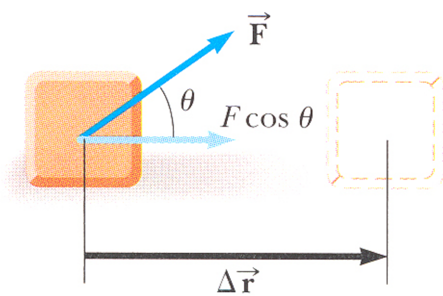
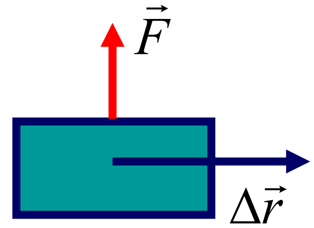
Physics 122: Electricity & Magnetism – Lecture 7 Electric Potential

Baris EMRE

Work Done by a Constant Force

$$W \equiv \vec{F} \cdot \Delta\vec{r} = F\Delta r \cos\theta$$



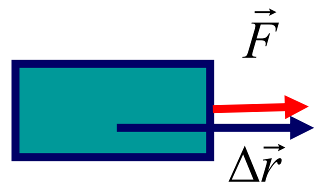


I

$$W_I = 0$$

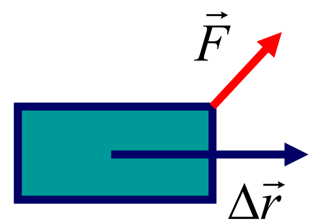
II

$$W_{II} = -F\Delta r$$



III

$$W_{III} = F\Delta r$$



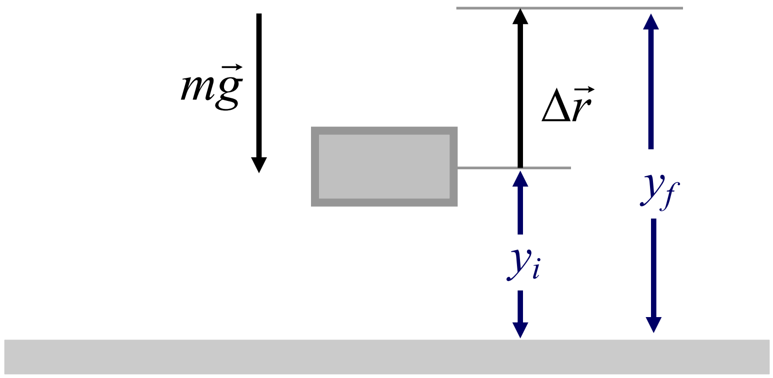
IV

$$W_{IV} = F\Delta r \cos\theta$$

Potential Energy, Work and Conservative Force

- Start

$$W_g = \vec{F} \cdot \Delta \vec{r} = -mg\hat{j} \cdot [(y_f - y_i)\hat{j}]$$
$$= mgy_i - mgy_f$$



- Then

$$U_g \equiv mgy$$

- So

$$W_g = U_i - U_f = -\Delta U$$

$$\Delta U = U_f - U_i = -W_g$$

Electric Potential Energy

- The potential energy of the system

$$\Delta U = U_f - U_i = -W$$

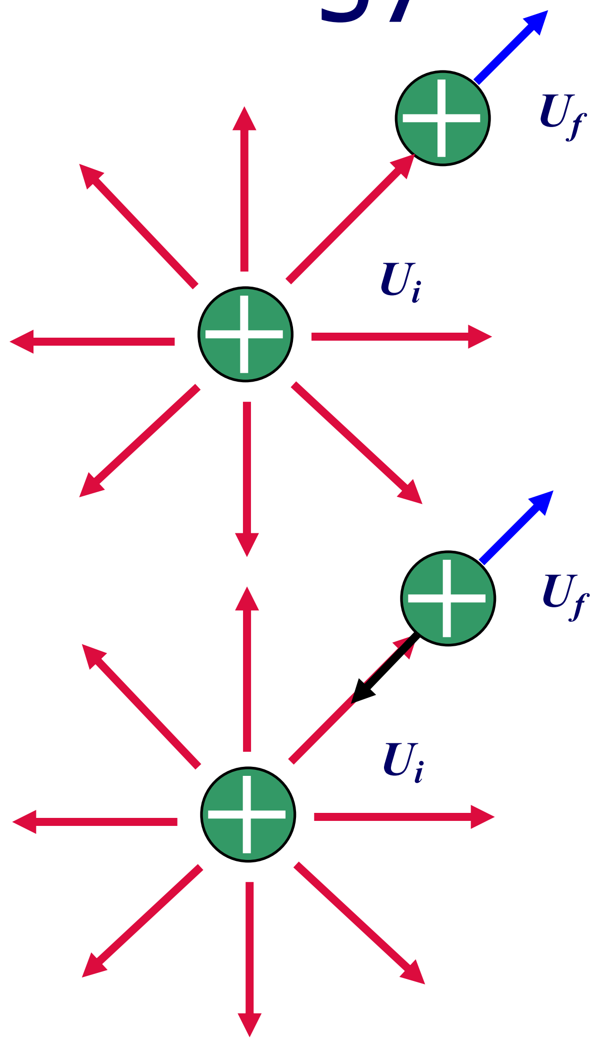
- The work done by the electrostatic force is path independent.
- Work done by a electric force or "field"

