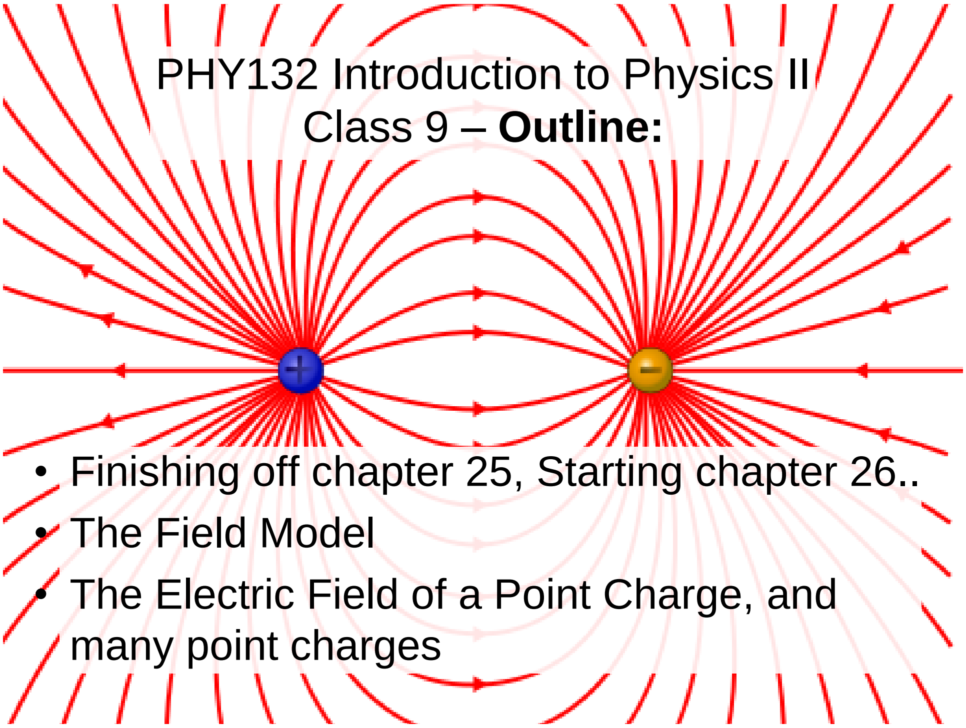
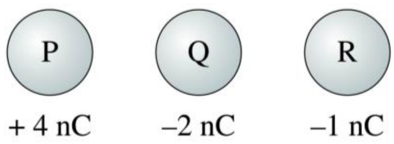


PHY132 Introduction to Physics II
Class 9 – **Outline:**

- 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.

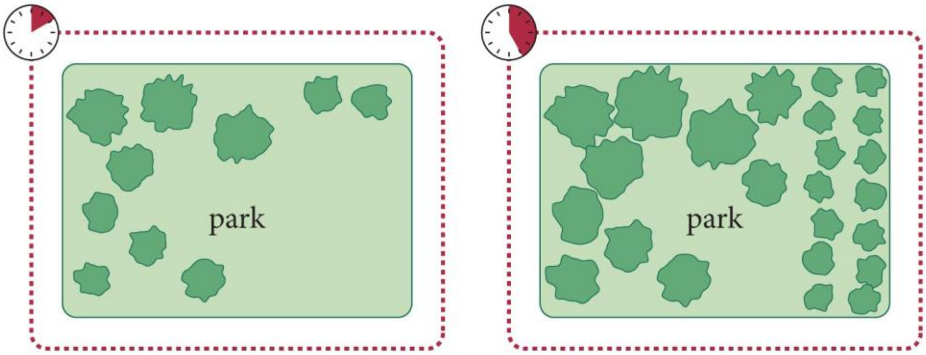
C. 0 nC.

D. +0.5 nC.

E. +1.0 nC or more.

Conservation Laws

- Consider the number of trees in a park.
- The "system" is outlined by the red dashed line.



