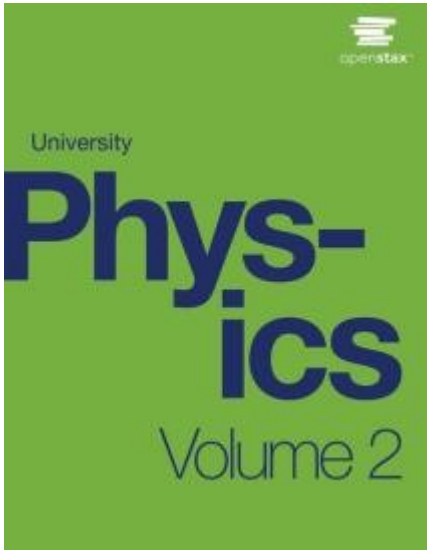
UNIVERSITY PHYSICS

Chapter 7 ELECTRIC POTENTIAL

PowerPoint Image Slideshow



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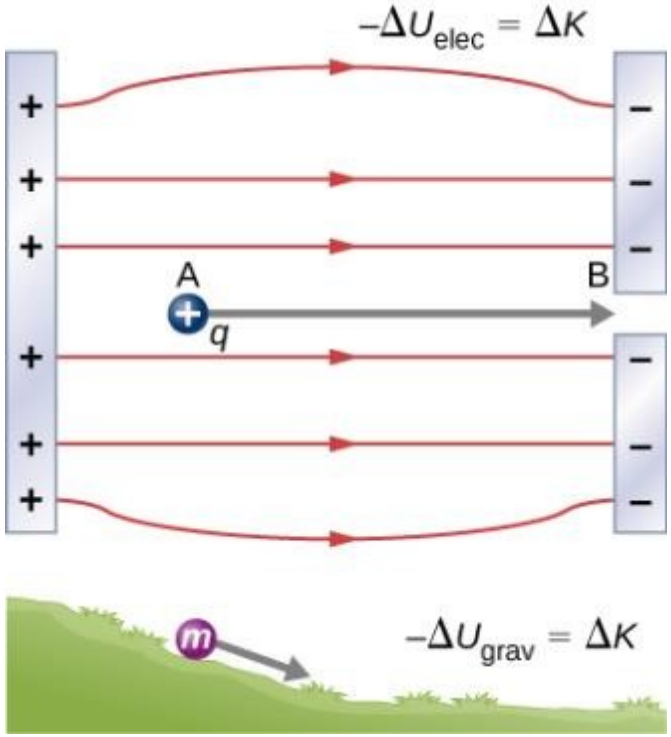
Energy

FIGURE 7.1

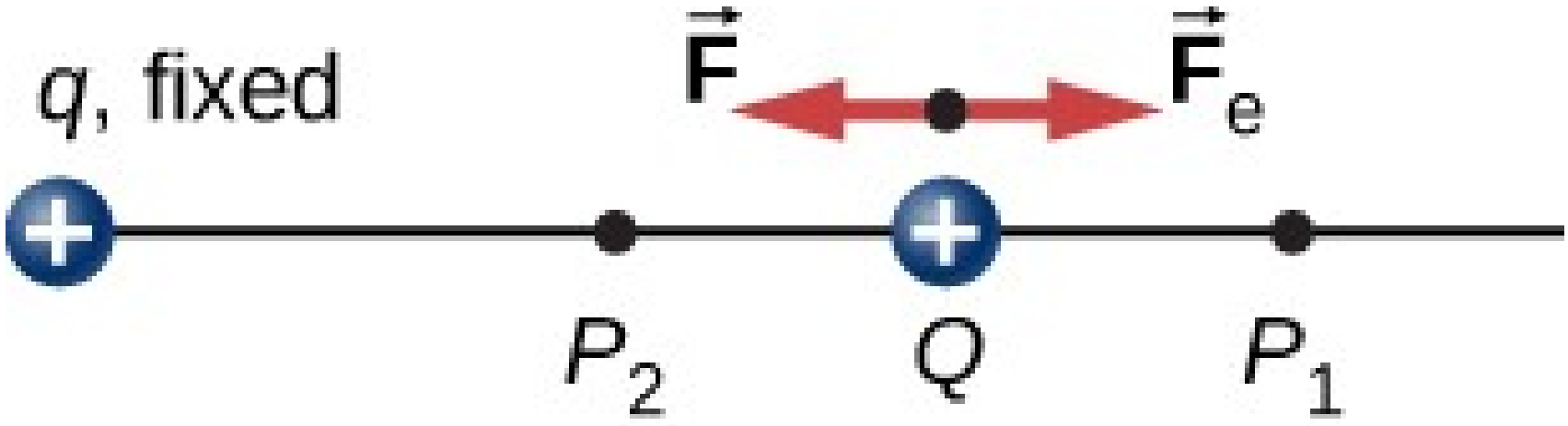
The energy released in a lightning strike is an excellent illustration of the vast quantities of energy that may be stored and released by an electric potential difference. In this chapter, we calculate just how much energy can be released in a lightning strike and how this varies with the height of the clouds from the ground. (credit: Anthony Quintano)

FIGURE 7.2



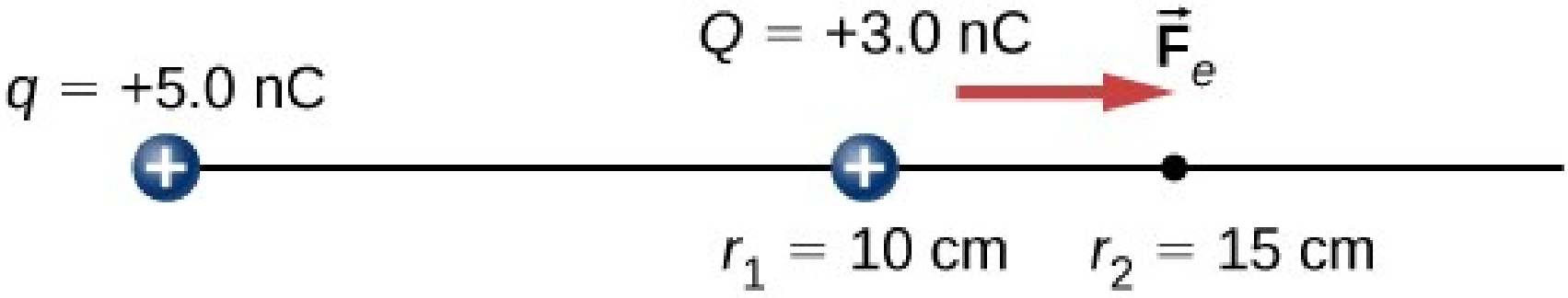
A charge accelerated by an electric field is analogous to a mass going down a hill. In both cases, potential energy decreases as kinetic energy increases, $-\Delta U = \Delta K$. Work is done by a force, but since this force is conservative, we can write $W = -\Delta U$.

FIGURE 7.3



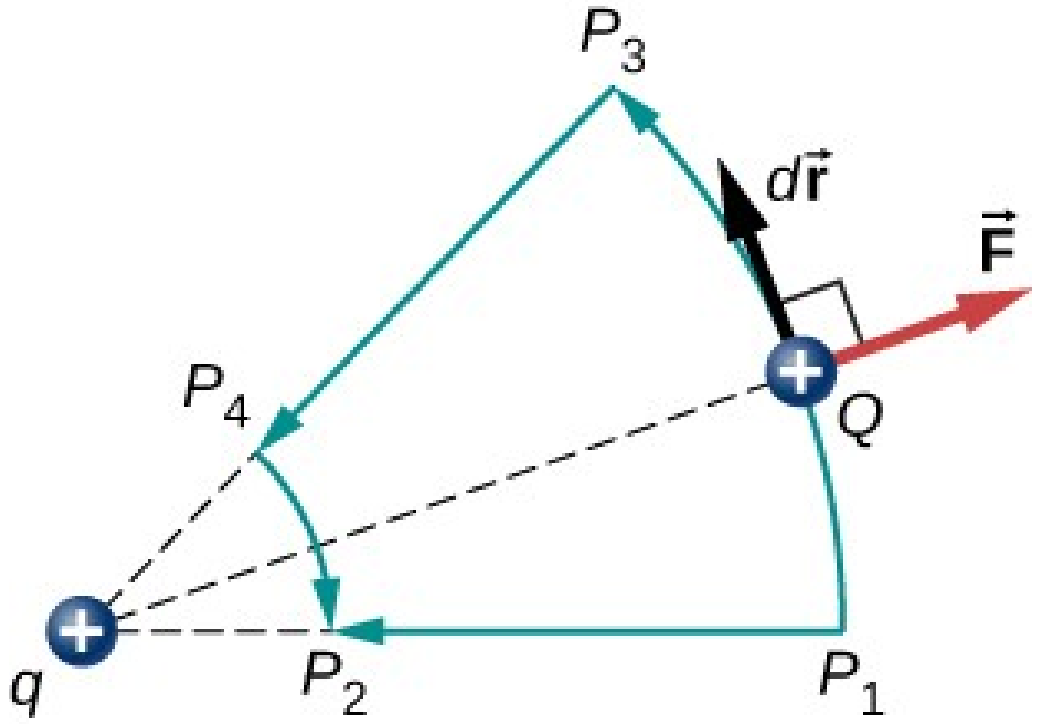
Displacement of “test” charge *Q* in the presence of fixed “source” charge *q*.

FIGURE 7.4



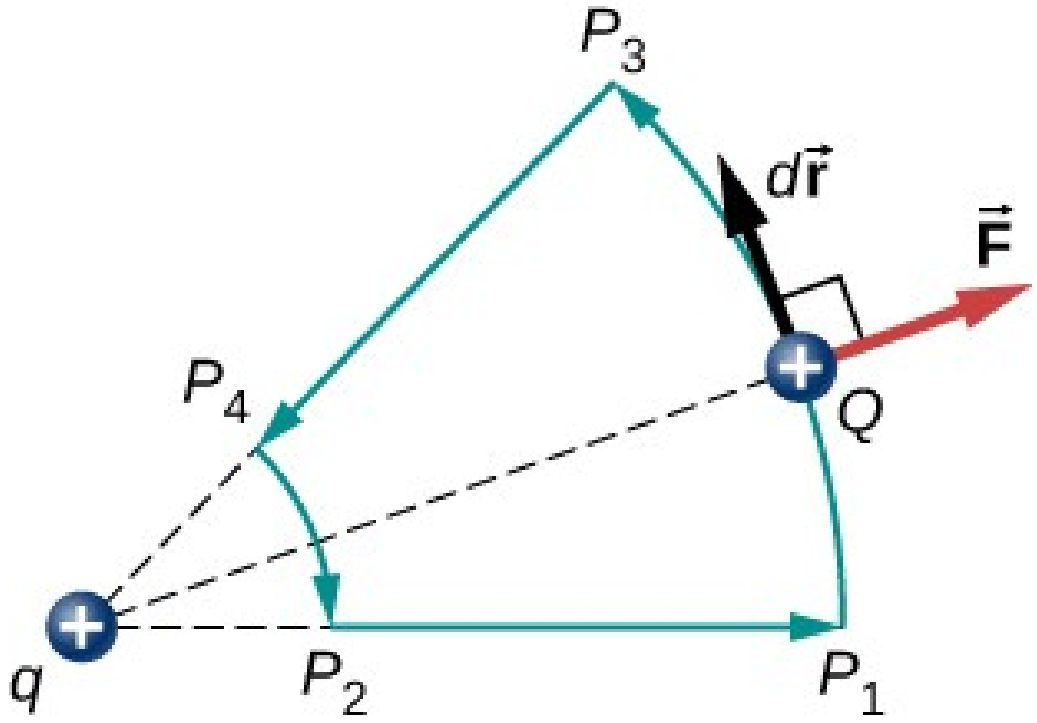
The charge Q is repelled by q, thus having work done on it and gaining kinetic energy.

FIGURE 7.5



Two paths for displacement P_1 to P_2. The work on segments P_1P_3 and P_4P_2 are zero due to the electrical force being perpendicular to the displacement along these paths. Therefore, work on paths P_1P_2 and $P_1P_3P_4P_2$ are equal.

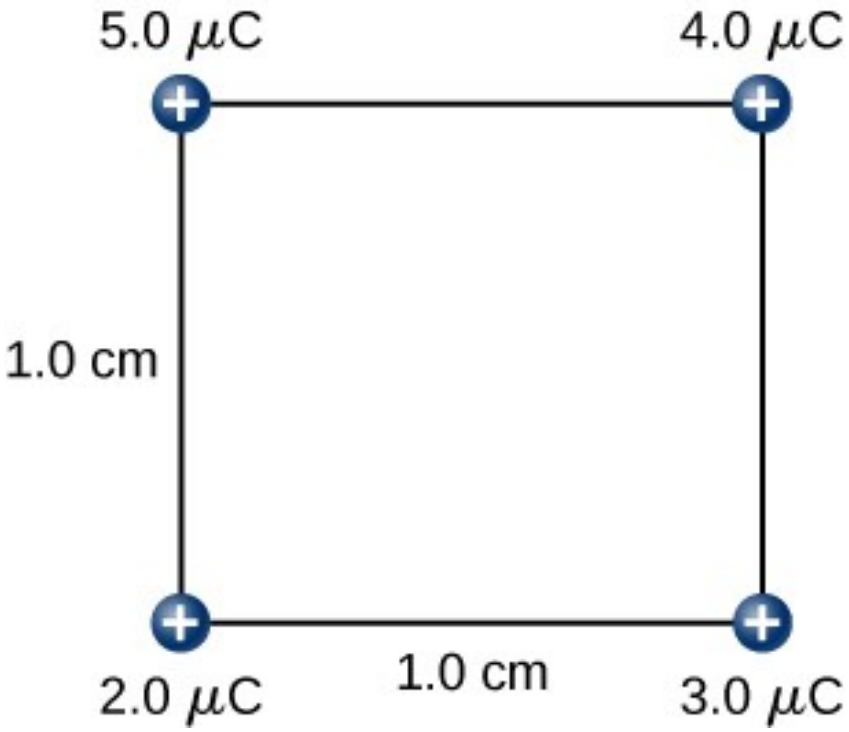
FIGURE 7.6



A closed path in an electric field. The net work around this path is zero.

