Section A

1. **(a)** A vacancy created when an electron leaves a covalent bond.
Explanation:
A **hole** is the absence of an electron in a particular place in an atom.

2. **(c)** 200°C
Explanation:
$\varepsilon = 20\theta - \frac{\theta^2}{20} \Rightarrow \frac{d\varepsilon}{d\theta} = 20 - \frac{\theta}{10}$
At $\theta = \theta_n$, $\frac{d\varepsilon}{d\theta} = 0$
$\therefore 20 - \frac{\theta_n}{10} = 0$
or $\theta_n = 200^\circ \mathrm{C}$

3. **(c)** red colour.
Explanation:
For a glass prism, the angle of minimum deviation will be smallest for the light of red color.
As wavelength of red color is maximum among all, hence, $\mu \propto \frac{1}{\lambda}$, hence $\mu$is smaller. As μ decreases, angle of deviation decreases.

4. **(c)** paramagnet
Explanation:
The susceptibility of a paramagnetic substance depends both on the temperature and strength of the magnetising field.

5. **(d)** $\frac{16C_1}{n_1n_2}$
Explanation:
$\frac{1}{2}C_pV^2 = \frac{1}{2}C_s(4V)^2$
or $\frac{1}{2}n_2C_2V^2 = \frac{1}{2}\frac{C_1}{n_1}(4V)^2$
or $C_2 = \frac{16C_1}{n_1n_2}$

6. **(c)** $\frac{B}{2}$
Explanation:
Magnetic field at the end of a current carrying solenoid is half of the magnetic field inside it.

7. **(a)** there is a constant current in the counterclockwise direction in A.
Explanation:
there is a constant current in the counterclockwise direction in A.

8. **(b)** MH
Explanation:
MH

9.

(c) five

Explanation:

According to the condition for interference maxima,

d $\sin\theta$ = n λ

Here, d = 2 λ

$\therefore$ 2 $\lambda\sin\theta$ = n λ

or n = 2 $\sin\theta$

For number of interference maxima to be maximum

$\sin\theta = 1$

$\therefore$ n = 2 $\times$ 1 = 2

The interference maxima will occur, when

n = 0, $\pm$ 1 and $\pm$ 2

Hence, the maximum number of possible interference maxima = 5

10.

(d) both on only on the system of units and only on medium between charges

Explanation:

both on only on the system of units and only on medium between charges.

11.

(b) D_2 is forward biased and D_1 is reverse biased and hence no current flows from B to A and vice versa.

Explanation:

In circuit, A is at -10V and B is at 0V. So B is positive than A. So D_2 is in forward bias and D_1 is in reverse bias so no current flows from A to B or B to A.

12.

(b) A + δ_m = 2i

Explanation:

For refraction through prism,

$i_1 + i_2 = \delta + A$ and $r_1 + r_2 = A$

For minimum deviation,

$i_1 = i_2 = i$ and $r_1 = r_2 = r$

So, i = $\frac{(A+\delta_m)}{2}$

$\therefore$ A + δ_m = 2i

13.

(d) A is false but R is true.

Explanation:

A is false but R is true.

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

Explanation:

The dielectric constant of any material is:

K = $\frac{E_0}{E} = \frac{F_0/q}{F/q} = \frac{F_0}{F}$ or F = $\frac{F_0}{K}$

Where, F_0 is force when conductor is not present between the charges. F is the force after the introduction of the conductor between the charges. Since, the dielectric constant of a conducting medium is infinity, therefore, F = 0.

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.

(d) A is false but R is true.

Explanation:

Like direct current, an alternating current also produces a magnetic field. But the magnitude and direction of the field go on changing continuously with time.

Section B

17. Wavelength,

$\lambda=\frac{c}{v}=\frac{3\times10^8}{4\times10^9}=\frac{3}{40}$ m = 0.075 m

These are microwaves which are used

i. in radar systems for aircraft navigation.
ii. in microwave ovens.

