Chapter 20: ELECTRIC CURRENT, RESISTANCE, AND OHM’S LAW

# 20.1 CURRENT

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| 1. | *What is the current in milliamperes produced by the solar cells of a pocket calculator through which 4.00 C of charge passes in 4.00 h?* |
| Solution | Using the equation , we can calculate the current given in the charge and the time, remembering that |
| 2. | *A total of 600 C of charge passes through a flashlight in 0.500 h. What is the average current?* |
| Solution |  |
| 3. | *What is the current when a typical static charge of  moves from your finger to a metal doorknob in ?* |
| Solution |  |
| 4. | *Find the current when 2.00 nC jumps between your comb and hair over a  time interval.* |
| Solution |  |
| 5. | *A large lightning bolt had a 20,000-A current and moved 30.0 C of charge. What was its duration?* |
| Solution |  |
| 6. | *The 200-A current through a spark plug moves 0.300 mC of charge. How long does the spark last?* |
| Solution |  |
| 7. | *(a) A defibrillator sends a 6.00-A current through the chest of a patient by applying a 10,000-V potential as in Figure 20.38. What is the resistance of the path? (b) The defibrillator paddles make contact with the patient through a conducting gel that greatly reduces the path resistance. Discuss the difficulties that would ensue if a larger voltage were used to produce the same current through the patient, but with the path having perhaps 50 times the resistance. (Hint: The current must be about the same, so a higher voltage would imply greater power. Use this equation for power: .)* |
| Solution | (a) Using the equation , we can calculate the resistance of the path given the current and the potential: , so that  (b) If a 50 times larger resistance existed, keeping the current about the same, the power would be increased by a factor of about 50, causing much more energy to be transferred to the skin, which could cause serious burns. The gel used reduces the resistance, and therefore reduces the power transferred to the skin. |
| 8. | *During open-heart surgery, a defibrillator can be used to bring a patient out of cardiac arrest. The resistance of the path is  and a 10.0-mA current is needed. What voltage should be applied?* |
| Solution |  |
| 9. | *(a) A defibrillator passes 12.0 A of current through the torso of a person for 0.0100 s. How much charge moves? (b) How many electrons pass through the wires connected to the patient? (See Figure 20.38.)* |
| Solution | (a)  (b) |
| 10. | *A clock battery wears out after moving 10,000 C of charge through the clock at a rate of 0.500 mA. (a) How long did the clock run? (b) How many electrons per second flowed?* |
| Solution | (a)  (b) |
| 11. | *The batteries of a submerged non-nuclear submarine supply 1000 A at full speed ahead. How long does it take to move Avogadro’s number () of electrons at this rate?* |
| Solution |  |
| 12. | *Electron guns are used in X-ray tubes. The electrons are accelerated through a relatively large voltage and directed onto a metal target, producing X-rays. (a) How many electrons per second strike the target if the current is 0.500 mA? (b) What charge strikes the target in 0.750 s?* |
| Solution | (a)  (b) |
| 13. | *A large cyclotron directs a beam of  nuclei onto a target with a beam current of 0.250 mA. (a) How many  nuclei per second is this? (b) How long does it take for 1.00 C to strike the target? (c) How long before 1.00 mol of  nuclei strike the target?* |
| Solution | (a) Since we know that a  ion has a charge of twice the basic unit of charge:    (b) , so that  (c) |
| 14. | *Repeat Example 20.3, but for a wire made of silver and given there is one free electron per silver atom.* |
| Solution | The number of atoms in a kg mol is . Using the atomic mass of silver  and the density , the electron density in the wire is: |
| 15. | *Using the results of Example 20.3, find the drift velocity in a copper wire of twice the diameter and carrying 20.0 A.* |
| Solution |  |
| 16. | *A 14-gauge copper wire has a diameter of 1.628 mm. What magnitude current flows when the drift velocity is 1.00 mm/s? (See Example 20.3 for useful information.)* |
| Solution |  |
