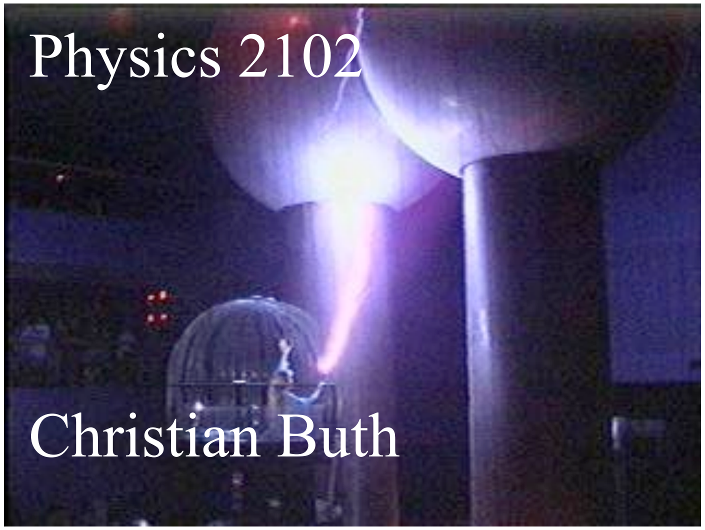
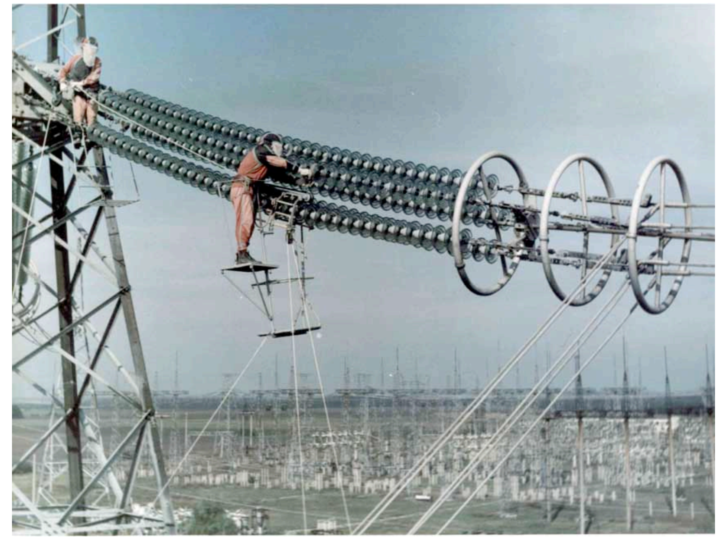
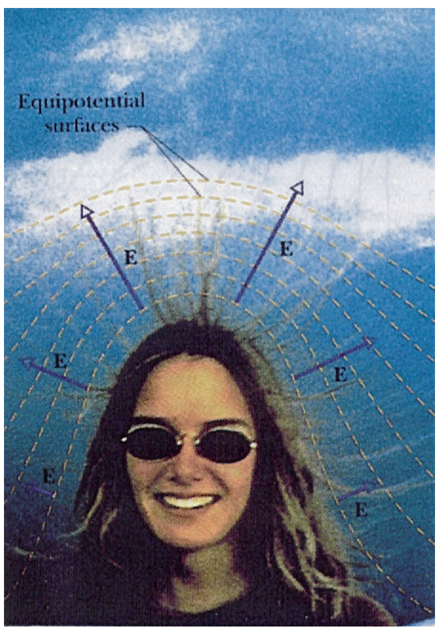


