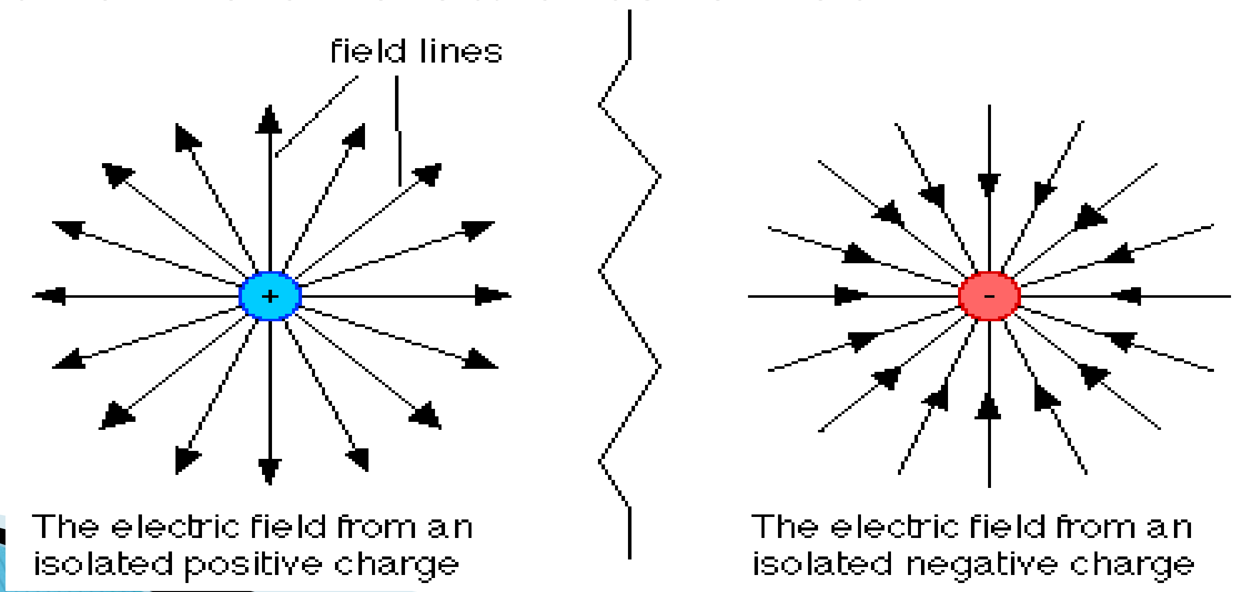
Electric Field

The electric force is a field force, it applies force without touching (like the gravitational force)

