CONNECT MICRO-WORLD TO MACRO-WORLD

microscopic properties of conductors & insulators

and behavior of electrons

emphasize fundamental principles

↳ fields: electric / magnetic

how charges create fields — affect

we will study this all semester

Four fundamental forces

- gravity — anything with mass, very very weak — very long range
- strong — ~~[scribble]~~ NUCLEAR .. holds ~~the~~ prot/neut — high energy/short range
- weak — radioactivity
- E/M — basis for contempory technology

VECTORS — magnitude & directions

$$\int \frac{1}{5} z^2 \, dz$$

$$\vec{r} = \langle x, y, z \rangle = x\hat{i} + y\hat{j} + z\hat{k}$$

4,3,5

$$\vec{r} = \langle 3, 4, 5 \rangle \text{ m}$$

magnitude

$$|\vec{r}| = \sqrt{3^2 + 4^2 + 5^2 \text{ m}^2} = \sqrt{50 \text{ m}^2} = \sqrt{50} \text{ m}$$

$$|\vec{r}| \geq 0 \quad \text{(property)}$$

unit vector

$$\hat{u} \rightarrow |\hat{u}| = 1$$

$$\hat{r} = \frac{\vec{r}}{|\vec{r}|} = \frac{\langle 4, 3, 5 \rangle \text{ m}}{7.1 \text{ m}}$$

$$= \langle 0.512, 0.384, 0.640 \rangle$$

vector addition: ~~tail-to~~ tip-to-tail

" subtraction: tip-to-tip

$$\Delta\vec{r} = \vec{r}_f - \vec{r}_i$$

CHARGED PARTICLES (μ-scopic props)

PHYS 152

① ELECTRIC FIELD

	charge	mass	radius
electron	$-e = -1.6 \times 10^{-19}$ C	9×10^{-31} kg	none? $< 10^{-17}$ m
positron	$+e$	9×10^{-31} kg	none?
proton	$+e$	1.7×10^{-27} kg	1×10^{-15} m quarks (BTW fractional charge)
Anti-proton	$-e$	1.7×10^{-27} kg	1×10^{-15} m
neutron	0		

most materials are neutral $\therefore$ $\Sigma \;\forall$ charges $= 0$

radius of nucleus is 10^{-10} m

ELECTRIC FIELD

GRAVITY

$9.8 \ m/s^2$

$$\frac{d\vec{p}}{dt} = \frac{d}{dt}(m\vec{v}) = m\frac{d\vec{v}}{dt} = m\vec{a}$$

$$\vec{F}_g = \langle 0, -mg, 0 \rangle$$

$\oplus \longrightarrow 1 \times 10^{11} \ m/s^2$

1.) + + + + + + $\oplus \longrightarrow$ or 2) $\oplus \longrightarrow$ − − − − − − − − or 3. some combo of 1 and 2

suppose

$1 \times 10^{11} \ m/s^2 \longleftarrow \ominus$

DEFN $\vec{F}_2 = q_2 \vec{E}_1$

Force felt by q_2

Electric field produced by everything else

ELECTRIC FIELDS AND MATTER

$\sum_i q_i$ = net charge

if neutral then $\sum_i q_i = 0$

charged $\neq 0$

Ex

hyerogen

proton + electron

$e^+ + e^- = 0$

no charge

sodium ion ~~A~~ Na^+

11 protons, 10 electrons

$11(+e) + 10(-e) = e$

dipole

$+q + -q = 0$

CONSERVATION OF CHARGE (LAW)

NET CHARGE OF AN OBJECT AND SURROUNDINGS DOES NOT CHANGE

CONDUCTORS

contains mobile charged particles which can move throughout material

INSULATORS

charges are in fixed positions

Ex

CHARGING AN INSULATOR

balloon

- charged objects has excess charge
- Most objects neutral
- Apparently, you can transfer charge from one to another

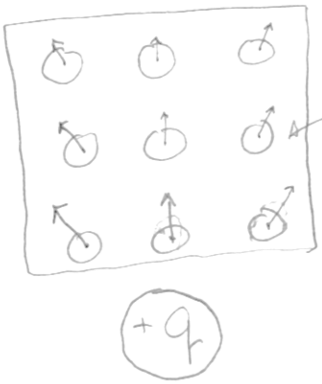
probably picks up electrons while hair loses

