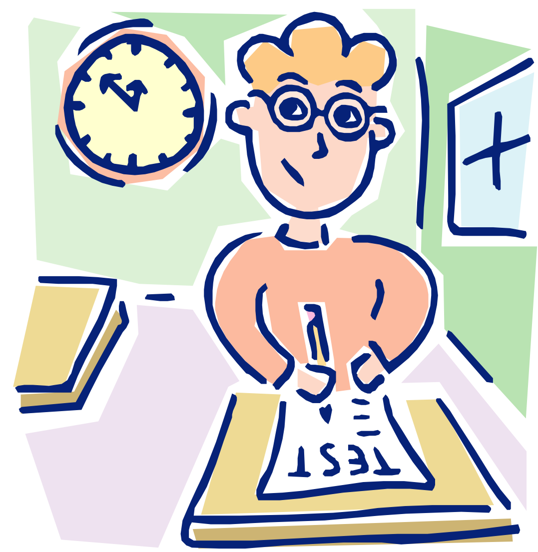
Review for Midterm-1

Midterm-1

- Wednesday Sept. 24th at 6pm
  - Section 1 (the 4:10pm class) exam in – BCC N130 (Business College)
  - Section 2 (the 6:00pm class) exam in – NR 158 (Natural Resources)
- Allowed one sheet of notes (both sides) and calculator
- Need photo ID
- Send Prof. Tollefson email if you need to take the make-up exam and explain why (tollefson@pa.msu.edu)
  - Make-up exam is at 8am Thursday (meet at 3234 BPS by 7:55am)
- Use the help-room to prepare
- Review in class on Tuesday



Electric Force

- The magnitude of the electrostatic force, *F*, between 2 charged particles with charges q_1 and q_2, respectively, and separated by a distance *r* is defined as

$$F = \frac{k\left|q_1\right|\left|q_2\right|}{r^2}$$

$$k = \frac{1}{4\pi\varepsilon_0} = 8.99\times10^9\, N\cdot m^2/C^2$$

- This is Coulomb's law where *k* is a constant
- The forces on 2 point charges are equal and opposite, pointing to (away from) the other particle for unlike (like) charges

Electric Field

- Electric field, *E*, is the force per unit positive test charge

$$E = \frac{F}{q_0}$$

- For a point charge

$$F = k\frac{|q_0||q|}{r^2}$$

so

$$E = k\frac{|q|}{r^2}$$

Electric Field

- *E* points towards a negative point charge and away from a positive point charge.

- Superposition principle

$$\vec{F} = \vec{F}_1 + \vec{F}_2 + \ldots + \vec{F}_n$$

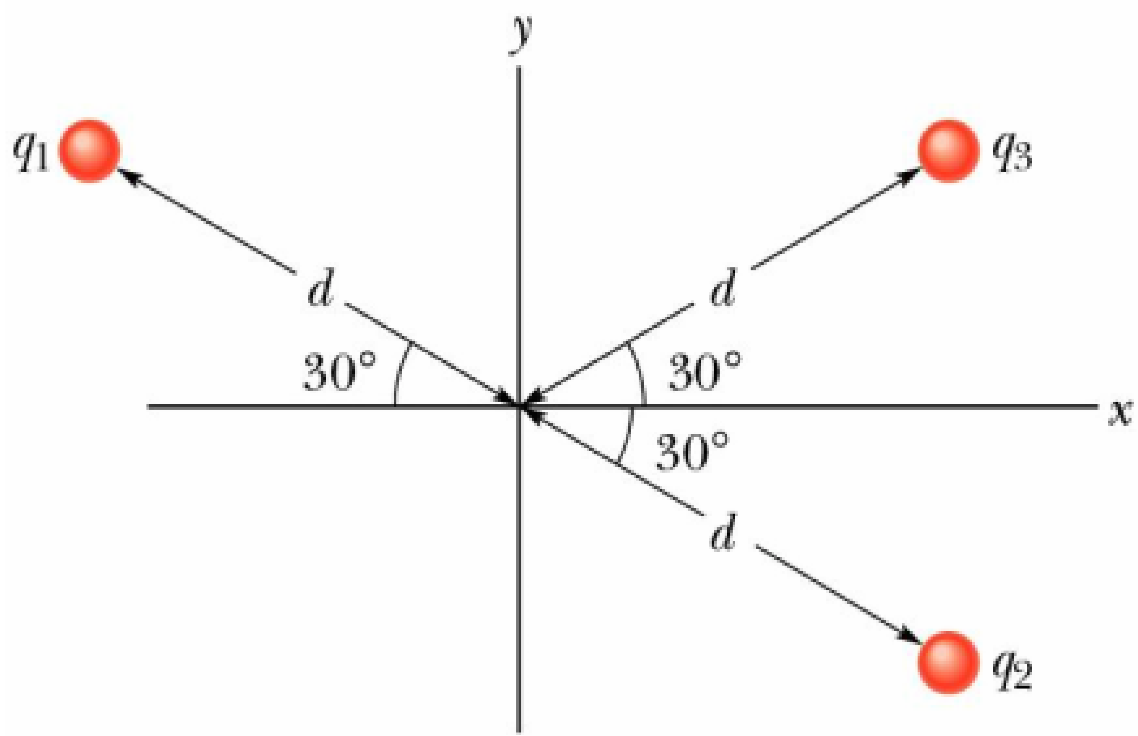
$$\vec{E} = \vec{E}_1 + \vec{E}_2 + \ldots + \vec{E}_n$$

