Chapter 21

Electric Charge and Electric Field

PowerPoint® Lectures for
University Physics, Twelfth Edition
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Lectures by James Pazun Modified by P. Lam for 15th edition

Important Objectives for Chapter 21

- Recognize the importance of electro-magnetic interaction in our daily lives
- Understand the atomic charge model – conductors, insulators, electric dipole
- Learn the force law (Coulomb's Law) for ***stationary charges (You will learn later that the force law will be different when the charges are moving)***
- Learn the concept of electric field
- Learn to extract information from drawings of electric field lines

Introduction

- As far as we know, there are only four fundamental forces (interactions):
  - 1. Gravitational force - arises from interaction between masses
  - 2. Electromagnetic force - arises from interaction between stationary or moving charges (electric force arises whether the charges are stationary or moving but the force laws for both cases are different; magnetic force arises only when the charges are moving). (Since whether a charge is moving or not depends on the frame of reference, this means that electric force and magnetic force are different viewpoints of the same "force"!)
  - 3. Strong nuclear force – binds nucleons together - not covered in this course
  - 4. Weak nuclear force – causes certain nuclear decays - not covered in this course

Importance of electro-magnetic interaction

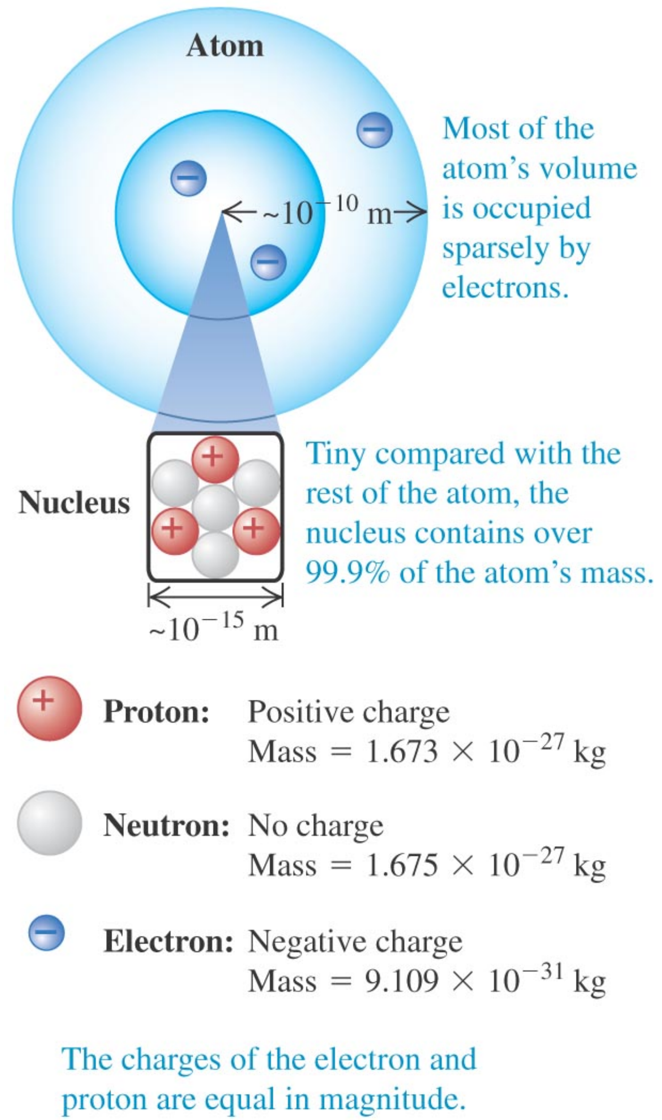
- Which fundamental interaction is responsible for the following?
  - Friction,
  - The "contact" force
  - Tension in a rope
  - Electric motor
  - Radio wave
  - Light
- If an interaction between **matters** is not gravitational nor nuclear interactions, you can with great certainty to attribute it to the electromagnetic interaction even though you may know how it works. All matters contain charges.
- ** Aside: "Dark Matters" seem not to involve the electromagnetic interaction but we don't have a definitive theory yet.

