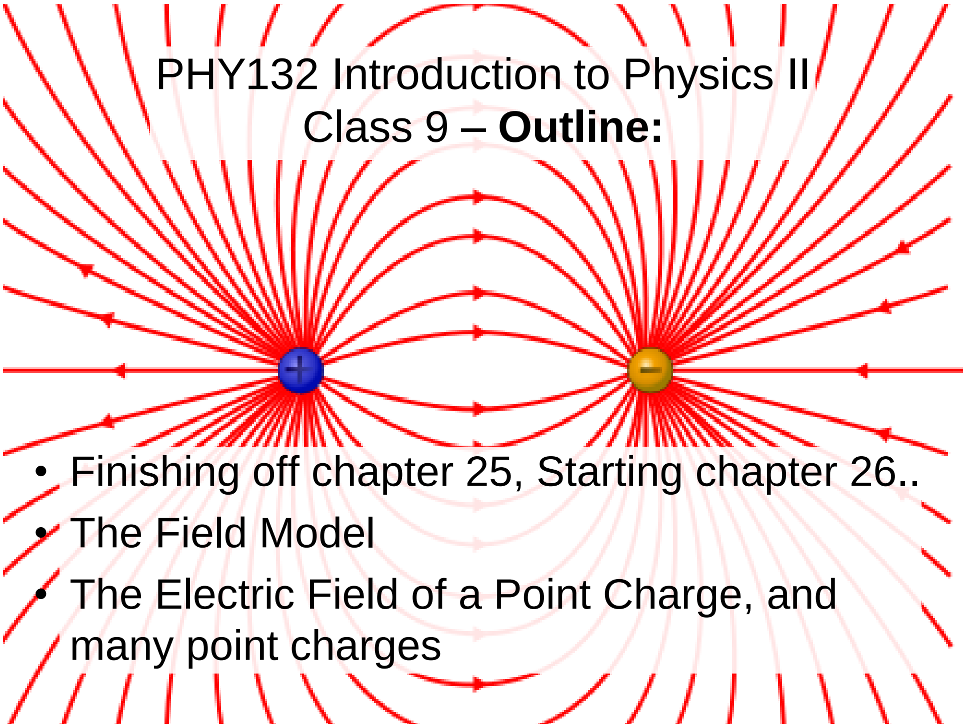


PHY132 Introduction to Physics II
Class 9 – **Outline:**

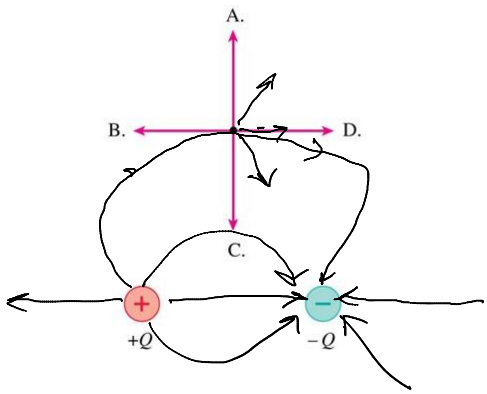
- Finishing off chapter 25, Starting chapter 26..
- The Field Model
- The Electric Field of a Point Charge, and many point charges

Class 9 Preclass Quiz on MasteringPhysics

- Vocabulary:
- 60% got:The electric field of a charge is defined by the force on a **positive probe charge**.
- 98 % 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

- 77% of students got the electric field of a dipole question.



Class 9 Preclass Quiz – Student Comments…

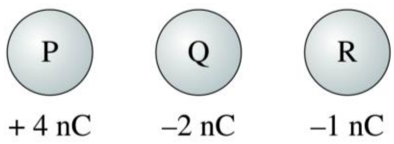
- *"The difference between a test charge and a probe charge. What are their purposes and how do they differ? Can the electric field of a charge be canceled out by another charge?"*
- *"Are positive and negative charges analogous to North and South poles on a magnet?"*
- *"Can we go over why in electric fields the charge moves from positive to negative, I find this very confusing."*
- **Harlow answer:** The electric field is in the direction that a positive probe charge would accelerate if placed there. Since like-charges repel, the electric field points away from positive source charges.