| 17. | *SPEAR, a storage ring about 72.0 m in diameter at the Stanford Linear Accelerator (closed in 2009), has a 20.0-A circulating beam of electrons that are moving at nearly the speed of light. (See Figure 20.39.) How many electrons are in the beam?* |
| Solution | First we calculate the circumference of the circular ring and use this value and the speed of light to determine , the time for the charge to complete one orbit around the ring.    Thus,  Let be the no. of electrons |
| 20.2 OHM’S LAW: RESISTANCE AND SIMPLE CIRCUITS | |
| 18. | *What current flows through the bulb of a 3.00-V flashlight when its hot resistance is ?* |
| Solution |  |
| 19. | *Calculate the effective resistance of a pocket calculator that has a 1.35-V battery and through which 0.200 mA flows.* |
| Solution |  |
| 20. | *What is the effective resistance of a car’s starter motor when 150 A flows through it as the car battery applies 11.0 V to the motor?* |
| Solution |  |
| 21. | *How many volts are supplied to operate an indicator light on a DVD player that has a resistance of , given that 25.0 mA passes through it?* |
| Solution |  |
| 22. | *(a) Find the voltage drop in an extension cord having a  resistance and through which 5.00 A is flowing. (b) A cheaper cord utilizes thinner wire and has a resistance of . What is the voltage drop in it when 5.00 A flows? (c) Why is the voltage to whatever appliance is being used reduced by this amount? What is the effect on the appliance?* |
| Solution | (a)  (b)  (c) The voltage supplied to whatever appliance is being used is reduced because the total voltage drop from the wall to the final output of the appliance is fixed. So, if the voltage drop across the extension cord is large, the voltage drop across the appliance is significantly decreased, so the power output by the appliance can be significantly decreased, reducing the ability of the appliance to work properly. |
| 23. | *A power transmission line is hung from metal towers with glass insulators having a resistance of . What current flows through the insulator if the voltage is 200 kV? (Some high-voltage lines are DC.)* |
| Solution |  |
| 20.3 RESISTANCE AND RESISTIVITY | |
| 24. | *What is the resistance of a 20.0-m-long piece of 12-gauge copper wire having a 2.053-mm diameter?* |
| Solution |  |
| 25. | *The diameter of 0-gauge copper wire is 8.252 mm. Find the resistance of a 1.00-km length of such wire used for power transmission.* |
| Solution | We know we want to use the equation , so we need to determine the radius for the cross-sectional area of. Since we know the diameter of the wire is 8.252 mm, we can determine the radius of the wire: . We also know from Table 20.1 that the resistivity of copper is . These values give a resistance of: |
| 26. | *If the 0.010-mm diameter tungsten filament in a light bulb is to have a resistance of  at* *, how long should it be?* |
| Solution |  |
| 27. | *Find the ratio of the diameter of aluminum to copper wire, if they have the same resistance per unit length (as they might in household wiring).* |
| Solution | so that . |
| 28. | *What current flows through a 2.54-cm-diameter rod of pure silicon that is 20.0 cm long, when  is applied to it? (Such a rod may be used to make nuclear-particle detectors, for example.)* |
| Solution |  |
| 29. | *(a) To what temperature must you raise a copper wire, originally at* *, to double its resistance, neglecting any changes in dimensions? (b) Does this happen in household wiring under ordinary circumstances?* |
| Solution | (a)  (b) No, under ordinary circumstances this temperature is unreachable in household wiring. The resistance is more likely to double because of a decrease in radius of the wire. |
| 30. | *A resistor made of Nichrome wire is used in an application where its resistance cannot change more than 1.00% from its value at* *. Over what temperature range can it be used?* |
| Solution | (Note:  expressed to two digits to avoid significant round-off errors.) |
| 31. | *Of what material is a resistor made if its resistance is 40.0% greater at*  *than at* *?* |
| Solution | Since    So, based on the values of in Table 20.2, the resistor is made of iron. |
| 32. | *An electronic device designed to operate at any temperature in the range from  contains pure carbon resistors. By what factor does their resistance increase over this range?* |
