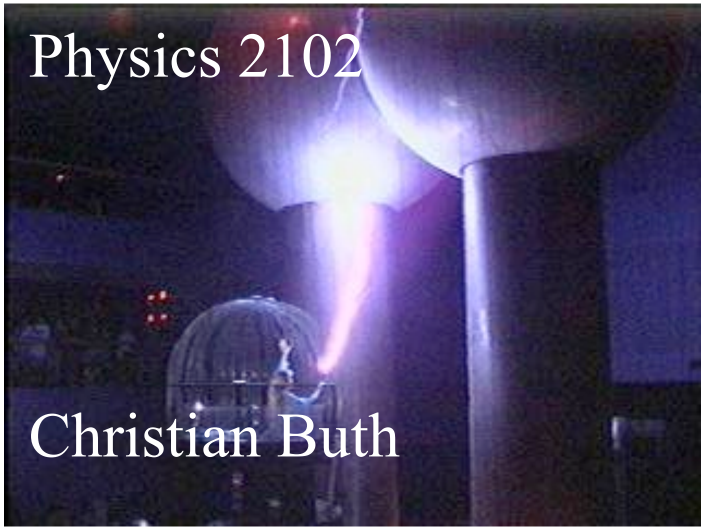
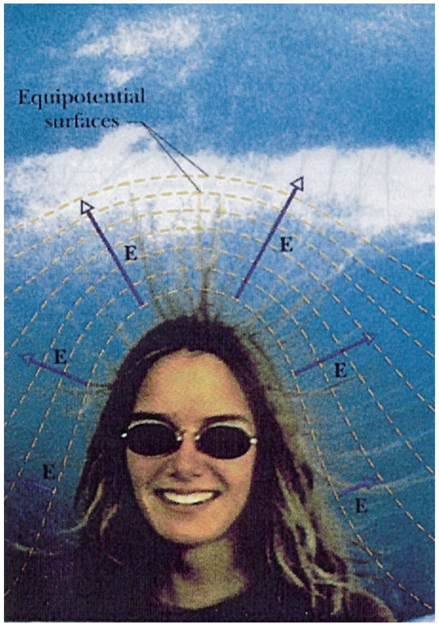
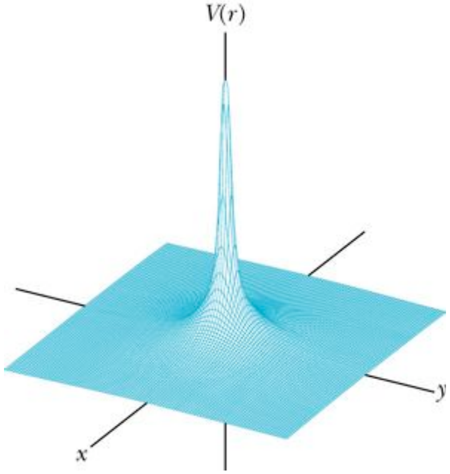


Physics 2102
Lecture 8



Electric Potential 1

Version: 01/30/2009



Review

- Gauss' law provides a very direct way to compute the electric field in situations with symmetry
- Field of an insulating plate: $\sigma/2\varepsilon_{0,}$; of a conducting plate: σ/ε_0
- Properties of conductors: field inside is zero; excess charges are always on the surface; field on the surface is perpendicular and $E=\sigma/\varepsilon_0$

Potential Energy

- Goal in physics to study basic forces
- **Conservative forces** can be deduced from a **potential**
- Potentials allow to exploit **conservation of mechanical energy** in a closed system
- This provides new insights and represents an enormous **simplification**

Electric Potential Energy

- **Electric potential energy** of a system is equal to **minus** the work done by electrostatic forces when building the system (assuming charges were initially infinitely separated)

$$U = -W_{\infty}$$

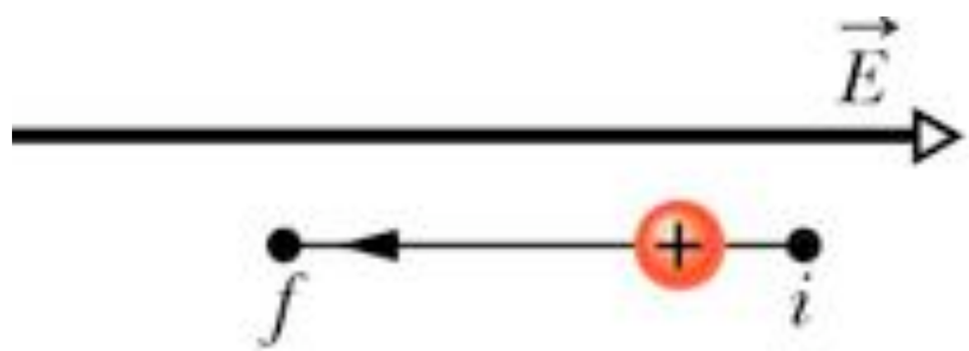
- The **change** in potential energy between an initial and final configuration is equal to **minus** the work done by the electrostatic forces:

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

Example: Proton in Uniform Field

A proton moves from **point *i* to point *f*** in a uniform electric field, as shown:

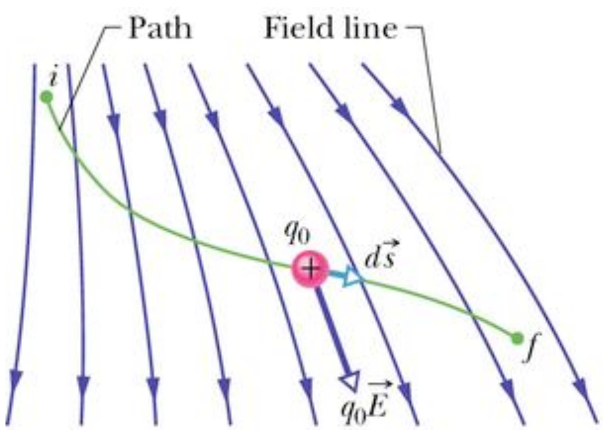
- Does the electric field do positive or negative **work** on the proton?
- Does the electric **potential energy** of the proton increase or decrease?



Electric potential

Electric potential difference between two points:

$$\Delta V = V_f - V_i = -W/q = \Delta U/q$$



$$dW = \vec{F} \bullet d\vec{s}$$

$$dW = q_0 \vec{E} \bullet d\vec{s}$$

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

$$\Delta V = V_f - V_i = -\frac{W}{q_0} = -\int_i^f \vec{E} \bullet d\vec{s}$$

Units of Potential and Energy

Units: [U] = [W] = Joule

[V]=[W/q] = Joule / C= Nm/C= Volt

[E]= N/C = V/m

1eV = 1 **electronvolt** = work to move electron through a potential difference of 1V:

$W = -q\Delta V = e$ x 1V

= 1.60 x 10^{-19} C x 1J/C = 1.60 x 10^{-19} J

Work by an External Agent

The change in potential energy of a charge q moving from point i to point f is equal to the work done by the **applied force**:

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

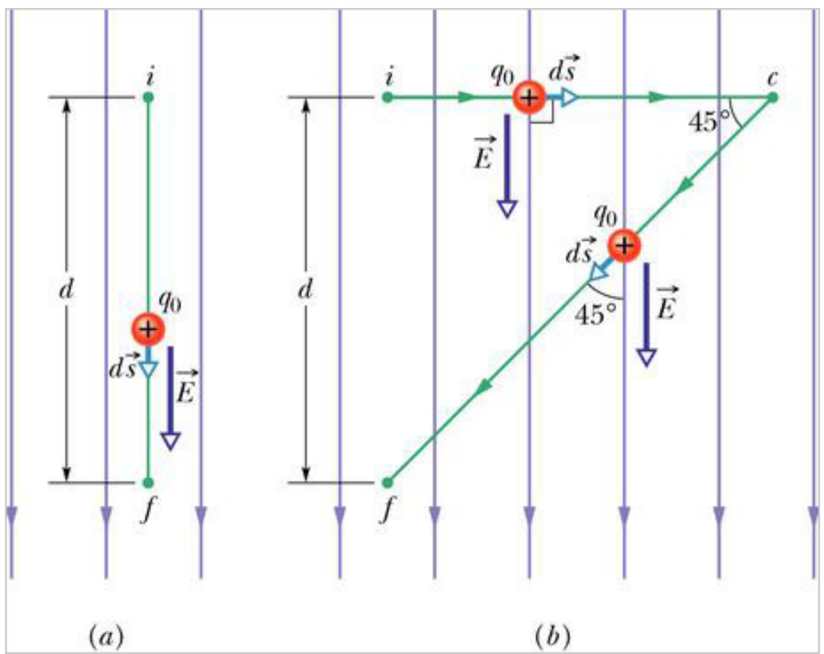
We move a proton from **point *i* to point *f*** in a uniform electric field, as shown:

- Does our **external force** do positive or negative work ?
- Does the proton **move** to a higher or lower potential?