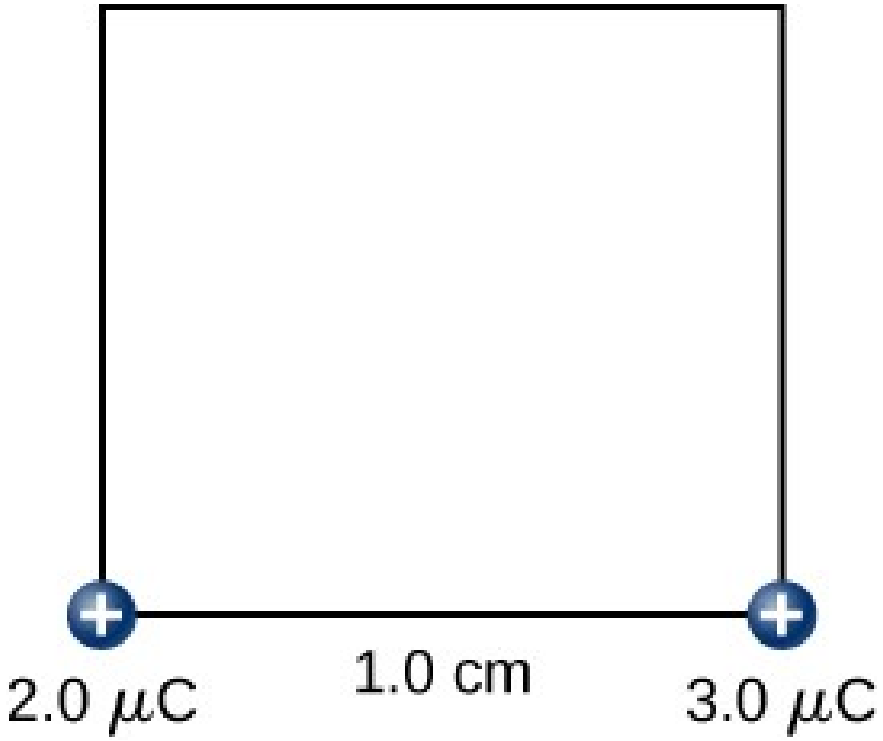
Energy: an example

FIGURE 7.8



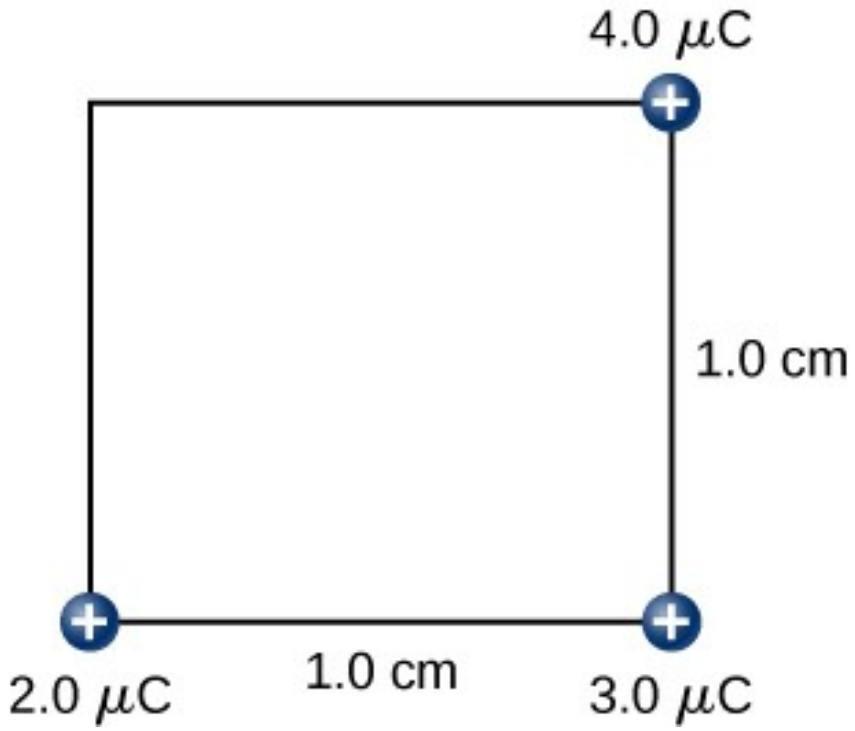
How much work is needed to assemble this charge configuration?

FIGURE 7.9



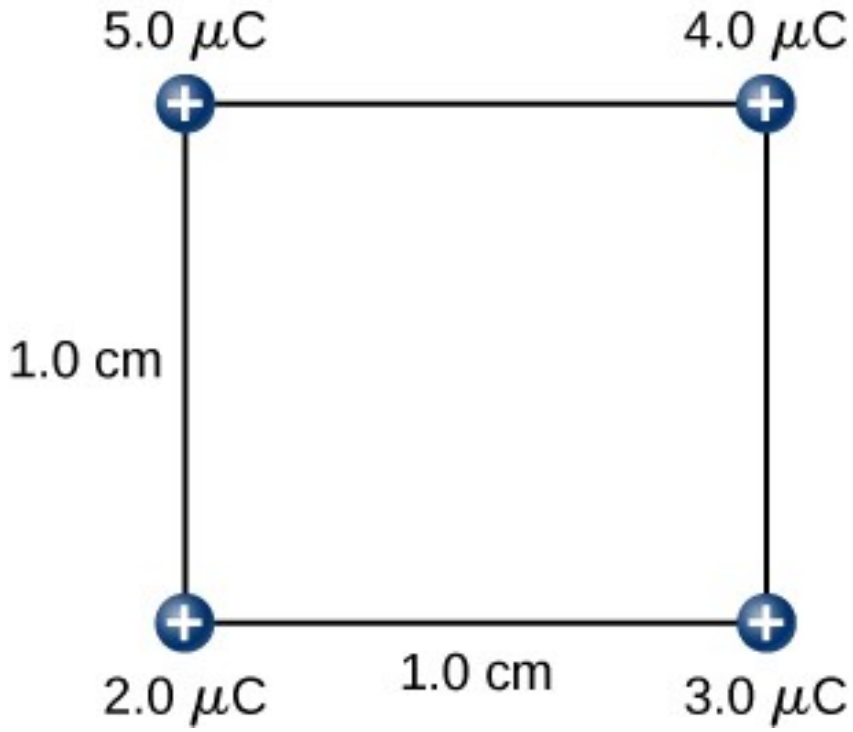
Step 2. Work W_2 to bring the $+3.0-$C charge from infinity.

FIGURE 7.10



Step 3. Work W_3 to bring the $+4.0-$C charge from infinity.

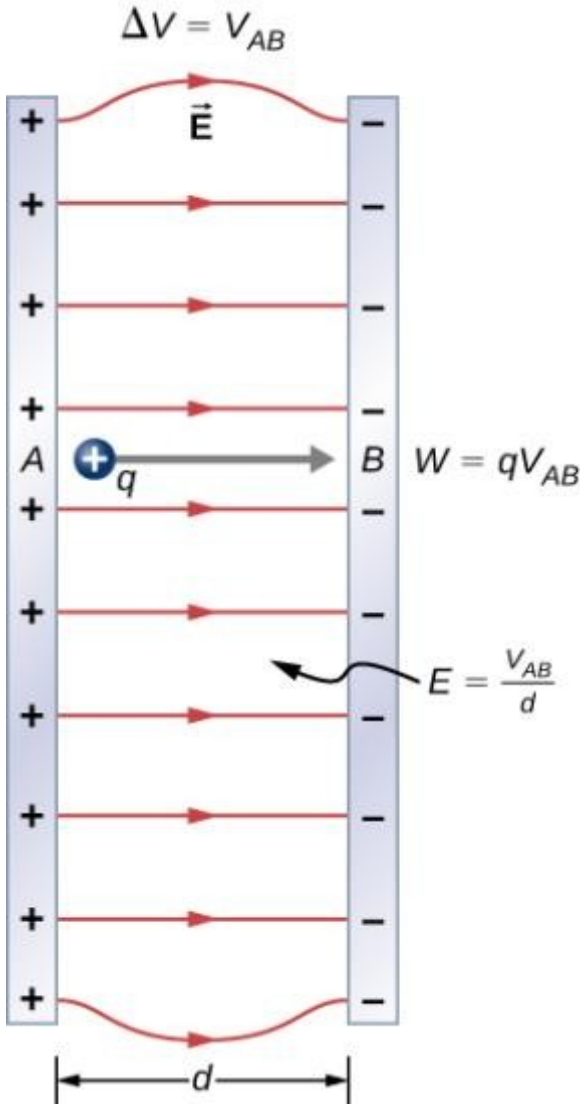
FIGURE 7.11



Step 4. Work W_4 to bring the $+5.0-$C charge from infinity.

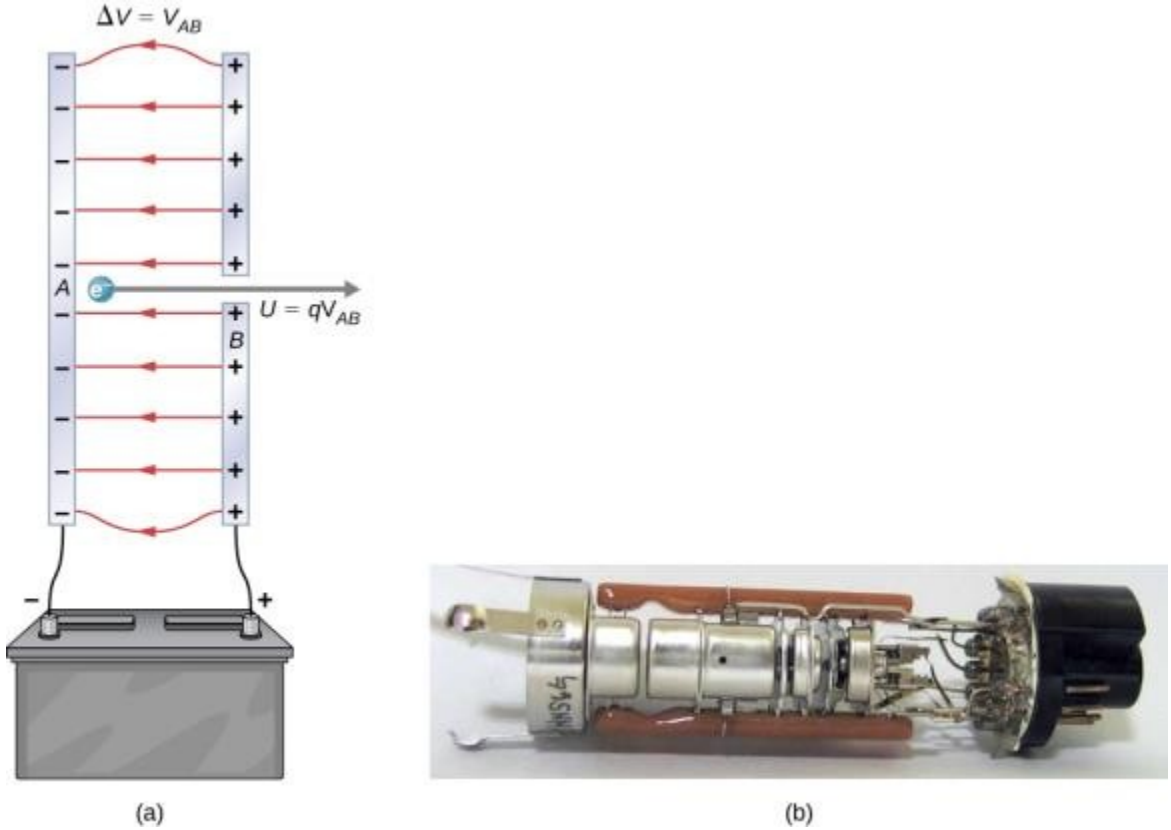
Electric potential

FIGURE 7.14



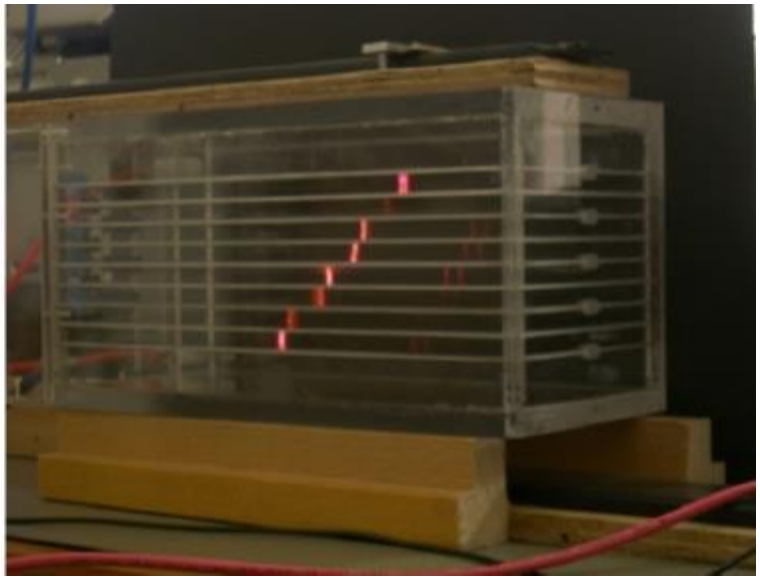
The relationship between V and E for parallel conducting plates is $E = V/d$. (Note that $\Delta V = V_{AB}$ in magnitude. For a charge that is moved from plate *A* at higher potential to plate *B* at lower potential, a minus sign needs to be included as follows: $-\Delta V = V_A - V_B = V_{AB}$.)

FIGURE 7.13



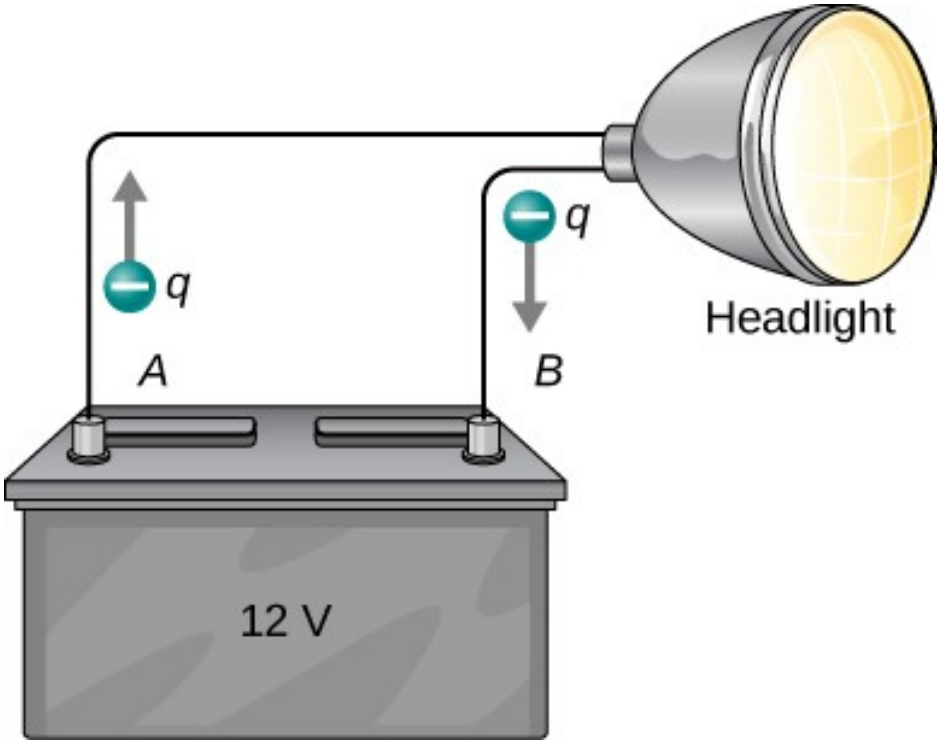
A typical electron gun accelerates electrons using a potential difference between two separated metal plates. By conservation of energy, the kinetic energy has to equal the change in potential energy, so $KE = qV$. The energy of the electron in electron-volts is numerically the same as the voltage between the plates. For example, a 5000-V potential difference produces 5000-eV electrons. The conceptual construct, namely two parallel plates with a hole in one, is shown in (a), while a real electron gun is shown in (b).

