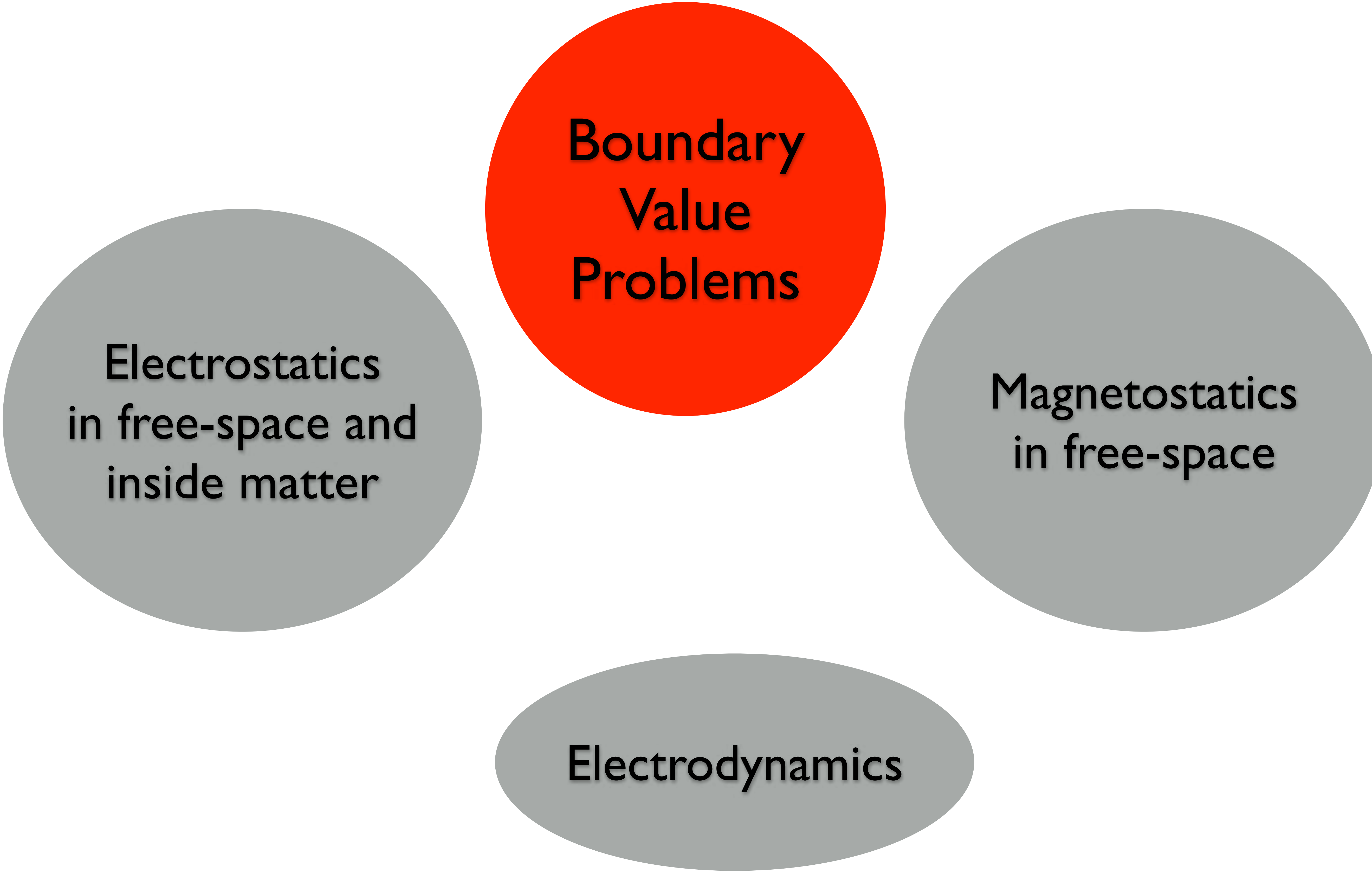
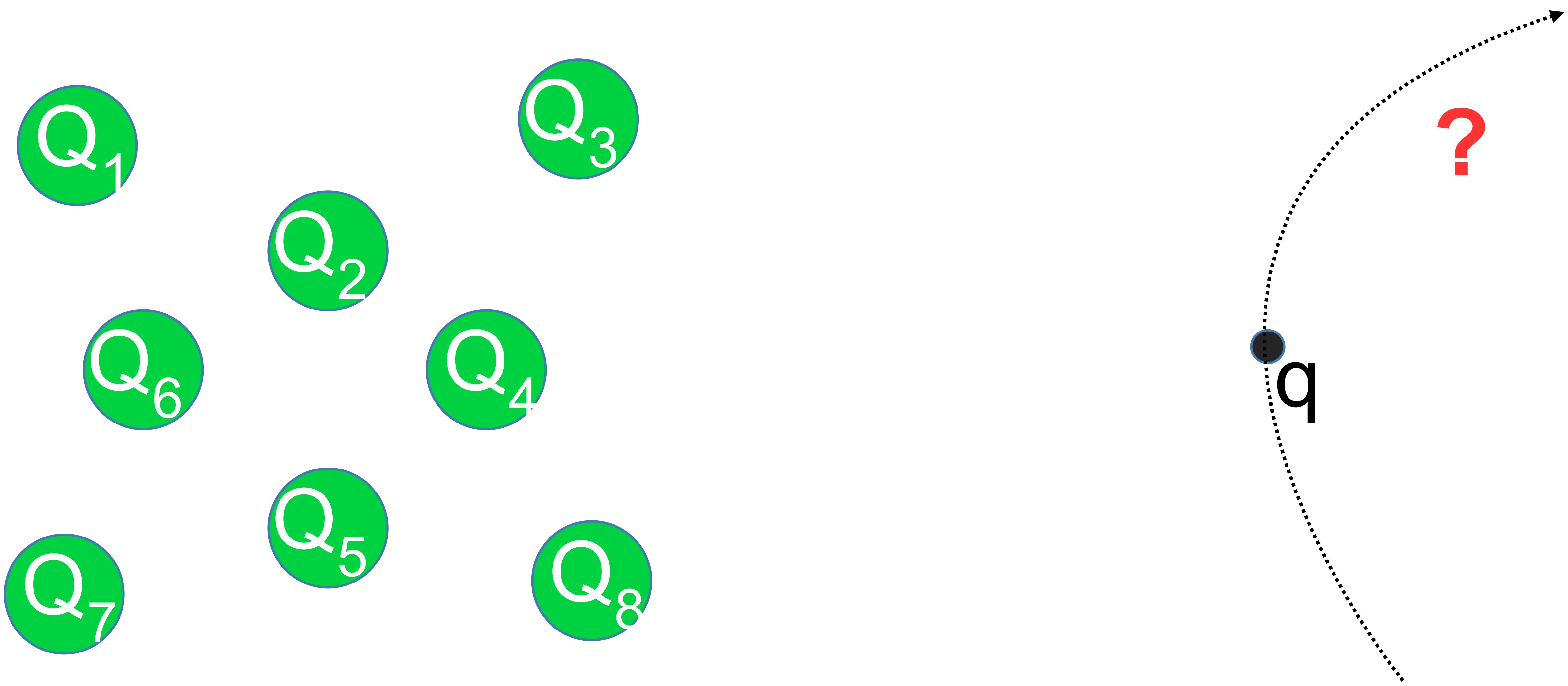
Introductory course where we will deal with electricity and magnetism



