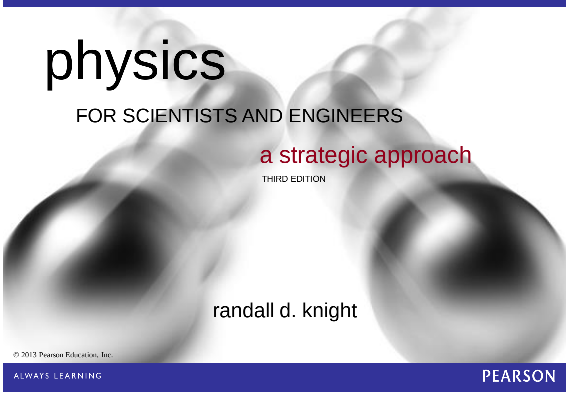
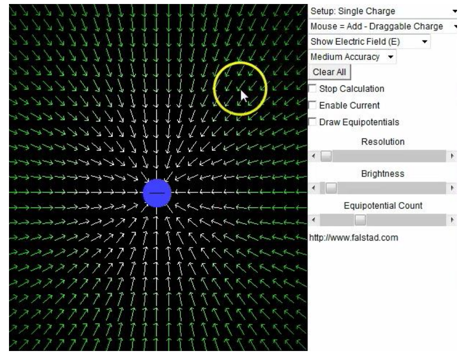
Class 9, Sections 25.5, 26.1, 26.2 Preclass Notes



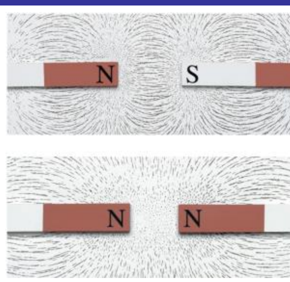
Electromagnetic Field Applet



http://www.falstad.com/emstatic/

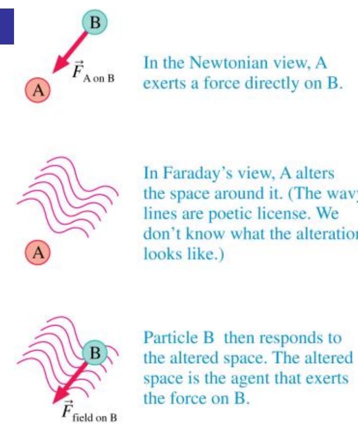
The Field Model

- The photos show the patterns that iron filings make when sprinkled around a magnet.
- These patterns suggest that *space itself* around the magnet is filled with magnetic influence.
- This is called the **magnetic field**.
- The concept of such a "field" was first introduced by Michael Faraday in 1821.



The Field Model

- A *field* is a function that assigns a vector to every point in space.
- The alteration of space around a mass is called the *gravitational field.*
- Similarly, the space around a charge is altered to create the **electric field**.



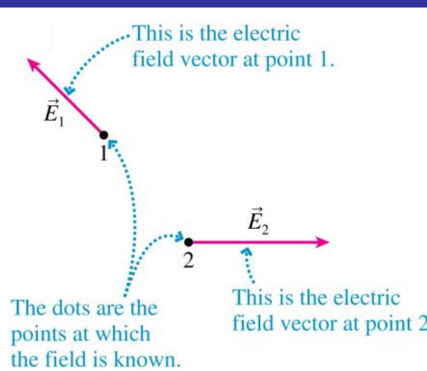
The Electric Field

If a probe charge q experiences an electric force at a point in space, we say that there is an electric field $\vec{E}$ at that point causing the force:

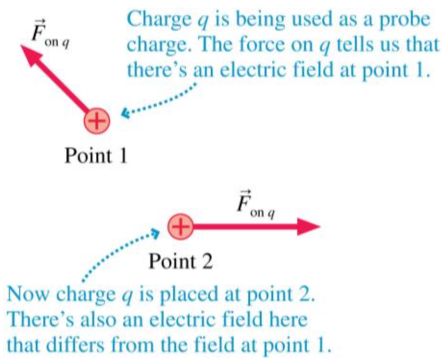
$$\vec{E}(x, y, z) \equiv \frac{\vec{F}_{\text{on } q} \text{ at } (x, y, z)}{q}$$

The units of the electric field are N/C. The magnitude E of the electric field is called the **electric field strength.**

The Electric Field



The Electric Field



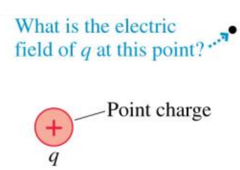
The Electric Field

A charged particle with charge q at a point in space where the electric field is $\vec{E}$ experiences an electric force:

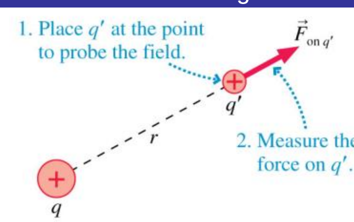
$$\vec{F}_{\text{on } q} = q\vec{E}$$

- If q is positive, the force on the particle is in the direction of $\vec{E}$.
- The force on a negative charge is *opposite* the direction of $\vec{E}$.

