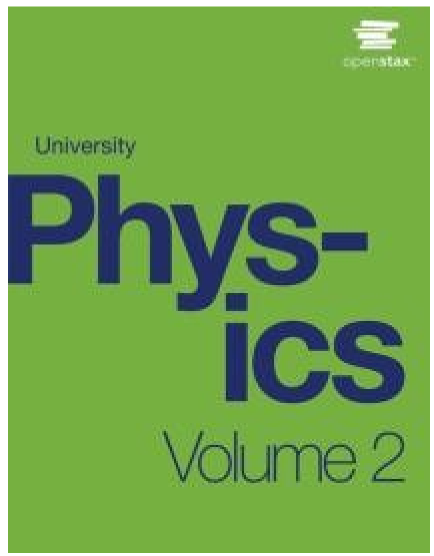
# UNIVERSITY PHYSICS

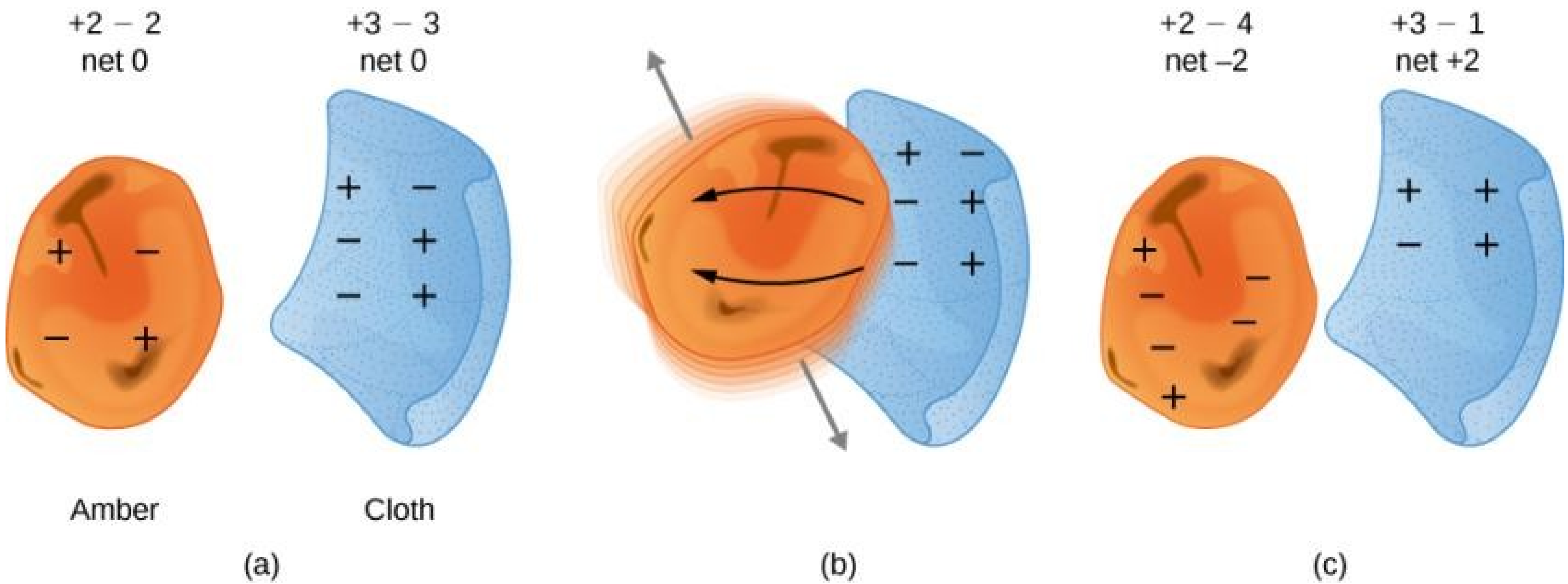
## Chapter 5 ELECTRIC CHARGES AND FIELDS

PowerPoint Image Slideshow



# Electric Charges

# FIGURE 5.5




## There are two electric charges, positive and negative.

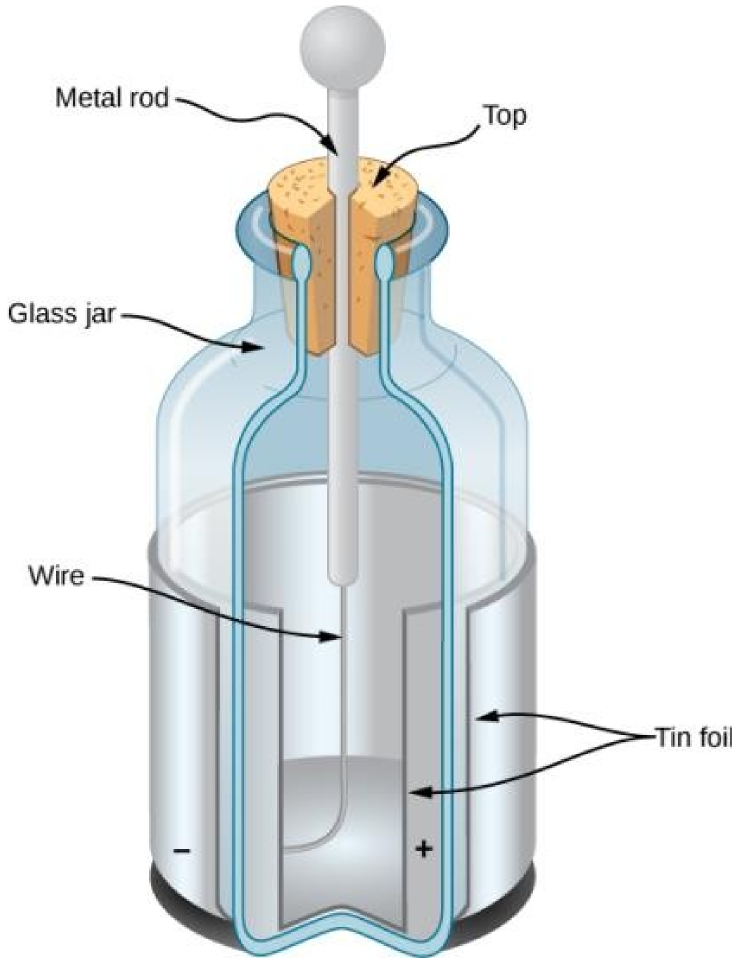
When materials are rubbed together, charges can be separated, particularly if one material has a greater affinity for electrons than another.

a) Both the amber and cloth are originally neutral, with equal positive and negative charges. Only a tiny fraction of the charges are involved, and only a few of them are shown here.

b) When rubbed together, some negative charge is transferred to the amber, leaving the cloth with a net positive charge.

c) When separated, the amber and cloth now have net charges, but the absolute value of the net positive and negative charges will be equal.