The Central Question

Given any configuration of source charges (in space and time) what force do they exert on another charge (the test charge)?



Principle of Superposition

The interaction of any two charges is completely unaffected by the presence of other charges.

The net force on a charge is the vector sum of the individual forces due to all the source charges.

$$\overrightarrow{F}_q = \overrightarrow{F}_1 + \overrightarrow{F}_2 + \cdots + \overrightarrow{F}_N = \sum_{i=1}^{N} \overrightarrow{F}_i$$

The interaction between two charges: What does it depend on??

Magnitude of the charges

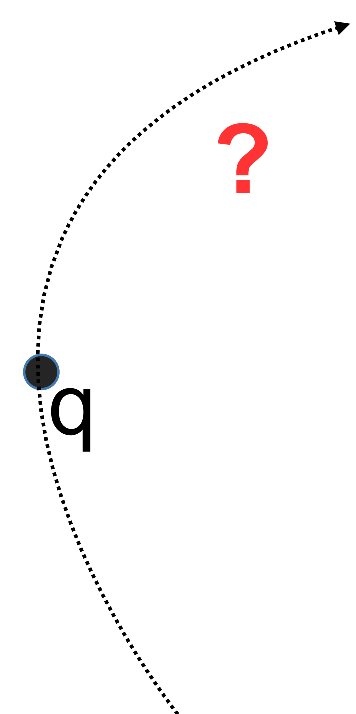
Separation distance between the charges

Velocities of the charges

Acceleration of the source charge

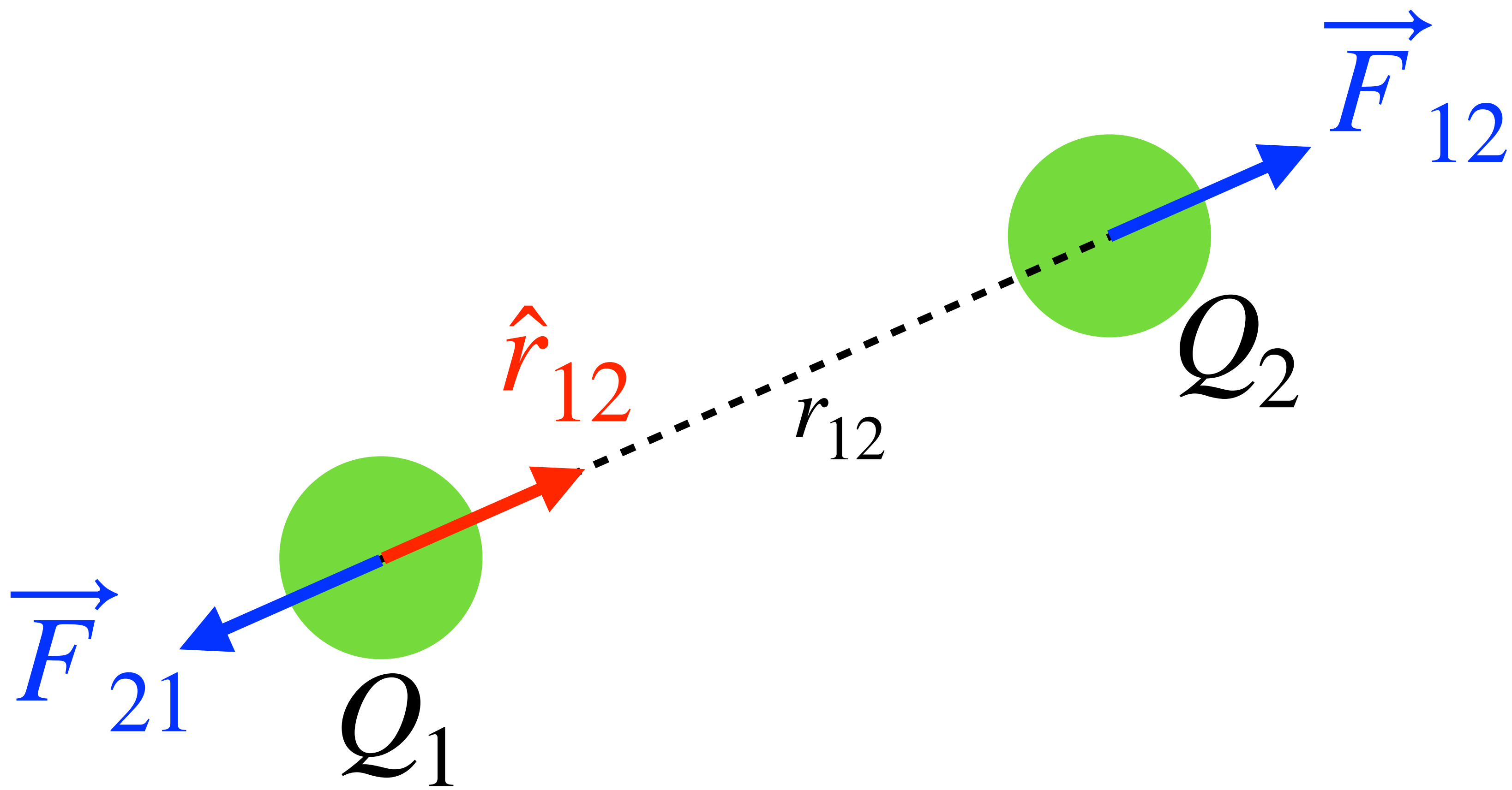
At a past instant of time!
(Electromagnetic radiation travels at the speed of light)

