Lecture 9: Chapter 30 Beginning, September 22 2005

How to find the Potential from the Electric Field?

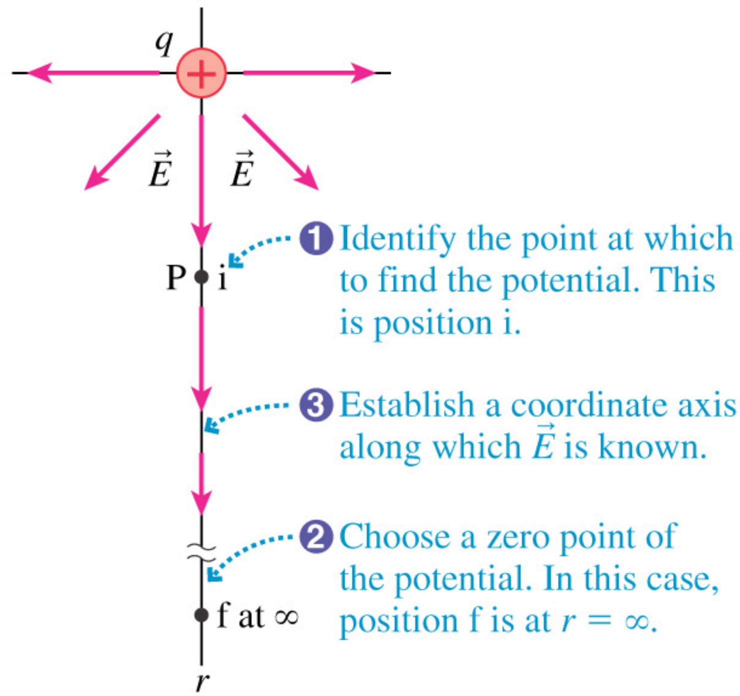
$$\Delta U = -W(i \rightarrow f) = -\int_{s_i}^{s_f} F_s ds$$

By dividing by *q* and using ***F*** = *q**E***:

$$\Delta V = V(s_f) - V(s_i) = -\int_{s_i}^{s_f} E_s ds$$

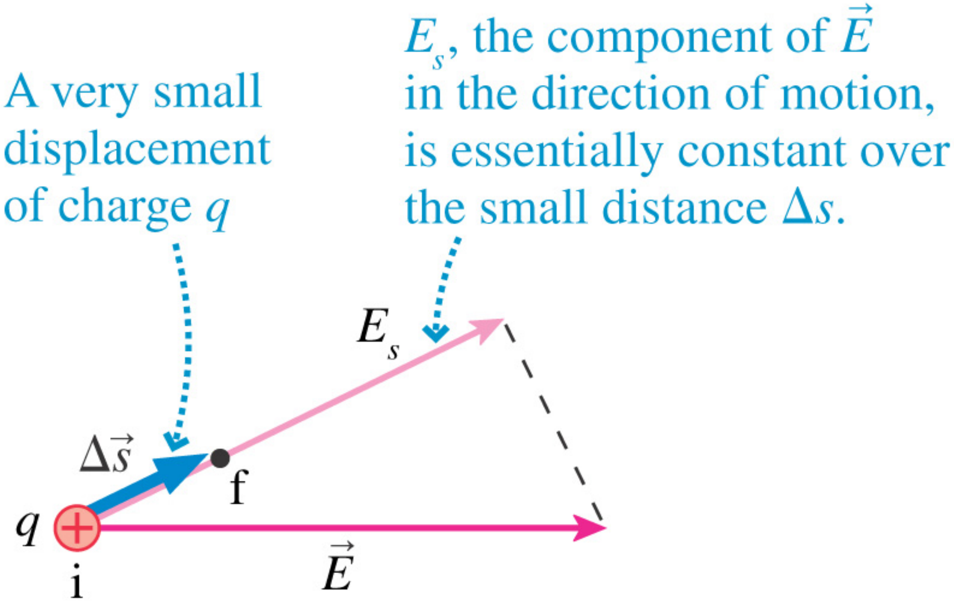
This allows finding *V*(*x*,*y*,*z*) if *E*(*x*,*y*,*z*) is known.

