Physics 202, Lecture 4

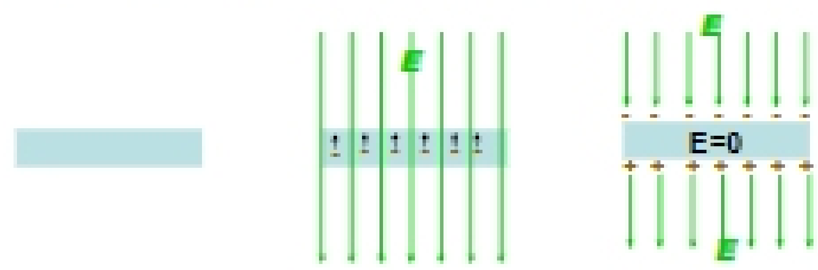
Today's Topics

- Conductors in Electrostatic Equilibrium (Ch. 24.4)
- Electric Potential (Ch. 25-Part I)
  - Electric Potential Energy & Electric Potential
  - Electric Potential And Electric Field

- Expected from preview:
  Conductors
  Conservative force, electric energy, electric potential difference, voltage….

Conductors And Electrostatic Equilibrium

- Conductors: Total charge are initially balanced (=0) but negative charge (electrons) are able to move freely inside its body.
  → capable of redistributing charges when subject to an external electric field.
- Charge redistribution → eventually electrostatic equilibrium.



initial → transient, <10^{-16}s (right after E applied) → equilibrium

Properties of Electrostatic Equilibrium

- Once in electrostatic equilibrium
  - The electric field is always zero inside the conductor
  - E field on the surface of conductor is always normal to the surface,
  - and has a magnitude of σ/ε_0 (Show using Gauss's law)
  - All net charges reside on the surface of conductor (i.e. no net charge inside the body of a conductor).
  - The electric field is also zero inside any cavity within the conductor. (why?)
  - Electric potential is the same over the whole conductor (Ch. 25)

The above properties are valid regardless of the shape and the total charge of the conductors !

Potential Energy (Phy201 Review)

- Ch-8: path independent work → conservative force.
- e.g. Gravitational Force is a conservative force (Ch-13):

$$\vec{F}_{12} = -G\frac{m_1 m_2}{r^2}\hat{r}_{12} \Rightarrow W = \int_{path} \mathbf{F} \bullet d\mathbf{s} = \frac{Gm_1m_2}{r_f} - \frac{Gm_1m_2}{r_i}$$

path independent!

→ Gravitational Potential energy:

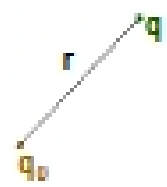
$$U = -\frac{Gm_1m_2}{r}$$

- Electric Force:

$$\vec{F}_{12} = k_e\frac{q_1q_2}{r^2}\hat{r}_{12} \xrightarrow{\text{Electric Potential Energy}} U = \frac{k_e q_1 q_2}{r}$$

Electric Potential Energy

- Electric energy between two point charges:
  $U = U - U_\infty = K_e\, q_0 q / r$
  - U is a scalar quantity
  - U=0 @ r= ∞ (convenient convention)
  - U can be positive or negative
    - +: between like-sign charges
    - -: between opposite charges
  - SI unit: Joule (J)

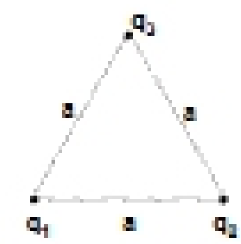


- Electric potential energy for system of multiple charges/charge distributions:
  U=Σ of all combination of pairs.
  Integral if continuous distribution

Example: Three Charge system

- What is the work required to assemble the three charge system as shown? ($q_1=q_2=q_3=Q$)

Answer: $k_e\, 3Q^2/a$ (see board)



- Quiz: What if $q_1=q_2=Q$ but $q_3=-Q$?

Answer: $-k_e Q^2/a$

Electric Potential Energy: Charge In An Electric Field

- Charge q is subject an electric force in electric field ***E***

  F=q***E***

- Work done by electric force:

$$W = \int_i^f \mathbf{F} \bullet ds = q\int_i^f \mathbf{E} \bullet ds = -\Delta U$$

$$\Delta U = U_f - U_i = -q\int_i^f \mathbf{E} \bullet ds$$

independent of q

Electric Potential Difference

- Electric Potential Energy: q in a Generic E. Field

$$\Delta U = U_B - U_A = -q\int_A^B \mathbf{E} \bullet ds = q\Delta V$$

system energy — test — source

- Electric Potential Difference

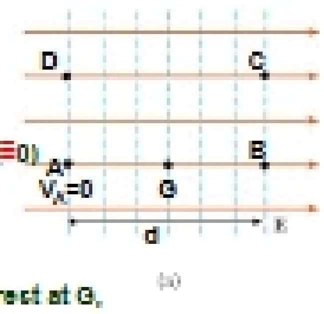
$$\Delta V \equiv \frac{\Delta U}{q} = -\int_A^B \mathbf{E} \bullet ds = V_B - V_A$$

Properties of Electric Potential Difference

- It is defined upon the fact that the electric force is a conservative force.
- It is associated to the source field only and is independent of test charge.
- It has a unit: J/C ≡ Volt (V)
- It is commonly called as just Potential, but it is meaningful only as potential difference V_B-V_A.
- Usually a convenient point (remote, earth..) is chosen as "ground" → $\Delta V=V-(V_A\equiv 0)=V$
- It is a scalar quantity. (No vector operation necessary!)
- $\Delta U=q\Delta V$

Exercise 1: Potential In Uniform E. Field

- In the uniform electric field shown.
  - Find E. potential at points: B,C,D,G
  - If a charge +q is placed at B,
- what is the potential energy U_B? ($U_A\equiv 0$)
  - If a charge –q is at B, what is U_B?

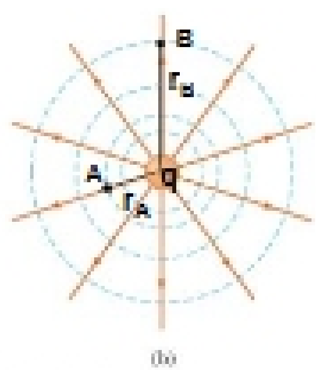


(a)

  - If a negative charge -q is initially at rest at G, will it move to A or B?
  - What is the kinetic energy when it reaches A?

Exercise 2: E. Potential and Point Charges

- In the configuration shown,
  - Find the potential difference V_B-V_A



(b)

Answer:

$V_B-V_A = k_e(q/r_B-q/r_A)$

(Exercise with your TA)

Exercise 3: Cathode Ray Tube (CRT)

- Electrons are emitted with almost zero velocity on plate C, what is the energy per electron when they reach plate A?

(Do with your TA)