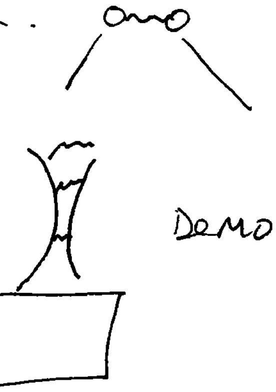
Conductor - charges can Move freely (in response to $\bar{E}$)

insulator - charges cannot Move freely
under Normal circumstaces

Remember.



Demo

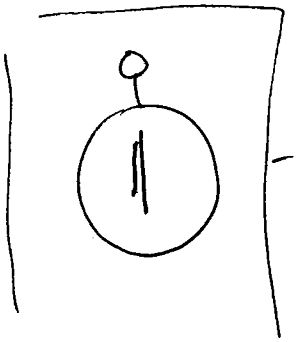
⇒ Do

Demo

insulators
can
break down

Semiconductor - "Conductivity" depends on environment
(size of electric field)

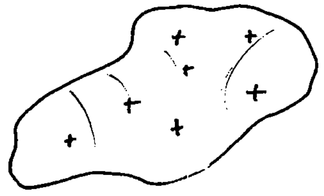
Do



Shielded Electro scope

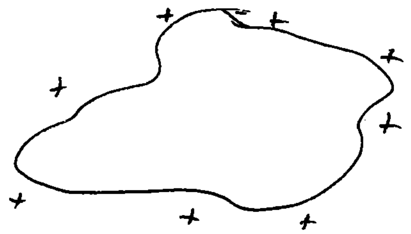
Demo

⇒ Why does this happen?



Solid conductor

⇒



Place charge instantaneously
in arbitrary spots
inside

⇒ What happens

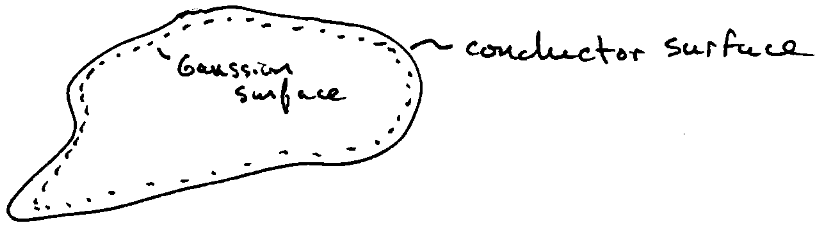
Charges rearrange until
No $\bar{E}$ inside

if $\bar{E}$ - charges flow
until No $\bar{E}$

∴ $\vec{E} = 0$ inside a conductor

Gauss's Law

$$\int \vec{E}\cdot d\vec{a} = \frac{Q_{inside}}{\epsilon_0} \Rightarrow \vec{E}=0 \text{ gives } Q_{inside}=0$$



∴ ~~all charge is~~ No charge inside

Excess charge on an isolated conductor rests entirely on the outside surface of that conductor

⇒ Now why does electroscope in demo NOT respond to charged rod?

Electro STATIC Shielding ⇒ Electro Magnetic Shielding

Microwave doors
Metal cabinets on computers } etc.

Little in life is STATIC ... But we will learn concept of light as induced fields

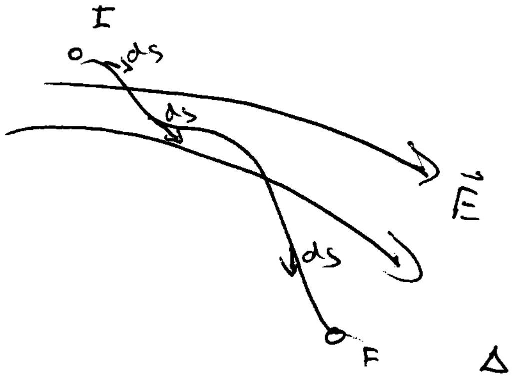
You are conducting an important expt. for Medical research

Discover Patients brainwaves go Nuts in anticipation of coffee from coffee Man

Actually electromag. "Noise" from Coffee Man's truck

Expt Noise problems in Morning and at ~~Night~~ evening

Let charge Move between points I (initial) and F (Final). The difference in the Potential Energy of the charge is equal to the work done against the $\vec{E}$ field to Move the charge



$$\underset{\text{Scalar}}{W} = \underbrace{\int_I^F}_{\text{line integral}} \vec{F}\cdot \underset{\text{dot product gives scalar}}{d\vec{s}} = -\int_I^F q_0 \vec{E}\cdot d\vec{s}$$

$$\Delta PE \equiv \Delta U = -\int_I^F q_0 \vec{E}\cdot d\vec{s}$$

$$\frac{W}{q_0} = \frac{\Delta PE}{q_0} \equiv \text{Potential difference between pts I and F} = V_F - V_I$$

⇒ what are units Joules/Coulomb)

If we define a "zero" of potential energy we can calculate Absolute Potential energy and Absolute Potential