In the region around a charged object, an *Electric Field* is said to exist



Electric Field

Rules for Drawing Electric Field Lines

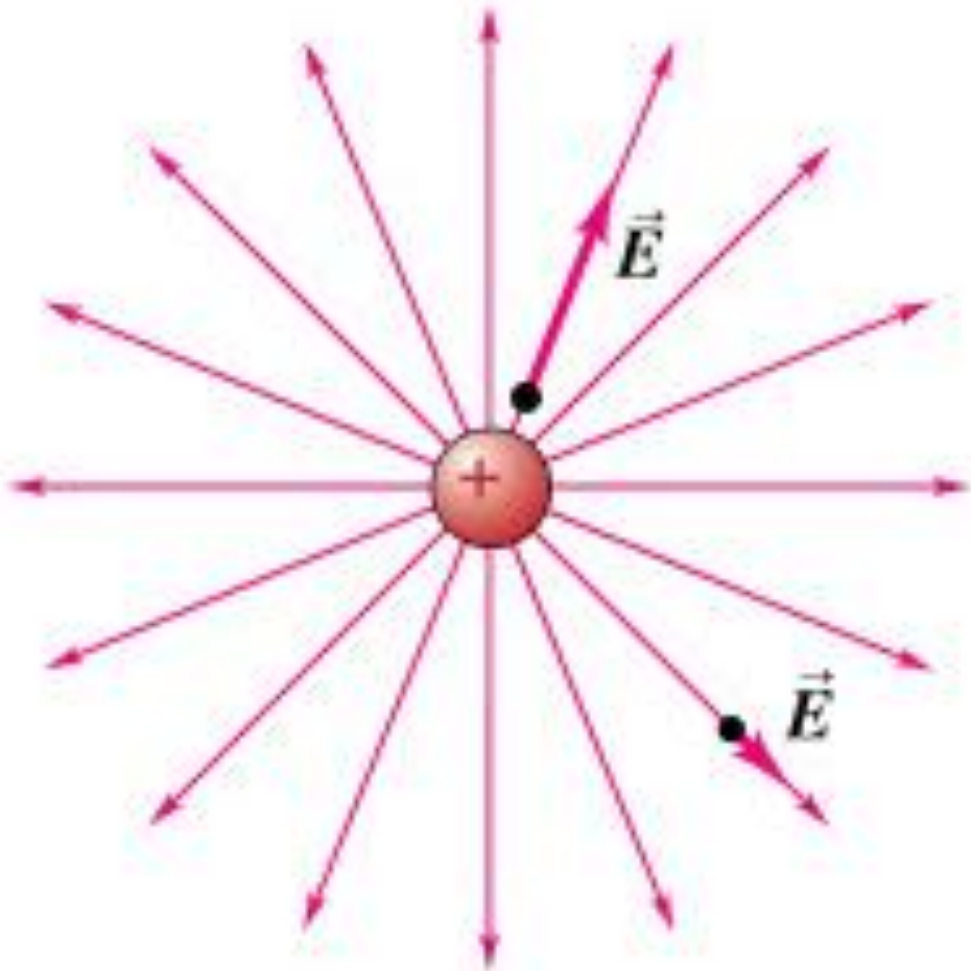
1. The lines must originate on a positive charge (or infinity) and end on a negative charge (or infinity).
2. The number of lines drawn leaving a positive charge or approaching a negative charge is proportional to the magnitude of the charge.
3. No two field lines can cross each other.
