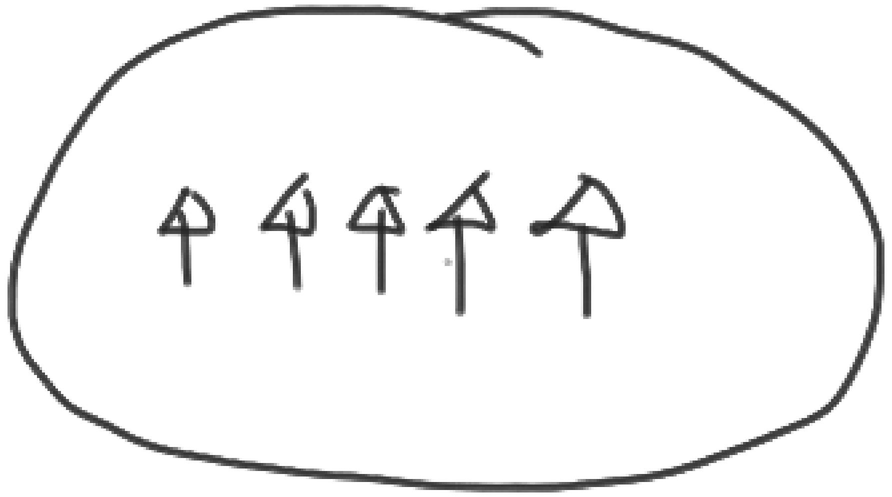
BPT-401

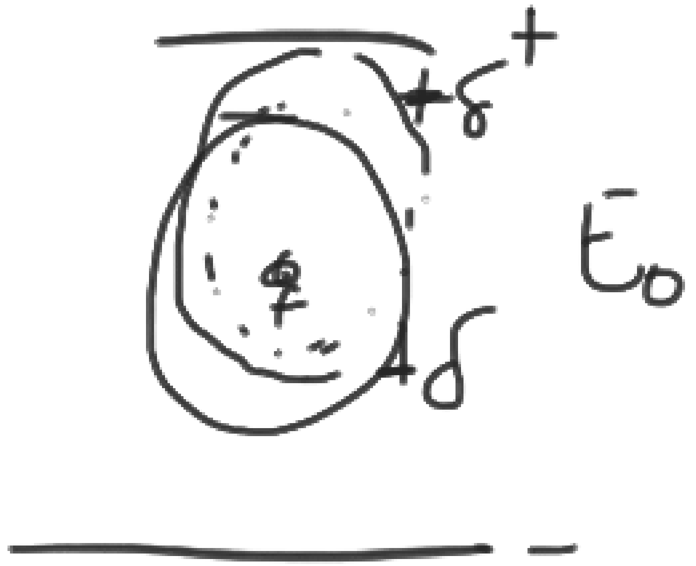
Date - 05/04/2021

$\vec{P}$

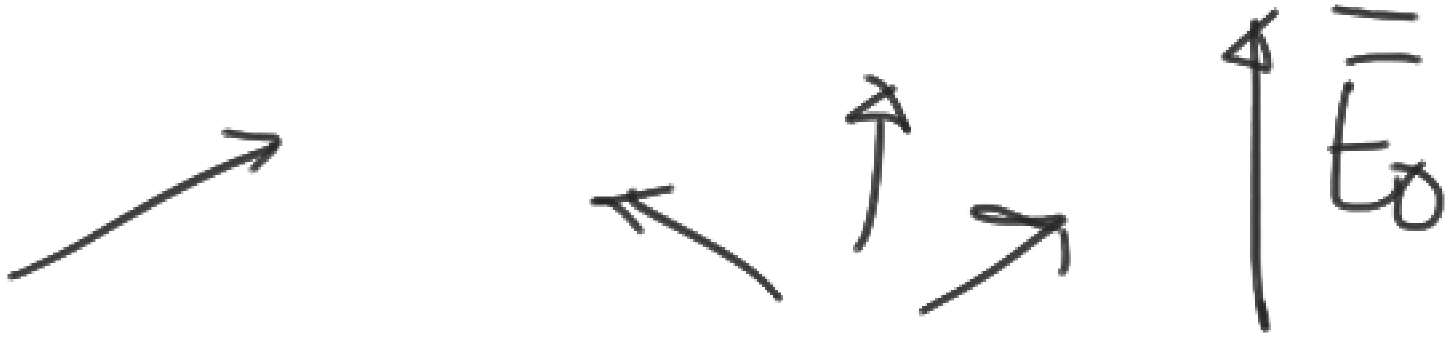


polar dielectric

①



$\vec{p}$ ②



$\checkmark\ \vec{P} = \dfrac{\#\ \text{of dipole moments}}{\text{Volume of the material}}$