Example: point charge



$$V = \frac{1}{4\pi\varepsilon_0} \frac{q}{r}$$

How to find the Electric Field from the Potential?



$\Delta V = -W/q = -E_s \Delta s$

$E_s = -dV/ds$ (1)

This is correct for any direction ***s***.

To find the individual components of *E* we need to extend Eq. (1):

$$E_x = -\frac{\partial V}{\partial x}$$

$$E_y = -\frac{\partial V}{\partial y}$$

$$E_z = -\frac{\partial V}{\partial z}$$

In practice: If we know the direction of *E*, then we know which derivative of *V* to take

GENERAL PRINCIPLES

Connecting V and $\vec{E}$

The electric potential and the electric field are two different perspectives of how source charges alter the space around them. V and $\vec{E}$ are related by

$$\Delta V = V(s_f) - V(s_i) = -\int_{s_i}^{s_f} E_s \, ds$$

where s is measured from point i to point f and E_s is the component of $\vec{E}$ parallel to the line of integration.

Graphically

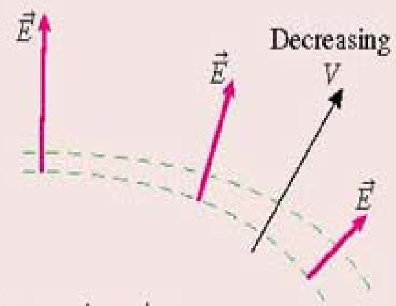
ΔV = the negative of the area under the E_s graph

and

$$E_s = -\frac{dV}{ds}$$

= the negative of the slope of the potential graph.

The Geometry of Potential and Field

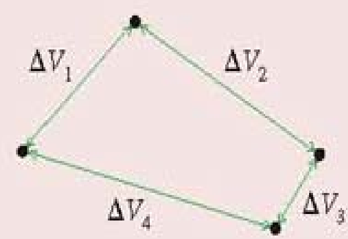


The electric field

- Is perpendicular to the equipotential surfaces.
- Points "downhill" in the direction of decreasing V.
- Is inversely proportional to the spacing Δs between the equipotential surfaces.

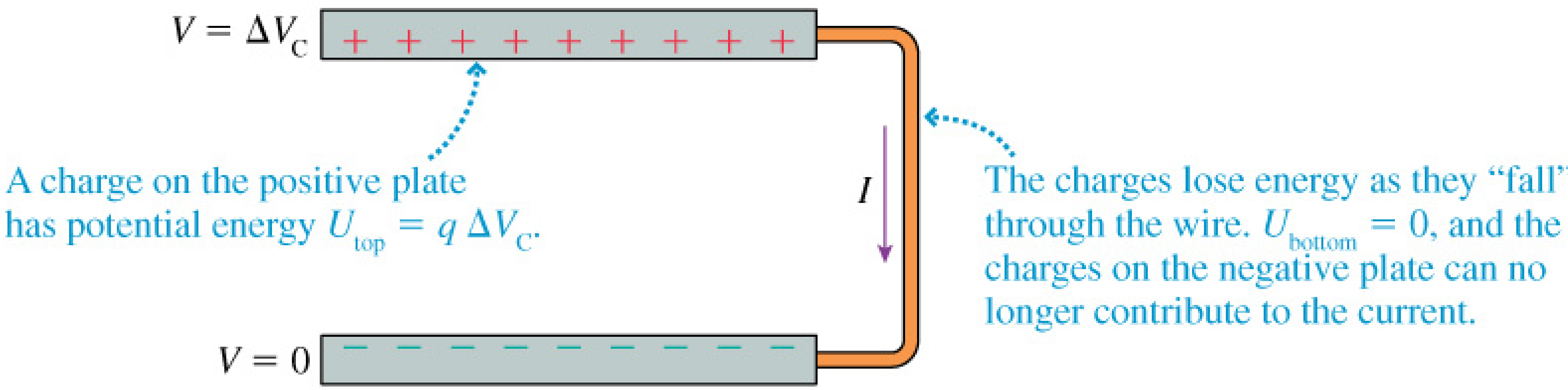
Conservation of Energy

The sum of all potential differences around a closed path is zero. $\sum(\Delta V)_i = 0$.