18. According to Curie's law,

$\chi=\frac{C}{T}$

$\therefore$ C = χT

From the given graph, when χ = 0.50,

$\frac{1}{T}=8.0\times10^{-3}\ \mathrm{K}^{-1}$

or T = 125 K

$\therefore$ C = 0.50 $\times$ 125 K = 62.5 K

OR

The work done in turning a dipole from orientation θ_1 to θ_2 in field B is given by

W = -MB (cos θ_2 - cos θ_1)

i. Here, θ_1 = 0^o and θ_2 = 180^o

$\therefore$ W = - MB (cos 180^o - cos 0^o)

= -MB (-1 - 1) = 2 MB

ii. Here, θ_1 = 0^o and θ_2 = 90^o

$\therefore$ W = - MB (cos 900^o - cos 0^o) = MB

19. For a p-n junction diode, the dynamic resistance is given by:

r = $\frac{\Delta V}{\Delta I}$

Given that:

ΔV = 0.71 - 0.70 = 0.01 V = 10^{-2} V

ΔI = 10^{-3} $\times$ 10A = 10^{-2} A

$\therefore$ r = $\frac{10^{-2}}{10^{-2}}$ = 1Ω

20. $E=\frac{2\pi^2mk^2e^4}{h^2}\cdot\frac{Z^2}{n^2}$ i.e; $E_n\propto\frac{Z^2}{n^2}$

Let $E_n\left(\mathrm{Li}^{2+}\right)=E_1(\mathrm{H})$

$\therefore\left[\frac{Z^2}{n^2}\right]_{Li^{2+}}=\left[\frac{Z^2}{n^2}\right]_H$

or $\frac{3^2}{n^2}=\frac{1^2}{1^2}$ or n = 3

21. a. The voltmeter, which has maximum resistance, will draw minimum current and allow maximum current to flow through resistor AB. Consequently, there will be maximum potential difference across AB.

In case (i), resistance of voltmeter, $R_y=20\mathrm{k}\Omega$

In case (ii),$R_V=1\mathrm{k}\Omega$

In case (iii),$\frac{1}{R_V}=\frac{1}{20}+\frac{1}{1}=\frac{1+20}{20}$ or $R_V=\frac{20}{21}\mathrm{k}\Omega$

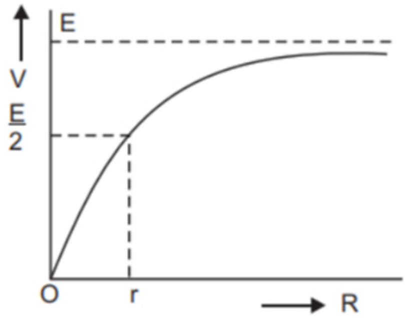
1. As the resistance of voltmeter is maximum in case (i), it will show maximum reading.
2. As the resistance of voltmeter is minimum in case (iii), it will show lowest reading.

b. In all cases, the voltmeter reading will be same if the battery has negligible internal resistance. But if the internal resistance is non-negligible, then the answers will be similar to those in (a).

Section C

22. When R $\rightarrow$ 0, V = 0 When R = r, V = $\frac{E}{2}$ When R = ∞, V = E

The graph is shown in fig.



23. Given that

Initial kinetic energy of photoelectrons is given by = K_1

Final kinetic energy of photoelectrons is given by $K_2 = 2K_1$

Wavelength of light changes from λ_1 to λ_2

Let the threshold frequency is ν_0 and work function is ϕ_0

Now, we know that:-

$\frac{hc}{\lambda} = \phi_0 + KE$

$\frac{hc}{\lambda_1} = \phi_0 + K_1$ ...(i)

$\frac{hc}{\lambda_2} = \phi_0 + K_2$ ...(ii)

$K_2 = 2K_1$

$\frac{hc}{\lambda_2} = \phi_0 + 2K_1$ ...(iii)

$\frac{2hc}{\lambda_1} = 2\phi_0 + 2K_1$ (eq (i) $\times$ 2)

$\frac{2hc}{\lambda_1} - \frac{hc}{\lambda_2} = \phi_0$

$\Rightarrow \phi_0 = hc\left(\frac{2\lambda_2-\lambda_1}{\lambda_1\lambda_2}\right)$

We know

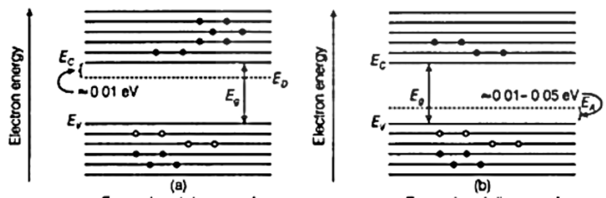
work function is given by $\phi_0 = \frac{hc}{\lambda_0}$

$\frac{hc}{\lambda_0} = hc\left(\frac{2\lambda_2-\lambda_1}{\lambda_1\lambda_2}\right)$

