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Assignment 1:-

SSp II

NUMERICALS

① A parallel plate condenser has capacitance 2μf. The dielectric has permitivity $\varepsilon_r = 100$.
(a) For an applied voltage of 1000V find energy stored in condenser. as well as in polarizing in dielectric. (b) A feild strength E applied to dielectric. Show stored energy in polarized atom equal to $\frac{1}{2}\alpha E^2$. where α is permitivity?

Sol:-

(a) $C = 2\mu f$, $\varepsilon_r = 100$, $V = 1000$ Volt

Energy stored in capacitor

$$W = \frac{1}{2} CV^2$$

$$= \frac{1}{2}(2\times10^{-6})(10^6)$$

$$W = 1 \text{ joule}$$

* Capacitance of capacitor when dielectric is removed.

$$C_0 = \frac{C}{\varepsilon_r} = \frac{2}{100}$$

$$C_0 = 0.02\mu f$$

energy stored in capacitor without dielect

$$W = C_0V^2/2$$

$$W_0 = C_0V^2/2$$

$C_0 = 0.02$

$$W_0 = \frac{(0.02\times10^{-6})(10^6)}{2}$$

$$'' = 0.01 \text{ joule}$$

Energy stored in dielectric

$$W' = W - W_0 = 1 - 0.01$$

$$W' = 0.99 \text{ Joule}$$

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(b) Energy stored in polarizing dielectric is

$$W = \frac{1}{2}[C - C_0]V^2$$

$$" = \frac{1}{2}\left[\frac{A\varepsilon_0\varepsilon_r}{d} - \frac{A\varepsilon_0}{d}\right]V^2$$

$$W' = \varepsilon_0\left[\frac{A}{2}\right]\frac{V^2}{d}(\varepsilon_r - 1)$$

Polarization $= P = E\varepsilon_0(\varepsilon_r - 1)$

$$\varepsilon_r - 1 = \frac{P}{E\varepsilon_0}$$

$$W' = \left[\frac{A\varepsilon_0 V^2}{2d}\right]\frac{P}{E\varepsilon_0}$$

$$" = \left[\frac{AV^2}{2d}\right]\frac{P}{E}$$

Energy stored for unit volume due to Polarization is :-

$$\frac{W'}{\text{Volume}} = \frac{W'}{Ad} = \left(\frac{1}{Ad}\right)\left[\frac{AV^2}{2d}\right]\left[\frac{P}{E}\right]$$

$$" = \frac{1}{2}\left[\frac{V^2}{d^2}\right]\left[\frac{P}{E}\right]$$

$$= \frac{PE^2}{2E} = \frac{1}{2}PE$$

But $P = N\sigma E$

Thus $\frac{W'}{\text{Volume}} = \frac{N\sigma E^2}{2}$

hence energy stored in polarized atom is $\boxed{\frac{1}{2}\sigma E^2}$

(2) Two parallel Plates have equal and opposite charges and are separated by dielectric 5mm thick of dielectric constant 3.

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If electric density in dielectric is 10^6 V/m. Calculate (a) free charge per unit area on conducting plate. (b) the bound charge per unit on surface of dielectric. (c) the polarization P in dielectric. (d) the displacement in dielectric (e) energy density in dielectric?

Sol:- Thickness = 5mm

Dielectric constant = 3

Electric density = 10^6 V/m

So Free charge per unit area = σ

(a) As $E = \frac{\sigma}{K\varepsilon_0}$ ε_0 = permitivity of free space

$\sigma = E K \varepsilon_0$

$\sigma = (10^6 \frac{V}{m}) \times 8.85 \times 10^{-12} \frac{C^2}{Nm^2} \times 3$

$\sigma = 26.55 \times 10^{-6} C/m^2$

(b) Bound charge per unit area on surface of dielectric = σ_B

$\sigma_B = \sigma \left(1 - \frac{1}{K}\right)$

$\sigma_B = (26.5 \times 10^{-6})(1 - 1/3)$

$\sigma_B = 17.766 \times 10^{-6} C/m^2$

(c) Polarization P in dielectric

$P = \varepsilon_0(\varepsilon_r - 1)E$ = $P = \varepsilon_0(K-1)E$

$P = 8.85 \times 10^{-12} (3-1) 10^6$

$P = 17.7 \times 10^{-6} C/m^2$

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d) displacement

$$D = E\varepsilon_0 + P$$

$$D = (10^6)(8.85\times10^{-12}) + 17.7\times10^{-6}$$

$$\boxed{D = 26.55\ C/m^2}$$

e) Energy = $U = \frac{1}{2}K\varepsilon_0 E^2$.