# FIGURE 5.6

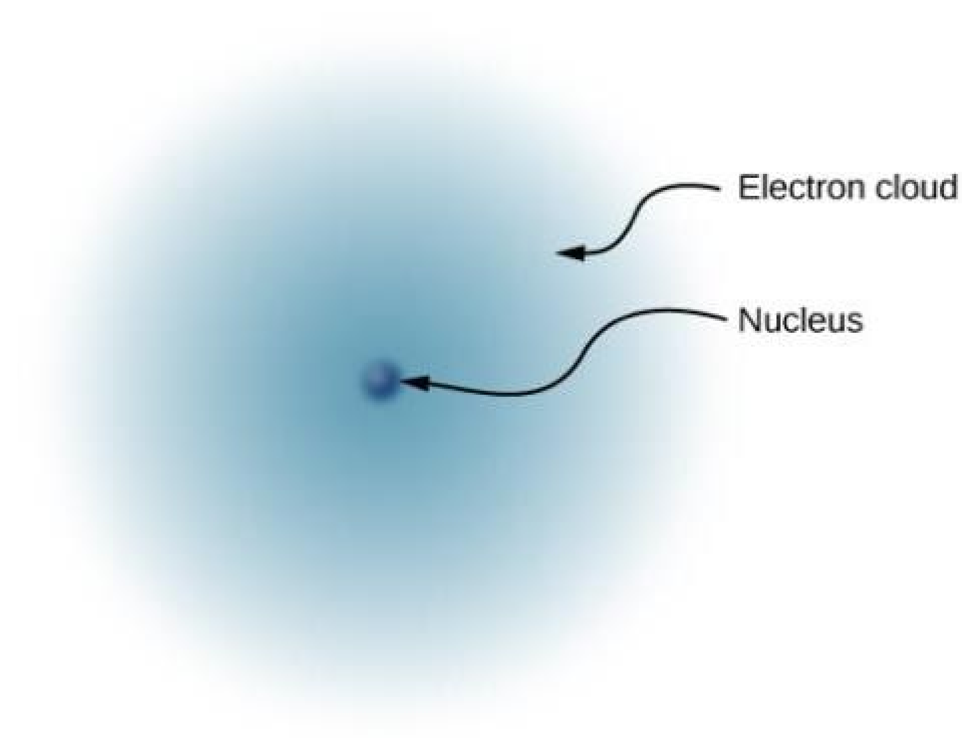



A Leyden jar (an early version of what is now called a capacitor) allowed experimenters to store large amounts of electric charge. Benjamin Franklin used such a jar to demonstrate that lightening behaved exactly like the electricity he got from the equipment in his laboratory.

You can see Leyden jars from 1789 in the Teyler museum in Haarlem, NL https://www.teylersmuseum.nl/