$\frac{1}{\lambda_0} = \frac{2\lambda_2-\lambda_1}{\lambda_1\lambda_2}$

$\lambda_0 = \frac{\lambda_1\lambda_2}{2\lambda_2-\lambda_1}$

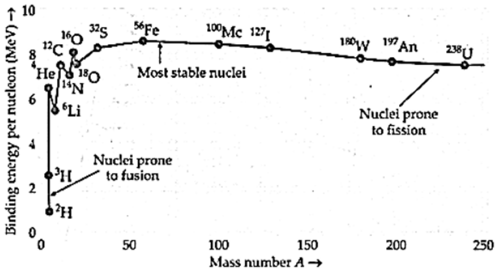
24. In an n-type semiconductor, the donor energy level E_D is slightly below the bottom E_C of the conduction band and electrons from this level move into the conduction band with a very small supply of energy. Fermi-level shifts towards the conduction band where a higher number of electrons are available for conduction. In an n-type semiconductor, the energy gap decreases.



(a) Energy band diagram of n-type semiconductor at $T > 0$ K

(b) Energy band diagram of p-type semiconductor at $T > 0$ K

In a p-type semiconductor, the acceptor energy level E_A is above the top E_V of the valence band, therefore with a small supply of energy, the electrons can jump from the valence band to the acceptor energy level. Fermi levels shift closer to the valence bond because holes are the majority carriers. In a p-type semiconductor, the energy band increases.

25. 

Binding energy per nucleon as a function of mass number A.

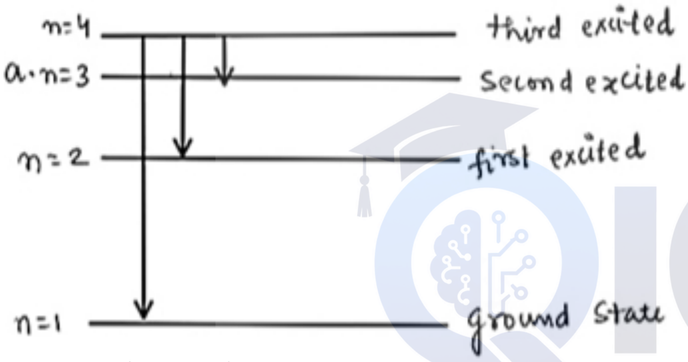
Two important conclusions from this graph are:

i. Nuclear forces non-central and short ranged force.

ii. Nuclear forces between proton-neutron and neutron-neutron are strong and attractive in nature.

Explanation of Nuclear Fission: When a heavy nucleus ($A \geq 235$ say) breaks into two lighter nuclei (nuclear fission), the binding energy per nucleon increases i.e, nucleons get more tightly bound. This implies that energy would be released in nuclear fission.

Explanation of Nuclear Fusion: When two very light nuclei ($A \leq 10$) join to form a heavy nucleus, the binding is energy per nucleon of fused heavier nucleus more than the binding energy per nucleon of lighter nuclei, so again energy would be released in nuclear fusion.

26. 

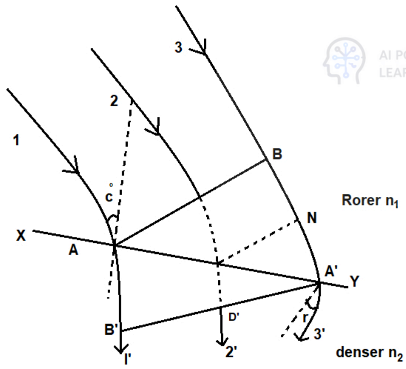
as $\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

$\frac{1}{\lambda_{\min}} = R\left(\frac{1}{1^2} - \frac{1}{4^2}\right) = \frac{15R}{16}$

$\lambda_{\min} = \frac{16}{15R} = \frac{16}{15 \times 1.09 \times 10^7}$

= 0.978×10^{-7} m

= 97.8 nm

27. 

Let XY be interface of two mediums and c_1 and c_2 are velocity of light is rarer and denser medium respectively.

