Phy 4B 4/27

Thursday, April 27, 2017 4:21 PM

Goals for the Lecture:

1) Understand that electric potential energy is related to the work done by the electric field as a particle moves in the field: $\Delta U = -q\int_A^B \vec{E}\cdot\overrightarrow{ds}$
2) Understand that electric potential is different than electric potential energy: $\Delta V = \frac{\Delta U}{q}$
3) Be able to calculate electric potential different (ΔV) from an electric field using $\Delta V = -\int_A^B \vec{E}\cdot\overrightarrow{ds}$
4) Be able to calculate the electric potential energy and the electric potential of point charges
5) Be able to calculate the electric potential difference (ΔV) from a charge distribution using $V = \int \frac{kdq}{r}$

Potential

$$\Delta V = -\frac{W}{q} = -\frac{1}{q}\underbrace{\int \vec{F}\cdot d\vec{s}}_{\text{Work}}$$

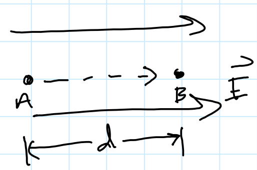
$$F = qE$$

$$= -\frac{1}{q}\int q\vec{E}\cdot d\vec{s}$$

$$\boxed{\Delta V = -\int \vec{E}\cdot d\vec{s}}$$

if E is constant

$$\Delta V = -\int \vec{E}\cdot d\vec{s}$$

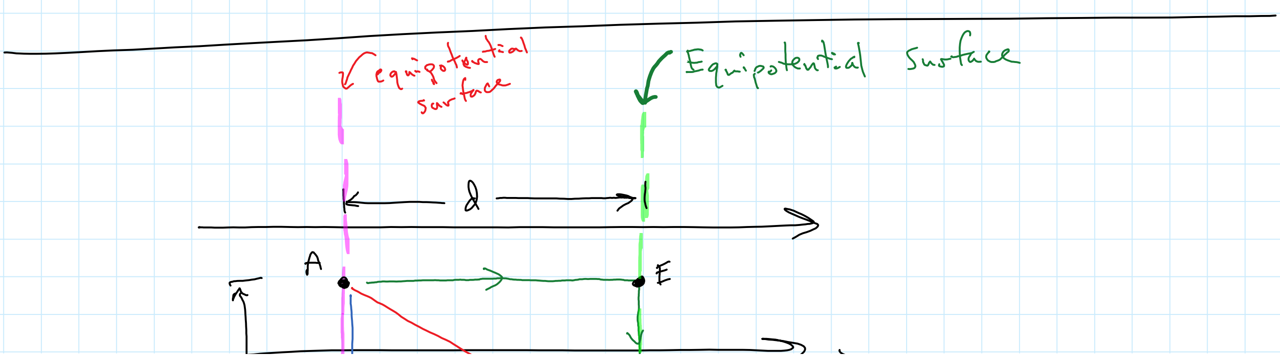


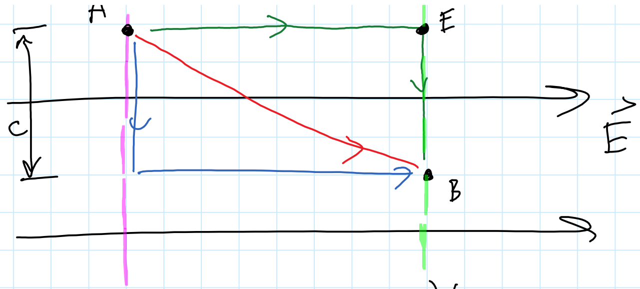
$$= -E\int ds$$

$$\Delta V_{AB} = -Ed$$

$$V_A > V_B$$

$\vec{E}$ always points toward lower potential





$$\Delta V_{AB} = \Delta V_{AE}$$

$$\Delta V_{AB} = -E\,d$$

---

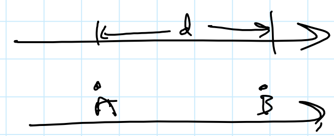
worksheet p. 52

1) $<$

$$\Delta V = -\int \vec{E} \cdot d\vec{s}$$

2) $|V_A - V_B| < |V_a - V_b|$

3) $=$ (both are zero)



$E_1 \longrightarrow$ increase E to E_2

$E_2 > E_1$

4) $<$

5) $<$

$|\Delta V| = E_1 d$

6) $=$

$|\Delta V| = E_2 d$

7) $<$

8) $<$ (see below about V near a pt charge)