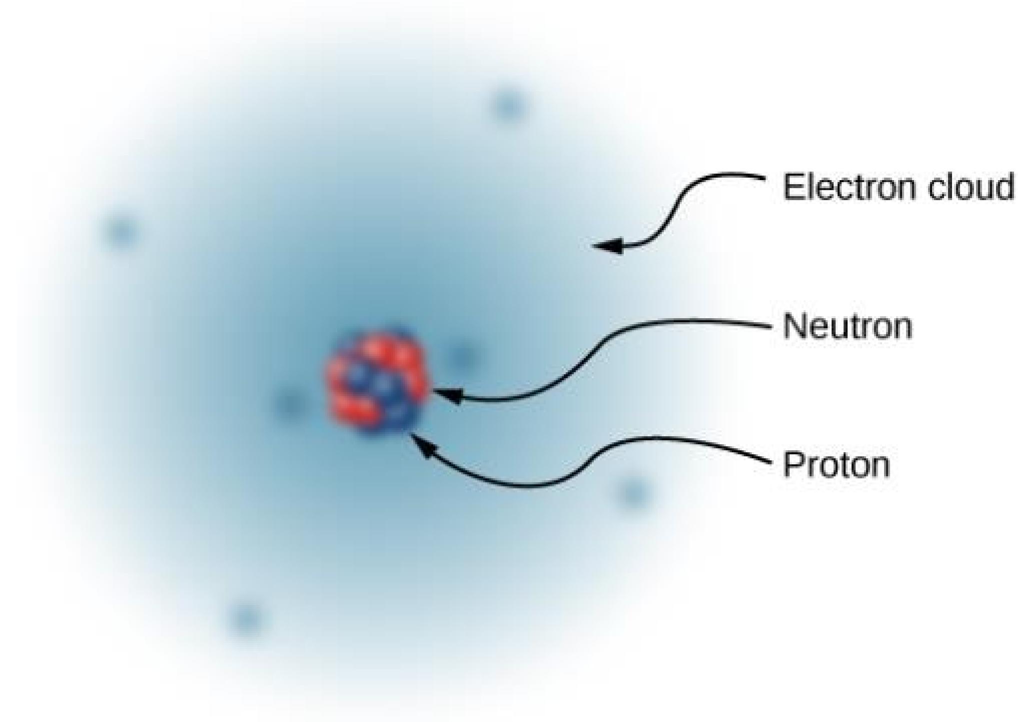
# Polarization

# FIGURE 5.7



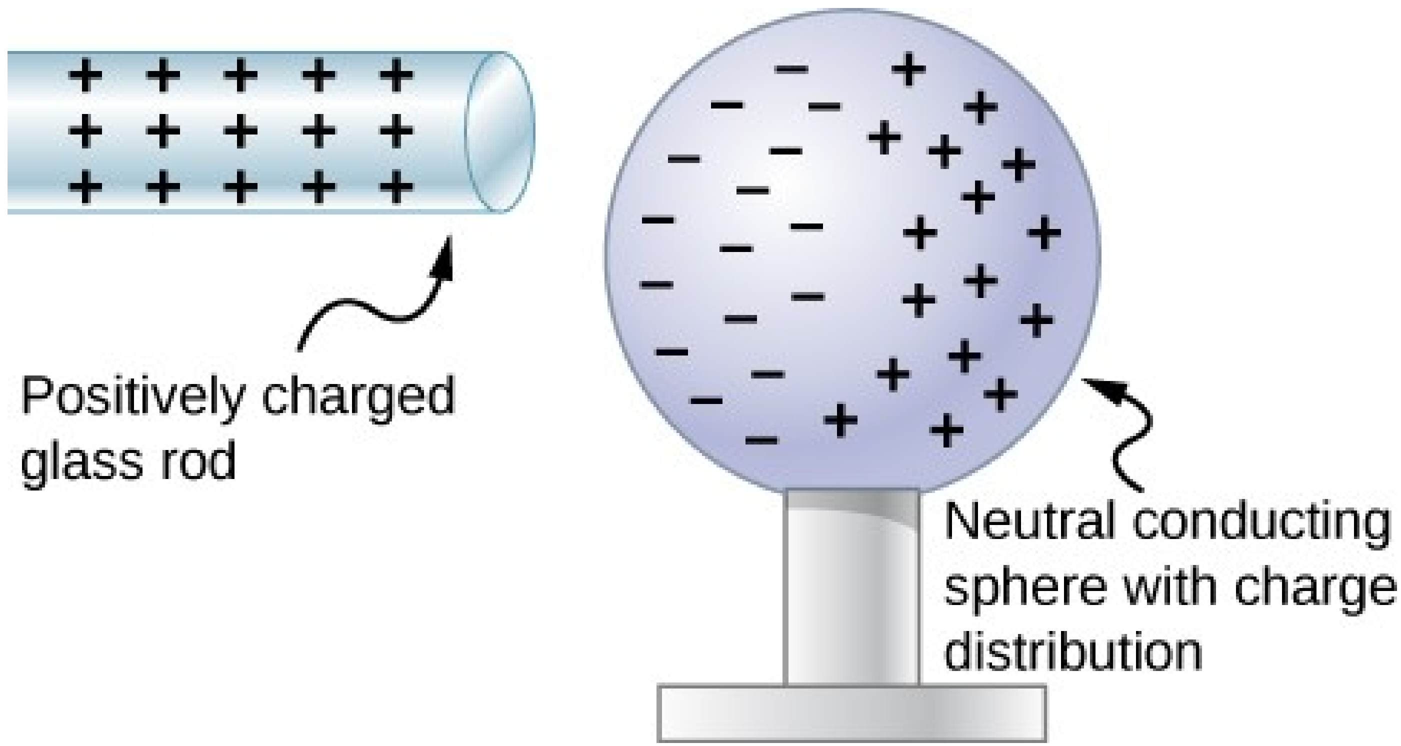

This simplified model of a hydrogen atom shows a positively charged nucleus (consisting, in the case of hydrogen, of a single proton), surrounded by an electron “cloud.” The charge of the electron cloud is equal (and opposite in sign) to the charge of the nucleus, but the electron does not have a definite location in space; hence, its representation here is as a cloud. Normal macroscopic amounts of matter contain immense numbers of atoms and molecules, and, hence, even greater numbers of individual negative and positive charges.

# FIGURE 5.8



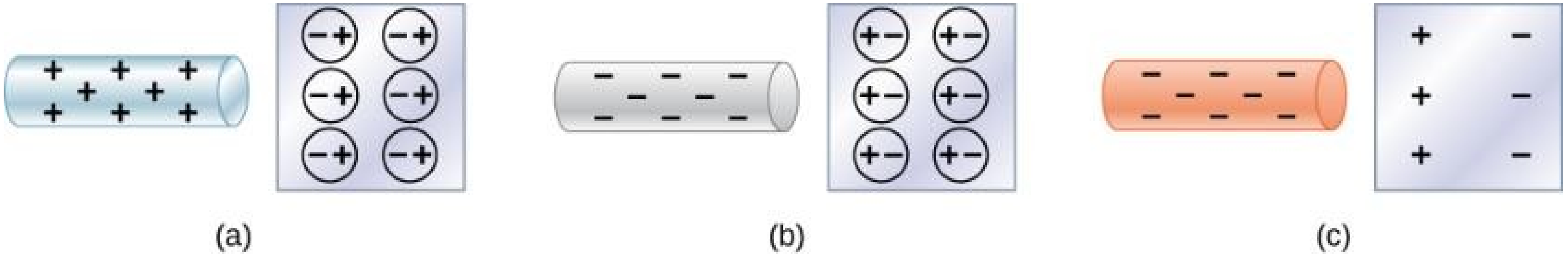

The nucleus of a carbon atom is composed of six protons and six neutrons. As in hydrogen, the surrounding six electrons do not have definite locations and so can be considered to be a sort of cloud surrounding the nucleus.

# FIGURE 5.10




Induced polarization. A positively charged glass rod is brought near the left side of the conducting sphere, attracting negative charge and leaving the other side of the sphere positively charged. Although the sphere is overall still electrically neutral, it now has a charge distribution, so it can exert an electric force on other nearby charges. Furthermore, the distribution is such that it will be attracted to the glass rod.

# FIGURE 5.11




Both positive and negative objects attract a neutral object by polarizing its molecules.

a) A positive object brought near a neutral insulator polarizes its molecules. There is a slight shift in the distribution of the electrons orbiting the molecule, with unlike charges being brought nearer and like charges moved away. Since the electrostatic force decreases with distance, there is a net attraction.

b) A negative object produces the opposite polarization, but again attracts the neutral object.

c) The same effect occurs for a conductor; since the unlike charges are closer, there is a net attraction.

# FIGURE 5.12

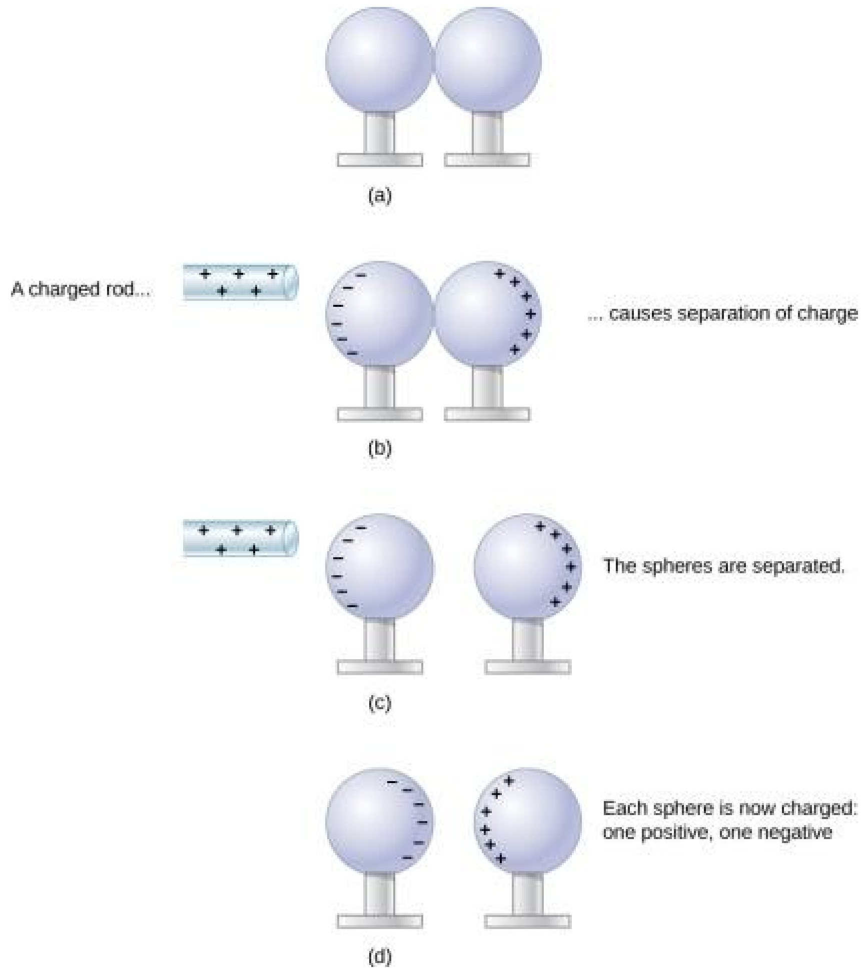
Charging by induction.

a) Two uncharged or neutral metal spheres are in contact with each other but insulated from the rest of the world.