Topics for Chapter 21

- 21.1 - Atomic charge model
- 21.2 Conductors and insulators
- 21.3 Electrostatic force - Coulomb’s Law
- Intermission
- 21.4 Electric force and electric field
- 21.5 Calculation of electric field (generated by multiple charges or continuous charge distribution – superposition principle)
- 21.6 Electric field lines (drawings and interpretations)
- 21.7 Electric dipoles

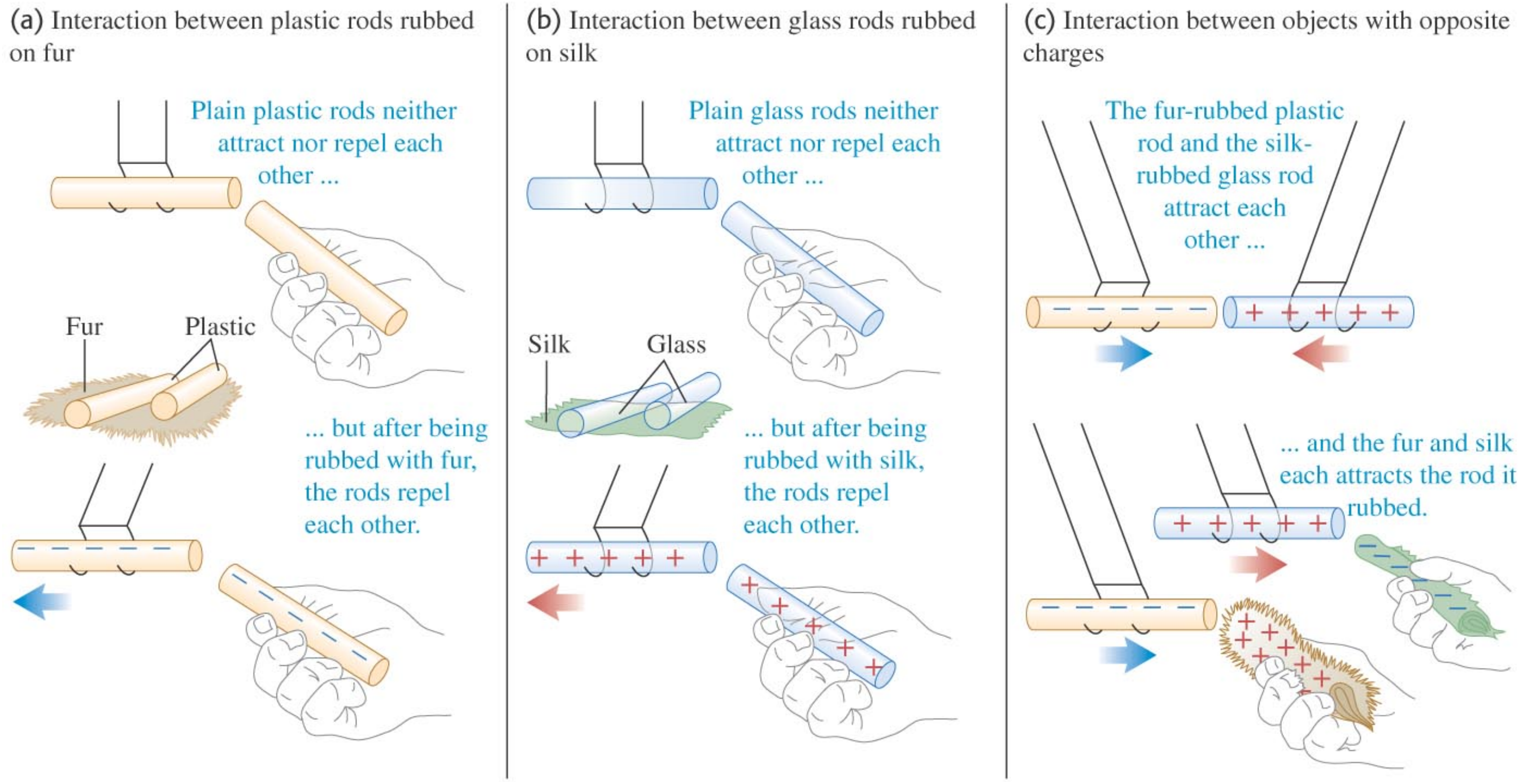
21.1 Atomic Charge Model-Neutral vs. Charged Objects

- When you read this section in the textbook, answer some of the following questions:
- (1) Most materials are electrically neutral. Does it means it contains no charges or something else?
- (2) When two neutral objects are "rubbed" against each other, one becomes positively charged and one becomes negatively charged. Did some of the protons move from one object to the other? Did some of the electrons move from one object to the other?
- (3) Which fundamental interaction is "rubbing"?



Charging by "rubbing" (electromagnetic interaction)

- Rubbing two materials is to force the atoms from the two materials to be very close to each other; the material with higher "electron affinity" will accept extra electrons while the other material with lower "electron affinity" will give up some electrons (Electron affinity can only be explained by quantum mechanics).



21.2 Conductors vs. Insulators

- A collection of atoms forms solid, the chemical bonding determine whether the solid is a conductor or insulator.
- Conductors are materials with weak chemical bonds which allow the electrons to move from one atom to another when subjected to a force conductors.
- Insulators are materials with strong chemical bond which does not allow the electrons to move freely.
- In this section, learn about different charging processes.

