University of Anbar

College of Science

Department of Applied Geology

Fourth Year

Electromagnetics

جامعة الانبار

كلية العلوم

قسم علوم الفيزياء

المرحلة الرابعة

الكهرومغناطيسية

# *Electrical Field in matter*

## Part two : Polarization

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**Part Two in this chapter: Polarization**

## Polarization :-

matter

**Conductors**

contain an unlimited charges that are free to move through the material

تتحرك بحرية تامة (مع الشحنات)

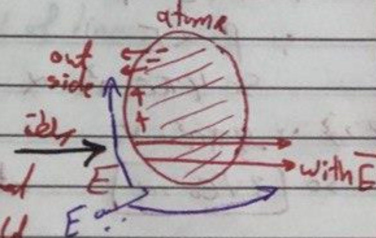
**insulator (dielectrics)**

all charges are attached to specific atoms or Moleculars.

تكون مقيدة لا تتحرك حتى بالذرة او الجزيئة

Dielectrics Polarization الاستقطاب في المواد العازلة

induced Dipoles

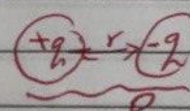



Apply Extenal Electric Field

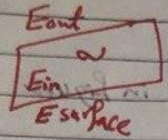
inside any atome oR surface or shape ... There is Two charges (+, -)

beTween +q and -q there is r and this is Called Dipole oR

Electric Dipole



# Electric Field on a Conductor, The Force on a surface charge




3 electric field in this surface

$E_{out}$, $E_{inside}$, $E_{surface}$

$E_{inside}$ = Zero inside

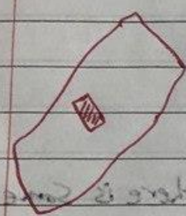
$$\vec{E}_{out} = \frac{\sigma}{\epsilon_0}\hat{n}$$

potential $-\nabla \cdot V = \vec{E}$

$$\frac{\partial V}{\partial n} = \frac{-\sigma}{\epsilon_0} \Rightarrow \sigma = -\epsilon_0 \frac{\partial V}{\partial n}$$ surface charge on the conductor

What is the force on this surface charge?

$$\vec{F} = \sigma \vec{E}_{(at\ the\ surface)}$$



$$\vec{E}_{above} = \vec{E}_{ot} + \frac{\sigma}{2\epsilon_0}\hat{n}$$

$$\vec{E}_{below} = \vec{E}_{ot} - \frac{\sigma}{2\epsilon_0}\hat{n}$$

$$\vec{E}_{outside} = \vec{E}_{above} - \frac{\sigma}{2\epsilon_0}\hat{n}$$

$$= \vec{E}_{below} + \frac{\sigma}{2\epsilon_0}\hat{n}$$

add them and Divided to 2

$$\vec{E}_{out} = \frac{1}{2}\left(\vec{E}_{above} + \vec{E}_{below}\right)$$

↑ For Conductor → E inside = Zero

$$= \frac{1}{2}\left(\frac{\sigma}{\epsilon_0}\right)$$

$$= \frac{1}{2}\frac{\sigma}{\epsilon_0}\hat{n}$$

$\vec{F} = \sigma \vec{E}_{at\ the\ surface}$

$= \sigma \frac{1}{2} \frac{\sigma}{\epsilon_0} \hat{n}$ ← normal direction

$= \frac{1}{2} \frac{\sigma^2}{\epsilon_0} \hat{n}$

$= \vec{E}_{out}^2 \hat{n}$

Polarization :-

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→ insulator (dielectrics): all charges are attached to specific atoms or Moleculars.