Class 9 Preclass Quiz – Student Comments…

- Jokes:
- *"I once sat in an electric chair; it was a shocking experience."*
- *"I am so charged for the test!---->not really"*
- *"What is the definition of a shock absorber? A careless electrician."*
- *"A neutron walks into a bar and asks how much drinks are. The bartender says 'NO CHARGE!'"*
- *"An electrician claimed that his truck was a volts wagon."*

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



$= +4\times10^{-9}$ C

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?**
- Umm….


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: $\Delta V = IR$

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:

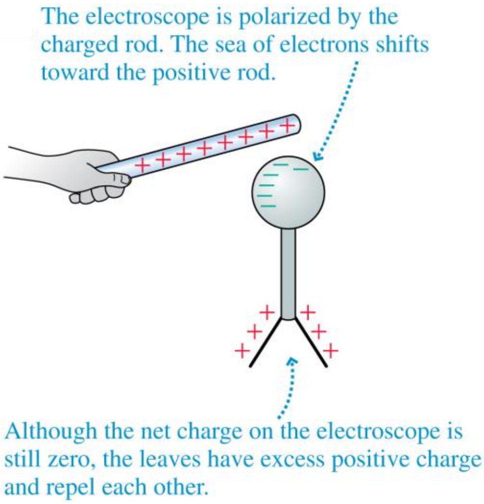
$$\epsilon_0 = \frac{1}{4\pi K} = 8.85 \times 10^{-12}\ \mathrm{C^2/N\,m^2}$$

- 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

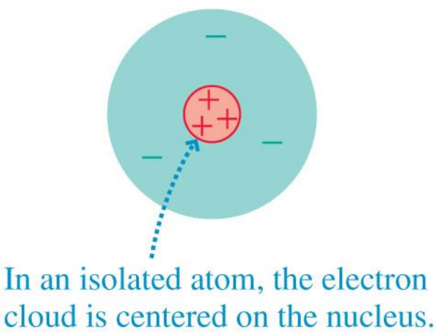
- Charge polarization produces an excess positive charge on the leaves of the electroscope, so they repel each other.
- Because the electroscope has no *net* charge, the electron sea quickly readjusts once the rod is removed.



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**.

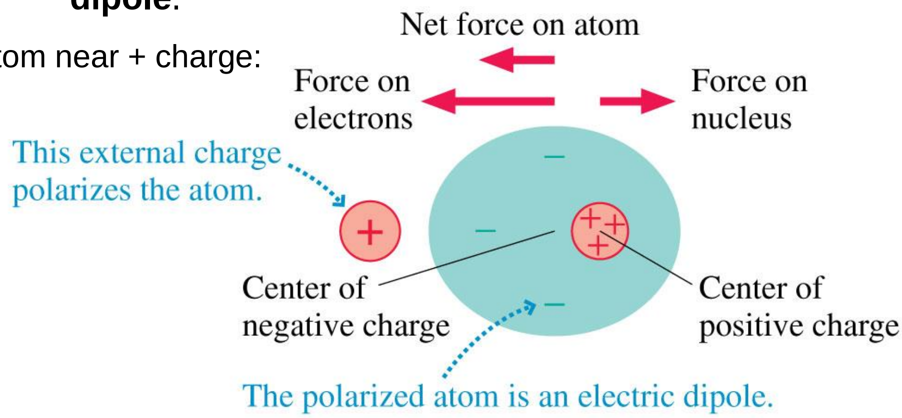
Atom all alone:



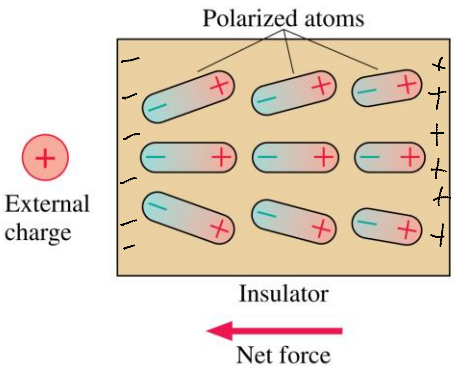
The Electric Dipole

- 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:



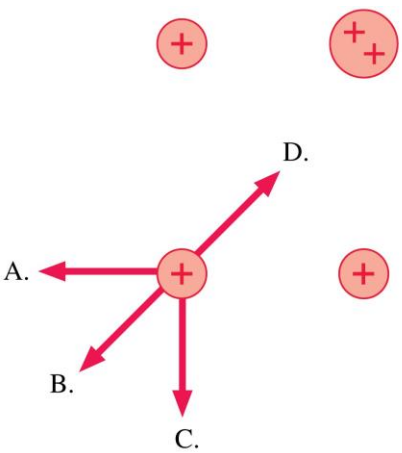
The Electric Dipole



- 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.