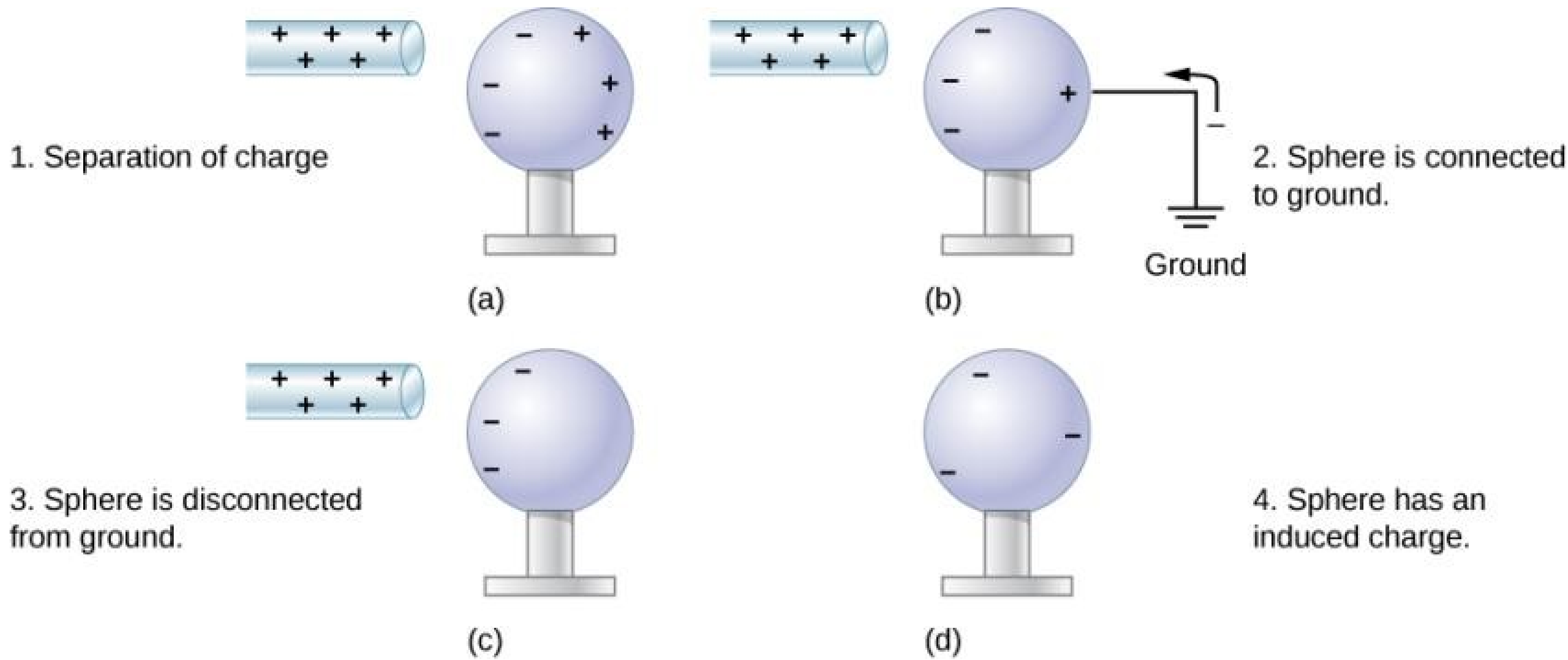
b) A positively charged glass rod is brought near the sphere on the left, attracting negative charge and leaving the other sphere positively charged.

c) The spheres are separated before the rod is removed, thus separating negative and positive charges.

d) The spheres retain net charges after the inducing rod is removed—without ever having been touched by a charged object.



# FIGURE 5.13




Charging by induction using a ground connection.

a) A positively charged rod is brought near a neutral metal sphere, polarizing it.

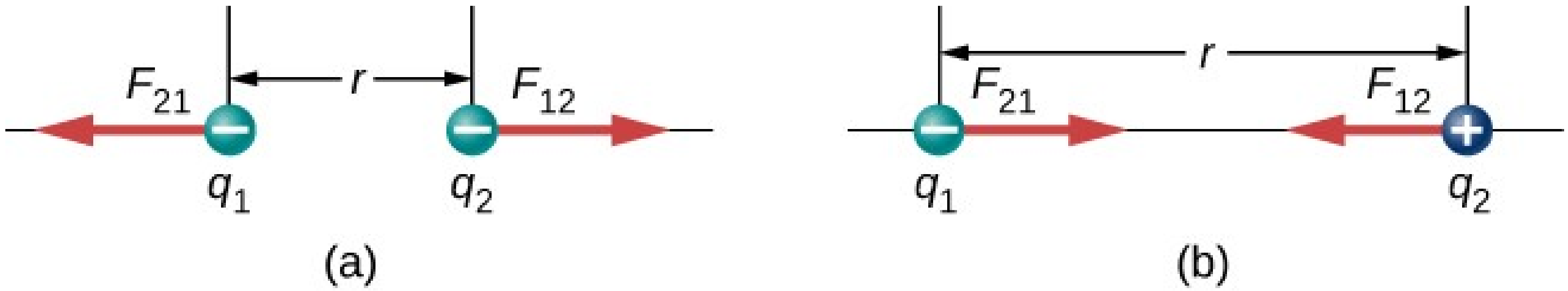
b) The sphere is grounded, allowing electrons to be attracted from Earth’s ample supply.

c) The ground connection is broken.

d) The positive rod is removed, leaving the sphere with an induced negative charge.