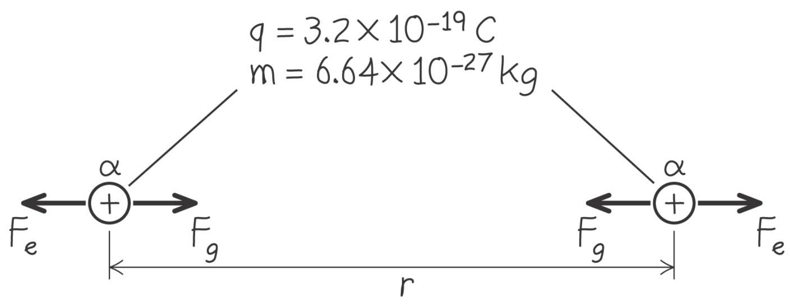
21.3 Coulomb's Law

- Electrostatic force – qualitative:
  - Like charges repel and unlike charges attract
  - The force is stronger when 2 charges are close and weaker when they are apart.
  - (***Use these qualitative behavior to explain how a charged object attracts a neutral object***)
- Electrostatic force – Quantitative
  - Coulomb's Law quantifies the electrostatic force between two stationary ***point*** charges. Macroscopic object contains many charges. When we are interested in the force on one particle (charge), we need to add up all the forces acting on this charge by the other charges (Superposition Principle)

Aside: It turns out that, as along as the relative velocity between the two charges is much less than the speed of light then the Coulomb's Law is approximately valid.

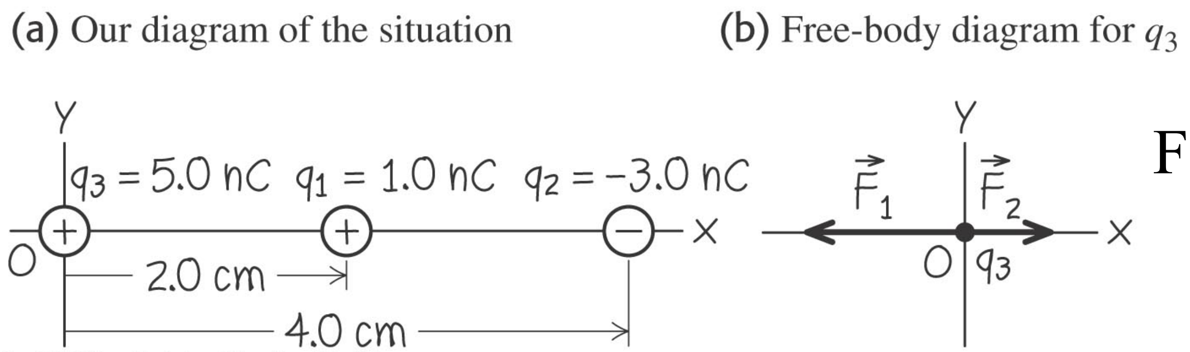
Examples of electrostatic force - I

- A comparison of gravitational force to electrostatic force is shown in Example 21.1 and Figure 21.11.
- Alpha particle=He^{2+} (Helium nucleus without the two electrons)
- Find the ratio of the electrostatic repulsion to the gravitational attraction.

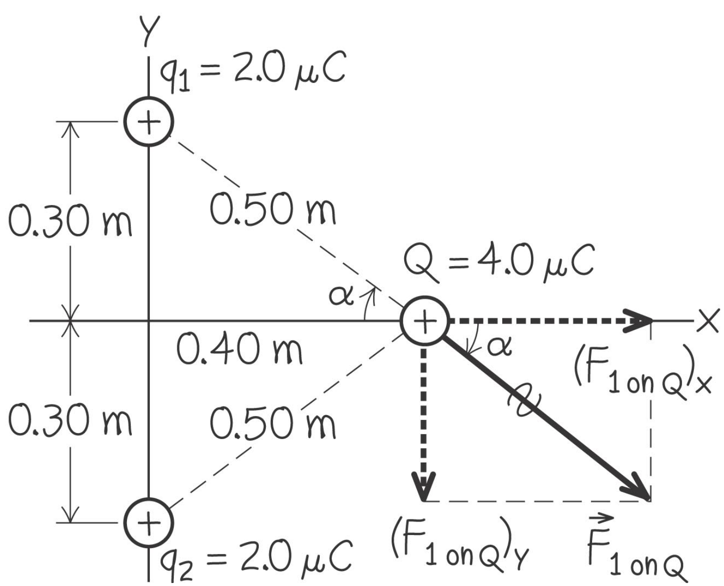


Examples of electrostatic force - II

- Consider Example 21.3 and Figure 21.13.
- See also Example 21.4 and Figure 21.14.



