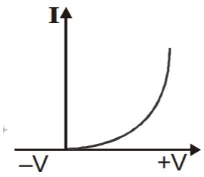
Class XII | Physics — Solutions (Set 7) | Session 2026-27

Section A

1.

(c) 

Explanation:

The correct graph for a PN junction under varying voltages shows a nonlinear relationship between voltage and current. As the voltage increases in the forward bias region, the current increases exponentially. This behavior is characteristic of diodes, where small increases in voltage lead to large increases in current after a certain threshold (the forward voltage). The graph typically starts at zero current, rises steeply, and levels off in reverse bias, indicating that the current remains very low until breakdown occurs. Correct option accurately represents this exponential increase in current with voltage.

2.

(c) potentiometer

Explanation:

The instrument among the following which measures the emf of a cell most accurately is a potentiometer.

3. **(a)** Difference between apparent and real depth of a pond

Explanation:

Difference between apparent and real depth of a pond

4.

(b) case (ii) contradicts Gauss's law for magnetic fields.

Explanation:

case (ii) contradicts Gauss's law for magnetic fields.

5.

(b) $12\pi\varepsilon_0 \frac{V}{A}$

Explanation:

$V = \frac{4}{3}\pi R^3$ and A = 4πR^2

$\therefore \frac{V}{A} = \frac{R}{3} \Rightarrow R = \frac{3V}{A}$

$C = 4\pi\varepsilon_0 R = 4\pi\varepsilon_0 \left(\frac{3V}{A}\right) = \frac{12\pi\varepsilon_0 V}{A}$

6.

(b) 10 μsec

Explanation:

$T_p = \frac{25}{5} = 5\mu\text{s}$

From the above problem,

$T_\alpha = 2T_p = 2 \times 5 = 10\mu$ sec

7.

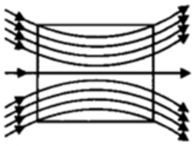
(c) [ML^{2}T^{-2}Q^{-1}]

Explanation:

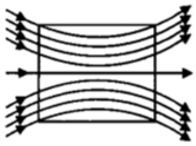
$\varepsilon = \frac{[W]}{[q]} = \frac{[ML^2T^{-2}]}{[Q]}$

= $[ML^2T^{-2}Q^{-1}]$

8.

(c) 

Explanation:



9.

(b) shift upward by nearly two fringes

Explanation:

Displacement of the central bright fringe,

$\Delta x = \frac{\beta}{\lambda}$ (μ - 1)t

$= \frac{\beta(1.5-1)\times 2\times 10^{-6}}{500\times 10^{-9}} = 2\beta$, upward

10.

(b) (i) s; (ii) q; (iii) r; (iv) p

Explanation:

The solution correctly matches the electric flux through the Gaussian surfaces with their corresponding values based on Gauss's law.

i. For surface S_1, the flux ϕ_{s1} is positive, indicating that it encloses a positive charge Q, leading to $\phi_{s_1} = +\frac{Q}{\varepsilon_0}$.
ii. For surface S_2, the flux ϕ_{s_2} is zero, suggesting that it does not enclose any net charge, hence $\phi_{s_2} = 0$.
iii. For surface S_3, the flux ϕ_{s_3} is negative, indicating that it encloses a negative charge, resulting in $\phi_{s_3} = -\frac{Q}{\varepsilon_0}$
iv. For surface S_4, the flux ϕ_{s_4} is negative and greater in magnitude, suggesting it encloses a net negative charge of $-2Q$, leading to $\phi_{s_4} = -\frac{2Q}{\varepsilon_0}$. Thus, the matches are: - ϕ_{s_1} with $+\frac{Q}{\varepsilon_0}$ (p) - ϕ_{s_2} with 0 (q) - ϕ_{s_3} with $-\frac{Q}{\varepsilon_0}$ (r) - ϕ_{s_4} with $-\frac{2Q}{\varepsilon_0}$ (s)

11.

(c)

Explanation:

When the input level is -5 V, the diode gets reverse biased. No output is obtained across R_L. When the input level becomes +5 V, the diode gets forward biased and the current flows through R_L. The diode is ideal, the output across R_L will be exactly 5V.

12.

(c) myopia

Explanation:

myopia

13.

(c) A is true but R is false.

Explanation:

A is true but R is false. Both X-ray photons and light photons travel at the same speed in a vacuum.