9) $>$

$q = 2Q$ count E field lines

$E_A \; ? \; E_b$ $\qquad r_B = 4 r_A$

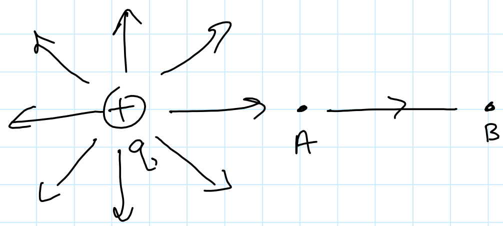
$$\frac{kQ}{r_A^2} \; ? \; \frac{kq}{r_b^2}$$

$$\frac{kQ}{r_A^2} \; ? \; \frac{k(2Q)}{(4r_A)^2}$$

$$\frac{kQ}{r_A^2} > \frac{1}{8}\frac{kQ}{r_A^2}$$

Electric Potential due to a pt. charge:

$$\Delta V = -\int \vec{E} \cdot d\vec{s}$$



$$E = \frac{k\,q}{r^2}$$

$$V_B - V_A = -\int_{r_A}^{r_B} \frac{k\,q}{r^2}\,dr$$

$$= -kq \int \frac{dr}{r^2}$$

$$= -kq \left(-\frac{1}{r} \Bigg|_{r_A}^{r_B} \right)$$

$$\underbrace{V_B - V_A}_{\text{must be Negative}} = kq \left(\underbrace{\frac{1}{r_B} - \frac{1}{r_A}}_{\text{Neg.}} \right)$$

Let's check our signs

$V_B < V_A$ (E points from A to B)

Check! Both sides are Negative → we are good!

Let $r_B \to \infty$

and $V_B \to 0$

$$\boxed{\begin{array}{c}\text{For pt charges } V = 0 \text{ at } r = \infty \\ V = \dfrac{k\,q}{r}\end{array}}$$

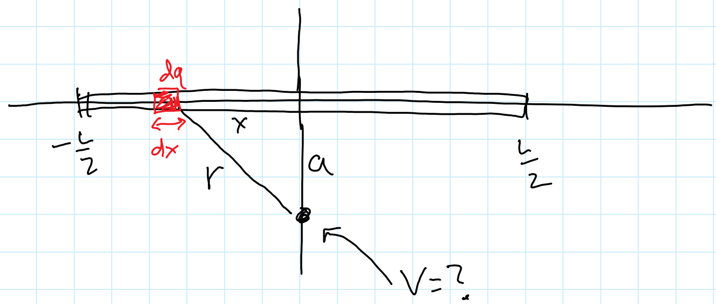
Potential : units Volts

$$V = \frac{J}{C}$$

Now, units for E field

$$\frac{N}{C} \text{ or } \frac{V}{m}$$

Find $V(r)$ near a line of charge (length $= L$)
if $V = 0$ at $r = \infty$



For a pt. charge $\quad V = \frac{kq}{r}$

potential due to dq: $\quad dV = \frac{k\,dq}{r}$

$$\int dV = \int \frac{k\,dq}{r}$$

$$V = \int \frac{k\,(\lambda\,dx)}{r}$$

$$= k\lambda \int_{-\frac{L}{2}}^{+\frac{L}{2}} \frac{dx}{\sqrt{x^2+a^2}} \qquad r = \sqrt{x^2+a^2}$$

$$= k\lambda \ln\left(x + \sqrt{x^2+a^2}\right)\Big|_{-\frac{L}{2}}^{+\frac{L}{2}}$$

$$= 2k\lambda \ln\left(x + \sqrt{x^2+a^2}\right)\Big|_{0}^{\frac{L}{2}}$$

Potential a distance "a" from a line charge of length L

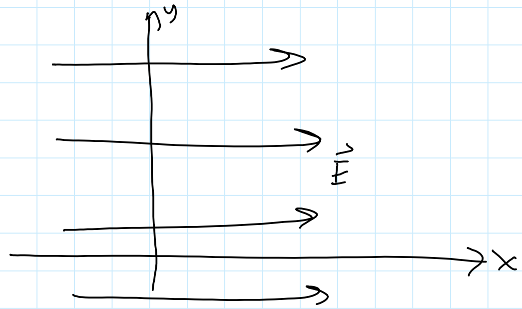
$$V = 2k\lambda \ln\left[\frac{\frac{L}{2} + \sqrt{\left(\frac{L}{2}\right)^2 + a^2}}{a}\right]$$

