Thermodynamics II

_____ 1. Of the following systems, which contains the most heat?
   a. 100 kg of water at 80°C  
   b. 250 kg of water at 40°C  
   c. 600 kg of ice at 0°C  
   d. Systems do not contain heat.

_____ 2. Carly places one end of a steel bar in a Bunsen flame and the other end in an ice cube. By what factor is the rate of heat flow changed when the bar's cross-sectional area is doubled?
   a. 2  
   b. 1/2  
   c. 4.0  
   d. 1/4

_____ 3. Dmitri places one end of a copper rod in a heat reservoir and the other end in a heat sink. By what factor is the rate of heat flow changed when the temperature difference between the reservoir and sink is tripled?
   a. 0.33  
   b. 1/9  
   c. 3.0  
   d. 9.0

_____ 4. The emissivity of an ideal reflector has which of the following values?
   a. 0  
   b. 1  
   c. 100  
   d. infinity

_____ 5. A 2.0-mol ideal gas system is maintained at a constant volume of 4.0 L. If 100 J of heat is added, what is the work done on the system?
   a. zero  
   b. 5.0 J  
   c. −6.7 J  
   d. 20 J

_____ 6. A closed 2.0-L container holds 3.0 mol of an ideal gas. If 200 J of heat is added, what is the change in internal energy of the system?
   a. zero  
   b. 100 J  
   c. 150 J  
   d. 200 J

_____ 7. A thermodynamic process that happens very quickly tends to be:
   a. isobaric.  
   b. isothermal.  
   c. isovolumetric.  
   d. adiabatic.

_____ 8. A 10-kg piece of aluminum (which has a specific heat of 900 J/kg·°C) is warmed so that its temperature increases by 5.0 °C. How much heat was transferred into it?
   a. 4.5 × 10^4 J  
   b. 9.0 × 10^4 J  
   c. 1.4 × 10^5 J  
   d. 2.0 × 10^5 J

_____ 9. Marc attaches a falling 500-kg object with a rope through a pulley to a paddle wheel shaft. He places the system in a well-insulated tank holding 25 kg of water. When the object falls, it causes the paddle wheel to rotate and churn the water. If the object falls a vertical distance of 100 m at constant speed, what is the temperature change of the water? (1 kcal = 4 186 J, the specific heat of water is 4 186 J/kg·°C, and g = 9.8 m/s^2)
   a. 19 600 C°  
   b. 4 700 C°  
   c. 4.7 C°  
   d. 0.8 C°
10. An inventor develops a stationary cycling device by which an individual, while pedaling, can convert all of the energy expended into heat for warming water. How much mechanical energy is required to increase the temperature of 300 g of water (enough for 1 cup of coffee) from 20°C to 95°C? (1 cal = 4.186 J, the specific heat of water is 4186 J/kg°C)
   a. 94 000 J  
   b. 22 000 J  
   c. 5 400 J  
   d. 14 J

11. An inventor develops a stationary cycling device by which an individual, while pedaling, can convert all of the energy expended into heat for warming water. What minimum power must be generated if 300 g water (enough for 1 cup of coffee) is to be heated in 10 min from 20°C to 95°C? (1 cal = 4.186 J, the specific heat of water is 4186 J/kg°C)
   a. 9 400 W  
   b. 590 W  
   c. 160 W  
   d. 31 W

12. A swimming pool heater has to be able to raise the temperature of the 40 000 gallons of water in the pool by 10.0°C. How many kilowatt-hours of energy are required? (One gallon of water has a mass of approximately 3.8 kg and the specific heat of water is 4186 J/kg°C.)
   a. 1 960 kWh  
   b. 1 770 kWh  
   c. 330 kWh  
   d. 216 kWh

13. A solar heated house loses about 5.4 \times 10^7 cal through its outer surfaces on a typical 24-h winter day. What mass of storage rock is needed to provide this amount of heat if it is brought up to initial temperature of 62°C by the solar collectors and the house is maintained at 20°C? (Specific heat of rock is 0.21 cal/g°C.)
   a. 163 kg  
   b. 1 230 kg  
   c. 6 100 kg  
   d. 12 700 kg

14. A waterfall is 145 m high. What is the increase in water temperature at the bottom of the falls if all the initial potential energy goes into heating the water? (g = 9.8 m/s², c_w = 4186 J/kg°C)
   a. 0.16°C  
   b. 0.34°C  
   c. 0.69°C  
   d. 1.04°C