$\vec{P} \propto \vec{E}$, when $\bar{E}$ is not too large,

$$\boxed{\vec{P} = \varepsilon_0 \chi_e \vec{E}}$$

External $\vec{E}$

Macroscopic quantity

electric susceptibility of the medium

χ_e depends on the microscopic structure of the substance (Temperature)

Linear dielectrics

$\vec{D}$, $\bar{E}$, $\vec{P}$

In linear dielectrics, we have

$$\vec{P} = \varepsilon_0 \chi_e \vec{E}$$

$$\vec{D} = \varepsilon_0 \bar{E} + \vec{P}$$

$$= \varepsilon_0 \bar{E} + \varepsilon_0 \chi_e \vec{E}$$

$$= \varepsilon_0 (1 + \chi_e) \vec{E}$$

$$= \varepsilon \vec{E}$$

where, $\varepsilon = \varepsilon_0 (1 + \chi_e)$

↳ Permittivity of the material

In Vacuum, $\varepsilon = \varepsilon_0 = 8.85 \times 10^{-12}\ C^2/N \cdot m^2$

$$\varepsilon = \varepsilon_0 (1 + \chi_e)$$

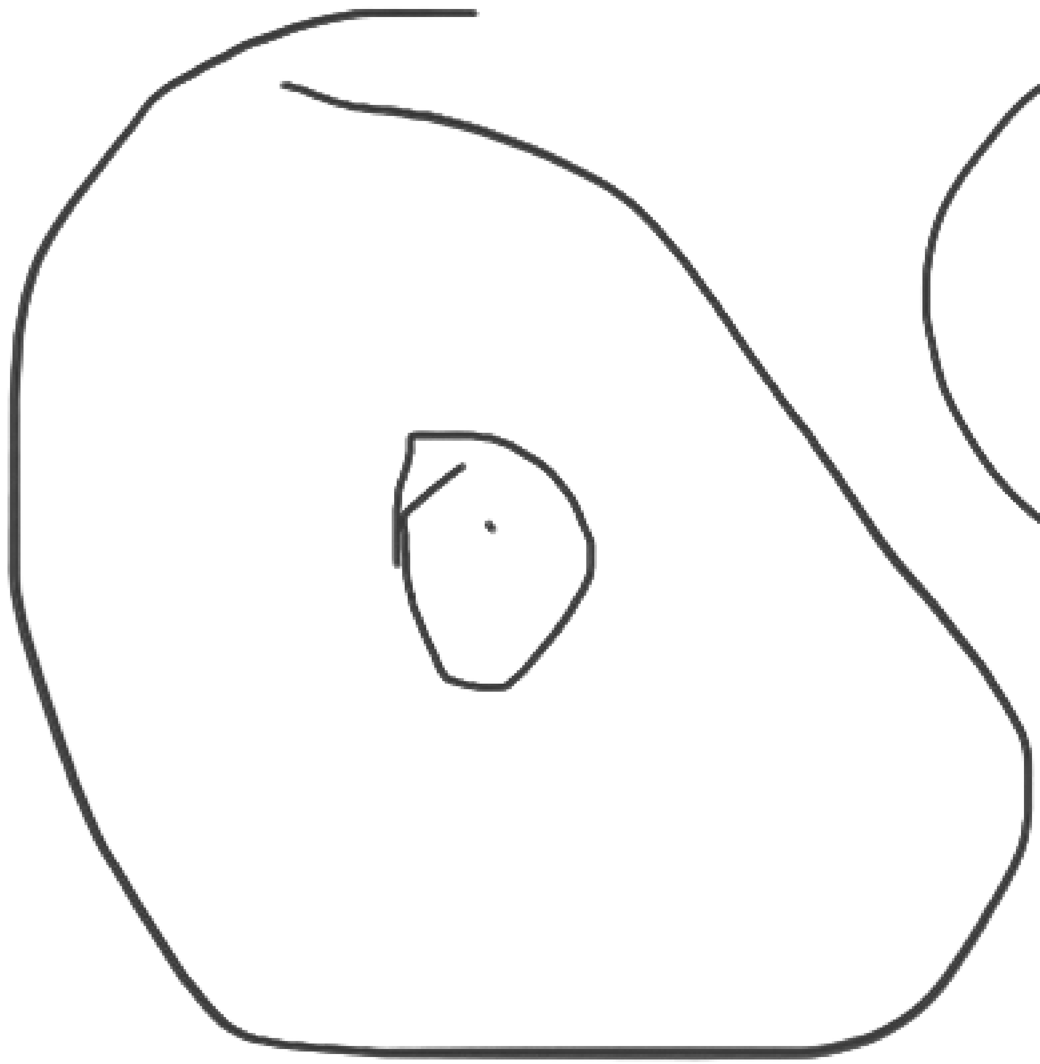
$$\varepsilon_r = \frac{\varepsilon}{\varepsilon_0} = (1 + \chi_e) \checkmark$$