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

Explanation:

The central spot of Newton's rings is dark when the medium between plano convex lens and plane glass is rarer than the medium of lens and glass. The central spot is dark because the phase change of π is introduced between the rays reflected from surfaces of denser to rarer and rarer to denser media.

16.

(d) A is false but R is true.

Explanation:

On introducing soft iron core, the bulb will glow dimmer. This is because on introducing soft iron core in the solenoid, its inductance L increases, the inductive reactance, $X_L = \omega L$ increases and hence the current through the bulb decreases.

Section B

17. a. Comparing the given equation with

$B_y = B_0 \sin\left[2\pi\left(\frac{x}{\lambda} + \frac{t}{T}\right)\right]$

We get $k = 0.5 \times 10^{-3}\ m^{-1}$, $\lambda = \frac{2\pi}{0.5 \times 10^3} m = 1.26$ cm.

and $\frac{1}{T} = \nu = \frac{1.5 \times 10^{11}}{2\pi} = 23.9$ GHz

b. $E_0 = B_0 C = 2 \times 10^{-7}\ T \times 3 \times 10^8\ m/s = 6 \times 10^1\ V/m$

The electric field component is perpendicular to the direction of propagation and the direction of magnetic field. Therefore, the electric field component along the z-axis is obtained as

$E_z = 60 \sin(0.5 \times 10^3 x + 1.5 \times 10^{11} t)\ V / m$

18. Dipole moment of each atomic dipole,

$m = 1.5 \times 10^{-23}\ JT^{-1}$

Total number of atomic dipoles, $N = 2.0 \times 10^{24}$

Initial total magnetic moment at temperature $T_1 = 4.2$ K is

$M_1 = 15\%$ of mN

$= \frac{15}{100} \times 1.5 \times 10^{-23} \times 2.0 \times 10^{24}\ JT^{-1} = 4.5\ JT^{-1}$

According to Curie's law,

$M = \text{Constant} \times \frac{B}{T}$

$\therefore \frac{M_2}{M_1} = \frac{B_2}{B_1} \times \frac{T_1}{T_2}$

Now $B_1 = 0.84$ T, $T_1 = 4.2$ K, $B_2 = 0.98$ T, $T_2 = 2.8$ K

Hence the final dipole moment at temperature $T_2 = 2.8$ K is

$M_2 = M_1 \times \frac{B_2}{B_1} \times \frac{T_1}{T_2} = 4.5 \times \frac{0.98}{0.84} \times \frac{4.2}{2.8} JT^{-1}$

$= 7.9\ JT^{-1}$

OR

Here, $2l = 10$ cm, $H = 0.3$ G, $M = ?$

$r = 10 + l = 10 + 5 = 15\ cm = 15 \times 10^{-2}$ m

As neutral point is on the axis of bar magnet, therefore,

$H = \frac{\mu_0}{4\pi} \frac{2M}{r^3} = 10^{-7} \frac{2 \times M}{(15 \times 10^{-2})^3}$

$M = \frac{(15 \times 10^{-2})^3 H}{2 \times 10^{-7}} = \frac{3375 \times 10^{-6} \times 0{\cdot}3 \times 10^{-4}}{2 \times 10^{-7}}$

$M = 506.25 \times 10^{-3} = 0.506\ Am^2$

19. a. From the given curve, V = 0.8 volt for current 20 mA and V = 0.7 volt for current 10 mA,

$\Rightarrow \Delta I = (20 - 10)\mathrm{mA}$

$\Rightarrow \quad \Delta I = 10mA = 10 \times 10^{-3}\mathrm{A}$

$\Rightarrow \quad \Delta I = 10^{-2}\mathrm{A}$

and $\Delta V = (0.8 - 0.7) = 0.1\mathrm{V}$

Resistance of the diode is given by, $R = \frac{\Delta V}{\Delta I}$

$\Rightarrow R = \frac{0.1}{10^{-2}}$

$\Rightarrow R = 10\Omega$

b. For V = -10V, we have

$I = -1\mu A = -1 \times 10^{-6} A$

resistance of diode is given by, R = $\frac{V}{I}$

$\Rightarrow \quad R = \frac{-10}{-1\times10^{-6}} = 1.0 \times 10^{7}\Omega$

20. Here Z = 80, K = 8 MeV = 8 $\times$ 1.6 $\times$ 10^{-13} J

$r_0 = \frac{1}{4\pi\varepsilon_0}\frac{2Ze^2}{K}$

$= \frac{9\times10^{9}\times2\times80\times\left(1.6\times10^{-19}\right)^{2}}{8\times1.6\times10^{-13}}$ m

