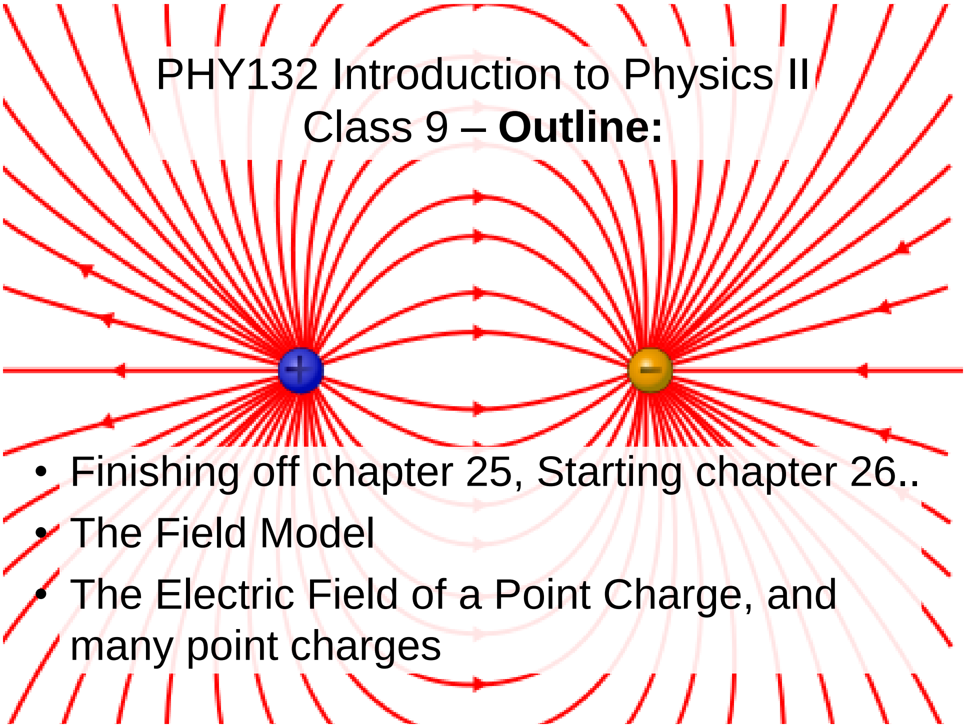
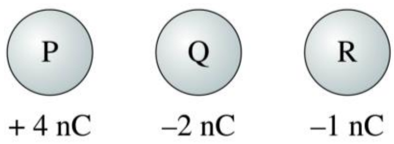


PHY132 Introduction to Physics II
Class 9 – **Outline:**

- Finishing off chapter 25, Starting chapter 26..
- The Field Model
- The Electric Field of a Point Charge, and many point charges

Fun with Charge Conservation!!!

Identical metal spheres are initially charged as shown. Spheres P and Q are touched together and then separated. Then spheres Q and R are touched together and separated. Afterward the charge on sphere R is



A. –1 nC or less.
B. –0.5 nC.
C. 0 nC.
D. +0.5 nC.
E. +1.0 nC or more.

- What is **electric current?**
- It's something to do with the electrons moving through the metal wires.

- What is **voltage?**
- It's what pushes the current.

Our goal: Circuits and Ohm's Law.

How do we get there?

- Electric Charge, q

↓

- Electric Force, F

↓

- Electric Field, E ← You are here

↓

- Electric Potential, V

↓

- Current and Ohm's Law:

$$current = \frac{voltage}{resistance}$$

Coulomb's Law, and The Permittivity Constant

- We can make many future equations easier to use if we rewrite Coulomb's law in a somewhat more complicated way.
- Let's define a new constant, called the **permittivity constant** ϵ_0:

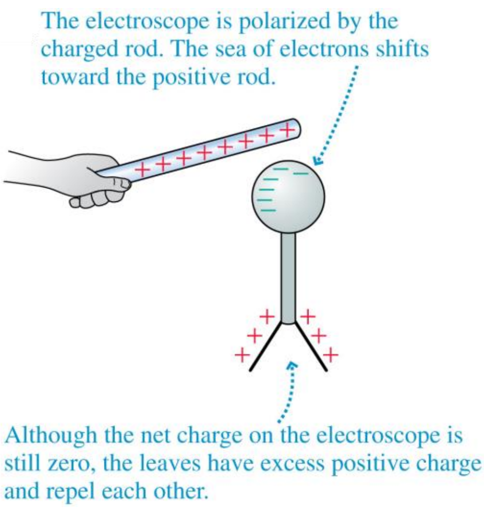
$$\epsilon_0 = \frac{1}{4\pi K} = 8.85 \times 10^{-12}\ \mathrm{C^2/N\,m^2}$$

- Rewriting Coulomb's law in terms of ϵ_0 gives us:

$$F = \frac{1}{4\pi\epsilon_0}\frac{|q_1||q_2|}{r^2}$$

Charge Polarization

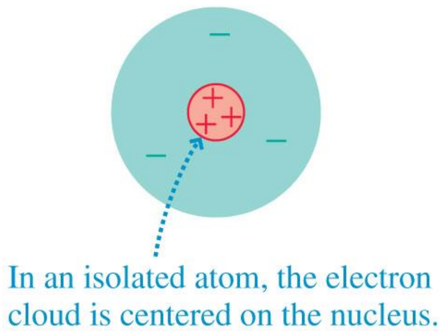
- Charge polarization produces an excess positive charge on the leaves of the electroscope, so they repel each other.
- Because the electroscope has no *net* charge, the electron sea quickly readjusts once the rod is removed.



The Electric Dipole

- Even a single atom can become polarized.
- The figure below shows how a neutral atom is polarized by an external charge, forming an **electric dipole**.

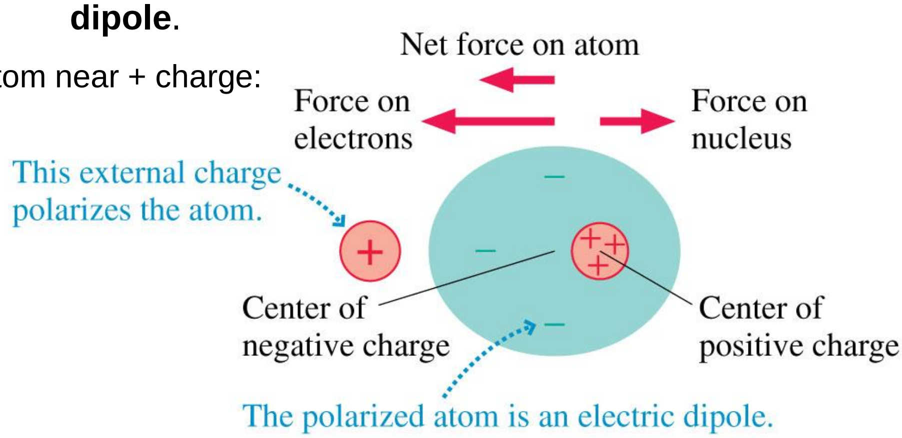
Atom all alone:



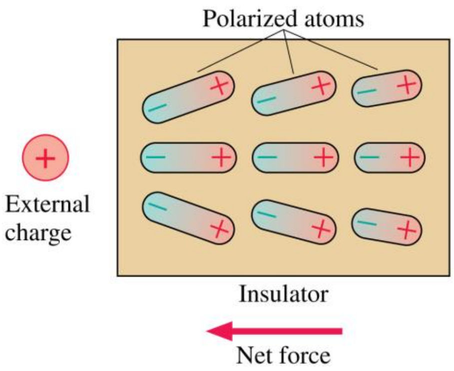
The Electric Dipole

- Even a single atom can become polarized.
- The figure below shows how a neutral atom is polarized by an external charge, forming an **electric dipole**.