# Electric force

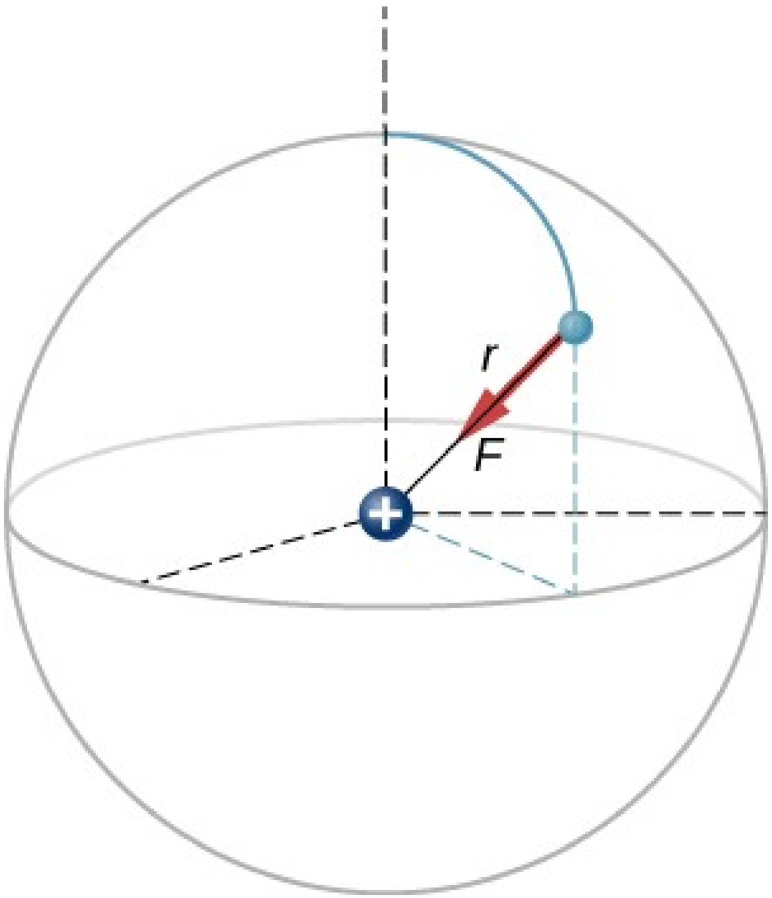
# FIGURE 5.14




$$F = \frac{K q_1 q_2}{r^2}$$

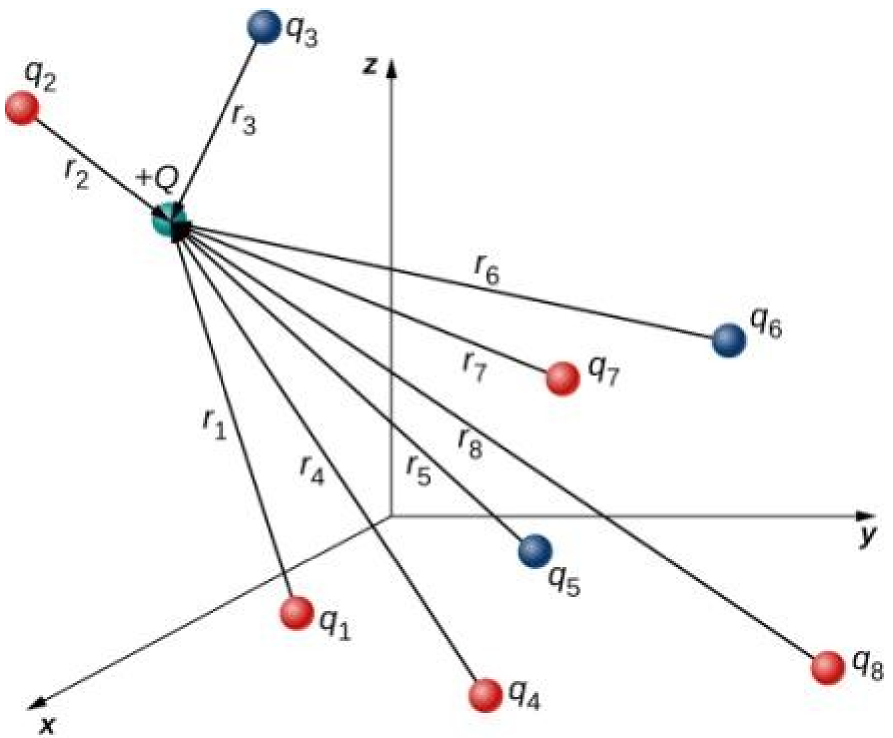
The electrostatic force between point charges $q_1$ and $q_2$ separated by a distance r is given by Coulomb's law. Note that Newton's third law (every force exerted creates an equal and opposite force) applies as usual—the force on $q_1$ is equal in magnitude and opposite in direction to the force it exerts on $q_2$. (a) Like charges; (b) unlike charges.

# FIGURE 5.15




A schematic depiction of a hydrogen atom, showing the force on the electron. This depiction is only to enable us to calculate the force; the hydrogen atom does not really look like this. Recall **Figure 5.7**.

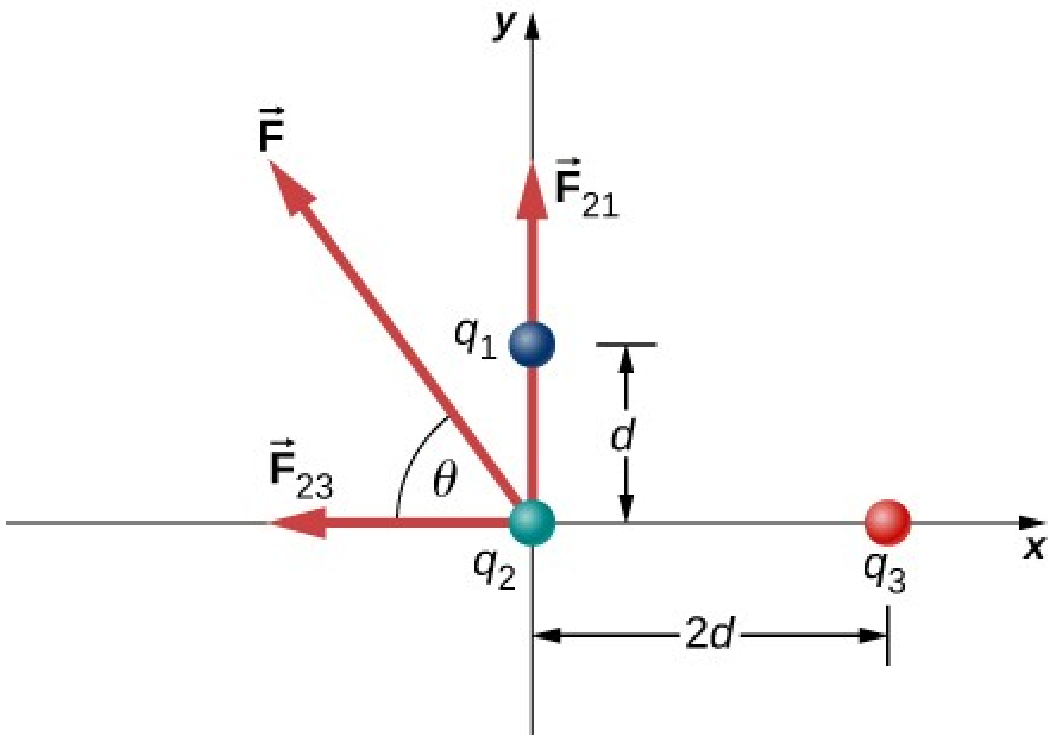
# FIGURE 5.16




The eight source charges each apply a force on the single test charge *Q*. Each force can be calculated independently of the other seven forces. This is the essence of the superposition principle.

Forces from different charges are additive.

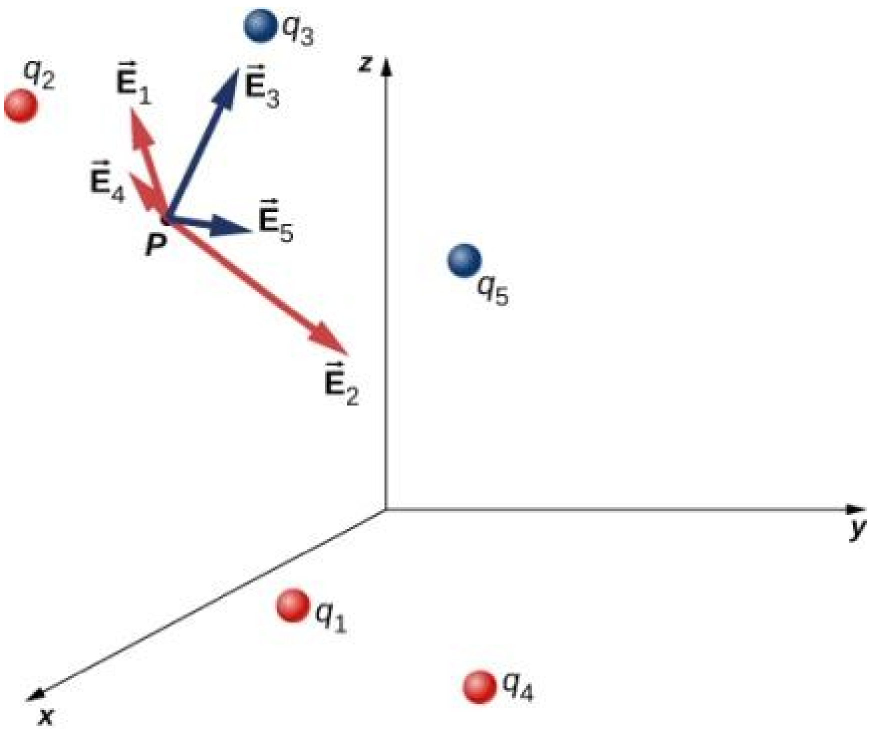
# FIGURE 5.17




Source charges $q_1$ and $q_3$ each apply a force on $q_2$.