- Only four processes can change the value of a quantity within a system: **input**, **output**, **creation**, **destruction**.
- Then, the change of a certain quantity over a time interval is given by

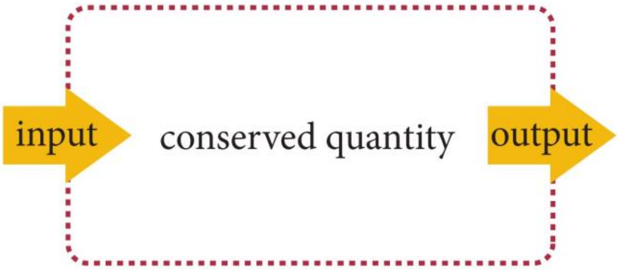
$$\textit{change} = \textit{input} - \textit{output} + \textit{creation} - \textit{destruction}$$

“Conserved” quantities.

- Any quantity that cannot be created or destroyed is said to be **conserved**:
- The change in the value of a conserved quantity is:

$$change = input - output$$

- **Electric charge**, **energy** and **momentum** are all *conserved* quantities.



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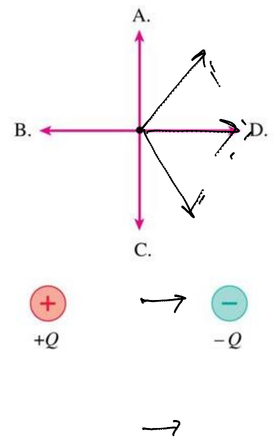
Class 9 Preclass Quiz on MasteringPhysics

- Vocabulary:
- 49% got:The electric field of a charge is defined by the force on a **positive probe charge**.
- 95 % of students got: A charge alters the space around it. This alteration of space is called the **Electric field**.

Class 9 Preclass Quiz on MasteringPhysics

- 58% of students got the electric field of a dipole question.
- *“Can you go over the electric field of a dipole?”*

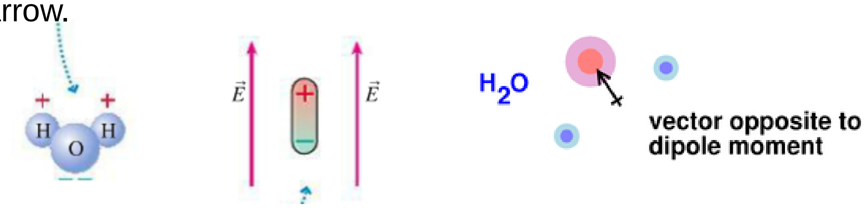


Class 9 Preclass Quiz – Student Comments…

- *“Oh no, its snowing outside. It took me about 1h 30m to get to the University today. It normally takes me 40 minutes...”*
- *“Sir, I think the last play made by Seahawks was so outrageously horrible, that we should all get a 5% boost on our test because of that stupidity.”*
- *“Does final cover the material that should be taught last Monday?”*
- **Harlow answer:** No. The final exam will not cover sections 23.5-23.8. (No colour and dispersion, no lenses, nor curved mirrors)

Class 9 Preclass Quiz – Student Comments…

- *"Please look at Figure 26.5 on page 754. This is kind of tripping my out because of the way we were taught to draw the dipole moment in chemistry. We were taught to draw the dipole moment using an arrow like (+-------->)"*
- **Harlow answer:** In physics, we always draw the dipole moment, $\vec{p}$, as being from the negative toward the positive charge. It has units of Coulombs-meters.
- In Chemistry (especially first-year Chem), when drawing polar molecules, is common to draw an arrow pointing in the opposite direction to $\vec{p}$, and to put a + sign at the tail of the arrow.