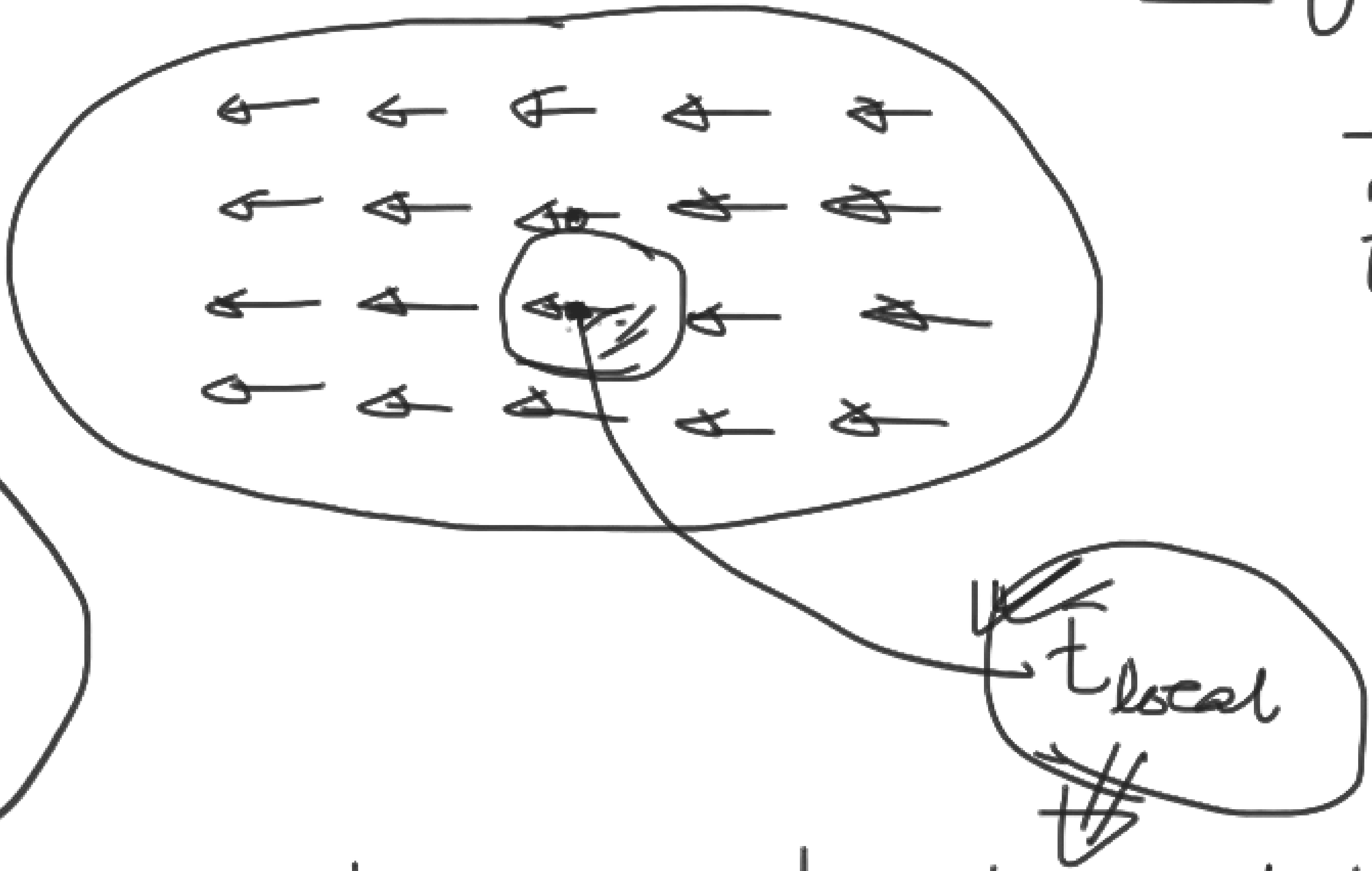
$\Downarrow$

✓ Dielectric constant of the material

Local Lorentz field :

