PHYS 212 Review 1

Exam 1

Queue

Exam 1 Overview

1) Coulomb’s Law

2) Electric Field

3) Electric Flux

4) Gauss’s Law

5) Electric Potential

6) Capacitance

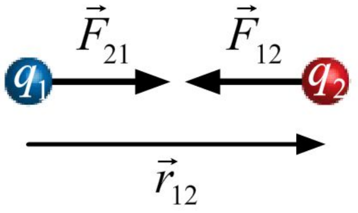
Coulomb's Law

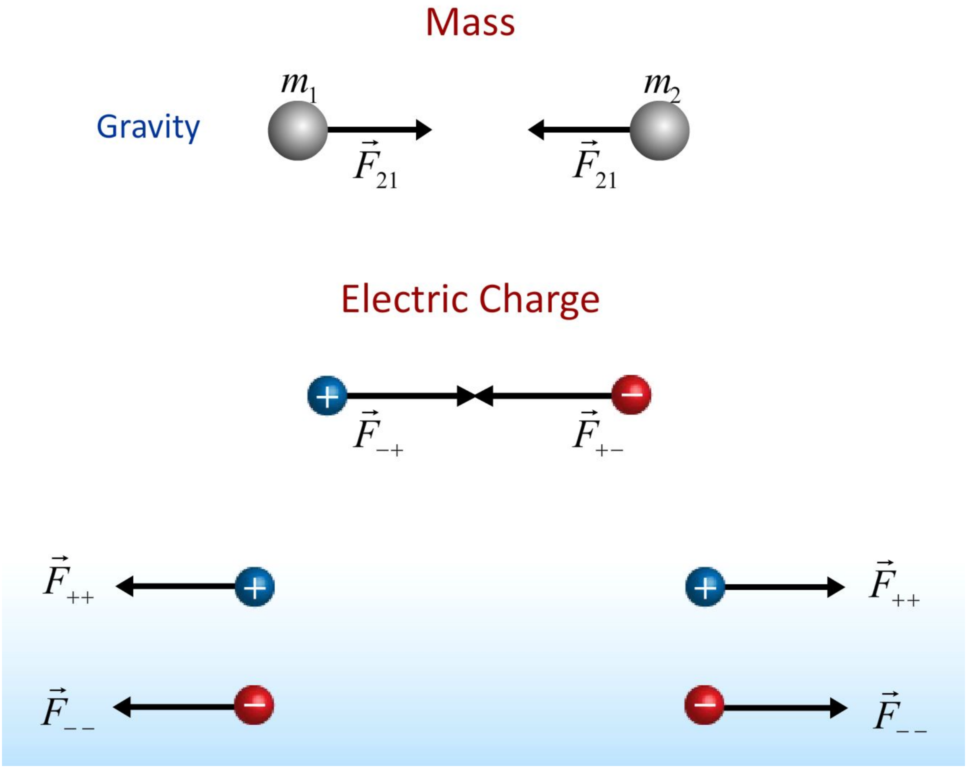
Electrostatic force between 2 charges

Newton's Third Law: $F_1 = - F_2$

Coulomb's Law (1785)