Find force vector on q_3

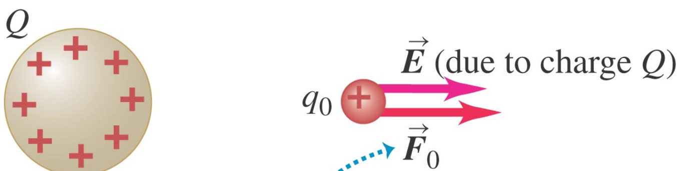


Find force vector on Q.

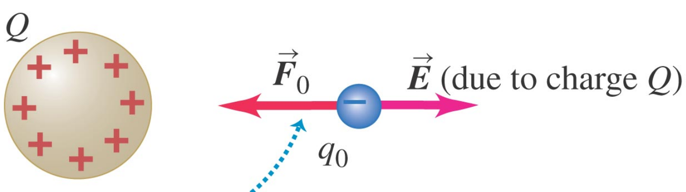
Intermission

21.4 Electric force and electric field

- Coulomb's Law states that charges can act on each other over long distances.
- Faraday came up with a field concept where he imagined that one charge (source charge; Q) produces a web of electric force field (**E**(**r**))over all space; the force it exerts on the second charge (q) at location **r** is simply q*E(**r**).
- If one measured the force on a positive test charge (q_o) at all points relative to source charge (or charges), one can map out the entire electric field generated by the source charge(s).
- Go through the tutorial in MP for electric force and electric field



The force on a positive test charge q_0 points in the direction of the electric field.

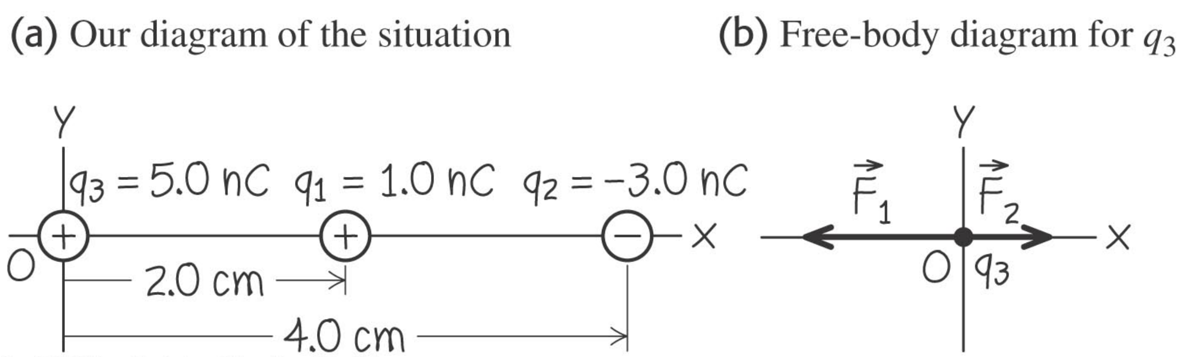


The force on a negative test charge q_0 points opposite to the electric field.

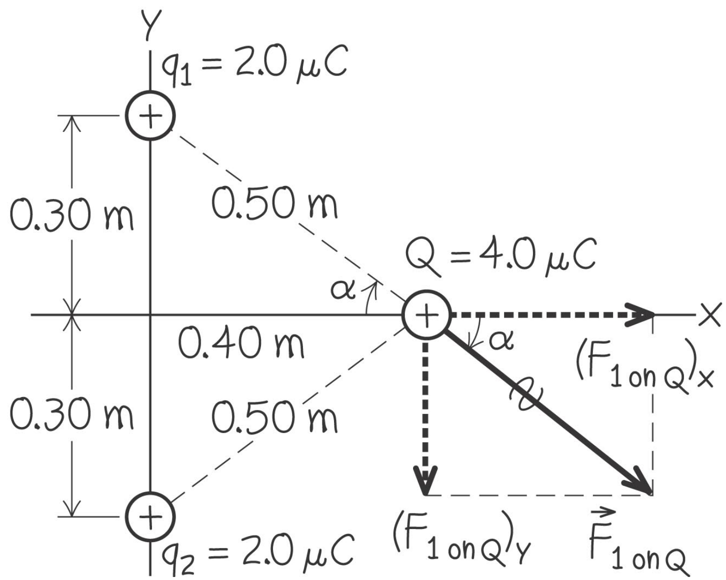
21.5 Calculation of electric field

- Go through the assigned tutorials in Mastering Physics for electric force and electric field.