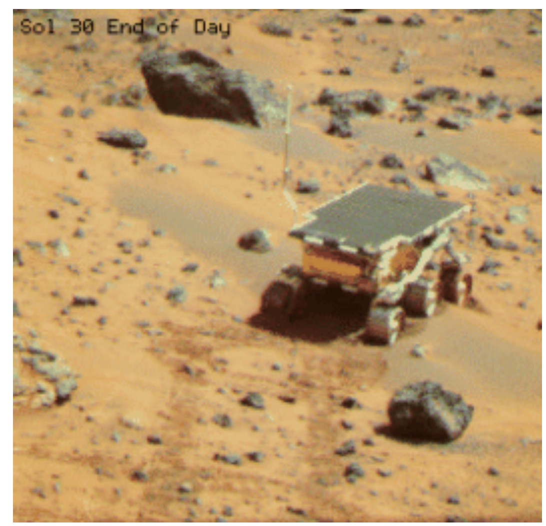


Physics 2102
Lecture 10



Electric Potential 3

Version: 02/04/2009



PHYS2102 FIRST MIDTERM EXAM!

6–7PM THU 05 FEB 2009

Buth's Sec. 6 in Lockett, Room 10

YOU MUST BRING YOUR STUDENT ID!

The exam will cover chapters 21 through 24, as covered in homework sets 1, 2, and 3. The formula sheet for the exam can be found here:

http://www.phys.lsu.edu/classes/spring2009/phys2102/formulasheet.pdf

THERE WILL BE A REVIEW SESSION 6–7PM WED 04 FEB 2009 in Williams 103

Review

- Potential by a **point charge**: $V=kq/r$
- Potential of a continuous **charge distribution**: $V=\int kdq/r$
- Potential of a **dipole** (with angular dependence):

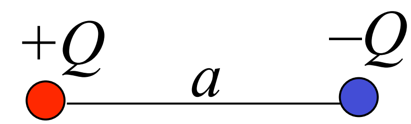
$$V = \frac{p\cos\theta}{4\pi\varepsilon_0 r^2}$$

- Electric field follows from potential by **derivation**:

$$\vec{E} = -\frac{\partial V}{\partial x}\hat{i} - \frac{\partial V}{\partial y}\hat{j} - \frac{\partial V}{\partial z}\hat{k}$$

Electric Potential Energy of a Dipole

What is the potential energy of a dipole?



- First bring charge $+Q$: **no work** involved, no potential energy.
- The charge $+Q$ has created an electric potential **everywhere**, $V(r) = kQ/r$
- The **work needed** to bring the charge $-Q$ to a distance a from the charge $+Q$ is $W_{app} = U = (-Q)V = (-Q)(+kQ/a) = -kQ^2/a$
- **Dipole potential energy**: $-kQ^2/a$
- We did **negative work** to build the dipole (and the electric field did positive work)

Potential Energy of A System of Point Charges

- The electric potential energy of a **pair of point charges**

$$U_{ij} = q_i V_j = \frac{1}{4\pi\varepsilon_0}\frac{q_i q_j}{r_{ij}}$$

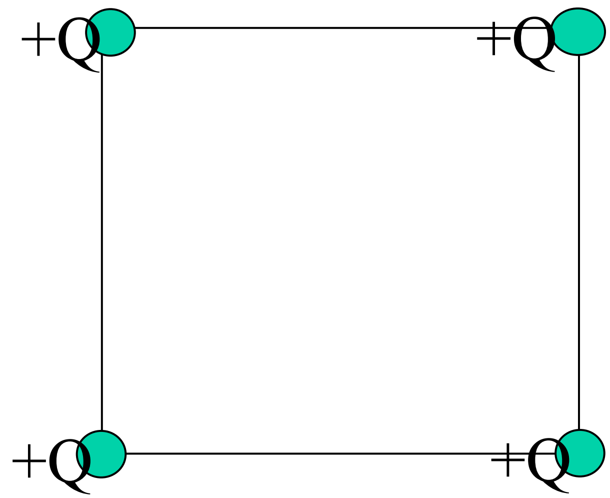
- Let *U* be the work required to **assemble** a system of *n* point charges one by one from infinity to its final position