15. What is the temperature increase of 4.0 kg of water when heated by an 800-W immersion heater for 10 min? (c_w = 4186 J/kg°C)
   a. 56°C  
   b. 51°C  
   c. 29°C  
   d. 14°C

16. A solar heating system has a 25.0% conversion efficiency; the solar radiation incident on the panels is 1 000 W/m². What is the increase in temperature of 30.0 kg of water in a 1.00-h period by a 4.00-m²-area collector? (c_w = 4186 J/kg°C)
   a. 14.3°C  
   b. 22.4°C  
   c. 28.7°C  
   d. 44.3°C

17. If a 1000-kg car was moving at 30 m/s, what would be its kinetic energy expressed in the unusual (for kinetic energy) units of calories? (1 cal = 4.186 J)
   a. 3.0 \times 10^4  
   b. 9.0 \times 10^5  
   c. 3.8 \times 10^6  
   d. 1.1 \times 10^5
18. A piece of copper of mass 100 g is being drilled through with a \( \frac{1}{2}'' \) electric drill. The drill operates at 40.0 W and takes 30.0 s to bore through the copper. If all the energy from the drill heats the copper, find the copper's increase in temperature. \( c_{\text{copper}} = 387 \text{ J/kg} \cdot ^\circ \text{C} \).

a. 40.6 \(^\circ\)C  

b. 34.7 \(^\circ\)C 

c. 31.0 \(^\circ\)C  

d. 27.3 \(^\circ\)C

19. A slice of bread contains about 100 kcal. If specific heat of a person were 1.00 kcal/kg \( \cdot ^\circ \)C, by how many \(^\circ\)C would the temperature of a 70.0-kg person increase if all the energy in the bread were converted to heat?

a. 2.25 \(^\circ\)C  

b. 1.86 \(^\circ\)C  

c. 1.43 \(^\circ\)C  

d. 1.00 \(^\circ\)C

20. A 120-g block of copper is taken from a kiln and quickly placed into a beaker of negligible heat capacity containing 300 g of water. The water temperature rises from 15 \(^\circ\)C to 35 \(^\circ\)C. Given \( c_{\text{Cu}} = 0.10 \text{ cal/g} \cdot ^\circ \text{C} \), and \( c_{\text{water}} = 1.00 \text{ cal/g} \cdot ^\circ \text{C} \), what was the temperature of the kiln?

a. 500 \(^\circ\)C  

b. 360 \(^\circ\)C  

c. 720 \(^\circ\)C  

d. 535 \(^\circ\)C

21. Find the final equilibrium temperature when 10.0 g of milk at 10.0 \(^\circ\)C is added to 160 g of coffee at 90.0 \(^\circ\)C. (Assume the specific heats of coffee and milk are the same as water and neglect the heat capacity of the container.) \( c_{\text{water}} = 1.00 \text{ cal/g} \cdot ^\circ \text{C} = 4186 \text{ J/kg} \cdot ^\circ \text{C} \)

a. 85.3 \(^\circ\)C  

b. 77.7 \(^\circ\)C  

c. 71.4 \(^\circ\)C  

d. 66.7 \(^\circ\)C

22. A 0.003 0-kg lead bullet is traveling at a speed of 240 m/s when it embeds in a block of ice at 0 \(^\circ\)C. If all the heat generated goes into melting ice, what quantity of ice is melted? (\( L_f = 80 \text{ kcal/kg} \), the specific heat of lead = 0.03 kcal/kg \( \cdot ^\circ \)C, and 1 kcal = 4 186 J)

a. \( 1.47 \times 10^{-2} \text{ kg} \)  

b. \( 5.8 \times 10^{-4} \text{ kg} \)  

c. \( 3.2 \times 10^{-3} \text{ kg} \)  

d. \( 2.6 \times 10^{-4} \text{ kg} \)

23. A puddle holds 150 g of water. If 0.50 g of water evaporates from the surface, what is the approximate temperature change of the remaining water? (\( L_v = 540 \text{ cal/g} \))

a. +1.8 \(^\circ\)C  

b. −1.8 \(^\circ\)C  

c. +0.18 \(^\circ\)C  

d. −0.18 \(^\circ\)C

24. Iced tea is made by adding ice to 1.8 kg of hot tea, initially at 80\(^\circ\)C. How many kg of ice, initially at 0\(^\circ\)C, are required to bring the mixture to 10\(^\circ\)C? (\( L_f = 3.33 \times 10^5 \text{ J/kg}, c_w = 4 \text{ 186 J/kg} \cdot ^\circ \text{C} \))

a. 1.8 kg  

b. 1.6 kg  

c. 1.4 kg  

d. 1.2 kg

25. How much heat energy is required to vaporize a 1.0-g ice cube at 0\(^\circ\)C? The heat of fusion of ice is 80 cal/g. The heat of vaporization of water is 540 cal/g, and \( c_{\text{water}} = 1.00 \text{ cal/g} \cdot ^\circ \text{C} \).

