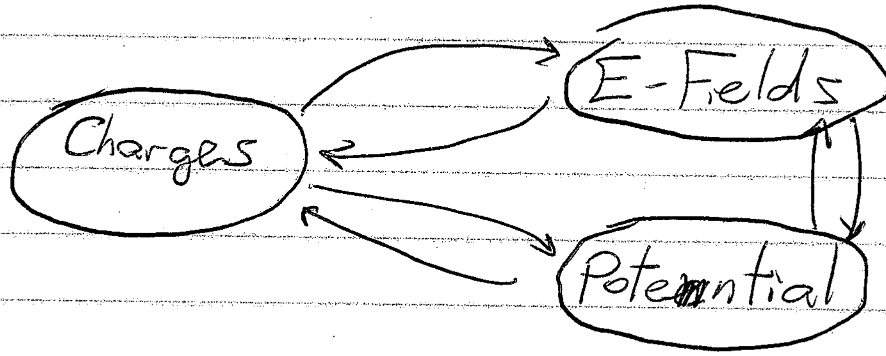
 Phys 2426   2017-07-05



Stuff   EM Fields

Effect of $\vec{E}$: $\vec{F}_E = q\vec{E}$

- ⊕ pushed along $\vec{E}$; ⊖ pulled against $\vec{E}$

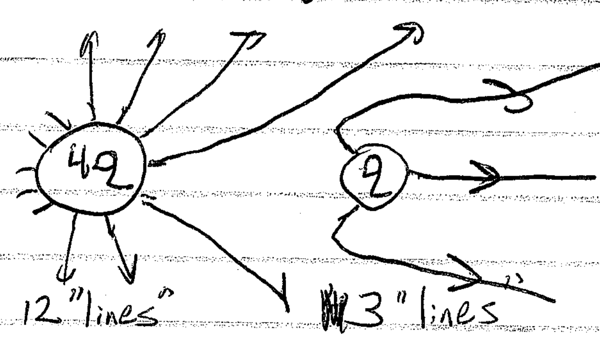
Cause of $\vec{E}$:   Charges, but math varies.

- Point Charge $E = \frac{kQ}{r^2}$ (away from ⊕)

- Charge Distribution $\vec{E} = \int \frac{k\,dQ}{r^2}\hat{r}$

  Ex: $dQ = \lambda\, dl$

- Gauss's Law - related to E-Field Lines



②

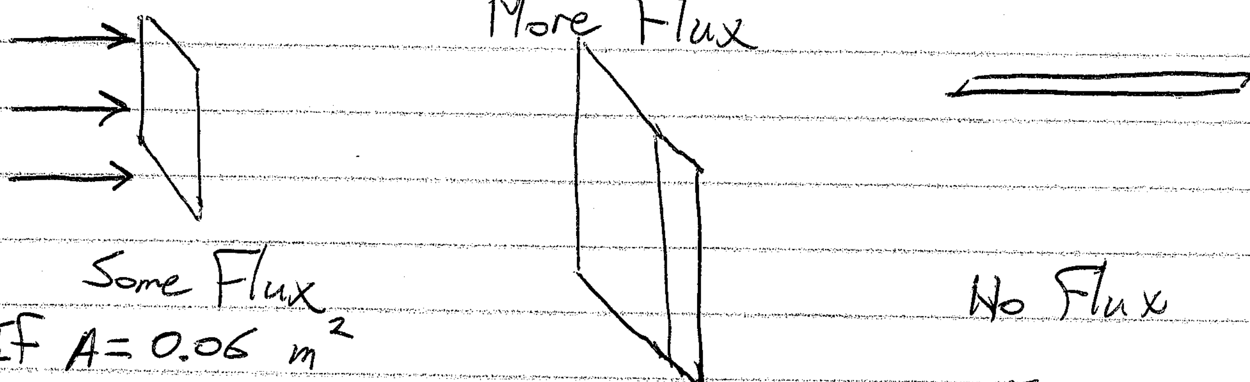
Gauss's Law

$$\oiint \vec{E} \cdot \vec{dA} = \frac{\iiint \rho \, dV}{\varepsilon_0}$$

$$\text{Electric Flux} = \Phi_E = \frac{Q_{enc}}{\varepsilon_0} = 4\pi k Q_{enc}$$

Electric Flux is the amount of electric field piercing an area, pointing outward.