FIGURE 7.16



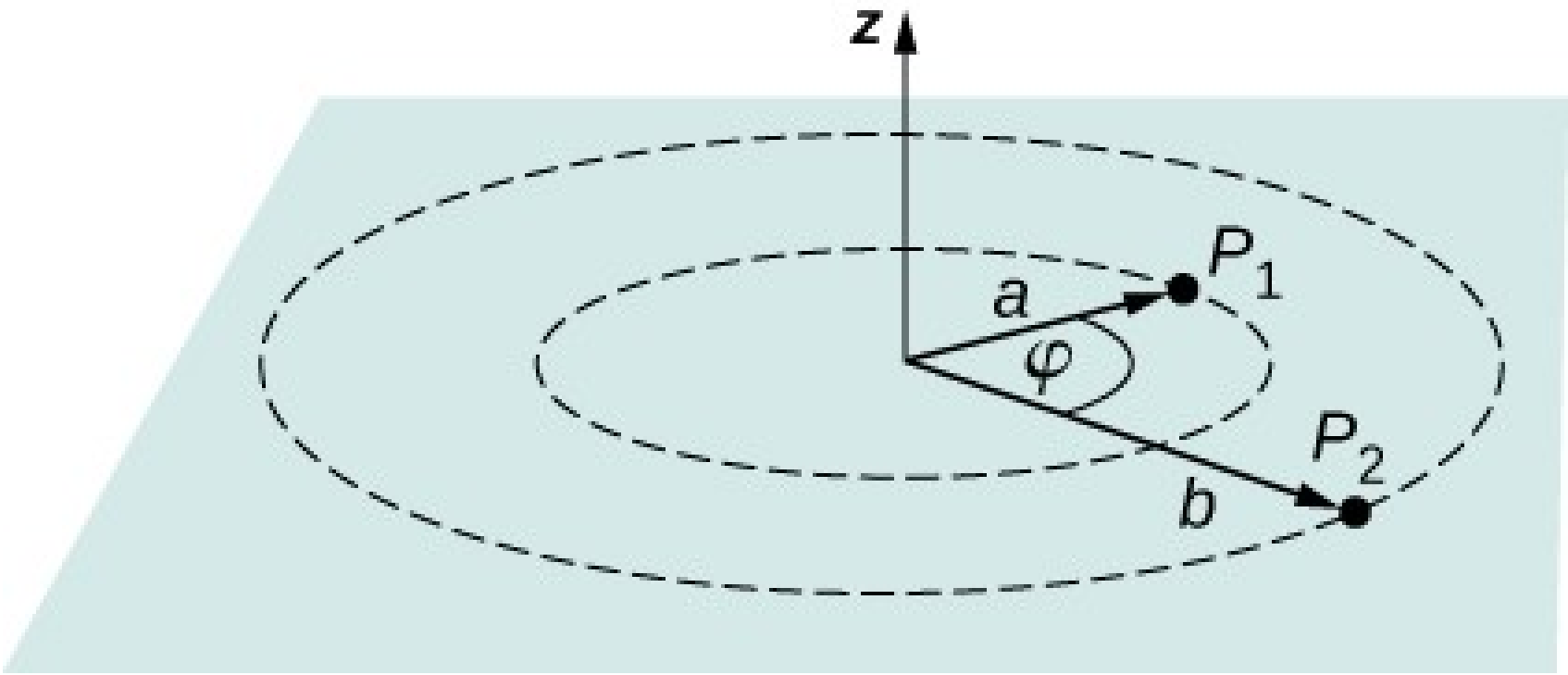
A spark chamber is used to trace the paths of high-energy particles. Ionization created by the particles as they pass through the gas between the plates allows a spark to jump. The sparks are perpendicular to the plates, following electric field lines between them. The potential difference between adjacent plates is not high enough to cause sparks without the ionization produced by particles from accelerator experiments (or cosmic rays). This form of detector is now archaic and no longer in use except for demonstration purposes. (credit b: modification of work by Jack Collins)

FIGURE 7.12



A battery moves negative charge from its negative terminal through a headlight to its positive terminal. Appropriate combinations of chemicals in the battery separate charges so that the negative terminal has an excess of negative charge, which is repelled by it and attracted to the excess positive charge on the other terminal. In terms of potential, the positive terminal is at a higher voltage than the negative terminal. Inside the battery, both positive and negative charges move.

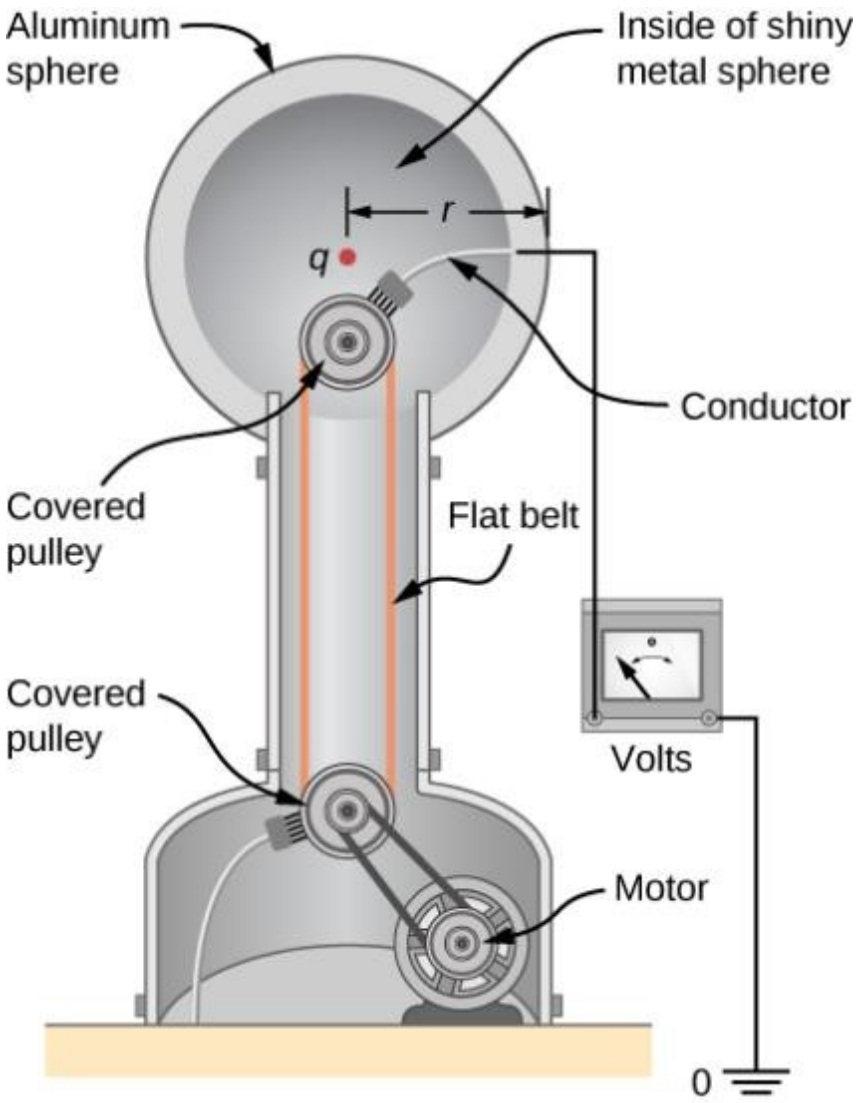
FIGURE 7.17



Find the difference in potential between P_1 and P_2.

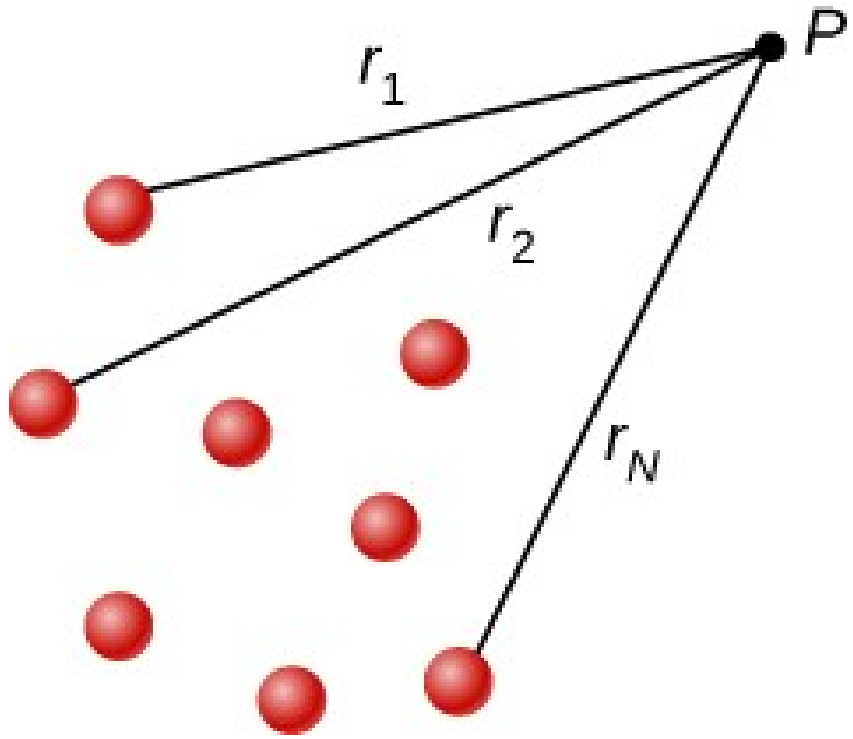
FIGURE 7.18

The voltage of this demonstration Van de Graaff generator is measured between the charged sphere and ground. Earth's potential is taken to be zero as a reference. The potential of the charged conducting sphere is the same as that of an equal point charge at its center.



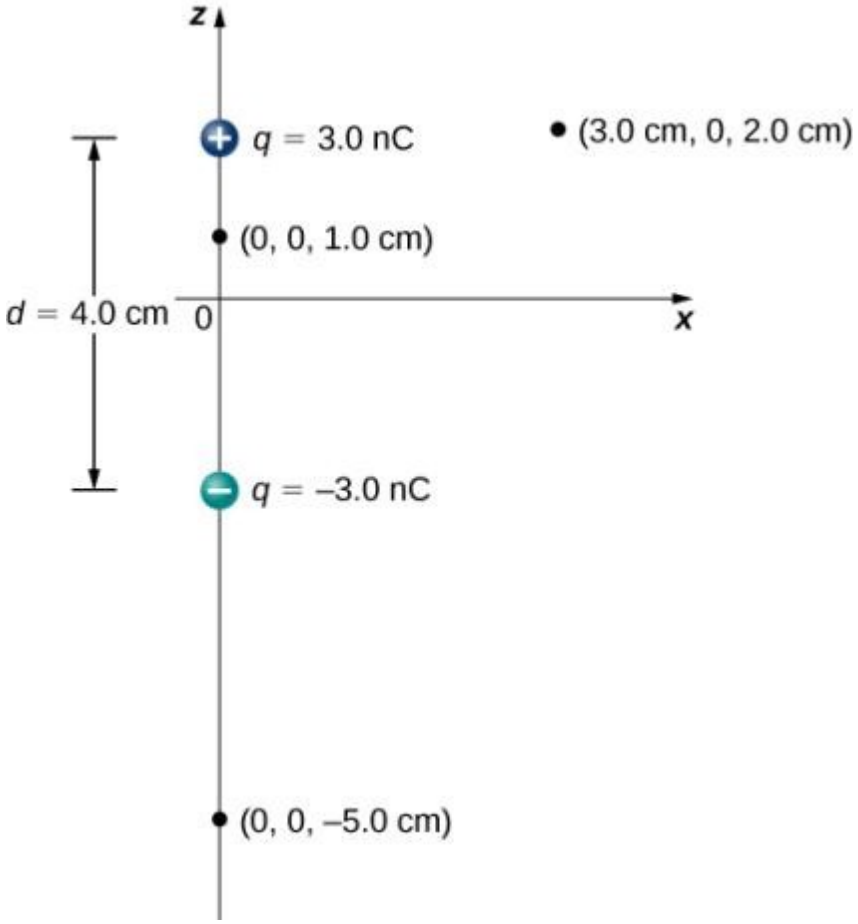
Multiple particles

FIGURE 7.19



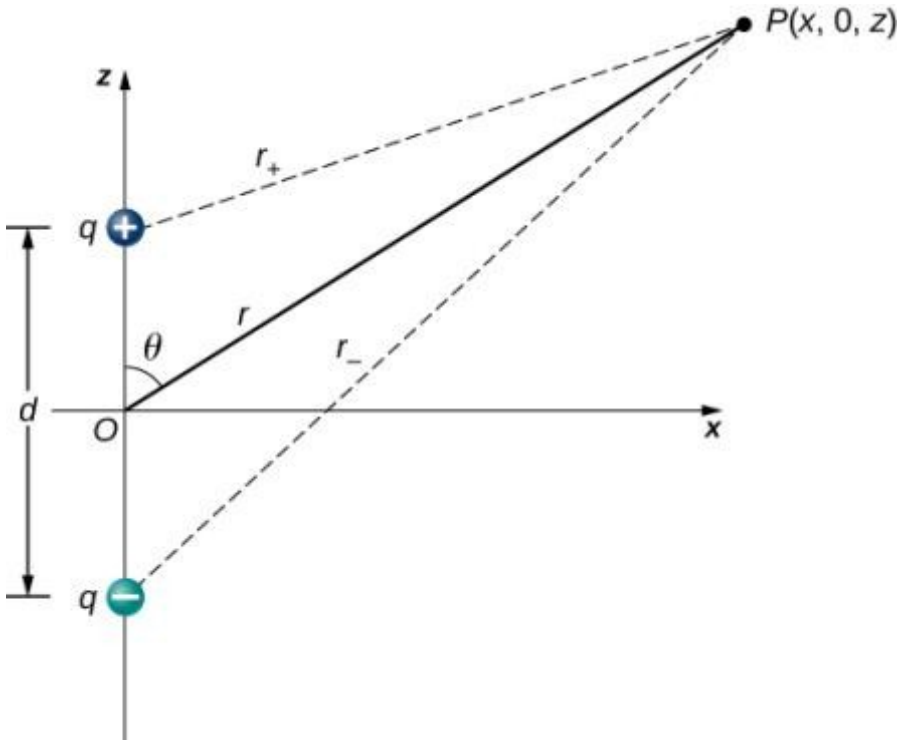
Notation for direct distances from charges to a space point *P*.

FIGURE 7.20



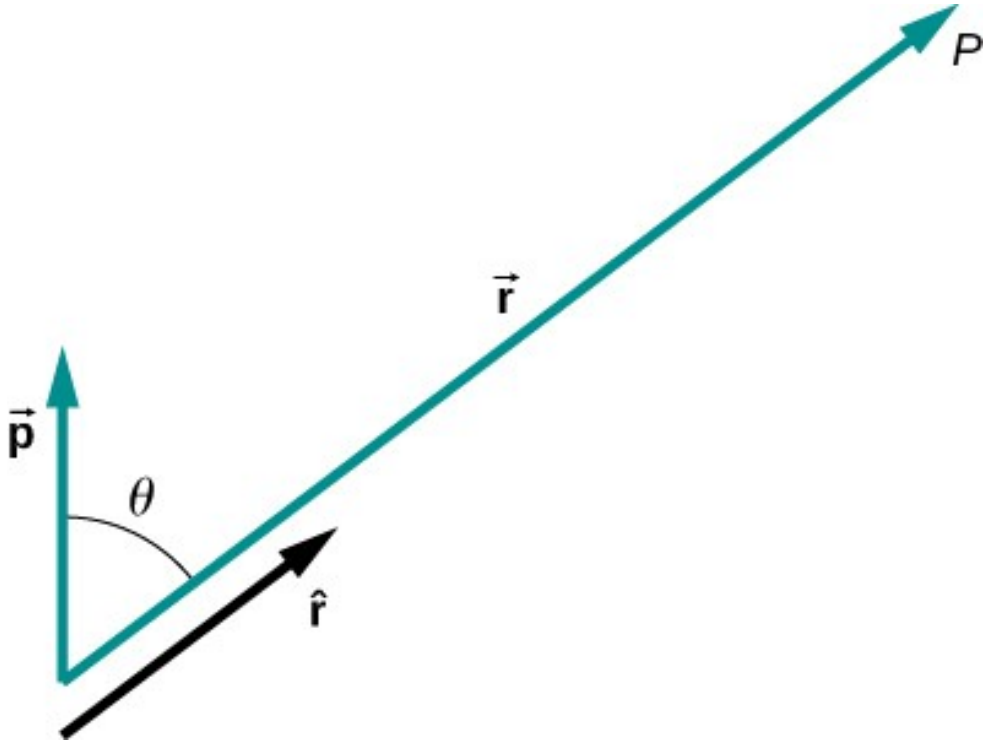
A general diagram of an electric dipole, and the notation for the distances from the individual charges to a point *P* in space.

FIGURE 7.21



A general diagram of an electric dipole, and the notation for the distances from the individual charges to a point *P* in space.