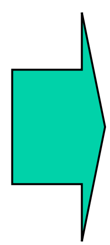
$$U = \frac{1}{4\pi\varepsilon_0}\sum_{\substack{i,j=1\\ i<j}}^{n}\frac{q_i q_j}{r_{ij}}$$

- Each pair of charges is counted only **once**

Potential Energy of A System of Charges

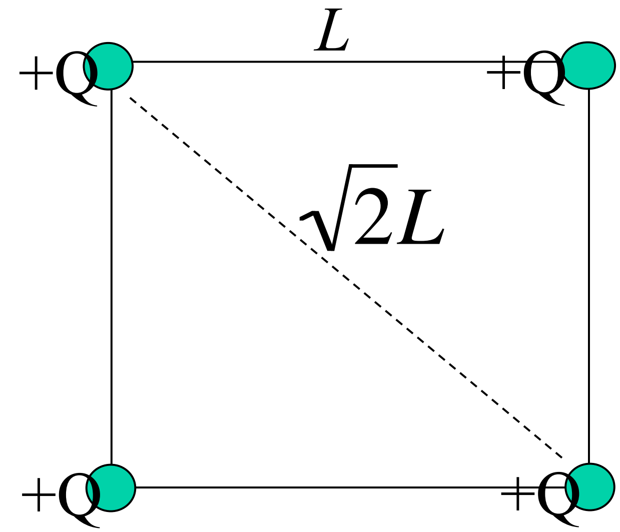
- 4 point charges (each +Q and equal mass) are connected by strings, forming a square of side L
- If all four strings suddenly snap, what is the kinetic energy of each charge when they are very far apart?
- Use conservation of energy:
  - Final kinetic energy of all four charges = initial potential energy stored = energy required to assemble the system of charges





Do this from scratch!

Potential Energy of A System of Charges: Solution



- No energy needed to bring in first charge: $U_1=0$
- Energy needed to bring in 2nd charge: $$U_2 = QV_1 = \frac{kQ^2}{L}$$
- Energy needed to bring in 3rd charge =

$$U_3 = QV = Q(V_1 + V_2) = \frac{kQ^2}{L} + \frac{kQ^2}{\sqrt{2}L}$$

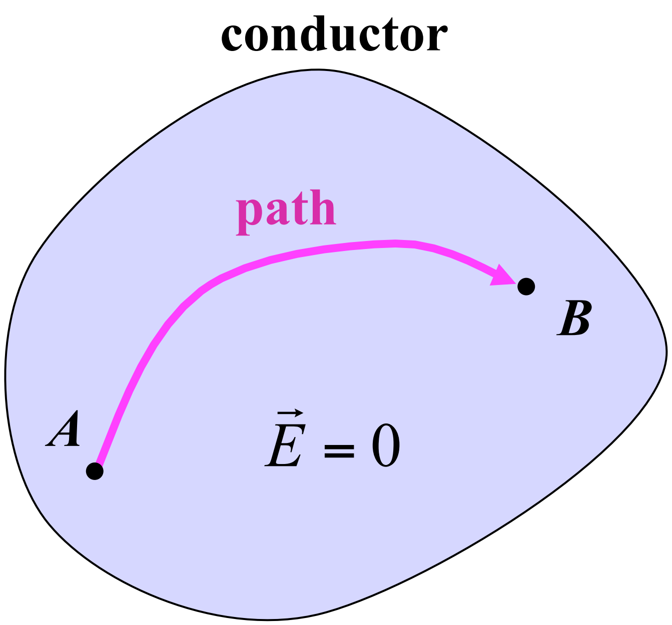
- Energy needed to bring in 4th charge =

$$U_4 = QV = Q(V_1 + V_2 + V_3) = \frac{2kQ^2}{L} + \frac{kQ^2}{\sqrt{2}L}$$

Total potential energy is sum of all the individual terms shown on left hand side = $\frac{kQ^2}{L}\left(4+\sqrt{2}\right)$

