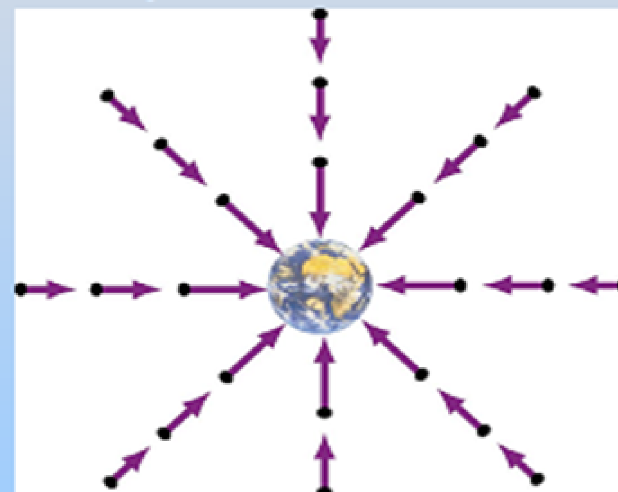
Example of vector Field Gravitation

Gravitational Force:

$$\vec{\mathbf{F}}_g = -G\frac{Mm}{r^2}\hat{\mathbf{r}}$$

Gravitational Field:

$$\vec{\mathbf{g}} = \frac{\vec{\mathbf{F}}_g}{m} = -\frac{GMm/r^2}{m}\hat{\mathbf{r}} = -G\frac{M}{r^2}\hat{\mathbf{r}}$$



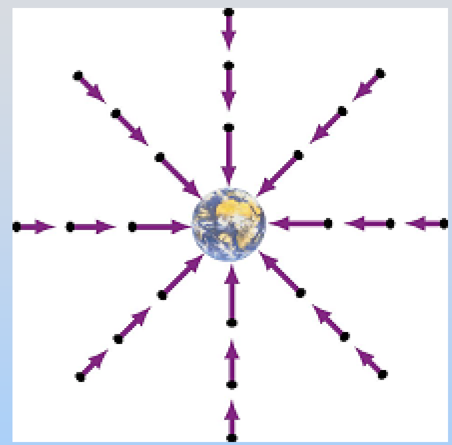
Example of vector Field Gravitation

Example Of Vector Field: Gravitation

Gravitational Field:

$$\vec{\mathbf{g}} = -G\frac{M}{r^2}\hat{\mathbf{r}} \qquad \vec{\mathbf{F}}_g = m\vec{\mathbf{g}}$$

Created by M *Felt* by m



$\hat{\mathbf{r}}$: unit vector from M to m

M : Mass of Earth

$$\hat{\mathbf{r}} = \frac{\vec{\mathbf{r}}}{r} \quad \Rightarrow \vec{\mathbf{g}} = -G\frac{M}{r^3}\vec{\mathbf{r}}$$

Electric charge

Two types of electric charge: positive and negative

Unit of charge is the ***coulomb*** [C]

Charge of electron (negative) or proton (positive) is

$$\pm e, \quad e = 1.602 \times 10^{-19}\, C$$

Charge is quantized

$$Q = \pm N e$$

Charge is conserved

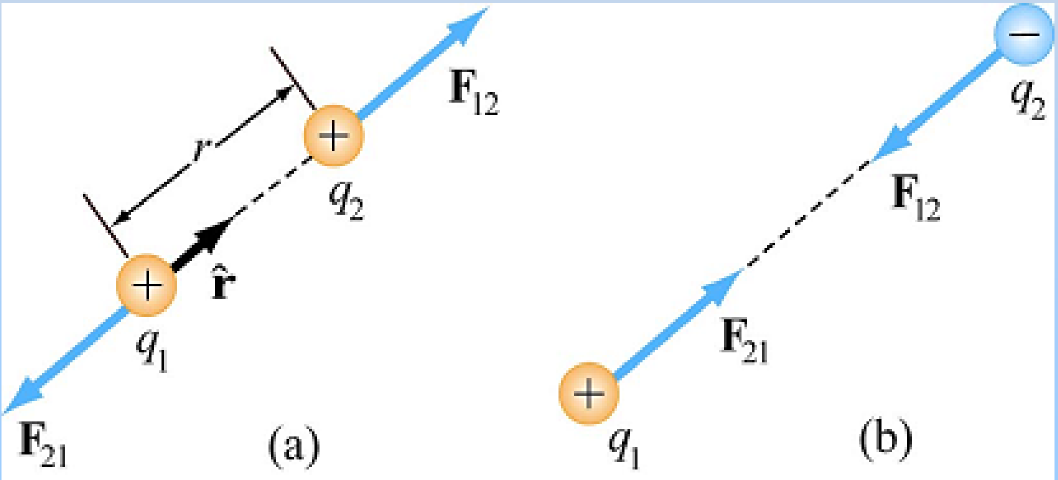
$$n \rightarrow p + e^- + \bar{\nu} \qquad e^+ + e^- \rightarrow \gamma + \gamma$$