- Given the E field we can find the force on charge q

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

If the vector addition gives zero you do not need to calculate each one.

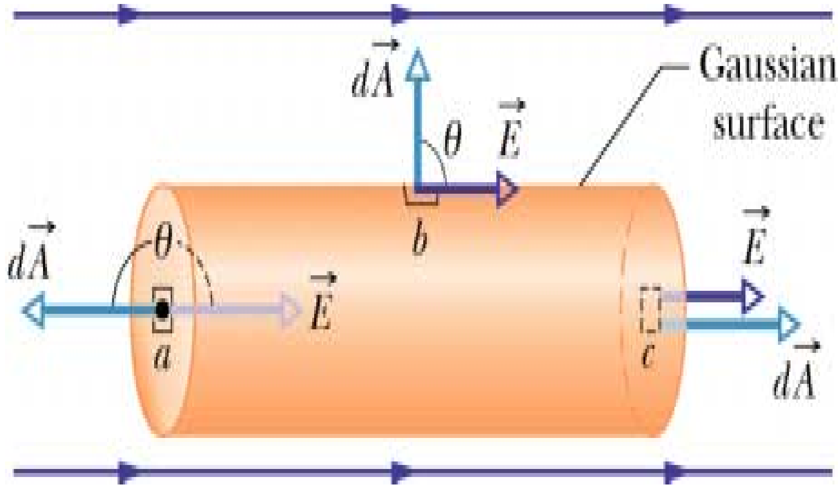
For example, in the figure below, if $q_1 = q_2$ then $\vec{E}_1 + \vec{E}_2 = 0$ at the origin and the field comes only from q_3.



Flux

- Calculate flux of uniform *E* through cylinder

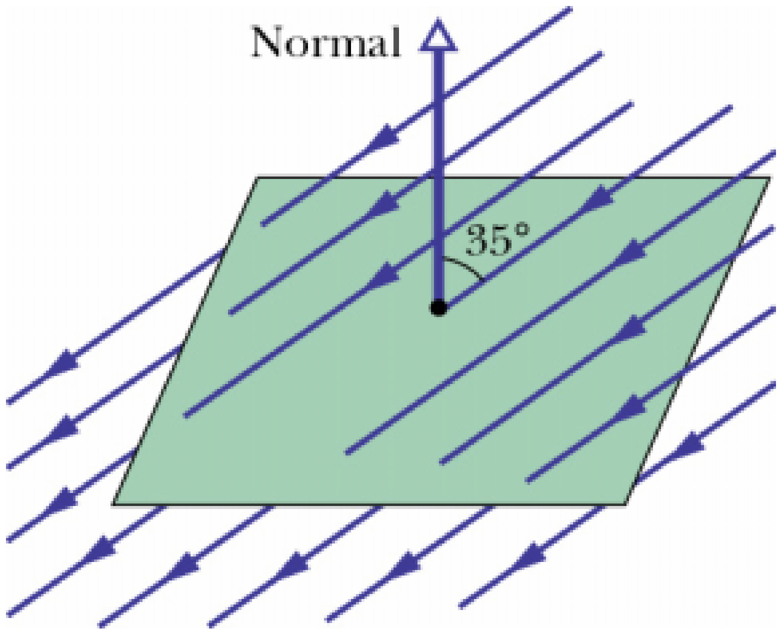
$$\Phi = \oint \vec{E} \bullet d\vec{A}$$