MECHANISMS

1. break chemical bonds 5 eV
2. remove electron 10 eV
3. remove proton 1×10^6 eV

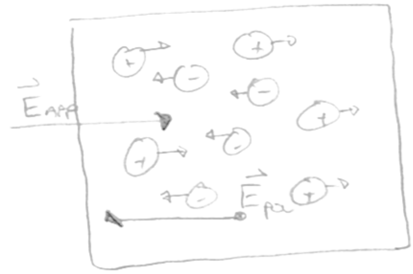
ON BACK

POLARIZATION OF INSULATOR



POLARIZATION OF CONDUCTOR

EX. SALT WATER



$$\vec{E}_{NET} = \vec{E}_{APP} + \vec{E}_{POL}$$

EVENTUALLY
$\vec{E}_{NET} = 0$ (equilibrium)

	CONDUCTOR	INSULATOR
mobile charges?	Y	N
polarization?	Y	YES, but each atom
equilibrium	$\vec{E}_{NET} = 0$	$\vec{E}_{NET} \neq 0$
excess charges	surface	anywhere
how are they distributed	uniformly	patches/clumps

CHARGED METAL

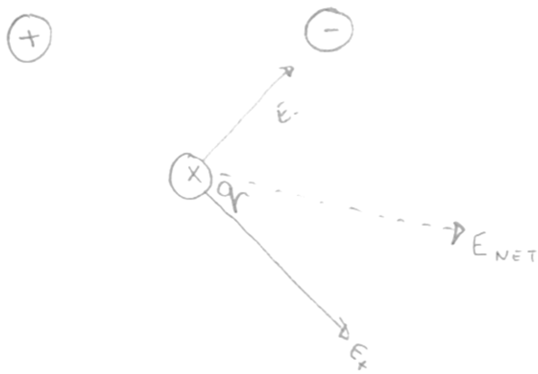
ALL EXCESS CHARGES ARE AT THE SURFACE BECAUSE THE EXCESS CHARGED PARTICLES MOVE AS FAR FROM ONE ANOTHER AS POSSIBLE

Superposition Principle (for Electric Fields)

WHAT IS THE NET ELECTRIC FIELD

$\vec{E}_{NET}$ = vector sum of all electric particles

$\boxed{\text{Ex. } 563 \text{ \& } 564}$



SPHERE W/ UNIFORM CHARGE

$$\vec{E} = \begin{cases} 0 & r<R \\ \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}\hat{r}, & r>R \end{cases}$$

ELECTRIC DIPOLE

EX) H CL

$\vec{E}_{NET} = \vec{E}_- + \vec{E}_+$

$$\vec{E}_+ = \frac{1}{4\pi\varepsilon_0}\frac{q}{(x-\frac{s}{2})^2}\langle 1,0,0\rangle$$

$$\vec{E}_- = \frac{1}{4\pi\varepsilon_0}\frac{-q}{(x+\frac{s}{2})^2}\langle 1,0,0\rangle$$

$$\vec{E}_{NET} = \frac{1}{4\pi\varepsilon_0}q\left(\frac{1}{(x-\frac{s}{2})^2} - \frac{1}{(x+\frac{s}{2})^2}\right)\langle 1,0,0\rangle$$

$$= \frac{1}{4\pi\varepsilon_0}q\left(\frac{(x+\frac{s}{2})^2-(x-\frac{s}{2})^2}{(x-\frac{s}{2})^2(x+\frac{s}{2})^2}\right)$$

$$= \frac{1}{4\pi\varepsilon_0}q\frac{2xs}{(x-\frac{s}{2})^2(x+\frac{s}{2})^2}$$

ON BACK

$\vec{E} = K \cdot \frac{q}{|r|^2} \hat{r}$

$\langle 0, 3e^4, 0 \rangle = K \frac{1.6e{-19}}{r^2} \langle 0,1,0 \rangle$

$r^2 =$

$\langle 0, 5e^4, 0 \rangle = K \frac{1.6e{-19}}{r^2} \langle 0,1,0 \rangle$

$r^2 = (9 \times 10^9)(1.6e^{-19})(5e^{+4})$

$2.88 \cdot 10^{9-19-4}$

$2.88 \cdot 10^{-14}$

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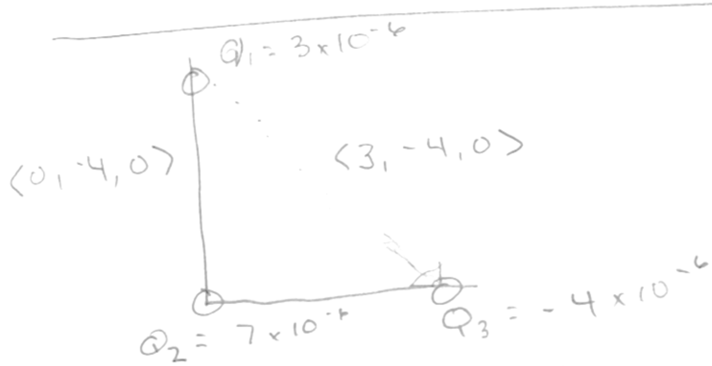
6. ~~M~~

