In 2 sec, the number of electrons is $2 \times 6.25 \times 10^{19} = 12.5 \times 10^{19}$.

Q5.4 Work = energy = 5 C × 1.5 V = 7.5 J

Q5.5 In the wire connecting the right plate to the minus end of the battery, the voltage is equal everywhere. There is no net force on the electrons.

EXERCISES AND PROBLEMS

Exercises

E5.1 A metal ball has an excess charge of 1,000 electrons, and a second metal ball has a deficit of 1,000 electrons.

(a) If the two balls are connected by a long, thin piece of copper metal, what will happen to the charge on the negatively charged metal ball?
(b) If the two balls are connected by a long, thin piece of glass, what will happen to the charge on the negatively charged metal ball? Explain.

E5.2 You have three insulated metal balls, A, B, and C, of equal size. You rub a Teflon (plastic) rod with rabbit fur, and then touch the rod to ball A to transfer charge. To charge ball B, you rub a glass rod with silk then touch the rod to ball B. Assume that the quantity of charge transferred in each case equals $-1 \times 10^{16} e$ (recall that $-e$ is the charge of 1 electron). Ball C is uncharged. Consider each case below separately, starting from the same initial conditions described above.

(a) If you connect ball A to ball B through a neutral copper rod, what is the net charge on each ball afterwards?
(b) If you connect ball A to ball B through a neutral glass rod, what is the net charge on each ball afterwards?
(c) If you connect ball A to ball C through a neutral copper rod, what is the net charge on each ball afterwards? (Think of the charges on A repelling each other.)
(d) If you connect ball B to ball C through a neutral copper rod, what is the net charge on each ball afterwards?
(e) If you connect ball B to a copper wire that connects to a copper plumbing pipe that goes into the Earth, what is the net charge on ball B afterwards?

E5.3 Explain why it is scientifically valid (and perhaps amusing) to claim that the Earth's magnetic "north pole" is actually in Antarctica, not in northern Canada.

E5.4 A small copper block has an excess charge of 2,000 electrons. A small gold block has an excess of 1,000 electrons. A small silver block has a deficit of negative charge corresponding to 1,000 electrons.

(a) Describe the forces between each pair of objects if separated by 1 mm. Which force is the strongest?
(b) If the silver block is put into contact with the gold block, describe the force between the copper block and the combined silver/gold object.
(c) If the silver block is put into contact with the copper block, describe the force between the combined silver/copper object and the gold object.

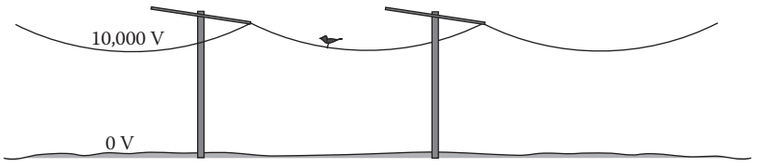
E5.5 Referring to the three blocks in E5.4:

(a) Sketch the electric field arrows (as in Figure 5.7) surrounding each object when isolated. How would a small piece of dust having 100 excess electrons be affected by the field around each object? Which force is strongest (for a fixed distance between charged object and piece of dust)?
(b) As the piece of dust is moved closer and farther from each object, how does the force that is felt by the dust piece change?
(c) Answer (a) in the case that the dust piece has a deficit of 100 electrons.

E5.6 All objects attract each other by the force of gravity, which can be described in terms of gravitation field lines, in analogy to electric field lines.

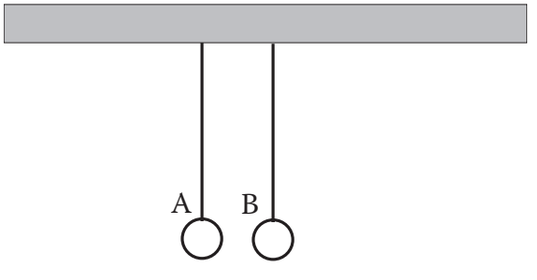
(a) Make a drawing showing the Earth surrounded by gravitation field lines. Which way do the arrows (forces) point?
(b) There is no repulsion, or repelling force, caused by gravity. If you were to invent the concept of "gravitational charge," how many different types of charges (none, one, or two) would you need to hypothesize to be consistent with the known facts? Explain.