So, final kinetic energy of each charge = $\frac{kQ^2}{4L}\left(4+\sqrt{2}\right)$

Potential of an Isolated Conductor



- **Potential difference** between points A and B is

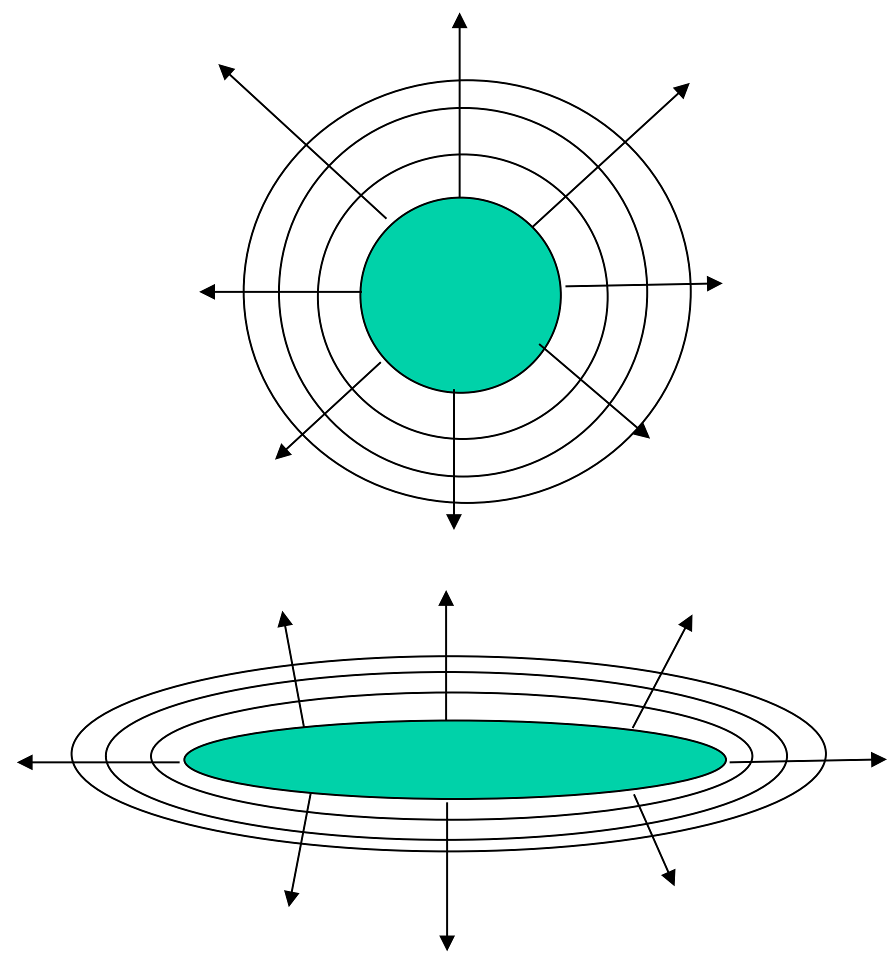
$$\Delta V = V_A - V_B = -\int_B^A \vec{E} \cdot d\vec{s}$$

- Field in conductor is **zero**
- Thus $V_A - V_B = 0$

A conductor is an equipotential surface.

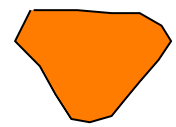
Equipotentials and Conductors

- Conducting surfaces are **equipotentials**
- At surface of conductor, E is **normal** to surface
- **No work** needed to move a charge on a conductor surface



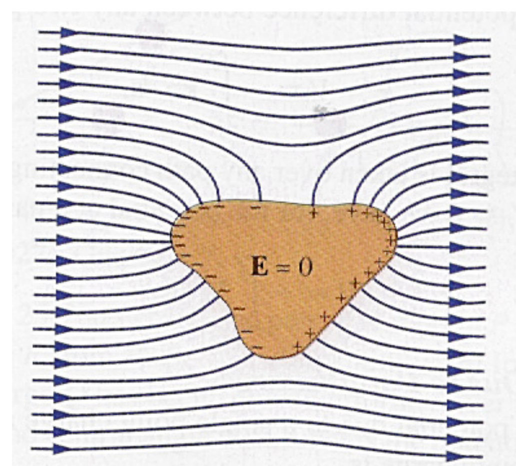
Conductors change the field around them!

