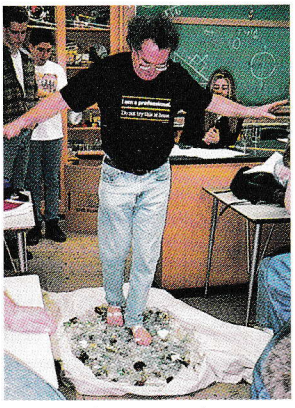
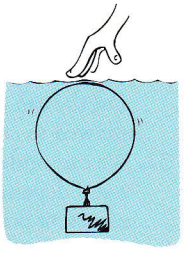
EXERCISES

1. Stand on a bathroom scale and read your weight. When you lift one foot up so you're standing on one foot, does the reading change? Does a scale read force or pressure?
2. The photo shows physics teacher Marshall Ellenstein walking barefoot on broken glass bottles in his class. What physics concept is Marshall demonstrating, and why is he careful that the broken pieces are small and numerous?

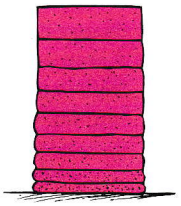


3. In a deep dive, a whale is appreciably compressed by the pressure of the surrounding water. What happens to the whale's density?
4. The density of a rock doesn't change when it is submerged in water. Does your density change when you are submerged in water? Defend your answer.
5. Why are persons who are confined to bed less likely to develop bedsores on their bodies if they lie on a waterbed rather than on an ordinary mattress?
6. If water faucets upstairs and downstairs are turned fully on, will more water per second flow out the downstairs faucet? Or will the flows from the faucets be the same?
7. Which do you suppose exerts more pressure on the ground—an elephant or a woman standing on spike heels? (Which will be more likely to make dents in a linoleum floor?) Can you approximate a rough calculation for each?
8. Suppose you wish to lay a level foundation for a home on hilly and bushy terrain. How can you use a garden hose filled with water to determine equal elevations for distant points?
9. When you are bathing on a stony beach, why do the stones hurt your feet less when you get in deep water?
10. If liquid pressure were the same at all depths, would there be a buoyant force on an object submerged in the liquid? Explain.
11. The Himalayas are slightly less dense than the mantle material upon which they "float." Do you suppose that, like floating icebergs, these mountains are deeper than they are high?
12. How much force is needed to push a nearly weightless but rigid 1-L carton beneath a surface of water?
13. Why is it inaccurate to say that heavy objects sink and that light objects float? Give exaggerated examples to support your answer.
14. Compared to an empty ship, would a ship loaded with a cargo of Styrofoam sink deeper into water or rise in water? Defend your answer.
15. A barge filled with scrap iron is in a canal lock. If the iron is thrown overboard, does the water level at the side of the lock rise, fall, or remain unchanged? Explain.
16. Would the water level in a canal lock go up or down if a battleship in the lock were to sink?
17. A balloon is weighted so that it is barely able to float in water. If it is pushed beneath the surface, will it return to the surface, stay at the depth to which it is pushed, or sink? Explain. (Hint: Does the balloon's density change?)

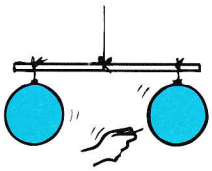


18. A ship sailing from the ocean into a freshwater harbor sinks slightly deeper into the water. Does the buoyant force on it change? If so, does it increase or decrease?
19. Suppose you are given the choice between two life preservers that are identical in size, the first a light one filled with Styrofoam and the second a very heavy one filled with lead pellets. If you submerge these life preservers in the water, upon which will the buoyant force be greater? Upon which will the buoyant force be ineffective? Why are your answers different?
20. The relative densities of water, ice, and alcohol are 1.0, 0.9, and 0.8, respectively. Do ice cubes float higher or lower in a mixed alcoholic drink? What can you say about a cocktail in which the ice cubes lie submerged at the bottom of the glass?
21. When an ice cube in a glass of water melts, does the water level in the glass rise, fall, or remain unchanged? Does your answer change if the ice cube contains many air bubbles? Does your answer change if the ice cube contains many grains of heavy sand?
22. A half-filled bucket of water is on a spring scale. Will the reading of the scale increase or remain the same if a fish is placed in the bucket? (Will your answer be different if the bucket is initially filled to the brim?)
23. We say that the shape of a liquid is that of its container. But with no container and no gravity, what is the natural shape of a blob of water? Why?
24. If you release a Ping-Pong ball beneath the surface of water, it will rise to the surface. Would it do the same if it were submerged in a big blob of water floating weightless in an orbiting spacecraft?
25. It is said that a gas fills all the space available to it. Why, then, doesn't the atmosphere go off into space?
26. Count the tires on a large tractor trailer that is unloading food at your local supermarket, and you may be surprised to count 18 tires. Why so many tires? (Hint: See Active Exploration 5.)
27. How does the density of air in a deep mine compare with the air density at Earth's surface?
28. Two teams of eight horses each were unable to pull the Magdeburg hemispheres apart (Figure 7.21). Why? Suppose two teams of nine horses each could pull them apart. Then would one team of nine horses succeed if the other team were replaced with a strong tree? Defend your answer.