$$\vec{F}_{12} = k \frac{q_1 q_2}{r_{12}^2} \hat{r}_{12}$$



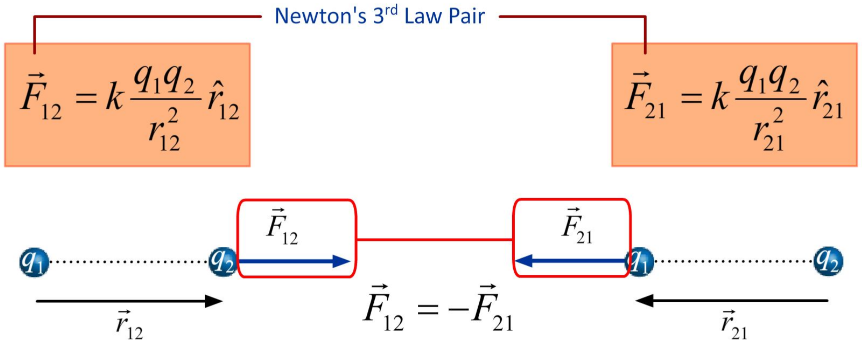


Superposition

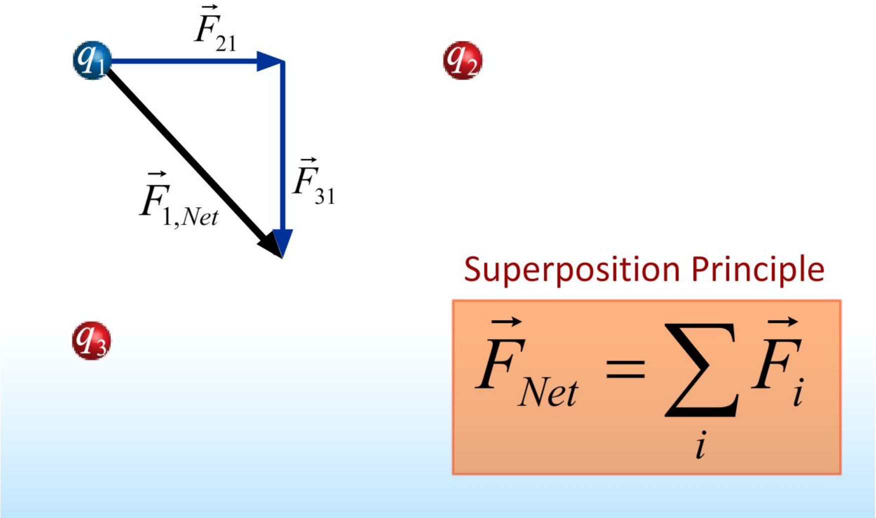
The total electric force on a charge

is the **sum of all the forces** exerted

by “n” charges on that one charge



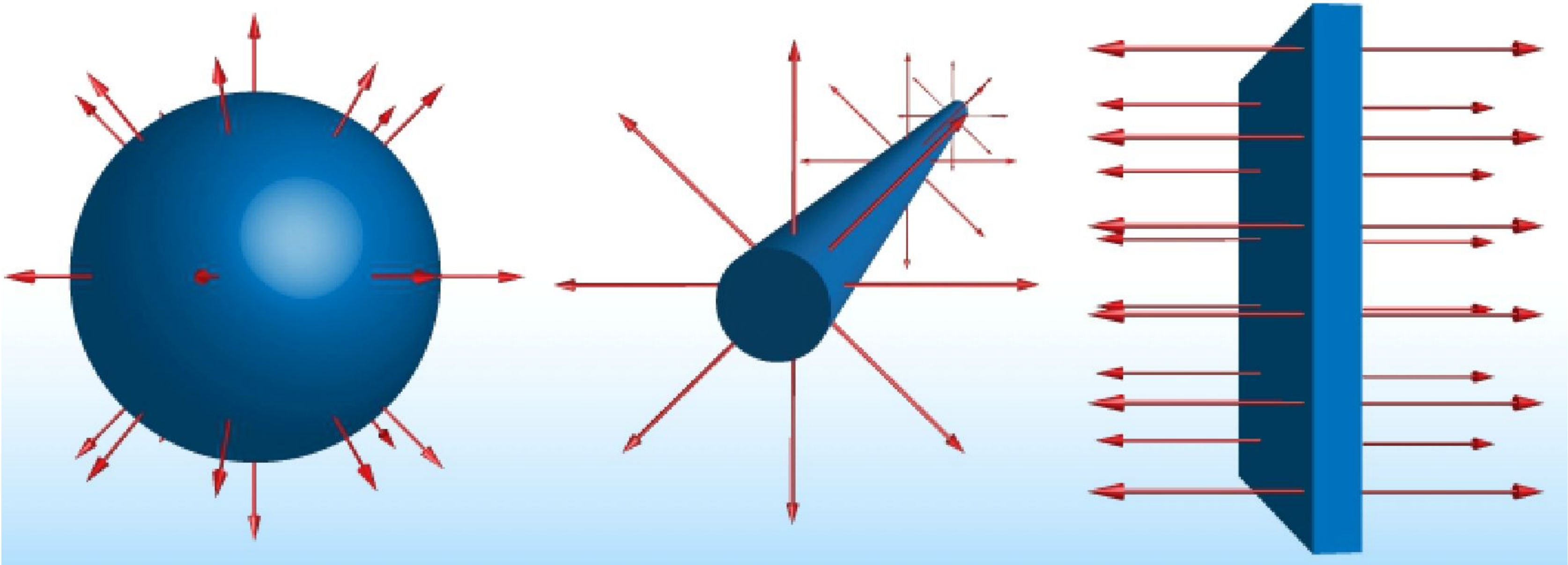
$$\vec{F}_{1,Net} = \vec{F}_{21} + \vec{F}_{31}$$