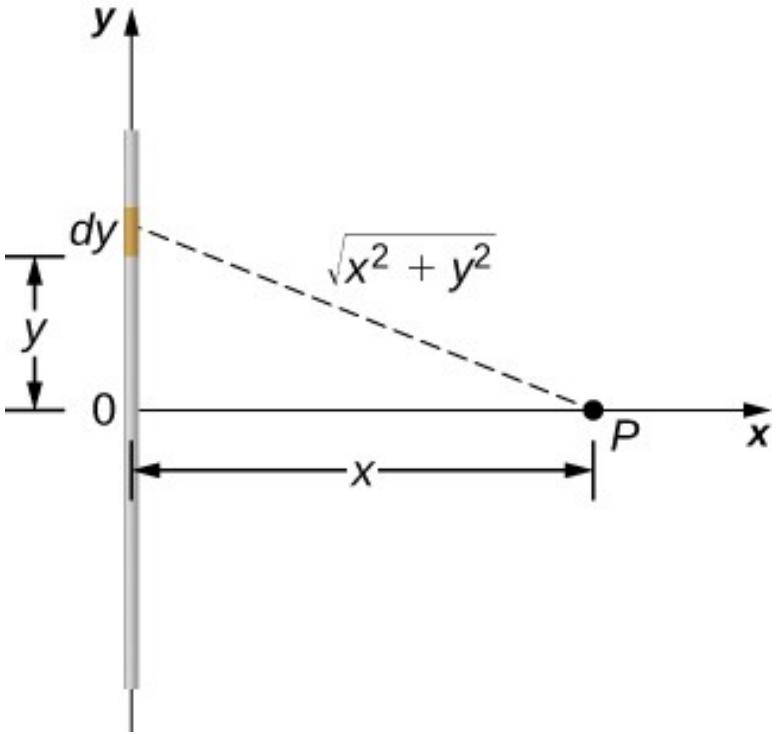
FIGURE 7.22



The geometry for the application of the potential of a dipole.

Electric potential: sample problems

FIGURE 7.23



We want to calculate the electric potential due to a line of charge.

FIGURE 7.24

We want to calculate the electric potential due to a ring of charge.

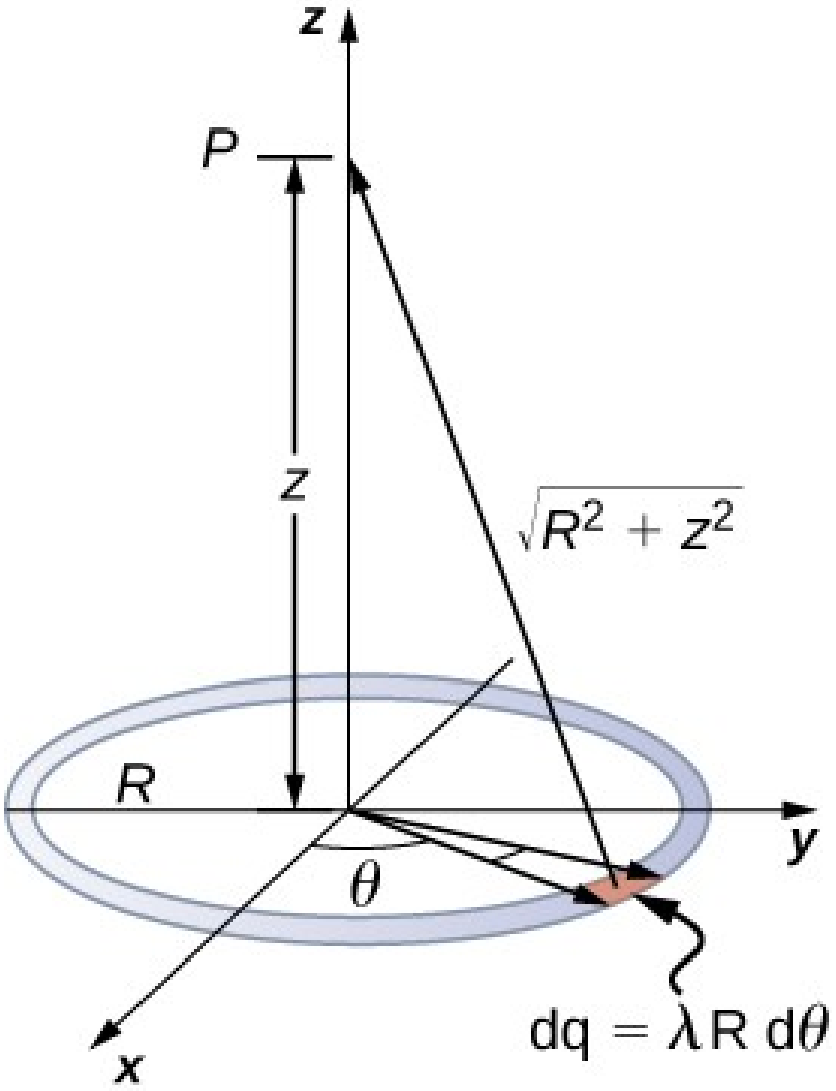
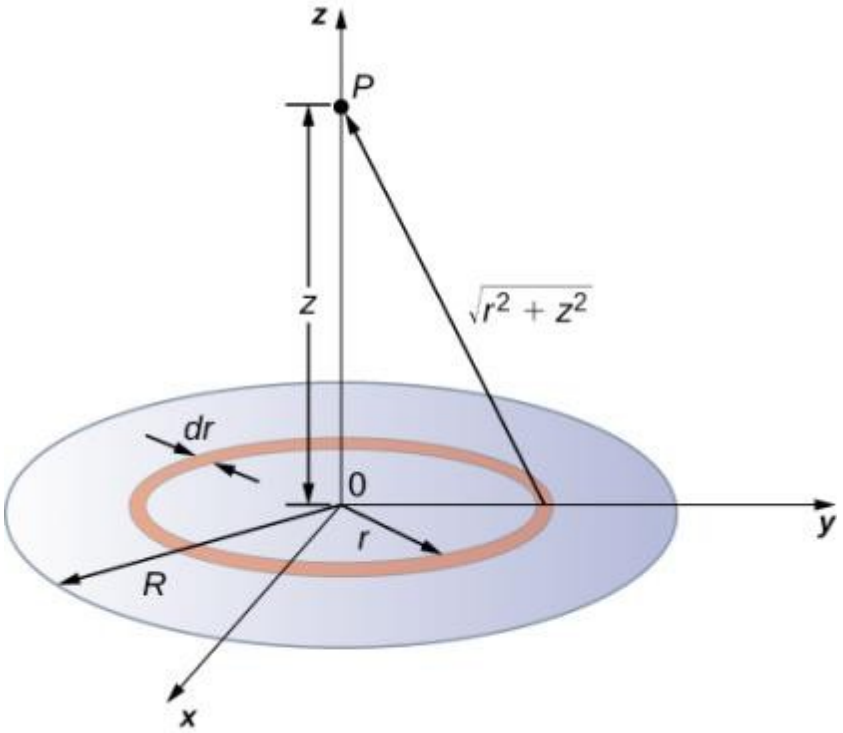


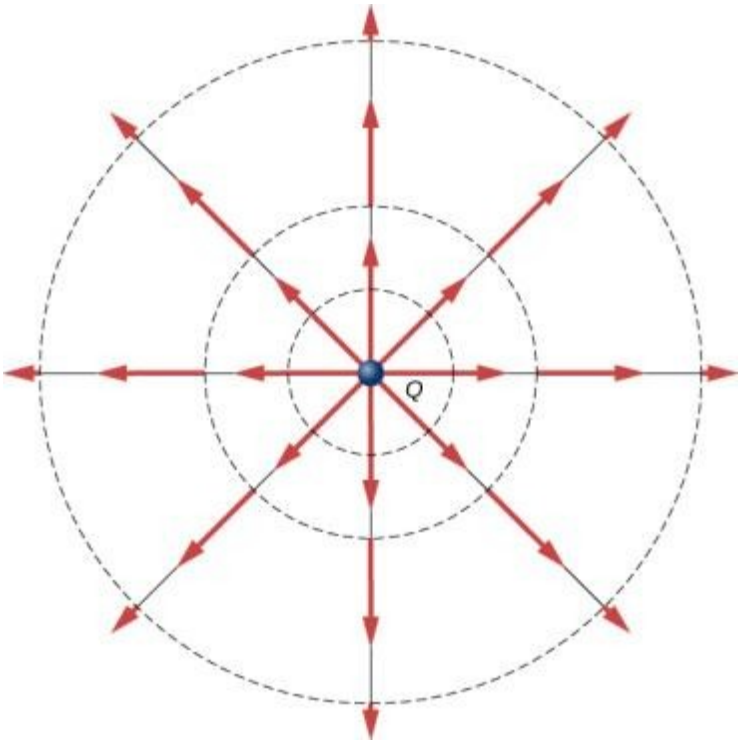
FIGURE 7.25



We want to calculate the electric potential due to a disk of charge.

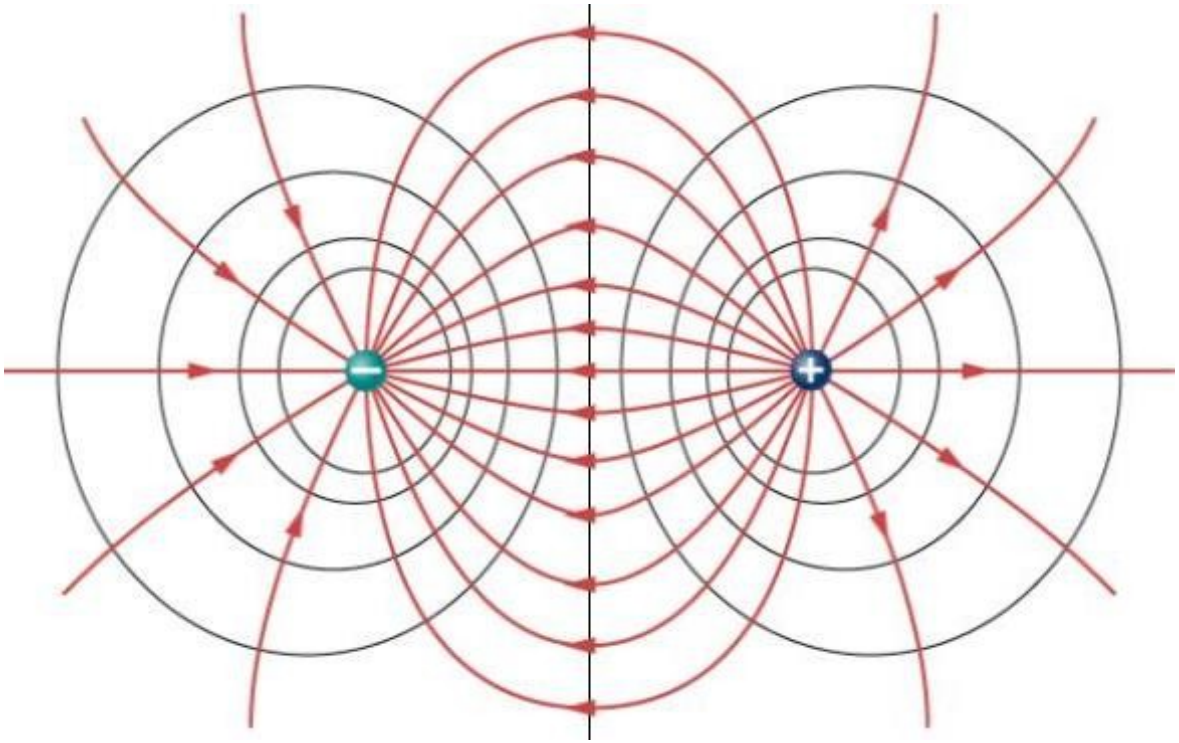
Field lines and equipotential surfaces

FIGURE 7.28



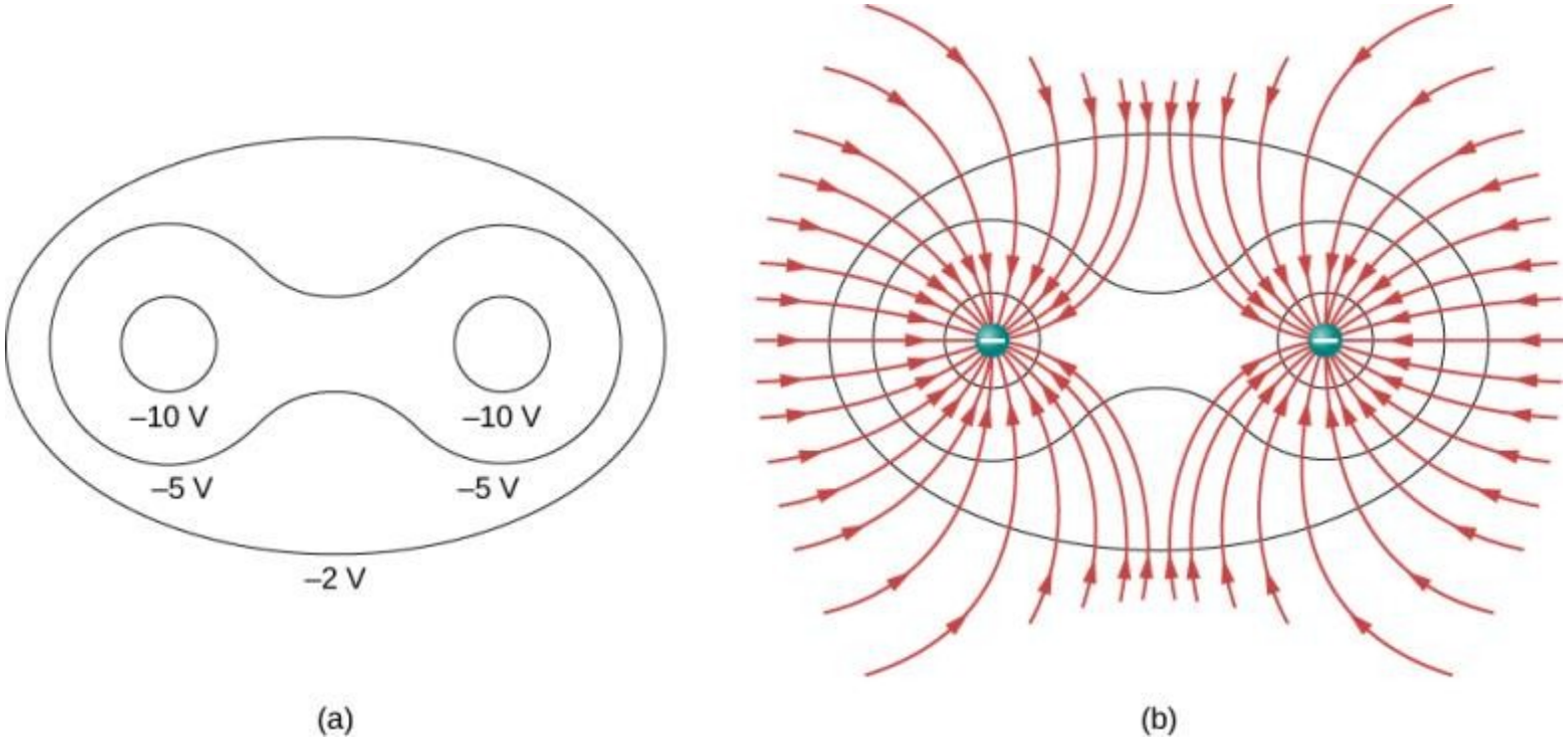
Electric field vectors inside and outside a uniformly charged sphere.

FIGURE 7.31



The electric field lines and equipotential lines for two equal but opposite charges. The equipotential lines can be drawn by making them perpendicular to the electric field lines, if those are known. Note that the potential is greatest (most positive) near the positive charge and least (most negative) near the negative charge. For a three-dimensional version, explore the first media link.

