Chapter 7. Heat Transfer and Change of Phase

Think and Solve (Mathematica Application)

47. Show that 9300 cal of heat is needed to change 15 g of 20°C water to 100°C steam.

48. Show that 100 g of 100°C steam will completely melt 800 g of 0°C ice.

49. A small block of ice at 0°C is subjected to 10 g of 100°C steam and melts completely. Show that the mass of the block of ice can be no more than 80 g.

50. The specific heat capacity of ice is about 0.5 cal/g°**C.** Suppose it remains at that value all the way to absolute zero. (a) Show that the quantity of heat needed to change a 1-g ice cube at absolute zero (–273°C) to 1 g of boiling water is 320 cal.

(b) How does 320 calories compare to the energy needed to simply bring 1 g of 100°C water to a boil?

51. A 10-kg iron ball is dropped onto a pavement from a height of 100 m. Suppose that half of the heat generated goes into warming the ball. (a) Show that the temperature increase of the ball is 1.1°**C.** (In SI units, the specific heat capacity of iron is 450 J/kg°**C.** Use 9.8 N/kg for g.)

(b) Why is the answer the same for an iron ball of any mass?

52. A block of ice at 0°C is dropped and completely melts upon impact. Assume that there is no air resistance and that all the energy goes into melting the ice.

(a) Show that the height necessary for this to occur is at least 34 km. [Hint: Equate the joules of gravitational potential energy to the product of the mass of ice and its heat of fusion (in SI units, L_f = 335,000 J/kg).]

(b) Explain why the answer doesn't depend on mass.

53. Fifty grams of hot water at 80°C is poured into a cavity in a very large block of ice at 0°**C.** The final temperature of the water in the cavity becomes 0°**C.** Show that the mass of ice that melts is 50 g.

54. A 100-g chunk of 80°C iron is dropped into a cavity in a very large block of ice at 0°**C.** Show that the mass of ice that melts is 11 g. (The specific heat capacity c of iron is 0.11 cal/g°C.) 55. The heat of vaporization of ethyl alcohol L_v is about 200 cal/g. Show that if 4 kg of this refrigerant were allowed to vaporize in a refrigerator, it could freeze 10 kg of 0°C water to ice.

Think and Rank:

56. From greatest to lowest, rank these materials for con ducting heat: (a) Copper wire. (b) Snow. (c) Glass rod.

57. From greatest to least, rank the frequency of radiation of these emitters of radiant energy: (a) Red-hot star. (b) Blue-hot star. (c) Sun.

58. Rank the boiling-water temperatures at the following locations from highest to lowest: (a) Death Valley (below sea level). (b) Sea level. (c) Denver, Colorado (the "mile high city").

59. From greatest to least, rank the energy needed for these phase changes for equal amounts of H2O. (a) From ice to ice-water. (b) From ice-water to boiling water. (c)From boiling water to steam.

Readiness Assurance Test (RAT)

1. A firewalker walking barefoot across hot wooden coals depends on wood's

A. good conduction. **B.** poor conduction. **C.** low specific heat capacity. **D.** wetness.

2. Thermal convection is linked most closely to

A. radiant energy. **B.** fluids. **C.** insulators. **D.** all of these

3. When air is rapidly compressed, its temperature normally

A. increases. **B.** decreases. **C.** remains unchanged. **D.** is unaffected, but not always.

4. An object that absorbs energy well also

A. conducts well. **B.** convects well. **C.** radiates well. **D.** none of these

5. Planet Earth loses heat mainly by

A. conduction. **B.** convection. **C.** radiation. **D.** all of these

6. Compared with terrestrial radiation, the radiation from the Sun has a

A. longer wavelength. **B.** lower frequency. **C.** both of these **D.** none of these

7. Glass is transparent to short-wavelength light and is

A. opaque to light of longer wavelengths.

B. opaque to the same light that is reflected from an interior surface.

C. both of these

D. none of these

8. When evaporation occurs in a dish of water, the molecules left behind in the water

A. are less energetic**.** **B.** have decreased average speeds.

C. result in lowered temperature. **D.** all of these

9. When steam changes phase to water, it

A. absorbs energy. **B.** releases energy.

C. neither absorbs nor releases energy. **D.** becomes more conducting.

10. Boiling and freezing can occur at the same time when water is subjected to

A. decreased temperatures. **B.** decreased atmospheric pressure.

C. increased temperatures. **D.** increased atmospheric pressure

Chapter 8. Static and Current Electricity

Think and Solve (Mathematica Application)

41. 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.

