Lecture 7

Electric Potential – Chapter 25

Review

- Electric field near an infinite non-conducting sheet of uniform charge does NOT depend on distance from sheet

$$E = \frac{\sigma}{2\varepsilon_0}$$

- How can that be?
  - Proved equation using Gauss' law
  - Get same relation by painful integration
    - Section 23-7 the field due to a charged disk

$$E = \frac{\sigma}{2\varepsilon_0}\left(1 - \frac{z}{\sqrt{z^2 + R^2}}\right)$$

$$R \to \infty, E = \frac{\sigma}{2\varepsilon_0}$$

Electric Potential (1)

- When electrostatic force acts between charged particles assign an electric potential energy, *U*
- Difference in *U* of a charge at two different points, initial *i* and final *f* is

$$\Delta U = U_f - U_i$$

Electric Potential (2)

- If change system from initial state *i* to final state *f* electrostatic force does work

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

- Electrostatic force is conservative
- Work done by force is path independent
  - Work is same for all paths between points *i* and *f*

Electric Potential (3)

- Potential energy, U, is a scalar
- Need to choose a reference point where $U = 0$
  - Choose sea level to be zero altitude
  - What if we define Denver to be zero altitude?
  - Does the difference in altitude change?
- Choose $U = 0$ at $i = \infty$ for electric potential

Electric Potential (4)

- Have several charges initially at ∞ so $U_i = 0$

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

- Move charges close together to state *f*

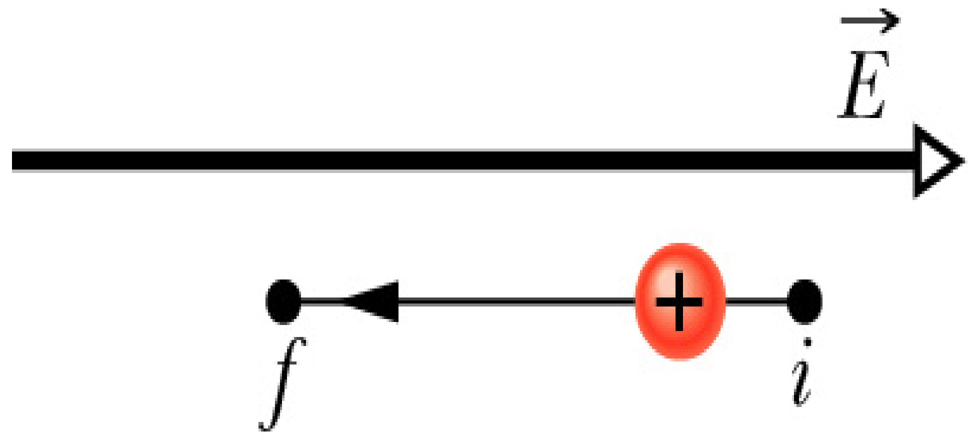
$$\Delta U = -W$$

- W_∞ is work done by force to move particles together from infinity

$$U_f = -W_\infty$$

Electric Potential (5)

- Checkpoint #1 – A proton moves from point *i* to point *f* in a uniform electric field.



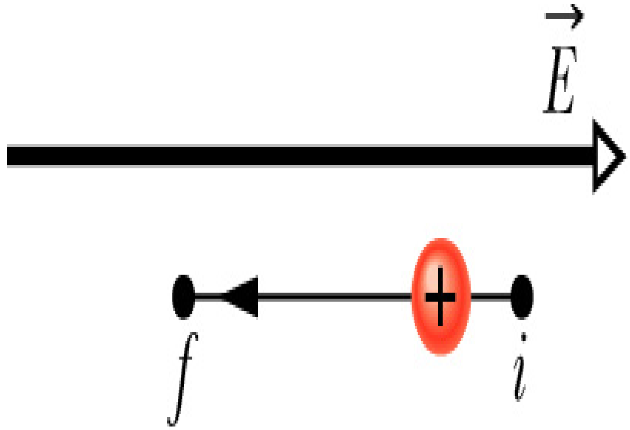
- Does the electric field do positive or negative on the proton?