Video: High Voltage line inspection

---

worksheet p. 62

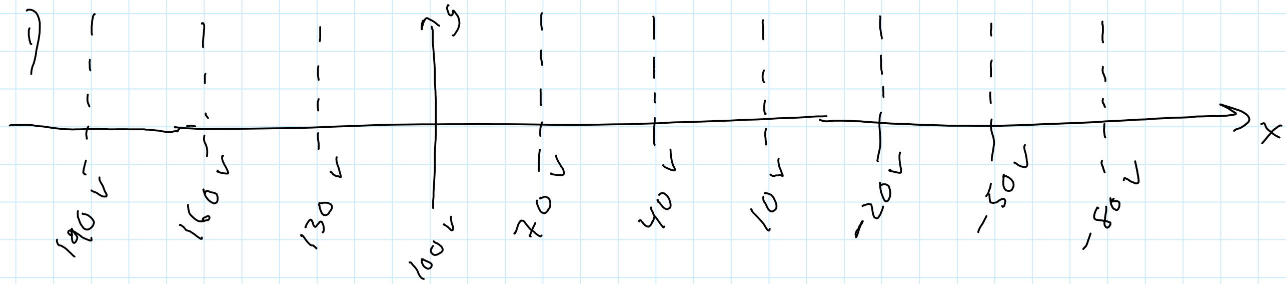
E field:



All the same (E is the same everywhere)

p. 63

1)



2) left

3) left

4) left

5) left

6) all the same

7) Right

8) Right

9) all the same

10) left

11) left

12) Right

13) Right

Use $\Delta V = -\int \vec{E} \cdot d\vec{s}$ and gauss's Law

to find $V(r)$ everywhere given

a cylindrical charge distribution

Infinite length cylinder

Conductor

Infinite length cylinder

Conductor

radius = R

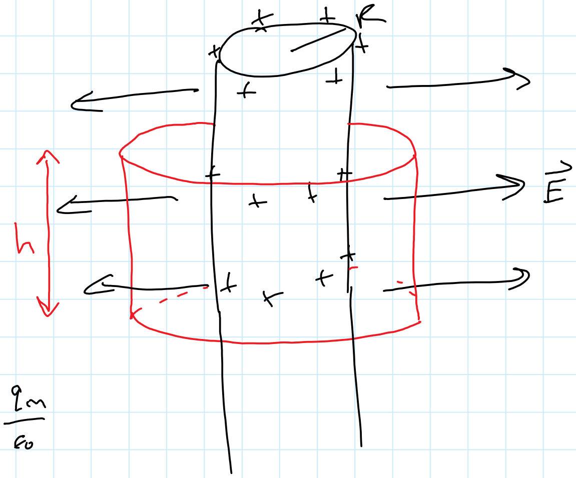
charge per length = λ (λ is positive)

Find V everywhere if $V=0$ at $r=R$

1st) Find E everywhere:

$r<R$

$$E = 0$$



$r>R$

$$\oint \vec{E}\cdot d\vec{A} = \frac{q_{in}}{\epsilon_0}$$

$$\underbrace{\int_{top} \vec{E}\cdot d\vec{A}}_{0} + \int_{side} \vec{E}\cdot d\vec{A} + \underbrace{\int_{Bottom} \vec{E}\cdot d\vec{A}}_{0} = \frac{q_{in}}{\epsilon_0}$$

$$E A_{side} = \frac{q_{in}}{\epsilon_0}$$

$$E(2\pi r h) = \frac{q_{in}}{\epsilon_0}$$

$$E = \frac{1}{2\pi\epsilon_0} \frac{q_{in}}{h} \frac{1}{r}$$

λ

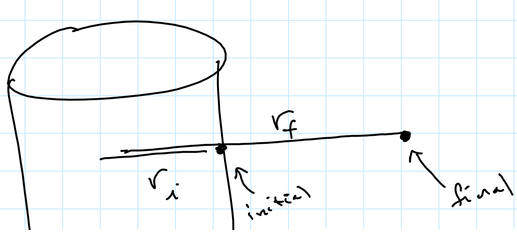
$$E = \frac{1}{2\pi\epsilon_0} \frac{\lambda}{r}$$