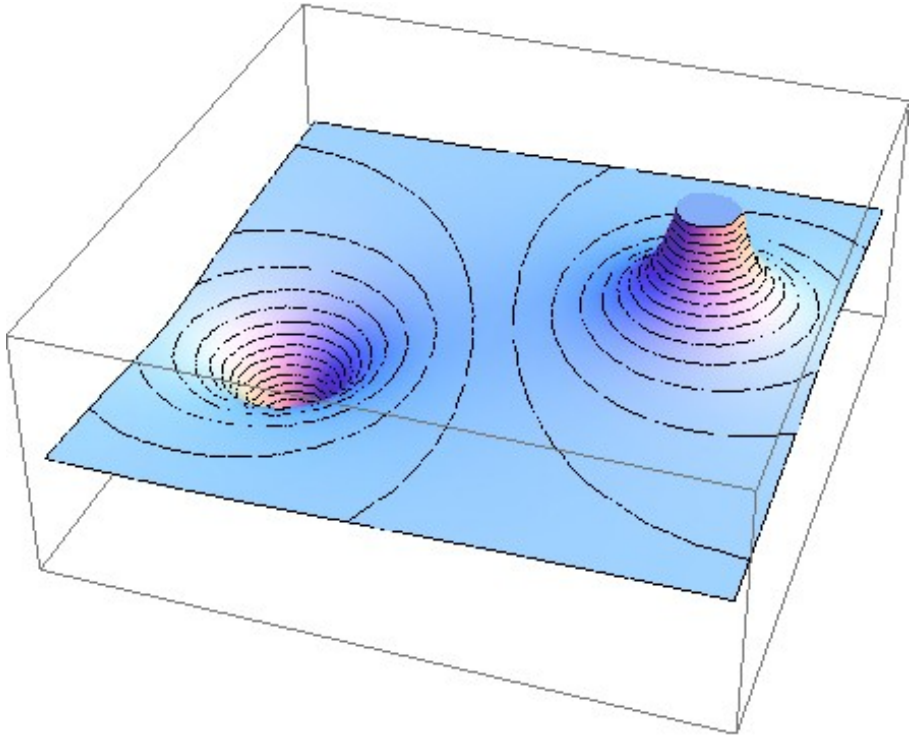
FIGURE 7.32



(a) These equipotential lines might be measured with a voltmeter in a laboratory experiment.

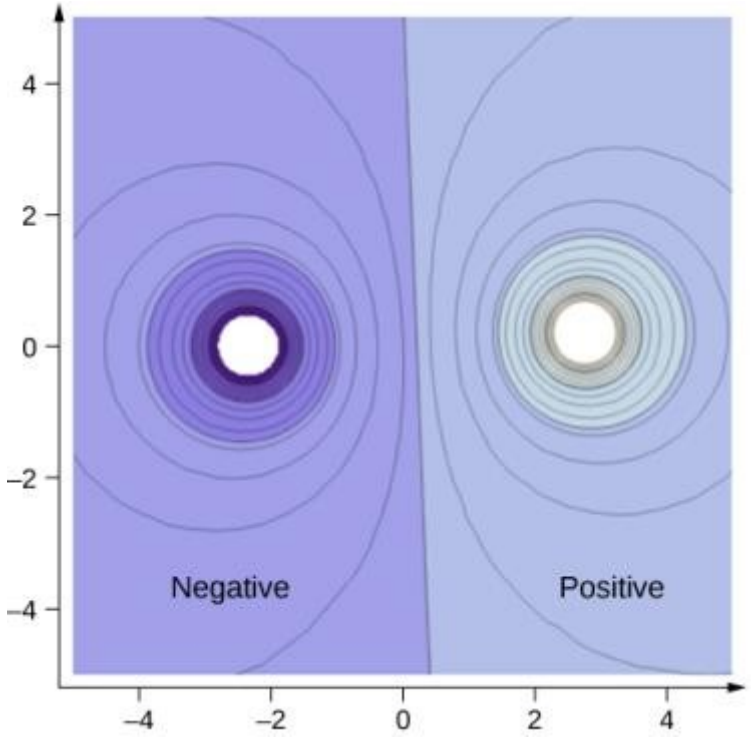
(b) The corresponding electric field lines are found by drawing them perpendicular to the equipotentials. Note that these fields are consistent with two equal negative charges. For a three-dimensional version, play with the first media link.

FIGURE 7.33



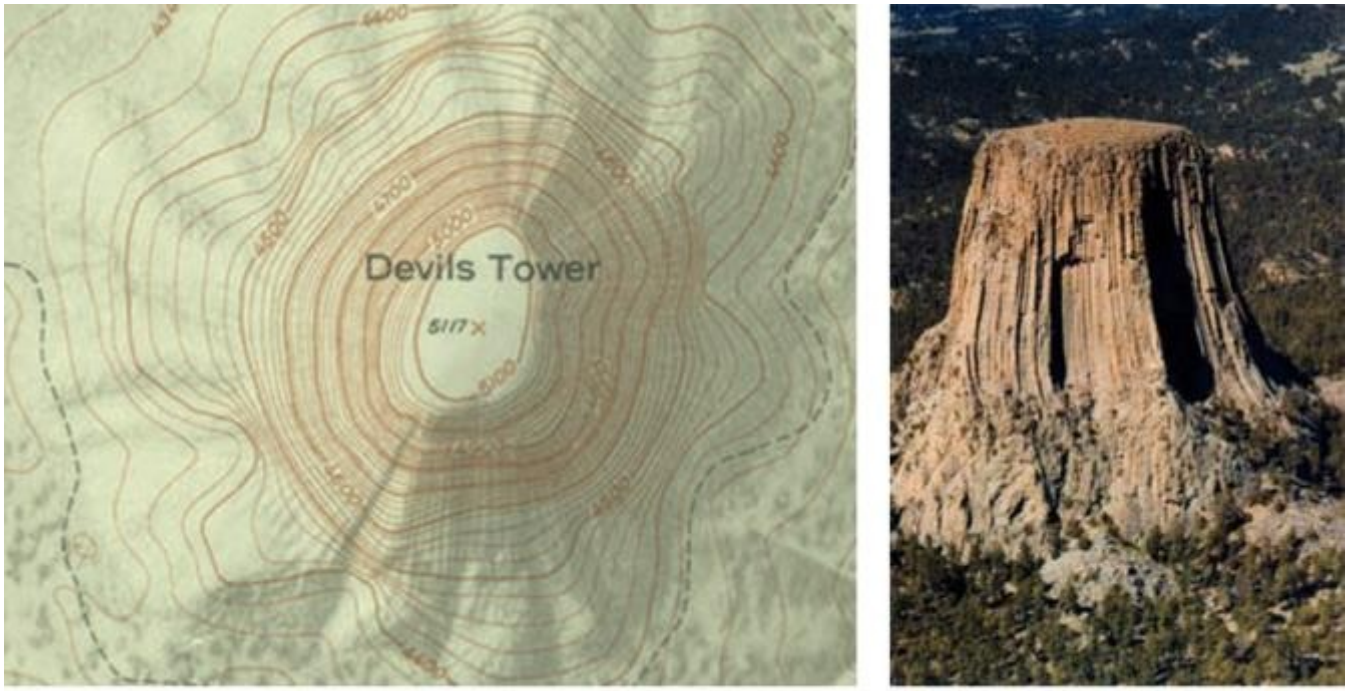
Electric potential map of two opposite charges of equal magnitude on conducting spheres. The potential is negative near the negative charge and positive near the positive charge.

FIGURE 7.34



A cross-section of the electric potential map of two opposite charges of equal magnitude. The potential is negative near the negative charge and positive near the positive charge.

FIGURE 7.36



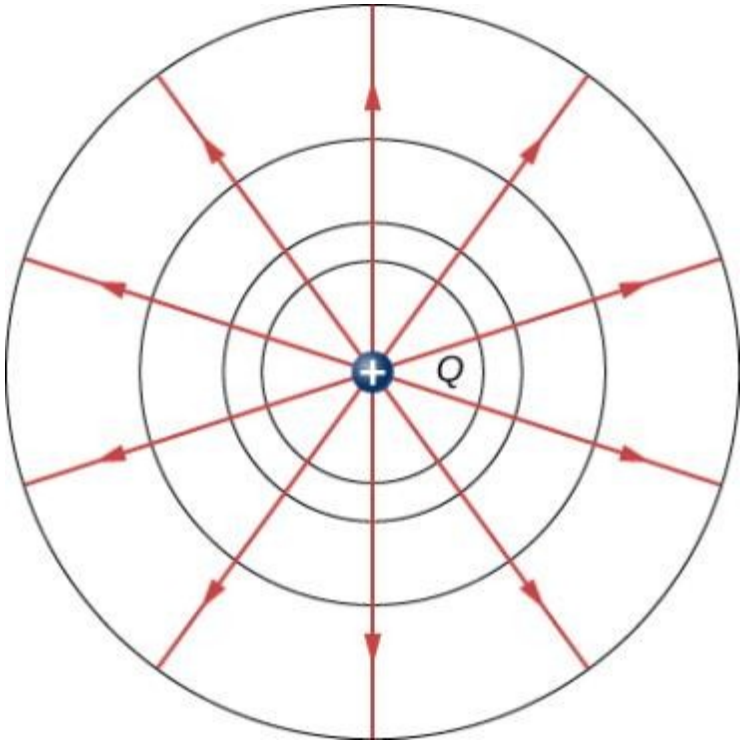
A topographical map along a ridge has roughly parallel elevation lines, similar to the equipotential lines in **Figure 7.35**.

(a) A topographical map of Devil's Tower, Wyoming. Lines that are close together indicate very steep terrain.

(b) A perspective photo of Devil's Tower shows just how steep its sides are. Notice the top of the tower has the same shape as the center of the topographical map.

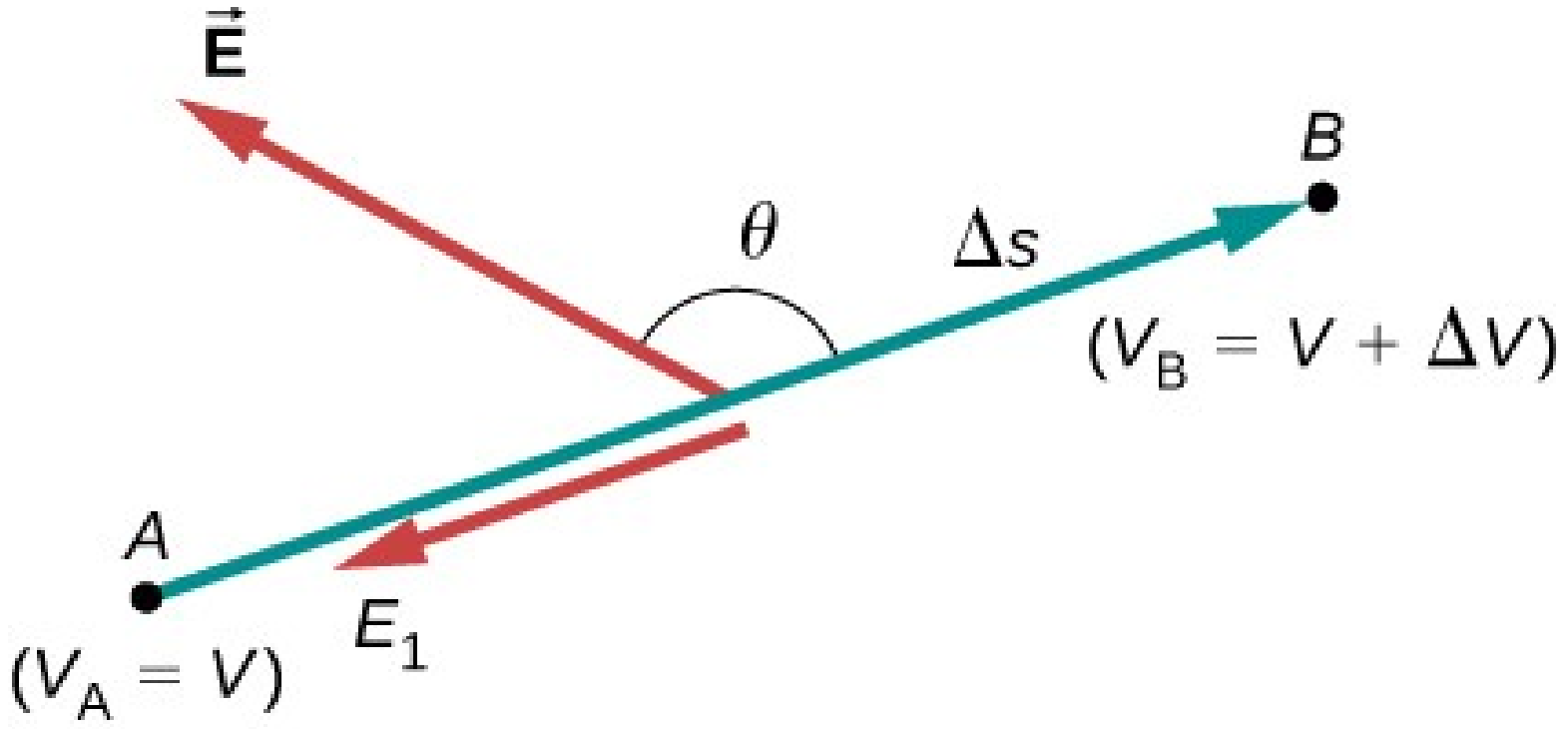
End

FIGURE 7.30



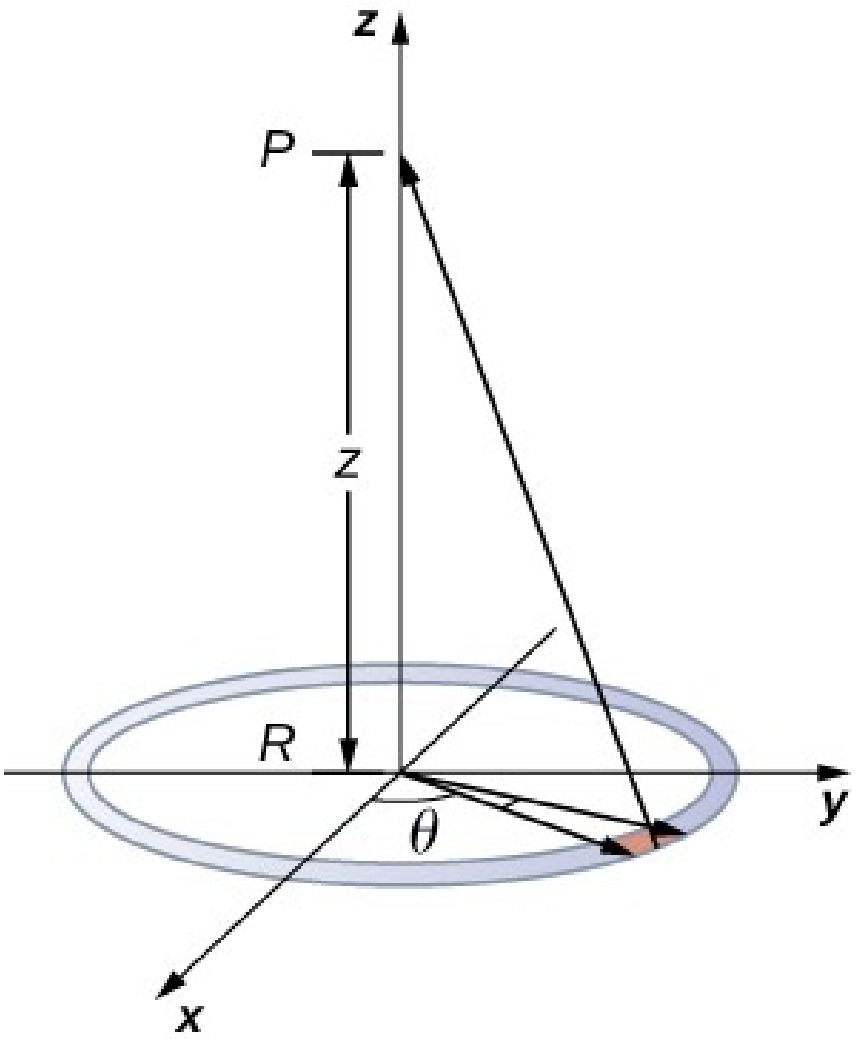
An isolated point charge Q with its electric field lines in blue and equipotential lines in green. The potential is the same along each equipotential line, meaning that no work is required to move a charge anywhere along one of those lines. Work is needed to move a charge from one equipotential line to another. Equipotential lines are perpendicular to electric field lines in every case. For a three-dimensional version, explore the first media link.