Electric Potential (6)

- What is the work done by an electric field?

$$W = \vec{F} \bullet \vec{d}$$

$$\vec{F} = q\vec{E}$$



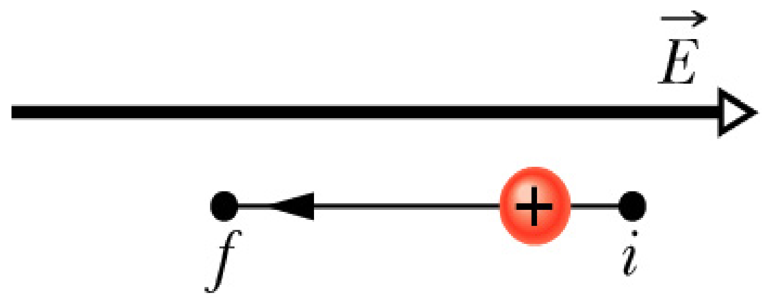
$$W = q\vec{E} \bullet \vec{d} = qEd\cos\theta$$

$$W = qEd\cos(180) = -qEd$$

Negative work

Electric Potential (7)

- Does the electric potential energy of the proton increase or decrease?



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

$$\Delta U = -(-qEd) = qEd$$

Increases

Electric Potential (8)

- Electric potential, *V*, is defined as the electric potential energy, *U*, per unit charge

$$V = \frac{U}{q}$$

- Potential, *V*, is characteristic of the electric field only
  - Unique value at any point in an electric field

Electric Potential (9)

- Electrostatic potential difference, ΔV, between points *i* and *f*

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

- *V* is a scalar and can be +, -, or 0
- Using reference point of U_i=0 at infinity

$$V = -\frac{W_\infty}{q}$$

Electric Potential (10)

- Important difference between U and V
- Electric Potential Energy, U, is energy of a charged object in an external E field
  - Measured in Joules (J)
- Electric Potential, V, is property of E field
  - Doesn't care if charged object is placed in E field or not
  - Measured in Joules per Coulomb (J/C)

Electric Potential (11)

- Define new SI unit for *V*, the volt
- 1 volt = 1 joule per coulomb
- Define *E* field in volts per meter (V/m)

$$E = \frac{F}{q}$$

$$\frac{N}{C} = \left(\frac{N}{C}\right)\left(\frac{V \cdot C}{J}\right)\left(\frac{J}{N \cdot m}\right) = \frac{V}{m}$$

Electric Potential (12)

- Equipotential surface - all points are at same electric potential, *V*

$$\Delta V = V_f - V_i = -\frac{W}{q}$$

- *W* =0 if move between points *i* and *f* which lie on same potential surface
  - True regardless of path taken between points

Electric Potential (13)