Electric Fields

3 main sources of electric fields:

Point Charges, Infinite Lines of Charge, and Infinite Sheets of Charge



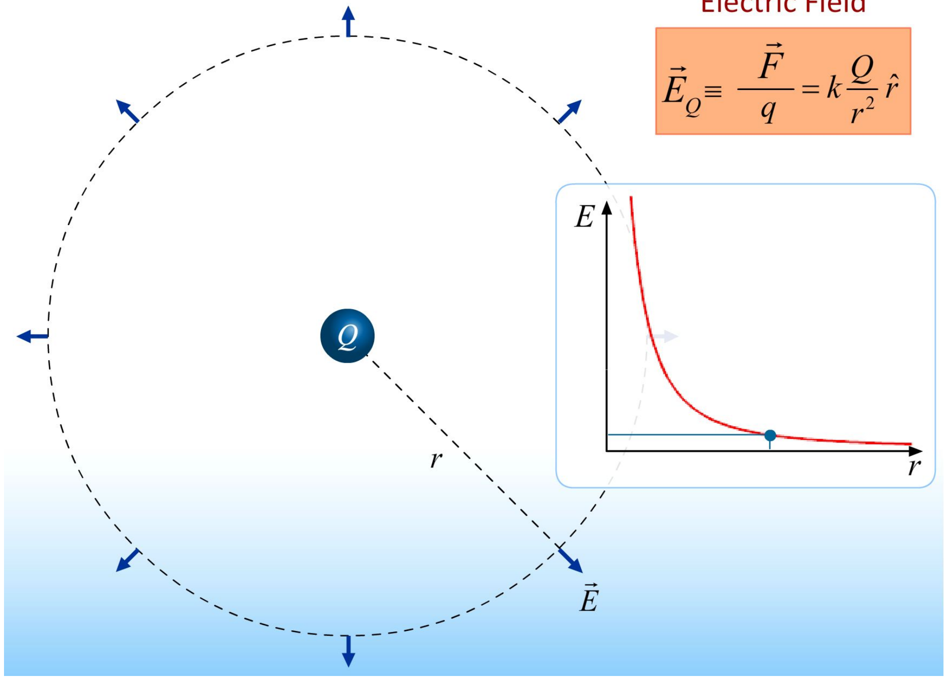
Point Charge

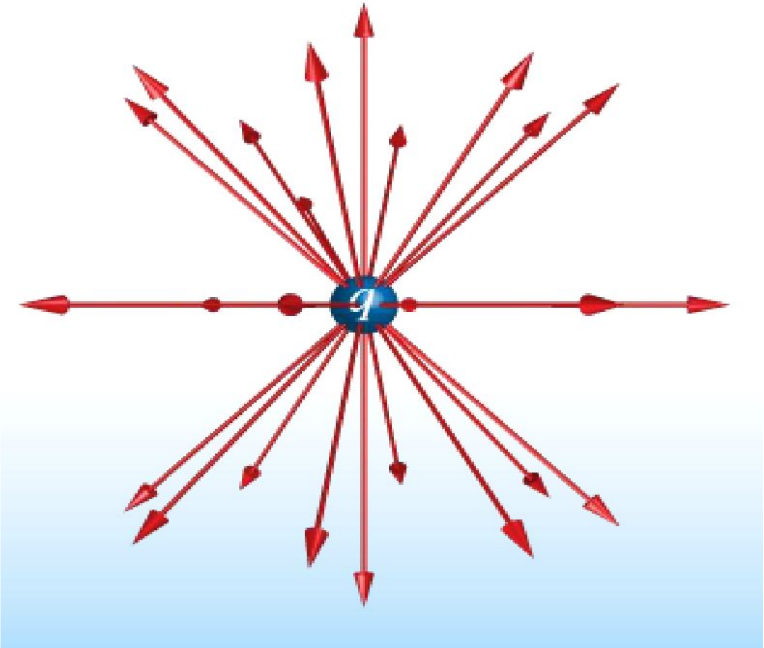
$$E = k\frac{q}{r^2}$$

3D symmetry - **magnitude depends on r²**

Electric Field

$$\vec{E}_Q \equiv \frac{\vec{F}}{q} = k\frac{Q}{r^2}\hat{r}$$





Infinite Line of Charge