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:

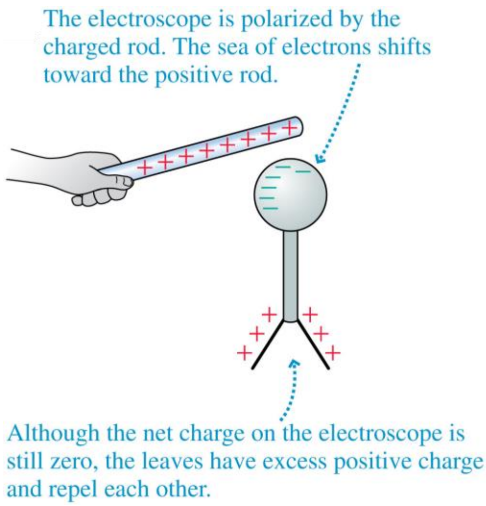
$$\epsilon_0 = \frac{1}{4\pi K} = 8.85 \times 10^{-12}\ \mathrm{C^2/N\,m^2}$$

- 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

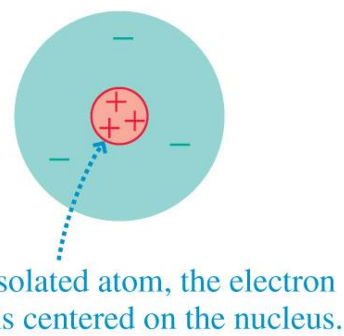
- Charge polarization produces an excess positive charge on the leaves of the electroscope, so they repel each other.
- Because the electroscope has no *net* charge, the electron sea quickly readjusts once the rod is removed.



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**.

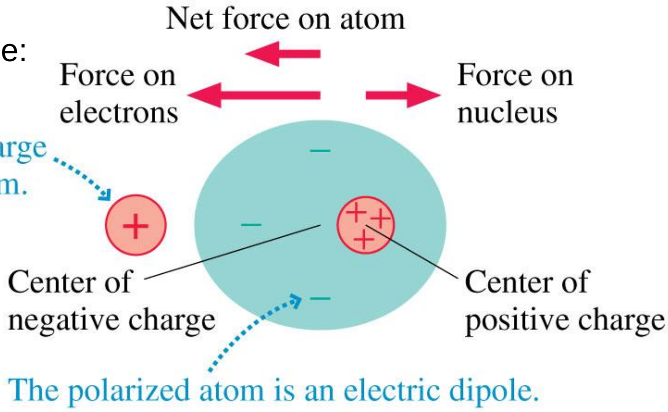
Atom all alone:



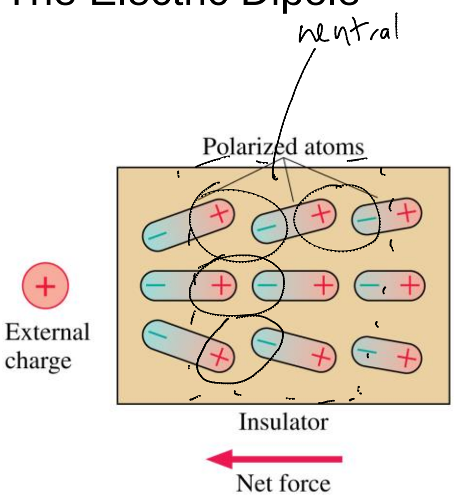
The Electric Dipole

- 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:



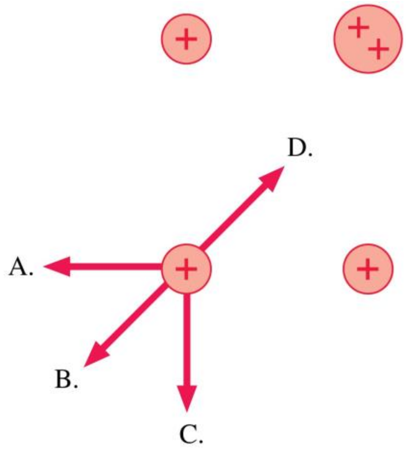
The Electric Dipole



- 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.

