous.

21. Magnetic field due to inner circle at O,

$B_1 = \frac{\mu_0 I}{2r}$

$= \frac{2\pi\times 10^{-7}\times 1}{4\times 10^{-2}}$

$= \frac{\pi}{2}\times 10^{-5}$ T into the page

Magnetic field due to semi-circle at O,

$B_2 = \frac{\mu_0 I}{2r}\cdot\frac{1}{2}$

$= \frac{2\pi\times 10^{-7}\times 2}{12\times 10^{-2}}$

$= \frac{\pi}{6}\times 10^{-5}$ T out of the page

as magnetic fields are in opposite directions so

$B_{net} = B_1 - B_2$

$= \left(\frac{\pi}{2}\times 10^{-5} - \frac{\pi}{6}\times 10^{-5}\right) T \approx 1.0\times 10^{-5} T$

Direction of the net magnetic field is into the page, since $B_1 > B_2$.

Section C

22. When a wire is stretched, then there is no change in the matter of the wire, hence its volume remains constant

Here, the potential V = constant, l' = 3 I

i. Drift speed of electrons $= \frac{V}{nel\rho}$

where, n is number of electrons, e is charge on electron, I is the length of the conductor and p is the resistivity of conductor.

$\therefore \quad v \propto \frac{1}{l}$ [∵ other factors are constant]

So, when length is tripled, drift velocity gets one-third.

ii. Resistance of the conductor is given as

$R = \rho(l/A)$ where ρ = Resistivity, l = length of the wire, A = Area of cross section of wire

Here, wire is stretched to triple its length, that means the mass of the wire remains same in both the conditions.

∴ Mass before stretching = Mass after stretching

(Volume × Density) before stretching = (Volume × Density) after stretching

(Area of cross-section × Length) before stretching = (Area of cross-section × Length) after stretching (∵ Density is same in both cases)

$\therefore A_1 l_1 = A_2 l_2 \Rightarrow A_1\, l = A_2\,(3\, l)$ [∵ length is tripled after stretching]

$A_2 = A_1/3$

i.e. When length is tripled area of cross-section is reduced to A/3.

Hence, $R' = \rho\frac{l'}{A'} = \rho\frac{3l}{A/3} = 9\rho\frac{l}{A} = 9R$

Thus, above calculation shows that new resistance will be 9 times of its initial value.

23. a. Purpose of Davisson Germer Experiment was to verify the wave nature of electron. It confirms the de Broglie relations for matter waves / Diffraction effect of electron beams from crystal

b. de Broglie wavelength

$\lambda = \frac{\mathrm{h}}{\sqrt{2\mathrm{mqV}}}$

$\therefore \frac{\mathrm{h}}{\sqrt{2\,\mathrm{m}_p \mathrm{eV_p}}} = \frac{\mathrm{h}}{\sqrt{2\,\mathrm{m}_\alpha \mathrm{eV}_\alpha}}$

$\therefore \frac{\mathrm{V_p}}{\mathrm{V}\alpha} = \frac{8}{1}$

24. LED is heavily doped p-n junction diode which emits spontaneous radiation in forward baising. The diode is encapsulated with a transparent cover so that emitted light can come out.

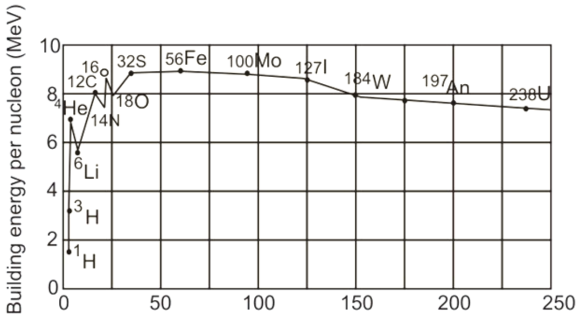
When LED is forward biased the electrons and holes approaches to the junction boundaries and on each recombination of electron

& hole at or near the junction \& hole at or near the junction boundary the LED emits radiation/photon.