2D symmetry - **magnitude depends on r**

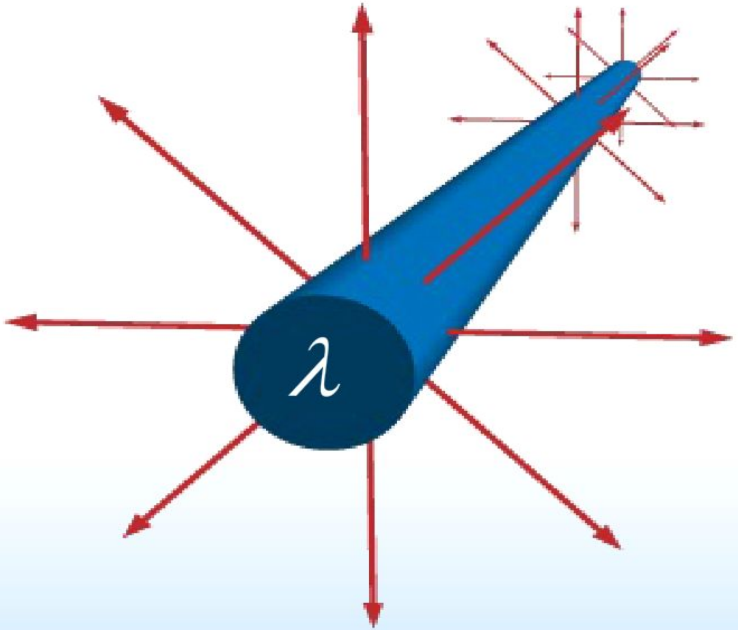
charge density - **λ = Q/L** (units: C/m)

Integral Setup Questions:

- Bounds are the **length** of the line of charge
- Inside the integral is of form **k(q/r²)**
- **dQ = λdx**

$$E_y = \int_{x=-\infty}^{x=\infty} dE_y \qquad E_y = \int_{x=-\infty}^{x=\infty} k\frac{dq}{s^2}\cos\theta = \int_{x=-\infty}^{x=\infty} k\frac{\lambda\,dx}{s^2}\cos\theta$$