Sources of Electric Potential

We can generate potential difference by creating a charge separation

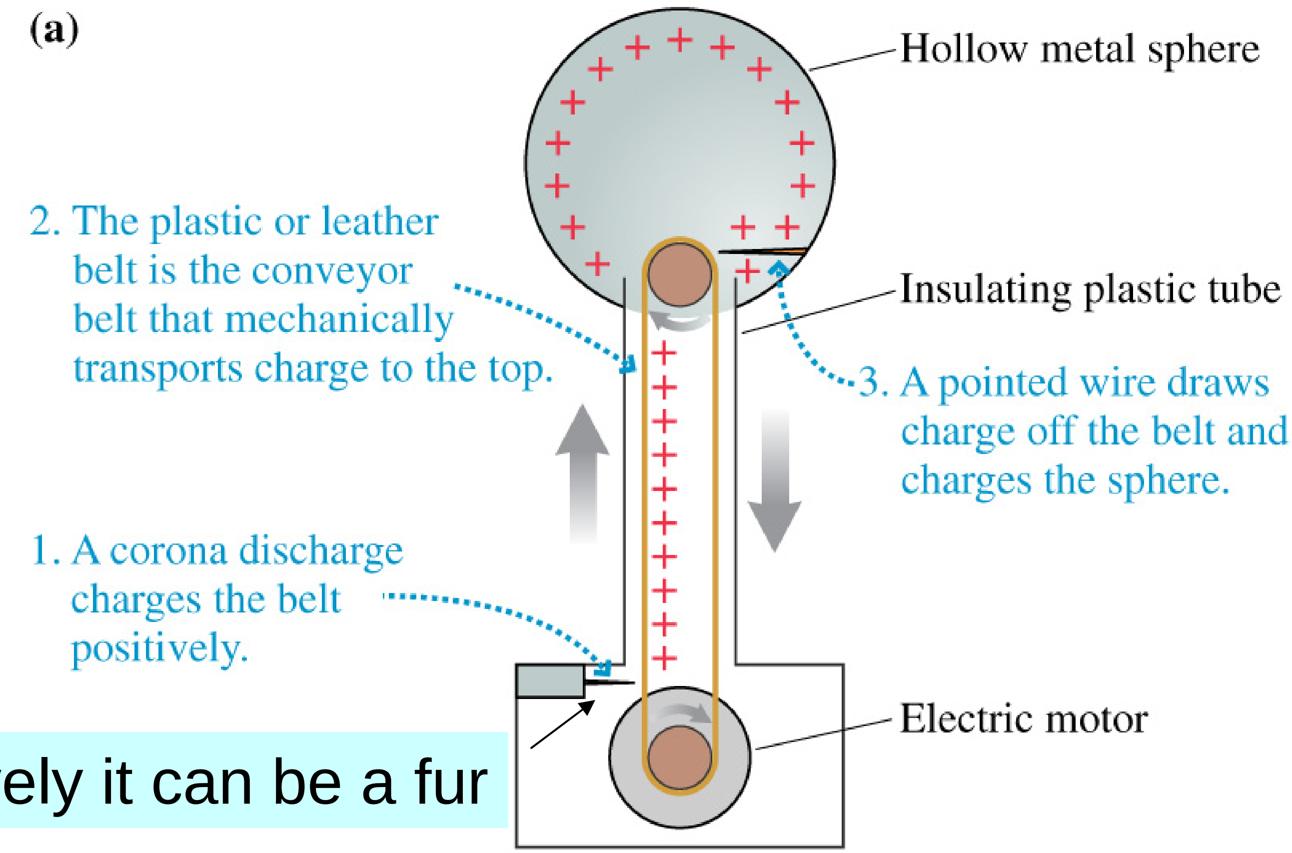


$$q \Rightarrow E \Rightarrow \Delta V$$

A charged capacitor is a source of potential difference, but it cannot sustain a current