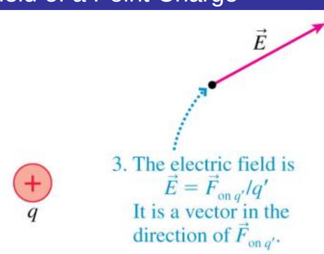
The Electric Field of a Point Charge



The Electric Field of a Point Charge



The Electric Field of a Point Charge

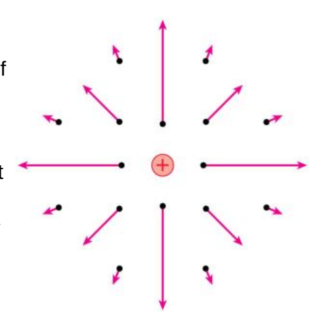


- The electric field a distance r from a point charge q is given by:

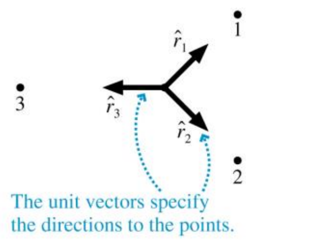
$$\vec{E} = \frac{\vec{F}_{\text{on } q'}}{q'} = \left(\frac{1}{4\pi\epsilon_0}\frac{q}{r^2}, \text{ away from } q\right)$$

The Electric Field of a Point Charge

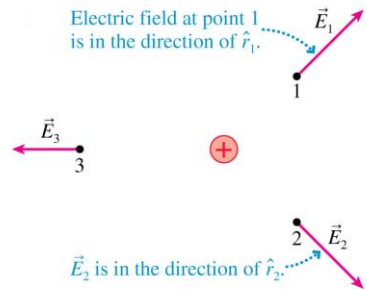
- If we calculate the field at a sufficient number of points in space, we can draw a **field diagram**.
- Notice that the field vectors all point straight away from charge q.
- Also notice how quickly the arrows decrease in length due to the inverse-square dependence on r.



Unit Vector Notation



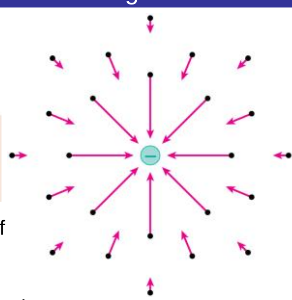
Unit Vector Notation



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

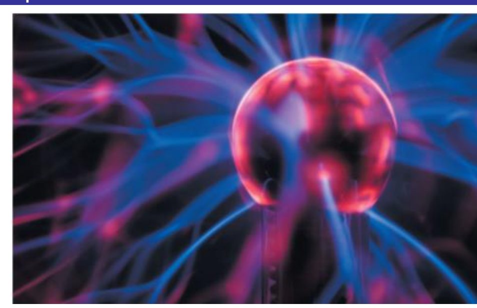
The Electric Field of a Point Charge

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



- A negative sign in front of a vector simply reverses its direction.
- The figure shows the electric field of a negative point charge.

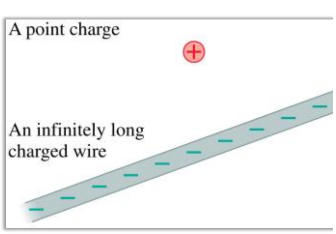
Chapter 26 The Electric Field



Chapter Goal: To learn how to calculate and use the electric field.

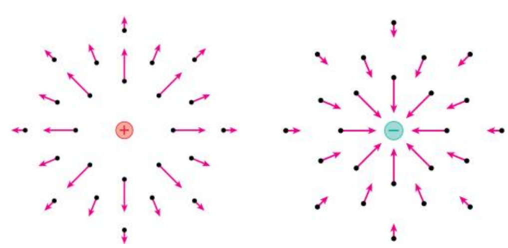
Electric Field Models

- Most of this chapter will be concerned with the *sources* of the electric field.
- We can understand the essential physics on the basis of simplified *models* of the sources of electric field.
- The drawings show models of a positive point charge and an infinitely long negative wire.
- We also will consider an infinitely wide charged plane and a charged sphere.



Electric Field of a Point Charge

$$\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\hat{r} \quad \text{(electric field of a point charge)}$$



The Electric Field

- The electric field was defined as:

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

  where $\vec{F}_{\text{on } q}$ is the electric force on test charge q.
- The SI units of electric field are therefore Newtons per Coulomb (N/C).

