0.700. (b) What is unreasonable about the temperature? (c) Which premise is unreasonable?

15.5 Applications of Thermodynamics: Heat Pumps and Refrigerators

37. What is the coefficient of performance of an ideal heat pump that has heat transfer from a cold temperature of -25.0ºC to a hot temperature of 40.0ºC ?

38. Suppose you have an ideal refrigerator that cools an environment at -20.0ºC and has heat transfer to another environment at 50.0ºC . What is its coefficient of performance?

39. What is the best coefficient of performance possible for a hypothetical refrigerator that could make liquid nitrogen at -200ºC and has heat transfer to the environment at 35.0ºC ?

40. In a very mild winter climate, a heat pump has heat transfer from an environment at 5.00ºC to one at 35.0ºC . What is the best possible coefficient of performance for these temperatures? Explicitly show how you follow the steps in the **Problem-Solving Strategies for Thermodynamics**.

41. (a) What is the best coefficient of performance for a heat pump that has a hot reservoir temperature of 50.0ºC and a cold reservoir temperature of -20.0ºC ? (b) How much heat transfer occurs into the warm environment if $3.60\times10^7\text{ J}$ of work ($10.0\text{kW}\cdot\text{h}$) is put into it? (c) If the cost of this work input is $10.0\text{ cents/kW}\cdot\text{h}$, how does its cost compare with the direct heat transfer achieved by burning natural gas at a cost of 85.0 cents per therm. (A therm is a common unit of energy for natural gas and equals $1.055\times10^8\text{ J}$.)

42. (a) What is the best coefficient of performance for a refrigerator that cools an environment at -30.0ºC and has heat transfer to another environment at 45.0ºC ? (b) How much work in joules must be done for a heat transfer of 4186 kJ from the cold environment? (c) What is the cost of doing this if the work costs 10.0 cents per $3.60\times10^6\text{ J}$ (a kilowatt-hour)? (d) How many kJ of heat transfer occurs into the warm environment? (e) Discuss what type of refrigerator might operate between these temperatures.

43. Suppose you want to operate an ideal refrigerator with a cold temperature of -10.0ºC , and you would like it to have a coefficient of performance of 7.00. What is the hot reservoir temperature for such a refrigerator?

44. An ideal heat pump is being considered for use in heating an environment with a temperature of 22.0ºC . What is the cold reservoir temperature if the pump is to have a coefficient of performance of 12.0?

45. A 4-ton air conditioner removes $5.06\times10^7\text{ J}$ (48,000 British thermal units) from a cold environment in 1.00 h. (a) What energy input in joules is necessary to do this if the air conditioner has an energy efficiency rating (EER) of 12.0? (b) What is the cost of doing this if the work costs 10.0 cents per $3.60\times10^6\text{ J}$ (one kilowatt-hour)? (c) Discuss whether this cost seems realistic. Note that the energy efficiency rating (EER) of an air conditioner or refrigerator is defined to be the number of British thermal units of heat transfer from a cold environment per hour divided by the watts of power input.

46. Show that the coefficients of performance of refrigerators and heat pumps are related by $COP_{\text{ref}} = COP_{\text{hp}} - 1$.

Start with the definitions of the COP s and the conservation of energy relationship between Q_{h} , Q_{c} , and W .

15.6 Entropy and the Second Law of Thermodynamics: Disorder and the Unavailability of Energy

47. (a) On a winter day, a certain house loses $5.00\times10^8\text{ J}$ of heat to the outside (about 500,000 Btu). What is the total change in entropy due to this heat transfer alone, assuming an average indoor temperature of 21.0º C and an average outdoor temperature of 5.00º C ? (b) This large change in entropy implies a large amount of energy has become unavailable to do work. Where do we find more energy when such energy is lost to us?

48. On a hot summer day, $4.00\times10^6\text{ J}$ of heat transfer into a parked car takes place, increasing its temperature from 35.0º C to 45.0º C . What is the increase in entropy of the car due to this heat transfer alone?

49. A hot rock ejected from a volcano's lava fountain cools from 1100º C to 40.0º C , and its entropy decreases by 950 J/K. How much heat transfer occurs from the rock?

50. When $1.60\times10^5\text{ J}$ of heat transfer occurs into a meat pie initially at 20.0º C , its entropy increases by 480 J/K. What is its final temperature?

51. The Sun radiates energy at the rate of $3.80\times10^{26}\text{ W}$ from its 5500º C surface into dark empty space (a negligible fraction radiates onto Earth and the other planets). The effective temperature of deep space is -270º C . (a) What is the increase in entropy in one day due to this heat transfer? (b) How much work is made unavailable?

52. (a) In reaching equilibrium, how much heat transfer occurs from 1.00 kg of water at 40.0º C when it is placed in contact with 1.00 kg of 20.0º C water in reaching equilibrium? (b) What is the change in entropy due to this heat transfer? (c) How much work is made unavailable, taking the lowest temperature to be 20.0º C ? Explicitly show how you follow the steps in the **Problem-Solving Strategies for Entropy**.

53. What is the decrease in entropy of 25.0 g of water that condenses on a bathroom mirror at a temperature of 35.0º C , assuming no change in temperature and given the latent heat of vaporization to be 2450 kJ/kg?

54. Find the increase in entropy of 1.00 kg of liquid nitrogen that starts at its boiling temperature, boils, and warms to 20.0º C at constant pressure.

55. A large electrical power station generates 1000 MW of electricity with an efficiency of 35.0%. (a) Calculate the heat transfer to the power station, Q_{h} , in one day. (b) How much