$$E = 2k\frac{\lambda}{r}$$

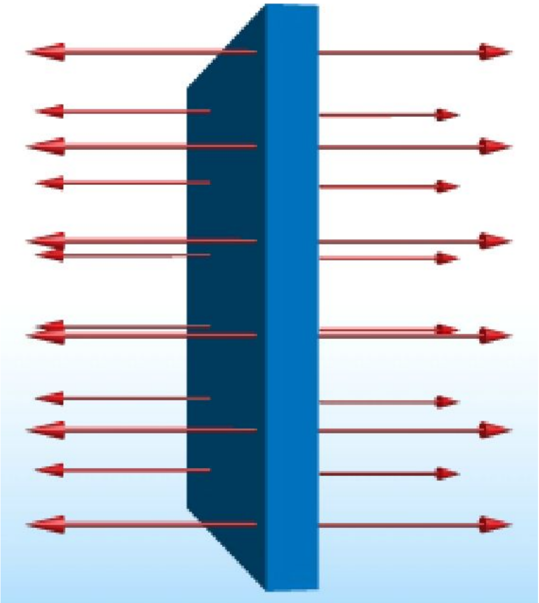


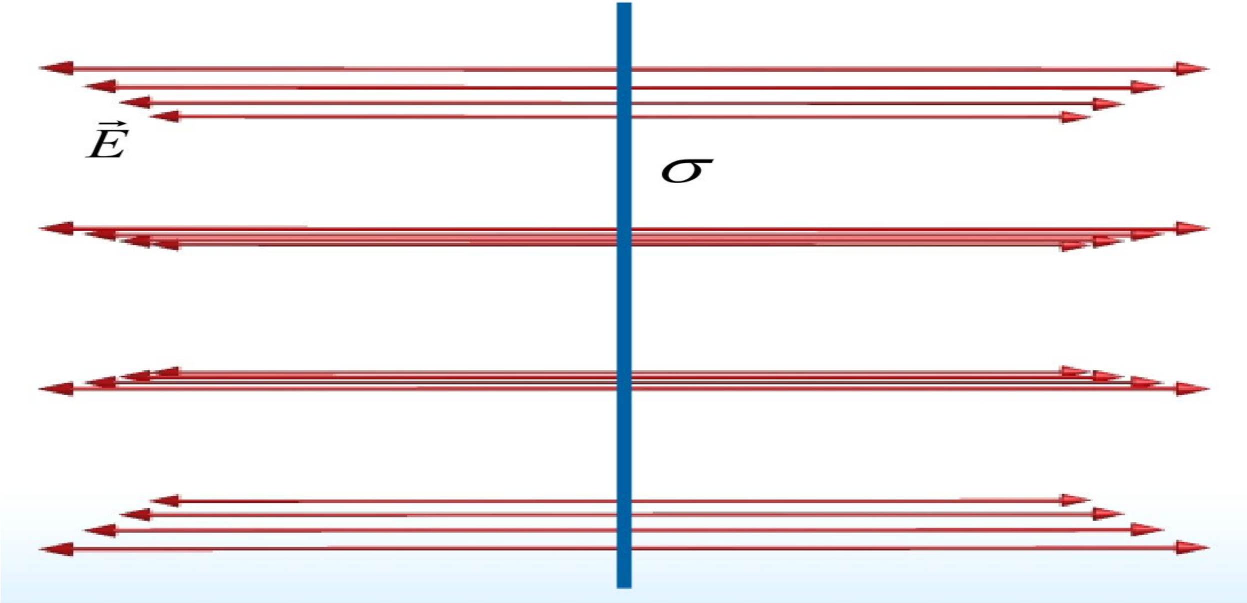
Infinite Sheet of Charge

1D symmetry - **magnitude has no dependance on r**

charge density - **σ = Q/A** (units: C/m^2)