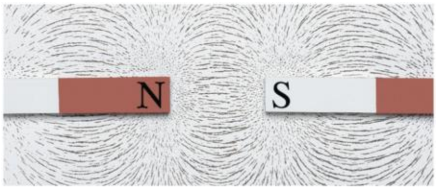
C. Left.

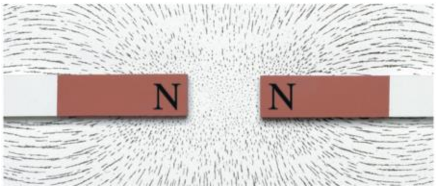
D. Right.

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

The Field Model

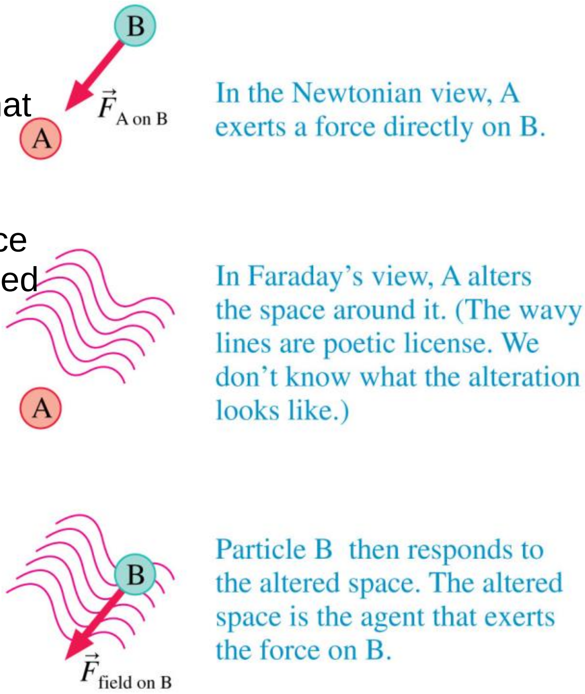
- The photos show the patterns that iron filings make when sprinkled around a magnet.
- These patterns suggest that *space itself* around the magnet is filled with magnetic influence.
- This is called the **magnetic field**.
- The concept of such a “field” was first introduced by Michael Faraday in 1821.





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:

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

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

- 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 $\vec{E}$.

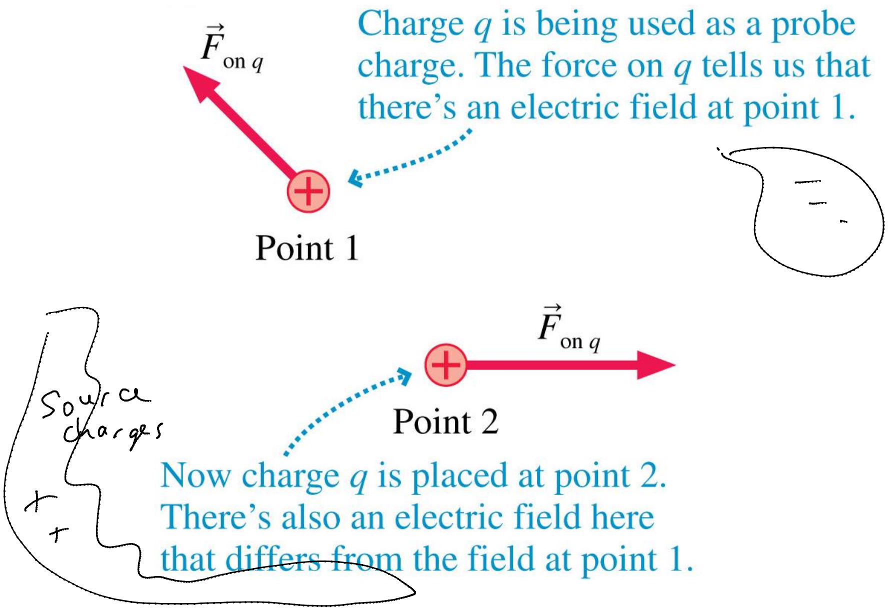
The units of the electric field are N/C. The magnitude E of the electric field is called the **electric field strength.**