Let's say $\vec{E} = 5 \ N/C \ \hat{i}$



More Flux

Some Flux

No Flux

If $A = 0.06 \ m^2$

$A = 0.12 \ m^2$

$\Phi = 0$

$\Phi = (5 \ N/C)(0.06 \ m^2)$
$= 0.3 \ Nm^2/C$

$\Phi = 0.6 \ Nm^2/C$

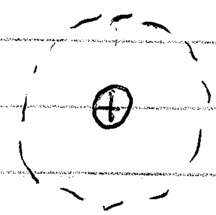
Units: $\varepsilon_0 = 8.85 \times 10^{-12} \ C^2/(Nm^2) = \frac{1}{4\pi k}$

$k = 9 \times 10^9 \ Nm^2/C^2$

Useful Rule: $\Phi_E = E_\perp A$ if $E_\perp$ is uniform

Spherical Symmetry

Point

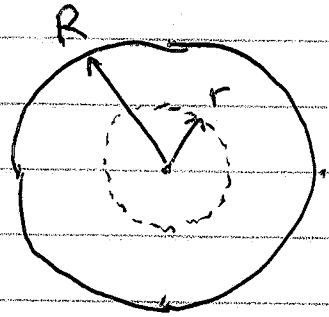


$$EA = Q_{enc}/\varepsilon_0$$

$$4\pi r^2 E = \frac{Q}{\varepsilon_0}$$

$$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2} = \frac{kQ}{r^2}$$

Uniformly charged sphere

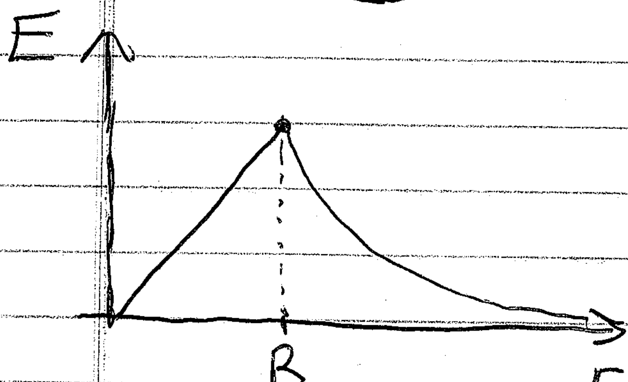


Outside: $E = \frac{kQ}{r^2}$

Inside:

$$EA = \frac{Q_{enc}}{\varepsilon_0}$$

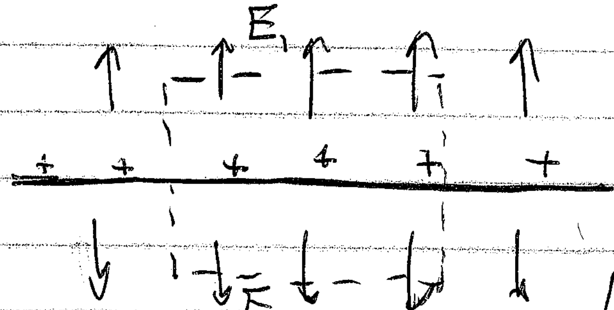
$$4\pi r^2 E = \frac{1}{\varepsilon_0}\frac{Q V_r}{V_R}$$



$$4\pi r^2 E = \frac{1}{\varepsilon_0}\frac{Q r^3}{R^3}$$

$$E = \frac{1}{4\pi\varepsilon_0}\frac{Q r}{R^3}$$

Slab Symmetry - Uniform Surface Charge



Gaussian Pillbox

$EA = Q_{enc}/\varepsilon_0$

Note: E_2 is negative as drawn.

Flux integral: $\Phi_{Top} = E_\perp A_{Top} = E_1 A_{XS}$

$$\Phi_{Bot} = E_\perp A_{Bot} = -E_2 A_{XS}$$

$$\Phi_{sides} = E_\perp A_{sides} = 0$$

- As drawn, $\vec{E_2}$ points outward, so $\Phi_{Bot} = + \ldots$
- Want E_2 (not vector) to be $\ominus$

If Surface has charge/Area $= \sigma$

$$Q_{enc} = \sigma A_{XS}$$

$$E_1 \cancel{A_{XS}} - E_2 \cancel{A_{XS}} = \frac{\sigma}{\varepsilon_0} \cancel{A_{XS}} = 4\pi k \sigma$$

- σ causes a "jump" in the value of $E_\perp$
- σ emits a total of $4\pi k\sigma$ of elec field.

Typical cases: Balanced: $E = 2\pi k\sigma$ above & below

One-sided: $E = 4\pi k\sigma$ above

$= 0$ below

Conductors & Insulators

All Matter: Same number of p^+ and e^-.