| Solution | )], so that |
| 33. | *(a) Of what material is a wire made, if it is 25.0 m long with a 0.100 mm diameter and has a resistance of  at* *? (b) What is its resistance at ?* |
| Solution | (a)  The wire is gold.  (b) |
| 34. | *Assuming a constant temperature coefficient of resistivity, what is the maximum percent decrease in the resistance of a constantan wire starting at* *?* |
| Solution | At absolute zero, , so that |
| 35. | *A wire is drawn through a die, stretching it to four times its original length. By what factor does its resistance increase?* |
| Solution |  |
| 36. | *A copper wire has a resistance of*  *at* *, and an iron wire has a resistance of*  *at the same temperature. At what temperature are their resistances equal?* |
| Solution |  |
| 37. | *(a) Digital medical thermometers determine temperature by measuring the resistance of a semiconductor device called a thermistor (which has* *) when it is at the same temperature as the patient. What is a patient’s temperature if the thermistor’s resistance at that temperature is 82.0% of its value at*  *(normal body temperature)? (b) The negative value for  may not be maintained for very low temperatures. Discuss why and whether this is the case here. (Hint: Resistance can’t become negative.)* |
| Solution | (a)  (b) If  is negative at low temperatures, then the term  can become negative, which implies that the resistance has the opposite sign of the initial resistance , or it has become negative. Since it is not possible to have a negative resistance, the temperature coefficient of resistivity cannot remain negative to low temperatures. In this example the magnitude is |
| 38. | ***Integrated Concepts*** *(a) Redo Example 20.6 taking into account the thermal expansion of the tungsten filament. You may assume a thermal expansion coefficient of* *. (b) By what percentage does your answer differ from that in the example?* |
| Solution | (a)  (from just thermal expansion effects), so that    (b) |
| 39. | ***Unreasonable Results*** *(a) To what temperature must you raise a resistor made of constantan to double its resistance, assuming a constant temperature coefficient of resistivity? (b) To cut it in half? (c) What is unreasonable about these results? (d) Which assumptions are unreasonable, or which premises are inconsistent?* |
| Solution | (a) Using the equation  and setting the resistance equal to twice the initial resistance, we can solve for the final temperature:    So the final temperature will be:  (b) Again, using the equation , we can solve for the final temperature when the resistance is half the initial resistance: , so the final temperature will be:  (c) In part (a), the temperature is above the melting point of any metal. In part (b) the temperature is far below , which is impossible.  (d) The assumption that the resistivity for constantan will remain constant over the derived temperature ranges in part (a) and (b) above is wrong. For large temperature changes,  may vary, or a non-linear equation may be needed to find . |
| 20.4 ELECTRIC POWER AND ENERGY | |
| 40. | *What is the power of a  lightning bolt having a current of ?* |
| Solution |  |
| 41. | *What power is supplied to the starter motor of a large truck that draws 250 A of current from a 24.0-V battery hookup?* |
| Solution |  |
| 42. | *A charge of 4.00 C passes through a pocket calculator’s solar cells in 4.00 h. What is the power output, given the calculator’s voltage output is 3.00 V? (See Figure 20.40.)* |
| Solution | From Exercise 20.1, Thus, |
| 43. | *How many watts does a flashlight that has  pass through it in 0.500 h use if its voltage is 3.00 V?* |
| Solution | From Exercise 20.2, . Thus, |
| 44. | *Find the power dissipated in each of these extension cords: (a) an extension cord having a*  *resistance and through which 5.00 A is flowing; (b) a cheaper cord utilizing thinner wire and with a resistance of* *.* |
| Solution | Using values from Exercise 20.22,  (a)  (b) |
| 45. | *Verify that the units of a volt-ampere are watts, as implied by the equation .* |
| Solution | Starting with the equation , we can get an expression for a watt in terms of current and voltage: , , so that a watt is equal to an ampere-volt. |