Electric Force

The electric force between charges q_1 and q_2 is

(a) repulsive if charges have same signs

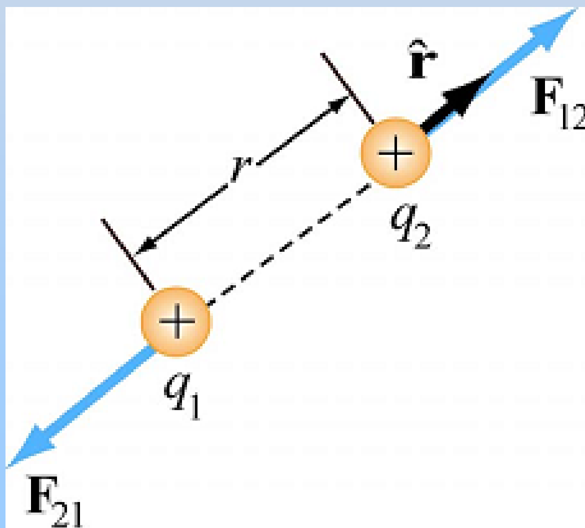
(b) attractive if charges have opposite signs



COULOMB'S LAW

Coulomb's Law:
Force by q_1 on q_2

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



$$k_e = \frac{1}{4\pi\varepsilon_0} = 8.9875\times10^9 \text{ N m}^2/\text{C}^2$$

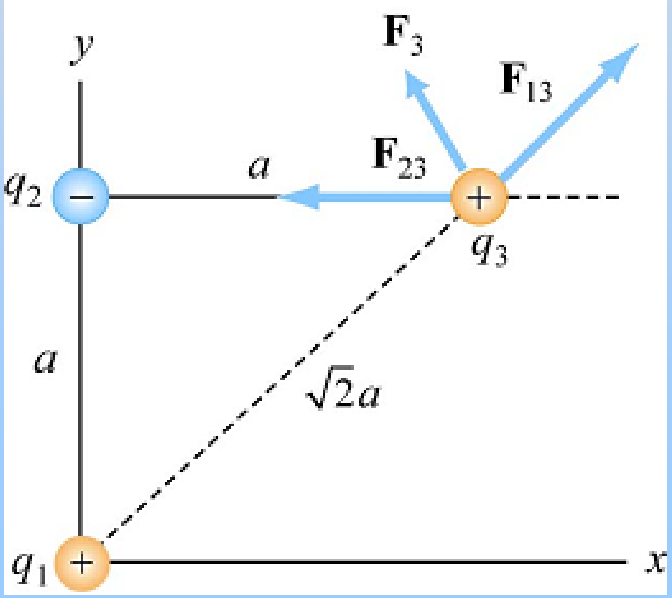
$\hat{\mathbf{r}}$: unit vector from q_1 to q_2

$$\hat{\mathbf{r}} = \frac{\vec{\mathbf{r}}}{r} \Rightarrow \vec{\mathbf{F}}_{12} = k_e \frac{q_1 q_2}{r^3}\vec{\mathbf{r}}$$

The Superposition Principle

Many Charges Present:
Net force on any charge is vector sum of forces from other individual charges

Example:



$$\vec{F}_3 = \vec{F}_{13} + \vec{F}_{23}$$

In general:

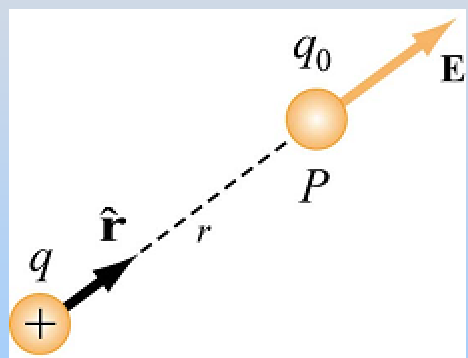
$$\vec{F}_j = \sum_{i=1}^{N} \vec{F}_{ij}$$

Electric Field

Electric Field (~g)