= 28.2 $\times$ 10^{-15}m = 28.2 fm

21. i. Force exerted by the magnetic field

= Centripetal force on the charge

or $qvB\sin 90^{\circ} = \frac{mv^2}{r}$

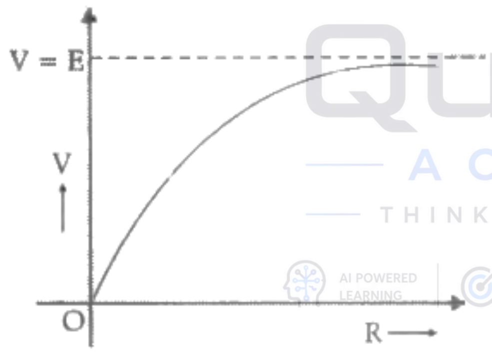
$\therefore$ Radius $r = \frac{mv}{qB}$

ii. Velocity,$v = \frac{qBr}{m}$

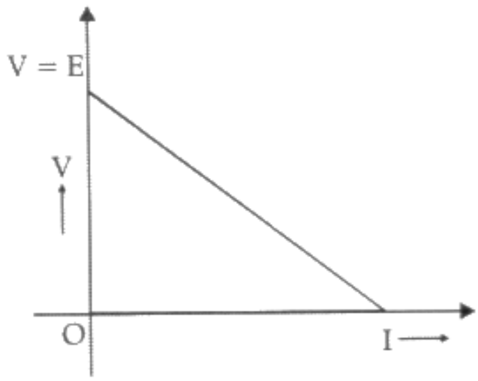
$\therefore \mathrm{K.E.} = \frac{1}{2}mv^2 = \frac{1}{2}m\left(\frac{qBr}{m}\right)^2 = \frac{B^2q^2r^2}{2m}$

Section C

22. i.



ii.



$I = \frac{E}{R+r}$ (V=E-Ir and V=IR)

$I = \frac{E}{4+r}$

$\Rightarrow$ E = 4 + r ...(i)

0.5 = $\frac{E}{9+r}$

Also E = 4.5 + 0.5r ...(ii)

From equation (i) and (ii),

$4 + r = 4.5 + 0.5r$

$\therefore r = 1\ \Omega$ (internal resistance)

Using this value of r, we get,

$E = 5V$

23. a. $\lambda = 200$ nm, stopping potential = -2.5 V

K.E. $= 2.5 \times 1.6 \times 10^{-19}$ J $= 4 \times 10^{-19}$ J

$E = h\nu = h\frac{c}{\lambda}$

$= \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{200 \times 10^{-9}}$

$= 9.945 \times 10^{-19}$ J

Work function = E - eV

$= (9.945 \times 10^{-19} - 4 \times 10^{-19})$J

$= 5.595 \times 10^{-19}$ J

b. Wavelength of red light = 6328 Å

$E = h\nu = h\frac{c}{\lambda}$

$= \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{6328 \times 10^{-10}}$

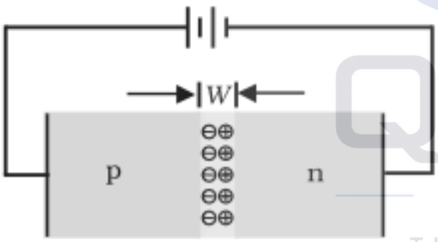
$= 0.00314 \times 10^{-16}$ J

$= 3.14 \times 10^{-19}$ J

Energy of red light < work function of metal surface

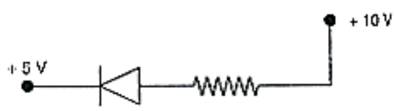
$\therefore$ No emission of photoelectrons takes place.

24. When an external voltage V is applied across a semiconductor diode such that p-side is connected to the positive terminal of the battery and n-side to the negative terminal [Fig.], it is said to be forward biased.