- 3 surfaces - a, b, and c

$$\Phi = \int_a \vec{E} \bullet d\vec{A} + \int_b \vec{E} \bullet d\vec{A} + \int_c \vec{E} \bullet d\vec{A}$$

Flux



$$\vec{E} \bullet d\vec{A} = E \; dA \cos\theta$$

Gauss' Law

- Gauss' Law

$$\varepsilon_0 \Phi = q_{enc}$$

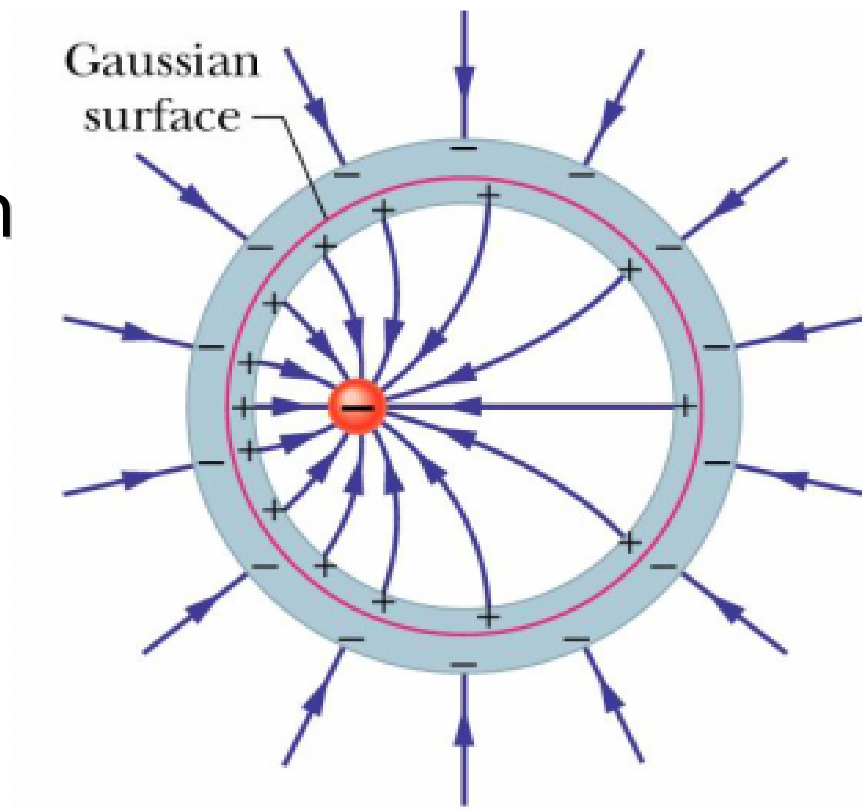
- Also write it as

$$\varepsilon_0 \oint \vec{E} \bullet d\vec{A} = q_{enc}$$

- Net charge q_{enc} is sum of all enclosed charges and may be +, -, or zero

Example for Gauss' Law

- Charge q_1 inside
- $E=0$ inside conductor
- Thus $\Phi=0$ for Gaussian surface (red line)
- So net charge enclosed must be 0
- Induced charge of $q_2 = -q_1$ lies on inner wall of sphere
- Shell is neutral so charge of $q_3 = -q_2$ on outer wall



Charge distributions

- E field from a continuous line or region of charge
- Use calculus and a charge density instead of total charge, Q