$E_{11} = K \cdot \frac{2qs}{d^3} = (9 \times 10^9) \cdot 2 \cdot (6 \times 10^{-6}) \cdot (.001) \cdot \frac{1}{(.06)^3}$

$= 18 \times 10^3 \cdot (0.001) \cdot \frac{1}{0.06^3}$

$= 5 \times 10^5$

$\langle 0, 7.5 \times 10^5, 0 \rangle$



$E_2 = K \cdot \frac{7 \times 10^{-6}}{16} \cdot \langle 0,-1,0 \rangle =$

$= (9 \times 10^9)(7 \cdot 10^{-6})(\frac{1}{16}) \langle 0,-1,0 \rangle$

$= \frac{63}{16} \cdot 10^3 \langle 0,-1,0 \rangle$

$= \langle 0, -3937.5, 0 \rangle$

$E_3 = K \cdot \frac{-4 \times 10^{-6}}{25} \cdot \langle \frac{3}{5}, -\frac{4}{5}, 0 \rangle$

$= (9 \times 10^9)(-4 \cdot 10^{-6})(\frac{1}{25}) \langle \frac{3}{5}, -\frac{4}{5}, 0 \rangle$

$= -\frac{36}{25} \cdot 10^3 \langle \frac{3}{5}, -\frac{4}{5}, 0 \rangle$

$= \langle -864, 1152, 0 \rangle$

$= \langle -864, -2785.5, 0 \rangle$

E_2: $\langle 0, 3937.5, 0 \rangle$

E_3: $\langle 432, -576, 0 \rangle$

$\langle 4.32e6, 3.361e7, 0 \rangle$

$F = \langle 12.96, 100.83 \rangle$

(a)

$\vec{E}_2 = (9\times10^9)\,\frac{7\times10^{-6}}{16}\,\langle 0,-1,0\rangle = 0, -\frac{63}{16}\times10^3, 0 = \langle 0,-3937.5,0\rangle$

$E_3 = (9\times10^9)\,\frac{-2\times10^{-6}}{25}\,\langle -\frac{3}{5}, \frac{4}{5}, 0\rangle = \langle 432, -576, 0\rangle$

$-\frac{18}{25}\times10^3$

$\vec{E}_{net} = \langle 432, -4513.5, 0\rangle$

$F = q E_{net} = 3\cdot10^{-6}\langle 432, -4513.5, 0\rangle$

$\langle 1.296\times10^{-3}, -1.3541e^{-2}, 0\rangle$

d) $F = ma$

$a = \frac{F}{m} =$

$\langle -4512, -891, 0\rangle$

$F = q\,2\cdot1.6\times10^{-19}$, $-1.44384e-15, -2.8512e^{-16}, 0\rangle$

$F = \langle -1.44384e^{-15}, -2.8512e^{-16}$

$a = \frac{\langle -1.44384e^{-15}, -2.8512e^{-16}}{6.646\times10^{-27}}$

$-2.17249e11, -4.2901e10$

3.

a) $\vec{E} = \langle 0, 3\times10^{4}, 0\rangle \frac{N}{C}$ @ $\langle 0,0,0\rangle m$

$\langle 0, 3\times10^{4}, 0\rangle = \frac{1}{4\pi\varepsilon_0} \cdot \frac{1.6\times10^{-19}}{|\vec{r}|^2} \langle 0,1,0\rangle m$

$|\vec{r}|^2 \langle 0, 3\times10^{4}, 0\rangle = (9\times10^{9}) \cdot (1.6\times10^{-19}) \langle 0,1,0\rangle$

$|\vec{r}|^2 = 14.4 \times 10^{-10} \frac{\langle 0,1,0\rangle}{\langle 0, 3\times10^{4}, 0\rangle}$