$$W = \vec{F} \cdot \Delta\vec{r} = q\vec{E} \cdot \Delta\vec{r}$$

- Work done by an Applied force

$$\Delta K = K_f - K_i = W_{app} + W$$

$$W_{app} = -W \qquad \Delta U = U_f - U_i = W_{app}$$



Electric Potential

- The electric potential energy
  - Start $dW = \vec{F}\cdot d\vec{s}$
  - Then $dW = q_0\vec{E}\cdot d\vec{s}$
  - So

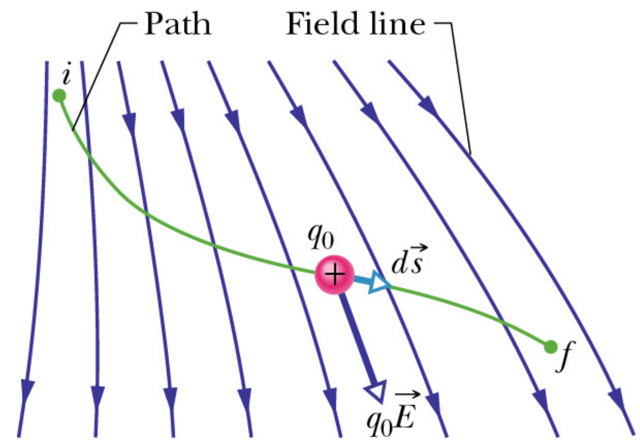
$$W = q_0\int_i^f \vec{E}\cdot d\vec{s}$$

$$\Delta U = U_f - U_i = -W = -q_0\int_i^f \vec{E}\cdot d\vec{s}$$

- The electric potential $V = \dfrac{U}{q}$

$$\Delta V = V_f - V_i = \frac{U_f}{q} - \frac{U_i}{q} = \frac{\Delta U}{q}$$

$$\Delta V \equiv \frac{\Delta U}{q_0} = -\int_i^f \vec{E}\cdot d\vec{s}$$



- Potential difference depends only on the source charge distribution (Consider points i and f without the presence of the test charge;

- The difference in potential energy exists only if a test charge is moved between the points.

Electric Potential

- Just as with potential energy, only *differences* in electric potential are meaningful.
  - Relative reference: choose arbitrary zero reference level for ΔU or ΔV.
  - Absolute reference: start with all charge infinitely far away and set $U_i = 0$, then we have $U = -W_\infty$ and $V = -W_\infty / q$ at any point in an electric field, where W_∞ is the work done by the electric field on a charged particle as that particle moves in from infinity to point f.