- Linear charge density $\lambda = Q / Length$

- Surface charge density $\sigma = Q / Area$

- Volume charge density $\rho = Q / Volume$

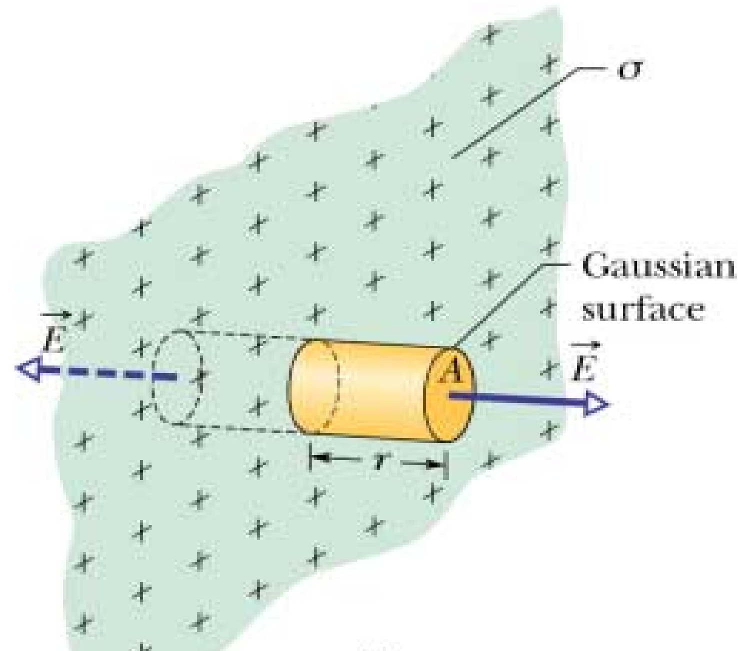
Gauss' Law (Fig. 24-15)

- Non-conducting sheet of charge σ

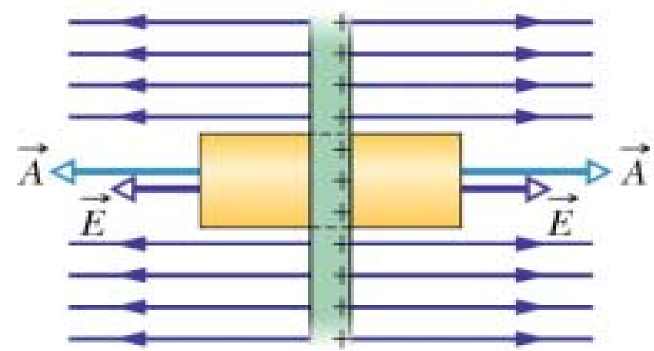
$$\varepsilon_0 \oint \vec{E} \bullet d\vec{A} = q_{enc}$$

$$\varepsilon_0 (EA + EA) = \sigma A$$

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



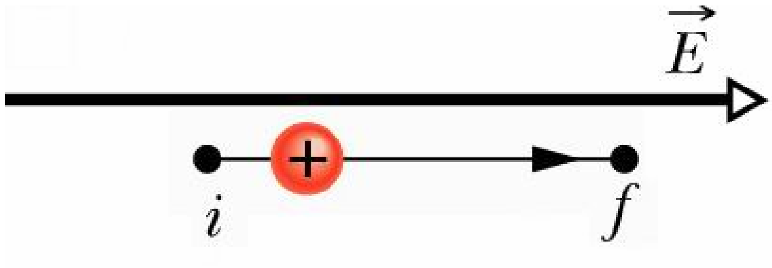
(a)



(b)