4. The line must be perpendicular to the surface of the charge

Rules for Drawing Electric Field Lines (Cont...)

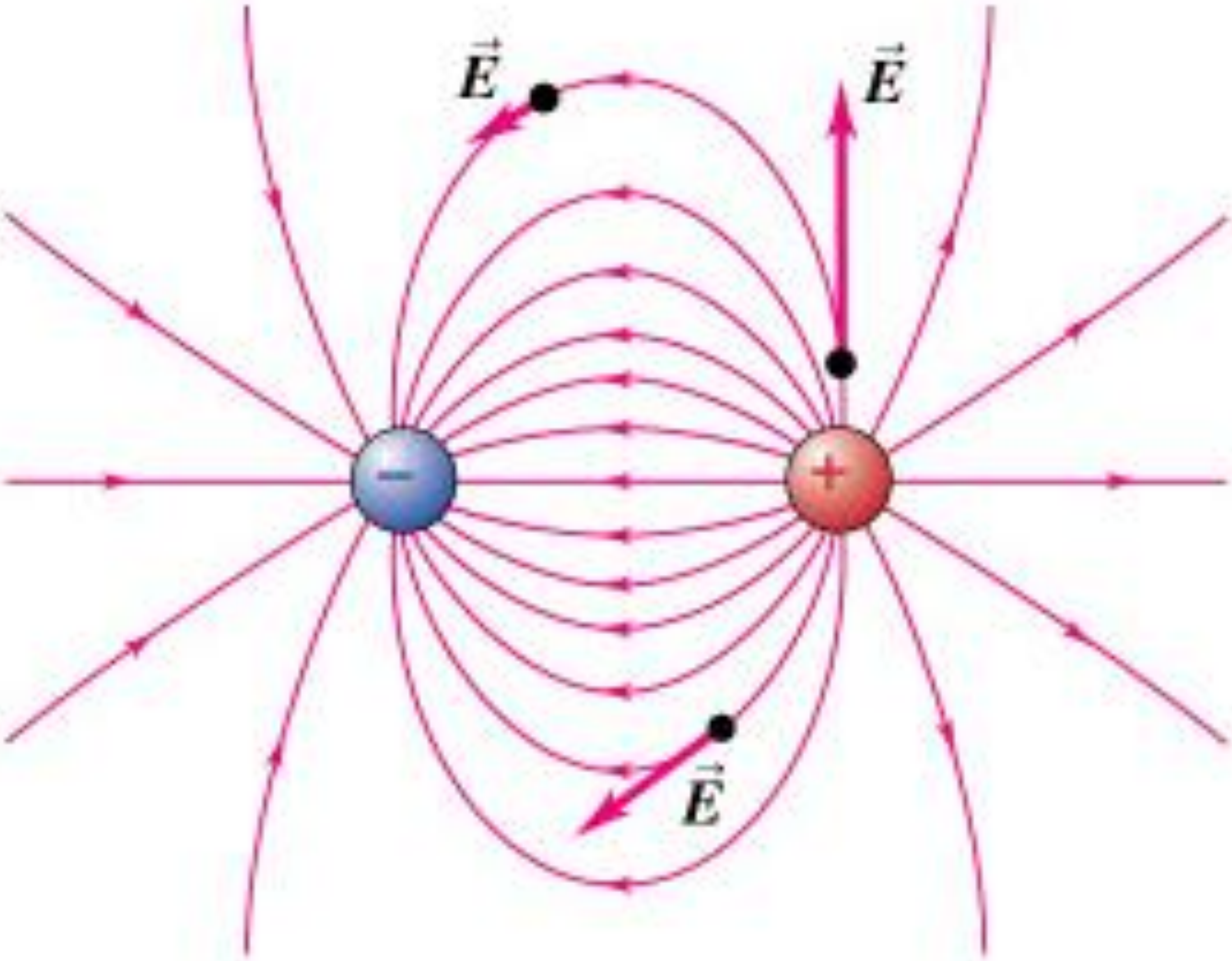
- The tangent to the field lines give the direction of electric intensity.
- Field lines never meet.
- We can draw lines through every point on the field.
- No field lines pass through a conductor.
- The field lines expand sidewise. This helps to understand repulsion.
- The field lines contract lengthwise This helps to understand attraction.