| 46. | *Show that the units , as implied by the equation .* |
| Solution |  |
| 47. | *Show that the units , as implied by the equation .* |
| Solution |  |
| 48. | *Verify the energy unit equivalence that .* |
| Solution |  |
| 49. | *Electrons in an X-ray tube are accelerated through  and directed toward a target to produce X-rays. Calculate the power of the electron beam in this tube if it has a current of 15.0 mA.* |
| Solution |  |
| 50. | *An electric water heater consumes 5.00 kW for 2.00 h per day. What is the cost of running it for one year if electricity costs ? See Figure 20.41.* |
| Solution |  |
| 51. | *With a 1200-W toaster, how much electrical energy is needed to make a slice of toast (cooking time = 1 minute)? At , how much does this cost?* |
| Solution |  |
| 52. | *What would be the maximum cost of a CFL such that the total cost (investment plus operating) would be the same for both CFL and incandescent 60-W bulbs? Assume the cost of the incandescent bulb is 25 cents and that electricity costs . Calculate the cost for 1000 hours, as in the cost effectiveness of CFL example.* |
| Solution | Energy consumption by an incandescent bulb in 1000 hrs is  Cost of electricity is ; the total cost for the incandescent bulb is then $0.25+$6.00 = $6.25. This is the maximum cost for the CFL. |
| 53. | *Some makes of older cars have 6.00-V electrical systems. (a) What is the hot resistance of a 30.0-W headlight in such a car? (b) What current flows through it?* |
| Solution | (a)  (b) |
| 54. | *Alkaline batteries have the advantage of putting out constant voltage until very nearly the end of their life. How long will an alkaline battery rated at  and 1.58 V keep a 1.00-W flashlight bulb burning?* |
| Solution | The total energy output of the battery is  or. So at  it can last |
| 55. | *A cauterizer, used to stop bleeding in surgery, puts out 2.00 mA at 15.0 kV. (a) What is its power output? (b) What is the resistance of the path?* |
| Solution | (a)  (b)  Note: this assumes the cauterizer obeys Ohm’s law, which will be true for ohmic materials like good conductors. |
| 56. | *The average television is said to be on 6 hours per day. Estimate the yearly cost of electricity to operate 100 million TVs, assuming their power consumption averages 150 W and the cost of electricity averages .* |
| Solution |  |
| 57. | *An old lightbulb draws only 50.0 W, rather than its original 60.0 W, due to evaporative thinning of its filament. By what factor is its diameter reduced, assuming uniform thinning along its length? Neglect any effects caused by temperature differences.* |
| Solution | ; therefore,    Thus, there is a 91.3% reduction in the diameter of the filament. |
| 58. | *00-gauge copper wire has a diameter of 9.266 mm. Calculate the power loss in a kilometer of such wire when it carries .* |
| Solution | so that |
| 59. | ***Integrated Concepts*** *Cold vaporizers pass a current through water, evaporating it with only a small increase in temperature. One such home device is rated at 3.50 A and utilizes 120 V AC with 95.0% efficiency. (a) What is the vaporization rate in grams per minute? (b) How much water must you put into the vaporizer for 8.00 h of overnight operation? (See Figure 20.42.)* |
| Solution | (a)  and since the vaporizer has an efficiency of 95.0%, the heat that is capable of vaporizing the water is .  This heat vaporizes the water according to the equation , where , from Table 14.2, so that , or    (b) If the vaporizer is to run for 8.00 hours, we need to calculate the mass of the water by converting units:    In other words, it requires  of water to run overnight. |
| 60. | ***Integrated Concepts*** *(a) What energy is dissipated by a lightning bolt having a 20,000-A current, a voltage of , and a length of 1.00 ms? (b) What mass of tree sap could be raised from*  *to its boiling point and then evaporated by this energy, assuming sap has the same thermal characteristics as water?* |
| Solution | (a)  (b) |
| 61. | ***Integrated Concepts*** *What current must be produced by a 12.0-V battery-operated bottle warmer in order to heat 75.0 g of glass, 250 g of baby formula, and  of aluminum from*  *to*  *in 5.00 min?* |