$$U = \frac{1}{2}(3)(8.85\times10^{-12})(10^6)^2$$

$$\boxed{U = 13.275\ J/m^3}$$

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③ If all molecular dipoles in 1cm radius water drop are pointed in same direction, Calculate the intensity of polarization. Dipole moment of water molecule 6×10^{-30} C.m ?

Sol:-

∴ Molecular Mass of water = 18gm

18gm of water contains 6.023×10^{23} mol

$\frac{18}{10^3}m^3$ will contain $\frac{6.02\times10^{26}}{18}$ mol. (water molecules)

Volume of water drop $= V = \frac{4}{3}\pi r^3$

$V = \frac{4}{3}(3.14)(10^{-2})^3\ m^3$

$V = 4.187\times10^{-6}m^3$

For No. of molecules in drop N can be find by using formula.

→ $N = \frac{6.023\times10^{26}\times4\times3.14\times10^{-6}}{18\times3}$

$N = 1.4\times10^{20}m^{-3}$

→ Polarization ~~P = NP~~ $P = N\mu$

$P = 1.4\times10^{20}m^{-3}\times6\times10^{-30}$

$P = 8.4\times10^{-10}\ C/m^2$

④ Assuming Polarizability of Kr atom is $2.18\times10^{-40}\ Fm^2$. Calculate dielectric constant of Kr at 0°C and 1 atmosphere?

Sol:- $\alpha_{Kr} = 2.18\times10^{-40}\ Fm^2$

$\varepsilon = \varepsilon_0\varepsilon_r$

$T = 0°C$ $P = 1\ atm$

$$\frac{\varepsilon_r-1}{\varepsilon_r+2} = \frac{1}{3\varepsilon_0}\sum N_i\alpha_i$$

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$$\varepsilon_r - 1 = \frac{N\alpha}{3\varepsilon_0}(\varepsilon_r + 2)$$

$$\text{"} = \frac{N\alpha\,\varepsilon_r}{3\varepsilon_0} + \frac{2N\alpha}{3\varepsilon_0}$$

$$\varepsilon_r - \frac{N\alpha\,\varepsilon_r}{3\varepsilon_0} = \frac{2N\alpha}{3\varepsilon_0} + 1$$

$$\left(1 - \frac{N\alpha}{3\varepsilon_0}\right)\varepsilon_r = \frac{2N}{3\varepsilon_0} + 1$$

$$\varepsilon_r = \frac{2N\alpha}{3\varepsilon_0} + 1 \div 1 - \frac{N\alpha}{3\varepsilon_0}$$

$$PV = nRT$$

$P = 1$ atm.

$$\frac{P}{KT} = \frac{N}{V} = N.$$

$$\frac{101325}{(273)(1.38 \times 10^{-23})} = N$$

$N = 2.69 \times 10^{25}$ atoms/m³

$$\frac{N\alpha}{3\varepsilon_0} = 2.2 \times 10^{-4}$$

$$\varepsilon_r = \frac{(2 \times 2.2 \times 10^{-4} + 1)}{1 - 2.2 \times 10^{-4}}$$

$$\varepsilon_r = 1.00066$$

$$\boxed{\varepsilon = 8.85 \times 10^{-12}}$$

(5) If a dielectric is introduced b/w the plates of parallel capacitor, show induced charge varies with dielectric as

$$\varepsilon_r = \left(1 - \frac{\sigma'}{\sigma}\right)^{-1}$$ where σ is surface density?