Practice calculating electric field I



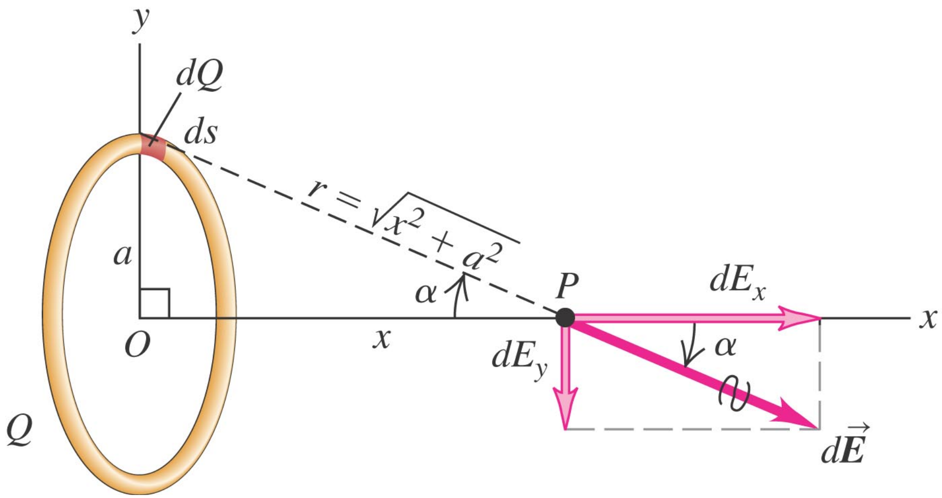
Find the electric field at the location of q_3 due to q_1 & q_2

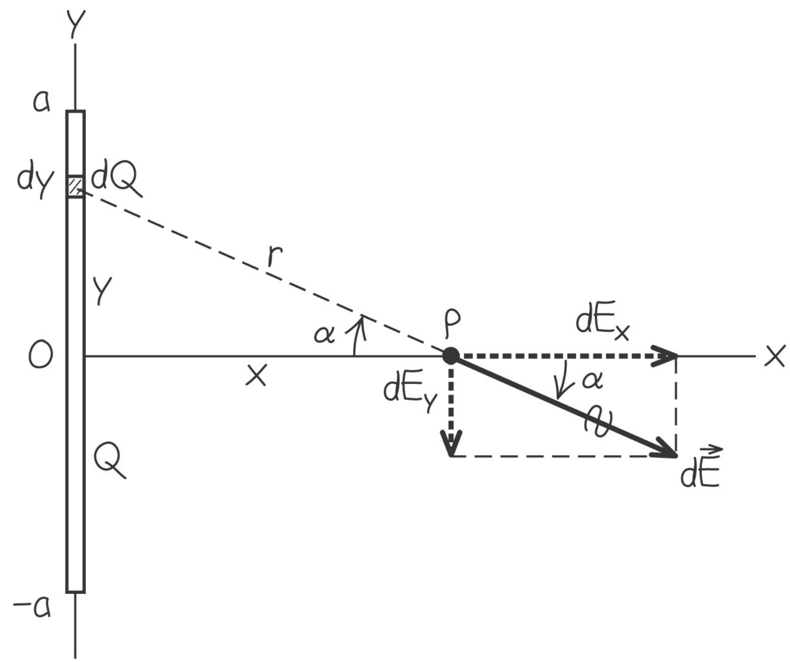


Find the electric field at the location of Q to q_1 & q_2.

Practice calculating electric field II

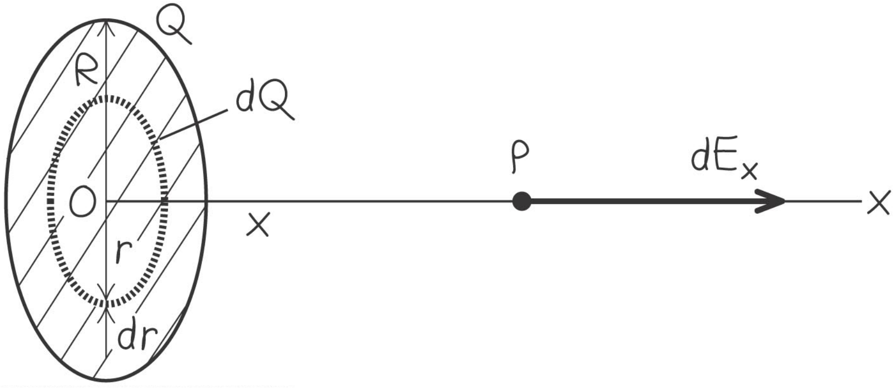
- Review Example 21.10 and Figure 21.24.
- Review Example 21.11 and Figure 21.25.