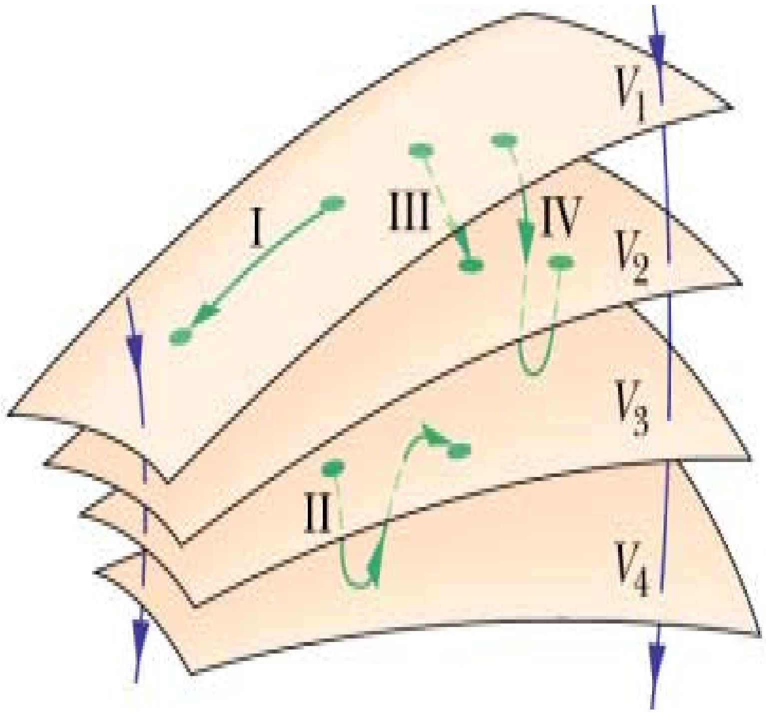
- For paths I and II

$$W = -q\Delta V = -q(V_1 - V_1) = 0$$

$$W = -q\Delta V = -q(V_3 - V_3) = 0$$

- For paths III and IV

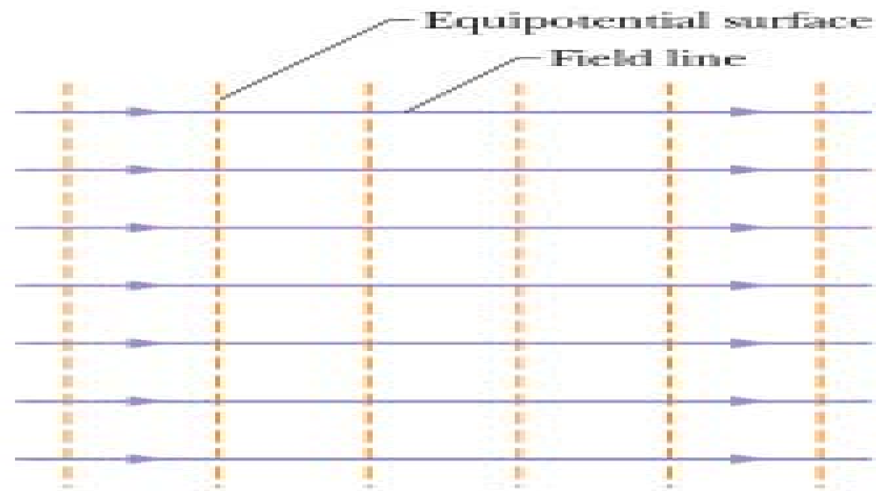
$$W = -q\Delta V = -q(V_2 - V_1)$$



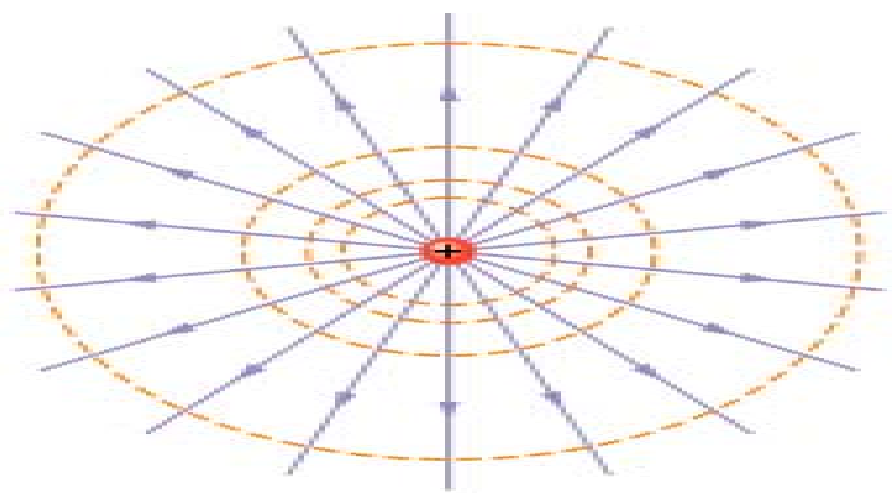
Electric Potential (14)

- Draw equipotential surfaces for distributions of charges

- Equipotential surfaces are always ⊥ to electric field lines and to *E*



(a)

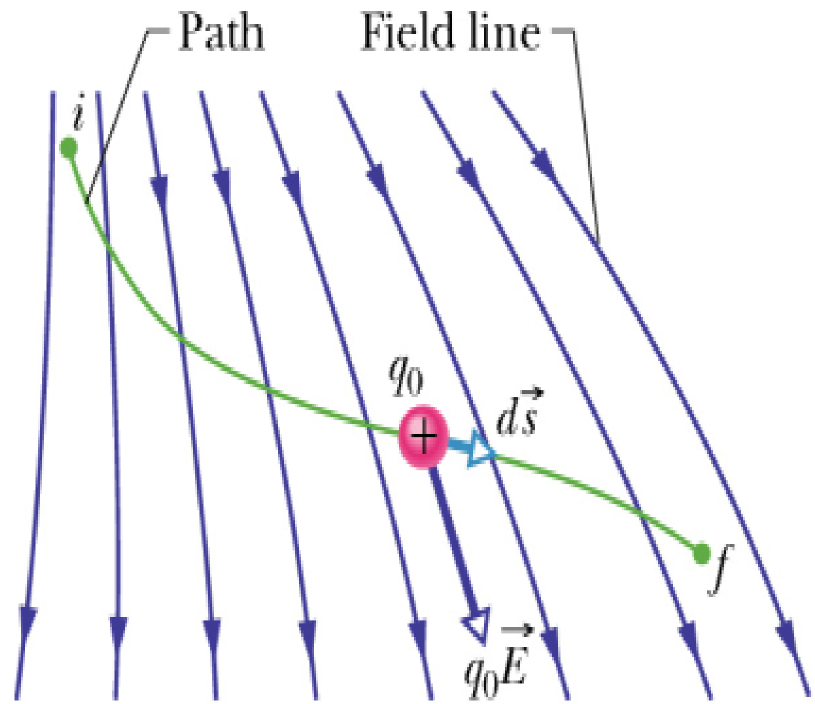


(b)