Electric Potential

- Electric potential energy *U* for a constant *E* and work done by the field



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

$$\Delta U = -Fd = -qEd$$

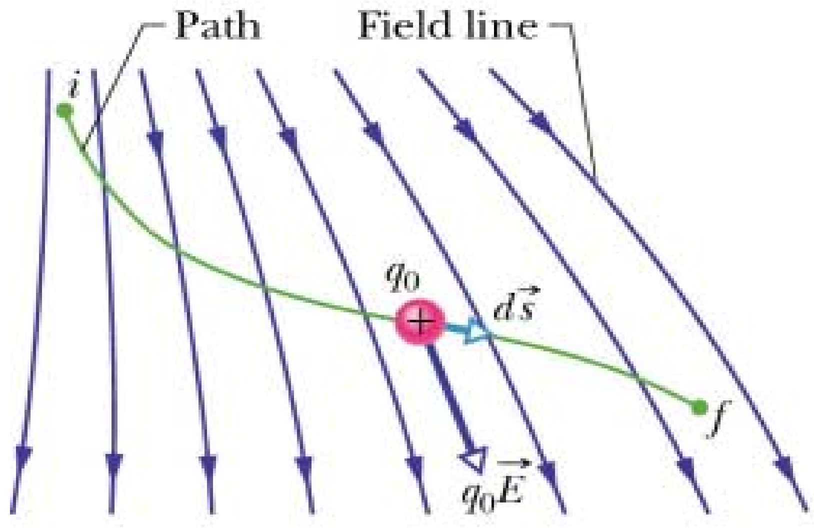
- Electric potential for a constant *E*

$$\Delta V = \frac{\Delta U}{q} = -Ed$$

Electric Potential (Fig. 25-5)

- Work done by field

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



- Used to find

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

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

Quiz - FGIIGG

- 1) Suppose we generate an electric field of

$$\vec{E} = 200.0\ (V/m)\,\hat{i}$$

- What is the change in the electric potential, measured in Volts, associated with a moving a charge of 1.4 C from (0,0) m to (2,2) m?

$$\Delta V = -\int_i^f \vec{E} \bullet d\vec{s}$$

- A) -400, B) -280, C) 600, D) -800, E) 1000

Quiz - FGIIGG

- 2) Suppose we generate an electric field of

$$\vec{E} = 1.0\ (V/m)\,\hat{i} + 2.0\,(V/m)\ \hat{j}$$

- What is the work done (in *J*) by an external agent (W*) to move a charge of 6.0 C from (0,0) m to (2,2) m?