Atom near + charge:



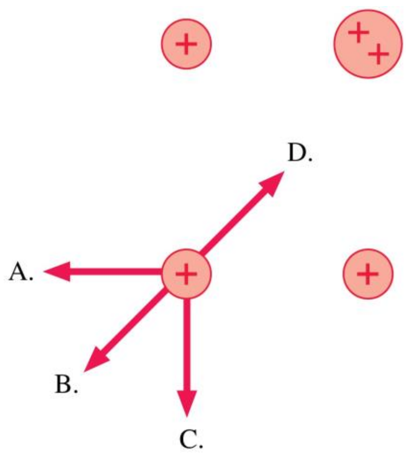
The Electric Dipole



- When an insulator is brought near an external charge, all the individual atoms inside the insulator become polarized.
- The polarization force acting *on each atom* produces a net polarization force toward the external charge.

Thinking about **Electric Force**

Which is the direction of the net force on the charge at the lower left?



E. None of these.

Thinking about **Electric Force**

The direction of the force on charge $-q$ is

A. Up.

B. Down.

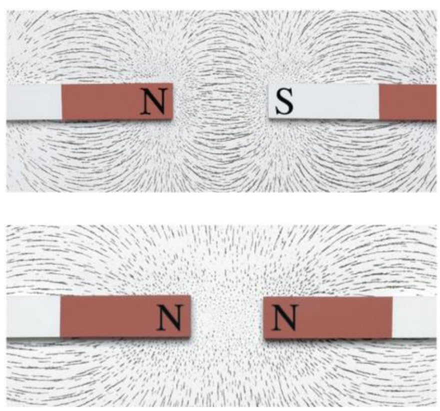
C. Left.

D. Right.

E. The force on $-q$ is zero.

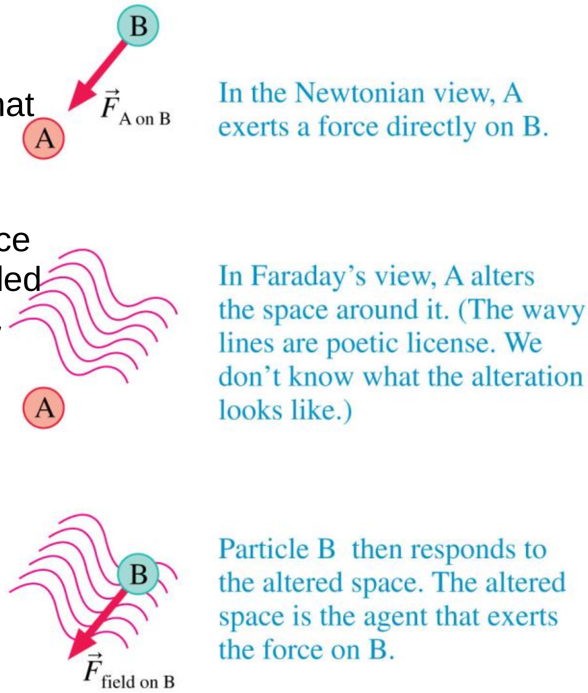
The Field Model

- 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

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

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

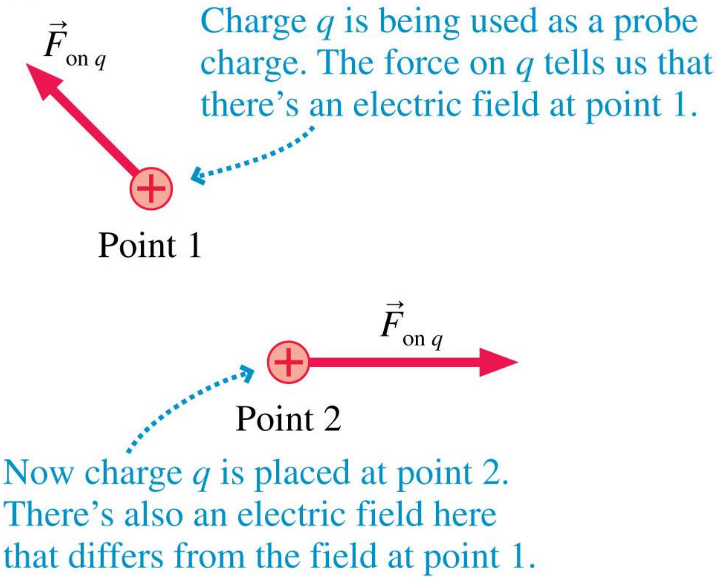
- If q is positive, the force on the particle is in the direction of $\vec{E}$.
- The force on a negative charge is *opposite* the direction of $\vec{E}$.