Electric Potential (15)

- Calculate ΔV between points i and f in an electric field E

$$\Delta V = V_f - V_i = -\frac{W}{q_0}$$



- Need to find W

Electric Potential (16)

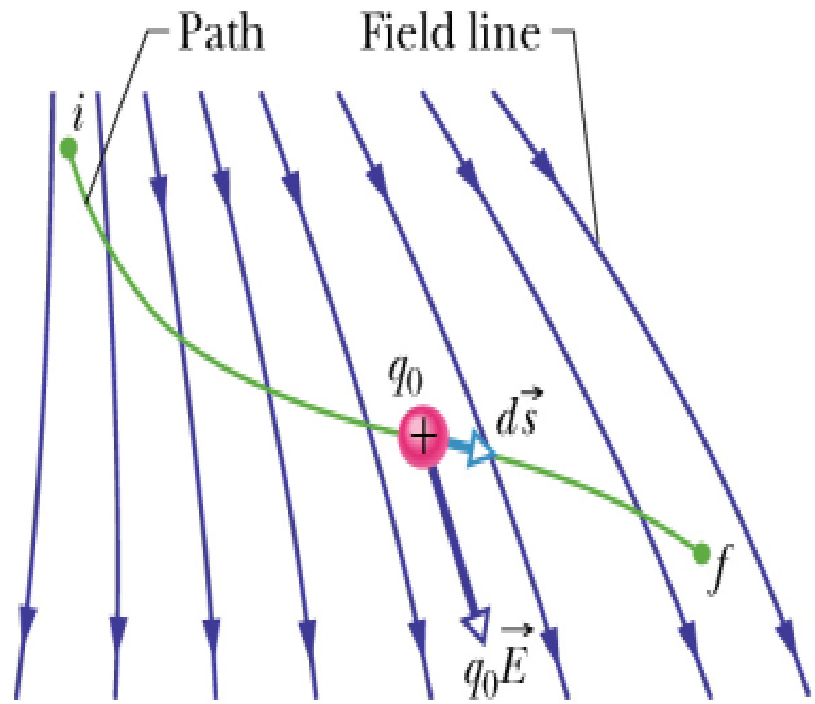
- Calculate differential amount of work

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

- Remember

$$\vec{F} = q\vec{E}$$

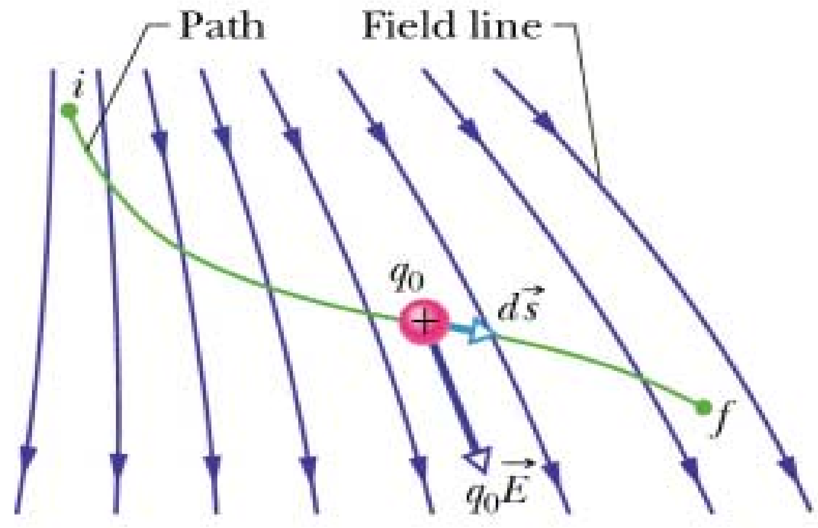
$$dW = q_0 \vec{E} \bullet d\vec{s}$$



Electric Potential (17)

- Work is

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



- Substitute to find Δ*V*

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

- Potential decreases if path is in the direction of the electric field