E5.7 A bird can land on a bare metal power line that is held at 10,000 V (relative to the ground) and usually not be harmed. Explain why. Think of a scenario wherein the bird would be harmed when landing on the wire. (*Hint*: There could be a tree branch nearby.)



E5.8 Why can it be dangerous to touch electronic components in a circuit, such as a stereo power amplifier circuit, even a significant time after its power has been turned off? *Hint*: Consider the capacitors in the circuit.

E5.9 Two small round stones labeled A and B have the same size and mass and are hanging from thin, nonconducting strings. Initially they are held (perhaps using non-conducting tweezers) in the downward position, as shown. Stone A has a charge of $+1.0\times10^{18}e$, and stone B has charge of $+3.0\times10^{18}e$. Do the stones feel equal or different strengths of repelling force? (*Hint*: Recall Newton's third law.) After the stones are released from the tweezers, they repel and move away from each other, and are also attracted downward toward the Earth by gravity. Draw a picture similar to the one below, showing the angles of the two strings (after any oscillations stop). (Do not try to calculate the angles; just indicate if one is greater than the other or not.)



E5.10 Consider three small objects A, B, and C, which are identical, except for having different amounts of electric charge. You carry out separate experiments and find the following results.

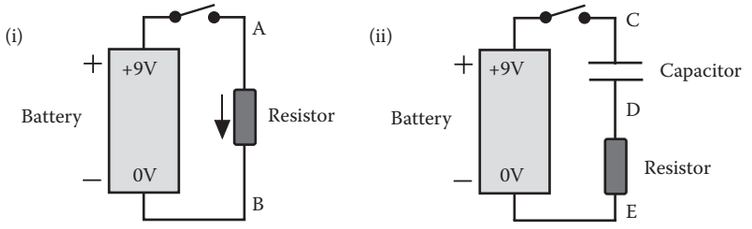
(i) At a distance of 10 cm, objects A and B attract strongly.
(ii) At a distance of 10 cm, objects A and C attract weakly.
   (a) Form a hypothesis explaining these results on the basis of amounts of charge (positive or negative) on each object. Give your reasoning.
   (b) Is there only one consistent hypothesis? If not, give another equally good hypothesis.
   (c) How could you determine by experiment which hypothesis is correct? (You may need to introduce new objects, such as Teflon and fur, into the experiment.) For (d) and (e), consider the case that A and B have equal but opposite charges:
   (d) What type and strength of force do you predict between B and C?
   (e) What would be the result if you stuck A and C together to make a single new object and then measured the force between this new object and object B?

E5.11 Two large, round stones have equal amounts of charge, but one is negative and the other is positive, as shown. The stones are fixed in position, and surrounded by nonconducting oil. If a small, light object (test object) is charged and placed at one of the positions labeled (i), (ii), or (iii), the object will feel forces and will move along the electric field line that it is located on. The oil puts frictional drag on the test object, preventing it from accelerating very much, so it moves very slowly.

(a) Make a careful sketch showing the field lines with arrows attached. (*Hint*: See In-Depth Look 5.3.)
(b) On a separate drawing, draw the path taken by the test object for each different starting location, assuming the test object is positively charged.
(c) Do the same, assuming the test object is negatively charged.

E5.12 Nine-volt batteries are connected in two circuits as shown below. Assume the battery maintains its voltage.

(a) If you suddenly close the switch in Figure (i), explain if any electric current will flow immediately after the switch is closed.
(b) If you suddenly close the switch in Figure (i), explain if any electric current will flow a long time after the switch is closed.
(c) After a long time, what will be the relationships between the voltages at points A and B?
(d) Answer (a) and (b) for Figure (ii) and explain.
(e) After a long time, what will be the relationships between the voltages at points C, D, and E?



E5.13 If you have an ordinary bar magnet, and you knock it sharply against a hard, dry, nonconducting, concrete floor, you can reduce its magnetic strength. Explain. (Assume the bar does not break.)

E5.14 If you bring a second wire coil, such as that in Figure 5.30, near to the coil shown, both with current flowing, will either loop or both loops feel a force from the other? Explain how the forces depend on the relative location and orientation of the coils.