FIGURE 7.27



The electric field component, E_1, along the displacement is given by E . Note that *A* and *B* are assumed to be so close together that the field is constant along .

FIGURE 7.29



We want to calculate the electric field from the electric potential due to a ring charge.

FIGURE 7.35

The electric field and equipotential lines between two metal plates. Note that the electric field is perpendicular to the equipotentials and hence normal to the plates at their surface as well as in the center of the region between them.

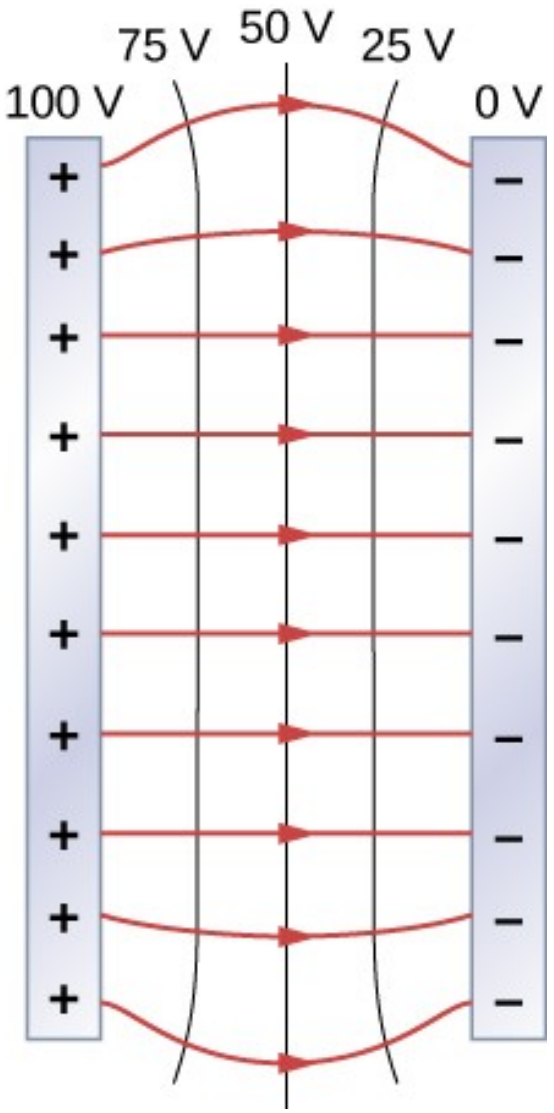
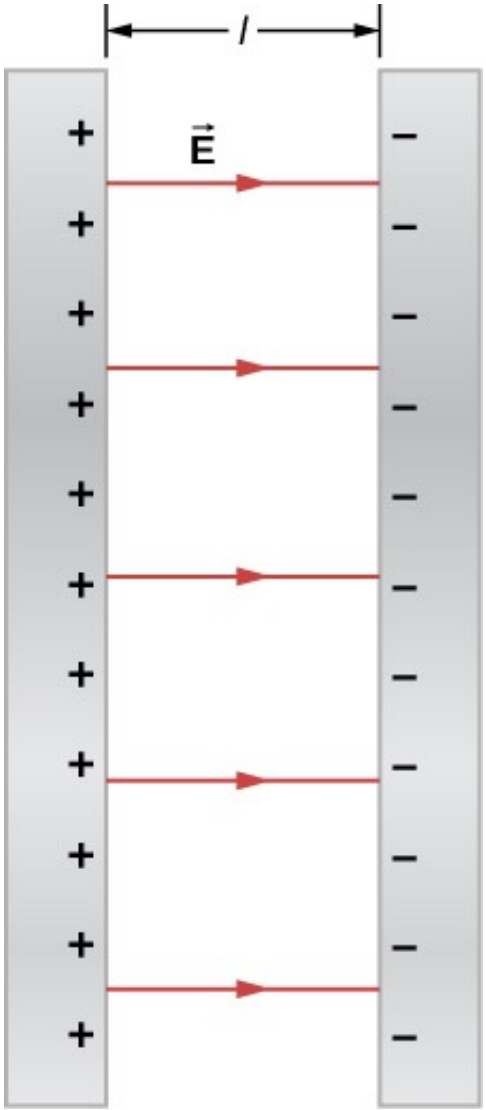
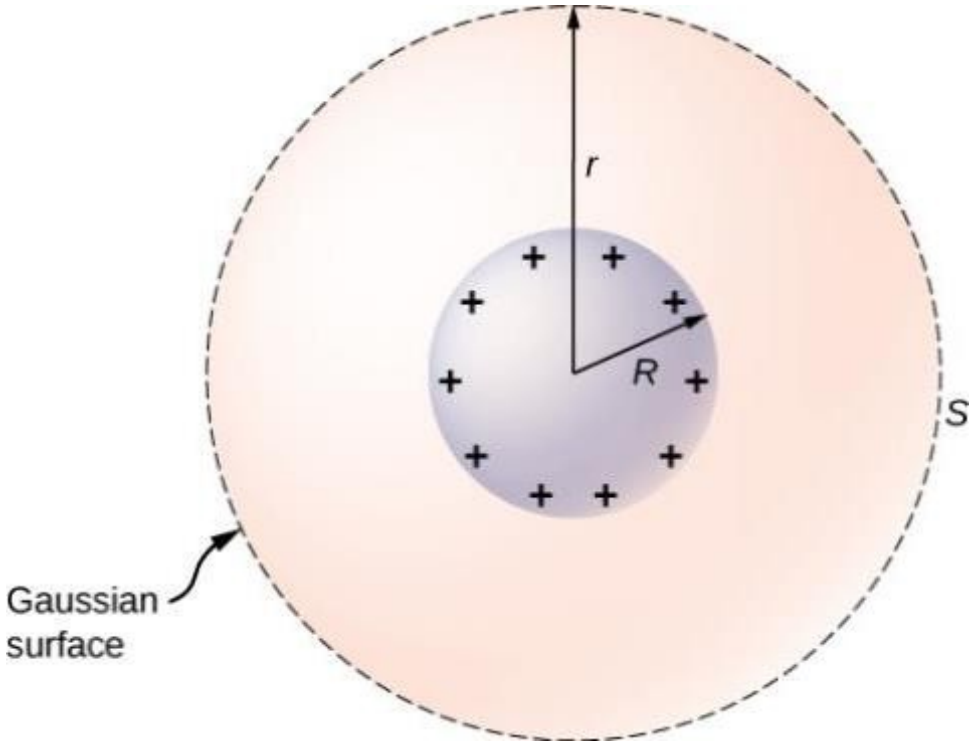


FIGURE 7.37



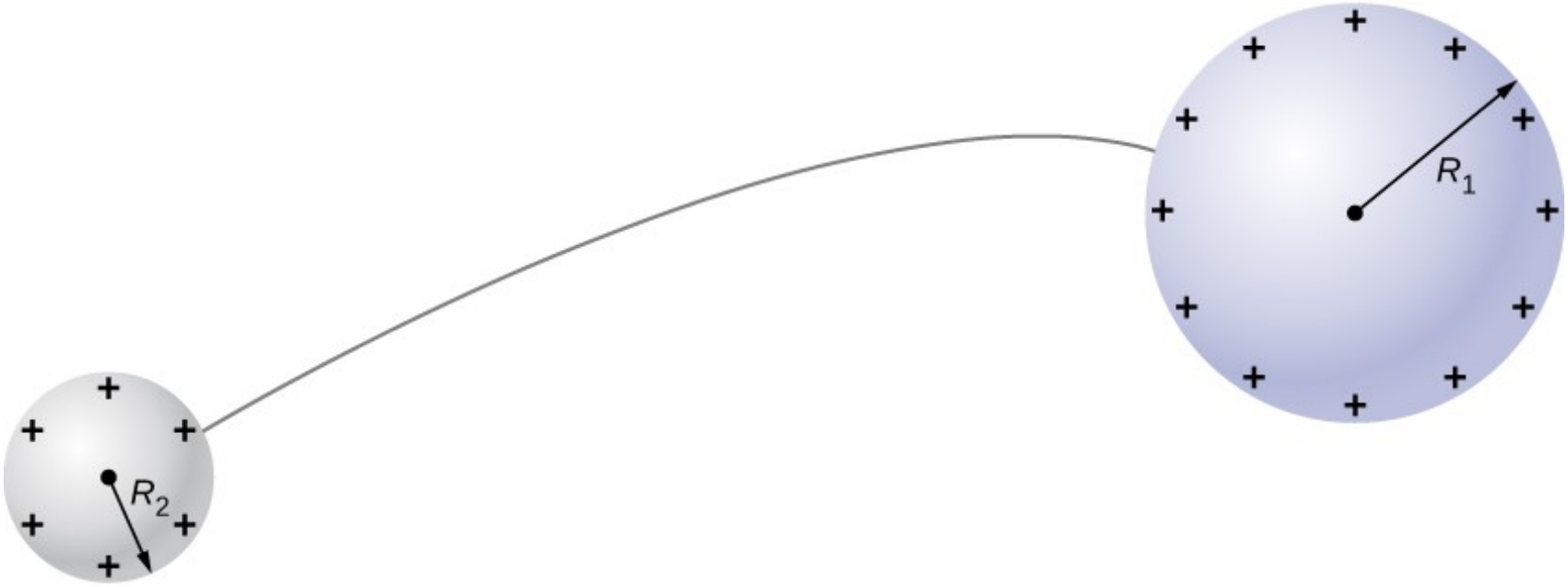
The electric field between oppositely charged parallel plates. A portion is released at the positive plate.

FIGURE 7.38



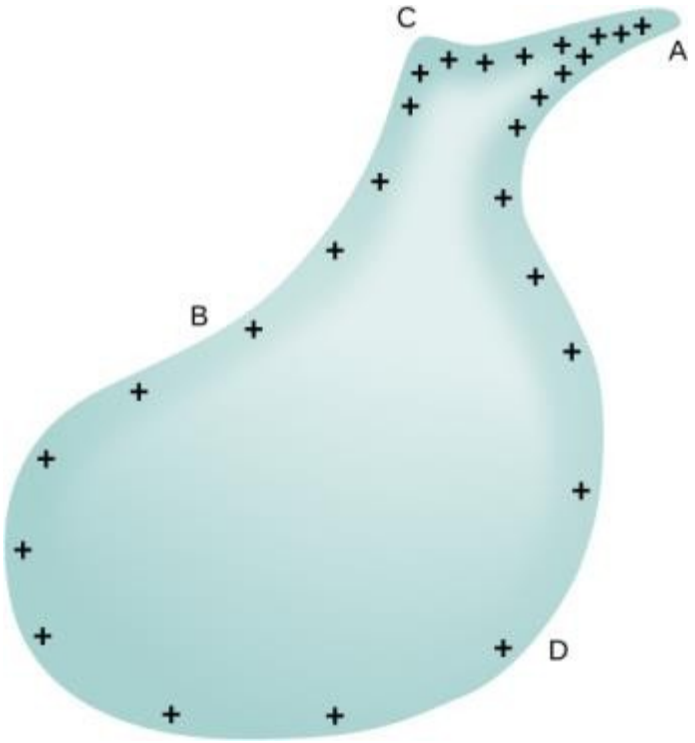
An isolated conducting sphere.

FIGURE 7.39



Two conducting spheres are connected by a thin conducting wire.

FIGURE 7.40



The surface charge density and the electric field of a conductor are greater at regions with smaller radii of curvature.

FIGURE 7.41

Schematic of Van de Graaff generator. A battery (*A*) supplies excess positive charge to a pointed conductor, the points of which spray the charge onto a moving insulating belt near the bottom. The pointed conductor (*B*) on top in the large sphere picks up the charge. (The induced electric field at the points is so large that it removes the charge from the belt.) This can be done because the charge does not remain inside the conducting sphere but moves to its outside surface. An ion source inside the sphere produces positive ions, which are accelerated away from the positive sphere to high velocities.