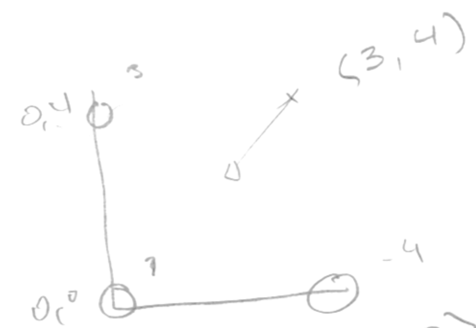
$r = \sqrt{14.4 \times \frac{1}{3} \times 10^{-14}}$

$(9\times10^{9})(1.6\times10^{-19}) \cdot \frac{\langle 0,1,0\rangle}{\langle 0, 3\times10^{4}, 0\rangle}$

5×10^{4}

$\frac{14.4\times10^{-10} \cdot \langle 0, 5\times10^{4}, 0\rangle}{\sqrt{14.4 \cdot 5 \cdot 10^{-14}}}$

4.



$\langle 3,0\rangle$

(c)

a) $\vec{E}_1 = (9\times10^{9}) \cdot \frac{3\cdot10^{-6}}{9} \langle -1,0,0\rangle = \langle 3\cdot10^{3},0,0\rangle$ $\langle -3000,0,0\rangle$

$E_3 = (9\times10^{9}) \cdot \frac{-2\times10^{-6}}{16} \langle 0,-1,0\rangle = \langle 0, -\frac{18}{16}\cdot10^{3}, 0\rangle$

$= \langle 0, +1125, 0\rangle$

$E_2 = (9\times10^{9}) \cdot \frac{7\cdot10^{-6}}{25} \langle \frac{3}{5}, \frac{4}{5}, 0\rangle =$

$= \frac{63}{25}\times10^{3} \langle -\frac{3}{5}, -\frac{4}{5}, 0\rangle = \langle -1512, -2016, 0\rangle$

a) $E_{net} = \langle -4512, -891, 0\rangle$

(a)

1. b.

$$|E| = \sqrt{9000^2 + 9000^2} = 12727.9$$

$$\hat{E} = 0.707107$$

$$\vec{F} = -7 \times 10^{-9}\,\vec{E} = -7 \times 10^{-9} \langle 9000, -9000, 0 \rangle = -6.3 \times 10^{-5}$$

$$\hat{F}$$

1. $\vec{E} = \frac{1}{4\pi\varepsilon_0} \frac{q_{src}}{|\vec{r}|^2} \hat{r}$

$|E| = \sqrt{7000^2 + 7000^2} = 9899.49$

$\vec{F} = q_{src}\vec{E} = \cancel{-8 \times 10^{-09} \langle 7000, 7000, 0 \rangle = \langle -0.000056, -0.000056, 0 \rangle}$ -5.6×10^{-5}

$\cancel{\hat{F} = \langle 0.000079, 0.000079, 0 \rangle}$

$\hat{E} = \frac{\vec{E}}{|E|} = \langle 0.707107, 0.707107, 0 \rangle$

$\vec{F} = -8 \times 10^{-09} \hat{E} = \langle -5.6 \times 10^{-5}, -5.6 \times 10^{-5}, 0 \rangle$

$\hat{F} =$

2. $q = 4 \times 10^{-9}$ C

$\vec{r} = \langle 0.3, 0, 0 \rangle$

$|\vec{r}| = 0.3$

$|\vec{r}|^2 = 0.09$

$\vec{E} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_{src}}{|\vec{r}|^2} \hat{r}$

$\vec{E} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{4 \times 10^{-9}}{0.3} \langle 1, 0, 0 \rangle$ $\hat{r} = \frac{\vec{r}}{|\vec{r}|} = \frac{\langle 0.3, 0, 0 \rangle}{0.3} = \langle 1, 0, 0 \rangle$

$\vec{E} = (9 \times 10^9) \frac{4 \times 10^{-9}}{0.3} \langle 1, 0, 0 \rangle$

$\vec{E} = 9 \cdot 4 \frac{1}{0.3} \langle 1, 0, 0 \rangle = 36 \cdot \frac{1}{0.3} \cdot \langle 1, 0, 0 \rangle = \langle 120, 0, 0 \rangle$

$36 \cdot \frac{1}{0.09}$

$\cancel{(4 \times 10^{9})}(3 \times \cancel{10^{-9}})(9 \times \cancel{10^{9}}) \cdot \frac{1}{0.1}$

$\frac{27}{0.1}$