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

- A) -6, B) 6, C) -36, D) 70, E) -24

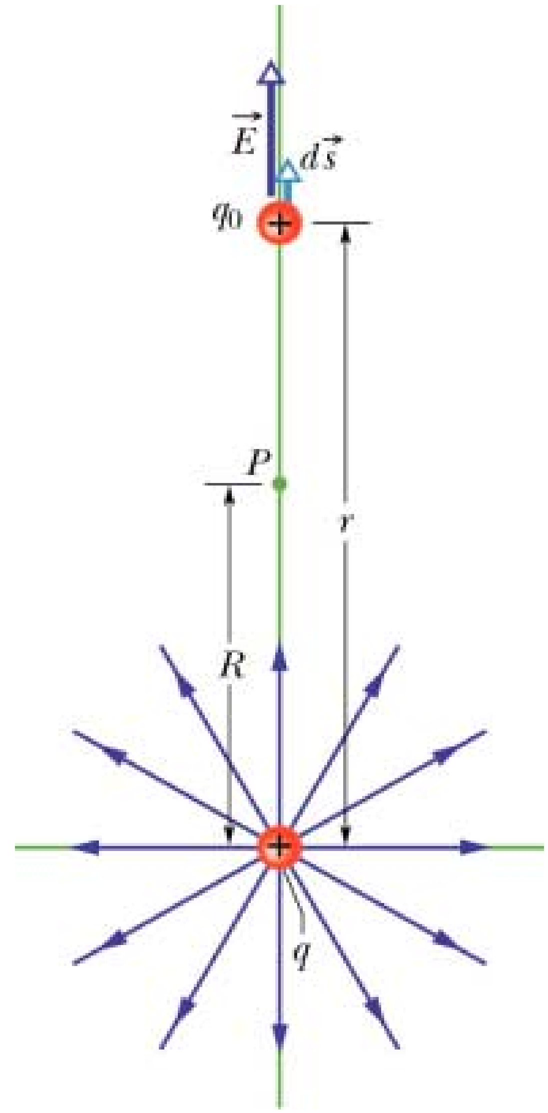
Electric Potential

Summary for a point change

$$F = k\frac{|q||q_0|}{r^2}$$

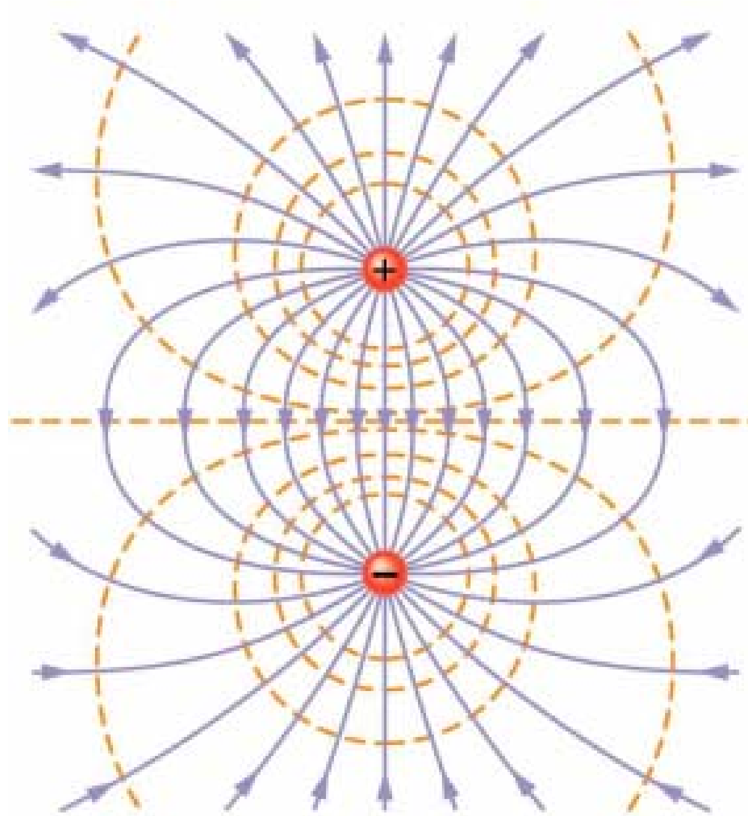
$$E = k\frac{q}{r^2}$$

$$V = k\frac{q}{r}$$



Electric Potential (Fig. 25-3)

- Dashed lines are the edge of equipotential surfaces where all points are at the same potential.
- Equipotential surfaces are always ⊥ to electric field lines and to *E*.
- In this example *V* decreases by constant intervals from the positive charge to the negative charge



(c)