Advantages-

i. Low operational voltage and less power

ii. Long life and ruggedness

25. 

The plot of the binding energy per nucleon versus the mass number A for a large number of nuclei

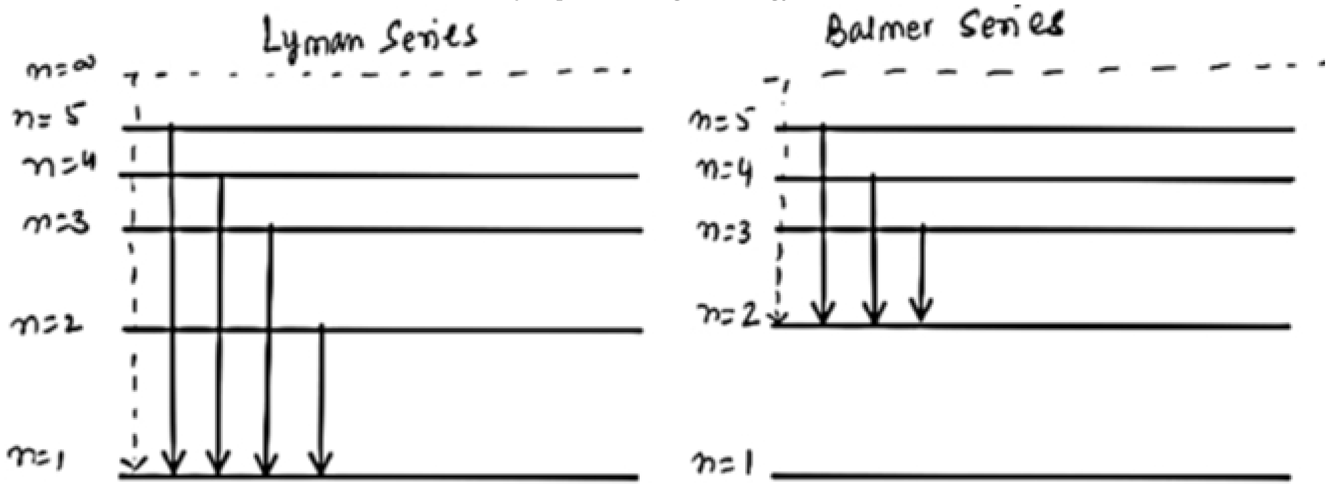
The nuclear force is short-ranged represents the consistency of binding energy in the range 30 < A < 170.

A heavy nucleus has lower binding energy per nucleon compared to a lighter one. Suppose a nucleus width A = 240 breaks into two nuclei of A = 120, nucleons get more tightly bounded. This implies that energy would be released in fission.

For two ling very light nuclei ($A \leq 10$) joining to form a heavier nucleus. The binding energy per nucleon of heavier nucleus > binding energy per nucleon of lighter nuclei. This implies that energy is released during fission.

26. a. Transition result in Lyman series if electron will jump from a higher energy orbit to n = 1 orbit

Transition result in Balmer series if electron will jump from a higher energy orbit to n = 2 orbit



b. Longest wavelength in Lyman Series

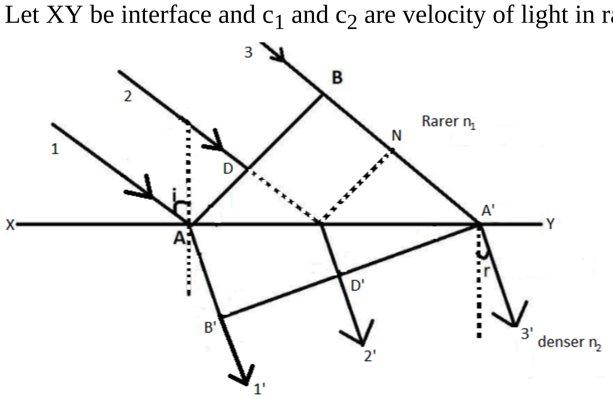
$$\frac{1}{\lambda_L} = R \cdot \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = \frac{3R}{4}$$