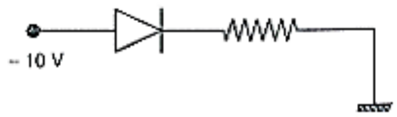


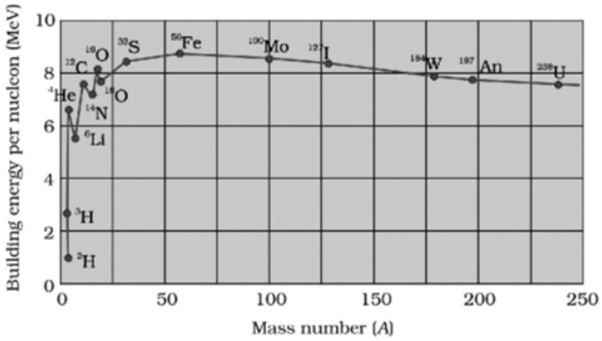
The applied voltage mostly drops across the depletion region and the voltage drop across the p-side and n-side of the junction is negligible. (This is because the resistance of the depletion region – a region where there are no charges – is very high compared to the resistance of n-side and p-side.) The direction of the applied voltage (V) is opposite to the built-in potential V_0. As a result, the depletion layer width decreases [Fig.]

i. In this case, the p-side is at +10V, whereas the n-side is at +5V. As, $V_p > V_n$, hence the diode is forward biased.



ii. In this case, the p-side is at -10V, whereas the n-side is at 0 V. As, $V_p < V_n$, hence the diode is reverse biased.



25. 

Salient feature of B.E. curve

i. B.E/nucleon is pratically constant i.e. independent of the atomic number for nuclei of middle mass number (30 < A < 17)
ii. Binding energy per nucleon is lower for both light nuclei (A < 30) and heavy nuclei (A > 70).

Very heavy nucleus has lower B.E./nucleon will undergo fission and split into two medium sized nuclei with large B.E./nucleon and release tremendous amount of energy (Fission process)

When two very light nuclei, having low binding energy per nucleon combine together and form a medium sized nuclei of higher B.E. per nucleon releases enormous amount of energy (Fusion process)

26. Energy of the electron in the first excited state

$E_1 = -\frac{13.6}{2^2}eV$ = -3.4 eV

= -3.4 $\times$ 1.6 $\times$ 10^{-19} J

= -5.44 $\times$ 10^{-19} J

Associated kinetic energy = Negative of total energy

K = 5.44 $\times$ 10^{-19} J

de-Broglie wavelength, $\lambda = \frac{h}{p}$

$\lambda = \frac{h}{\sqrt{2mK}}$

$\lambda = \frac{6.63\times10^{-34}}{(2\times9.1\times10^{-31}\times5.44\times10^{-19})^{\frac{1}{2}}}$ m

$\lambda = \frac{6.63\times10^{-34}}{(99.008)^{\frac{1}{2}}\times10^{-25}}$ m

$\approx$ 0.663 $\times$ 10^{-9} m = 0.663 nm = 6.63 A^o

Hence, the de-Broglie wavelength associated with the electron is 6.63 A^o

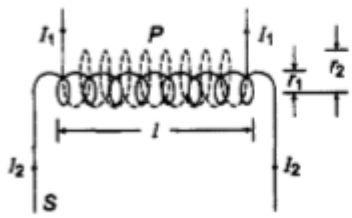
27. a. Conditions for light sources to be coherent:-

Two sources produce waves of same frequency.

Two sources produce waves of constant phase difference.

b. In interference pattern the fringes are equally spaced (dark and bright) and of equal intensity and in diffraction the central maxima is brightest and is wider two times as the other maxima with intensity decreasing away from the Centre.

28. Let coaxial solenoid P is wound over an another solenoid.



Let l = length of both solenoid

r_1 and r_2 = radii of P and S

$A_2 = \pi r_2^2$ [area of secondary coil, S]

Magnetic induction in solenoid, P

$B_1 = \mu_0 n_1 I_1$

where, $n_1 = \frac{N_1}{l}$

$\therefore$Total flux linked with solenoid S,

$\phi_2 = B_1 A_2 N_2$

$\Rightarrow \quad \phi_2 = B_1\left(\pi r_2^2\right)N_2 = (\mu_0 n_1 I_1)\pi r_2^2 N_2$

$\phi_2 = \left(\mu_0 \frac{N_1}{l} I_1\right) \pi r_2^2 N_2$

$\Rightarrow \quad \phi_2 = \frac{\mu_0 \pi I_1 N_1 N_2 r_2^2}{l}$ ...(i)