42. Two point charges are separated by 4 cm. The attractive force between them is 20 N. Show that when they are separated by 8 cm, the force between them is 5 N. (Why can you solve this problem without knowing the magnitudes of the charges?)

43. Show that if the charges attracting each other in the pre ceding problem have equal magnitudes, each charge has a magnitude of 1.9 microcoulombs (1.9×10^{-6} C).

44. 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 $(E = F/q)$ required to produce this force is 2×10^{6} N/C.

45. A 12-V battery moves 4 C of charge from one terminal to the other. Show that the battery does 48 J of work.

46. Suppose you could expend 10 joules of work to push a 1-coulomb charged particle against an electric field. What would be its change of voltage? If the particle is released, what will be its kinetic energy as it flies past its starting position?

47. The potential difference between a storm cloud and the ground is 100 million volts. If a charge of 2C flashes in a bolt from cloud to Earth, show that the change of poten tial energy of the charge is 2×10^{8}J.

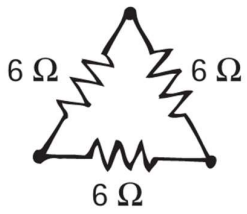
48. The current driven by voltage V in a circuit of resistance R is given by Ohm's law, $I = \frac{V}{R}$. Show that the resistance of a circuit carrying current I and driven by voltage V is given by the equation $R = \frac{V}{I}$.

49. The same voltage V is impressed on each of the branches of a parallel circuit. The voltage source provides a total current Itotal 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

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

50. The power in watts 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. (a) Show that the current in a 300-W bulb connected in a 120-V circuit is 2.5 A. (b) Compute the resistance of the bulb's filament. (c) Assuming this resistance does not change, compute the bulb's power output if the bulb is instead connected to a 24-V battery.

51. Rearrange the formula Current = voltage/resistance $(I = \frac{V}{R})$ 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. 52. Three 6-ohm (6-Ω) resistors are arranged in a triangle as shown. A voltage source of 12 V is impressed across one of the resistors. (a) How much current is in that resistor? (b) How much current is in each of the other two resistors.



53. 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 use the same method you used to solve the previous problem, and show that the resistance of the hair dryer is 12 Ω.

54. The power of an electric circuit is given by the formula P = IV. Use Ohm's law to express V and show that power can be expressed by the equation $P = I^2R$.

55. A dehumidifier with a resistance of 20 Ω draws 6.0 A when connected to an electrical outlet. Show that the power consumed by the iron is 720 W.

56. An electric space heater dissipates 1320 W of power via electromagnetic radiation and convection when con nected to 120 V. When current is unknown, power can be expressed as P = V 2 R . Use this formula to show that the resistance of the space heater is about 11 Ω.

57. The total charge that an automobile battery can sup ply 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 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 go dead in about 10 h.

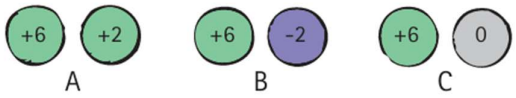
58. Show that it costs 7 cents to operate a 25-W porch light for 24 h if electric energy costs 12¢ per kW.h.

59. Suppose you operate a 100-W lamp continuously for 1 week when the power utility rate is 12¢/kW.h. Show that the cost is $2.02.

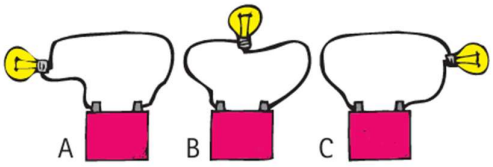
60. An electric dryer connected to a 120-V source draws 8.4 A of current. Show that the amount of heat generated in 1 min is about 60 kJ.