Shorted wavelength in Balmer Series

$$\frac{1}{\lambda_S} = R\left[\frac{1}{{n_1}^2} - \frac{1}{n_2^2}\right] = R\left[\frac{1}{2^2} - \frac{1}{\infty}\right] = \frac{R}{4}$$

Ratio $\frac{\lambda_2}{\lambda_S} = \frac{4}{3R} \times \frac{R}{4} = \frac{1}{3}$

27. Let XY be interface and c_1 and c_2 are velocity of light in rarer and denser medium respectively.



then, $\mu = \frac{c_1}{c_2}$

μ is refractive index of medium 2 with respect to medium 1.

According to Huygens principle, every point of plane wavefront AB acts as a source of secondary wavelet. Let the secondary wavelets from B strikes XY at A' in t seconds

$BA' = c_1 \times t$

Similarly from A secondary wavelet travels in denser medium with velocity c_2

$AB' = c_2 \times t$

In $\triangle AA'B$

$\sin i = \frac{BA'}{AA'} = \frac{C_1 t}{AA'}$

In $\triangle AA'B'$ $\sin r = \frac{AB'}{AA'} = \frac{C_2 \times t}{AA'}$

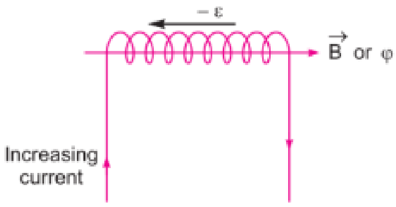
$\frac{\sin i}{\sin r} = \frac{c_1}{c_2} = u = \frac{n_2}{n_1}$ This proves snell's law of refraction.

28. Using formula, $|-\varepsilon| = L\frac{dI}{dt}$

If $\frac{dI}{dt} = 1$ A/s, then $L = |-\varepsilon|$

Self inductance of the coil is equal to the magnitude of induced emf produced in the coil itself when the current varies at rate 1 A/s.

Expression for magnetic energy:



When a time varying current flows through the coil, back emf $(-\varepsilon)$ produces, which opposes the growth of the current flow. It means some work needs to be done against induced emf in establishing a current I. This work done will be stored as magnetic potential energy.

For the current I at any instant, the rate of work done is

$\frac{dW}{dt} = (-\varepsilon)I$

Only for inductive effect of the coil $|-\varepsilon| = L\frac{dI}{dt}$

$\therefore \quad \frac{dW}{dt} = L\left(\frac{dI}{dt}\right)I \quad \Rightarrow dW = LIdI$

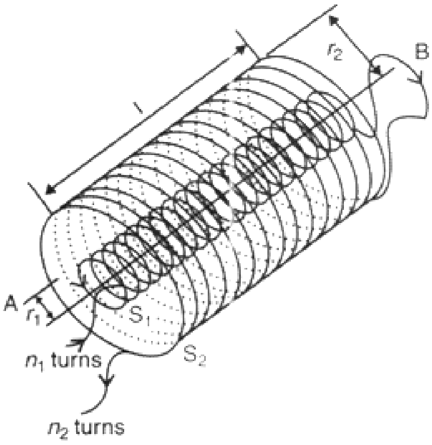
From work-energy theorem,

dU = LIdI

$\therefore U = \int_0^I LIdI = \frac{1}{2}LI^2$

OR

i. Mutual inductance is numerically equal to the induced emf in the secondary coil when the current in the primary coil changes by unity.
ii. in the question mutual inductance of two long coaxial solenoids of same length l wound one over the other is given by:-



Let a current l_2 flow in the secondary coil

$\therefore B_2 = \frac{\mu_0 N_2 i_2}{l}$

$\therefore$ Flux linked with the primary coil = $\frac{\mu_0 N_2 N_1 A_1 i_2}{l}$