✓ $E_{macroscopic} = \overline{E}_{avg}$





$\vec{E}_0$

↳ External

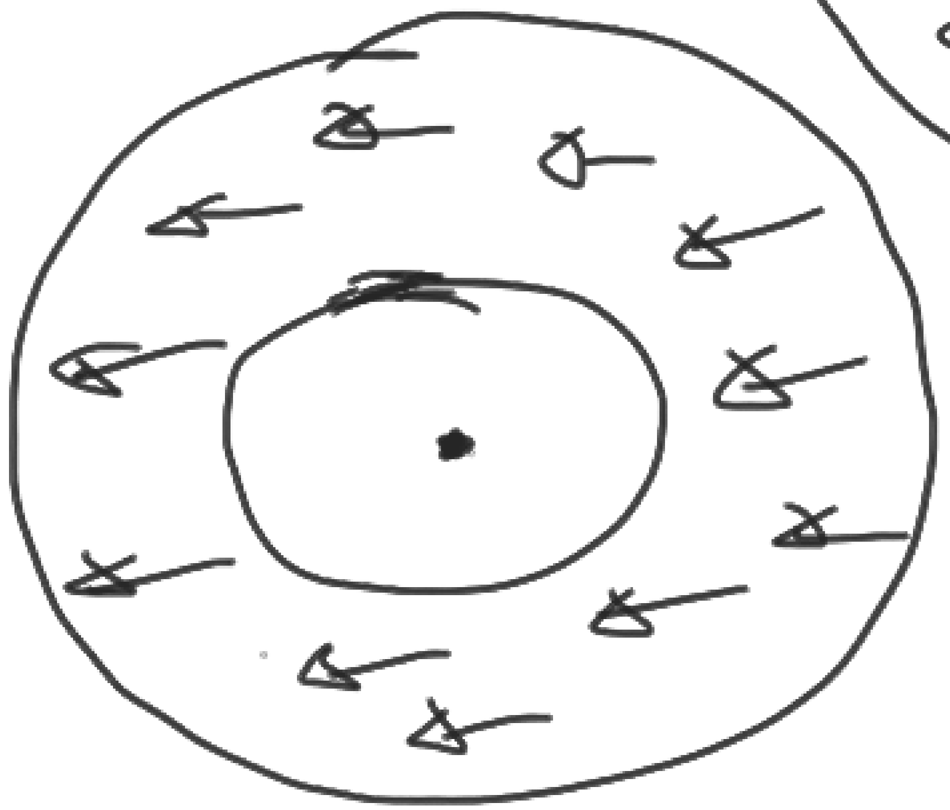
is responsible for polarisation of molecule.