2nd) $\Delta V = -\int \vec{E}\cdot d\vec{s}$

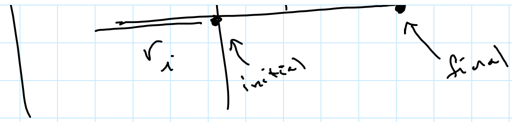
start where you know V

in this case, $V=0$ at $r=R$

$r>R$



product



$$\Delta V = -\int \vec{E}\cdot d\vec{s}$$

from dot product

$$V_f - \cancel{V_i}^{\,0} = -\int_{r_i=R}^{r_f} \frac{\lambda}{2\pi\epsilon_0 r}\cos 0^\circ \, dr$$

$$= -\frac{\lambda}{2\pi\epsilon_0}\int_R^{r_f}\frac{dr}{r}$$

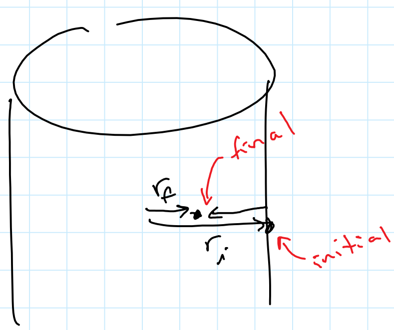
$$\underbrace{V_f}_{\text{must be Negative}} = \underbrace{-\underbrace{\left(\frac{\lambda}{2\pi\epsilon_0}\right)}_{+}\underbrace{\ln\left(\frac{r_f}{R}\right)}_{+}}_{-}$$

$$\boxed{\text{always check signs}}$$

both sides are Negative! good

$$V_f = -\frac{\lambda}{2\pi\epsilon_0}\ln\frac{r}{R}$$

Now, $r<R$



$$\Delta V = -\int \vec{E}\cdot d\vec{s}$$

$$V_f - V_i = -\int \cancel{\vec{E}}^{\,0}\cdot ds$$

$$V_f - \cancel{V_i}^{\,0} = 0$$

$$V_f = 0 \quad \text{since } V_i = 0$$

Inside a conductor in electrostatic equilibrium:

$$\Delta V = 0$$

but, V does Not have to be zero

it just has to be constant

Inside a conductor in electrostatic equilibrium:

$$\Delta V = 0$$

but, V does Not have to be zero

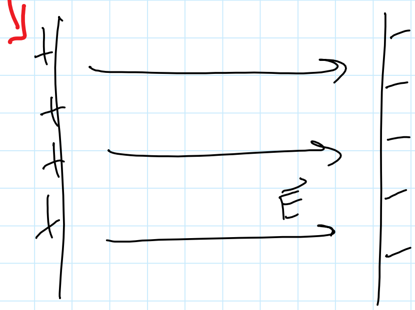
it just has to be constant

Uniform E field

$$\Delta V = -\int \vec{E} \cdot d\vec{s}$$

uniform E field

For this case: $\boxed{\Delta V = -E\,d}$



$+V_0$ $\quad$ $V=0$

or

$V=0$ $\quad$ $-V_0$

or

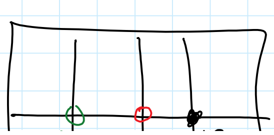
$+\frac{V_0}{2}$ $\quad$ $V=0$ $\quad$ $-\frac{V_0}{2}$

worksheet p. 64

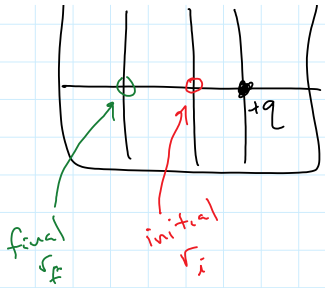
A) positive

q that is creating the E field

$V = \frac{kq}{r}$ for pt charge if $V=0$ at $r=\infty$



$k\,q$



$$V_i = \frac{kq}{d}$$

$$V_f = \frac{kq}{2d}$$

$$\Delta V = V_f - V_i = \frac{kq}{2d} - \frac{kq}{d} = -\frac{kq}{2d}$$

q that is moving in the electric field

$$|W| = |q \Delta V|$$

$$= \left|(4q)\left(-\frac{kq}{2d}\right)\right|$$

$$= \frac{2kq^2}{d}$$

$$W = +\frac{2kq^2}{d}$$

Look at situation to get the sign