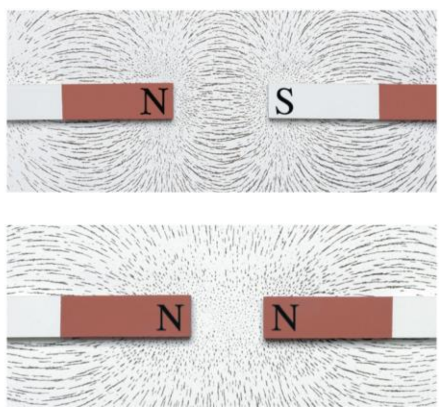
C. Left.

D. Right.

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

The Field Model

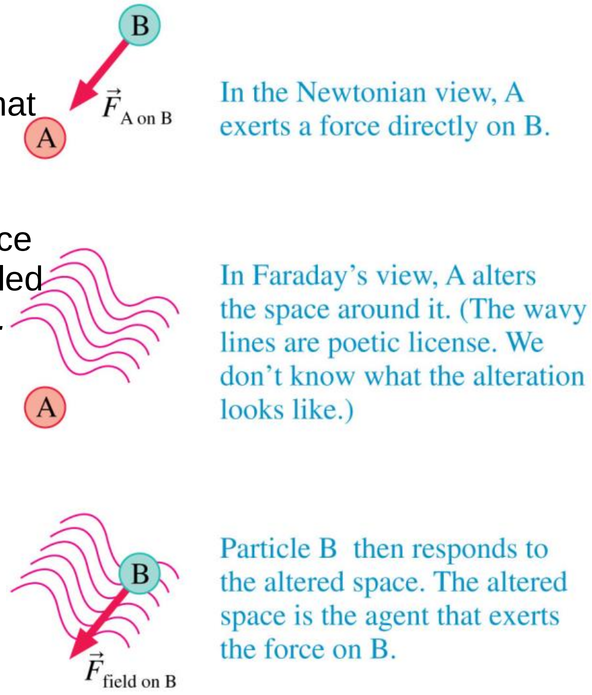
- The photos show the patterns that iron filings make when sprinkled around a magnet.
- These patterns suggest that *space itself* around the magnet is filled with magnetic influence.
- This is called the **magnetic field**.



- 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:

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

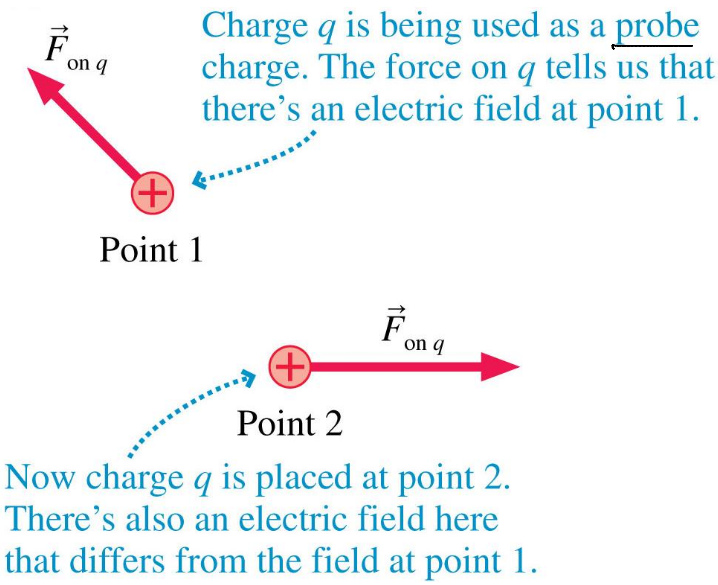
- If q is positive, the force on the particle is in the direction of $\vec{E}$.
- The force on a negative charge is *opposite* the direction of $\vec{E}$.