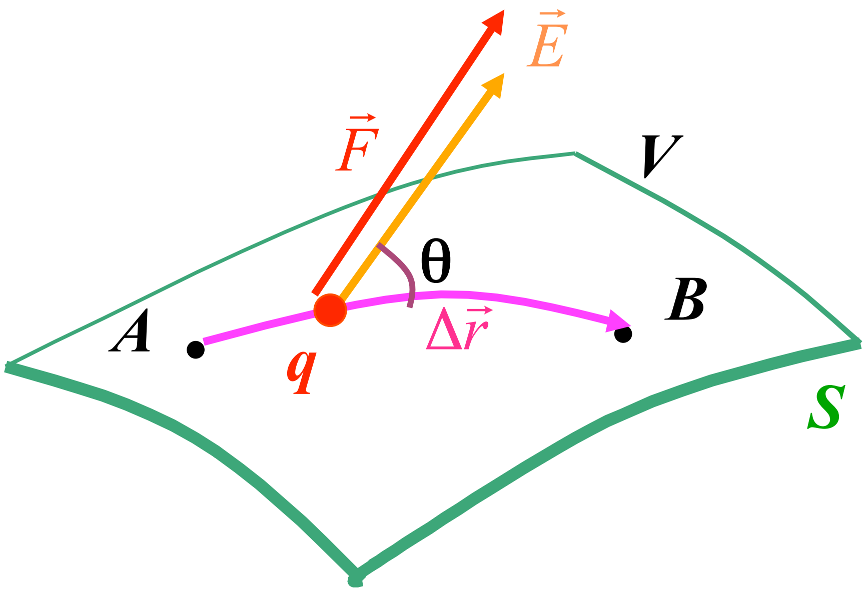
Conservative Forces

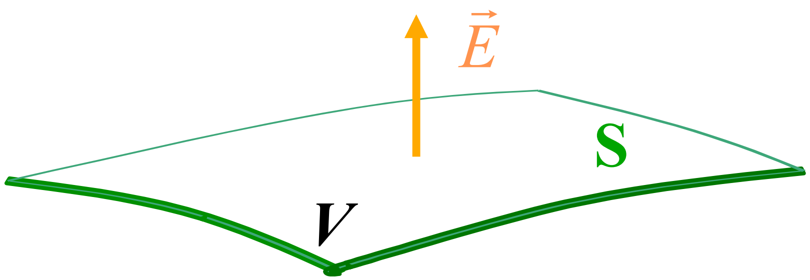
The potential difference between two points is independent of the path taken to calculate it: electric forces are "conservative"

$$\Delta V = V_f - V_i = -\frac{W}{q_0} = \frac{\Delta U}{q_0} = -\int_i^f \vec{E} \bullet d\vec{s}$$



Equipotential surfaces

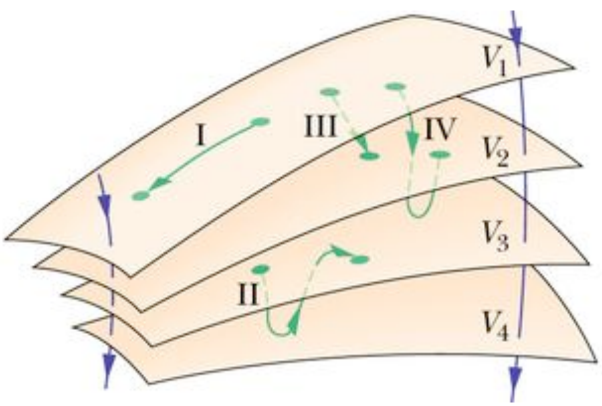




$$\Delta V = V_f - V_i = -\frac{W}{q_0} = -\int_i^f \vec{E} \bullet d\vec{s}$$

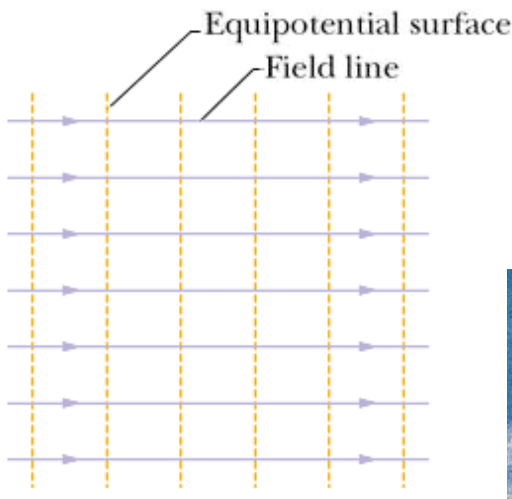
- Draw electric field lines: field is **tangent** to the field lines
- Draw equipotential surfaces: electric potential is **constant** on surface
- Electric field lines **perpendicular** to equipotential surfaces
- If they were not, there would be a tangential force and V not constant on the surface