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





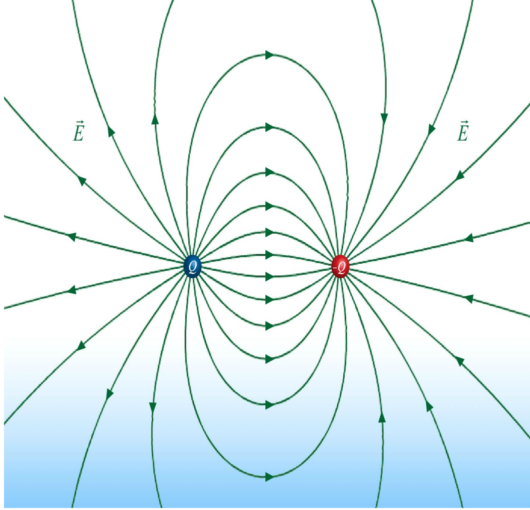
Electric Field Lines and Flux

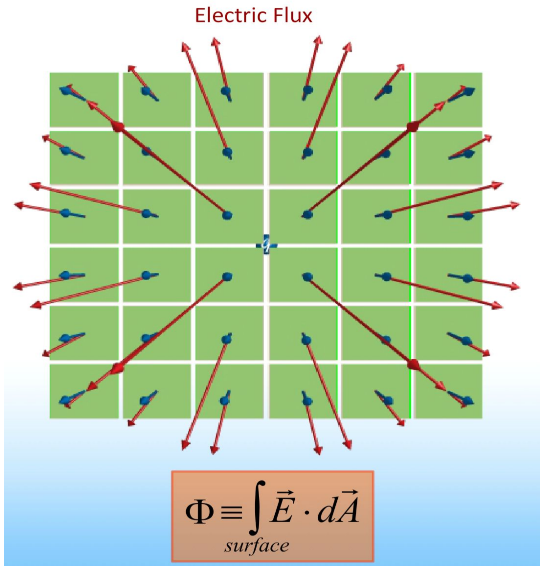
Density of field lines indicates electric field strength

- More dense lines => stronger electric field
- Less dense lines => weaker electric field
- **# of field lines is proportional to charge's magnitude**

Flux is the number of field lines that pass through a surface

- Positive flux points outwards
- Negative flux points inwards
- **Pay close attention** to Φ_{net} vs Φ_{left} or Φ_{right}





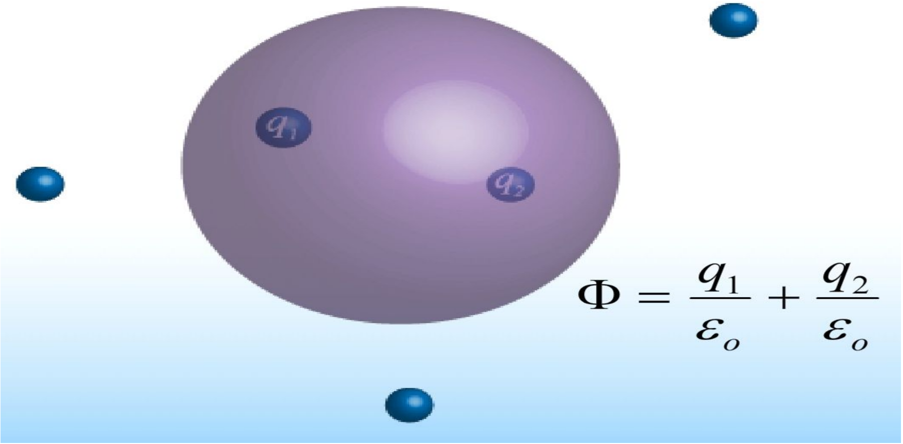
Gauss's Law

$$\Phi_{Net} = \oint_{surface} \vec{E} \cdot d\vec{A} = \frac{q_{enclosed}}{\varepsilon_o}$$

3 shapes have enough symmetry for easy

integration, so that we can get **E · A = Q$_{enc}$**

- Sphere (Point Charge)
- Cylinder (Infinite Line of Charge)
- Plane (Infinite Sheet of Charge)



Generally, a cylinder will be used but any symmetrical object would suffice (cube, sphere, etc.)

Gauss's Law says the number of field lines out of a surface is directly related to the charge(s) enclosed

Gauss's Law cont.