$= M_{12} i_2$

Hence, $M_{12} = \frac{\mu_0 N_2 N_1 A_1}{l}$

$\mu_0 n_2 n_1 A_1 l \left(n_1 = \frac{N_1}{l}; n_2 = \frac{N_2}{l}\right)$

Section D

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

Microwave oven: The spectrum of electromagnetic radiation contains a part known as microwaves. These waves have frequency and energy smaller than visible light and wavelength larger than it. What is the principle of a microwave oven and how does it work? Our objective is to cook food or warm it up. All food items such as fruit, vegetables, meat, cereals, etc., contain water as a constituent. Now, what does it mean when we say that a certain object has become warmer? When the temperature of a body rises, the energy of the random motion of atoms and molecules increases and the molecules travel or vibrate or rotate with higher energies. The frequency of rotation of water molecules is about 2.45 gigahertz (GHz). If water receives microwaves of this frequency, its molecules absorb this radiation, which is equivalent to heating up water. These molecules share this energy with neighbouring food molecules, heating up the food. One should use porcelain vessels and non-metal containers in a microwave oven because of the danger of getting a shock from accumulated electric charges. Metals may also melt from heating. The porcelain container remains unaffected and cool, because its large molecules vibrate and rotate with much smaller frequencies, and thus cannot absorb microwaves. Hence, they do not get eaten up. Thus, the basic principle of a microwave oven is to generate microwave radiation of appropriate frequency in the working space of the oven where we keep food. This way energy is not wasted in heating up the vessel. In the conventional heating method, the vessel on the burner gets heated first and then the food inside gets heated because of transfer of energy from the vessel. In the microwave oven, on the other hand, energy is directly delivered to water molecules which is shared by the entire food.

(i) **(c)** less than visible light

Explanation:

Microwaves have frequency and energy smaller than visible light and wavelength larger than it.

(ii) **(d)** the energy of the random motion of atoms and molecules increases

Explanation:

When the energy of the random motion of atoms and molecules of a substance increases and the molecules travel or vibrate or rotate with higher energies, the substance becomes hot.

(iii) **(b)** 2.45 GHz

Explanation:

The frequency of rotation of water molecules is about 2.45 gigahertz.

OR

(d) Energy is directly delivered to water molecules which is shared by the entire food

Explanation:

In the conventional heating method, the vessel on the burner gets heated first and then the food inside gets heated because of transfer of energy from the vessel. In the microwave oven, on the other hand, energy is directly delivered to water molecules which is shared by the entire food.

(iv) **(c)** Because of the danger of getting a shock from accumulated electric charges

Explanation:

One should use porcelain vessels and non-metal containers in a microwave oven because of the danger of getting a shock from accumulated electric charges. Metals may also melt from heating. The porcelain container remains unaffected and cool, because its large molecules vibrate and rotate with much smaller frequencies and thus cannot absorb microwaves. Hence, they do not get heated up.

30. i. From, q = ne, n = $\frac{q}{e} = \frac{3.2\times10^{-18}}{1.6\times10^{-19}}$ = 20

Hence, the number of electrons on the body is 20.

ii. Charge on the body is q = ne

$\therefore$ No. of electrons present on the body is n = $\frac{q}{e} = \frac{1\times10^{-9}\text{C}}{1.6\times10^{-19}\text{C}}$ = 6.25×10^9

iii. Here, n = 10^9 electrons per second

The charge given per second, q = ne = $10^9 \times 1.6 \times 10^{-19}$ C

q = 1.6×19^{-10} C

Total charge, Q = 1 C ...(given)

$\therefore$ Time required = $\frac{Q}{q} = \frac{1}{1.6\times10^{-10}}s$ = 6.25 × 10^9 s