The electric field at a point is the force acting on a test charge q_0 at that point, divided by the charge q_0 :

$$\vec{\mathbf{E}} \equiv \frac{\vec{\mathbf{F}}}{q_0}$$

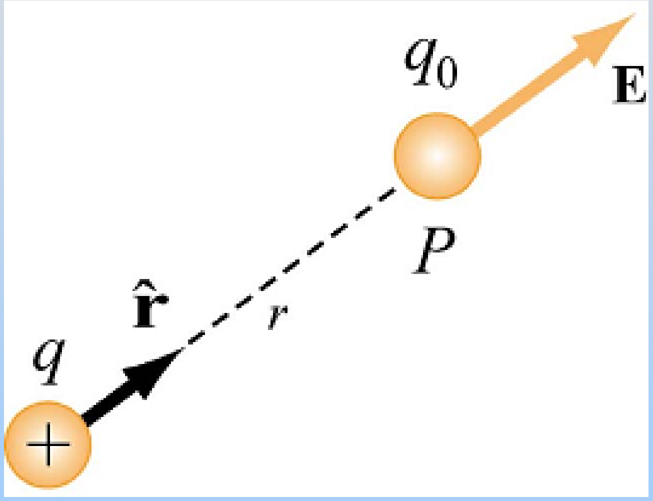


For a point charge q:

$$\vec{\mathbf{E}} = k_e \frac{q}{r^2} \hat{\mathbf{r}}$$

Electric Field of point charge

An electric charge produces an electric field:



$$\vec{\mathbf{E}} = \frac{1}{4\pi\varepsilon_o}\frac{q}{r^2}\hat{\mathbf{r}}$$

$\hat{\mathbf{r}}$: unit vector directed from q to *P*

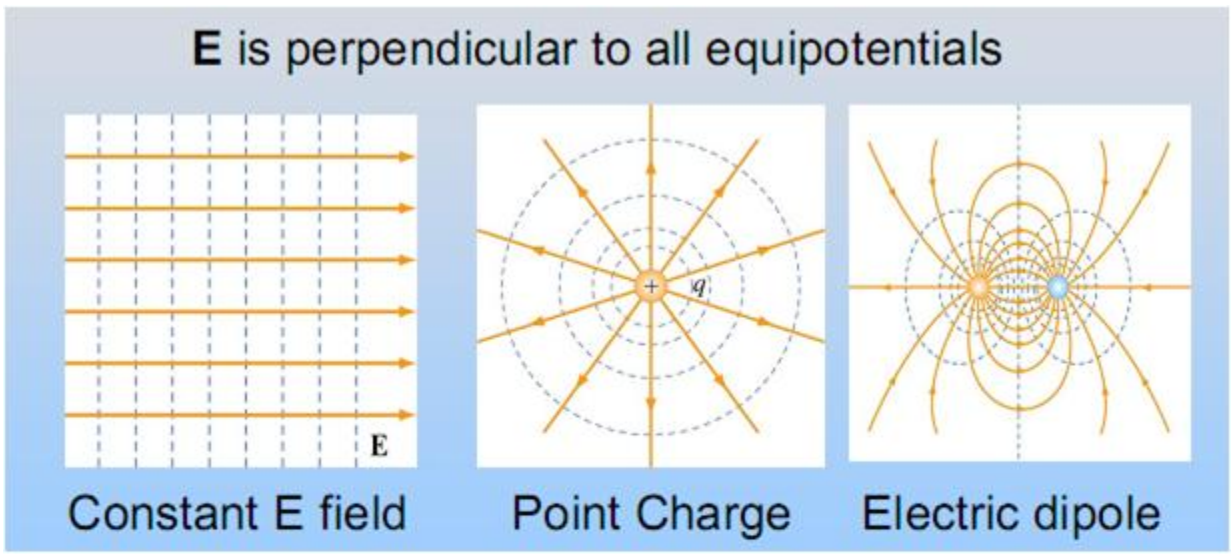
Superposition Principle

Superposition Principle

The electric field due to a collection of *N* point charges is the vector sum of the individual electric fields due to each charge