TABLE 26.1 Typical electric field strengths

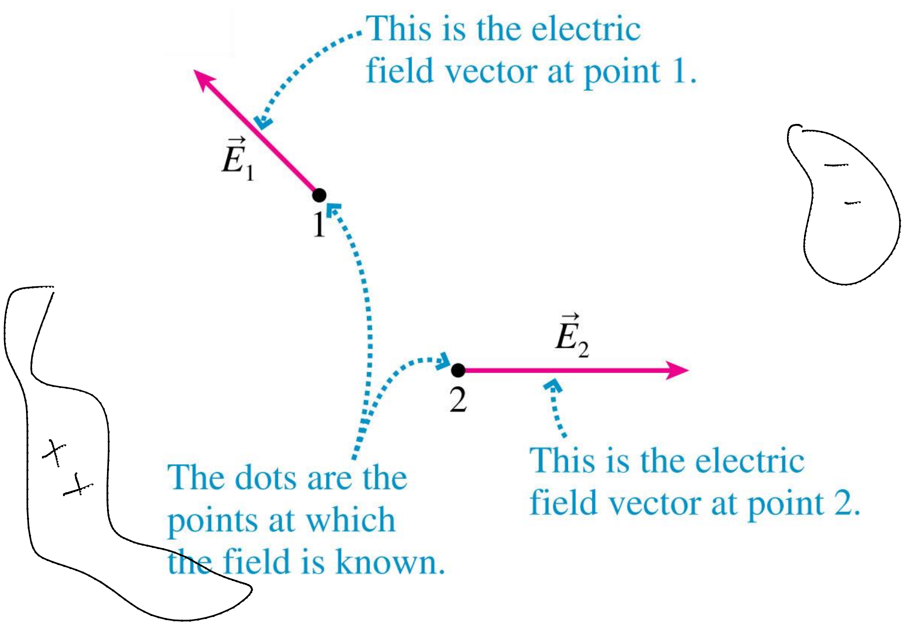
Note $1 \frac{N}{C} = 1 \frac{\text{Volt}}{\text{meter}}$

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. $m = 0.1 \times 10^{-3}$ kg.

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?

$\vec{E} = 100 \frac{N}{C}$

f.b.d.

F_e

mg

If the bee had a negative charge, the electric force would be up.

$|F_e| = q|\vec{E}| = mg$

equilibrium
bee hovers.