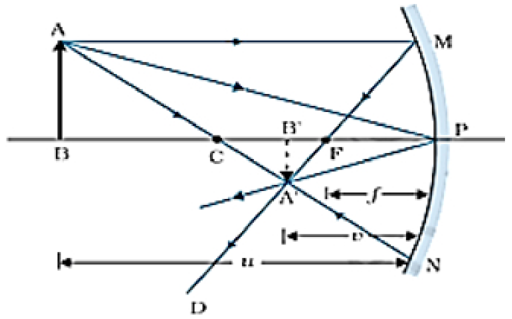
$\therefore \frac{6.25\times10^9}{3600\times24\times365}$year = 198.19 years

iv. As q = ne, n = $\frac{3.2\times10^{-7}}{1.6\times10^{-19}}$

$\Rightarrow$ n = 2 × 10^{12} electrons

$\therefore$ the number of electrons transferred will be 2 × 10^{12}

Section E

31. a. 

$\triangle A'B'F \sim \triangle MPF$

$\frac{B'A'}{BA} = \frac{B'F}{FP}$ ($\because$ PM = AB) ...(i)

Also, $\triangle A'B'P \sim \triangle ABP$

$\frac{B'A'}{BA} = \frac{B'P}{BP}$ ...(ii)

Comparing eq. (i) and (ii)

$\frac{B'F}{FP} = \frac{B'P-FP}{FP} = \frac{B'P}{FP}$

B'P = -v

FP = -f

BP = -u

On solving we get, $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$

b. $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$

$\frac{1}{u} = \frac{1}{f} - \frac{1}{v}$

$-\frac{v}{u}$ = -3

v = 3u

$\frac{1}{u} = \frac{1}{f} - \frac{1}{3u}$

$\frac{1}{u} + \frac{1}{3u} = \frac{1}{f}$

$\frac{4}{3u} = \frac{1}{f}$

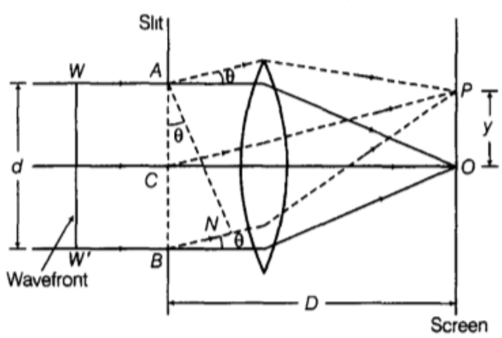
$u = \frac{4f}{3} = -\frac{40}{3}$ cm

Hence, the distance of the object from the mirror $\frac{40}{3}$ cm.

OR

i. A single narrow slit is illuminated by a monochromatic source of light. The diffraction pattern is obtained on the screen placed in front of the slits. There is a central bright region called as central maximum. All the waves reaching this region are in phase hence the intensity is maximum. On both side of central maximum, there are alternate dark and bright regions, the intensity becoming weaker away from the center. The intensity at any point P on the screen depends on the path difference between the waves arising from different parts of the wave-front at the slit.

Diffraction of light at a single slit A parallel beam of light with a plane wavefront WW' is made to fall on a single slit AB. As width of the slit AB = dis of the order of wavelength of light, therefore, diffraction occurs on passing through the slit.



The wavelets from the single wavefront reach the centre O on the screen in same phase and hence, interfere constructively to give central maximum (bright fringe).

The diffraction pattern obtained on the screen consists of a central bright band having alternate dark and weak bright band of decreasing intensity on both sides.

Consider a point P on the screen at which wavelets travelling in a direction making an angle θ with CO are brought to focus by the lens. The wavelets from points A and B will have a path difference equal to BN.

From the right angled ΔANB, we have BN = AB sinθ or BN = d sinθ.

To establish the condition for secondary minima, the slit is divided into 2,4,6... equal parts such that corresponding wavelets from parts such that corresponding wavelets from successive regions interfere with path difference $\lambda/2$

or for nth secondary minlmum.the slit can be divided into 2n equal parts. Hence, for nth secondary minimum, path difference= $= d \sin\theta_n = n\lambda$.

or $\sin\theta_n = \frac{n\lambda}{d}(n = 1, 2, 3, \ldots)$

To establish the condition for secondary maxima, the slit is divided into 3,5,7... equal parts such that corresponding wavelets from alternate regions interfere with path difference of A./2 or for nth secondary maximum, the slit can be divided into (2n+ 1)equal parts.