Sol:-

Electric feild b/w the plates of a parallel plate capacitor is

$$E = \sigma/\varepsilon_0$$

in presence of dielectric

$$E = \frac{\sigma}{\varepsilon_0\varepsilon_r}.$$

The induced charge σ' is given as

$$\sigma' = \varepsilon_0 [E_0 - E]$$

$$\sigma' = \varepsilon_0 \left(\frac{\sigma}{\varepsilon_0} - \frac{\sigma}{\varepsilon_r \varepsilon_0} \right)$$

$$\sigma' = \varepsilon_0 \frac{\sigma}{\varepsilon_0} \left(1 - 1/\varepsilon_r \right)$$

$$\sigma' = \sigma \left(1 - 1/\varepsilon_r \right)$$

$$\frac{\sigma'}{\sigma} = \left(1 - 1/\varepsilon_r \right)$$

$$\frac{1}{\varepsilon_r} = 1 - \sigma'/\sigma$$

$$\boxed{\varepsilon_r = (1 - \sigma'/\sigma)^{-1}}$$

$$\varepsilon_r = 1 + \frac{N\alpha}{3\varepsilon_0}$$

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(6) The Polarizability of neon gas $0.35 \times 10^{-40} Fm^2$. If gas contains 2.7×10^{25} atoms/m^3 at 0°C and one atmosphere pressure, Calculate is relative dielectric constant Also solve ε_r of Krypton having $\alpha_e = 3.54 \times 10^{-40} Fm^2$.

Sol:-

$$\varepsilon_r = 1 + \frac{N\alpha}{\varepsilon_0}$$

Formula same as previous questions.

(7) An elemental dielectric material has $\varepsilon_r = 12$ and it contains 5×10^{28} atoms/m^3 Calculate its electronic polarizability assuming Lorentz field?

Sol:—

$$P = N\alpha_e E$$

$$\alpha_e = \frac{P}{NE} \rightarrow (1)$$

as $P = (\varepsilon_r - 1)\varepsilon_o E \rightarrow (2)$

$$\alpha_e = \frac{(\varepsilon_r - 1)\varepsilon_o E}{NE}$$

$$\alpha_e = \frac{8.85\times10^{-12}(12-1)}{5\times10^{28}}$$

$$\boxed{\alpha_e = 1.948\times10^{-40}\ Fm^2}$$

(8) A sphere of radius R carries a polarization $P(r) = kr$ where k is constant and r is centr... Find feild outside and inside of sphere?

Sol:— Inside:- $\oint E\cdot da = Q_{enc}/\varepsilon_o \rightarrow (1)$

$$Q_{enc} = \frac{4}{3}\pi r^3 \rho$$

$$E(4\pi r^2) = \frac{4/3\pi r^3 \rho}{\varepsilon_o} \rightarrow (2)$$

$$E = \frac{r\rho}{3\varepsilon_o}\hat{r} = \frac{r(-3K)}{3\varepsilon_o}\hat{r}$$

$$\boxed{= -\frac{rK}{\varepsilon_o}\hat{r}}$$

Outside:- $\oint E\cdot da = Q_{enc}/\varepsilon_o$

$$Q_{enc} = 0.$$

$$\boxed{E = 0\hat{r}.}$$

(10) A solid dielectric material has 5×10^{28} atoms/m^3. If polarizability is 3.6×10^{-40} Fm^2. Calculate the Lorentz field normalized with respect to external field i.e E_L/E?

Sol:- $N = 5\times10^{28}$ atoms/m^3

$\alpha = 3.6\times10^{-40}\ Fm^2$.

We know Lorentz field, in the internal field

$$E_i = E + \frac{P}{3\varepsilon_0}$$

$P = N\alpha E_i$

$$E_i = E + \frac{N\alpha E_i}{3\varepsilon_0}$$

$$E_i - \frac{N\alpha E_i}{3\varepsilon_0} = E$$

$$E_i\left(1 - \frac{N\alpha}{3\varepsilon_0}\right) = E$$

$$\frac{E_i}{E} = \frac{1}{\left(1 - \frac{N\alpha}{3\varepsilon_0}\right)}$$

$$'' = \frac{1}{\left(1 - \frac{5\times10^{28}\times3.6\times10^{-40}}{3\times8.85\times10^{-12}}\right)}$$

$'' = 1.6774$.

$$E_i = E + \frac{N\alpha E}{3\varepsilon_0}$$

$$E_i = E(1 + N\alpha/3\varepsilon_0).$$

$$E_i/E = 1 + N\alpha/3\varepsilon_0$$

$$'' = 1 + \frac{(5\times10^{28})(3.6\times10^{-40})}{3(8.85\times10^{-12})}$$

$'' = 1 + 0.6779$

$'' = 1.677$

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(11) Three identical atoms in a string are subjected to a homogenous electric field E volt/m along the line joining their centres. If polarizability is 2.5×10^{-40} Fm^2 and centre spacing is 0.3mm. Find E_L/E at position of centre of atom.