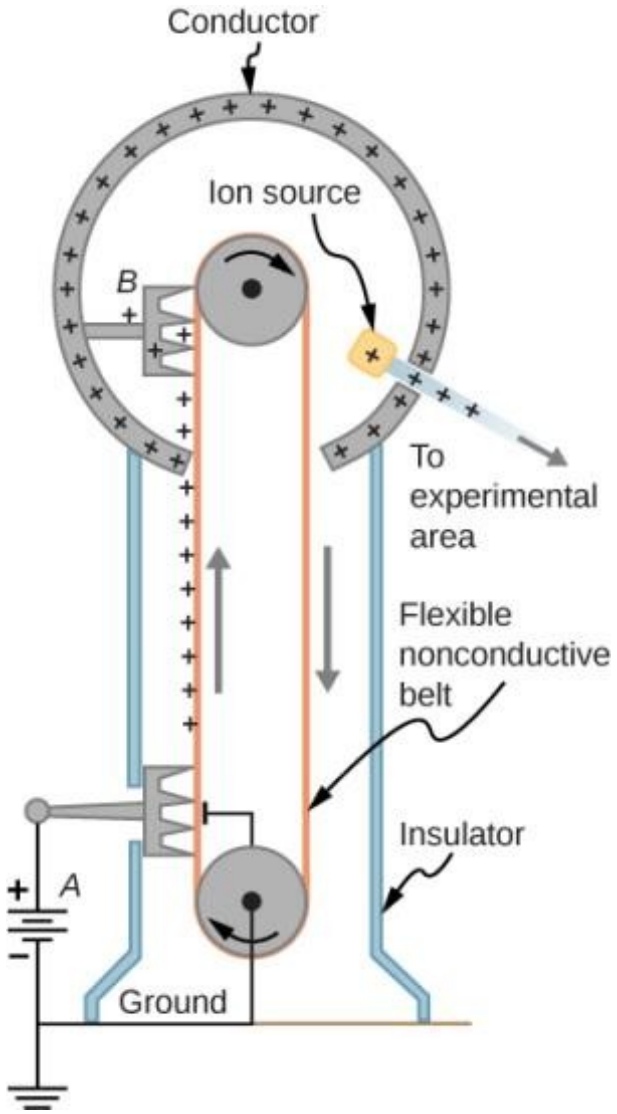
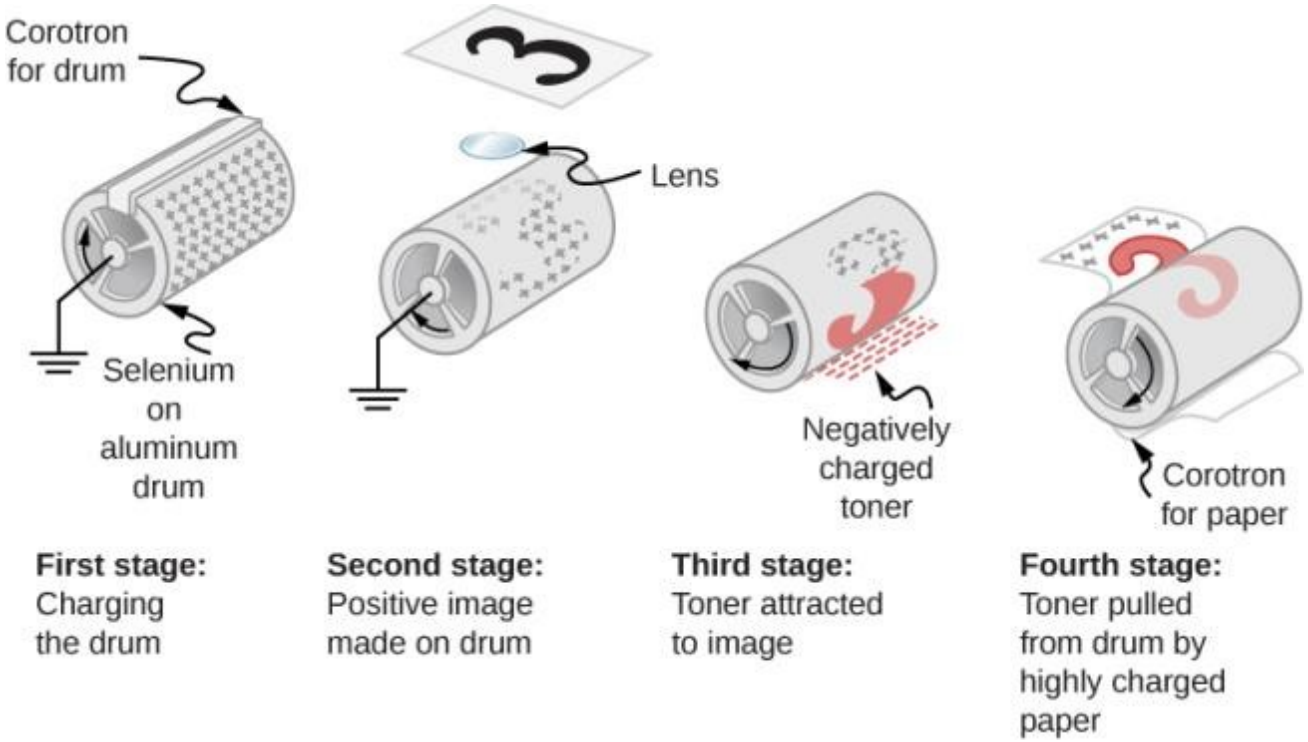
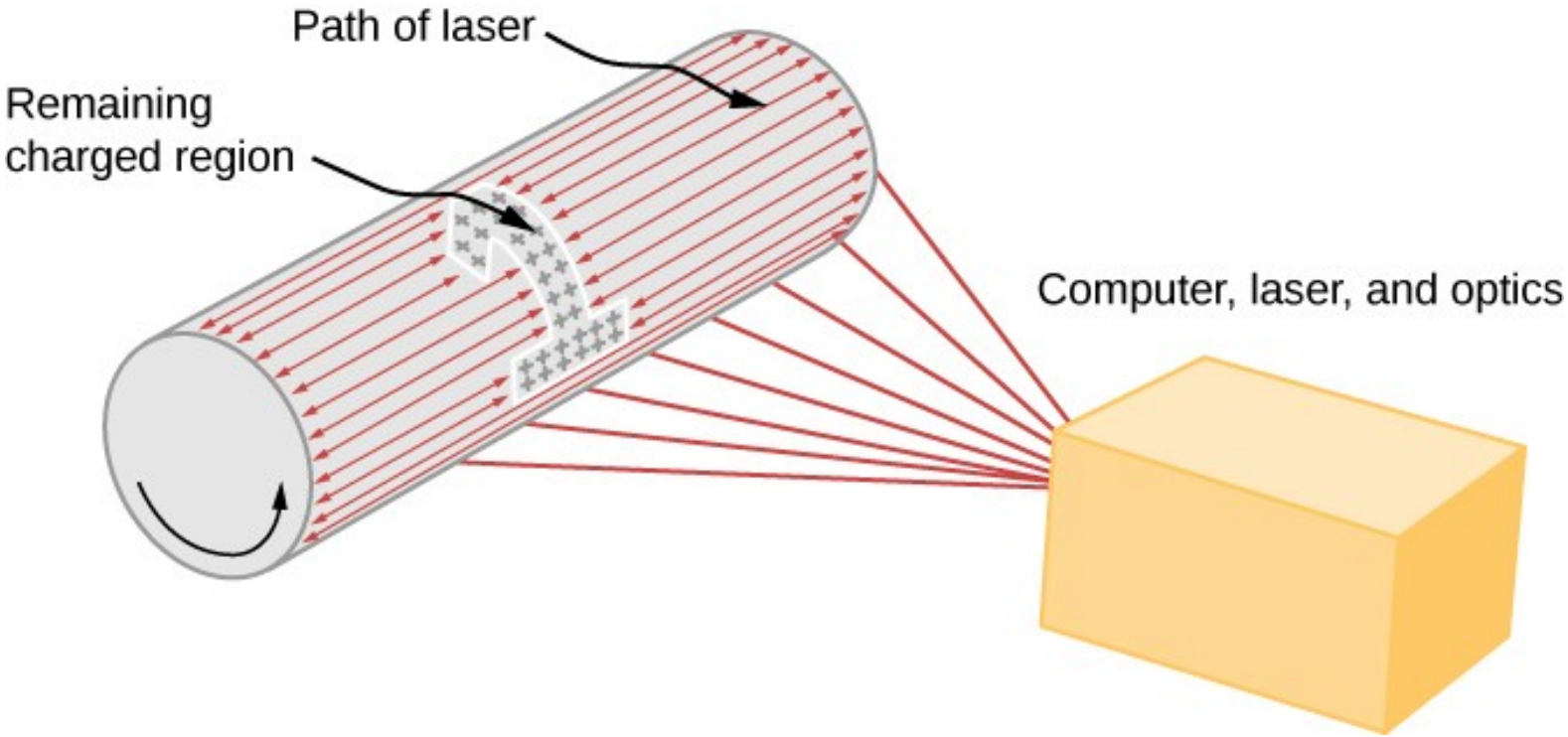


FIGURE 7.42



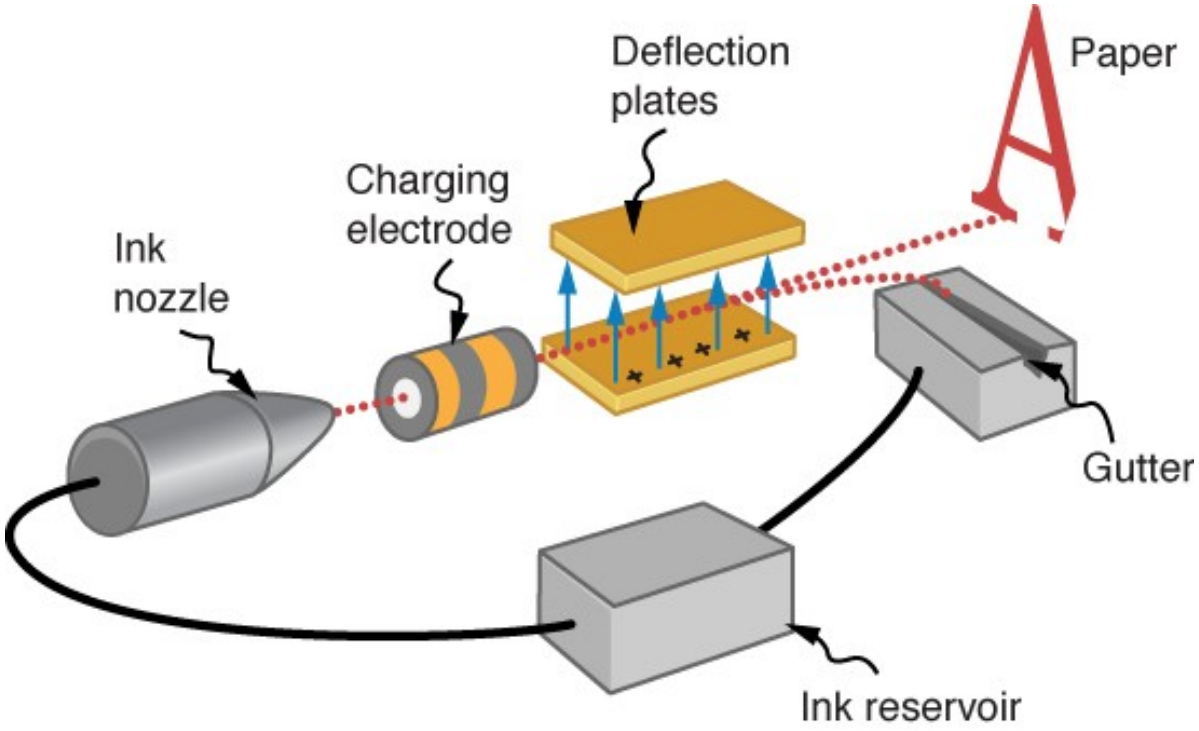
Xerography is a dry copying process based on electrostatics. The major steps in the process are the charging of the photoconducting drum, transfer of an image, creating a positive charge duplicate, attraction of toner to the charged parts of the drum, and transfer of toner to the paper. Not shown are heat treatment of the paper and cleansing of the drum for the next copy.

FIGURE 7.43



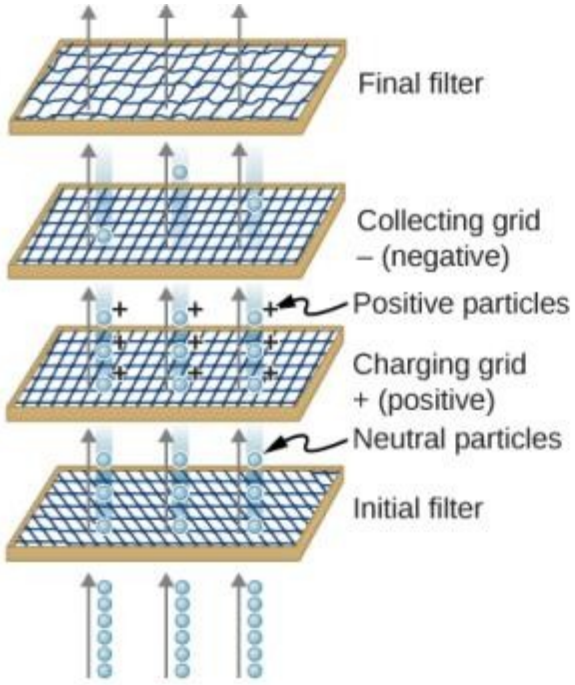
In a laser printer, a laser beam is scanned across a photoconducting drum, leaving a positively charged image. The other steps for charging the drum and transferring the image to paper are the same as in xerography. Laser light can be very precisely controlled, enabling laser printers to produce high-quality images.

FIGURE 7.44



The nozzle of an ink-jet printer produces small ink droplets, which are sprayed with electrostatic charge. Various computer-driven devices are then used to direct the droplets to the correct positions on a page.

FIGURE 7.45



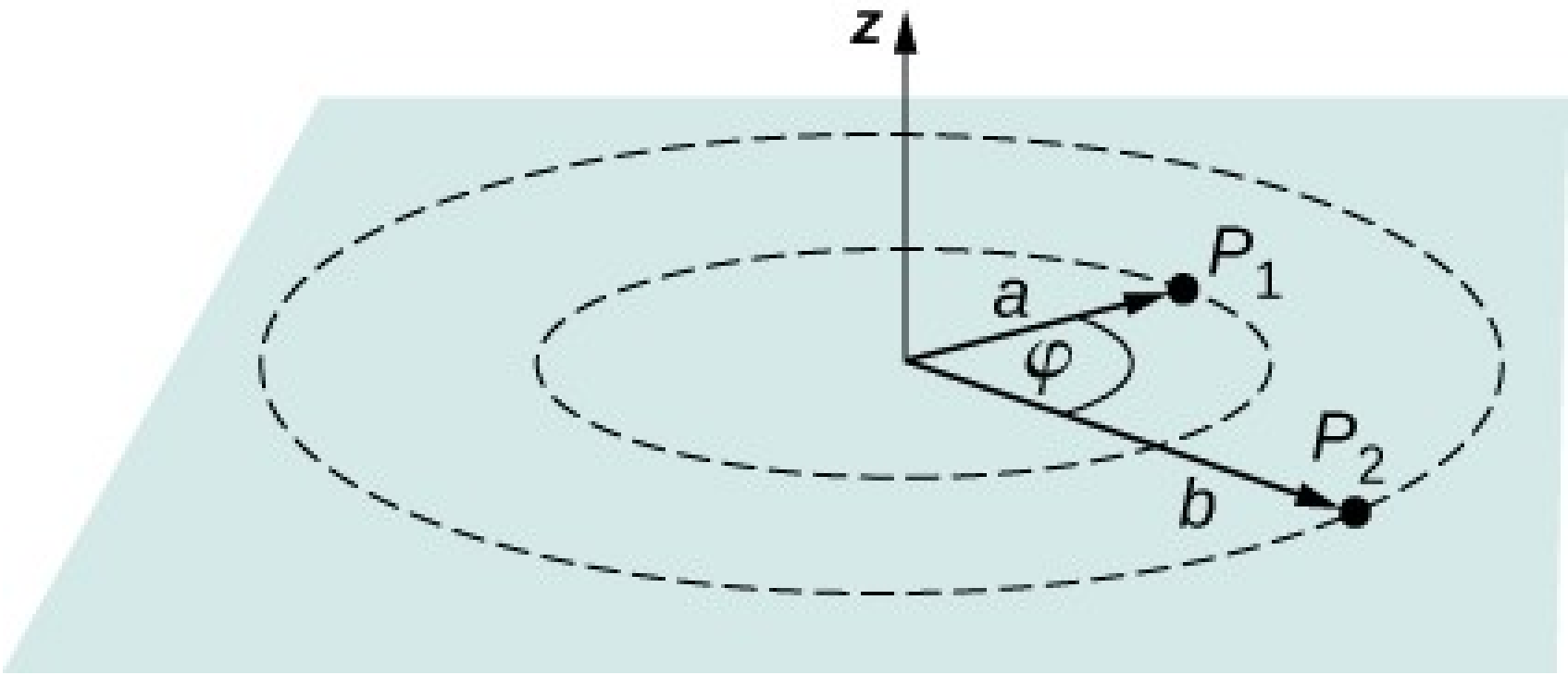
(a)

(b)

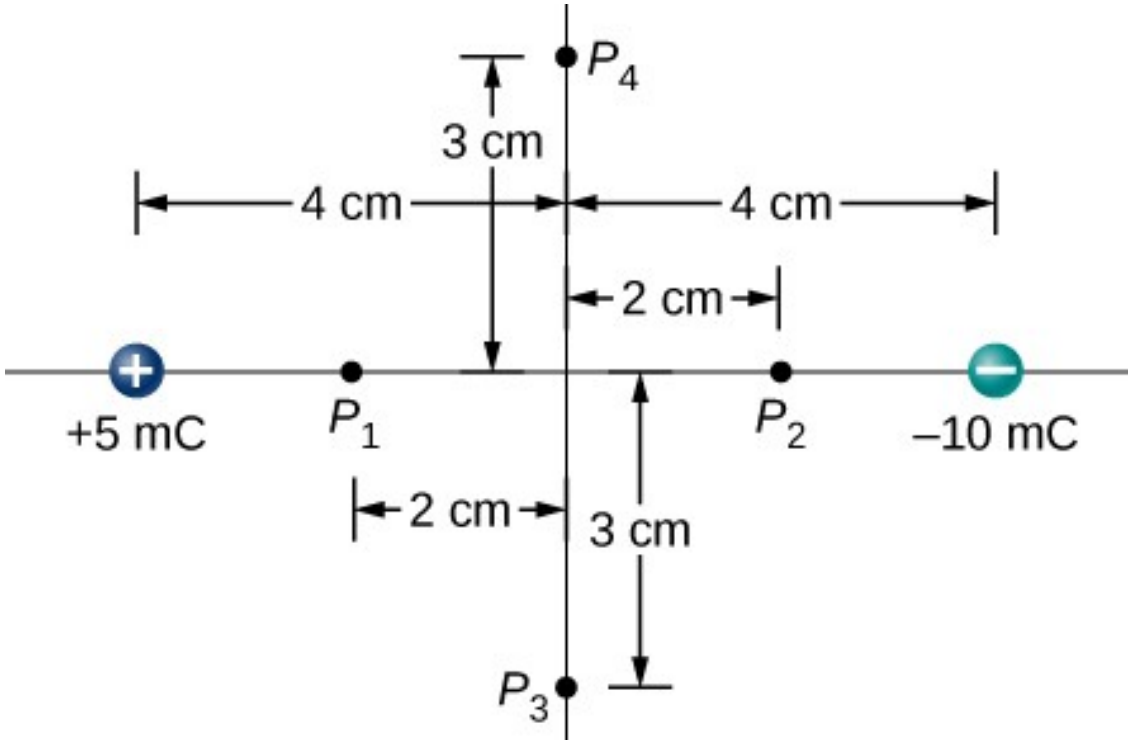
(a) Schematic of an electrostatic precipitator. Air is passed through grids of opposite charge. The first grid charges airborne particles, while the second attracts and collects them.