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

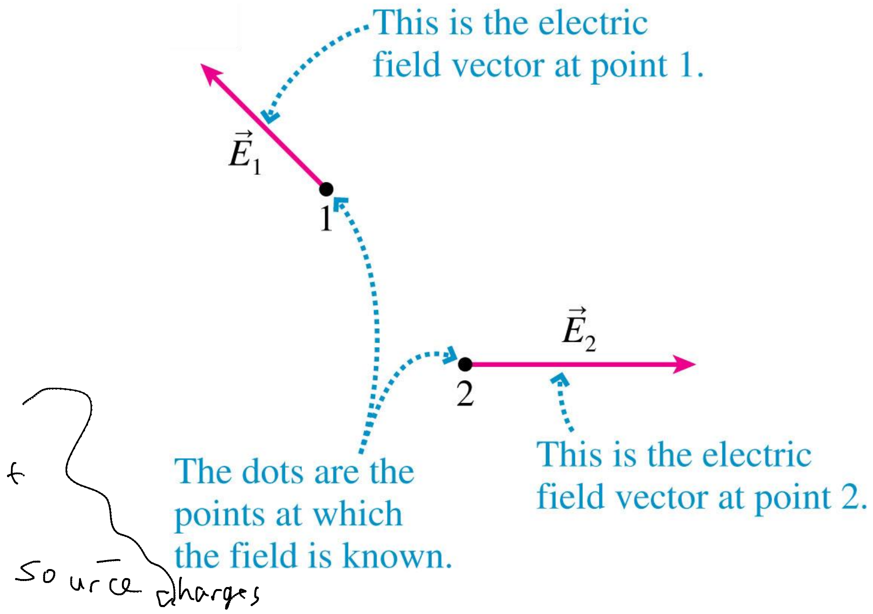
TABLE 26.1 Typical electric field strengths

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

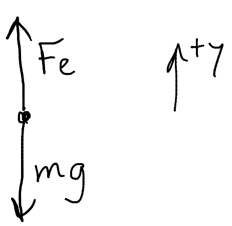


The Electric Field



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?

fbd. of bee:



$$(F_{Net})_y = 0 = F_e - mg = 0$$

$$(F_e)_y = mg$$

$$F_e = Eq$$

$$(\vec{E})_y = -100 \text{ N/C}$$

$$E_y q = mg$$

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

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

$$= -9800 \text{ nC}$$

The Electric Field of a Point Charge

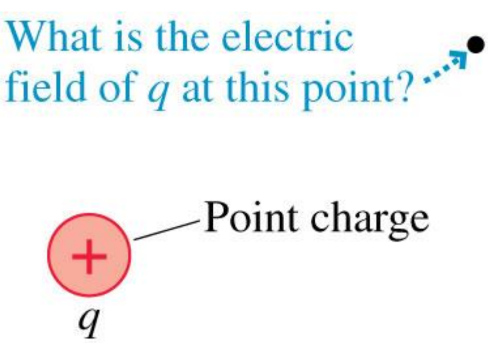
q' = probe charge
q = source charge.

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

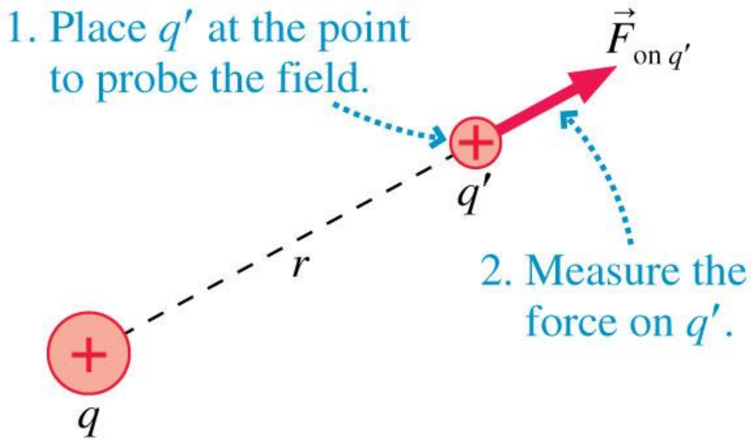
$$\vec{E} = \frac{\vec{F}_{\text{on } q'}}{q'} = \left(\frac{1}{4\pi\epsilon_0} \frac{q}{r^2}, \text{ away from } q \right)$$