$-q E = mg$

$q = -\frac{mg}{E} = \frac{-0.1\times10^{-3}(9.8)}{100\,N/C}$

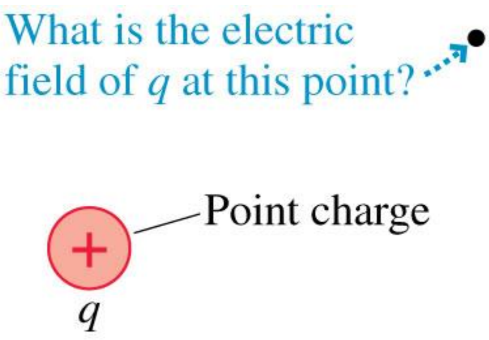
$\boxed{q = -9.8\times10^{-6}\ C}$

The Electric Field of a Point Charge

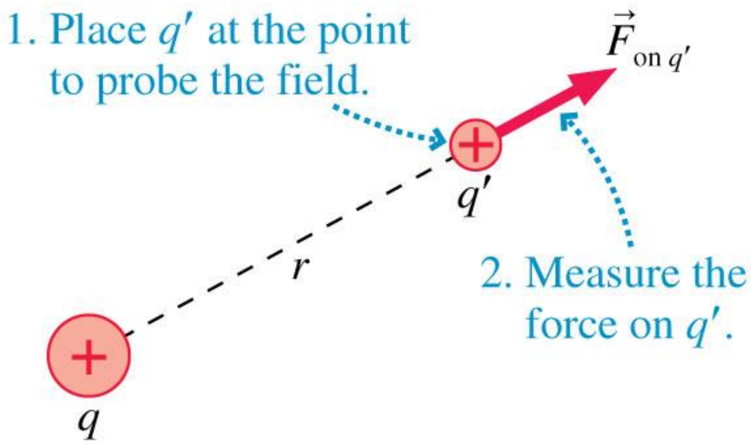
- The electric field at a distance r away from a point charge, q, is given by:

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

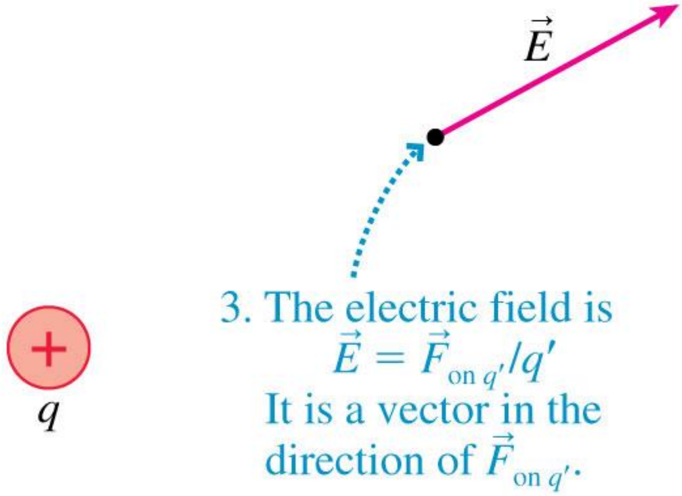
The Electric Field of a Point Charge



The Electric Field of a Point Charge

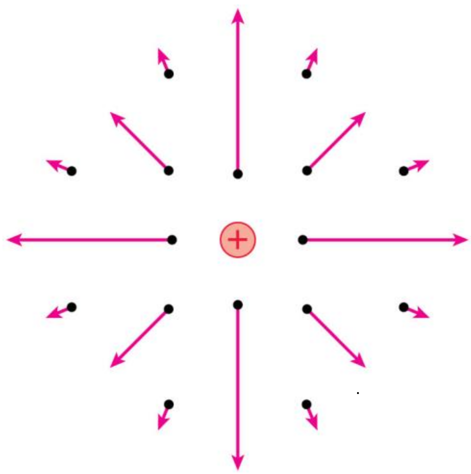


The Electric Field of a Point Charge

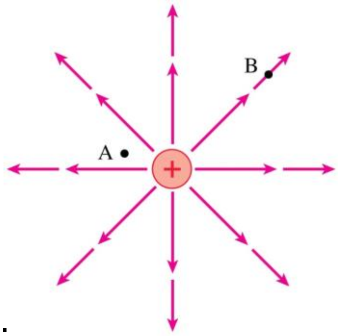


The Electric Field of a Point Charge

- 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.

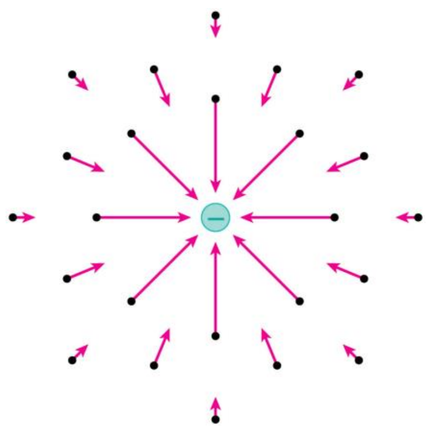
C. Not enough information to tell.