# Electric field

# FIGURE 5.18




$$E = \frac{Kq}{r^2}$$

Each of these eight source charges creates its own electric field at every point in space; shown here are the field vectors at an arbitrary point *P*. Like the electric force, the net electric field obeys the superposition principle.

The electric field points where a positive charge wants to go.

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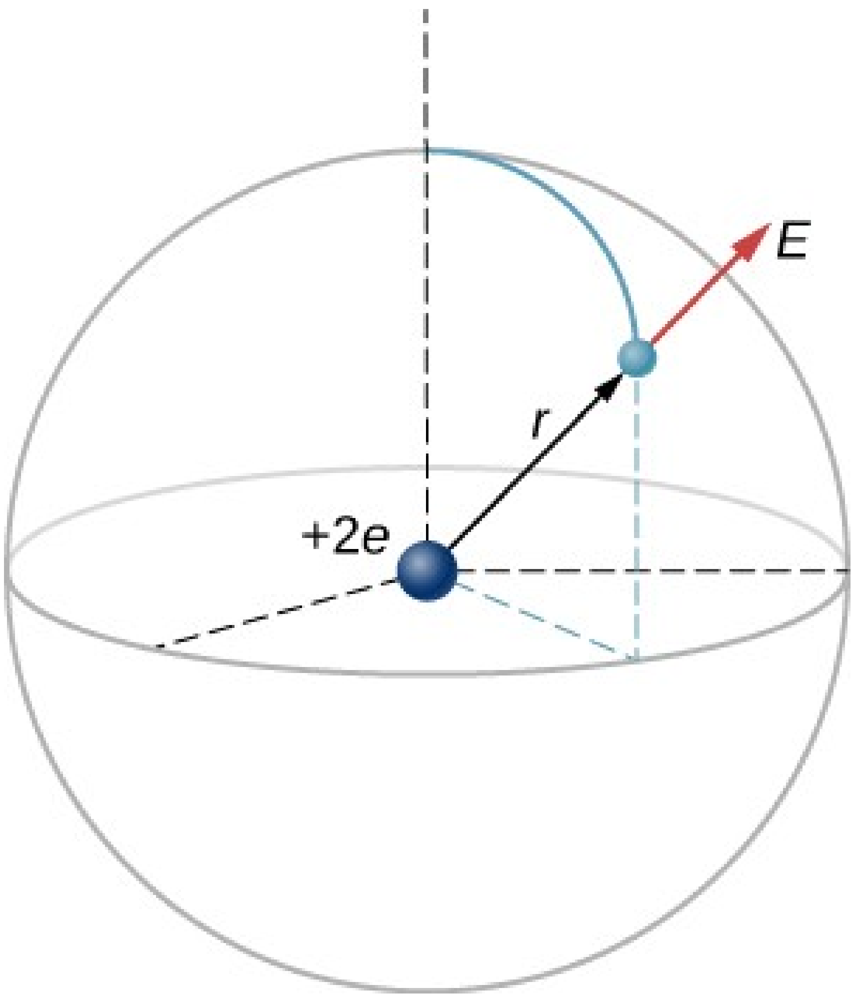
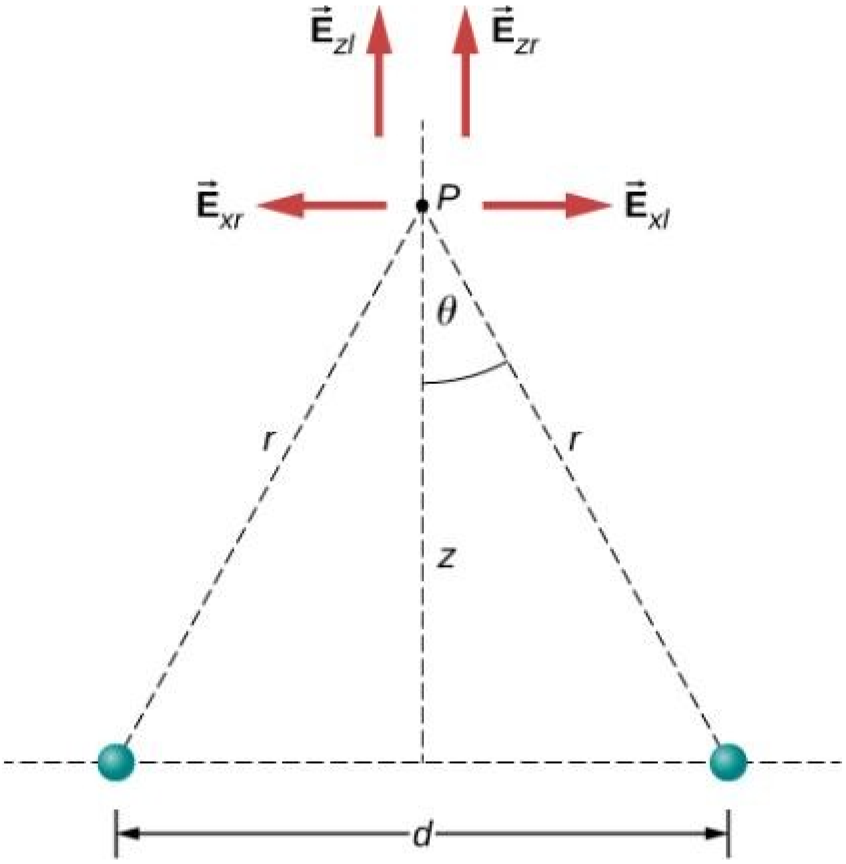
# FIGURE 5.19

A schematic representation of a helium atom. Again, helium physically looks nothing like this, but this sort of diagram is helpful for calculating the electric field of the nucleus.



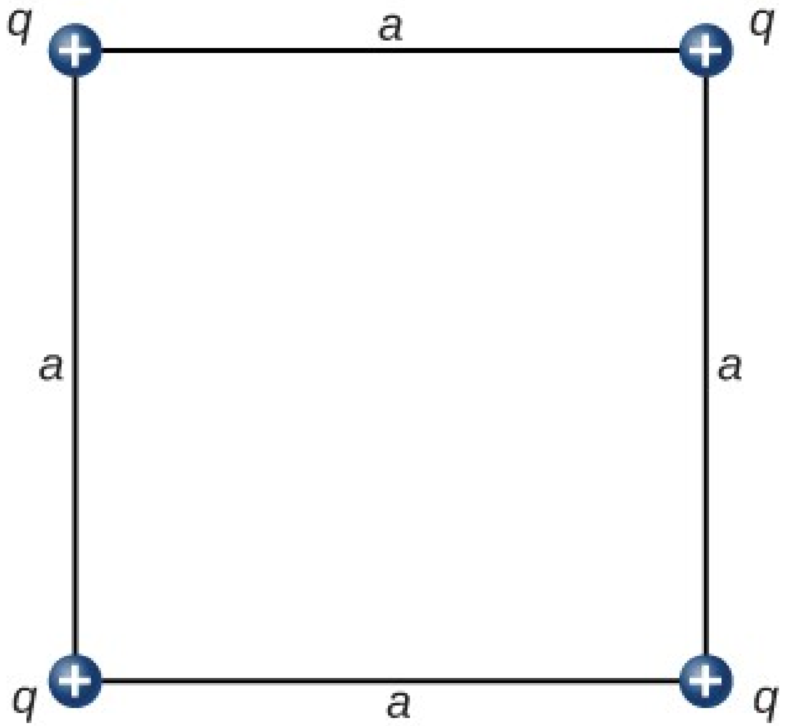
# FIGURE 5.21




Note that the horizontal components of the electric fields from the two charges cancel each other out, while the vertical components add together.