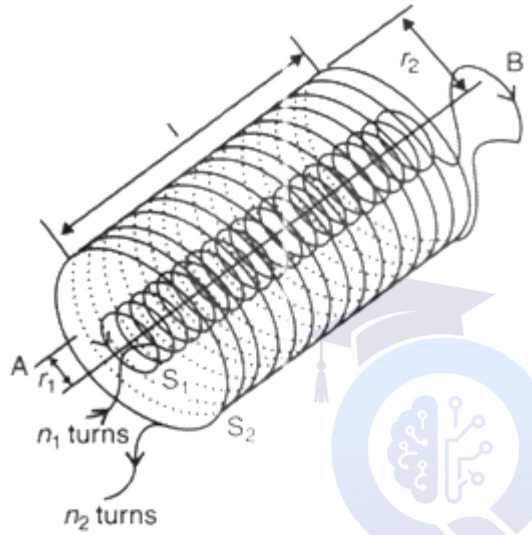
But $\phi_2 = MI_1$

were, M = coefficient of mutual induction

$\Rightarrow MI_1 = \frac{\mu_0 \pi N_1 N_2 r_2^2}{l} I_1 \Rightarrow M = \frac{\mu_0 \pi N_1 N_2 r_2^2}{l}$

OR

i. Self-Inductance is the property by which an opposing induced emf is produced in a coil due to a change in current, or magnetic flux, linked with the coil.
The S.I. unit of self-inductance is Henry (H).
ii. In this question, a long co-axial solenoids S_1 and S_2 wound one over the other, each of length L and radii r_1 and r_2 and n_1 and n_2 number of turns per unit length, when a current I is set up in the outer solenoid S_2.



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 = $\frac{\mu_0 N_2 N_1 A_1 i_2}{l}$

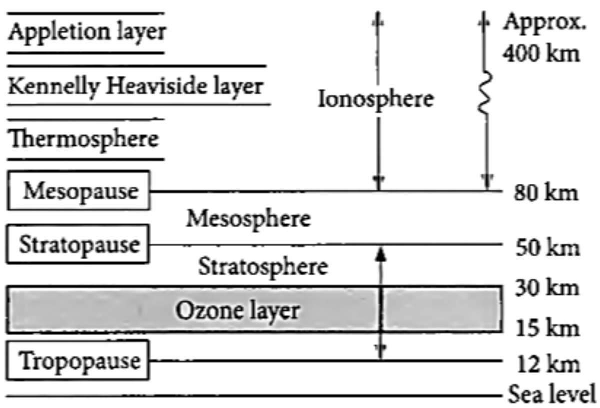
= $M_{12} i_2$

Hence, $M_{12} = \frac{\mu_0 N_2 N_1 A_2}{l}$

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

Section D

29. **Read the text carefully and answer the questions:**
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) **(d)** Option (i)
Explanation:
transverse electromagnetic wave

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

Explanation:

Greenhouse effect is due to infrared rays.

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

Explanation:

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

OR

(d) infrared

Explanation:

The atmosphere of earth is richest in infrared radiation.

(iv) **(c)** stratosphere

Explanation:

Ozone layer lies in stratosphere.

30. i. $\vec{\tau} = \vec{P} \times \vec{E}$

As τ = either force $\times$ perpendicular distance between the two forces

= qaE sin θ or τ = PE sin θ

or $\vec{P} \times \vec{E}$ ($\because$ qa = P)

ii. The maximum torque on the dipole in an external field is given by

τ = pE = q(2a) $\times$ E

Here, q = $1\mu\mathrm{C} = 10^{-6}\mathrm{C}$, 2a = 2 cm = 2 $\times$ 10^{-2} m, E = 10^5 NC^{-1}, τ = ?

$\therefore$ τ = $10^{-6} \times 2 \times 10^{-2} \times 10^5 = 2 \times 10^{-3}$ Nm

$\therefore$ the maximum torque on the dipole 2×10^{-3} Nm.

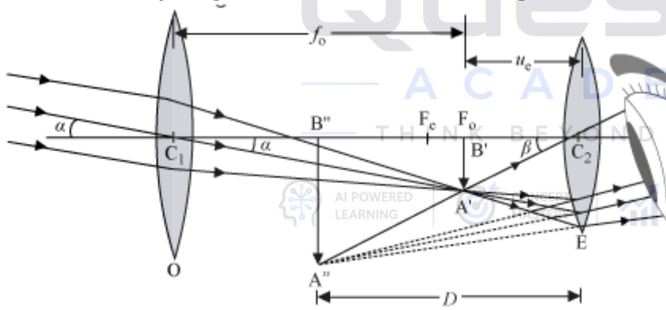
iii. When θ is 0 or 180^o, the τ is minimum, which means the dipole moment should be parallel to the direction of the uniform electric field.

iv. The net force is zero and torque acts on the dipole, trying to align p with E.

v. Torque, τ = pE sin θ and potential energy U = -pE cos θ

Section E

31. a. Consider the ray diagram of Astronomical telescope.