The Potential Difference Should be Supported by "Foreign" Forces

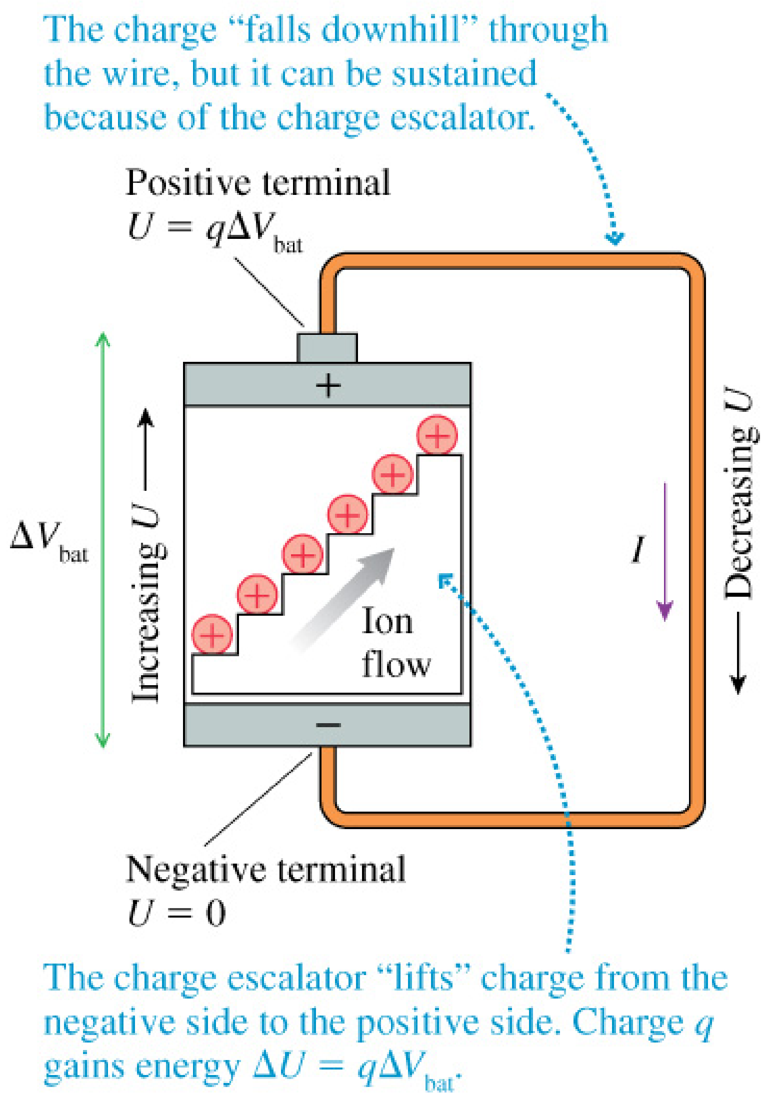
A Van de Graaff generator



Alternatively it can be a fur

Which forces provide charge separation?