or $F = \dfrac{K q' q}{r^2}$ $\quad E = \dfrac{F}{q'} = \dfrac{Kq}{r^2}$

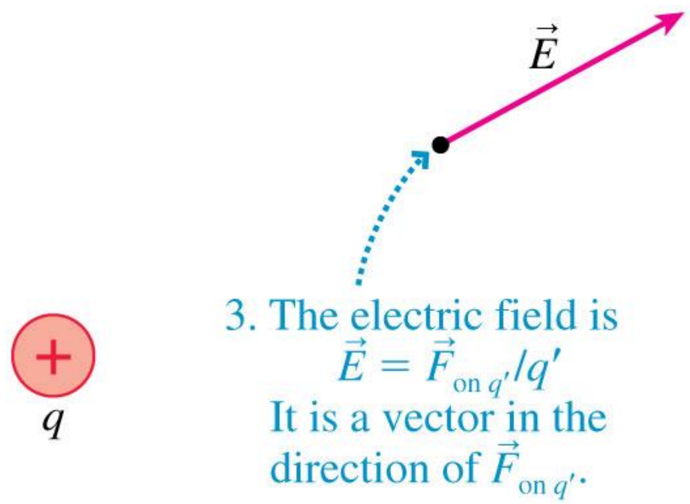
The Electric Field of a Point Charge



The Electric Field of a Point Charge

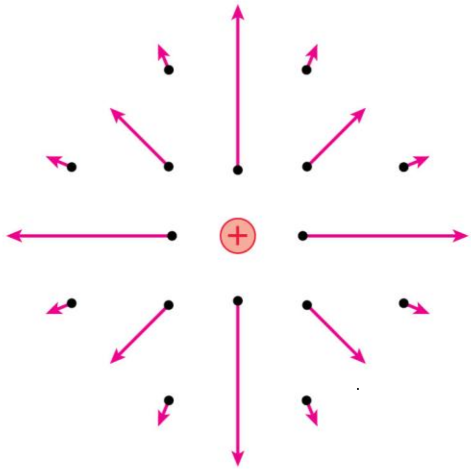


The Electric Field of a Point Charge



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*.

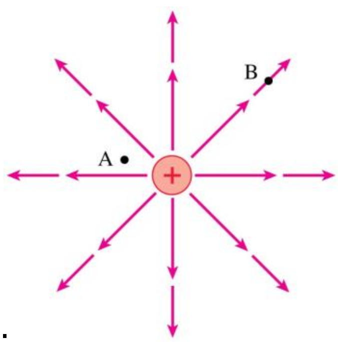


At which point is the electric field stronger?

A. Point A.

B. Point B.

C. Not enough information to tell.

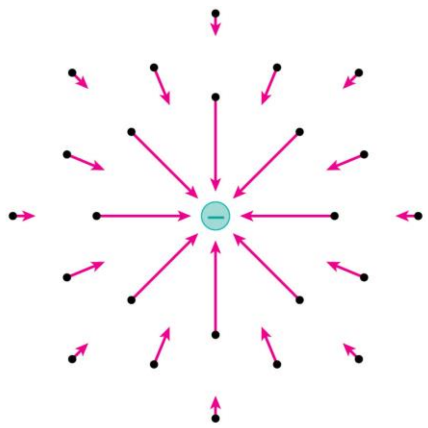


The Electric Field of a Point Charge

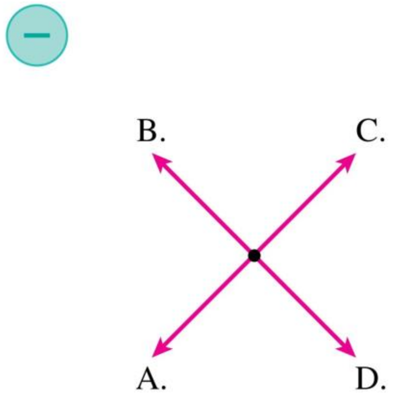
- Using unit vector notation, the electric field at a distance r from a point charge q is:

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

- 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.

- Test 1 is Tomorrow from 6:00-7:30pm.
- Room is based on your **Practical Group**.

Group	Room
M2A	HA 401
M2B	SF 2202
M3A	HA 316
M3B	SF 3201

Group	Room
T1A	HA 403
T2A	SF 3202
T2B	HA 403
T3A	SF 3202
T3B	HA 403

Group	Room
W2A	UC 266 (East Hall)
W2B	UC 273 (West Hall)
W3A	UC 266 (East Hall)
W3B	UC 273 (West Hall)
W4A	UC 266 (East Hall)
W4B	UC 273 (West Hall)

Group	Room
R2A	SF 3201
R2B	HA 410
R3A	SF 3201
R3B	SF 2202

Group	Room
F1A	BA 1170
F1B	SF 3202
F2A	BA 1170

What will tomorrow evening's test cover?