(b) The dramatic effect of electrostatic precipitators is seen by the absence of smoke from this power plant. (credit b: modification of work by “Cmdalgleish”/Wikimedia Commons)

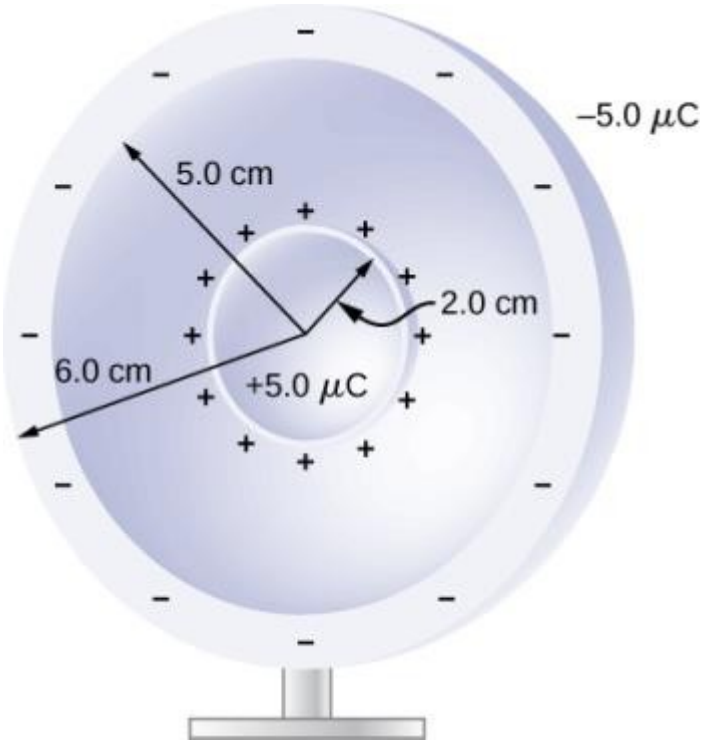
EXERCISE 43



EXERCISE 52

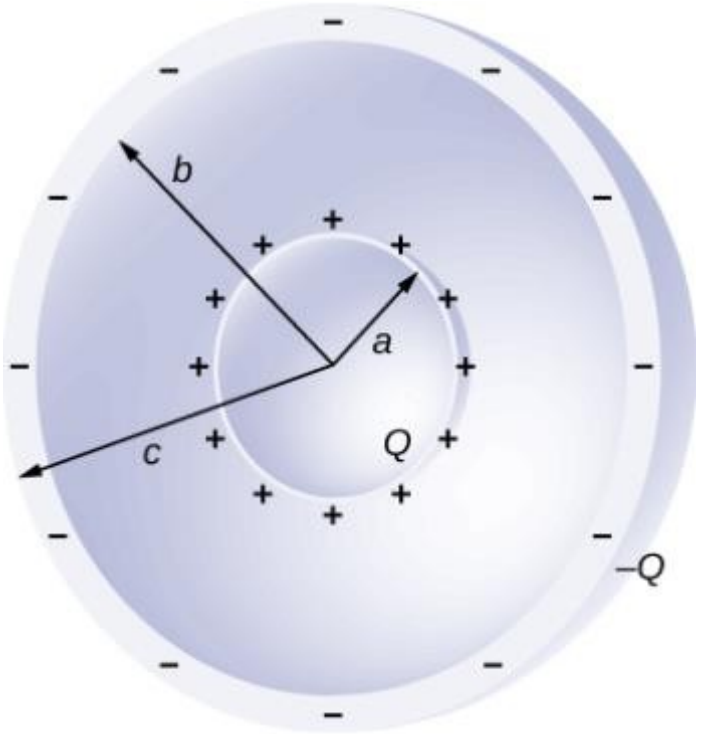


EXERCISE 60



EXERCISE 64

EXERCISE 65



EXERCISE 66

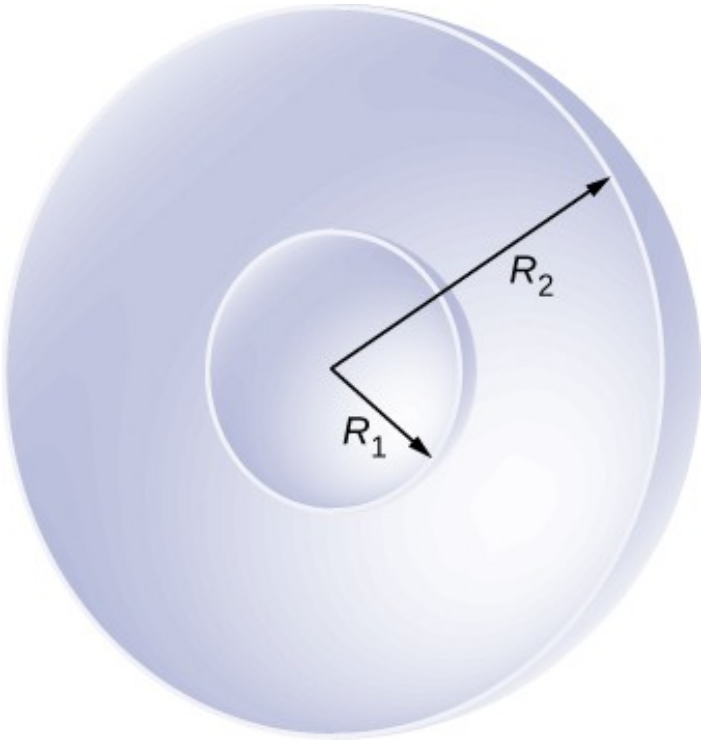
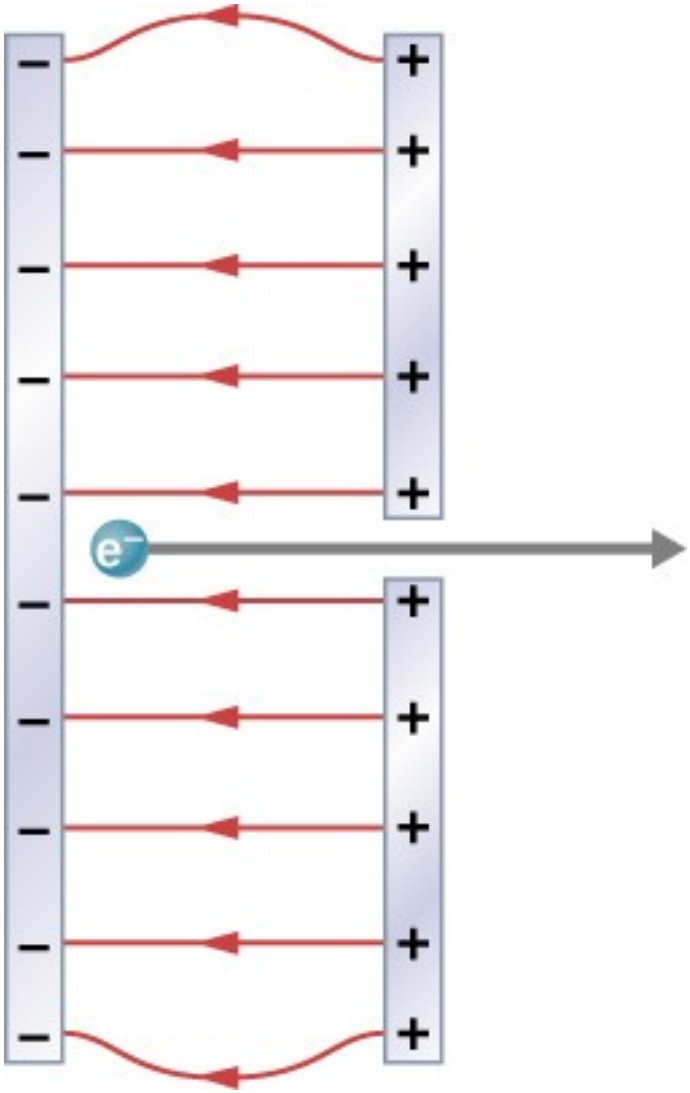
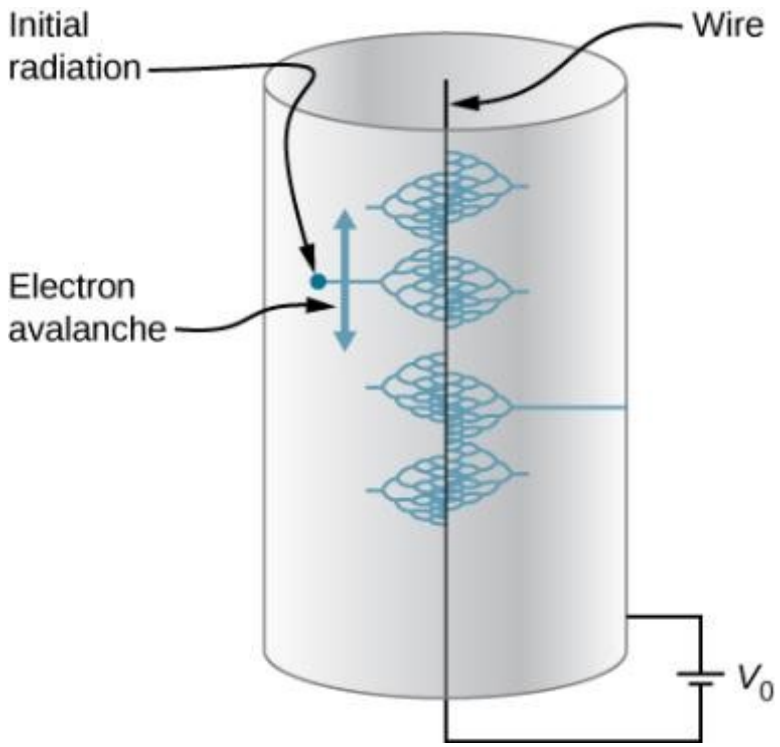


FIGURE 7.46

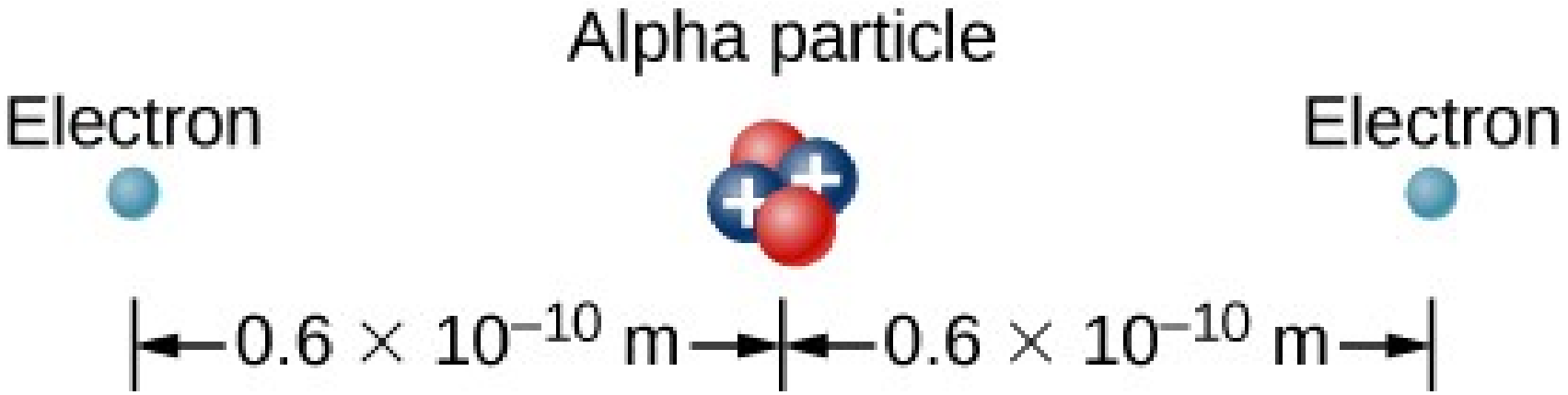
Parallel conducting plates with opposite charges on them create a relatively uniform electric field used to accelerate electrons to the right. Those that go through the hole can be used to make a TV or computer screen glow or to produce X-rays.



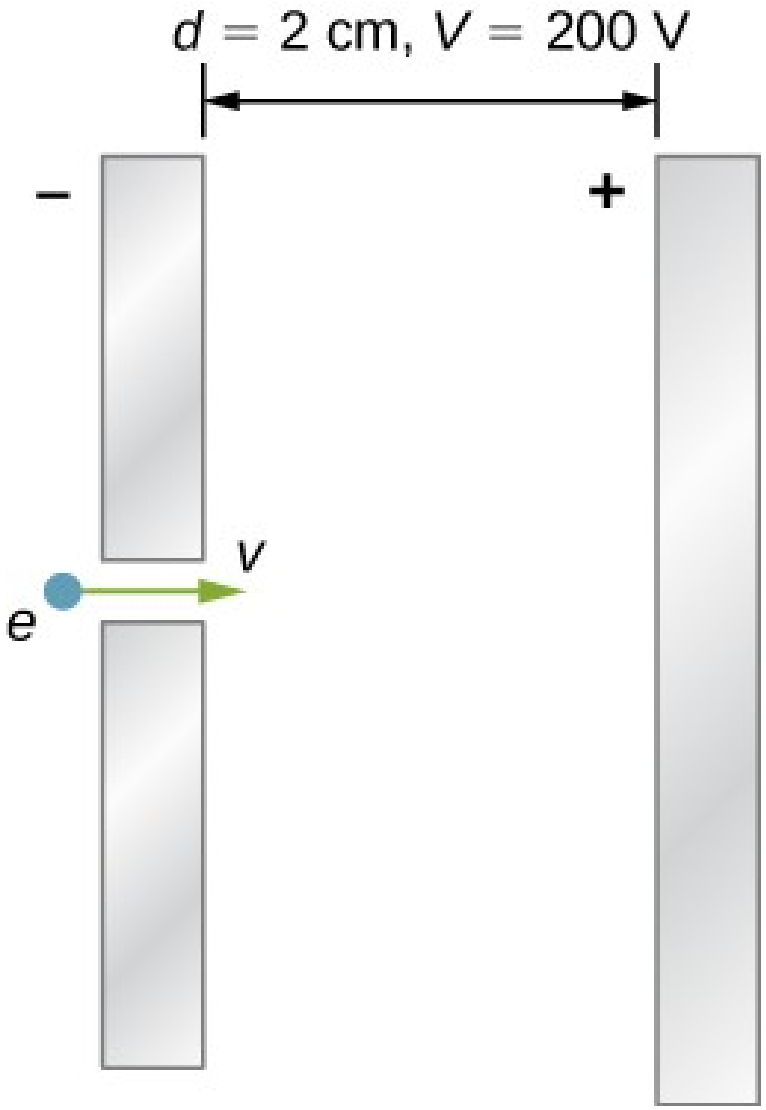
EXERCISE 71



EXERCISE 73


Alpha particle
Electron
Electron
0.6×10^{-10} m
0.6×10^{-10} m

EXERCISE 77



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