Hence, for nth secondary maximum

$d\sin\theta_n = (2n+1)\frac{\lambda}{2}$ (n = 1, 2, 3,...)

ii. For $\lambda_1 = 590\text{mm}$

Location of 1 maxima $y_1 = (2n+1)\frac{D\lambda_1}{2d}$

If $n = 1 \Rightarrow y_1 = \frac{3D\lambda_1}{2d}$

For $\lambda_2 = 596\text{nm}$

Location of III maxima

$y_2 = (2n+1)\frac{D\lambda_2}{2d}$, if n = 1

$\Rightarrow y_2 = \frac{3D\lambda_2}{2d}$

$\therefore$ Path difference $= y_2 - y_1 = \frac{3D}{2d}(\lambda_2 - \lambda_1)$

$= \frac{3\times1.5}{2\times2\times10^{-6}}(596 - 590)\times10^{-9}$

$= 6.75\times10^{-3}\text{m}$

32. i. Total energy stored in the two capacitors before they are connected,

$u_i = \frac{1}{2}C_1V_1^2 + \frac{1}{2}C_2V_2^2$

ii. After the two capacitors are connected in parallel, the common potential is

$V = \frac{\text{Total charge}}{\text{Total capacitance}} = \frac{q_1+q_2}{C_1+C_2} = \frac{C_1V_1+C_2V_2}{C_1+C_2}$

Total energy stored in the parallel combination,

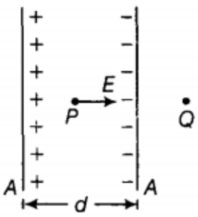
$U_f = \frac{1}{2}(C_1+C_2)V^2 = \frac{1}{2}(C_1+C_2)\left(\frac{C_1V_1+C_2V_2}{C_1+C_2}\right)^2$

$= \frac{1}{2}\frac{(C_1V_1+C_2V_2)^2}{C_1+C_2}$

iii. Clearly, $U_f < U_i$. Thus the total energy of the parallel combination is less than the sum of the energies stored in the two capacitors before they are connected. During sharing of charges, some energy is lost as heat due to the flow of charges in connecting wires.

OR

a. Consider the figure shown below:



i. Electric field due to the plate of the positive charge of charge density $+\sigma$ at point P, is given by

$E_1 = \sigma/2\varepsilon_0$

Magnitude of electric field due to the other plate of negative charge density $-\sigma$,is given by

$E_2 = -\sigma/2\varepsilon_0$

In , the inner region between the plates 1 and 2 , electric field due to the two charged plates add up, is given by

$E_{\text{net}} = E_1 + E_2 = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0}$

Outside the plate, electric field will be equal to zero because of the opposite directions of the electric fields E_1 and E_2 there.

ii. Potential difference between the plates of the capacitor is given by

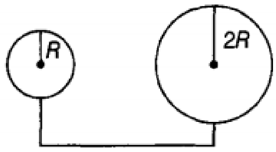
V = Ed = $\sigma d/\varepsilon_0$ ($\because E = \sigma/\varepsilon_0$)

iii. Capacitance of the capacitor is given by

($\because$ Q = CV)

$C = \frac{Q}{V} = \frac{\sigma A}{\sigma d}\varepsilon_0 = \frac{\varepsilon_0 A}{d}$

b. Consider the figure shown below:



Potential at the surface of the sphere of radius R,

{tex}= \frac { k q } { R } \quad \left[\because q = \sigma \times 4πR ^ { 2 } \right]{/tex}

$= \frac{k\sigma 4\pi R^2}{R} = \sigma k 4\pi R = 4k\sigma\pi R$

Potential at the surface of the second sphere of radius twice the previous one i.e. 2R,