Then, refractive index of denser medium relative to rarer medium $\mu = \frac{c_1}{c_2}$

Also, according to Huygens principle, every point of plane wavefront AB acts as a source of secondary wavelet. Let the secondary wavelets takes time t from B to strike at XY surface at A'

BA' = $c_1 \times t$

in same time t wavelet from A travels with speed c_2 and strikes B'

AB' = $c_2 \times t$

In $\triangle$AA'B

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

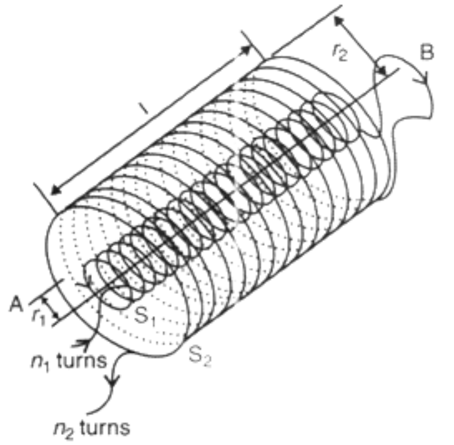
In $\triangle$AA'B'

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

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

28. 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 I_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, $M_{12} = \frac{\mu_0 N_2 N_1 A_1}{l}$

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

OR

a. **Mutual inductance**: It is the property of the coils that enables it to oppose the changes in the current in another coil. Its S.I unit is Henry (H).

b. Force on the part of the loop which is parallel to infinite straight wire and at a distance x from it.

$F_1 = \frac{\mu_0}{2\pi} \frac{I_1 I_2 a}{x}$ (away from the infinite straight wire)

Force on the part of the loop which is at a distance (x + a) from it

$F_2 = \frac{\mu_0}{2\pi} \frac{\mathbf{I_1 I_2} a}{(\mathbf{x+a})}$ (towards the infinite straight wire)

Net force $F = F_1 - F_2$

$F = \frac{\mu_0 I_1 I_2 a}{2\pi}\left[\frac{1}{x} - \frac{1}{x+a}\right]$

$F = \frac{\mu_0}{2\pi} \frac{I_1 I_2 a^2}{x(x+a)}$

Section D

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

All the known radiations from a big family of electromagnetic waves which stretch over a large range of wavelengths. Electromagnetic wave include radio waves, microwaves, visible light waves, infrared rays, UV rays, X-rays and gamma rays. The orderly distribution of the electromagnetic waves in accordance with their wavelength or frequency into distinct groups having widely differing properties is electromagnetic spectrum.

(i) **(a)** infrared waves

Explanation:

Infrared rays can be converted into electric energy as in solar cell.

(ii) **(d)** radiowaves

Explanation:

Radiowaves have longest wavelength.

(iii) **(c)** cathode rays

Explanation:

Cathode rays are invisible fast moving streams of electrons emitted by the cathode of a discharge tube which is maintained at a pressure of about 0.01 mm of mercury.

OR

(d) microwave, infrared, ultraviolet, gamma rays

Explanation:

$\lambda_{\text{micro}} > \lambda_{\text{infra}} > \lambda_{\text{ultra}} > \lambda_{\text{gamma}}$

(iv) **(d)** γ-rays

Explanation:

γ-rays have minimum wavelength.

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

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

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

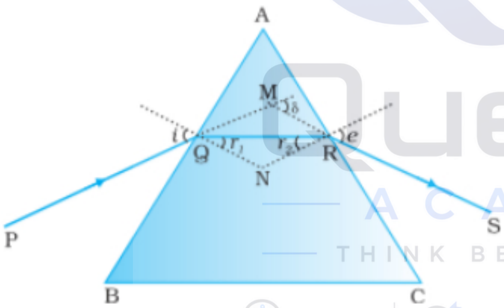
iii. When θ is 0 or 180^o, the τ is minimum, which means the dipole moment should be parallel to the direction of the uniform electric field.

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. i.



ii. Derivation

From the above figure

$\angle A + \angle QNR = 180^o$ (i)

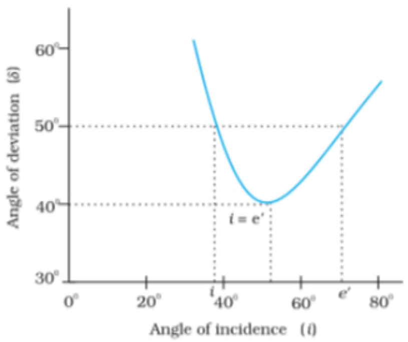
In ΔQNR $r_1 + r_2 + \angle QNR = 180^o$ (ii)

Comparing equation (i) and (ii) we get

$r_1 + r_2 = A$ (iii)

Total deviation produced $\delta = (i - r_1) + (e - r_2)$

$\delta = i + e - (r_1 + r_2) = i + e - A$ (iv)