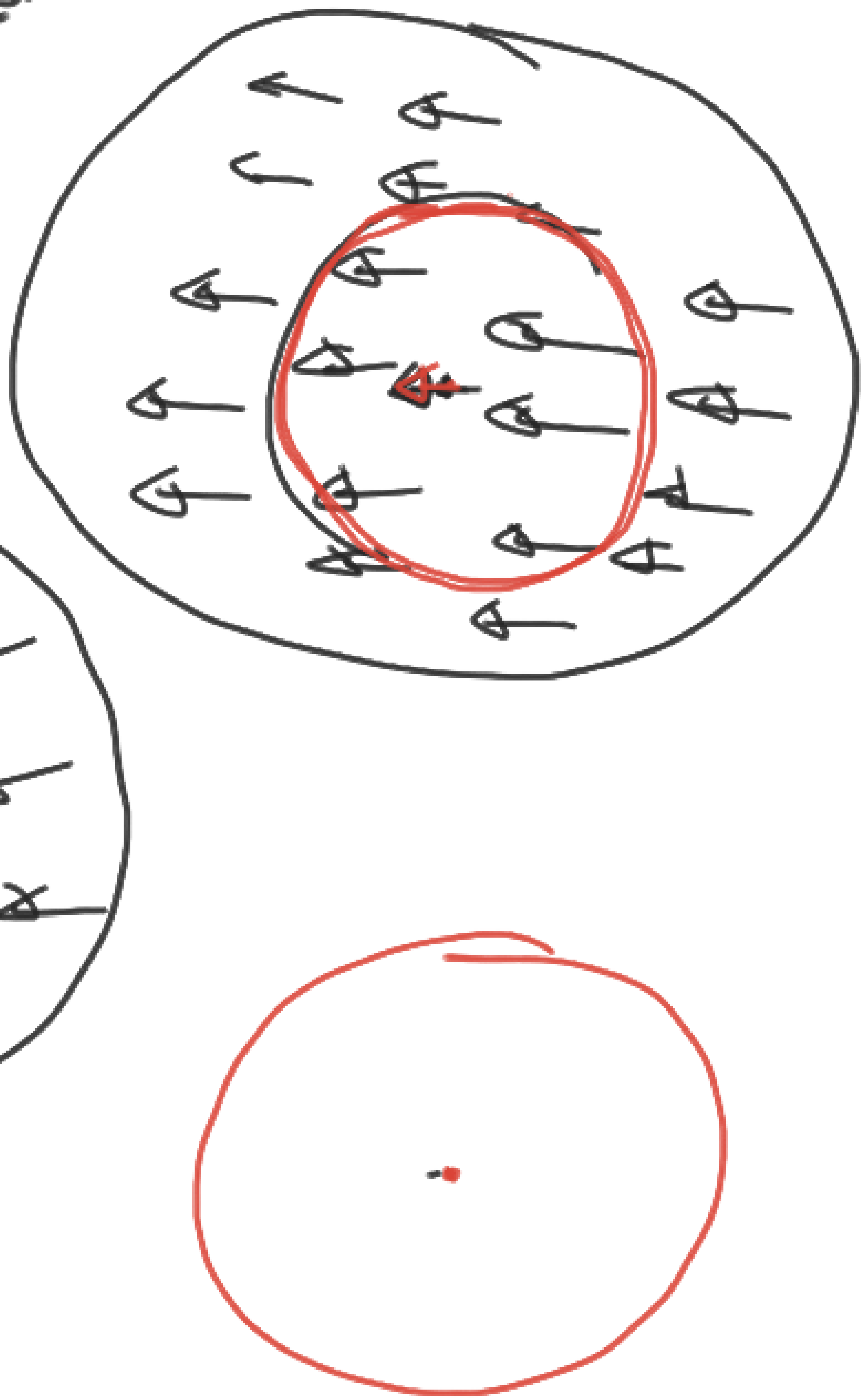
$\bar{E}$ macroscopic field of this dielectric

$\vec{E}_{local}$?