- Test 1 is on:
  - Knight Chs. 20, 21, 23, 24 and 25 .

including 25.5

- The midterm test will have:
  - **8** multiple-choice questions
  - 2 unrelated long-answer problems counting for a total of **16** marks, which will be graded in detail; part marks may be awarded, but **only if you show your work**.

Test 1 on Tuesday Evening

- Please bring:
  - ❑ **Your student card.**
  - ❑ A calculator without any communication capability.
  - ❑ A single, original, handwritten 8 1/2 × 11 inch sheet of paper on which you may have written anything you wish, on both sides. You may also type it if you wish, but it must be prepared by you. No photocopies.
  - ❑ A ruler

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

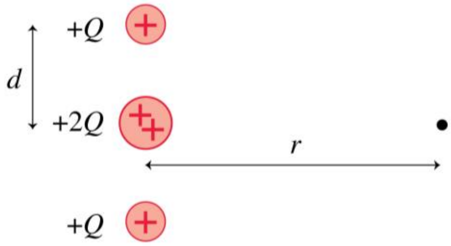
A. $\dfrac{Q}{4\pi\epsilon_0 r^2}$

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

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

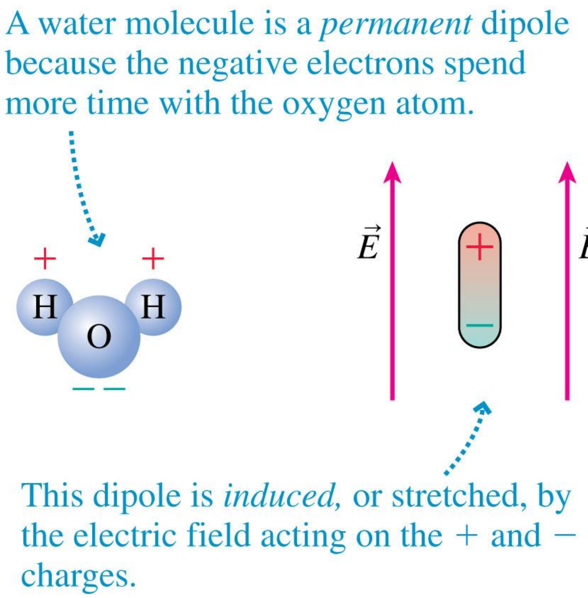
D. $\dfrac{4Q}{4\pi\epsilon_0 (r^2 + d^2)}$

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



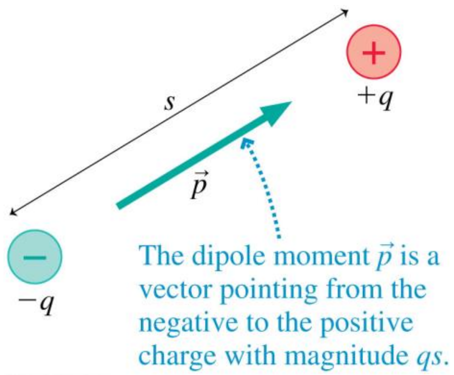
Electric Dipoles

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



The Dipole Moment

Total charge of dipole = zero.

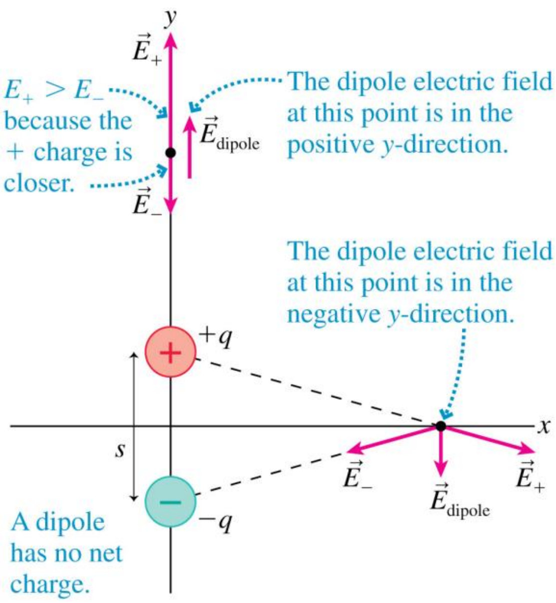


- It is useful to define the dipole moment $\vec{p}$, shown in the figure, as the vector:

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

- 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:

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

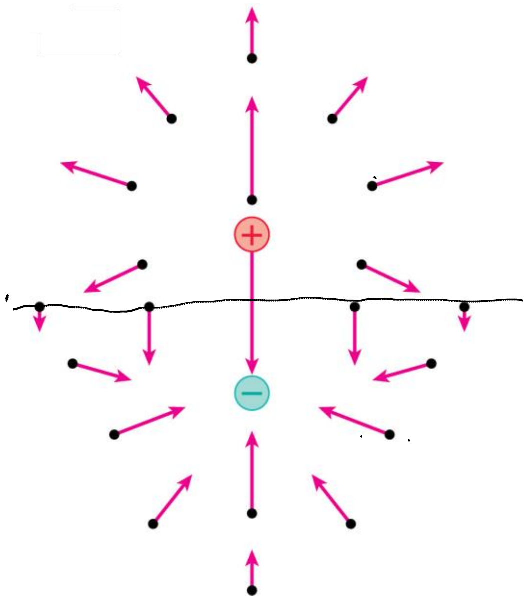
where r is the distance measured from the *center* of the dipole.

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

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

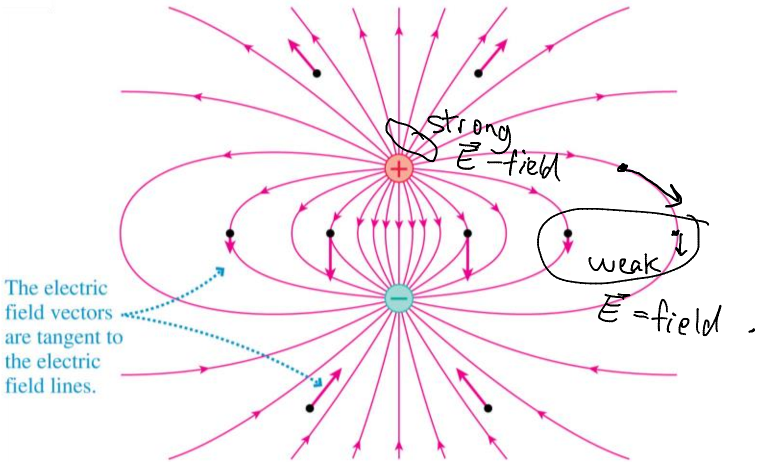
- This field is opposite to the dipole direction, and it is only half the strength of the on-axis field at the same distance.

The Electric Field of a Dipole



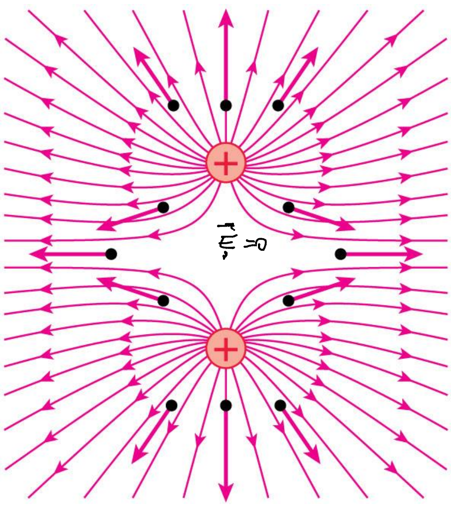
This figure represents the electric field of a dipole as a field-vector diagram.

The Electric Field of a Dipole



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

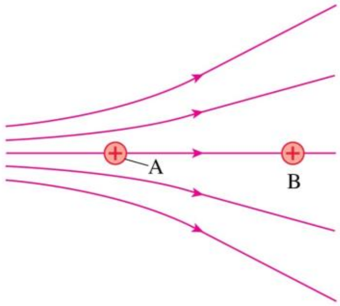
The Electric Field of Two Equal Positive Charges



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

- There is NO pre-class quiz due on Wednesday morning.
- However, if you could read over the rest of Chapter 26 before coming to class on Wednesday, I would appreciate it.

- Something to think about: What causes lightning? If the ground is neutral and the cloud-cover is positive, is lightning the electrons jumping up to the clouds?
- Good luck on the test tomorrow night!