Conductors in Electrostatic Equilibrium

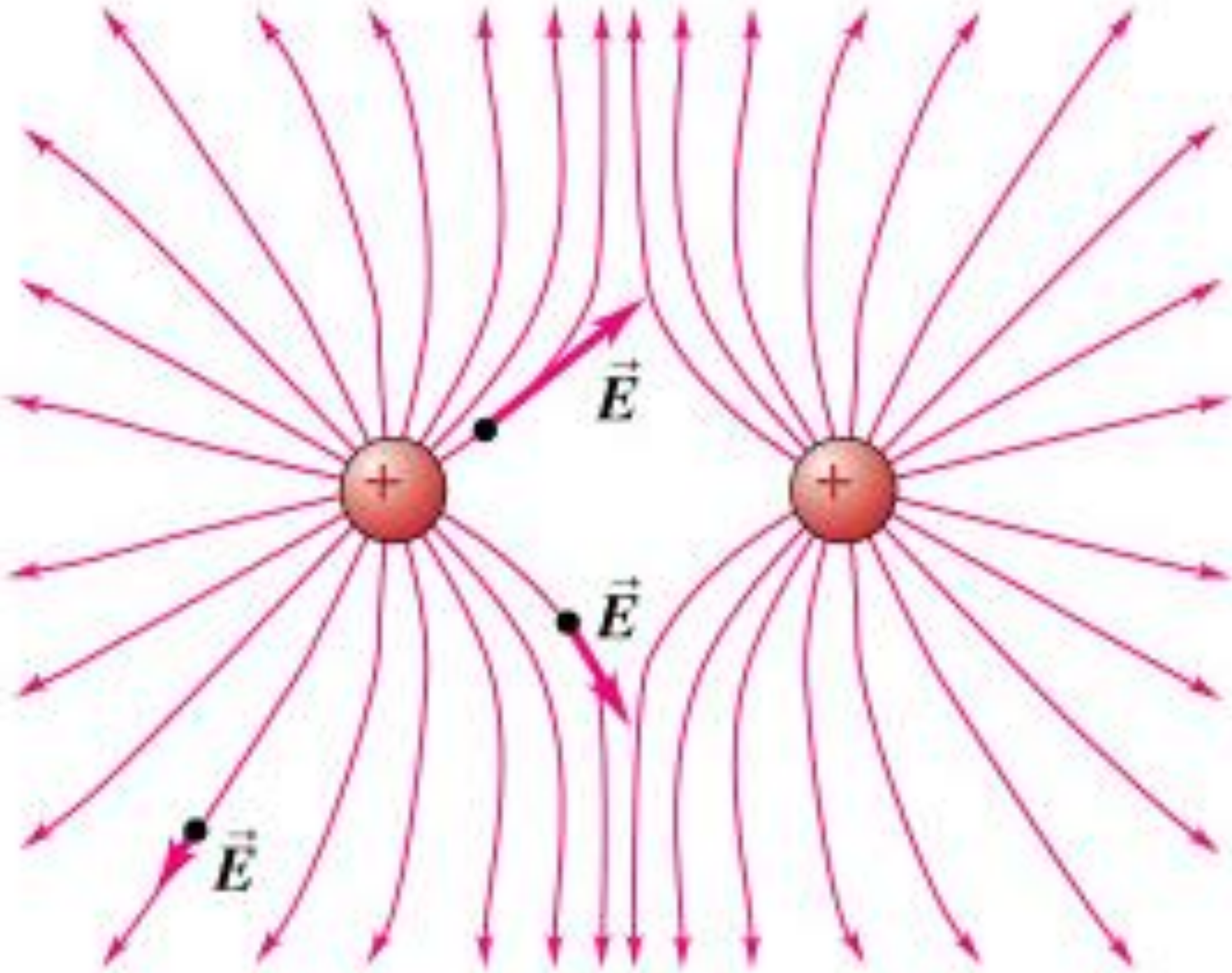
1. The electric field is zero everywhere inside a conductor.
2. Any excess charge on an isolated conductor resides entirely on the outside surface of the conductor.
3. The electric field just outside the charged conductor is perpendicular to the conductor's surface.
4. On an irregularly shaped conductor, charge tends to accumulate where the radius of curvature is the smallest, i.e. AT SHARP POINTS.