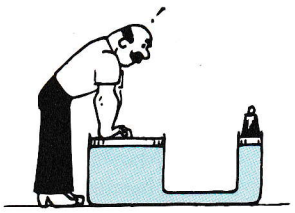
29. Before boarding an airplane, you buy a bag of chips (or any item packaged in an airtight bag) and, while in flight, you notice that the bag is puffed up. Explain why this occurs.
30. Why do you suppose that airplane windows are smaller than bus windows?
31. A half cup or so of water is poured into a 5-L can, which is placed on a source of heat until most of the water has boiled away. Then the top of the can is screwed on tightly and the can is removed from the source of heat and allowed to cool. What happens to the can and why?
32. We can understand how pressure in water depends on depth by considering a stack of bricks. The pressure below the bottom brick is determined by the weight of the entire stack. Halfway up the stack, the pressure is half because the weight of the bricks above is half. To explain atmospheric pressure, we should consider compressible bricks, like foam rubber. Why is this so?



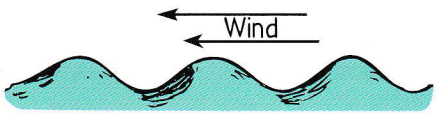
33. The "pump" in a vacuum cleaner is merely a high-speed fan. Would a vacuum cleaner pick up dust from a rug on the Moon? Explain.
34. If you could somehow replace the mercury in a mercury barometer with a denser liquid, would the height of the liquid column be greater or less than with mercury? Why?
35. Would it be slightly more difficult to draw soda through a straw at sea level or on top of a very high mountain? Explain.
36. Your friend says that the buoyant force of the atmosphere on an elephant is significantly greater than the buoyant force of the atmosphere on a small helium-filled balloon. What do you say?
37. Why is it so difficult to breathe when snorkeling at a depth of 1 m, and practically impossible at a 2-m depth? Why can't a diver simply breathe through a hose that extends to the surface?
38. When you replace helium in a balloon with hydrogen, which is less dense, does the buoyant force on the balloon change if the balloon remains the same size? Explain.
39. A steel tank filled with helium gas doesn't rise in air, but a balloon containing the same helium easily does? Why?
40. Two identical balloons of the same volume are pumped up with air to more than atmospheric pressure and suspended on the ends of a stick that is horizontally balanced. One of the balloons is then punctured. Is there a change in the stick's balance? If so, which way does it tip?



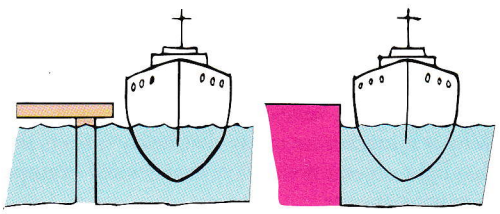
41. The force of the atmosphere at sea level against the outside of a 10-square-meter store window is about a million N. Why does this not shatter the window? Why might the window shatter in a strong wind blowing past the window?
42. In the hydraulic arrangement shown, the larger piston has an area that is 50 times that of the smaller piston. The strong man hopes to exert enough force on the large piston to raise the 10 kg that rest on the small piston. Do you think he will be successful? Defend your answer.



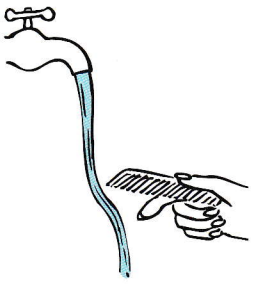
43. When a steadily flowing gas flows from a larger-diameter pipe to a smaller-diameter pipe, what happens to (a) its speed, (b) its pressure, and (c) the spacing between its streamlines?
44. How is an airplane able to fly upside down?
45. When a jet plane is cruising at a high altitude, the flight attendants have more of a "hill" to climb as they walk forward along the aisle than when the plane is cruising at a lower altitude. Why does the pilot have to fly with a greater "angle of attack" at a high altitude than at a lower one?
46. What physics principle underlies the following three observations? When passing an oncoming truck on the highway, your car tends to sway toward the truck. The canvas roof of a convertible automobile bulges upward when the car is traveling at high speeds. The windows of older passenger trains sometimes break when a high-speed train passes by on the next track.
47. On a windy day, waves in a lake or the ocean are higher than their average height. How does Bernoulli's principle contribute to the increased height?