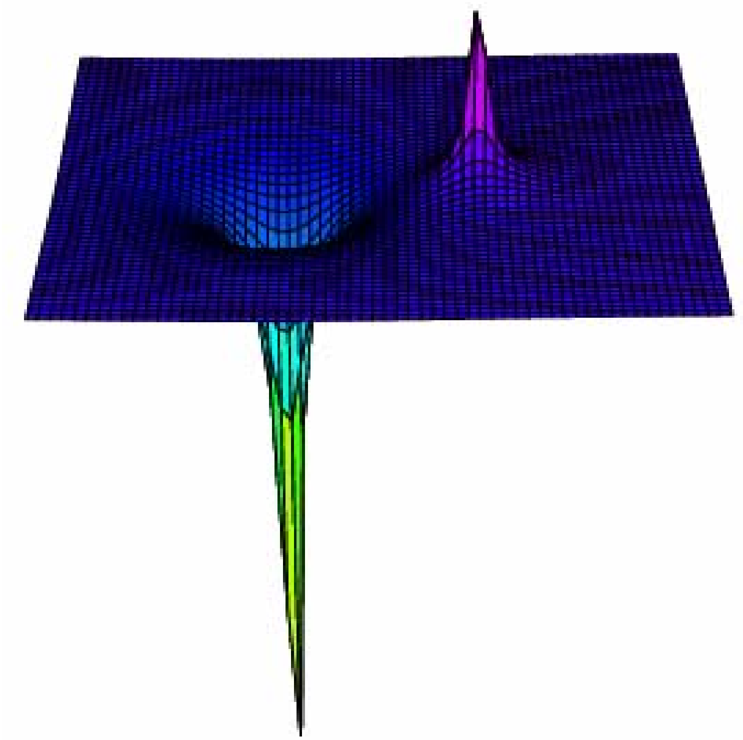
Electric Potential

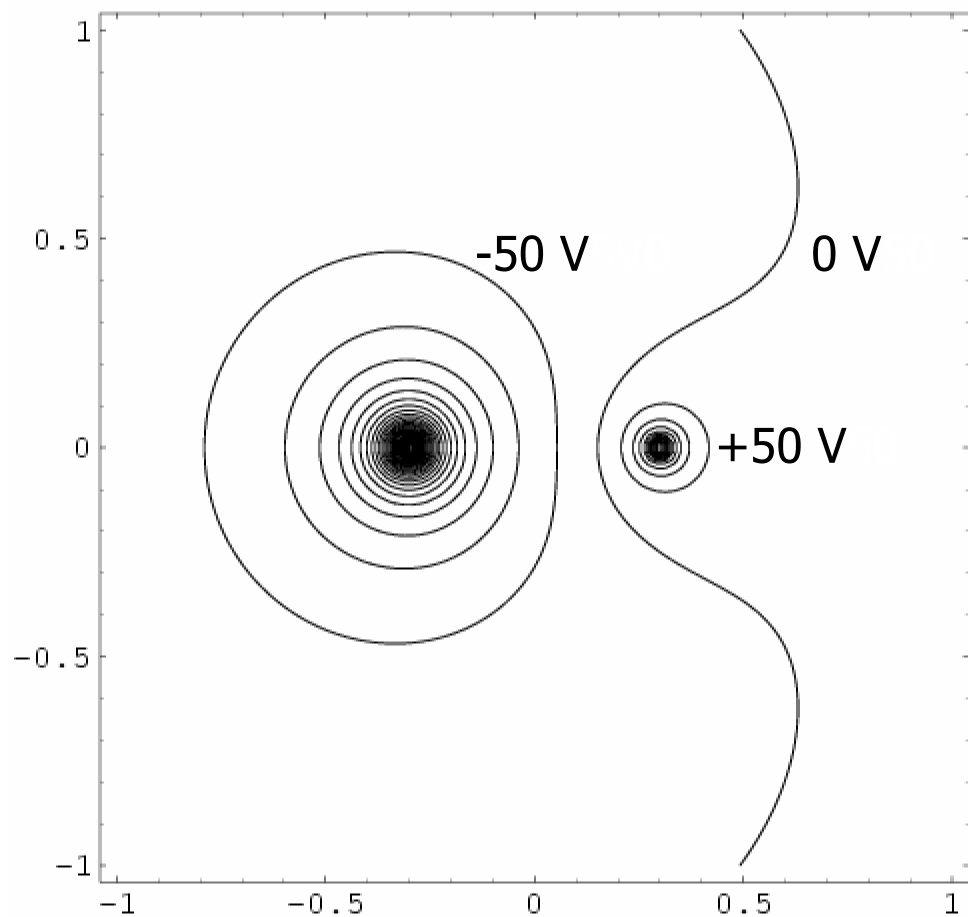
- Use superposition principle to find the potential due to *n* point charges

$$V = \sum_{i=1}^{n} V_i = k \sum_{i=1}^{n} \frac{q_i}{r_i}$$

- This is an algebraic sum, not a vector sum
- Include the sign of the charge

Electric Potential (Mathematica)





Electric Field from Potential

- Take *s* axis to be *x*, *y*, or *z* axes

$$E_x = -\frac{\partial V}{\partial x}, \quad E_y = -\frac{\partial V}{\partial y}, \quad E_z = -\frac{\partial V}{\partial z}$$

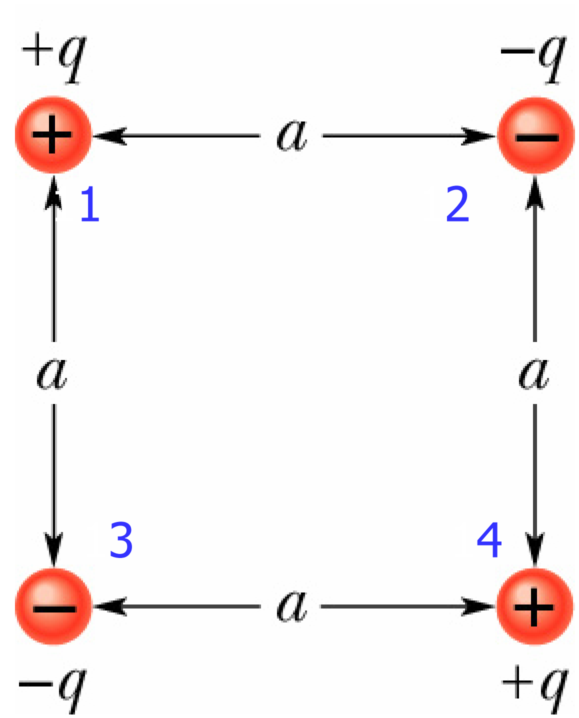
- If *E* is uniform and *s* is ⊥ to equipotential surface