(a) A single positive charge
(compare Figure 21.16)

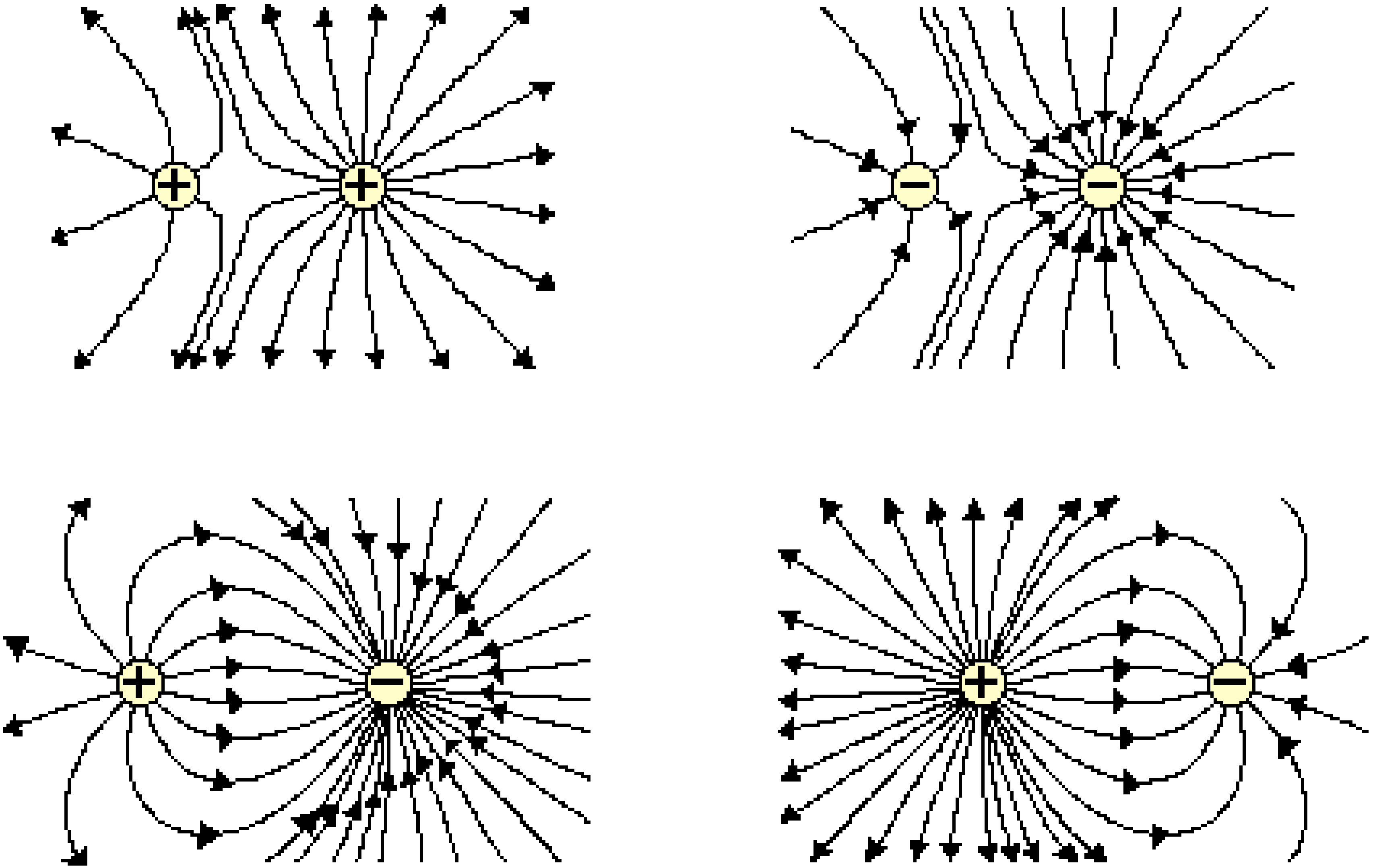


(b) A positive charge and a negative charge of equal magnitude (an electric dipole)