$= \frac{kq}{2R} \quad \left[\because q = \sigma \times 4\pi(2R)^2 = 16\sigma\pi R^2\right]$

$= \frac{k16\sigma\pi R^2}{2R} = 8k\sigma\pi R$

We know that charge always flows from the higher potential surface to lower potential surface. Since the potential of the bigger sphere is more, so charge will flow from sphere of radius 2R to the sphere of radius R after connecting both the spheres by a conducting wire

33. i. Given ε = 100 sin 314 t volt

As the current in a capacitor leads the voltage by 90^{o}, so the instantaneous current is given by

I = $I_0 \sin(314t + 90^\circ) = I_0 \cos 314t$

where $I_0 = \frac{\varepsilon_0}{X_C} = \frac{\varepsilon_0}{1/\omega C} = \varepsilon_0 \omega C$

But ε_0 = 100 V, $\omega = 314$ rads^{-1}, C = 637×10^{-6} F

$\therefore I_0 = 100 \times 314 \times 637 \times 10^{-6} = 20$ A

Where $I_0 = \frac{\varepsilon_0}{X_C} = \frac{\varepsilon_0}{1/\omega C} = \varepsilon_0 \omega C$

But ε_0 = 100 V, $\omega = 314$ rad s^{-1} , $C = 637 \times 10^{-6}$ F

$\therefore I_0 = 100 \times 314 \times 637 \times 10^{-6} = 20$ A

Hence I = 20 cos 314 t ampere

ii. Instantaneous power,

P = $\varepsilon I = 100 \sin 314t \times 20 \cos 314t$

= 1000 sin 628 t watt

iii. Angular frequency of power, $\omega_p = 628$ rads^{-1}

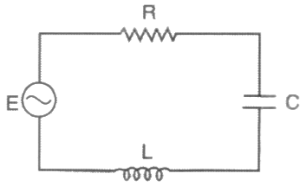
$\therefore$ Frequency of power, $f_p = \frac{\omega_p}{2\pi} = \frac{628}{2\pi} = 100$ Hz

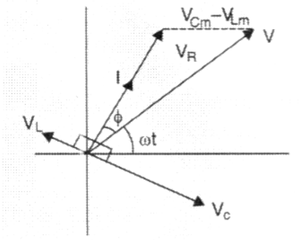
iv. The maximum energy stored in the capacitor is

$U_0 = \frac{1}{2}CE_0^2 = \frac{1}{2} \times 637 \times 10^{-6} \times (100)^2$ = 3.185 J

OR

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 right-angled triangle with sides as V_R and $(V_C + V_L)$, so the Pythagoras Theorem results as :

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

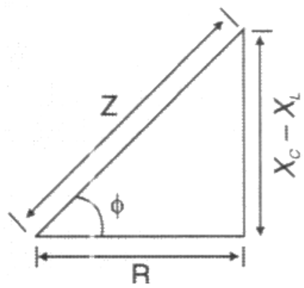
$V_m^2 = (I_m R)^2 + (I_m X_C - I_m X_L)^2$

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

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 the figure.

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

$\tan\phi = \frac{X_C-X_L}{R}$ andϕ= $\frac{\tan^{-1}(X_C-X_L)}{R}$ condition for current and voltage are in phase $V_L=V_C$ and $X_L=X_C$and the circuit is said resonant circuit.

ii. Power factor

$P_1 = \frac{R}{Z} = \frac{R}{\sqrt{R^2+R^2}}$ (as $X_L = R$)

$= \frac{1}{\sqrt{2}}$

Power factor when capacitor C of Reactance $X_C = X_L$ is put in series in the circuit as Z = R (at resonance)

$P_2 = \frac{R}{Z} = \frac{R}{R}$ = 1

$\therefore \frac{P_1}{P_2} = \frac{\frac{1}{\sqrt{2}}}{1} = \frac{1}{\sqrt{2}}$