| Solution | , where  is heat and  is the change in temperature. Assume the specific heat of baby formula is equal to that of water. Then |
| 62. | ***Integrated Concepts*** *How much time is needed for a surgical cauterizer to raise the temperature of 1.00 g of tissue from*  *to*  *and then boil away 0.500 g of water, if it puts out 2.00 mA at 15.0 kV? Ignore heat transfer to the surroundings.* |
| Solution |  |
| 63. | ***Integrated Concepts*** *Hydroelectric generators (see Figure 20.43) at Hoover Dam produce a maximum current of  at 250 kV. (a) What is the power output? (b) The water that powers the generators enters and leaves the system at low speed (thus its kinetic energy does not change) but loses 160 m in altitude. How many cubic meters per second are needed, assuming 85.0% efficiency?* |
| Solution | (a)  (b)  For  efficiency , we divide the value for  by |
| 64. | ***Integrated Concepts*** *(a) Assuming 95.0% efficiency for the conversion of electrical power by the motor, what current must the 12.0-V batteries of a 750-kg electric car be able to supply: (a) To accelerate from rest to 25.0 m/s in 1.00 min? (b) To climb a -m-high hill in 2.00 min at a constant 25.0-m/s speed while exerting  of force to overcome air resistance and friction? (c) To travel at a constant 25.0-m/s speed, exerting a  force to overcome air resistance and friction? See Figure 20.44.* |
| Solution | (a)  (b)  (c) Take a time interval of 1 s |
| 65. | ***Integrated Concepts*** *A light-rail commuter train draws 630 A of 650-V DC electricity when accelerating. (a) What is its power consumption rate in kilowatts? (b) How long does it take to reach 20.0 m/s starting from rest if its loaded mass is , assuming 95.0% efficiency and constant power? (c) Find its average acceleration. (d) Discuss how the acceleration you found for the light-rail train compares to what might be typical for an automobile.* |
| Solution | (a)  (b) Since the efficiency is , the effective power is: . Then,  Set that equal to the change in kinetic energy, , so that    (c) , so that  (d) A typical automobile can go from 0 to 60 mph in 10 seconds, so that its acceleration is:  Thus, a light-rail train accelerates much slower than a car, but it can reach final speeds substantially faster than a car can sustain. Typically, light-rail tracks are very long and straight, to allow them to reach these faster final speeds without decelerating around sharp turns. |
| 66. | ***Integrated Concepts*** *(a) An aluminum power transmission line has a resistance of . What is its mass per kilometer? (b) What is the mass per kilometer of a copper line having the same resistance? A lower resistance would shorten the heating time. Discuss the practical limits to speeding the heating by lowering the resistance.* |
| Solution | (a) Let  be the resistivity of the transmission line, and  be the density of the transmission line.    Now let  be the mass of the transmission line, and be the volume of the transmission line.    (b) |
| 67. | ***Integrated Concepts*** *(a) An immersion heater utilizing 120 V can raise the temperature of a -g aluminum cup containing 350 g of water from*  *to*  *in 2.00 min. Find its resistance, assuming it is constant during the process. (b) A lower resistance would shorten the heating time. Discuss the practical limits to speeding the heating by lowering the resistance.* |
| Solution | (a)  (b) The resistance of the heater must be substantially larger than the resistance of the wires carrying the current to the heater. For instance, if the immersion heater was connected to an extension cord, as discussed in Exercise 20.22(b), the resistance of the cord is approximately 2% of the resistance of the heater. Heat will be dissipated through the extension cord and, if large enough, could lead to a fire hazard. |
| 68. | ***Integrated Concepts*** *(a) What is the cost of heating a hot tub containing 1500 kg of water from*  *to* *, assuming 75.0% efficiency to account for heat transfer to the surroundings? The cost of electricity is* 9 cents/kW·h*. (b) What current was used by the 220-V AC electric heater, if this took 4.00 h?* |
| Solution | (a)  (b) , where , so that |