a. 620 cal  

b. 720 cal  

c. 820 cal  

d. 1 kcal

26. How much heat energy must be removed from 100 g of oxygen at 22\(^\circ\)C to liquefy it at −183\(^\circ\)C? (The specific heat of oxygen gas is 0.218 cal/g \( \cdot ^\circ \)C, and its heat of vaporization is 50.9 cal/g.)

a. 13 700 cal  

b. 9 560 cal  

c. 4 320 cal  

d. 2 160 cal
27. A windowpane is half a centimeter thick and has an area of 1.0 m². The temperature difference between the inside and outside surfaces of the pane is 15 °C. What is the rate of heat flow through this window? (Thermal conductivity for glass is 0.84 J/s·m·°C.)
   a. 50 000 J/s       c. 1 300 J/s
   b. 2 500 J/s       d. 630 J/s

28. The filament temperature of a light bulb is 2 000 K when the bulb delivers 40 W of power. If its emissivity remains constant, what power is delivered when the filament temperature is 2 500 K?
   a. 105 W       c. 98 W
   b. 62 W       d. 50 W

29. The thermal conductivity of aluminum is 238 J/s·m·°C and of copper is 397 J/s·m·°C. A rod of each material is used as a heat conductor. If the rods have the same geometry and are used between the same temperature differences for the same time interval, what is the ratio of the heat transferred by the aluminum to the heat transferred by the copper?
   a. 0.599       c. 0.359
   b. 1.67       d. 2.78

30. At high noon, the sun delivers 1 000 W to each square meter of a blacktop road. What is the equilibrium temperature of the hot asphalt, assuming its emissivity $e = 1$? ($\sigma = 5.67 \times 10^{-8}$ W/m²·K⁴).
   a. 75°C       c. 91°C
   b. 84°C       d. 99°C

31. The surface of the Sun has a temperature of about 5 800 K. If the radius of the Sun is $7 \times 10^8$ m, determine the power output of the sun. (Take $e = 1$, and $\sigma = 5.67 \times 10^{-8}$ W/m²·K⁴).
   a. $3.95 \times 10^{26}$ W       c. $9.62 \times 10^{28}$ W
   b. $5.17 \times 10^{27}$ W       d. $6.96 \times 10^{30}$ W

32. The tungsten filament of a light bulb has an operating temperature of about 2 100 K. If the emitting area of the filament is 1.0 cm², and its emissivity is 0.68, what is the power output of the light bulb? ($\sigma = 5.67 \times 10^{-8}$ W/m²·K⁴)
   a. 100 W       c. 60 W
   b. 75 W       d. 40 W

33. An object at 27°C has its temperature increased to 37°C. The power then radiated by this object increases by how many percent?
   a. 3.3       c. 37
   b. 14       d. 253

34. What temperature increase is necessary to increase the power radiated from an object by a factor of 8?
   a. 8 K       c. 100%
   b. 2 K       d. about 68%

35. A metal bar is used to conduct heat. When the temperature at one end is 100°C and at the other is 20°C, heat is transferred at a rate of 16 J/s. If the temperature of the hotter end is reduced to 80°C, what will be the rate of heat transfer?
   a. 4 J/s       c. 9 J/s
   b. 8 J/s       d. 12 J/s
36. A metal bar is used to conduct heat. When the temperature at one end is 100°C and at the other is 20°C, heat is transferred at a rate of 16 J/s. The bar is then stretched uniformly to twice its original length. If again it has ends at 100°C and 20°C, at what rate will heat be transferred between it ends?
   a. 4 J/s  c. 16 J/s
   b. 8 J/s  d. 32 J/s

37. The volume of an ideal gas changes from 0.40 to 0.55 m³ although its pressure remains constant at 50 000 Pa. What work is done on the system by its environment?
   a. −7 500 J  c. 7 500 J
   b. −200 000 J  d. 200 000 J

38. In an isobaric process $4.5 \times 10^4$ J of work is done on a quantity of gas while its volume changes from 2.6 m³ to 1.1 m³. What is the pressure during this process?
   a. $1.2 \times 10^4$ Pa  c. $3.0 \times 10^4$ Pa
   b. $2.4 \times 10^4$ Pa  d. $4.1 \times 10^4$ Pa