Sol:- The internal field line joining the centre of atom is

$$E_i = E + E_r$$

where $E_r = \frac{1}{4\pi\epsilon_0}\left[\frac{\mu_{in}}{a^3}\right]$.

due to each atom 'a' is centre to centre spac

$$\mu_{in} = \alpha E_i$$

$$E_i = E + \frac{\alpha E_i}{4\pi\epsilon_0 a^3}$$

in case of two central atom, Thus

$$E_i\left[1 - \frac{\alpha}{4\pi\epsilon_0 a^3}\right] = E$$

$$\frac{E_i}{E} = \frac{1}{\left[1 - \frac{\alpha}{4\pi\epsilon_0 a^3}\right]}$$

$a = 3 \times 10^{-3}$

$$\therefore \frac{\alpha}{4\pi\epsilon_0 a^3} = \frac{2.5 \times 10^{-40}}{4\pi \times 8.8 \times 10^{-12} \times 27 \times 10^{30}}$$

$$= 0.33$$

$$\frac{E_i}{E} = \frac{1}{[1 - 0.33]}$$

$$\boxed{\frac{E_i}{E} = 1.5}$$

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(12) Suppose the field inside a large piece of dielectric is E_0 so the electric displacement is equal to $D_0 = \epsilon_0 E_0 + P$.

(a) Now a small spherical cavity is hollowed out of material. Find the field at centre of cavity in terms of E_0 and P. Also find displacement at centre of cavity in terms of D_0 and P? (b) D_0 same for long needle shaped cavity running parallel to P? (c) D_0 same for water shaped cavity perpendicular to P?

Sol:- Consider the field inside a large piece of dielectric is E_0

(a) Consider the dielectric displacement is

$$D_0 = \epsilon_0 E_0 + P$$

The displacement at centre of cavity in terms of D_0 and P

$$D = \epsilon_0 E \rightarrow (1)$$

$\because \epsilon_0$ = relative Permitivity
$\because E$ = Electric field.

The E_0 plus the the field of spherically equally polarized with polarization will make the E.F within the hollowed hole.

$$\vec{E} = E_0 - \left(-P/3\epsilon_0\right) = E_0 + P/3\epsilon_0 \rightarrow (2)$$

Subsitute in eq (1)

$$D = \epsilon_0 E_0 + \frac{P}{3\epsilon_0}$$

$$\vec{D}_0 = P + P/3$$

$$\vec{D}_0 = -2/3 \vec{P}$$

→ value of displacement at centre of cavity in terms of D_0 and P.

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(b) The thin needle may be modeled as a very thin cylinder, acting as a dipole, with dipole moment antiparallel to P. So,

$\vec{E} \approx \vec{E}_0$

Subsitute $\vec{E}_0$ for $\vec{E}$ in eq (1)

$D = \epsilon_0 \vec{E}_0 = \vec{D}_0 - \vec{P}$

So value for long needle shaped cavity running parallel to P is

$D = D_0 - P$

(c) $\vec{E} = \vec{E}_0 - \frac{\sigma b}{\epsilon_0} \hat{P} = \vec{E}_0 - \frac{(-\vec{P})}{\epsilon_0}$

$= \vec{E}_0 + \vec{P}/\epsilon_0$

Subsituting $\vec{E}_0 + \vec{P}/\epsilon_0$ for $\vec{E}$

$D = \epsilon_0 (\vec{E}_0 + \vec{P}/\epsilon_0)$

$= D_0.$

So value of same for a thin water shaped cavity ⊥ to P is $\vec{D} = \vec{D}_0$

(14) The ~~ratio of two identical atoms of~~ electronic Polarizability of Ar atom is $\alpha_e = 1.7 \times 10^{-40} Fm^2$ What is dielectric constant ε_r of solid Ar below (84K) if density is $1.8 g/cm^3$ and atomic mass is 39.95?