We will first consider a simpler problem!



ELECTROSTATICS

Coulomb Force Law



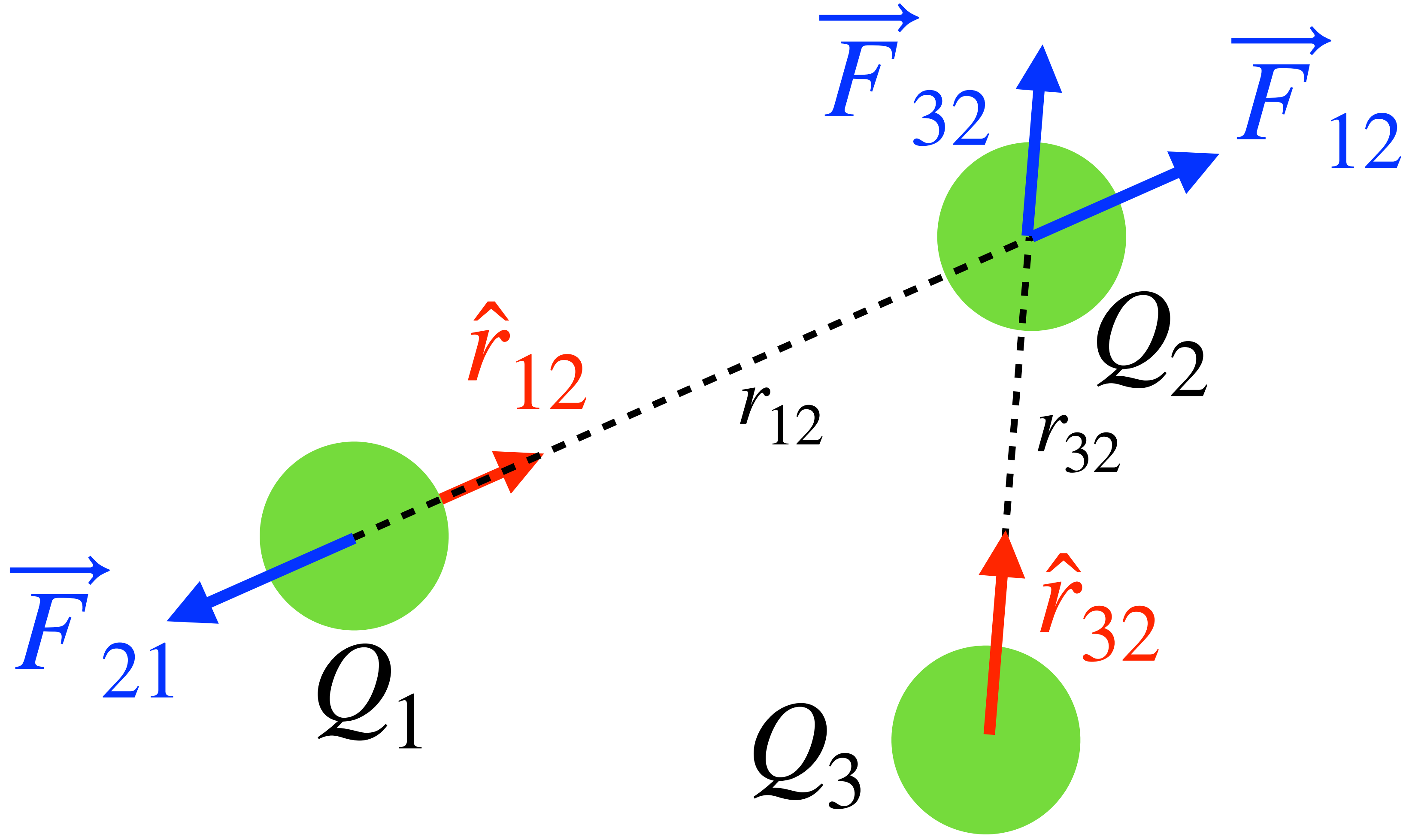
$$r_{12} = |\vec{r}_{12}|$$

$$\overrightarrow{F}_{12} = \frac{1}{4\pi\epsilon_0}\frac{Q_1 Q_2}{r_{12}^2}\hat{r}_{12}$$