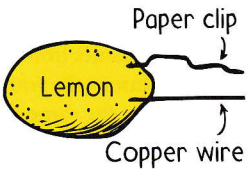
48. Wharves are made with pilings that permit the free passage of water. Why would a solid-walled wharf be disadvantageous to ships attempting to pull alongside?



3. Briskly rub a comb against your hair or a woolen garment and bring it near a small but smooth stream of running water. Is the stream of water charged? (Before you say yes, note the behavior of the stream when an opposite charge is brought nearby.)



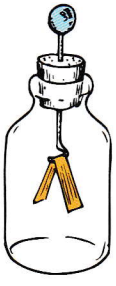
4. An electric cell is made by placing two plates of different materials that have different affinities for electrons in a conducting solution. You can make a simple 1.5-V cell by placing a strip of copper and a strip of zinc in a tumbler of saltwater. The voltage of a cell depends on the materials used and the solution they are placed in, not the size of the plates. A battery is actually a series of cells.



An easy cell to construct is the citrus cell. Stick a paper clip and a piece of copper wire into a lemon. Hold the ends of the wire close together, but not touching, and place the ends on your tongue. The slight tingle you feel and the metallic taste you experience result from a slight current of electricity pushed by the citrus cell through the wires when your moist tongue closes the circuit.

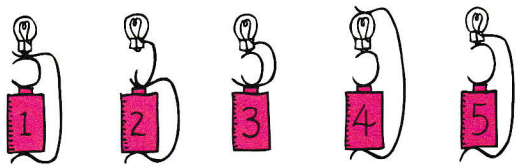
EXERCISES

1. We do not feel the gravitational forces between ourselves and the objects around us because these forces are extremely small. Electrical forces, in comparison, are extremely huge. Since we and the objects around us are composed of charged particles, why don't we usually feel electrical forces?
2. With respect to forces, how are electric charge and mass alike? How are they different?
3. When combing your hair, you scuff electrons from your hair onto the comb. Is your hair then positively or negatively charged? How about the comb?
4. An electroscope is a simple device consisting of a metal ball that is attached by a conductor to two thin leaves of metal foil protected from air disturbances in a jar, as shown. When the ball is touched by a charged body, the leaves that normally hang straight down spread apart. Why? (Electroscopes are useful not only as charge detectors but also for measuring the quantity of charge: the greater the charge transferred to the ball, the more the leaves diverge.)

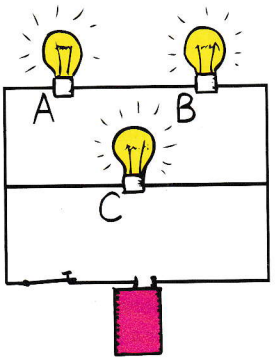


5. The leaves of a charged electroscope collapse in time. At higher altitudes, they collapse more rapidly. Why is this true? (Hint: The existence of cosmic rays was first indicated by this observation.)
6. Strictly speaking, will a penny be slightly more massive if it has a negative charge or a positive charge? Explain.
7. When one material is rubbed against another, electrons jump readily from one to the other, but protons do not. Why is this? (Think in atomic terms.)
8. If electrons were positive and protons were negative, would Coulomb's law be written the same or differently?
9. The five thousand billion billion freely moving electrons in a penny repel one another. Why don't they fly out of the penny?
10. Two equal charges exert equal forces on each other. What if one charge has twice the magnitude of the other? How do the forces they exert on each other compare?
11. How does the magnitude of electric force compare with the charge between a pair of charged particles when they are brought to half their original distance of separation? To one-quarter their original distance? To four times their original distance? (What law guides your answers?)
12. Suppose that the strength of the electric field about an isolated point charge has a certain value at a distance of 1 m. How will the electric field strength compare at a distance of 2 m from the point charge? What law guides your answer?
13. Why is a good conductor of electricity also a good conductor of heat?
14. When a car is moved into a painting chamber, a mist of paint is sprayed around it. When the body of the car is given a sudden electric charge and the mist of paint is attracted to it, presto—the car is quickly and uniformly painted. What does the phenomenon of polarization have to do with this?
15. If you place a free electron and a free proton in the same electric field, how will the forces acting on them compare? How will their accelerations compare? Their directions of travel?
16. If you put in 10 joules of work to push 1 coulomb of charge against an electric field, what will be its voltage with respect to its starting position? When released, what will be its kinetic energy if it flies past its starting position?
17. What is the voltage at the location of a 0.0001 C charge that has an electric potential energy of 0.5 J (both voltage and potential relative to the same reference point)?