Sol:- $M_{atomic} = 39.95 g\ mol^{-1}$

$$N = N_A d / M_{at}$$

$$N = \frac{(6.02 \times 10^{23} mol^{-1})(1.8 g cm^{-3})}{39.95 g mol^{-1}}$$

$$N = 2.71 \times 10^{22} cm^{-3}$$

$$\alpha_e = 1.7 \times 10^{-40} Fm^2$$

$$\varepsilon_r = 1 + \frac{N\alpha}{\varepsilon_0}$$

$$" = \frac{(2.7 \times 10^{28})(1.7 \times 10^{-40})}{8.85 \times 10^{-12}}$$

$$" = 1.55$$

Clausis Mossoti eq:-

$$\varepsilon_r = \frac{1 + N\alpha_e/3\varepsilon_0}{1 - 2N\alpha_e/3\varepsilon_0}$$

$$\boxed{\varepsilon_r = 1.87}$$

(13) The center of two identical atoms of polarizability $\sigma = 2\times10^{-40}\ Fm^2$ are separated at distance 5×10^{-10} m. A homogonous electric feild is applied in direction to the line joining the centers of two atoms. Calculate b/w E_L and E?

Sol:-

$\sigma_e = 2\times10^{-40}\ Fm^2$ $d = 5\times10^{-50}$ m.

$$E_i = E + \frac{1.2\mu}{\pi d^3 \varepsilon_0} \qquad \mu = \alpha E$$

$$E_i/E = 1 + \frac{1.2\alpha_e}{\pi d^3 \varepsilon_0}$$

$$'' = 1 + \frac{1.2\times2\times10^{-40}}{3.14\times8.85\times10^{-12}\times(5\times10^{-10})^3}$$

$$\boxed{E_i/E = 1.069}$$

"OR"

$$E_i = E + \frac{\mu_{ind}}{4\pi\varepsilon_0 a^3} \rightarrow (1)$$

$$\mu = \alpha E$$

$$E_i = E + \alpha E_i/4\pi\varepsilon_0 a^3$$

$$E_i - \frac{\alpha E_i}{4\pi\varepsilon_0 a^3} = E$$

$$E_i(1 - \alpha/4\pi\varepsilon_0 a^3) = E$$

$$E_i = E\frac{1}{(1 - \alpha/4\pi\varepsilon_0 a^3)}$$

$$E_i/E = \frac{1}{1 - \alpha/4\pi\varepsilon_0 a^3}$$

$$'' = \frac{1}{1 - \frac{(2\times10^{-40})}{4\pi\varepsilon_0(5\times10^{-10})}}$$

$$\boxed{E_i/E = 1.069}$$

(15) Find the polarizability of CO_2 if its susceptibility is 0.985×10^{-3}. Density of carbon dioxide is $1.977\ kg/m^3$?

Sol:- $\chi_e = 0.98 \times 10^{-3}$

$\rho = 1.977\ kg/m^3$

$\alpha = ?$

Clausis Mosotti eq.

$$\frac{\varepsilon_r - 1}{\varepsilon_r + 2} = \frac{N\alpha}{3\varepsilon_0}$$

$$\alpha = \frac{3\varepsilon_0}{N}\left(\frac{\varepsilon_r - 1}{\varepsilon_r + 2}\right)$$

$\varepsilon_r = 1 + \chi_e$

$\text{"} = 1 + 0.98 \times 10^{-3}$

$\text{"} = 1.000985$

$n = m/M$

$nN_A = N_i = \frac{m}{M} N_a$

$$\frac{nN_A}{V} = \frac{N_i}{V} = \frac{m N_a}{MV}$$

$$N = \frac{m}{V} \cdot \frac{N_A}{M} = \frac{\rho N_a}{M}$$

$M = C + 2 \times 16$

$\text{"} = 12 + 2 \times 16$

$\text{"} = 44\ g/mol$

$$N = \frac{1.977 \times 6.02 \times 10^{23}}{44 \times 10^{-3}}$$

$N = 2.7 \times 10^{25} / m^3$

$$\alpha = 3(1.000985)\left(\frac{1.000985 - 1}{\text{"} + 2}\right)$$

$\boxed{\alpha = 3.227 \times 10^{-40}\ Fm^2}$

(16) The dielectric constant of helium measure at 0°C and atmosphere $\varepsilon_r = 1.000684$.

under these conditions. gas contains 2.7×10^{25} atom/m^3
Calculate radius of electron cloud (atomic radius)
Also calculate the displacement x when a helium atom subjected to field 10^6 volt/m?