From the above graph of δ vs i we can find when δ becomes minimum i.e. δ_m

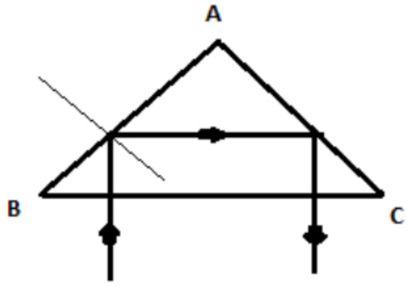
i = e and $r_1 = r_2$

From (iv) i = $\frac{(A+\delta_m)}{2}$

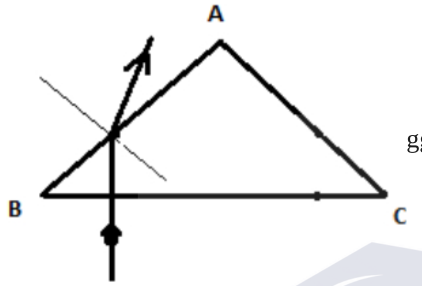
and from (iii) r = $\frac{A}{2}$

$\mu = \frac{\sin i}{\sin r} = \frac{\sin^{(A+\delta_m)/2}}{\sin\frac{A}{2}}$

b. i.



ii. For μ = 1.4 total internal reflection will not occur according to the figure that we have

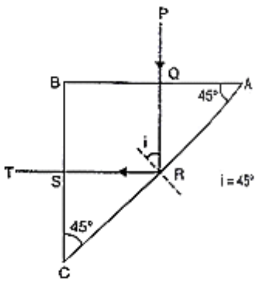


gg

OR

i. ABC is the section of the prism, B is a right angle. A and C are equal angles i.e. A = C = 45°.

The ray PQ is normally incident on the face AB. Hence it is normally refracted and the ray QR strikes the face AC at an angle of incidence 45°. It is given that the ray does not undergo refraction but is totally reflected at the face AC. This gives a maximum value for the critical angle as 45°.



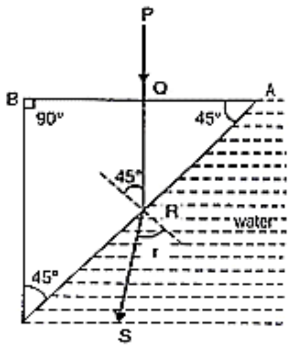
sin C = sin 45° $= \frac{1}{\sqrt{2}}$ in the limit

Since $\mu = \frac{1}{\sin C} = \frac{1}{\sqrt{2}}$

or, $\mu = \frac{1}{\sin 45}$ $or\ \mu_{\min} = \sqrt{2}$

The minimum value of refractive index $= \sqrt{2}$.

ii. When the prism is immersed in water the critical angle for the glass water interface is given by



$\sin C_1 = \frac{4/3}{\sqrt{2}} = \frac{4}{3\sqrt{2}}$

C_1 = 70.53°

The angle of incidence at R continues to be 45° and since 45° < 70.53°, refraction taking place and the refracted ray is RS.

The angle of refraction r is given by $\mu_g \sin i = \mu_w \sin r$

$g\mu_\omega = \frac{\sin i}{\sin r}$
$\frac{\mu_\omega}{\mu_g} = \frac{\sin i}{\sin r}$
$\sqrt{2}\sin 45^\circ = \frac{4}{3}\sin r$
$\sin r = \frac{3\sqrt{2}}{4}\sin 45^\circ = \frac{3\sqrt{2}}{4} \times \frac{1}{\sqrt{2}} = \frac{3}{4}$
$r = \sin^{-1}\frac{3}{4} = 48^\circ 36'$
$\therefore$The angle of refraction in water = $48^\circ 36'$

32. i. A. A dielectric material gets polarized when it is placed in an external electric field. The field produced due to the polarization of material reduces the effect of external electric field. Hence, the electric field inside a dielectric decreases.