18. What happens to the brightness of light emitted by a lightbulb when the current in it increases?
19. One example of a water system is a garden hose that waters a garden. Another is the cooling system of an automobile. Which of these exhibits behavior more analogous to that of an electric circuit? Why?
20. Is it correct to say that the energy from a car battery ultimately comes from fuel in the gas tank? Defend your answer.
21. Your tutor tells you that an ampere and a volt really measure the same thing, and the different terms only serve to make a simple concept seem confusing. Why should you consider getting a different tutor?
22. In which of the circuits below does a current exist to light the bulb?

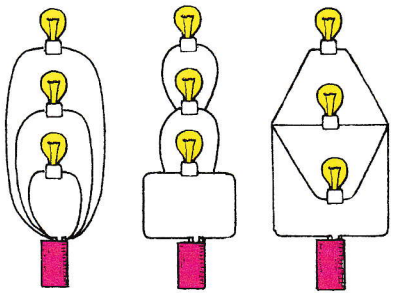


23. Does more current flow out of a battery than into it? Does more current flow into a lightbulb than out of it? Explain.
24. Sometimes you hear someone say that a particular appliance "uses up" electricity. What is it that the appliance actually consumes, and what becomes of it?
25. A simple lie detector consists of an electric circuit, one part of which is part of your body, such as having wires connected to two of your fingers so that your hand is part of the circuit. A sensitive meter shows the current that flows when a small voltage is applied. How does this technique indicate that a person is lying? (And when does this technique not indicate when someone is lying?)
26. Only a small percentage of the electric energy fed into a common lightbulb is transformed into light. What happens to the rest?
27. Will a lamp with a thick filament draw more current or less current than a lamp with a thin filament?
28. A 1-mile-long copper wire has a resistance of 10 ohms. What will be its new resistance when it is shortened by (a) cutting it in half or by (b) doubling it over and using it as if it were one wire of half the length but twice the cross-sectional area?
29. Will the current in a lightbulb connected to a 220-V source be greater or less than that in the same bulb when it is connected to a 110-V source?
30. Which will do less damage—plugging a 110-V appliance into a 220-V circuit or plugging a 220-V appliance into a 110-V circuit? Explain.
31. If a current of one- or two-tenths of an ampere were to flow into one of your hands and out the other, you would probably be electrocuted. But, if the same current were to flow into your hand and out the elbow above the same hand, you could survive, even though the current might be large enough to burn your flesh. Explain.
32. Would you expect to find dc or ac in the filament of a lightbulb in your home? How about in the headlight of an automobile?
33. Are automobile headlights wired in parallel or in series? What is your evidence?
34. A car's headlights dissipate 40 W on low beam and 50 W on high beam. Is there more or less resistance in the high-beam filament?
35. What unit is represented by (a) joule per coulomb, (b) coulomb per second, and (c) watt-second?
36. To connect a pair of resistors so that their equivalent resistance will be greater than the resistance of either one, should you connect them in series or in parallel?
37. To connect a pair of resistors so that their equivalent resistance will be less than the resistance of either one, should you connect them in series or in parallel?
38. A friend says that a battery provides not a source of constant current, but a source of constant voltage. Do you agree or disagree, and why?
39. A friend says that adding bulbs in series to a circuit provides more obstacles to the flow of charge, so there is less current with more bulbs. However, she also says that adding bulbs in parallel provides more paths so more current can flow. Do you agree or disagree, and why?
40. Why might the wingspans of birds be a consideration in determining the spacing between parallel wires on power poles?
41. Estimate the number of electrons that a power company delivers annually to the homes of a typical city of 50,000 people.
42. If electrons flow very slowly through a circuit, why doesn't it take a noticeably long time for a lamp to glow when you turn on a distant switch?
43. Consider a pair of flashlight bulbs connected to a battery. Will they glow brighter if they are connected in series or in parallel? Will the battery run down faster if they are connected in series or in parallel?
44. If several bulbs are connected in series to a battery, they may feel warm to the touch even though they are not visibly glowing. What is your explanation?
45. In the circuit shown, how do the brightnesses of the identical lightbulbs compare? Which lightbulb draws the most current? What will happen if bulb A is unscrewed? If bulb C is unscrewed?



46. As more and more bulbs are connected in series to a flashlight battery, what happens to the brightness of each bulb? Assuming that the heating inside the battery is negligible, what happens to the brightness of each bulb when more and more bulbs are connected in parallel?