Sol:-

$$\varepsilon_0(\varepsilon_r - 1) = N\alpha_E$$

$$N(4\pi\varepsilon_0 r_0^3) = \varepsilon_0(\varepsilon_r - 1)$$

$$r_0^3 = \frac{\varepsilon_0(\varepsilon_r - 1)}{N 4\pi \varepsilon_0}$$

$$r_0^3 = \frac{1.0000684}{4\pi \times 2.7 \times 10^{25}}$$

$$r_0 = 5.87 \times 10^{-11} \text{ metre}$$

$$r_0 = 0.0587 \text{nm}$$ (atomic radius)

Displacement :-

$$x = \frac{4\pi\varepsilon_0 E r_0^3}{Ze}$$

$$x = \frac{4\pi\varepsilon_0 \times 10^6 \times (0.0587 \times 10^{-9})^3}{2 \times 1.6 \times 10^{-19}}$$

$$x = 7.03 \times 10^{-17} \text{m}$$

Q17. Calculate the induced dipole moment per unit volume (density of Polarization) of He gas if placed in field 6×10^5 V/m. The atomic Polarizability of helium is 0.18×10^{-40} Fm^2 a concentration of helium atom is 2.6×10^{25}/m^3
Also calculate separation of positive and negative charges in each atom?

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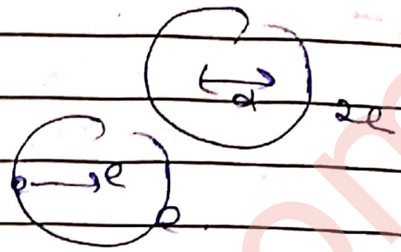
Sol:- $P = p/V$ → Induced dipole moment

$E_{local} = 6 \times 10^5 \, V/m$

$\alpha = 0.18 \times 10^{-40} \, Fm^2$

$N = 2.6 \times 10^{25} \, Fm^2$

$d = ?$



$P = \alpha E_{local} = qd.$

$P = N \alpha E_{local}$

$P = (2.6 \times 10^{25})(6 \times 10^5) \times 0.18 \times 10^{-40}$

$P = 2.808 \times 10^{-10} \, C/m^2$

$\frac{\alpha E_{local}}{q} = d$

$d = (0.18 \times 10^{-40})(6 \times 10^5) / 1.602 \times 10^{-19}$.

$d = 6.74 \times 10^{-17} \, m$

OR

$P = Nq$

$P = Nqd$

$d = P/Nq$

(18) The polarizability of NH_3 molecules in gaseous state, from the measurement of dielectric constant is found to be $2.5 \times 10^{-39} \, Fm^2$ and $2 \times 10^{-39} \, Fm^2$ at temp 300K and 400K respectively. Calculate the contribution to polarizability because of deformation and contribution of permanent dipole moment of each temp.

Sol. -

According to Langevin-Debye's theory, the total polarizability :-

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$\alpha = \alpha_1$ (due to deformation) $+ \alpha_2$ (due to permanent dipole)

$\therefore \alpha = \alpha_1 + \frac{\mu_0^2}{3 k_B T}$

$\alpha = \alpha_1 + \beta/T$

with 2.5×10^{-39} at 300 K and

2×10^{-39} at 400 K.