When the final image is formed at the least distance of distinct vision,

Magnifying power, $M = \frac{\beta}{\alpha}$

Since α and β are small, we have:

$\therefore M = \frac{\tan\beta}{\tan\alpha}$ ...(i)

In $\Delta\mathrm{A'B'C_2}, \tan\beta = \frac{\mathrm{A'B'}}{\mathrm{C_2B'}}$

In $\Delta A'B'C_1, \tan\alpha = \frac{\mathrm{A'B'}}{\mathrm{C_1B'}}$

From equation (i), we get:

$M = \frac{\mathrm{A'B'}}{\mathrm{C_2B'}} \times \frac{\mathrm{C_1B'}}{\mathrm{A'B'}}$

$\Rightarrow M = \frac{C_1B'}{C_2B'}$

Here, $\mathrm{C_1B'} = +f_0$

$\Rightarrow \mathrm{C_2B'} = -u_e$

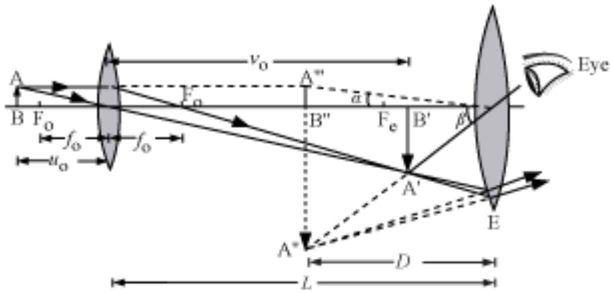
$\Rightarrow M = \frac{f_0}{-u_e}$ ...(ii)

Using the lens equation $\left(\frac{1}{v} - \frac{1}{u} = \frac{1}{f}\right)$ for the eyepieces, we get,

$\frac{1}{-D}-\frac{1}{-u_e}=\frac{1}{f_e}$
$-\frac{1}{D}+\frac{1}{u_e}=\frac{1}{f_e}$
$\Rightarrow \frac{1}{u_e}=\frac{1}{f_e}+\frac{1}{D}$
$\Rightarrow \frac{f_0}{u_e}=\frac{f_0}{f_e}\left(1+\frac{f_e}{D}\right)$
$\Rightarrow \frac{-f_0}{u_e}=\frac{-f_0}{f_e}\left(1+\frac{f_e}{D}\right)$
or $M=-\frac{f_0}{f_e}\left(1+\frac{f_e}{D}\right)$

In order to have a large magnifying power and high resolution of the telescope, its objective lens should have a short length.

b.



Distance between the objective and the eyepiece, L = $v_0+|u_e|$

To find v_0, we have:

u_0 = -2.5 cm and f_0 = 1.25 cm

Now, $-\frac{1}{u_0}+\frac{1}{v_0}=\frac{1}{f_0}$

or v_0 = 2.5 cm

To find u_e, we have:

$v_e=\infty$ and f_e = 5 cm

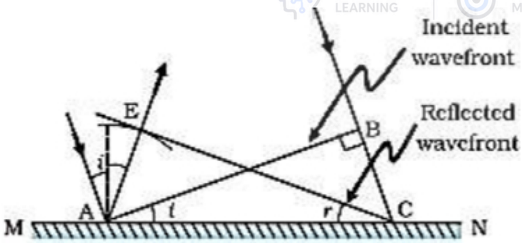
Calculating using the same formula as above, we get:

u_e = -5 cm

$\therefore$ L = 2.5 + 5 = 7.5 cm

OR

i. Each point of the wavefront is the source of a secondary disturbance and the wavelets emanating from these points spread out in all directions with the spread of the wave. Each point of the wavefront is the source of a secondary disturbance and the wavelets emanating from these points spread out in all directions with the speed of the wave. These wavelets emanating from the wavefront are usually referred to as secondary wavelets and if we draw a common tangent to all these spheres, we obtain the new position of the wavefront at a later time.



$\triangle$EAC is congruent to $\triangle$BAC; so <i = <r

ii. Two sources are said to be coherent if the phase difference between them does not change with time.

No, two independent sodium lamps cannot be coherent.