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

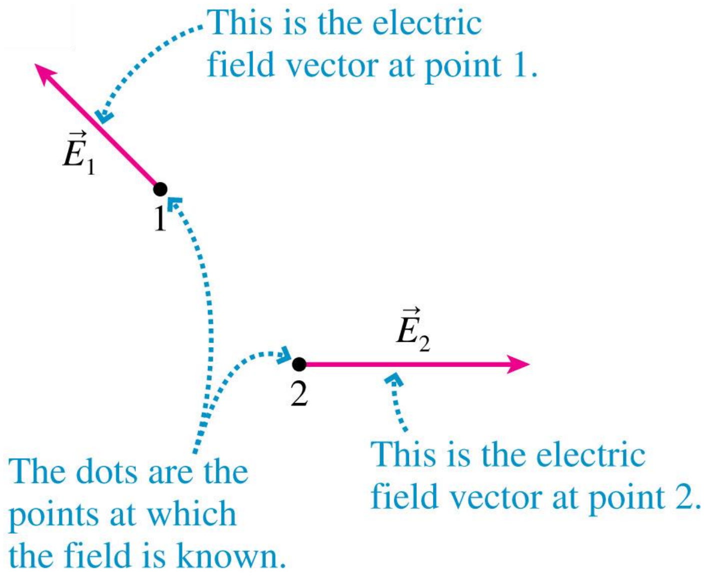
TABLE 26.1 Typical electric field strengths

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 Force



The Electric Field



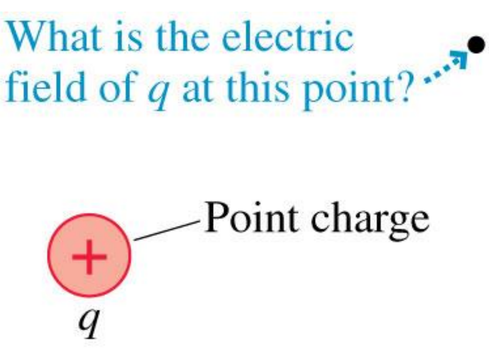
Example.
A 0.10 g honeybee has an electric charge.
There is a natural electric field near the earth's surface of 100 N/C, downward.
What electric charge would the bee have to have to hang suspended in the air, without even flapping her wings?

The Electric Field of a Point Charge

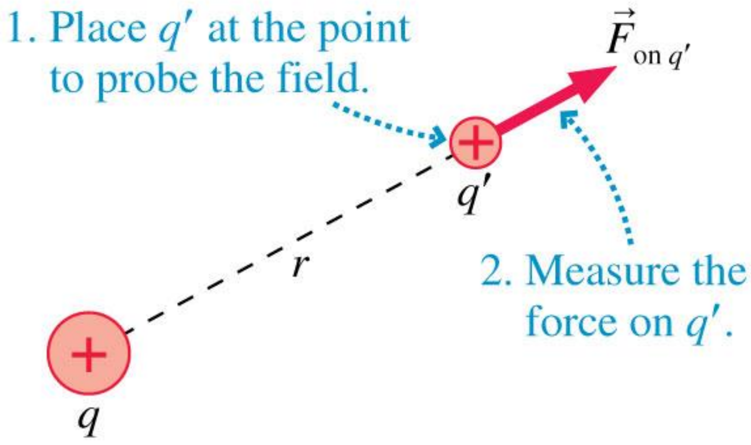
- The electric field at a distance r away from a point charge, q, is given by:

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

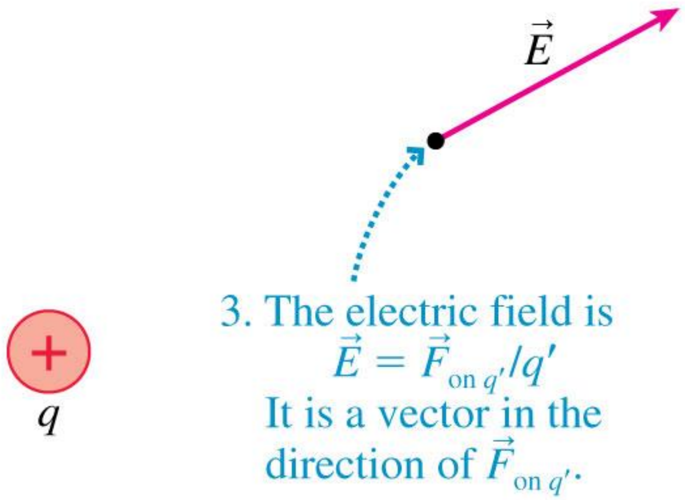
The Electric Field of a Point Charge



The Electric Field of a Point Charge

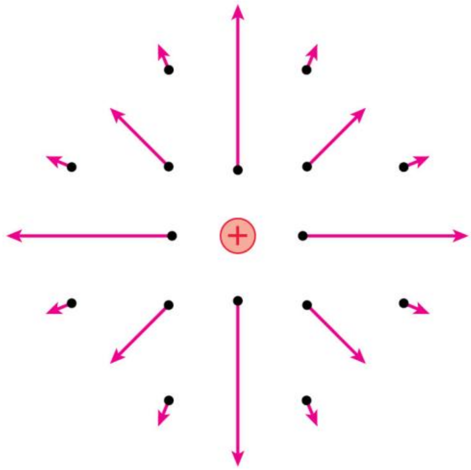


The Electric Field of a Point Charge

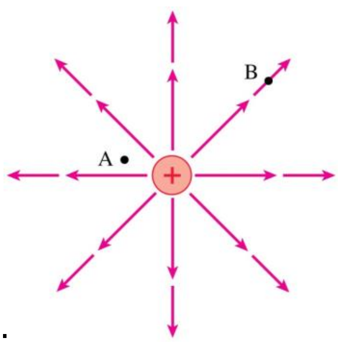


The Electric Field of a Point Charge

- 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*.



At which point is the electric field stronger?



A. Point A.

B. Point B.

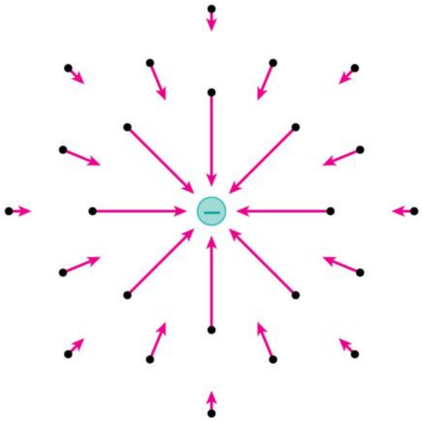
C. Not enough information to tell.

The Electric Field of a Point Charge

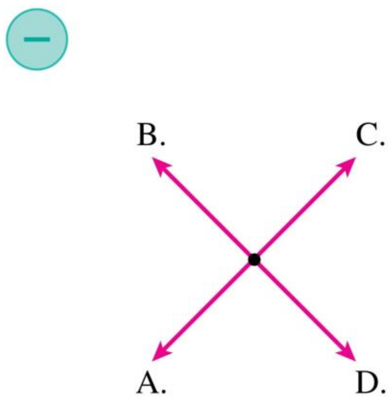
- Using unit vector notation, the electric field at a distance r from a point charge q is:

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

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



Which is the electric field at the dot?