| 69. | ***Unreasonable Results*** *(a) What current is needed to transmit  of power at 480 V? (b) What power is dissipated by the transmission lines if they have a  resistance? (c) What is unreasonable about this result? (d) Which assumptions are unreasonable, or which premises are inconsistent?* |
| Solution | (a)  (b)  (c) The power dissipated is greater than the power transmitted.  (d) The voltage is too low for transmission of power of this magnitude along the transmission line. |
| 70. | ***Unreasonable Results*** *(a) What current is needed to transmit  of power at 10.0 kV? (b) Find the resistance of 1.00 km of wire that would cause a 0.0100% power loss. (c) What is the diameter of a 1.00-km-long copper wire having this resistance? (d) What is unreasonable about these results? (e) Which assumptions are unreasonable, or which premises are inconsistent?* |
| Solution | (a)  (b)  (c)  (d) This is an unreasonably thick “wire.”  (e) The assumption of such a small power loss is unreasonable, and the voltage should be much higher so that a lower current can carry the power. |
| 20.5 Alternating Current versus Direct Current | |
| 72. | *(a) What is the hot resistance of a 25-W light bulb that runs on 120-V AC? (b) If the bulb’s operating temperature is , what is its resistance at* *?* |
| Solution | (a)  (b)  Where  is the temperature coefficient of resistivity for tungsten. |
| 73. | *Certain heavy industrial equipment uses AC power that has a peak voltage of 679 V. What is the rms voltage?* | |
| Solution |  | |
| 74. | *A certain circuit breaker trips when the rms current is 15.0 A. What is the corresponding peak current?* | |
| Solution |  | |
| 75. | *Military aircraft use 400-Hz AC power, because it is possible to design lighter-weight equipment at this higher frequency. What is the time for one complete cycle of this power?* | |
| Solution |  | | |
| 76. | *A North American tourist takes his 25.0-W, 120-V AC razor to Europe, finds a special adapter, and plugs it into 240 V AC. Assuming constant resistance, what power does the razor consume as it is ruined?* | |
| Solution |  | |
| 77. | *In this problem, you will verify statements made at the end of the power losses for Example 20.10. (a) What current is needed to transmit 100 MW of power at a voltage of 25.0 kV? (b) Find the power loss in a*  *transmission line. (c) What percent loss does this represent?* | |
| Solution | (a)  (b)  (c) | |
| 78. | *A small office-building air conditioner operates on 408-V AC and consumes 50.0 kW. (a) What is its effective resistance? (b) What is the cost of running the air conditioner during a hot summer month when it is on 8.00 h per day for 30 days and electricity costs ?* | |
| Solution | (a)  (b) |
| 79. | *What is the peak power consumption of a 120-V AC microwave oven that draws 10.0 A?* |
| Solution |  |
| 80. | *What is the peak current through a 500-W room heater that operates on 120-V AC power?* |
| Solution |  |
| 81. | *Two different electrical devices have the same power consumption, but one is meant to be operated on 120-V AC and the other on 240-V AC. (a) What is the ratio of their resistances? (b) What is the ratio of their currents? (c) Assuming its resistance is unaffected, by what factor will the power increase if a 120-V AC device is connected to 240-V AC?* |
| Solution | (a)  (b)  (c) |
| 82. | *Nichrome wire is used in some radiative heaters. (a) Find the resistance needed if the average power output is to be 1.00 kW utilizing 120-V AC. (b) What length of Nichrome wire, having a cross-sectional area of , is needed if the operating temperature is* *? (c) What power will it draw when first switched on?* |
| Solution | (a)  (b)  (c) |
| 83. | *Find the time after*  *when the instantaneous voltage of 60-Hz AC first reaches the following values: (a)  (b)  (c) 0.* |
| Solution | (a) From the equation , we know how the voltage changes with time for an alternating current (AC). If we want the voltage to be equal to , we know that , so that: , or  Since we have a frequency of 60 Hz, we can solve for the time that this first occurs (remembering to have your calculator in radians!):  (b) Similarly, for, so that  (c) Finally, for , so that  or for the first time after |
| 84. | *(a) At what two times in the first period following*  *does the instantaneous voltage in 60-Hz AC equal ? (b) ?* |
| Solution | (a)  (b) |