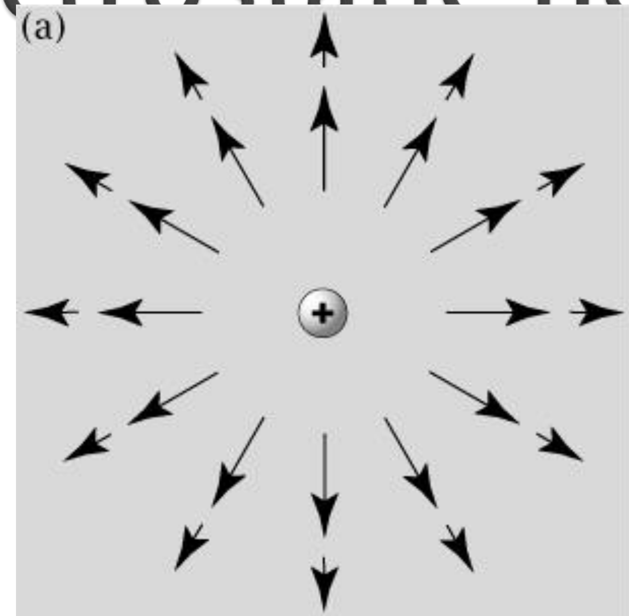


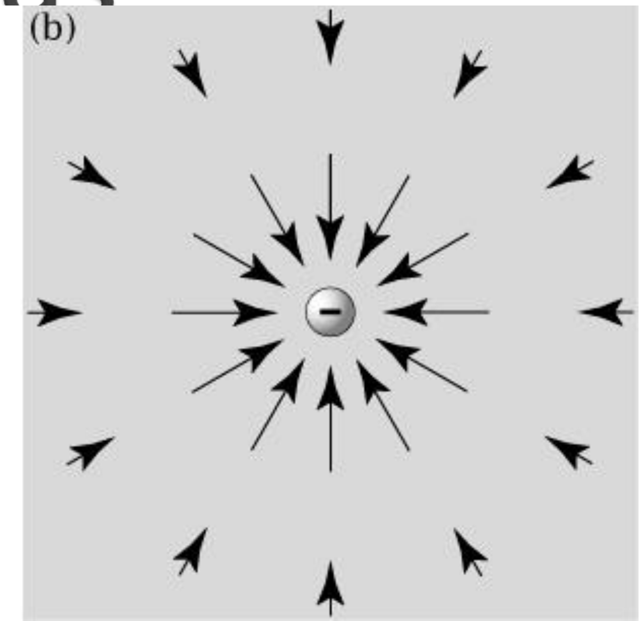
(c) Two equal positive charges

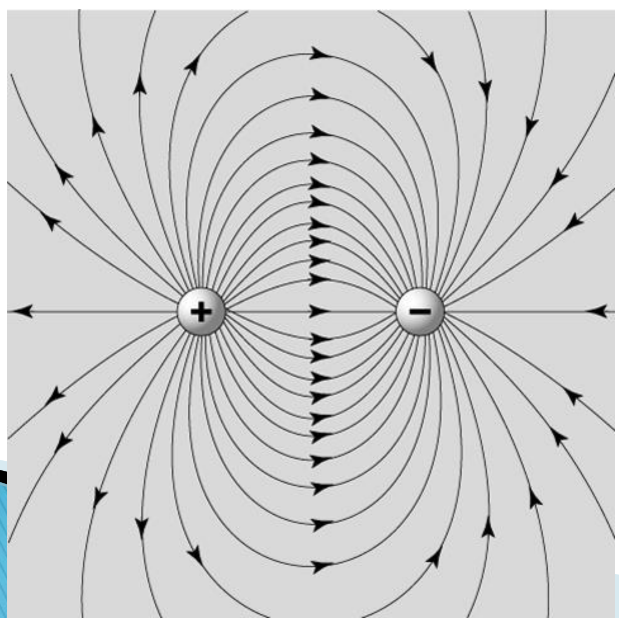
Electric Field Line Patterns for Objects with Unequal Amounts of Charge