TABLE 26.1 Typical electric field strengths

Field location	Field strength (N/C)
Inside a current-carrying wire	10^{-3}–10^{-1}
Near the earth's surface	10^{2}–10^{4}
Near objects charged by rubbing	10^{3}–10^{6}
Electric breakdown in air, causing a spark	3×10^{6}
Inside an atom	10^{11}

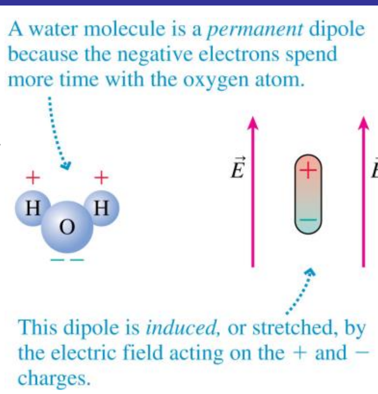
The Electric Field of Multiple Point Charges

- Suppose the source of an electric field is a group of point charges $q_1, q_2, \ldots$
- The net electric field $\vec{E}_{\text{net}}$ at each point in space is a superposition of the electric fields due to each individual charge:

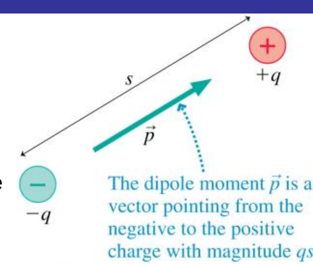
$$(E_{\text{net}})_x = (E_1)_x + (E_2)_x + \cdots = \sum (E_i)_x$$
$$(E_{\text{net}})_y = (E_1)_y + (E_2)_y + \cdots = \sum (E_i)_y$$
$$(E_{\text{net}})_z = (E_1)_z + (E_2)_z + \cdots = \sum (E_i)_z$$

Electric Dipoles

- Two equal but opposite charges separated by a small distance form an *electric dipole.*



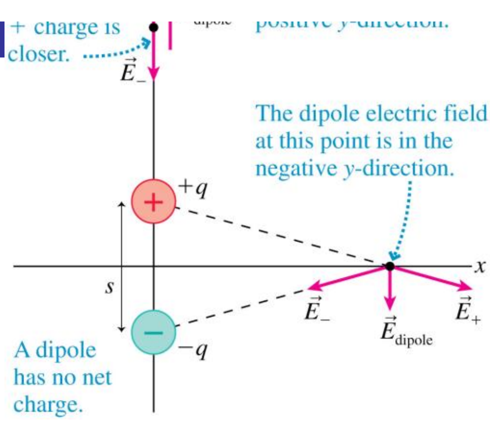
The Dipole Moment



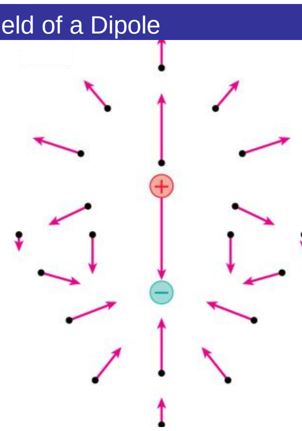
- It is useful to define the dipole moment $\vec{p}$, shown in the figure, as the vector:

$$\vec{p} = (qs, \text{ from the negative to the positive charge})$$

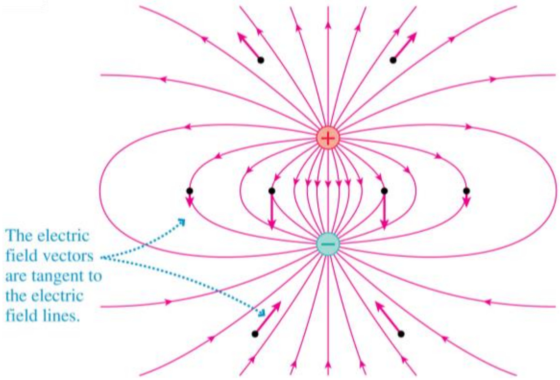
- The SI units of the dipole moment are C m.



The Electric Field of a Dipole



The Electric Field of a Dipole



The Electric Field of a Dipole

- The electric field at a point on the axis of a dipole is:

$$\vec{E}_{\text{dipole}} \approx \frac{1}{4\pi\epsilon_0}\frac{2\vec{p}}{r^3} \qquad \text{(on the axis of an electric dipole)}$$

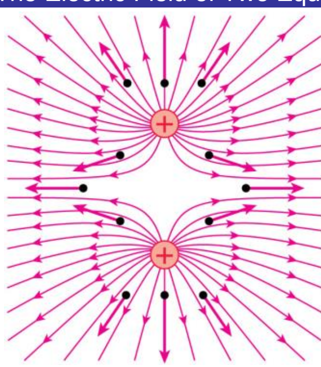
where r is the distance measured from the *center* of the dipole.

- The electric field in the plane that bisects and is perpendicular to the dipole is

$$\vec{E}_{\text{dipole}} \approx -\frac{1}{4\pi\epsilon_0}\frac{\vec{p}}{r^3} \qquad \text{(bisecting plane)}$$

- This field is opposite to the dipole direction, and it is only half the strength of the on-axis field at the same distance.

The Electric Field of Two Equal Positive Charges



This figure represents the electric field of two same-sign charges using electric field lines.