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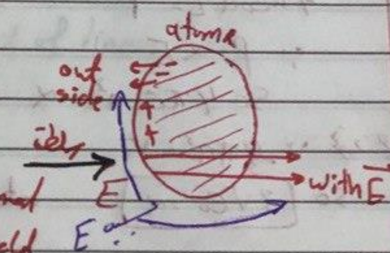


inside any atoms or surface or shape... There is Two charges (+, -)

between +q and -q there is r and this is called Dipole or

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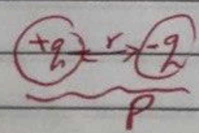


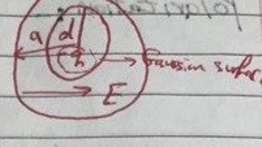
if we have Electric dipole between +q, -q
there is dipole moment عزم ثنائي القطب

$P = \alpha E$ — يتناسب طردي $P \propto E$

$P$: dipole moment
$\alpha$: Polarizibility Constant
$E$: Electric field

P161 back

Ex: A primitive mode for an atom consist of a point nucleus $+q$, surrounded by a uniformaly charged particle $(-q)$ of Radius $d$, calculate The atomic polarization for an atom ?




$$\int_{surface} \vec{E} \cdot d\vec{a} = \frac{Q_{in}}{\epsilon_0}$$

$$E \oint da = \frac{Q_{in}}{\epsilon_0}$$

$$E\, 4\pi d^2 = \frac{q \cdot \frac{4}{3}\pi d^3}{\epsilon_0 \, \frac{4}{3}\pi a^3}$$

$$E = \frac{1}{4\pi\epsilon_0}\frac{qd}{a^3}$$

here $Q_{in} = \rho V = \rho \frac{4}{3}\pi d^3$

a: radius of the atom

$qd = P$

$$E\, 4\pi\epsilon_0 a^3 = qd$$

$$4\pi\epsilon_0 a^3 E = P \Rightarrow E = \frac{P}{4\pi\epsilon_0 a^3}$$

$\because P = \alpha E$

So $4\pi\epsilon_0 a^3 = \alpha$

$\because \frac{4}{3}\pi a^3 = V$ حجم الذرة

So $\boxed{3V\epsilon_0 = \alpha}$ atomic polarizibity atome

(O)(C)(O)

$\vec{P}_{total} = \alpha E_{\perp} + \alpha E_{\parallel}$

Perpendicular parallel

$\vec{P} =$ ---- Tensor X

غير مطلوب

Molecules

أكثر من ذرة مثل $CO_2$

الحقل الكهربائي البسيط ممكن ان يكون عمودياً

او ممكن ان يكون مع الحقل الكهربائي الموازي

والعادة يكون مع الكهربائي البسيط

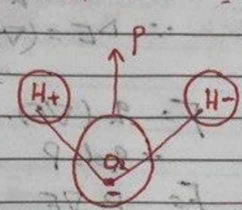
منتظم (Uniform)

Alignment of Polar Molecules like $HN_3$, $H_2O$ الجزيئات القطبية

water molecules have dipole moment Toward $+q$,

في عزم ثنائي القطب باتجاه الشحنة الموجبة

(مجال كهربائي منتظم)




if we Apply Electric Field (uniform)

باتجاه الشحنات الموجبة → $F = qE$ الشحنات الموجبة ستتحرك باتجاه E والشحنات السالبة عكس E

↑

Exactly Cancled The Force on The Negative direction

So $\vec{F} =$ Zero. الشحنات الموجبة والشحنات السالبة في مكانها.

ولكن لا تولد عزم دوراني Torque

Torque in Physics: is the rotational equivalent of linear force.

$\tau = r \times F$ (القوة × البعد)

to determine $\tau$ For water

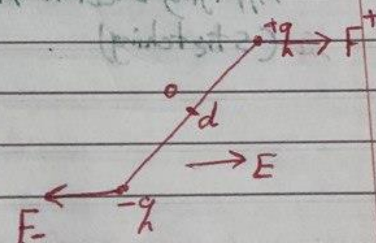
$$\tau = (r \times F^{+}) + (r \times F^{-})$$

$$= \left[\left(\frac{d}{2} \times qE\right)\right] + \left[-\frac{d}{2} \times (-qE)\right]$$

$$= qd \times E$$

ص ٤٣ $\because qd = P$

$$\therefore \tau = P \times E$$



## NET Force due to Non-uniform Field

مجال كهربية غير منتظمة
[illegible]

if The electric Field nonuniform, F does not exaclty balanced.