Completely Analagous to gravitational Potential and potential energy

What is real are Potential differences

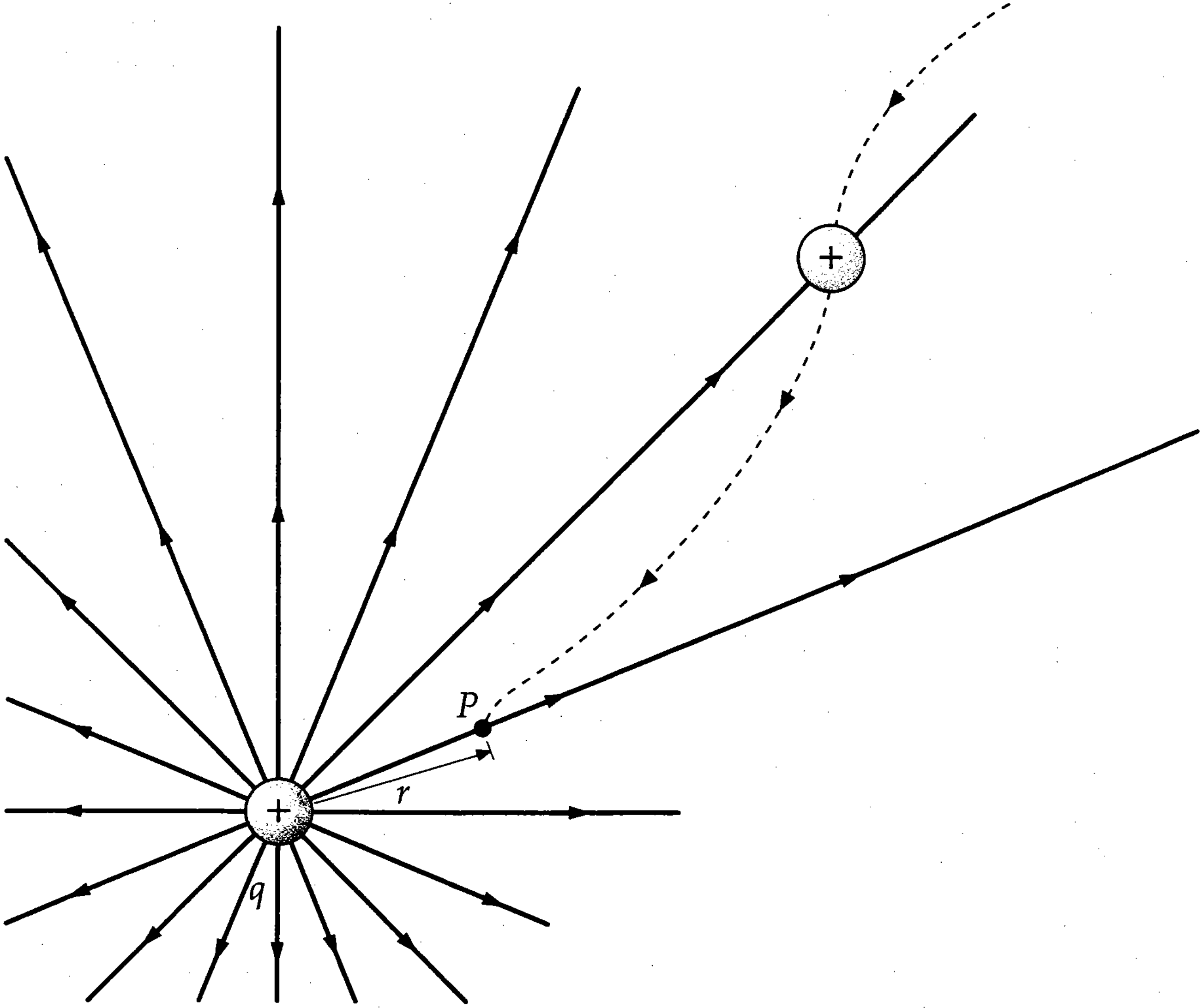
Absolute value of Potential at a point depends on Definition of "zero" of potential

Transparency 13

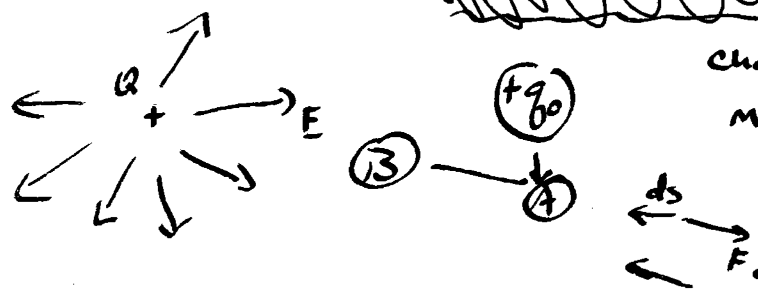
Figure 24-3, page 724

Work required to bring a test charge to a point a distance *r* from a point charge