- SI Unit of electric potential: Volt (V)

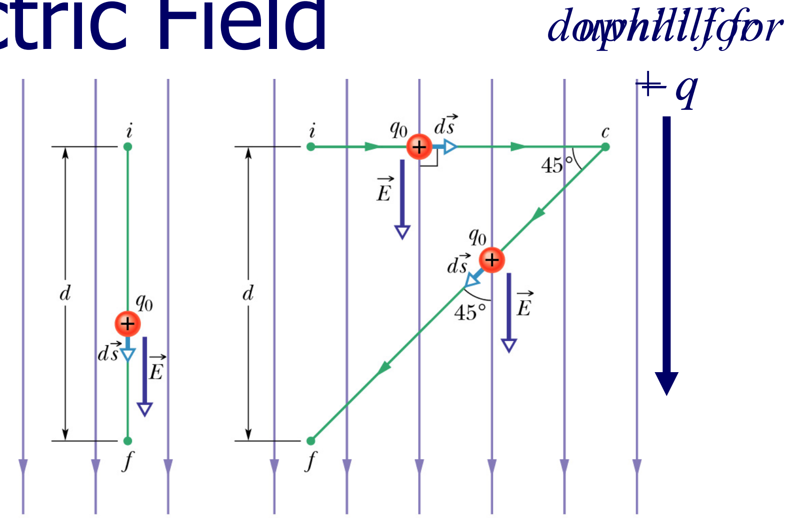
  1 volt = 1 joule per coulomb

  1 J = 1 VC and 1 J = 1 N m

- Electric field: 1 N/C = (1 N/C)(1 VC/J)(1 J/Nm) = 1 V/m
- Electric energy: 1 eV = e(1 V)

  $= (1.60 \times 10^{-19}$ C)(1 J/C) $= 1.60 \times 10^{-19}$ J

Potential Difference in a Uniform Electric Field



(a) (b)

$$\Delta V = V_f - V_i = -\int_i^f \vec{E}\cdot d\vec{s} = -\int_i^f (E\cos 0°)ds = -\int_i^f E ds$$

$$\Delta V = V_f - V_i = -E\int_i^f ds = -Ed$$

$$\Delta U = q_0 \Delta V = -q_0 E d$$

$$V_c - V_i = -\int_i^c \vec{E}\cdot d\vec{s} = -\int_i^c (E\cos 90°)ds = 0$$

$$V_f - V_i = -\int_c^f \vec{E}\cdot d\vec{s} = -\int_c^f (E\cos 45°)ds = -E\cos 45°\int_c^f ds$$

$$V_f - V_i = -E\cos 45° \frac{d}{\sin 45°} = -Ed$$

Equipotential Surface

- The name equipotential surface is given to any surface consisting of a continuous distribution of points having the same electric potential.

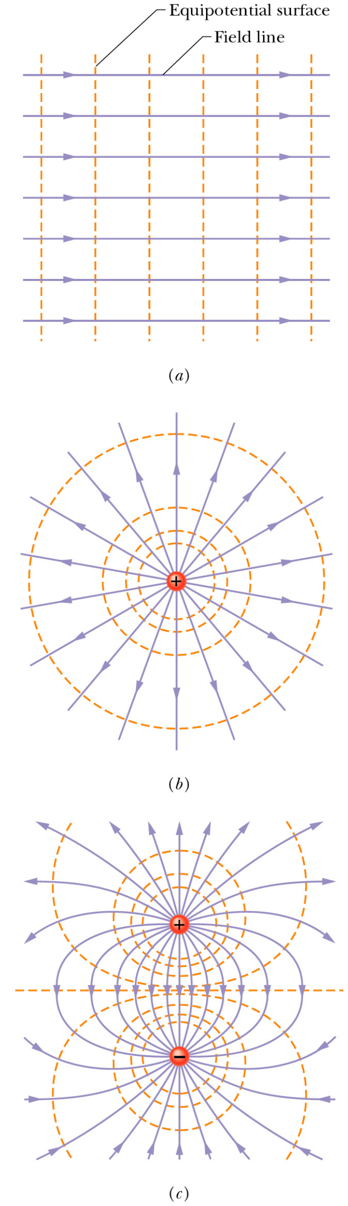
- Equipotential surfaces are always perpendicular to electric field lines.

- No work is done by the electric field on a charged particle while moving the particle along an equipotential surface.

Analogy to Gravity

- The equipotential surface is like the "height" lines on a topographic map.

- Following such a line means that you remain at the same height, neither going up nor going down—again, no work is done.



Work: positive or negative?

Ex: $V1=100$ V, $V2=80$ V, $V3=60$ V, $V4=40$ V. W_{I}, W_{II}, W_{III} and W_{IV} are

A. $W_{I} = W_{II}$

B. W_{III} is not equal to zero

C. W_{II} equals to zero

D. $W_{III} = W_{IV}$

E. W_{IV} is positive