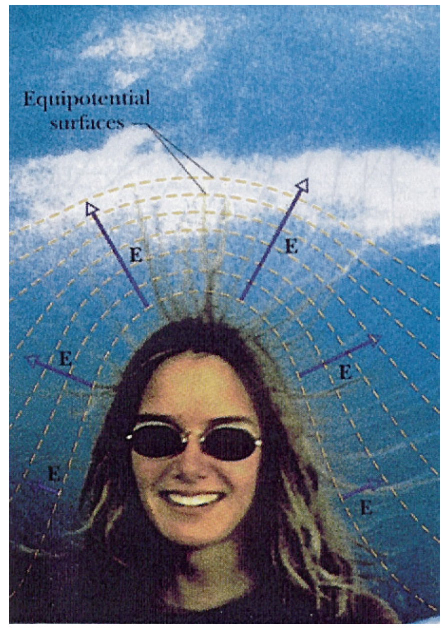
Equipotential surfaces

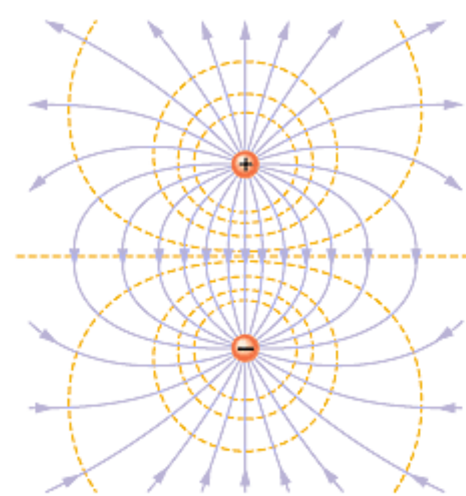


- No work is needed to move a charge **along** an equipotential surface
- Electric field lines always point **towards** equipotential surfaces with lower potential

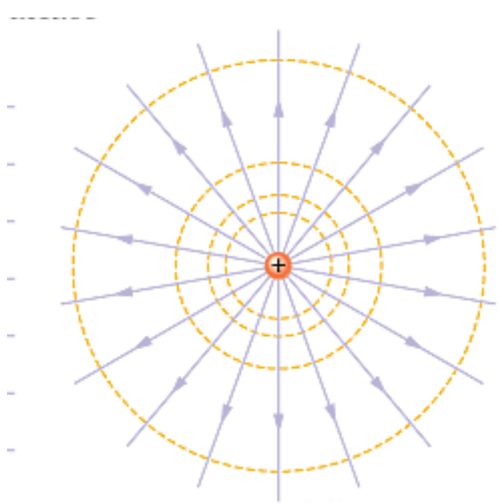
Electric field lines and equipotential surfaces







(c)



(b)

http://www.cco.caltech.edu/~phys1/java/phys1/EField/EField.html

Example

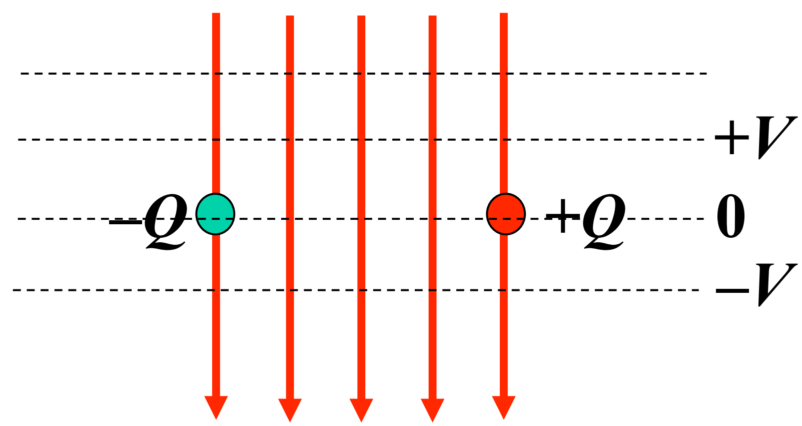
Consider a positive and a negative charge, freely moving in a uniform electric field. True or false?

(a) Positive charge moves to points with lower potential

(b) Negative charge moves to points with lower potential

(c) Positive charge moves to a lower potential energy position

(d) Negative charge moves to a lower potential energy position



(a) True
(b) False
(c) True
(d) True

Summary

- **Electric potential**: work needed to bring +1C from infinity; unit: V = Volt
- Work equals minus applied work equals potential energy difference

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

- **Equipotential surface**: constant potential, electric field lines are **perpendicular**
- Electric force is **conservative**: electric potential uniquely defined -- independent of path!