- A is the surface area of the **chosen Gaussian surface** (sphere, cylinder, cube, etc.)
- Charge denstitions (λ, σ, ρ) come from the **given physical object** we are working with

- We can use charge densities to find q_{enc}
  - $\boldsymbol{\lambda} = \mathbf{q_{enc}}$ **/ L** (L is length - m)
  - $\boldsymbol{\sigma} = \mathbf{q_{enc}}$ **/ A** (A is area - m^2)
  - $\boldsymbol{\rho} = \mathbf{q_{enc}}$ **/ V** (V is volume - m^3)

$$\Phi_{Net} = \oint_{surface} \vec{E} \cdot d\vec{A} = \frac{q_{enclosed}}{\varepsilon_o}$$

Conductors

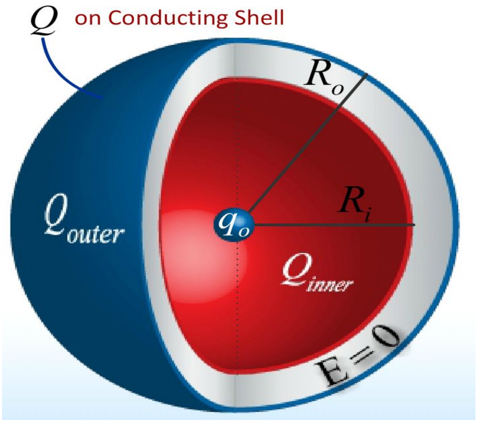
Electric field inside a conductor is **ALWAYS 0,** since all the charge goes the surface

For charges inside a conducting shell:

- **Q_{inner} = opposite value of the center charge**
- **Q_{outer} = value of the charge on the surface + value of the center charge**

$$Q_{inner} = -q_o$$

$$Q_{outer} = Q + q_o$$



Insulators

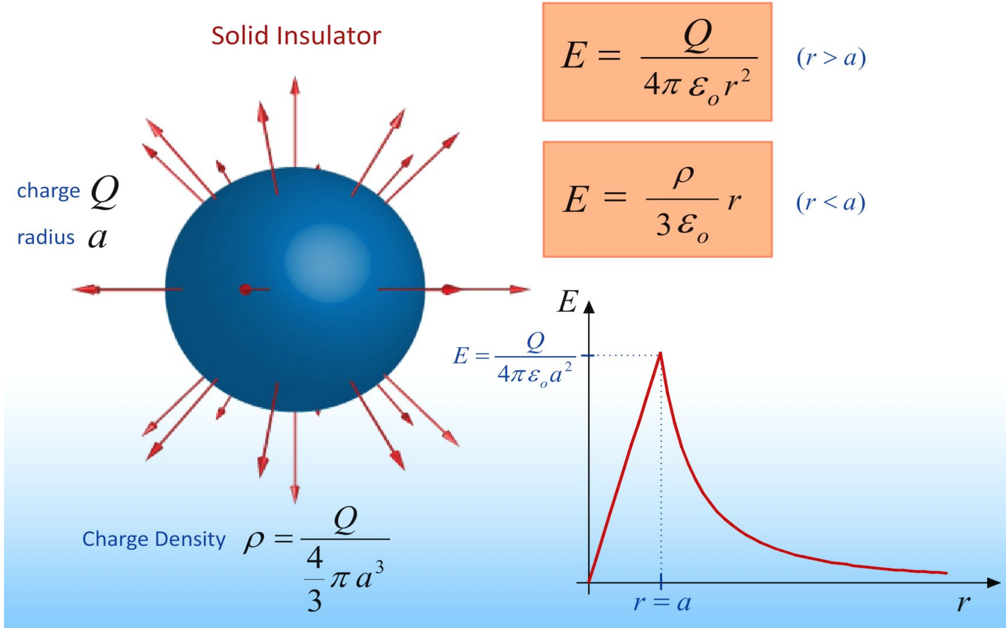
Charge is **uniformly (equally) distributed** throughout the entire insulator