47. Are these circuits equivalent to one another? Why or why not?



48. A battery has internal resistance, so, if the current it supplies goes up, the voltage it supplies goes down. If too many bulbs are connected in parallel across a battery, will their brightness diminish? Explain.
49. Your friend says that electric current takes the path of least resistance. Why is it more accurate in the case of a parallel circuit to say that *most* current travels in the path of least resistance?
50. If a 60-W bulb and a 100-W bulb are connected in series in a circuit, across which bulb will there be the greater voltage drop? How about if they are connected in parallel?

PROBLEMS

● BEGINNER ■ INTERMEDIATE ◆ EXPERT

1. ● Two pellets, each with a charge of 1 microcoulomb (10^{-6} C), are located 3 cm (0.03 m) apart. Show that the electric force between them is 10 N.
2. ● Two point charges are separated by 6 cm. The attractive force between them is 20 N. Show that when they are separated by 12 cm the force between them is 5 N. (Why can you solve this problem without knowing the magnitudes of the charges?)
3. ● If the charges attracting each other in the preceding problem have equal magnitudes, show that the magnitude of each charge is 2.8 microcoulombs.
4. ● A droplet of ink in an industrial ink-jet printer carries a charge of 1.6×10^{-10} C and is deflected onto paper by a force of 3.2×10^{-4} N. Show that the strength of the electric field required to produce this force is 2×10^{-6} N/C.
5. ● When an electric field does 12 J of work on a charge of 0.0001 C, (a) show that the change in voltage is 120,000 V. (b) When the same electric field does 24 J of work on a charge of 0.0002 C, show that the voltage change is the same.
6. ■ The current driven by voltage V in a circuit of resistance R is given by Ohm's law, $I = V/R$. Show that the resistance of a circuit carrying current I and driven by voltage V is given by the equation $R = V/I$.
7. ■ The same voltage V is impressed on each of the branches of a parallel circuit. The voltage source provides a total current I_{total} to the circuit, and "sees" a total equivalent resistance of R_{eq} in the circuit. That is, $V = I_{total} R_{eq}$ The total current is equal to the sum of the currents through each branch of the parallel circuit. In a circuit with n branches, $I_{total} = I_1 + I_2 + I_3 \ldots I_n$. Use Ohm's law ($I = V/R$) and show that the equivalent resistance of a parallel circuit with n branches is given by

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots + \frac{1}{R_n}$$

8. ● The wattage marked on a light bulb is not an inherent property of the bulb; rather, it depends on the voltage to which it is connected, usually 110 or 120 V. Show that the current in a 60-W bulb connected in a 120-V circuit is 0.5 A.
9. ● Rearrange the equation current = voltage/resistance to express *resistance* in terms of current and voltage. Then consider the following: a certain device in a 120-V circuit has a current rating of 20 A. Show that the resistance of the device is 6 Ω.
10. ● Using the formula Power = current × voltage, show that the current drawn by a 1200-W hair dryer connected to 120 V is 10 A. Then using your same method for the solution to the previous problem, show that the resistance of the hair dryer is 12 Ω.
11. ■ The power in an electric circuit is given by the equation $P = IV$. Use Ohm's law to express V and show that power can be expressed by the equation $P = I^2R$.
12. ■ The total charge that an automobile battery can supply without being recharged is given in terms of ampere-hours. A typical 12-V battery has a rating of 60 ampere-hours (60 A for 1 h, 30 A for 2 h, and so on). Suppose that you forget to turn off the headlights in your parked automobile. If each of the two headlights draws 3 A, show that your battery will be dead in about 10 hours.
13. ■ Suppose you operate a 100-W lamp continuously for 1 week when the power utility rate is 20¢/kWh. Show that this will cost you $3.36.
14. ■ An electric iron connected to a 110-V source draws 9 A of current. Show that the amount of heat generated in 1 minute is almost 60 kJ.
15. ■ For the electric iron of the previous problem, show that the number of coulombs that flow through it in 1 minute is 540 C.
16. ◆ A certain lightbulb with a resistance of 95 ohms is labeled "150 W." Was this bulb designed for use in a 120-V circuit or a 220-V circuit?
17. ◆ In periods of peak demand, power companies lower their voltage. This saves them power (and saves you money)! To see the effect, consider a 1200-W toaster that draws 10 A when connected to 120 V. Suppose the voltage is lowered by 10 percent to 108 V. By how much does the current decrease? By how much does the power decrease? (Caution: The 1200-W label is valid only when 120 V is applied. When the voltage is lowered, it is the resistance of the toaster, not its power, that remains constant.)