$F_{on(+q)} \neq F_{on(-q)}$

There is The Net force

$F = F^{(+)} + F^{(-)} \qquad \because F = qE$

$= q(E^{+} + E^{-})$

$= q \Delta E$

$\because \Delta E = (\nabla E) \cdot d$ ← المسافة بين الشحنات

$F = q(\nabla E) \cdot d$

$\because qd = P$

$F = P \cdot \nabla E$

الاستقطاب Polarization

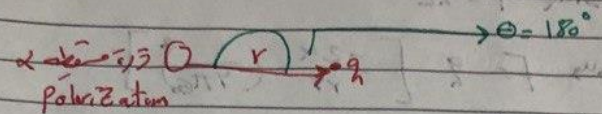
→ الذرات عديمة الشحنة
Neutral atoms
There is a dipole moment with The same direction of The Applying Electric Field
تمدد (Stretching)

→ polar molecules
الجزيئات القطبية
كل جزيئة لها تكون لها عزم دوراني Tourqe
إنها تصبح بإتجاه خطوط المجال الكهربائي
experiening a Tourqe, Tending to line it up along The field ~~direct~~ direction (Rotating)
دوران

$P^{163}$

Ex 4.4

A point charg q is situted a large distance r from neutral atom of polariziabitiy α, Find The Force of attraction beTween them?



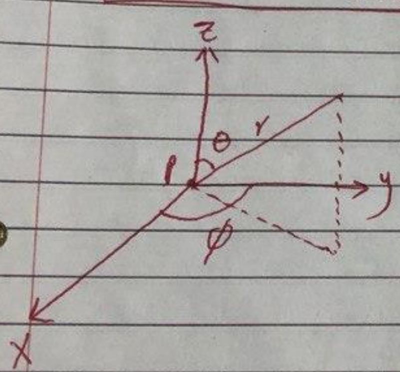

The Electric Field $\quad E = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2} \hat{r}$

$\because P = \alpha E$

$= \frac{\alpha q}{4\pi\epsilon_0 r^2} \hat{r}$

$$\boxed{E_{dip}(r,\theta) = \frac{P}{4\pi\epsilon_0 r^3}(2\cos\theta\,\hat{r} + \sin\theta\,\hat{\theta})}$$

حفظاً P 153 back [illegible]




Since θ = 180°

$$E_{dip} = \frac{P}{4\pi\epsilon_0 r^3}(2 * (-1) + 0)$$

$$E_{dip} = \frac{-2P}{4\pi\epsilon_0 r^3} \hat{r}$$

but $P = \frac{\alpha q}{4\pi\epsilon_0 r^2} \hat{r}$

thus

$$E_{dip} = \frac{-2}{4\pi\epsilon_0 r^3} \left(\frac{\alpha q}{4\pi\epsilon_0 r^2}\right) \hat{r}.\hat{r}$$

unit vector = 1

like i.i = 1 dot product

but i x i = 0 cross product

$$E = \frac{-2\alpha q}{r^5}\left(\frac{1}{4\pi\epsilon_0}\right)^2$$

since $F = qE$

thus $F = q\left[\frac{-2\alpha}{r^5}\cdot\left(\frac{1}{4\pi\epsilon_0}\right)^2\right]$

$$F = 2\alpha\left(\frac{q}{4\pi\epsilon_0}\right)^2 \cdot \frac{1}{r^5} \quad \text{to Right} +$$

OR

$\because K = \frac{1}{4\pi\epsilon_0}$

$F = (q^2 K^2)\, 2\alpha \cdot \frac{1}{r^5}$

$= 2\alpha (qK)^2 \cdot \frac{1}{r^5}$

طريقة

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2022

## Reference:

1) INTRODUCTION to ELECTRODYNAMICS, Third Edition, David j.Griffths