An uncharged conductor:



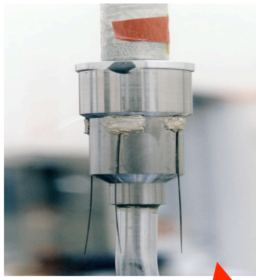
A uniform electric field:

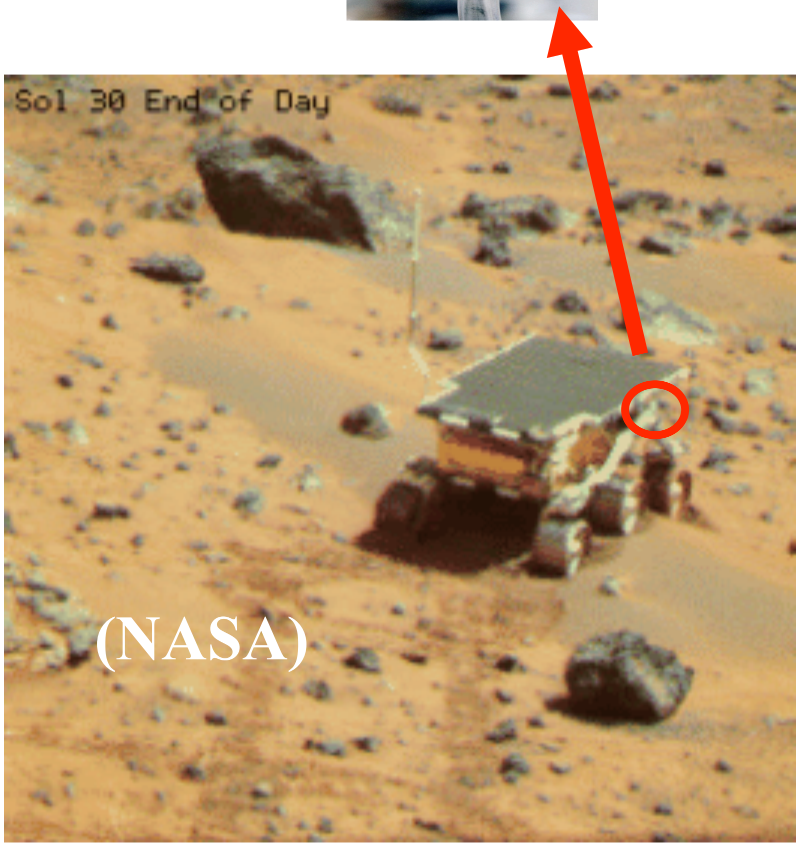
An uncharged conductor in the initially uniform electric field:



“Sharp” conductors

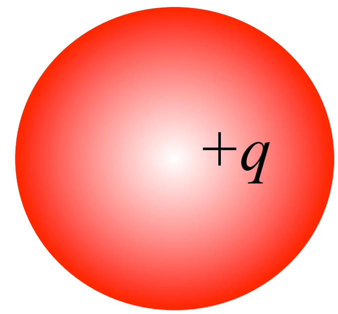
- Charge density is **higher** at conductor surfaces that have small radius of curvature
- $E = \sigma/\varepsilon_0$ for a conductor, hence **stronger** electric fields at sharply curved surfaces!
- Used for attracting or getting rid of charge:
  - Lightning rods
  - Van de Graaf -- metal brush transfers charge from rubber belt
  - Mars pathfinder mission -- tungsten points used to get rid of accumulated charge on rover (electric breakdown on Mars occurs at ~100 V/m)