| 20.6 ELECTRIC HAZARDS AND THE HUMAN BODY | |
| 85. | *(a) How much power is dissipated in a short circuit of 240-V AC through a resistance of ? (b) What current flows?* |
| Solution | (a)  (b) |
| 86. | *What voltage is involved in a 1.44-kW short circuit through a  resistance?* |
| Solution |  |
| 87. | *Find the current through a person and identify the likely effect on her if she touches a 120-V AC source: (a) if she is standing on a rubber mat and offers a total resistance of ; (b) if she is standing barefoot on wet grass and has a resistance of only  .* |
| Solution | (a)  This is a small current and will have no effect, since it is below the threshold of sensation.  (b)  Such a current will cause a muscular contraction for the duration of the shock. |
| 88. | *While taking a bath, a person touches the metal case of a radio. The path through the person to the drainpipe and ground has a resistance of* *. What is the smallest voltage on the case of the radio that could cause ventricular fibrillation?* |
| Solution | Ventricular fibrillation can initiate at  (Table 20.3). Thus, a voltage of  could cause ventricular fibrillation. |
| 89. | *Foolishly trying to fish a burning piece of bread from a toaster with a metal butter knife, a man comes into contact with 120-V AC. He does not even feel it since, luckily, he is wearing rubber-soled shoes. What is the minimum resistance of the path the current follows through the person?* |
| Solution | From Table 20.3, we know that the threshold of sensation is . So, since |
| 90. | *(a) During surgery, a current as small as  applied directly to the heart may cause ventricular fibrillation. If the resistance of the exposed heart is , what is the smallest voltage that poses this danger? (b) Does your answer imply that special electrical safety precautions are needed?* |
| Solution | (a)  (b) It would not be necessary to take extra precautions regarding the power coming from the wall. However, it is possible to generate voltages of approximately this value from static charge built up on gloves, for instance, so some precautions are necessary. |
| 91. | *(a) What is the resistance of a 220-V AC short circuit that generates a peak power of 96.8 kW? (b) What would the average power be if the voltage was 120 V AC?* |
| Solution | (a)  (b) |
| 92. | *A heart defibrillator passes 10.0 A through a patient’s torso for 5.00 ms in an attempt to restore normal beating. (a) How much charge passed? (b) What voltage was applied if 500 J of energy was dissipated? (c) What was the path’s resistance? (d) Find the temperature increase caused in the 8.00 kg of affected tissue.* |
| Solution | (a)  (b)  (c)  (d) |
| 93. | ***Integrated Concepts*** *A short circuit in a 120-V appliance cord has a*  *resistance. Calculate the temperature rise of the 2.00 g of surrounding materials, assuming their specific heat capacity is  and that it takes 0.0500 s for a circuit breaker to interrupt the current. Is this likely to be damaging?* |
| Solution | Yes, this would be damaging, as it would likely raise the temperature to above the melting point, or ignition of the materials. |
| 20.7 nerve conduction–electrocardiograms | |
| 95. | ***Integrated Concepts*** *Use the ECG in Figure 20.34 to determine the heart rate in beats per minute assuming a constant time between beats.* |
| Solution | The time from diastolic to diastolic on the upper graph is 0.75 s, so the heart rate is: |
| 96. | ***Integrated Concepts*** *(a) Referring to Figure 20.34, find the time systolic pressure lags behind the middle of the QRS complex. (b) Discuss the reasons for the time lag.* |
| Solution | (a) The lag is approximately , or  of a heart cycle.  (b) The QRS complex is created by the depolarization of the ventricles, which causes it to contract. With this contraction comes a decrease in pressure, leading to the diastolic pressure. After contraction the heart is repolarized, raising the pressure to its maximum (systolic) value, readying the heart for its next beat. The fact that the maximum pressure is approximately 1/3 of a heart cycle after the QRS complex says that during 2/3 of the cycle the heart is doing work; during the last 1/3 it is resetting to start again. |