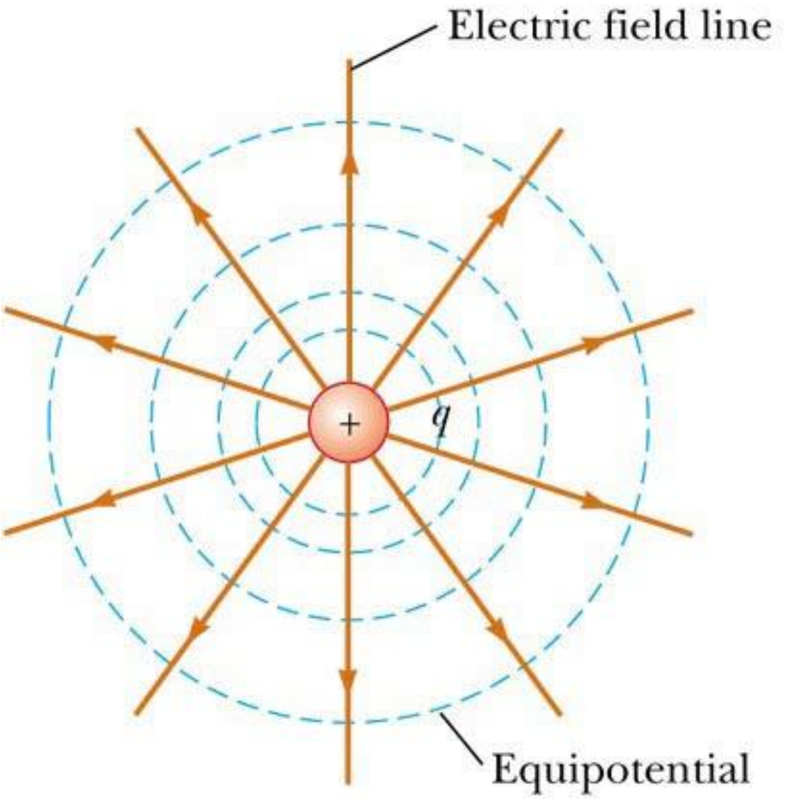
$$\vec{\mathbf{E}}_{total} = \vec{\mathbf{E}}_1 + \vec{\mathbf{E}}_2 + \ldots\ldots = \sum_{i=1}^{N} \vec{\mathbf{E}}_i$$

Direction of Electric Field E



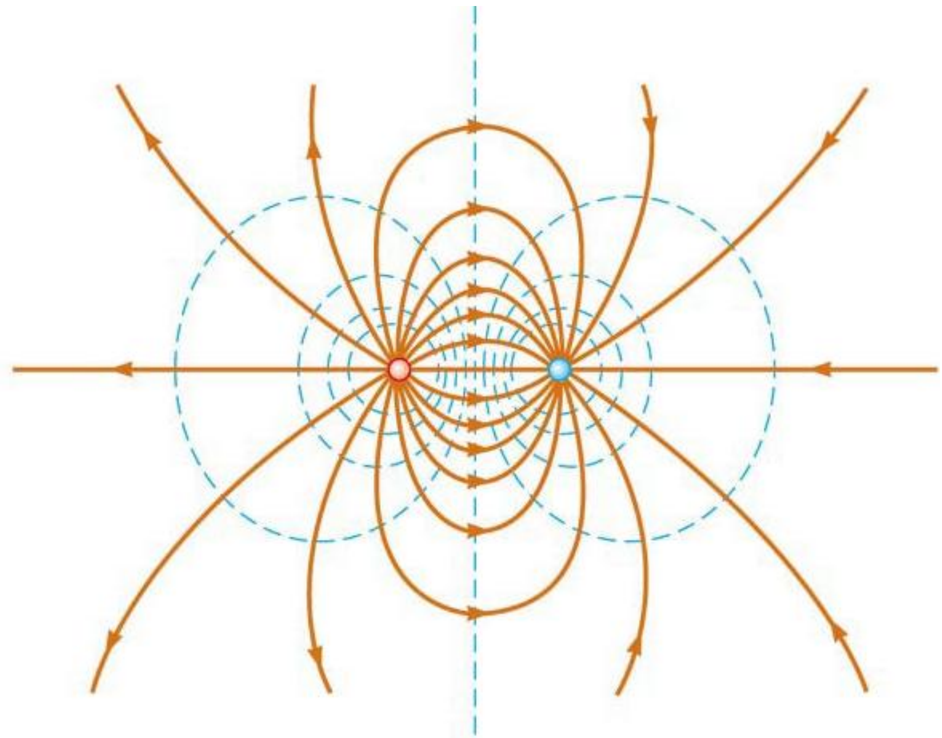
Equipotentials and Electric Fields Lines (Positive Charge):

- The equipotentials for a point charge are a family of spheres centered on the point charge
- The field lines are perpendicular to the electric potential at all points



Equipotentials and Electric Fields Lines (Dipole):

- Equipotential lines are shown in blue
- Electric field lines are shown in orange
- The field lines are perpendicular to the equipotential lines at all points



Summary

Summary Thus Far

	Mass M	Charge q (±)
CREATE:	$\vec{\mathbf{g}} = -G\dfrac{M}{r^2}\hat{\mathbf{r}}$	$\vec{\mathbf{E}} = k_e\dfrac{q}{r^2}\hat{\mathbf{r}}$
FEEL:	$\vec{\mathbf{F}}_g = m\vec{\mathbf{g}}$	$\vec{\mathbf{F}}_E = q\vec{\mathbf{E}}$

This is easiest way to picture field