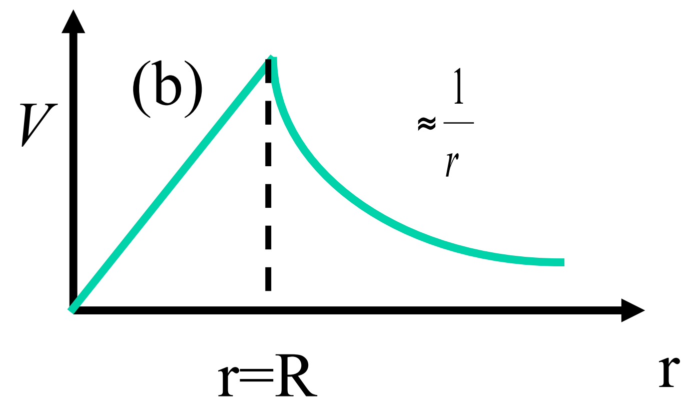


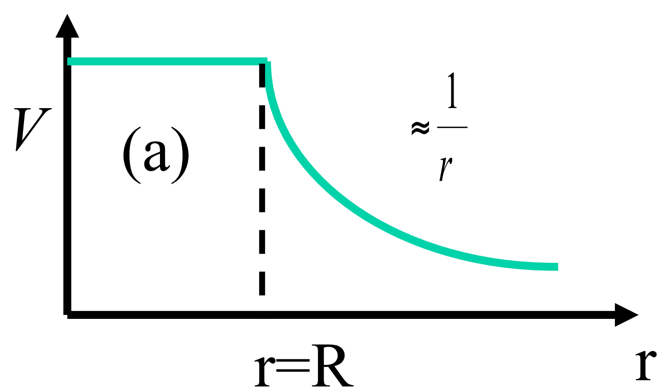


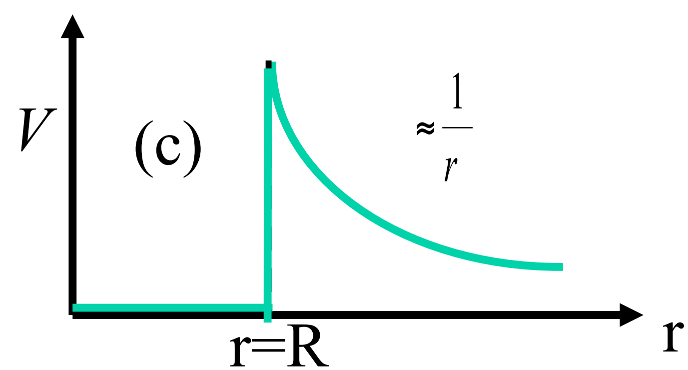
Electric Field & Potential: Example

- Hollow **metal** sphere of radius R has a charge $+q$
- Which of the following is the electric potential V as a function of distance r from center of sphere?