Tipler: **Physics for Scientists and Engineers 4/e**



~~Last class I blew the subtle sign~~



Charge Q

Move charge q_0 from A to B

$$W = \int_A^B \vec{F}\cdot d\vec{s} = \cancel{\int_A^B -q_0 E\, ds}$$

$$= \int_A^B |F|\, ds = -\int_A^B q_0 E\, dr$$

$$= -\int_A^B q_0 \frac{Q}{r^2}\frac{1}{4\pi\epsilon_0}\, dr = \frac{1}{4\pi\epsilon_0}\left[\frac{Q q_0}{r}\right]_A^B$$

$$= \frac{1}{4\pi\epsilon_0} Q q_0 \left(\frac{1}{r_B} - \frac{1}{r_A}\right)$$

$r_A > r_B$ $\therefore$ W is $\oplus$

I have done work on system

I have increased the potential energy of the system

$W_{\text{put into system}} = \Delta PE_{\text{of system}}$

$\frac{W}{q_0} = \frac{\Delta PE}{q_0}$ work per unit charge in moving from A → B

or ΔPE per unit charge moving from A → B

$\equiv$ Potential Difference, ΔV

$V_B - V_A$

Completely analogous to gravitational potential energy
and gravitational potential

Suppose I define "zero" of
electrostatic potential energy of Q-q_0 system
to be when q_0 is at ∞

$$r_A = \infty$$

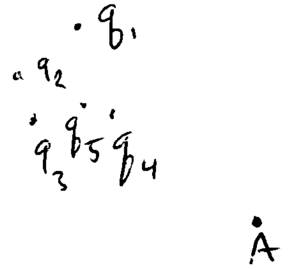
Then
Δ PE as go from ∞ to r_B

$$\Delta PE = \frac{1}{4\pi\epsilon} \frac{Qq_0}{r_B}$$

$$\frac{\Delta PE}{q_0} = V_B - V_\infty = V_B = \frac{1}{4\pi\epsilon_0} \frac{Q}{r_B}$$

This is the absolute potential at the point r_B !

Suppose I have



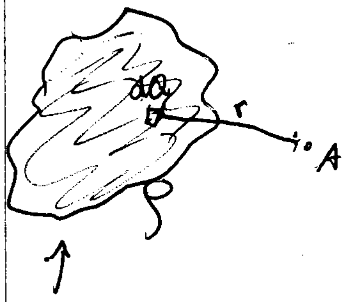
instead of Q

What is potential at A due to $q_1 - q_N$

$$V_A = \sum_n V_i = \sum_n \frac{kq_i}{r_i}$$

If charge distribution is continuous

$$V_A = \int \underbrace{dV}_{\text{Not volume}} = \int k\frac{dq}{r}$$



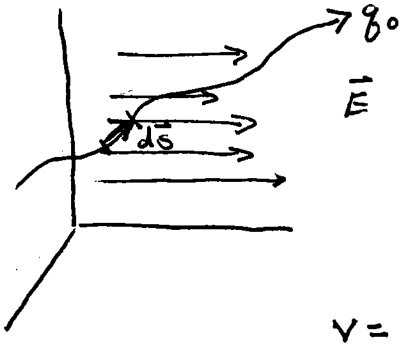
Continuous Charge Dist.

~ sometimes harder
. vector parts sometimes cancel
. $1/r^2$ sometimes easier

This is sometimes easier to calculate ~~than~~ $\vec{E}$

1) scalar
2) $1/r$ Not $1/r^2$

This is impt because V CAN be used TO calculate $\vec{E}$ (Always want $\vec{E}$ to find force on charges)



$\vec{E} = |\vec{E}|\,\hat{i}$ ~ or $\hat{x}$ if you prefer

$$V = \frac{W}{q_0} \Rightarrow dV = \frac{dW}{q_0} = -\vec{E}\cdot\vec{ds}$$

$$= -E_s\,ds$$

$$\therefore \quad E_s = -\frac{dV}{ds}$$

The "negative of the" rate of change of the potential in any direction is equal to the component of the electric field in that direction

$$E_x = -\frac{\partial V}{\partial x} \qquad E_y = -\frac{\partial V}{\partial y} \qquad E_z = -\frac{\partial V}{\partial z}$$

=> what are these funny symbols ? ∂

Know This - you'll see a 1-d problem on this, maybe a simple 2-d

$$\vec{E} = -\left(\overbrace{\frac{\partial V}{\partial x}\hat{i}}^{\text{vector}} + \overbrace{\frac{\partial V}{\partial y}\hat{j}}^{\text{vector}} + \overbrace{\frac{\partial V}{\partial z}\hat{k}}^{\text{vector}}\right)$$

> must add w/ vector addition

Really using This is Beyond Scope of This course

define a Vector operator, $\vec{\nabla}$ or grad, called the gradient

$$\vec{\nabla} \text{ or } \vec{\text{grad}} \equiv \left(\frac{\partial}{\partial x}\hat{i}, \frac{\partial}{\partial y}\hat{j}, \frac{\partial}{\partial z}\hat{k}\right)$$

So $\vec{E} = -\vec{\nabla}V$ or $\vec{E} = -\vec{\text{grad}}\,V$