$$\boxed{\vec{E} = \vec{E}_1 + \vec{E}_2}$$

$\vec{E}_1$ within the cavity due to all charges outside the cavity

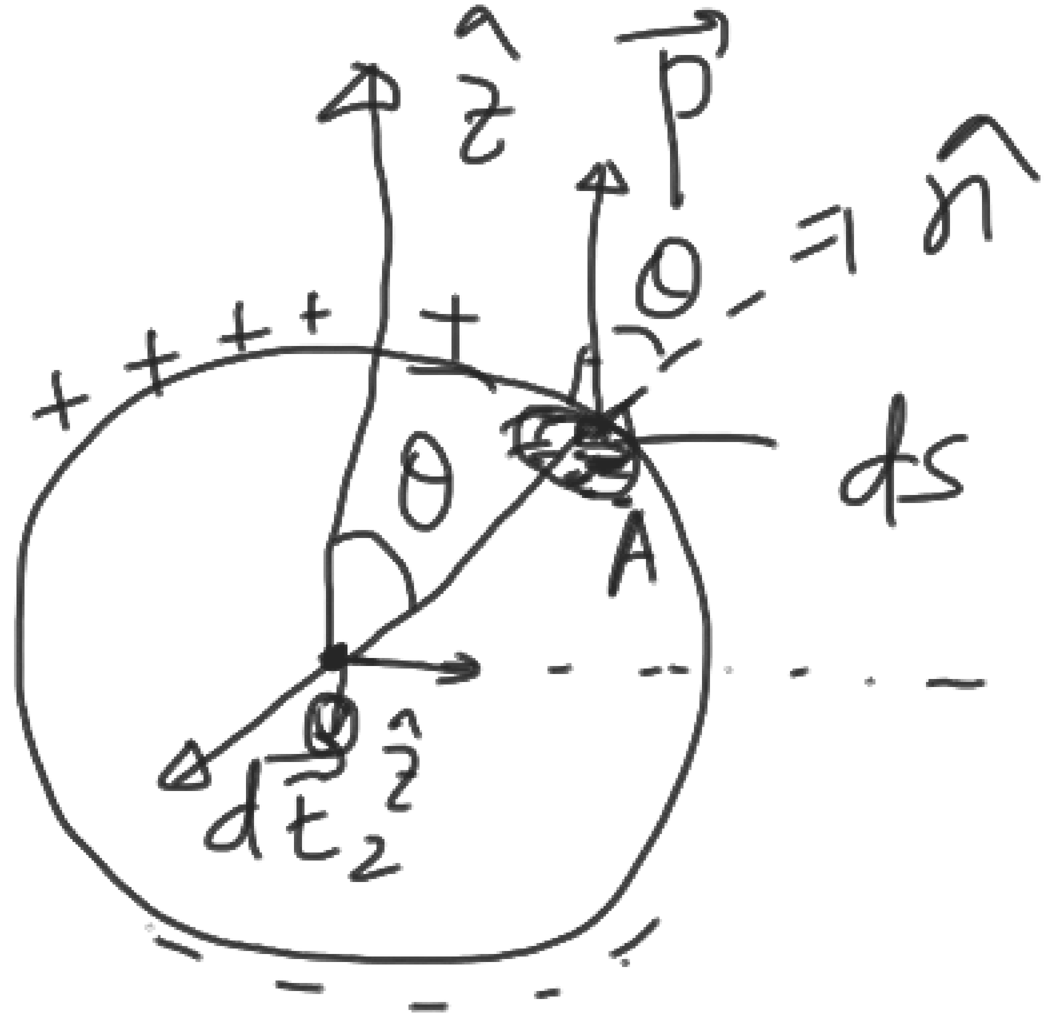




$\vec{E}_2$ = field due to all charges within the removed polarized sphere.

Calculate $\bar{E}_2$

$\vec{P} = P\hat{z}$, radius r



$d\vec{S} = ds\,\hat{n}$

$\sigma_b = \vec{P}\cdot\hat{n} = P\cos\theta$

$$d\vec{E}_2 = -\frac{1}{4\pi\varepsilon_0}\frac{P\cos\theta}{r^2}\,\hat{n}$$

$dE_2\cos\theta$, Total, $\bar{E}_2 = -\frac{1}{4\pi\varepsilon_0}\int dE_2\cos\theta$

$$\bar{E}_2 = -\frac{1}{4\pi\varepsilon_0}\int \frac{P\cos\theta\, ds}{r^2}\cos\theta\,\hat{z}$$