E5.15 Photocopy or draw the coil and magnetic field lines in the lower half of Figure 5.30. Draw ten small compasses located at various places around and inside of the coil and indicate in which direction the needle of each compass would point. (Assume the compasses do not affect each other.)

E5.16 What electromagnetism principle(s) are behind the operation of:

(a) microphones (explain)
(b) loud speakers (You may need to do some research for this.)
(c) magnetic hard drives (explain)
(d) magnetic tape recordings (You may need to do some research for this.)

E5.17 Oil can be sprayed into a fine mist made of tiny droplets. Under the influence of gravity, the drops will slowly settle through the air toward the Earth. If the oil mist is exposed to a source of static electricity, a small amount of electric charge can attach itself to each drop. If the mist is located between two metal plates attached to the opposite sides of a battery, the resulting electric force can be adjusted to oppose the force of gravity. Devise and explain a way that this apparatus could be used to prove that electric charge comes in discrete amounts. That is, the charge of an object is always equal to an integer (whole number 0, 1, 2, etc.) multiplied by e, which is the charge on a single electron. Robert Millikan carried out this experiment in 1909.

E5.18 A known joke is a sign on a laboratory door declaring:

WARNING! — ONE MILLION OHMS

Why is this amusing to physicists and engineers?

Problems

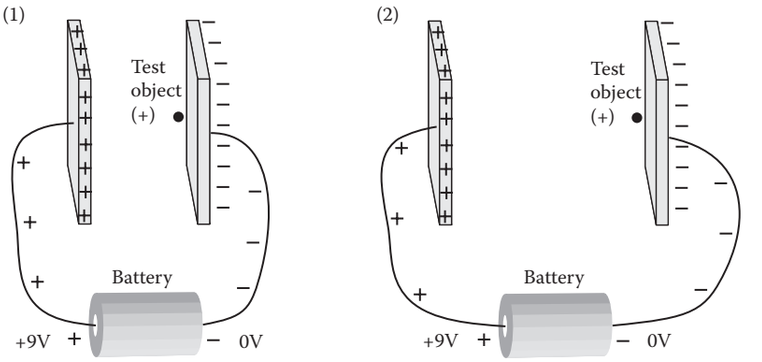
P5.1 An automobile battery contains about 0.03 kW · hr of energy per kg of battery mass. How much energy (in joules) is contained in a 44 lb (20 kg) battery?

P5.2 A kitchen blender uses 4.5 A of current when operating. How many electrons pass through the motor coil of this device in 1 sec?

P5.3 In an experimental setup, labeled (1) in the figure below, a 9 V battery is connected to two large, fixed metal plates (a capacitor), using metal wires as shown. A

test object, with a positive electric charge, is located very near the right plate, as shown. You are holding the test object using long, nonconducting tweezers. You now move the test object from its shown location to a location very near the left positively charged plate.

(a) In moving this object from right to left, do you (using the tweezers) have to do work on the object, or does the object do work on you (i.e., on the tweezers)? Explain.
(b) Is the effect of having moved this test object that its potential energy has increased, decreased, or stayed the same?
(c) In a second experiment, labeled (2) in the figure below, the same experiment is carried out, but in this case the distance between the two plates is larger. Is the change of potential energy in this experiment greater when compared with that in the first experiment? Explain.
(d) Is the magnitude of the electric force felt by the test object in the second experiment greater than that felt by the object in the first experiment? Explain. (*Hint*: It turns out that in this situation the force felt by the object is approximately independent of its location between the plates.)



P5.4 A 9 V battery is connected to a resistor as in Figure 5.24.

(a) If the resistor has resistance equal to 50 ohms, what is the current? (*Hint*: Use Ohm's law.)
(b) If the resistor has resistance equal to one Mohm (megaohm), what is the current?

P5.5 Magnetic effects can be used to build computer memory. In the 1960s, computer memory was built by using one small magnet for each bit of information stored. This was called magnetic core memory. Cite two descriptions, in a library or online, explaining how magnetic core memory functions and write a one-page article describing the function. Drawings or other figures should be used and are in addition to the page of text. Identify and cite the source of all information and materials used in your report.

P5.6 Do research online to learn and describe the operating principles of a shakable flashlight, that is, one that requires no batteries and is powered by shaking it back and forth. Explain how the light can stay on for minutes or hours after you stop shaking it. What type of circuit components would enable this operation?