$2.5 \times 10^{-39} = \alpha_1 + \frac{\beta}{300}$ → (1)

$2 \times 10^{-39} = \alpha_1 - \beta/400$ → (2)

$\frac{\beta}{300} - \frac{\beta}{400} = 2.5 \times 10^{-39} - 2 \times 10^{-39}$

" $= 0.5 \times 10^{-39}$

$\frac{\beta(400 - 300)}{700} = 0.5 \times 10^{-39}$

$100\beta = 12 \times 10^4 \times 0.5 \times 10^{-39}$

$\beta = 6 \times 10^{-37}$

Subsitute in eq (1)

$\alpha_1 = 2.5 \times 10^{-39} - \frac{6 \times 10^{-37}}{300}$

$\boxed{\alpha_1 = 0.5 \times 10^{-39}\ Fm^2.}$

Similarly: -

$\alpha_2 = \beta/T$ with $\beta = 6 \times 10^{-37}$ $T = 300$

" " " $T = 400$

$\alpha_2 = \frac{6 \times 10^{-37}}{300}$

$\boxed{\alpha_2 = 2 \times 10^{-39}\ Fm^2}$

$$\alpha_2 = \frac{6\times10^{-37}}{400}$$

$$\boxed{\alpha_2 = 1.5\times10^{-39} Fm^2}$$

(19)

An atom of oxygen on being polarized produces a dipole moment of 0.5×10^{22} C-m. If distance of centre of ~~gravity~~ negative charge cloud from the nucleus be 4×10^{-17}m. Calculate polarizability of oxygen atom?

Sol:-

In equillibrium position both Lorentz force and colunb interaction will be equal.

$$(8e)E = \frac{(8e)(8e)}{4\pi\varepsilon_0 d^2}$$

$$E = \frac{8e}{4\pi\varepsilon_0 d^2} \rightarrow (1)$$

$$E = \frac{8\times1.6\times10^{-19}}{4\times3.14\times8.85\times10^{-12}\times(4\times10^{-17})^2}$$

$$E = 2.6\times10^{34} \text{ volt/metre.}$$

Dipole moment

$$\mu = \alpha E$$

$$\alpha = \mu / E$$

$$\alpha = \frac{0.5\times10^{22}}{2.6\times10^{34}}$$

$$\boxed{\alpha = 1.9\times10^{-45} Fm^2}$$

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(20) Two water molecules each having dipole moment 6.2×10^{-30} C.m. point on same direction along line joining their centres. Calculate the potential energy due to dipole interaction with their centres at 3.1×10^{-10} m apart?

Sol:-

Let μ_1 and μ_2 be dipole moments of two dipoles. We may consider first dipole to be placed in field produced by second.

$$W = -(\mu_1 E)$$

where E is field produced by second dipole

$$W = -\left[\mu_1 \times \frac{1}{4\pi\varepsilon_0 r^3}\left\{\frac{3\,\mu_2 r}{r^2}\,r - \mu_2\right\}\right].$$

$$= \frac{1}{4\pi\varepsilon_0 r^3}\left[\mu_1\mu_2 - 3\mu_1\mu_2\right].$$

$$W = \frac{1}{4\pi\varepsilon_0 (3.1\times10^{-10})^3}\left[(6.2\times10^{-30})^2 - 3(6.2\times10^{-30})^2\right]$$

$$W = -0.0232 \times 10^{-19} \text{ Joule.}$$

$$\boxed{W = -0.0145\,eV}$$

(21) Calculate the individual dipole moment of molecule of carbon tetrachloride with following data. Find also average electron displacement. Relative permeativity

$\varepsilon_r = 1.24$ Density $= 1.6 \times 10^3 kg/m^3$ Date: / /
Molecular weight $= 156$. Field 10^7 volt/m

Sol:-

Molecular Density $= N = \frac{N_A \times \rho}{M_A}$

$$N = \frac{6.02 \times 10^{23} \times 1.6 \times 10^3}{156}$$

$N = 6.17 \times 10^{27}$ molecules/m^3

$P = E\varepsilon_0(\varepsilon_r - 1)$

$$\mu_0 = \frac{P}{N} = \frac{E\varepsilon_0(\varepsilon_r - 1)}{N}$$

$$\mu_0 = \frac{10^7 \times 8.85 \times 10^{-12} (1.24)}{6.17 \times 10^{27}}$$

$\mu_0 = 1.77 \times 10^{-32}$ C.m

Displacement = Since 74 electrons in CCl_4 so

$\mu_0 = Ze(x)$

$$x = \frac{\mu_0}{Ze}$$

$$x = \frac{1.77 \times 10^{-32}}{74 \times 1.6 \times 10^{-19}}$$

$x = 1.5 \times 10^{-15}$ m