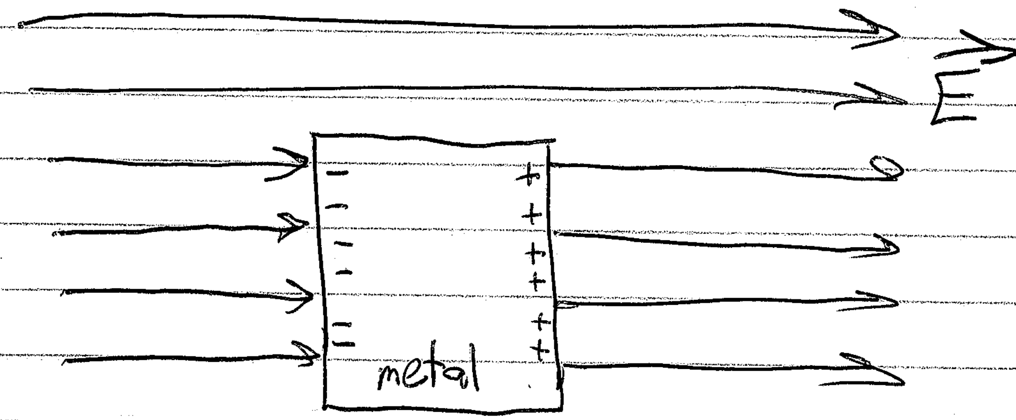
Static Charge: Add or remove e^-.

Insulator: p^+ Locked in place
e^- Stuck in cubbyholes

Ex: Charge-induced-dipole

Conductors: Many e^- are mobile

Ex: Metal placed in $\vec{E}$



From the outside, metal is "cloaked".
In the metal, $E=0$.

Induced Surface Charge obeys $E=4\pi k\sigma$

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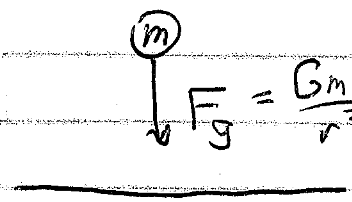
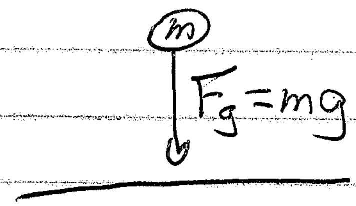
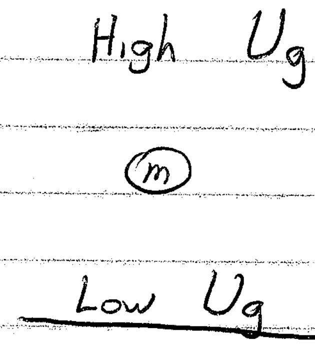
3 Views of why a ball Falls





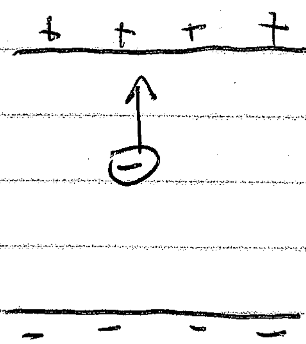


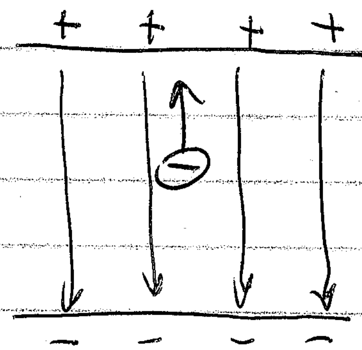
Attraction to Earth's Mass

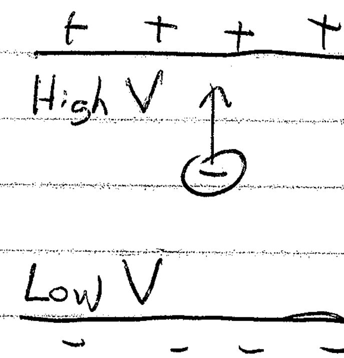
Pushed by gravity field (g)

Attracted to Low Pot. Energy

Similar ideas for electrons:







Attracted to ⊕, repelled from ⊖

Pulled up against $\vec{E}$: $\vec{F}_E = q\vec{E}$

Electron attracted to high potential (V)

- For an e^-, High V ⟺ Low U_E (Pot Energy)

$$U_E = q V$$

Pot. Energy = q (Elec. Potential)