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| 1. | *Which of the following can be explained on the basis of conservation of charge in a closed circuit consisting of a battery, resistor, and metal wires?*   1. The number of electrons leaving the battery will be equal to the number of electrons entering the battery. 2. The number of electrons leaving the battery will be less than the number of electrons entering the battery. 3. The number of protons leaving the battery will be equal to the number of protons entering the battery. 4. The number of protons leaving the battery will be less than the number of protons entering the battery. |
| Solution | (a) |
| 2. | *When a battery is connected to a bulb, there is 2.5 A of current in the circuit. What amount of charge will flow though the circuit in a time of 0.5 s?*   1. 0.5 C 2. 1 C 3. 1.25 C 4. 1.5 C |
| Solution | (c) |
| 3. | *If 0.625 × 1020 electrons flow through a circuit each second, what is the current in the circuit?* |
| Solution | 10 A |
| 4. | *Two students calculate the charge flowing through a circuit. The first student concludes that 300 C of charge flows in 1 minute. The second student concludes that 3.125 × 1019 electrons flow per second. If the current measured in the circuit is 5 A, which of the two students (if any) have performed the calculations correctly?* |
| Solution | Both students are correct. |
| 5. | *If the voltage across a fixed resistance is doubled, what happens to the current?*   1. It doubles. 2. It halves. 3. It stays the same. 4. The current cannot be determined. |
| Solution | (a) |
| 6. | *The table below gives the voltages and currents recorded across a resistor.*  [Table 20\_02\_01]   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | Voltage (V) | 2.50 | 5.00 | 7.50 | 10.00 | 12.50 | | Current (A) | 0.69 | 1.38 | 2.09 | 2.76 | 3.49 |  * 1. *Plot the graph and comment on the shape.*   2. *Calculate the value of the resistor.* |
| Solution | a) the shape is linear because of Ohm’s law, b) 3.6 Ω |
| 7. | *What is the resistance of a bulb if the current in it is 1.25 A when a 4 V voltage supply is connected to it? If the voltage supply is increased to 7 V, what will be the current in the bulb?* |
| Solution | 3.2 Ω, 2.19 A |
| 8. | *Which of the following affect the resistivity of a wire?*   1. length 2. area of cross section 3. material 4. all of the above |
| Solution | (c) |
| 9. | *The lengths and diameters of four wires are given below:*    [Figure\_Ch20\_S03]  *If the four wires are made from the same material, which of the following is true? Select two answers.*   1. Resistance of Wire 3 > Resistance of Wire 2 2. Resistance of Wire 1 > Resistance of Wire 2 3. Resistance of Wire 1 < Resistance of Wire 4 4. Resistance of Wire 4 < Resistance of Wire 3 |
| Solution | (b), (d) |
| 10. | *Suppose the resistance of a wire is R Ω. What will be the resistance of another wire of the same material having the same length but double the diameter?*   1. *R*/2 2. 2*R* 3. *R*/4 4. 4*R* |
| Solution | (c) |
| 11. | *The resistances of two wires having the same lengths and cross section areas are 3 Ω and 11 Ω. If the resistivity of the 3 Ω wire is 2.65 × 10−8 Ω∙m, find the resistivity of the 1Ω wire.* |
| Solution | 9.72 × 10−8 Ω∙m |
| 12. | *The lengths and diameters of three wires are given below. If they all have the same resistance, find the ratio of their resistivities.*  [Table 20\_03\_01]   |  |  |  | | --- | --- | --- | | *Wire* | *Length* | *Diameter* | | Wire 1 | 2 m | 1 cm | | Wire 2 | 1 m | 0.5 cm | | Wire 3 | 1 m | 1 cm | |
| Solution | 2:1:4 |
| 13. | *Suppose the resistance of a wire is 2 Ω. If the wire is stretched to three times its length, what will be its resistance? Assume that the volume does not change.* |
| Solution | 18 Ω |
| 14. | [Figure\_Ch20\_S05]  *The circuit shown above contains a resistor R connected to a voltage supply. The graph shows the total energy E dissipated by the resistance as a function of time. Which of the following shows the corresponding graph for double resistance, i.e. if R is replaced by 2R?*        [Figure\_Ch20\_S06] |
| Solution | (c) |
| 15. | *What will be the ratio of the resistance of a 120 W, 220 V lamp to that of a 100 W, 110 V lamp?* |
| Solution | 10:3 or 3.33 |

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