39. A system is acted on by its surroundings in such a way that it receives 50 J of heat while simultaneously doing 20 J of work. What is its net change in internal energy?
   a. 70 J  c. zero
   b. 30 J  d. −30 J

40. A 4-mol ideal gas system undergoes an adiabatic process where it expands and does 20 J of work on its environment. What is its change in internal energy?
   a. −20 J  c. zero
   b. −5 J  d. +20 J

41. A quantity of monatomic ideal gas expands adiabatically from a volume of 2.0 liters to 6.0 liters. If the initial pressure is $P_0$, what is the final pressure?
   a. $9.0 \times P_0$  c. $3.0 \times P_0$
   b. $6.2 \times P_0$  d. $0.16 \times P_0$

42. A 5-mol ideal gas system undergoes an adiabatic free expansion (a rapid expansion into a vacuum), going from an initial volume of 10 L to a final volume of 20 L. How much work is done on the system during this adiabatic free expansion?
   a. −50 J  c. zero
   b. −10 J  d. +50 J

43. A heat engine exhausts 3 000 J of heat while performing 1 500 J of useful work. What is the efficiency of the engine?
   a. 15%  c. 50%
   b. 33%  d. 60%

44. A heat engine operating between a pair of hot and cold reservoirs with respective temperatures of 500 K and 200 K will have what maximum efficiency?
   a. 60%  c. 40%
   b. 50%  d. 30%
45. An electrical power plant manages to send 88% of the heat produced in the burning of fossil fuel into the water-to-steam conversion. Of the heat carried by the steam, 40% is converted to the mechanical energy of the spinning turbine. Which of the following choices best describes the overall efficiency of the heat-to-work conversion in the plant (as a percentage)?
   a. greater than 88%  
   b. 64%  
   c. less than 40%  
   d. 40%

46. A heat engine receives 6 000 J of heat from its combustion process and loses 4 000 J through the exhaust and friction. What is its efficiency?
   a. 33%  
   b. 40%  
   c. 67%  
   d. 73%

47. If a heat engine has an efficiency of 30% and its power output is 600 W, what is the rate of heat input from the combustion phase?
   a. 1 800 W  
   b. 2 400 W  
   c. 2 000 W  
   d. 3 000 W

48. A turbine takes in 1 000-K steam and exhausts the steam at a temperature of 500 K. What is the maximum theoretical efficiency of this system?
   a. 24%  
   b. 33%  
   c. 50%  
   d. 67%

49. An electrical generating plant operates at a boiler temperature of 220°C and exhausts the unused heat into a nearby river at 18°C. What is the maximum theoretical efficiency of the plant? (0°C = 273 K)
   a. 61%  
   b. 32%  
   c. 21%  
   d. 41%

50. An electrical generating plant operates at a boiler temperature of 220°C and exhausts the unused heat into a nearby river at 19°C. If the generating plant has a power output of 800 megawatts (MW) and if the actual efficiency is 3/4 the theoretical efficiency, how much heat per second must be delivered to the boiler? (0°C = 273 K)
   a. 5 200 MW  
   b. 1 810 MW  
   c. 3 620 MW  
   d. 2 620 MW

51. The efficiency of a Carnot engine operating between 100°C and 0°C is most nearly:
   a. 7%  
   b. 15%  
   c. 27%  
   d. 51%

52. An 800-MW electric power plant has an efficiency of 30%. It loses its waste heat in large cooling towers. Approximately how much waste heat (in MJ) is discharged to the atmosphere per second?
   a. 1 200 MJ  
   b. 1 900 MJ  
   c. 800 MJ  
   d. 560 MJ

53. A gasoline engine with an efficiency of 30.0% operates between a high temperature $T_1$ and a low temperature $T_2 = 320$ K. If this engine operates with Carnot efficiency, what is the high-side temperature $T_1$?
   a. 1 070 K  
   b. 868 K  
   c. 614 K  
   d. 457 K
Thermodynamics II
Answer Section

MULTIPLE CHOICE

1. D
2. A
3. C
4. A
5. A
6. D
7. D
8. A
9. C
10. A
11. C
12. B
13. C
14. B
15. C
16. C
17. D
18. C
19. C
20. D
21. A
22. D
23. B
24. C
25. B
26. B
27. B
28. C
29. A
30. C
31. A
32. B
33. B
34. D
35. D
36. A
37. A
38. C
39. B
40. A
41. D
42. C
43. B
44. A
45. C
46. A
47. C
48. C
49. D
50. D
51. C
52. B
53. D