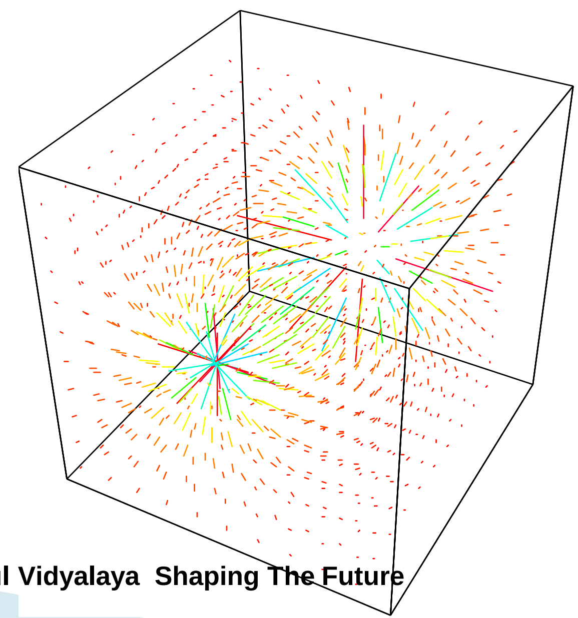


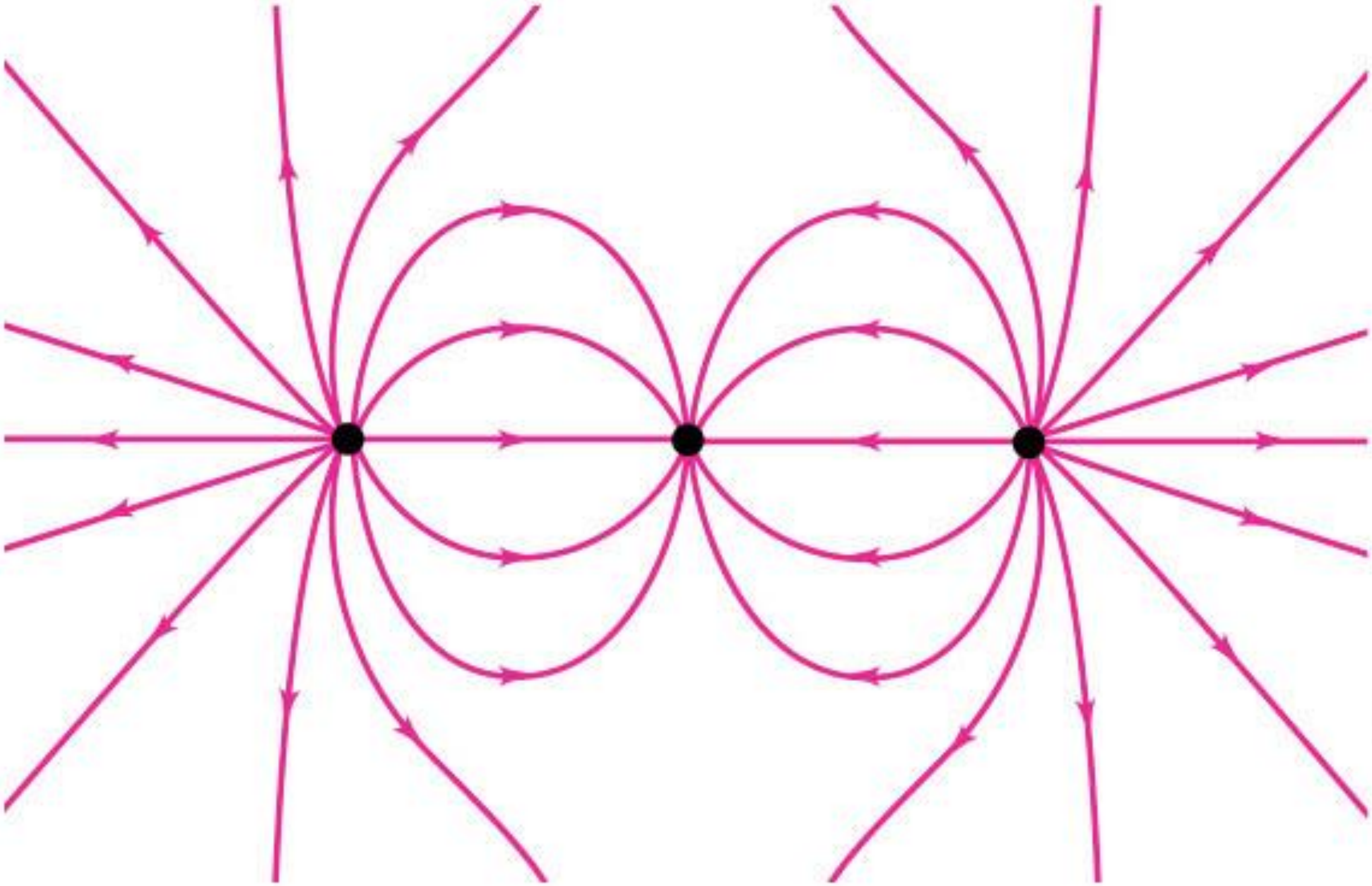
Electrostatic fields











Electric Field

$$\vec{E} = \frac{\vec{F}_E}{q_0} \quad \textit{becomes} \quad E = k_c \frac{q}{r^2}$$

- E → electric field strength, N/C → VECTOR
- q_0 → + test charge, C
- q → charge producing field, C
- r → distance between charges, m
- F_E → Electric Force, N → VECTOR
- k_c → coulomb constant, $8.99 \times 10^9 Nm^2/C^2$

E-Field vs g-field

$$E - Field$$

$$g - field$$

$$\vec{E} = \frac{\vec{F}_0}{q_0}$$

$$\vec{g} = \frac{\vec{F}_g}{m_0}$$

E-Field

$$\vec{E} = \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2} \hat{r}$$

E-Field Calculus

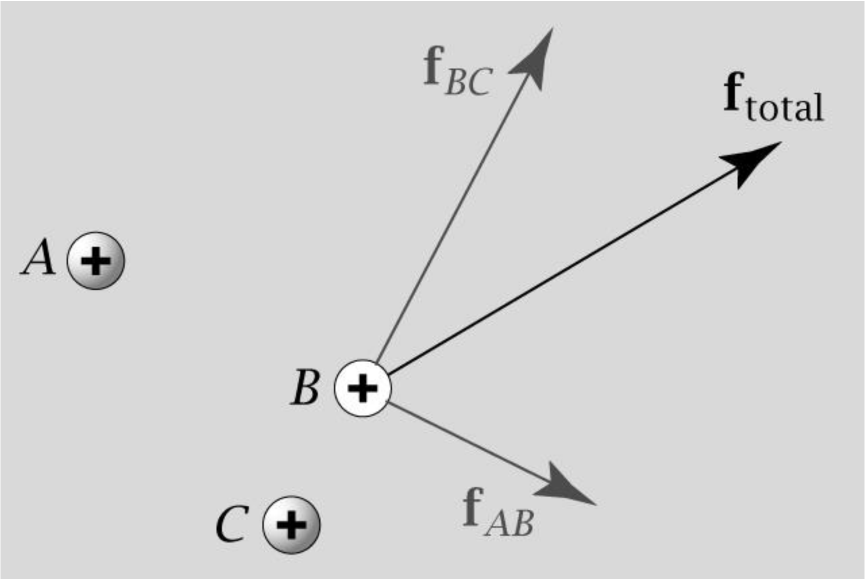
$$d\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{dQ}{r^2}$$