Think and rank

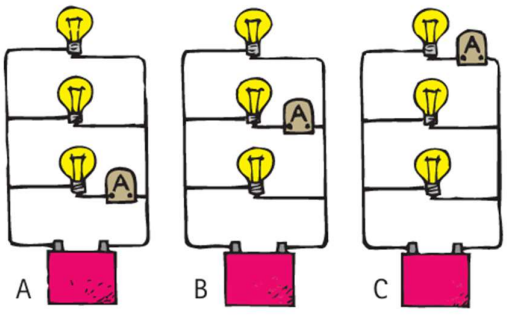
64. The three pairs of same-size metal spheres have different charges on their surfaces, as indicated. The members of each pair are brought together, allowed to touch, and then separated. Rank, from greatest to least, the total amount of charge on the pairs of spheres after separation.



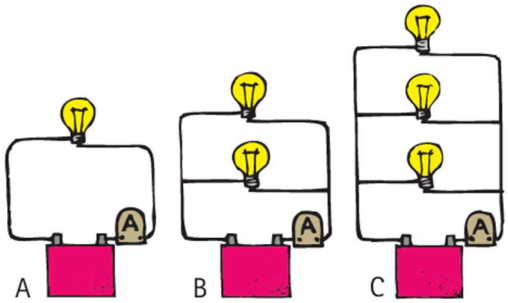
65. Rank, from brightest to dimmest, the identical bulbs in the following circuits.



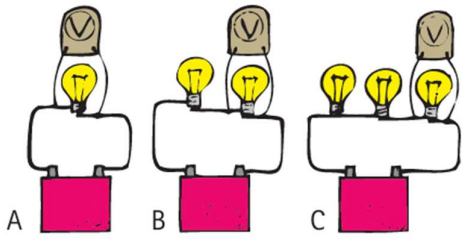
66. The bulbs are identical. Ammeters are placed in different locations, as shown. Rank, from greatest to least, the current readings in the three ammeters.



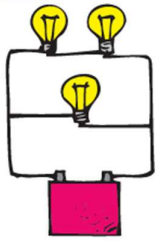
67. All bulbs are identical in the circuits. An ammeter is connected next to each battery, as shown. Rank, from greatest to least, the current readings in the three ammeters.



68. All bulbs are identical in the circuits. A voltmeter is connected across a single bulb in each circuit to measure the voltage drop across it, as shown. Rank, from greatest to least, the voltage readings in the three voltmeters.



69. Consider the three parts of the circuit. First rank, from greatest to least, the current through each part. Then rank, from greatest to least, the voltage across each part: (a) The top branch with two bulbs. (b) The lower branch with one bulb. (c) The battery.



Readiness Assurance Test (RAT)

1. When we say electric charge is conserved, we mean that it can
   (a) be saved, like money in a bank. (b) assume equivalent forms.
   (c) be neither created nor destroyed.
   (d) be either created or destroyed, but only in nuclear reactions.

2. When a pair of charged particles are brought twice as close to each other, the force between them becomes
   (a) twice as strong. (b) four times as strong.
   (c) half as strong. (d) one-quarter as strong.

3. An electric field surrounds all
   (a) electrons. (b) protons. (c) both of these (d) neither of these

4. Electric potential and electric potential energy are
   (a) one and the same in most cases.
   (b) two terms for the same concept.
   (c) both of these
   (d) neither of these

5. Which statement(s) is(are) correct?
   (a) Voltage flows in a circuit.
   (b) Charge flows in a circuit.
   (c) A battery is the source of electrons in a circuit.
   (d) All are correct.

6. When you double the voltage in a simple electric circuit, you double the
   (a) current. (b) resistance. (c) both of these (d) neither of these

7. When you double both the current and the voltage in a circuit, the power
   (a) remains unchanged if the resistance remains constant.
   (b) halves.
   (c) doubles.
   (d) quadruples.

8. In a simple circuit consisting of a single lamp and a single battery, when the current in the lamp is 2 amperes (A), the current in the battery is
   (a) 1 A.
   (b) 2 A.
   (c) dependent on internal battery resistance.
   (d) There is not enough information for us to say.

9. In a circuit with two lamps in parallel, if the current in one lamp is 2 amperes (A), the current in the battery is
   (a) 1 A.
   (b) 2 A.
   (c) more than 2 A.
   (d) There is not enough information for us to say.

10. What is the power rating of a lamp connected to a 12-V source when it carries 2.5 A?
   (a) 4.8 W (b) 14.5 W (c) 30 W (d) none of these