The net charge inside an insulator behaves differently than outside the insulator

Outside - behaves like a point charge

Inside - behaves linearly

- **Memorize second equation**
- **Saves you time from deriving it**



Electric Potential Energy (Units: J)

Solving Systems of Particle Problems

1. $U_1 = 0$, for whatever particle you chose first
2. $U_2 = kq_2q_1 / (d_{21})$
3. $U_3 = kq_3q_1 / (d_{31}) + kq_3q_2 / (d_{32})$
4. Repeat process for all additional charge pairs and sum them up ($U_1 + U_2 + U_3$ +... U_n) to get U_{sys}
5. **Remember that W = - U**

$$U_{12} = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r_{12}}$$

Electric Potential (Voltage - Units: V=J/C)

Energy required to move a positive test charge through a constant electric field

- **$V_{point\ charge}$ = U / q (where little q is the test charge)**

Electric Potential Difference

$$\Delta V_{A \to B} = -\int_A^B \vec{E} \cdot d\vec{l}$$

Equipotential Lines:

- Perpendicular to electric field lines
- Electric field lines always point from higher to lower electric potential
- **More dense lines => Stronger electric potential**
- **Equal electric potential along on the same equipotential lines**

Capacitance (Units: Farads - F)

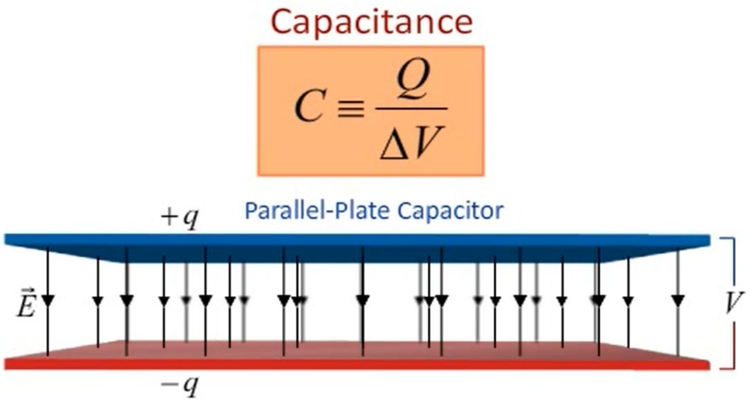
Capacitance primarily depends on the **geometry**

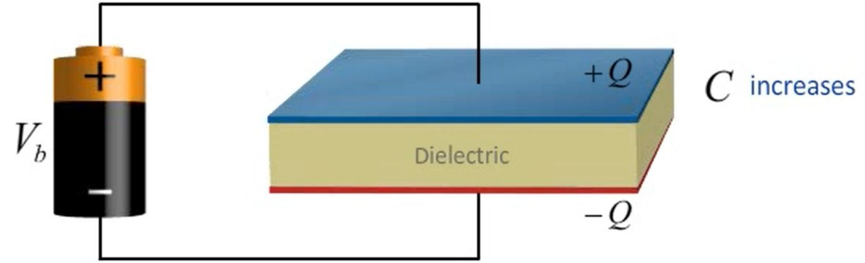
$$C = \frac{\kappa \epsilon_0 A}{d}$$

Units - Farads (F)

Energy of a capacitor: $U = 0.5CV^2$

Dielectric - adding a dielectric to a capacitor increases its capacitance





Capacitors in Series/Parallel

Series - $1/C_1 + 1/C_2 + 1/C_3 + \ldots 1/C_n = 1/C_{total}$

***Shortcut (Product over Sum)**: only works with **2 capacitors at a time**, repeat process for all capacitors until C_{total}

$(C_1 \times C_2) / (C_1 + C_2) = C_{1,2}$ ==> **Multiply C_1 and C_2 (product) and divide by their sum**

Parallel - just add them up

$C_1 + C_2 + C_3 + \ldots C_n = C_{total}$