$$q_e \sim 1.6 \times 10^{-19}\mathrm{C}$$

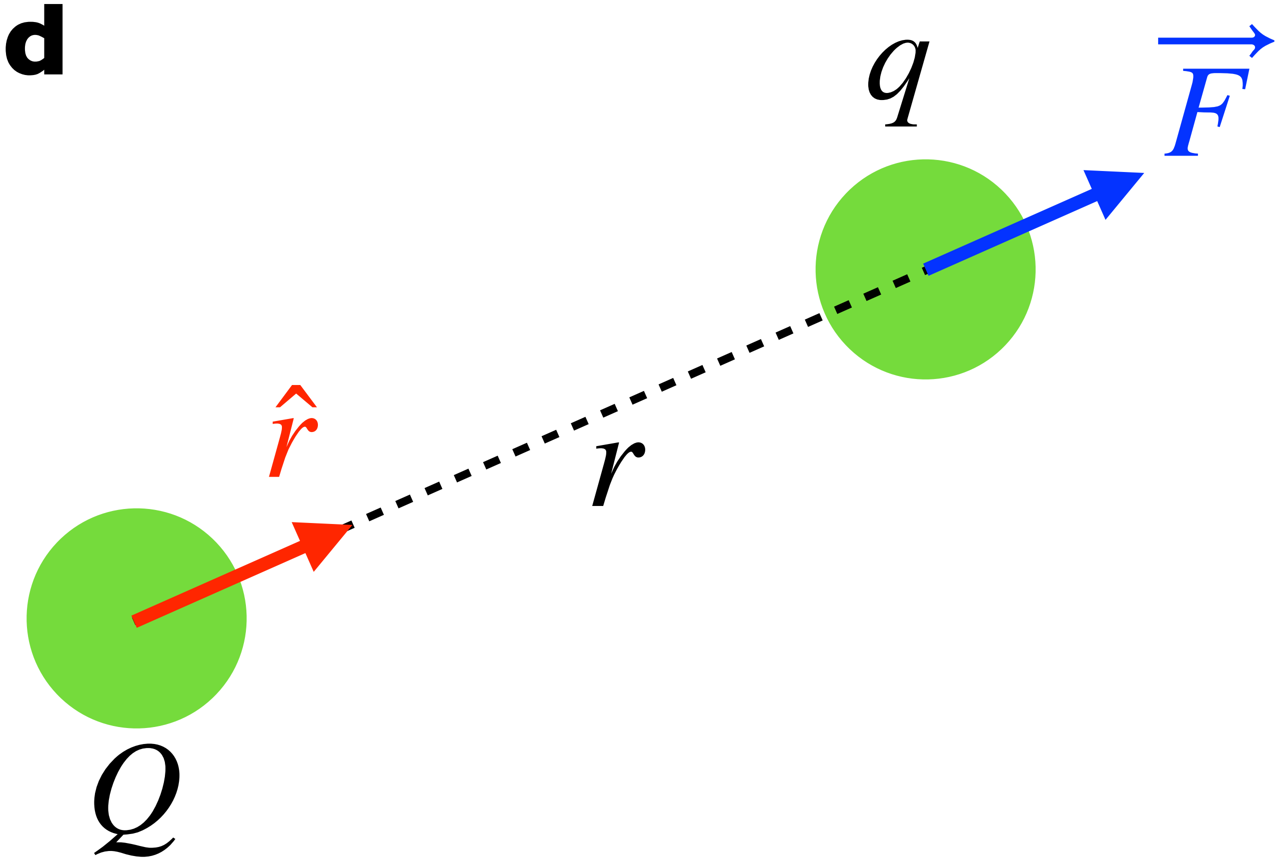
$$\frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \frac{\mathrm{Nm}^2}{\mathrm{C}^2}$$