Two independent sodium lamps cannot be coherent as the phase between them does not remain constant with time.

iii. $4\beta_2=5\beta_1$

$4\times\frac{\lambda D}{d}=5\times\frac{\lambda_{\text{known}}D}{d}$

$\Rightarrow \lambda=\frac{5}{4}\times\lambda_{\text{hnoun}}$

$=\frac{5}{4}\times 520$

= 650 nm

32. a. Consider a parallel plate capacitor which is connected across a battery. The electrons are transferred from the negative terminal of the battery to the metallic plate connected to the negative terminal and acquires a negative charge. Similarly, the

electrons move from the second plate to the positive terminal of the battery and acquire a positive charge. This process continues until the potential difference between the two plates becomes equal to the potential difference between the terminals of the battery. Thus, the charge is developed on the capacitor.

Let 'dW' be the work done by the battery in increasing the charge on the capacitor is given by, having the charge q and potential V is:

dW = V dq

where V = $\frac{q}{C}$

$\therefore$ dW = $\frac{q}{C}$dq

Total work done in charging up the capacitor is given by,

W = $\int$ dW = $\int_0^Q \frac{q}{c}$dq

$\therefore$ W = $\frac{Q^2}{2C}$

Hence total energy stored in the plates of the capacitor is given by, W = $\frac{Q^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}QV$

b. Charge on the plates of the capacitor is given by q = CV

When uncharged capacitor of same capacitance is connected to the charged capacitor, sharing of charges takes place between the two capacitors till both the capacitors acquire same potential $\frac{V}{2}$

Energy stored in the combination of capacitors is given by,

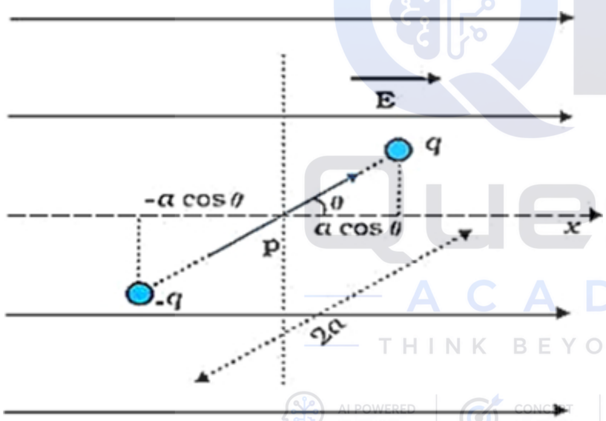
$U_2 = \frac{1}{2}C(\frac{V}{2})^2 + \frac{1}{2}C(\frac{V}{2})^2 = \frac{CV^2}{4}$

Energy stored by a single capacitor before connecting is given by, $U_1 = \frac{1}{2}CV^2$

Ratio of energy stored in the combination to that in the single capacitor is given by,

$\frac{U_2}{U_1} = \frac{CV^2/4}{CV^2/2}$ = 1 : 2 , Hence these are required results.

OR

i. 

The amount of work done in rotating the dipole from $\theta = \theta_0$ to $\theta = \theta_1$ by the external torque

$W = \int_{e_0}^{\theta_1} \tau_{ext} d\theta$

$= \int_{\theta_0}^{a} pE \sin\theta d\theta$

$W = pE(\cos\theta_0 - \cos\theta_1)$

For $\theta_0 = \frac{\pi}{2}$ and $\theta_1 = \theta$

$= pE\left(\cos\frac{\pi}{2} - \cos\theta\right)$

$U(\theta) = -pE\cos\theta = -\vec{p}\cdot\vec{E}$

1. Potential energy is maximum when:
   $\vec{p}$ is antiparallel to $\vec{E}$
2. Potential energy is minimum when:
   $\vec{p}$ is along to $\vec{E}$

ii. **Dipole Moment Calculation:**

The charge q = 1.0 $\times$ 10^{-12}C.

Separation vector $\vec{d}$ = (3 mm, 4 mm) = (3 $\times$ 10^{-3} m, 4 $\times$ 10^{-3} m)

Dipole moment $\vec{p} = q\vec{d}$ = (1.0 $\times$ 10^{-12} $\times$ 3 $\times$ 10^{-3}, 1.0 $\times$ 10^{-12} $\times$ 4 $\times$ 10^{-3}) = (3.0 $\times$ 10^{-15}, 4.0 $\times$ 10^{-15}) C.m.