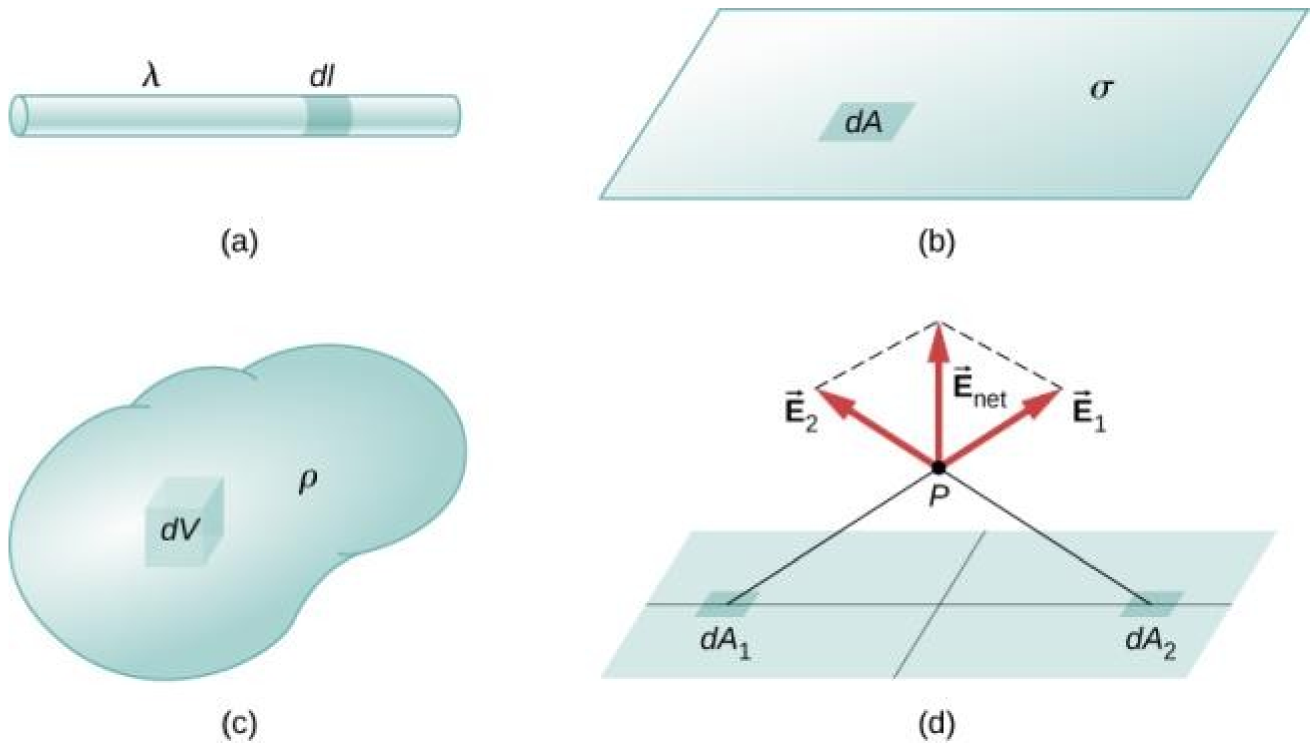
# More calculations

# EXERCISE 63



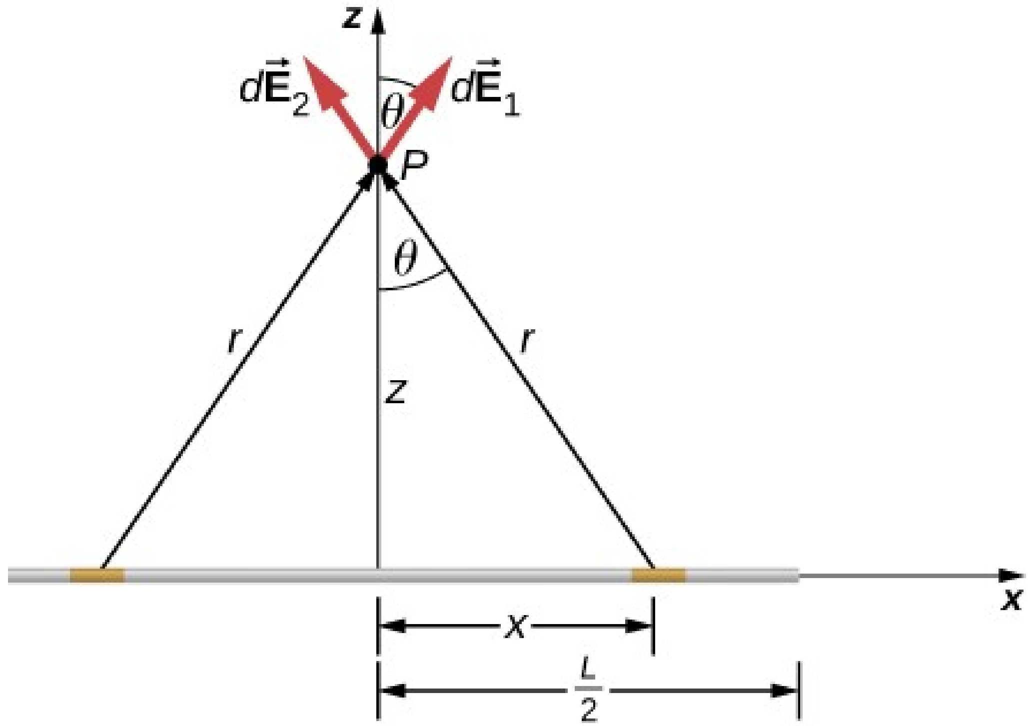
# EXERCISE 59

# FIGURE 5.22




The configuration of charge differential elements for a (a) line charge, (b) sheet of charge, and (c) a volume of charge. Also note that (d) some of the components of the total electric field cancel out, with the remainder resulting in a net electric field.