$$\vec{P} = P\hat{z}$$

$$= -\frac{\vec{P}}{4\pi\varepsilon_0}\int_0^{2\pi} d\phi \int_0^{\pi} \cos^2\theta \sin\theta\, d\theta$$

$$(ds = r^2 \sin\theta\, d\theta\, d\phi$$

$$= -\frac{\vec{P}}{4\pi\varepsilon_0}\, 2\pi \cdot \frac{2}{3}$$

$$= -\frac{\vec{P}}{3\varepsilon_0}$$

Macroscopic field

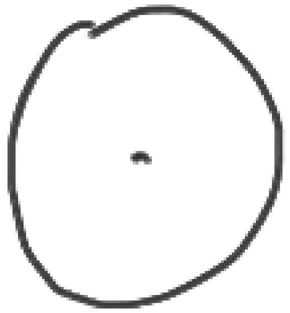
$$\bar{E} = \bar{E}_1 + \vec{E}_2$$

local field,

$$\bar{E}_1 = \bar{E} - \bar{E}_2$$

$$\boxed{E_1 = \bar{E} + \frac{\vec{P}}{3\varepsilon_0}}$$

Local field ~~is~~ is responsible for polarization of molecule

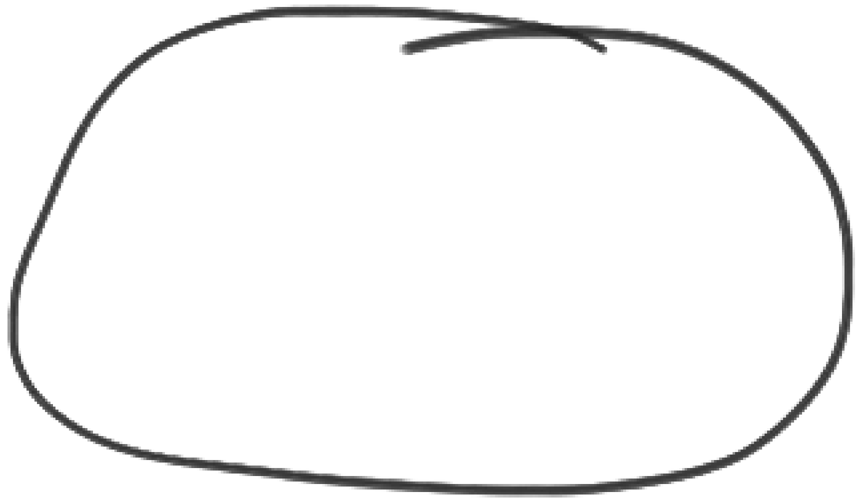


$$\bar{E}_1$$

$$\vec{p} \propto \bar{E}_1$$

$$\Rightarrow \vec{p} = \alpha \vec{E}_1$$

↳ electronic polarizibility.
(molecular)



n = molecules per unit volume,

Polarisation

$$\vec{P} = n\vec{p} = n\alpha\vec{E}_1$$

$$= n\alpha\left(\bar{E} + \frac{\vec{P}}{3\varepsilon_0}\right)$$

$$\Rightarrow \vec{P}\left[1-\frac{n\alpha}{3\varepsilon_0}\right] = n\alpha\vec{E}$$

$$\Rightarrow \underline{\vec{P}} = \frac{n\alpha^{*}}{1-\frac{n\alpha}{3\varepsilon_0}}\vec{E}$$

ε_r = ~~~~dielectric constant, & $\underline{\alpha}$

$\Rightarrow$

we know, $\vec{D} = \varepsilon_0\bar{E} + \vec{P}$

$$\varepsilon\bar{E} = \varepsilon_0\bar{E} + \vec{P}$$

$$\vec{P} = \bar{E}(\varepsilon - \varepsilon_0) = \varepsilon_0\bar{E}(\varepsilon_r - 1)$$

$$\varepsilon_0(\varepsilon_r - 1) = \frac{n\alpha}{1 - \frac{n\alpha}{3\varepsilon_0}}$$

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

Clasius-Mossotti equation

microscopic

ε_r is the dielectric constant

Macroscopic quantity