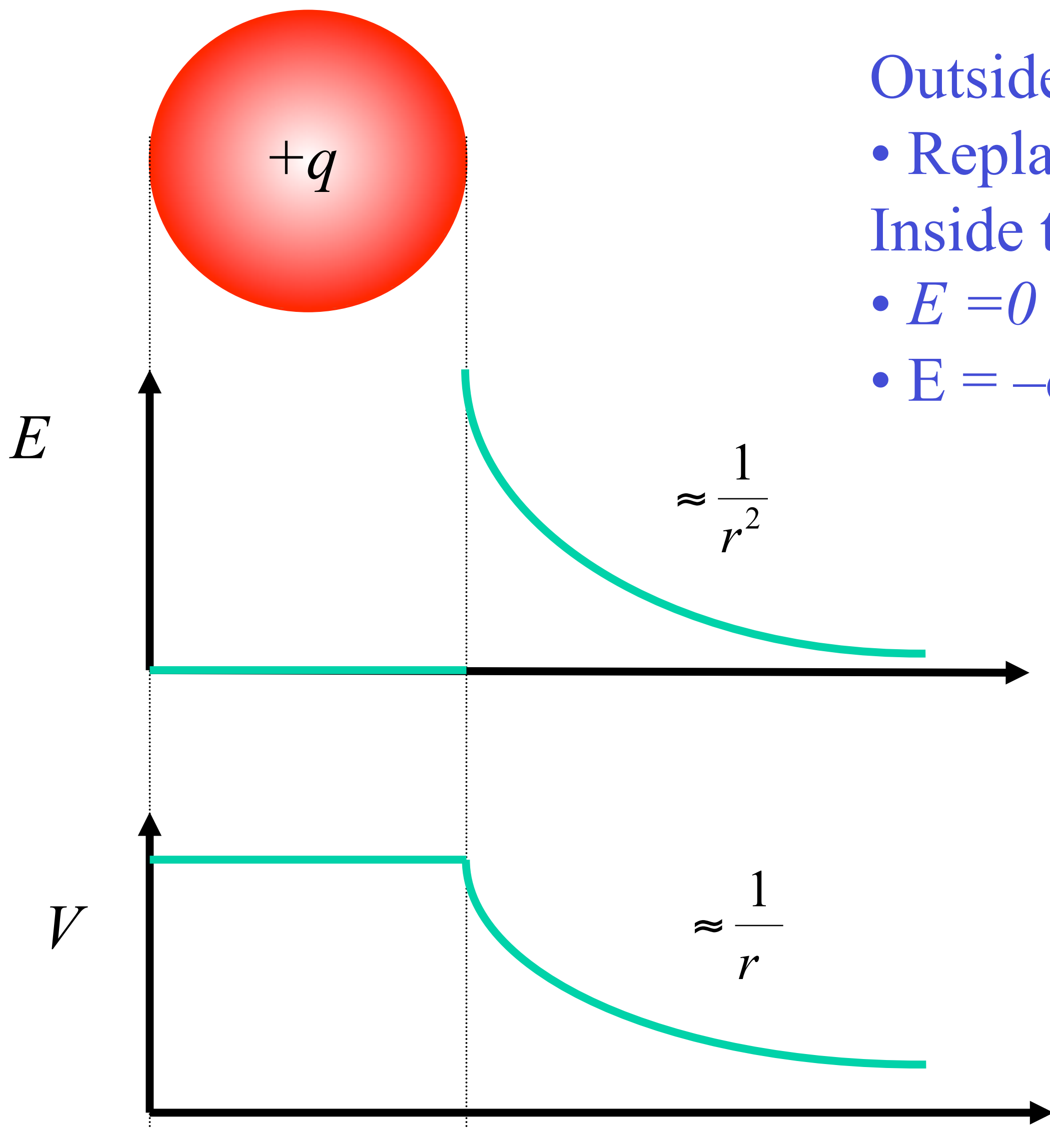








Electric Field and Potential: Example



Outside the sphere:

• Replace by point charge!

Inside the sphere:

• $E = 0$ (Gauss' Law)

• E = –dV/dr = 0 => V=constant

$$E = -\frac{dV}{dr}$$

$$= -\frac{d}{dr}\left[k\frac{Q}{r}\right]$$

$$= k\frac{Q}{r^2}$$

Summary

- **Electric potential energy**: work used to build the system, charge by charge:

$$U = \frac{1}{4\pi\varepsilon_0} \sum_{\substack{i,j=1 \\ i<j}}^{n} \frac{q_i q_j}{r_{ij}}$$

- Charges move to make surface of **conductors** equipotentials
- Thus conductors **change the field** around them!
- Charge density and electric field are higher on **sharp points** of conductor