Electrostatic superposition

- For a *homogeneous system*…
  - Total electrostatic potential is the sum of individual electrostatic potentials
  - Total electrostatic force is the sum of individual electrostatic forces
- This works for arbitrary charge distributions
- This is because Coulomb's law is a "Green function" for a particular partial differential equation (coming up…)

$$U = \frac{q_{\mathrm{ref}}}{4\pi\varepsilon_0 D}\sum_i \frac{q_i}{\left\|\mathbf{x}_i - \mathbf{x}_{\mathrm{ref}}\right\|}$$

$$\mathbf{F} = \frac{q_{\mathrm{ref}}}{4\pi\varepsilon_0 D}\sum_i \frac{q_i}{\left\|\mathbf{x}_i - \mathbf{x}_{\mathrm{ref}}\right\|^2}\frac{\mathbf{x}_i - \mathbf{x}_{\mathrm{ref}}}{\left\|\mathbf{x}_i - \mathbf{x}_{\mathrm{ref}}\right\|}$$

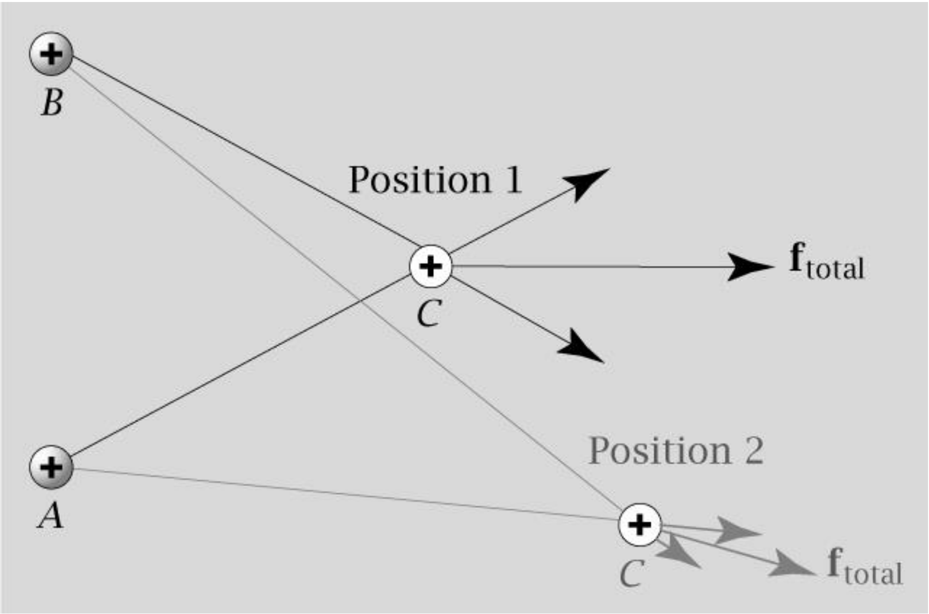


Electrostatic fields and potentials

- Potential:
  - What is the energy of placing a unit charge at position **x**?
  - A scalar-valued function
  - Factoring charge (C) out of energy (J) gives units of V = J C^{-1}
- Field:
  - What is the force experienced by a unit charge at position **x**?
  - A vector-valued function
  - Factoring charge (C) out of force (N = J m^{-1}) gives units of N C^{-1}
- Superposition applies: potentials and forces can be added
- Purpose: a good way to represent the electrostatics of a charge distribution

$$\psi(\mathbf{x}) = \frac{1}{4\pi\varepsilon_0 D}\sum_i \frac{q_i}{\|\mathbf{x}_i - \mathbf{x}\|}$$

$$\mathbf{E}(\mathbf{x}) = \frac{q}{4\pi\varepsilon_0 D}\sum_i \frac{q_i}{\|\mathbf{x}_i - \mathbf{x}\|^2}\frac{\mathbf{x}_i - \mathbf{x}}{\|\mathbf{x}_i - \mathbf{x}\|}$$



Electrostatic fields