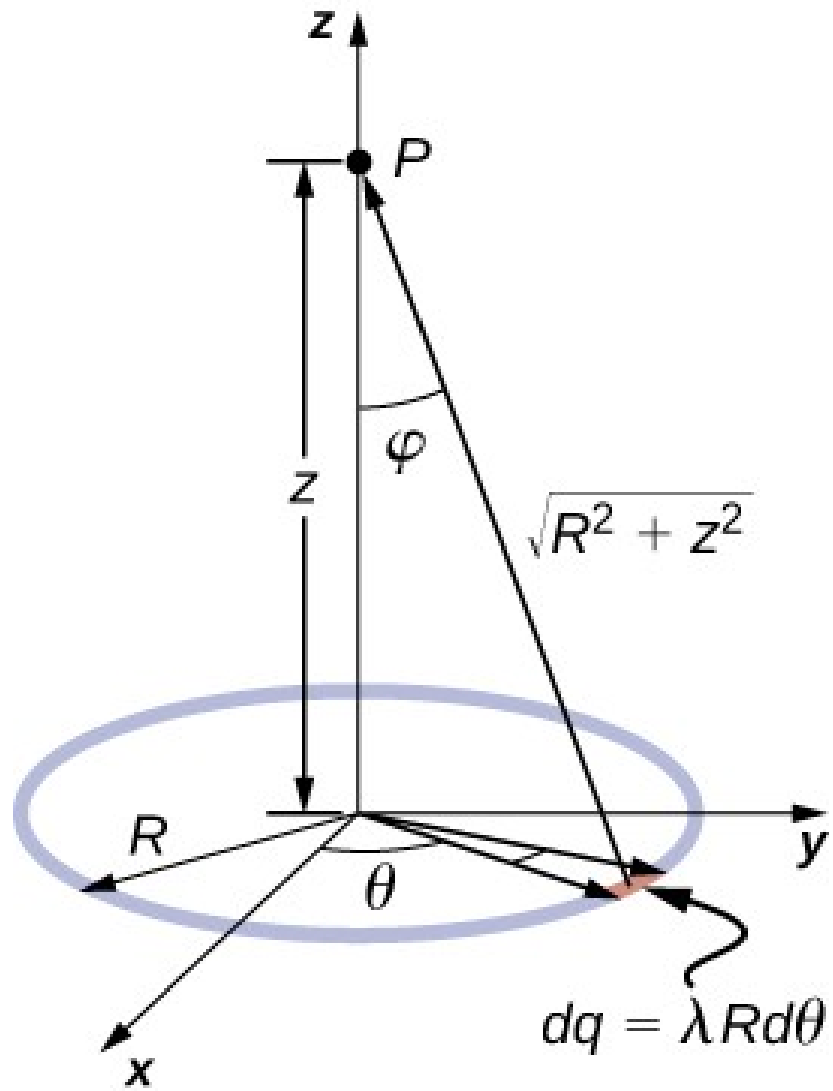
# FIGURE 5.23



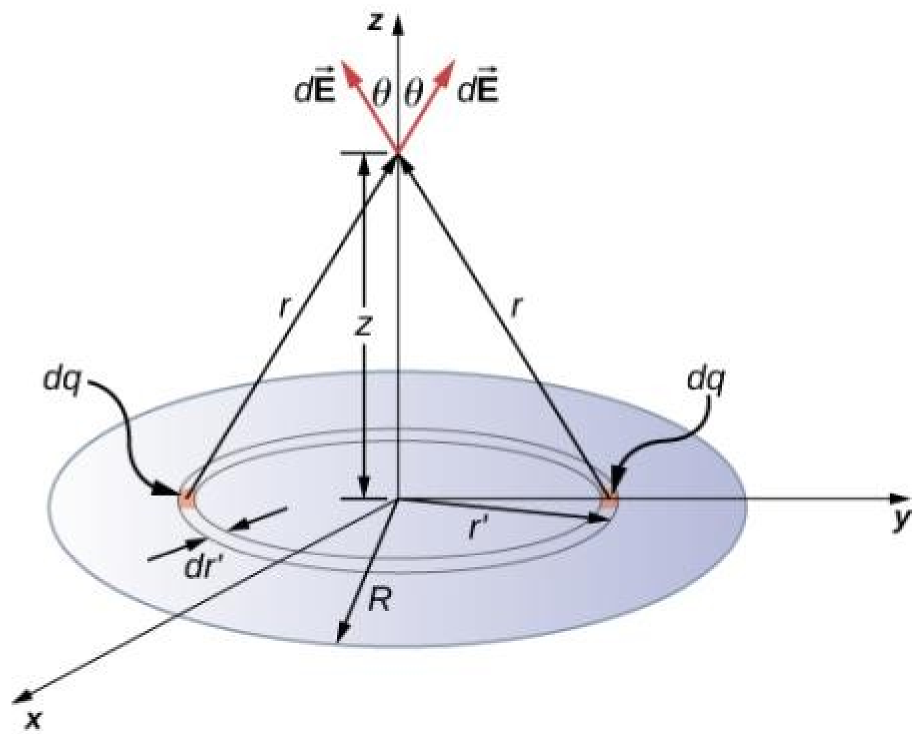

A uniformly charged segment of wire. The electric field at point *P* can be found by applying the superposition principle to symmetrically placed charge elements and integrating.

# FIGURE 5.24

The system and variable for calculating the electric field due to a ring of charge.

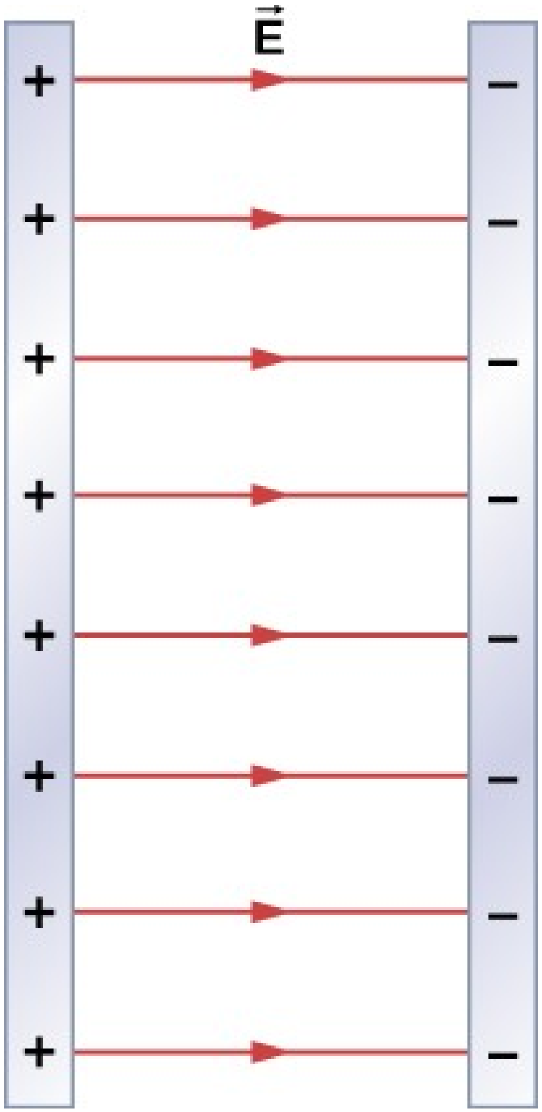


# FIGURE 5.25




A uniformly charged disk. As in the line charge example, the field above the center of this disk can be calculated by taking advantage of the symmetry of the charge distribution.

# FIGURE 5.26




Two charged infinite planes. Note the direction of the electric field.