Batteries and EMF



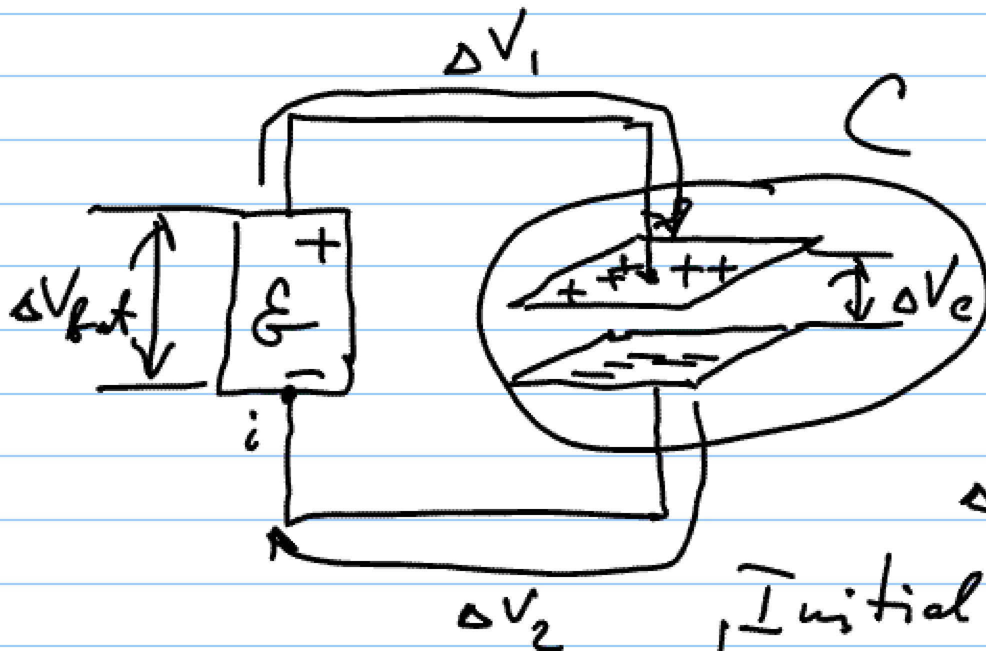
By definition, $\Delta V = \Delta U / q$, where $\Delta U = W_{chem} \Rightarrow$

$\Delta V_{bat} = W_{chem}/q = \varepsilon$

Which forces provide charge separation?

Capacitance, Chapter 30

Capacitance and Capacitors



$$C = \frac{Q}{\Delta V} \quad [1\ \text{Farad}]$$

$$\left[1\ \text{Farad} = \frac{1C}{1V}\right]$$

$$\Delta V_{bat} - \Delta V_1 - \Delta V_c - \Delta V_2 = 0.$$

Initial State: $\Delta V_c = 0$

Immediately after connecting to the battery

$$\Delta V_{bat} = \Delta V_1 + \Delta V_2 \Rightarrow E \neq 0$$

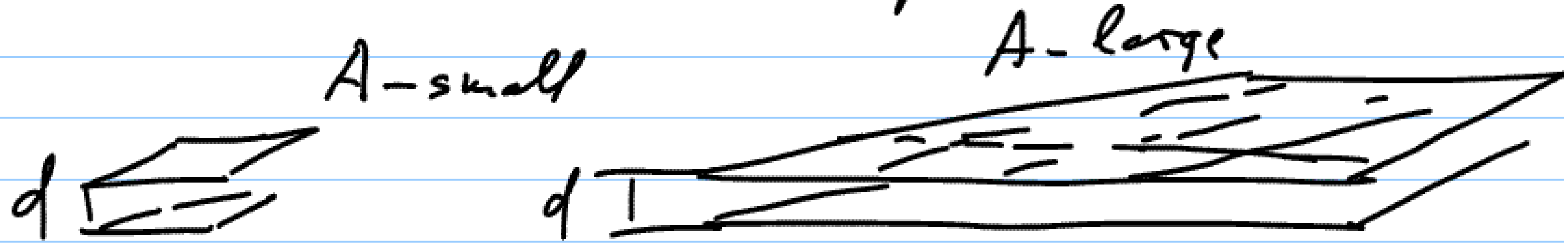
Q (charge on each plate) $\rightarrow$ E (in the air gap) $\rightarrow$ $\Delta V_c \uparrow$

Final State: $\Delta V_1 = \Delta V_2 = 0$

$$\Delta V_{bat} (\mathcal{E}) = \Delta V_c$$

$$C = \frac{Q}{\Delta V_c}$$

Path to calculate C in general case:



Recipe:

Sequence of Steps in Calculating Capacitance

1. Assume charge *Q*

2. Calculate *E* using Gauss's Law

$$\Phi_e = \frac{Q_{enc}}{\varepsilon_0}, \_ where \_ \Phi_e = \oint \vec{E} d\vec{A}$$

3. Find $\Delta V = -\int_i^f E ds$

4. Calculate capacitance $C = Q/\Delta V$. In this calculation *Q* will be cancelled

End of Lecture 9 (Capacitors to be continued)
Reading: Chapter 30
Home Work 4