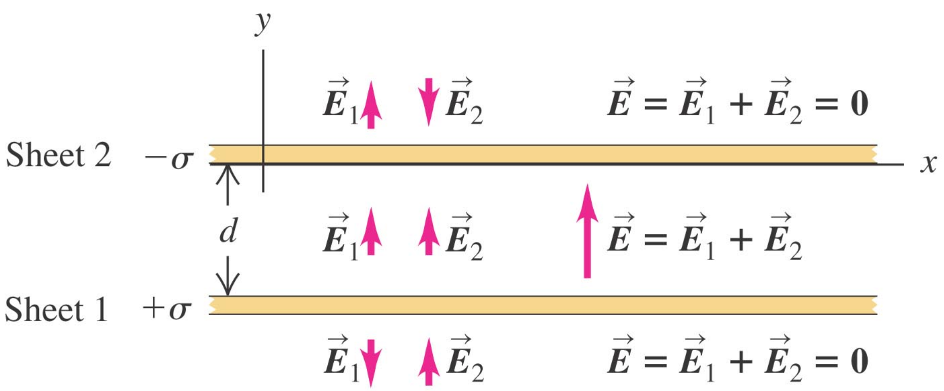




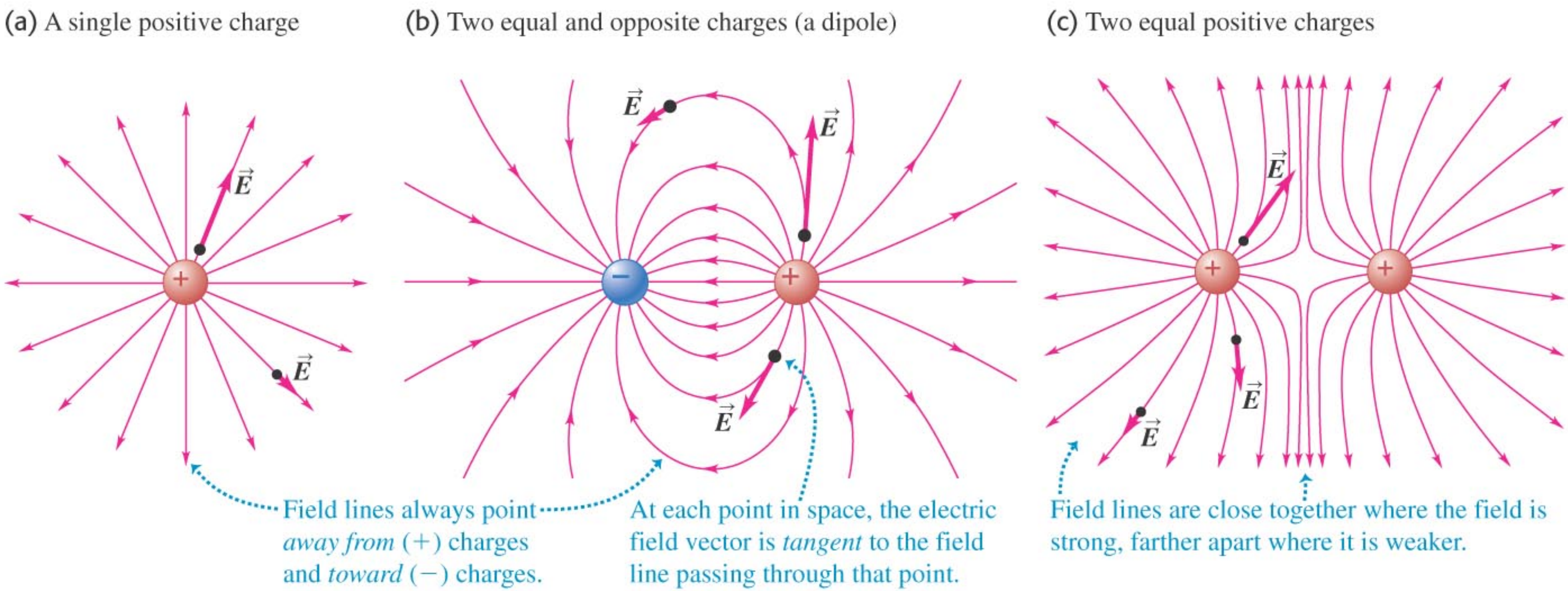
A field around a disk or sheet of charge

- Review Example 21.12 and Figure 21.26.
- Review Example 21.13 and Figure 21.27.