E. None of these.

The Electric Field of Multiple Point Charges

- Suppose the source of an electric field is a group of point charges q_1, q_2, …
- 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:

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

When $r >> d$, the electric field strength at the dot is

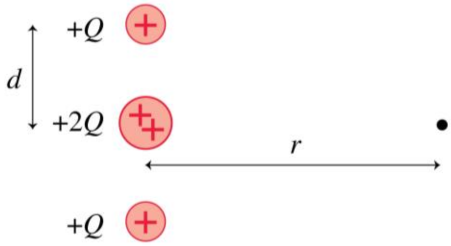
A. $\frac{Q}{4\pi\epsilon_0 r^2}$

B. $\frac{2Q}{4\pi\epsilon_0 r^2}$

C. $\frac{4Q}{4\pi\epsilon_0 r^2}$

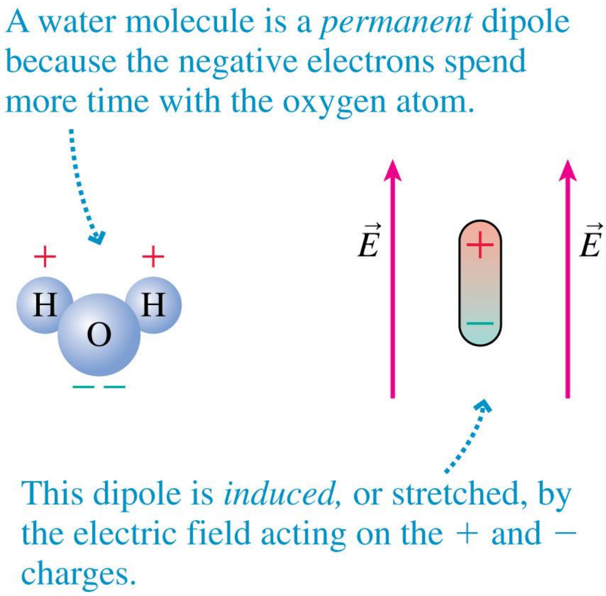
D. $\frac{4Q}{4\pi\epsilon_0 (r^2 + d^2)}$

E. $\frac{4Q}{4\pi\epsilon_0 r}$



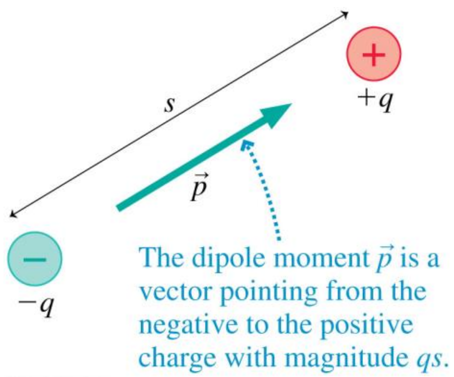
Electric Dipoles

- Two equal but opposite charges separated by a small distance for an *electric dipole.*
- The figure shows two examples.



The Dipole Moment

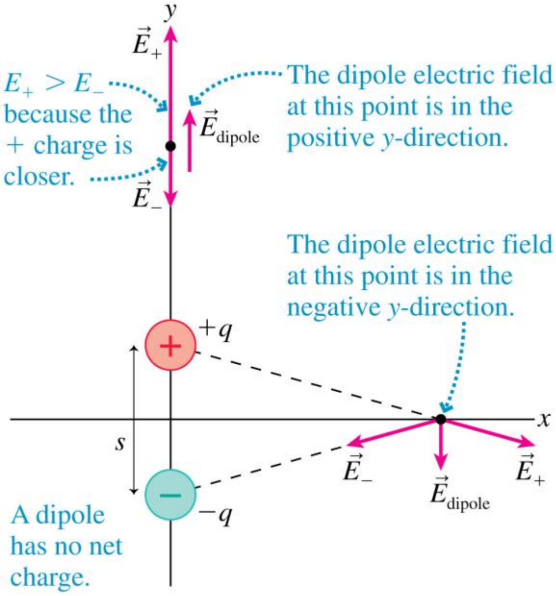
- It is useful to define the dipole moment $\vec{p}$, shown in the figure, as the vector:



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

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

The Dipole Electric Field at Two Points



The Electric Field of a Dipole

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

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

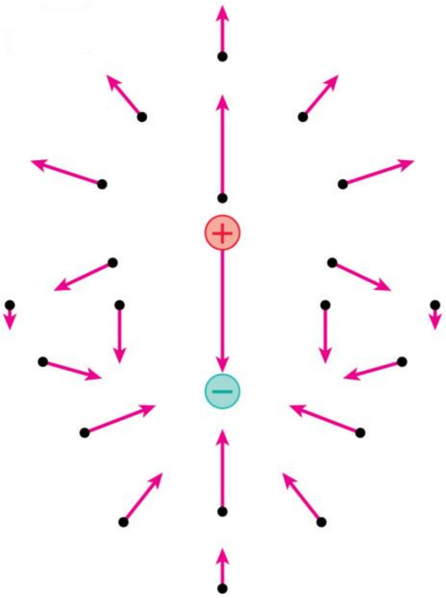
where r is the distance measured from the *center* of the dipole.

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

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

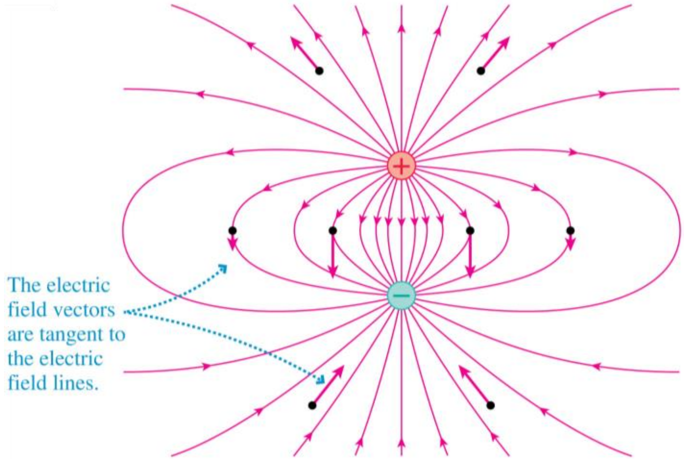
- This field is opposite to the dipole direction, and it is only half the strength of the on-axis field at the same distance.

The Electric Field of a Dipole



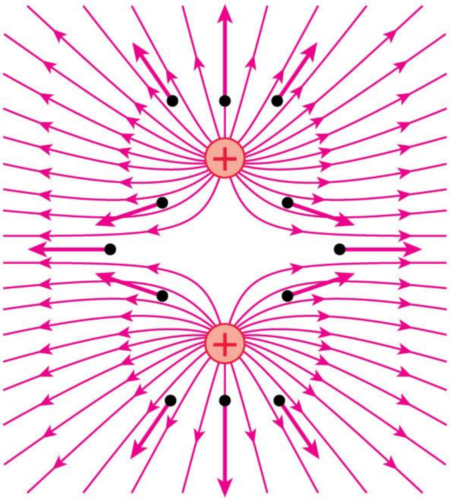
This figure represents the electric field of a dipole as a field-vector diagram.

The Electric Field of a Dipole



This figure represents the electric field of a dipole using electric field lines.

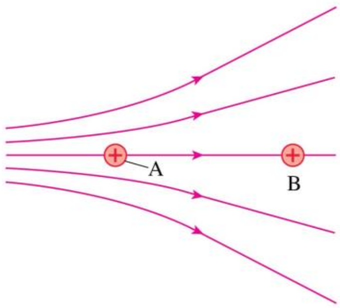
The Electric Field of Two Equal Positive Charges



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

Two protons, A and B, are in an electric field. Which proton has the larger acceleration?

A. Proton A.
B. Proton B.
C. Both have the same acceleration.



Before Class 10 on Wednesday

- Please read over the rest of Chapter 26, or at least watch the pre-class video.
- Please complete the pre-class quiz due on Wednesday morning.

- Something to think about or google: Does lightning go up or down? If the ground is neutral and the cloud-cover is positive, can lightning be the electrons jumping up to the clouds?