Coulomb Force Law + Superposition



$$\overrightarrow{F}_2 = \overrightarrow{F}_{12} + \overrightarrow{F}_{32}$$

Electric Field



$$\overrightarrow{F} = \frac{1}{4\pi\epsilon_0}\frac{qQ}{r^2}\hat{r}$$

$$\overrightarrow{E} = \frac{\overrightarrow{F}}{q} = \frac{1}{4\pi\epsilon_0}\frac{Q}{r^2}\hat{r}$$

CLASSICAL FIELD THEORIES

A field is a physical quantity that has a value for each point in space and time.

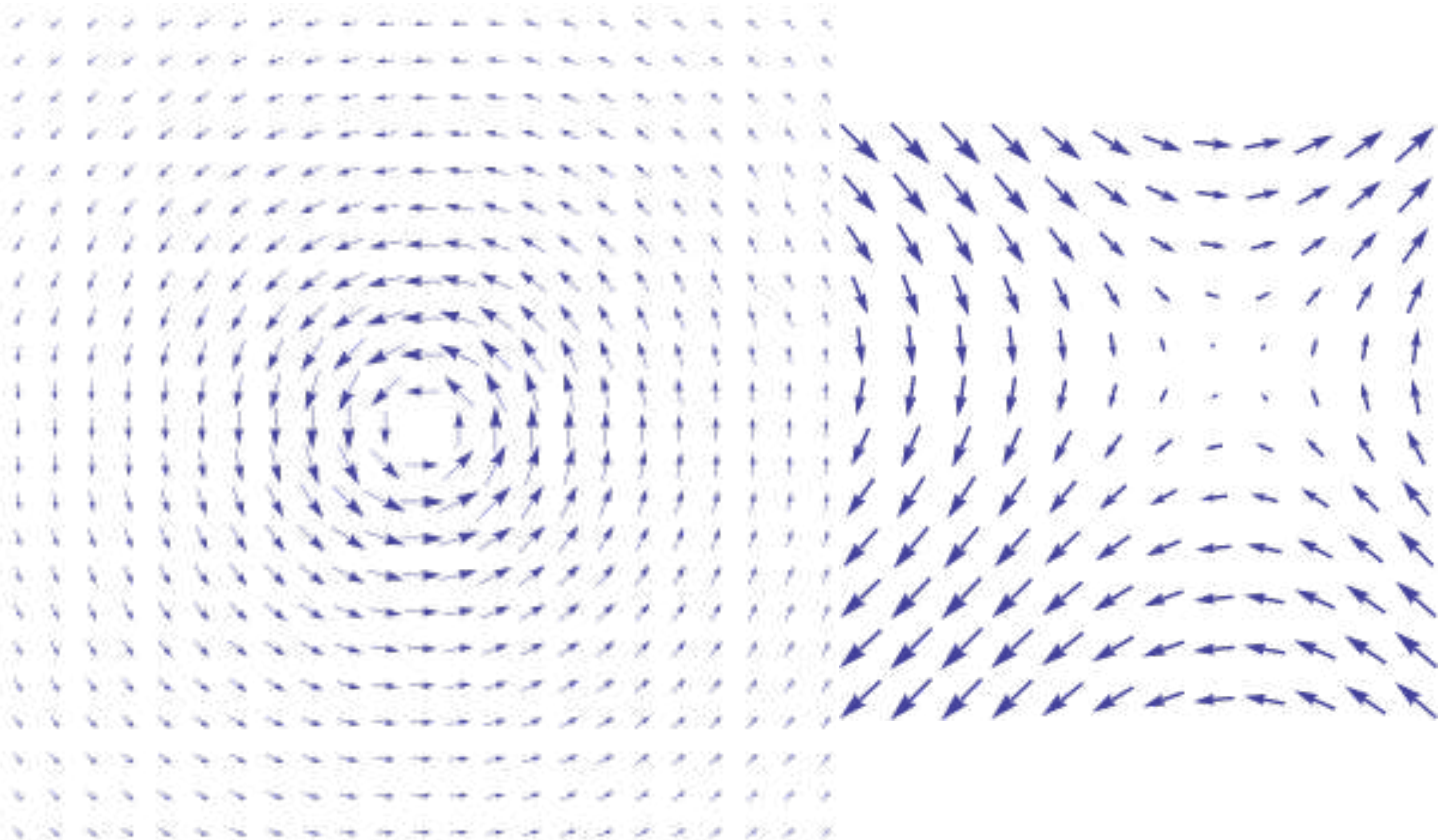
Scalar field: Temperature T(x,y,z)
Vector fields: Electric field, Magnetic Field, Velocity Field
Tensor field: Stress/strain tensor field

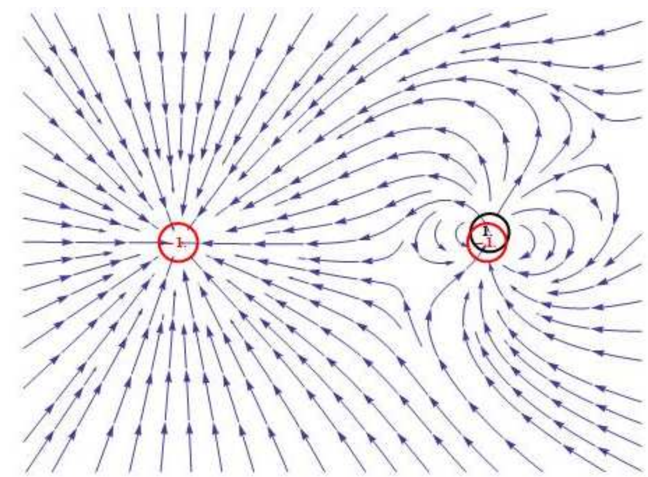
A classical field theory describes how physical fields interact with matter through field equations.

Newtonian gravity / Electrodynamics / Hydrodynamics
General theory of relativity
Quantum field theory / Quantum electrodynamics

Particles and fields both carry energy and momentum.

Mathematics of Vector Fields





Differential calculus of fields – Gradient, divergence, curl

Integral calculus of fields – Line, surface and volume integrals

Fundamental theorems – Gauss’ Theorem, Stokes Theorem

Maxwell's Equations

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon_0}$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{B} = \mu_0 \mathbf{j} + \frac{1}{c^2} \frac{\partial \mathbf{E}}{\partial t}.$$