B. Electric field in vacuum between the plates = E0 = $\frac{\sigma}{\varepsilon_o}$
Electric field in dielectric between the plates, E = $\frac{E_0}{K}$
Potential difference between the capacitor plates
V = Et + E_0(d - t)
where 't' is the thickness of dielectric slab.
V = $\frac{E_0}{K}\mathrm{t} + \mathrm{E}_0(\mathrm{d} - \mathrm{t})$
V = $\frac{\sigma}{\varepsilon_o}\left[\frac{t}{K} + (\mathrm{d} - \mathrm{t})\right]$
V = $\frac{\sigma}{\varepsilon_o}\left[\frac{t+K(d-t)}{K}\right]$
As C = $\frac{Q}{V}$
$\Rightarrow$ C = $\frac{\varepsilon_0 AK}{t+K(d-t)}$

ii. The surface of the sphere is equipotential. So, the work done in moving the charge from one point to the other is zero.
W = q Δ V ($\because$ Δ V = 0)
= 0

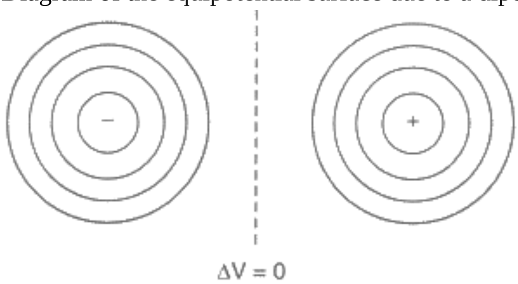
iii. P = χ E

OR

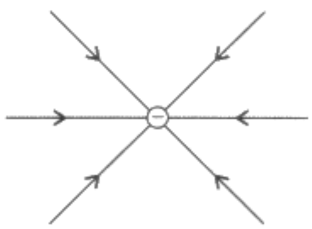
i. C_A = $4\pi\varepsilon_0 R$, C_B = $4\pi\varepsilon_0$ (2R) (in general form C = $4\pi \in 0r$)

a. $\therefore$ $C_B > C_A$
b. $U = \frac{1}{2}\varepsilon_0 E^2$
$E = \frac{\sigma}{\varepsilon_P} = \frac{Q}{A\varepsilon_0}$
$\therefore U \propto \frac{1}{A^2}$
$\therefore$ $U_A > U_B$

ii. a. $E = -\frac{dV}{dr}$
For the same change in dV, E $\propto \frac{1}{dr}$
where, ‘dr' represents the distance between equipotential surfaces.
Diagram of the equipotential surface due to a dipole



b. The polarity of charge: negative
The direction of the electric field is radially inward,(for a negative charge electric field lines are radially inward)



33. i. Calculation of Capacitance

As power factor is unity,

$\therefore X_L = X_C$ also L=200mH and R= 10 Ω

$\Rightarrow \omega = \frac{1}{\sqrt{LC}}$

100 = $\frac{1}{\sqrt{200 \times 10^{-3} \times C}}$

$10^4 \times 2 \times 10^2 \times 10^{-3} \times C = 1$

hence ca[pacitance is given by ,C = $\frac{1}{2 \times 10^3}$ F

= 0.5×10^{-3} F

= 0.5mF

ii. Q-factor of circuit and its importance Calculation of average power dissipated

Quality factor, $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$

$= \frac{1}{10}\sqrt{\frac{200 \times 10^{-3}}{0.5 \times 10^{-3}}}$

$= \frac{1}{10} \times$ 20 = 2

Significance: It measures the sharpness of resnance.

Average Power dissipated,

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

$= 50 \times \frac{50}{10} \times$ 1 W

= 250 watts

OR

Given, C = 25 pF = 25 $\times 10^{-6}$ F, L = 0.10 H, R = 25.0 ohm, E_0 = 310 V

i. E = 310 sin 314t

Comparing with the equation E = $E_0 \sin \omega t$

ω = 314

$2\pi f$ = 314

Frequency, f = $\frac{314}{2\pi}$ = 50 Hz

ii. a. $X_L = 2\pi f L$ = 2 $\times$ 3.14 $\times$ 50 $\times$ 0.10 = 2 $\times$ 3.14 $\times$ 5 = 31.4 ohm

$X_C = \frac{1}{2\pi f C}$

$= \frac{1}{2 \times 3.14 \times 50 \times 25 \times 10^{-6}}$ = 127.4 ohm

Thus the reactance of the circuit is,

$X_C - X_L$ = 127.4 - 31.4 = 96 ohm

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

Z = $\sqrt{(25)^2 + (96)^2}$ = 99.2 ohm

c. Current, I = $\frac{E_{rms}}{Z}$

Now, $E_{rms} = \frac{E_o}{\sqrt{2}}$

Thus, I = $\frac{310}{\sqrt{2} \times 99.2}$ = 2.21 A