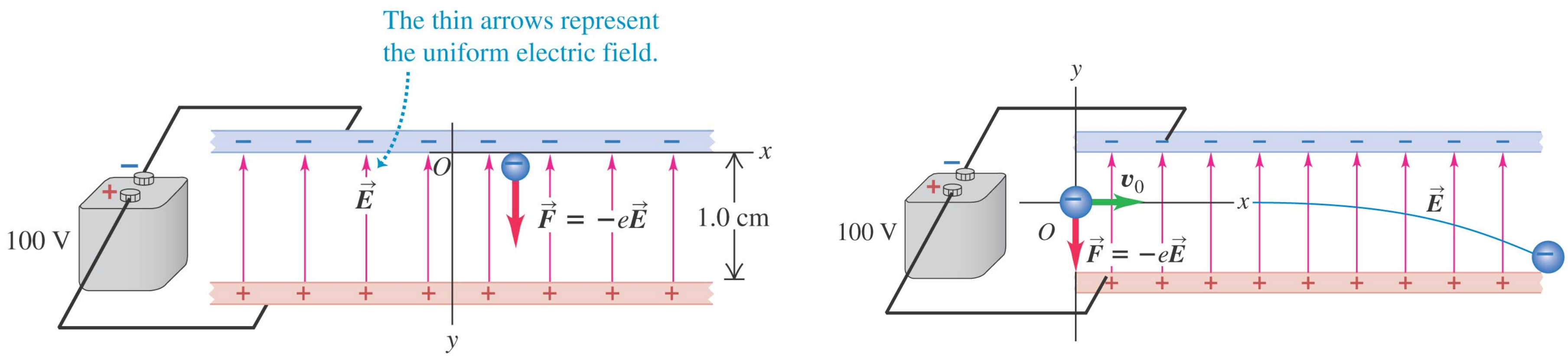
21.6 Electric field lines drawings



(1) What does the direction of the arrow mean?
(2) How is the electric field strength related to the spacing between the lines?

Electric fields II—charges in motion within a field

- Consider Example 21.7.
- Consider Example 21.8 and Figure 21.21.

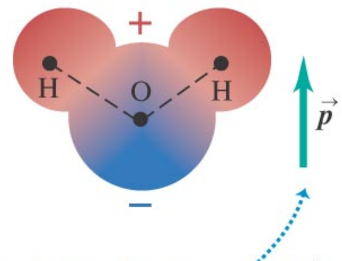


Note: Technically, this is not a electrostatic situation.
In principle, when the charge Q moves, it will affect the (source) charges on the two plates thus altering the electric field.
As long as Q is small enough, the redistribution of source charges are negligible.

21.7 Electric dipoles

- What is the difference between permanent electric dipole and induced electric dipole?
- Water molecule has a permanent electric dipole and as a consequence it is a good solvent, why?

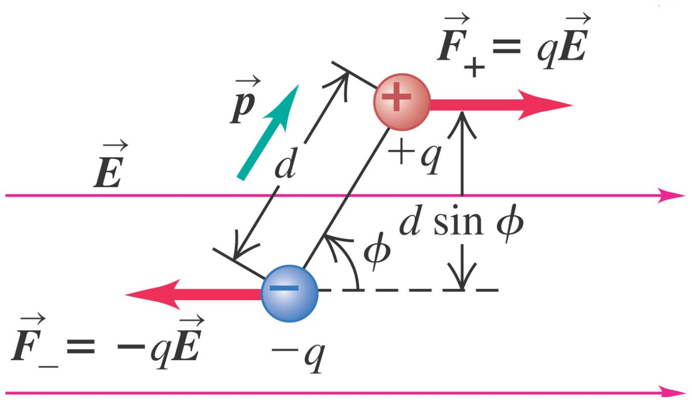
(a) A water molecule, showing positive charge as red and negative charge as blue

