2 The Electric Field I

The Electric Field Concept

The electric field is an alteration of space surrounding charge. It is created by source charge and exerts an electric force on other charge.

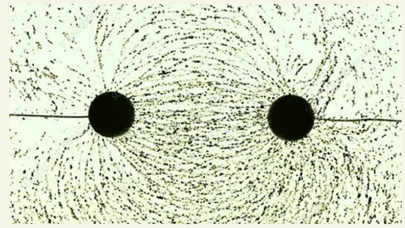
The electric field is defined by its effect on a *test charge* q:

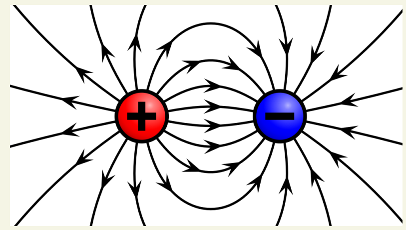
$$\vec{E} = \frac{\vec{F}_{\text{on } q}}{q}.$$

The units of the electric field are N/C or V/m.

We can visualize the electric field through *electric field lines*:

- The field direction is tangent to the curve at each point.
- Lines closer together indicate stronger electric fields.
- Field lines start on positive charge and end on negative.
- Field lines never cross.

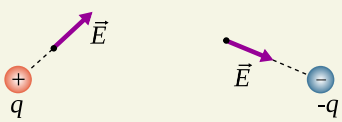




A Single Point Charge

A single point charge q generates an electric field given by

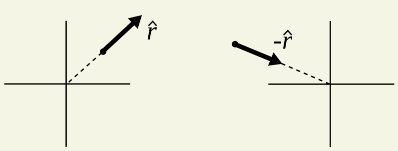
$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\,\hat{r}.$$



The electric field points *away* from positive charge and *toward* negative charge.

The Unit Vector $\hat{r}$

We can specify the direction of the electric field by using the unit vector $\hat{r}$, which, like $\hat{i}$, $\hat{j}$, and $\hat{k}$, has no units and a magnitude equal to 1. Its only job is to point outward from the origin (where the charge is). Note that $-\hat{r}$, which would result if the point charge was negative, would then point toward the origin.



Multiple Point Charges

Multiple point charges q_i generate an electric field given by the principle of superposition – we just add up each individual electric field:

$$\vec{E}_{\text{net}} = \sum_i \frac{1}{4\pi\varepsilon_0}\frac{q_i}{r_i^2}\,\hat{r}_i.$$

Charge Densities

For extended charged objects, we can define three charge densities depending on the shape:

- Linear charge density (C/m): $\lambda = Q/L$.
- Surface charge density (C/m^2): $\eta = Q/A$.
- Volume charge density (C/m^3): $\rho = Q/V$.

Continuous Charge Distributions

If an extended object contains many excess electrons or protons we can consider the charge to be continuous rather than at a point. To calculate the electric field, we use the principle of superposition:

1. Divide the total charge Q of the object into many small charges dQ, each of which acts like a point charge.
2. Find the electric field $d\vec{E}$ of each small charge dQ:

$$d\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{dQ}{r^2}\,\hat{r}.$$

3. Add all electric fields $d\vec{E}$ together by integrating over the object to find the net electric field $\vec{E}$.