$$E = -\frac{\Delta V}{\Delta s}$$

Potential Energy

- Total potential energy for a collection of charges is the scalar sum of individual potential energies - work required to assemble the charges

$$U = U_{12} + U_{13} + U_{14} + U_{23} + U_{24} + U_{34}$$



- where $U_{12} = k\dfrac{q_1 q_2}{d}$ etc

Capacitance

- Calculate *C* of a capacitor from its geometry using steps:
- 1) Assume charge, *q*, on the capacitor
- 2) Find *E* between using *q* and Gauss' law

$$\varepsilon_0 \oint \vec{E} \bullet d\vec{A} = q_{enc}$$

- 3) Find *V* from *E* using

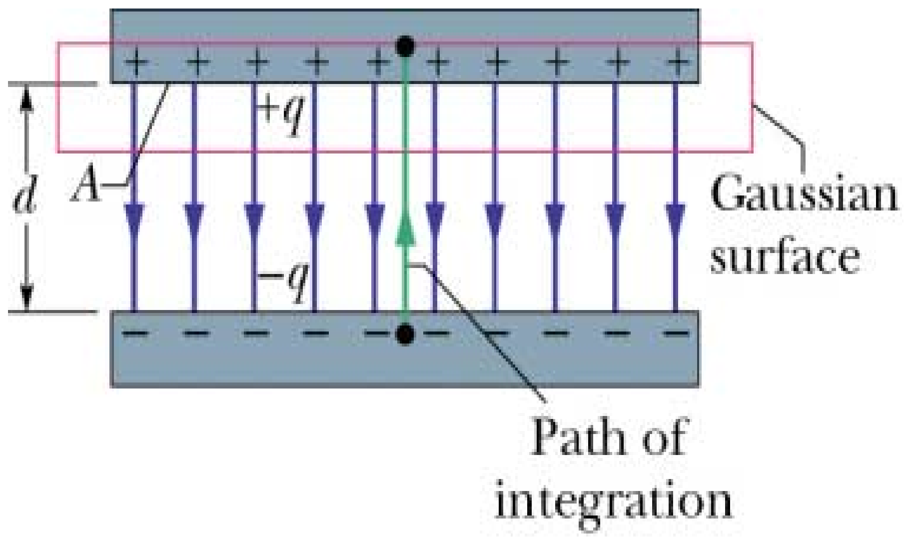
$$\Delta V = -\int_i^f \vec{E} \bullet d\vec{s}$$

- 4) Get *C* using

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

Capacitance (Fig. 26-5)

- Parallel-plate capacitor



$$C = \frac{\varepsilon_0 A}{d} = \frac{A}{4\pi\, k\, d}$$

- Only depends on area *A* of plates and separation *d*
- *C* increases if we increase *A* or decrease *d*

Energy in a Capacitor

- Work required from 0 to total charge q is

$$W = \frac{1}{C}\int_0^q q'\,dq' = \frac{q^2}{2C}$$

- Potential energy = work

$$U = \frac{q^2}{2C}$$

- Or, use

$$q = CV$$

$$U = \frac{1}{2}CV^2$$

Capacitance

- Capacitors in parallel
  - V across each is equal
  - Total q is sum

$$C_{eq} = \sum_{i}^{n} C_i$$

- Capacitors in series
  - q is equal on each
  - Total V is sum

$$\frac{1}{C_{eq}} = \sum_{i}^{n} \frac{1}{C_i}$$

Capacitance

- Place a dielectric in capacitor its capacitance increases by numerical factor.
- Called dielectric constant, κ

$$C_{dielectric} = \kappa C_{air}$$