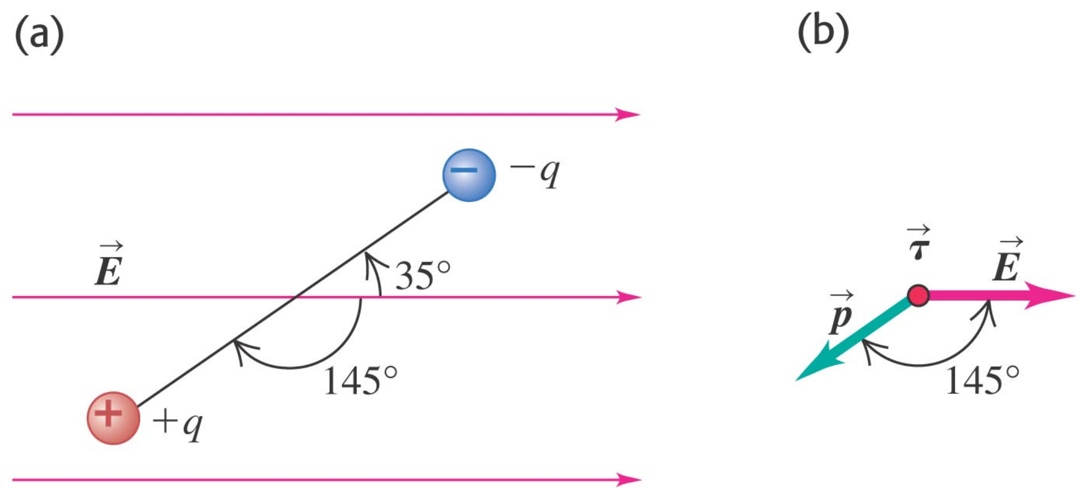


(b) Various substances dissolved in water

Consider the net force on a dipole due to an external E-field

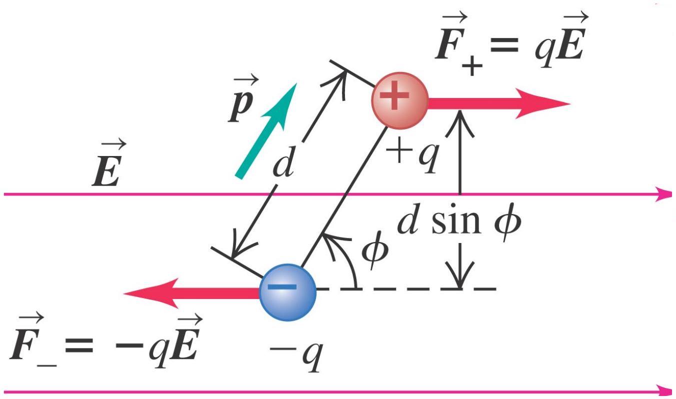
- Regard Figure 21.32.
- Follow Example 21.14 and Figure 21.33.

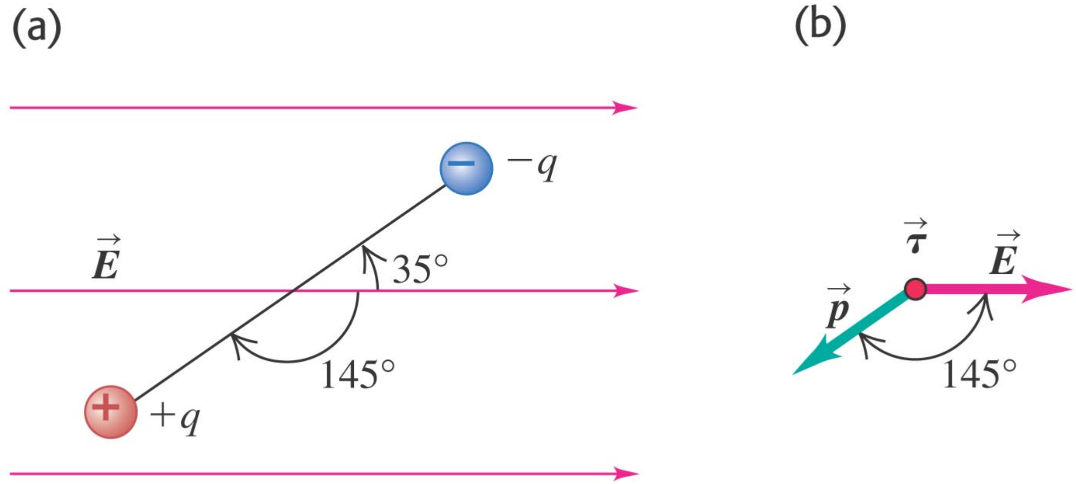




Is there a net force on an electric dipole if the electric field (produced by the source charges) is uniform?

Consider the net torque on a dipole due to an external E-field





Is there a net torque on an electric dipole if the electric field (produced by the source charges) is uniform?

If the electric dipole is free to rotate, what is its stable configuration?

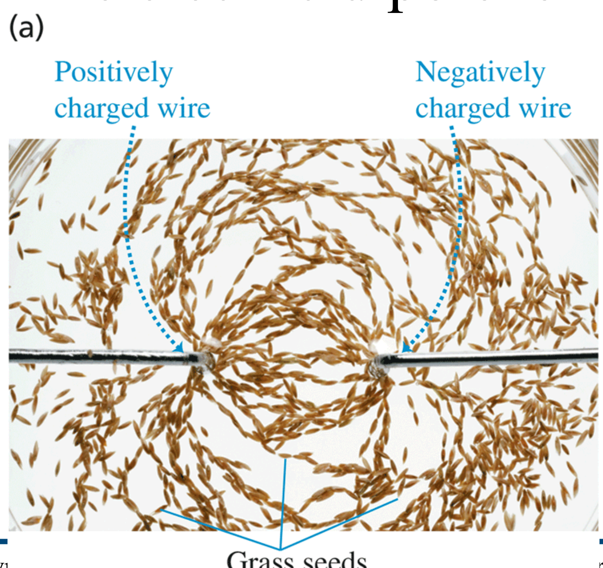


Fig. 21.29 shows a demonstration of electric field lines. Using what you learn on this slide to explain how the demonstration work.