Torque Calculation:

Electric field $\vec{E} = 1000\hat{i}$ V/m

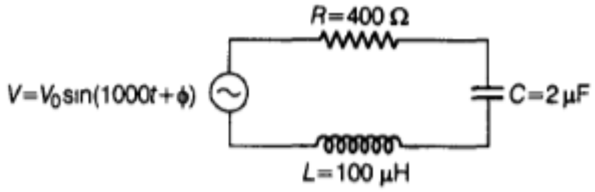
Torque $\vec{\tau} = \vec{p} \times \vec{E}$

$\vec{\tau} = \left(3.0 \times 10^{-15}\hat{i} + 4.0 \times 10^{-15}\hat{j}\right) \times 1000\hat{i} = \left(4.0 \times 10^{-15} \times 1000\right)\hat{k}$

$\vec{\tau} = 4.0 \times 10^{-12}\ \mathrm{N \cdot m}\hat{k}$

The torque is $\vec{\tau} = 4.0 \times 10^{-12}\ \mathrm{N \cdot m}\hat{k}$

33. i.



$V = V_0 \sin(1000t + \phi) \Rightarrow \omega = 1000\mathrm{Hz}$

$R = 400\Omega, C = 2\mu F, L = 100\mathrm{mH}$

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

$\Rightarrow \quad X_C = \frac{1}{1000 \times 2 \times 10^{-6}}$

$\Rightarrow \quad X_c = \frac{10^3}{2} \Rightarrow X_c = 500\Omega$

Inductive reactance, $X_L = \omega L$

$\Rightarrow \quad X_L = 1000 \times 100 \times 10^{-3} \Rightarrow X_L = 100\Omega$

So, $X_c > X_L$

$\Rightarrow \tan\phi$ is negative.

Hence, the voltage lags behind the current by a phase angle ϕ .

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

$\tan\phi = \frac{100-500}{400} \Rightarrow \tan\phi = \frac{-400}{400}, \tan\phi = -1$

$\Rightarrow \quad \tan\phi = -\tan\left(\frac{\pi}{4}\right) \Rightarrow \phi = -\frac{\pi}{4}$

This is the required value of the phase difference between the current and the voltage in the given series L-C-R circuit.

ii. Suppose, new capacitance of the circuit is C'. Thus, to have power factor unity

$\cos\phi' = 1 = \frac{R}{\sqrt{R^2 + (X_L - X_C')^2}}$

$\Rightarrow \quad R^2 = R^2 + \left(X_L - X_C'\right)^2$

$\Rightarrow \quad X_L = X_C' = \frac{1}{\omega C'}$ or $\quad \omega L = \frac{1}{\omega C'}$

$\Rightarrow \omega^2 = \frac{1}{LC'}$ or $(1000)^2 = \frac{1}{LC'}$ $(\because \omega = 1000)$

$\Rightarrow \quad C' = \frac{1}{L \times 10^6} = \frac{1}{100 \times 10^{-3} \times 10^6}$

$= \frac{10}{10^6} = \frac{1}{10^5} = 10^{-5}$

$\Rightarrow \quad C' = 10^{-5}\mathrm{F} = 10 \times 10^{-6}\mathrm{F} = 10\mu\mathrm{F}$

As, C' > C, hence, we have to add an additional capacitor of capacitance = $10\mu F - 2\mu F = 8\mu F$ in parallel with previous capacitor.

OR

a. Power dissipation = P = V_{rms} I_{rms} cos ϕ

cos ϕ = $\frac{R}{Z}$

For ideal inductor R = 0

$\therefore$ cos ϕ = 0

$\therefore$ P = V_{rms} I_{rms} cos ϕ = 0

Thus, ideal inductor does not dissipate power in an ac circuit.

b. i. Inductive reactance = X_L = 2πfL

$\therefore$ L = $\frac{X_L}{2\pi f}$

From graph, at f = 100 Hz

X_L = 20 Ω

$\therefore$ L = $\frac{X_L}{2\pi f}$ = $\frac{20}{2\pi \times 100}$

= 0.032 H = 32 mH

ii. Power dissipation is maximum when

$2\pi fL = \frac{1}{2\pi fC}$

$f = 300\ s^{-1}$

$L = 0.032\ H$

$2\pi fL = \frac{1}{2\pi fC}$

Or, $2\pi \times 300 \times 0.032 = \frac{1}{2\pi \times 300 \times C}$

$\therefore C = 8.8 \times 10^{-6}\ F = 8.8\ \mu F$