The Electric Field of a Point Charge

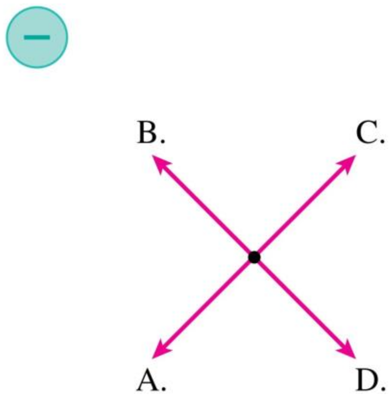
- Using unit vector notation, the electric field at a distance r from a point charge q is:

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

- 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

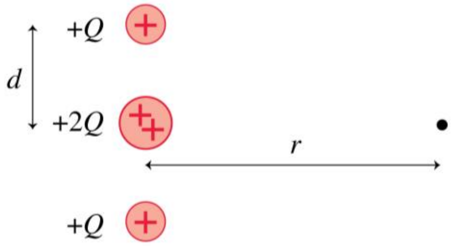
A. $\dfrac{Q}{4\pi\epsilon_0 r^2}$

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

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

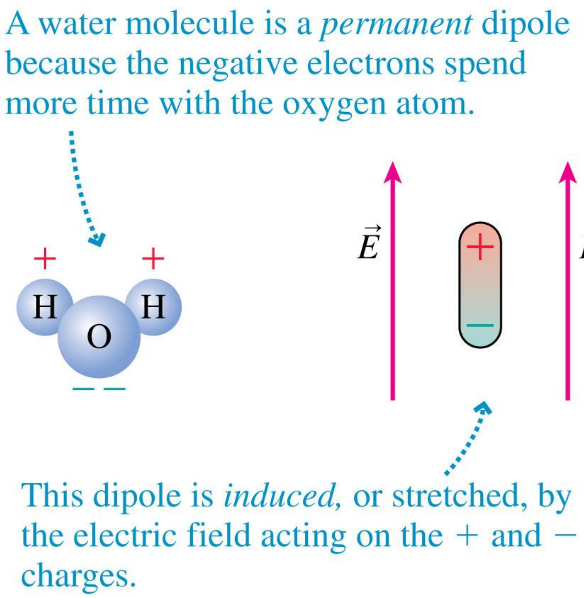
D. $\dfrac{4Q}{4\pi\epsilon_0 (r^2 + d^2)}$

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

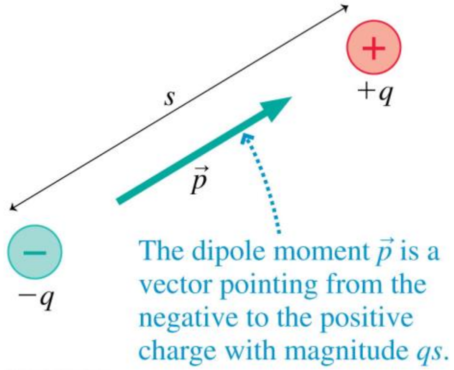


Electric Dipoles

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



The Dipole Moment

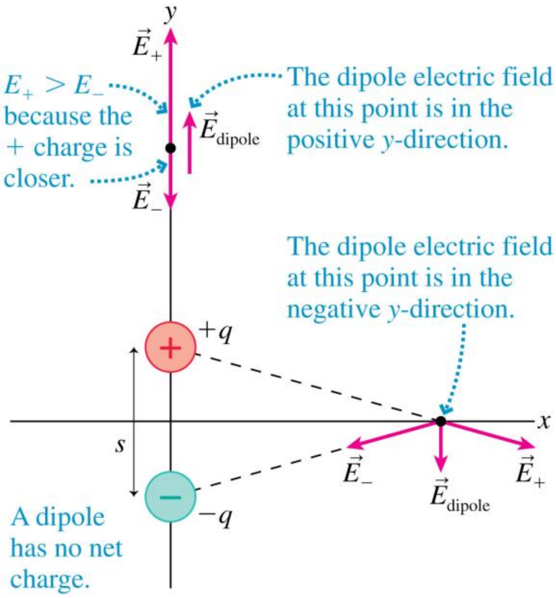


- It is useful to define the dipole moment $\vec{p}$, shown in the figure, as the vector:

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

- 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:

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

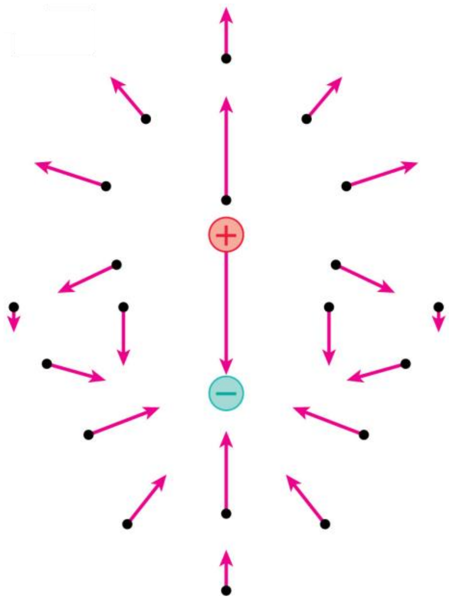
where r is the distance measured from the *center* of the dipole.

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

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

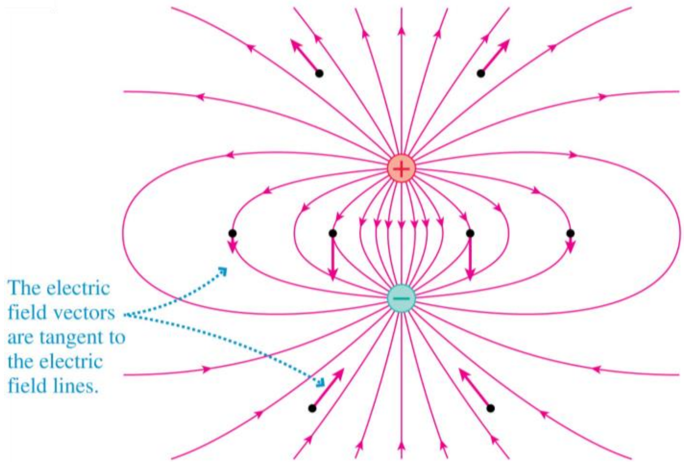
- This field is opposite to the dipole direction, and it is only half the strength of the on-axis field at the same distance.

The Electric Field of a Dipole



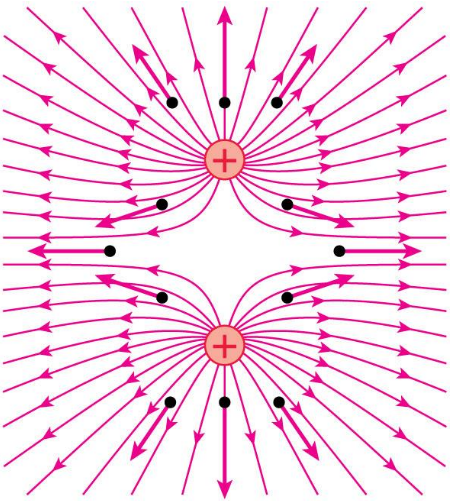
This figure represents the electric field of a dipole as a field-vector diagram.

The Electric Field of a Dipole



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

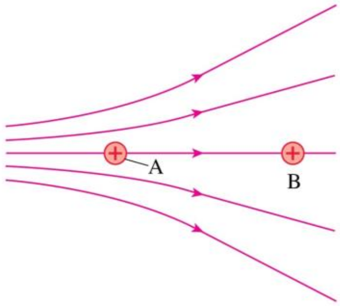
The Electric Field of Two Equal Positive Charges



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?