Thermodynamics I

Chapter 6 2nd Law of Thermodynamics

Selected Problems

Source: *Cengel, Y.A., and Boles, M.A.,THERMODYNAMICS :An Engineering Approach, 5th Edition in SI unit,McGraw-Hill, 2006.*
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5-5C Describe an imaginary process that violates both the first and the second laws of thermodynamics.

5-6C An experimentalist claims to have raised the temperature of a small amount of water to 150°C by transferring heat from high-pressure steam at 120°C. Is this a reasonable claim? Why? Assume no refrigerator or heat pump is used in the process.

Heat Engines and Thermal Efficiency

5-12C Is it possible for a heat engine to operate without rejecting any waste heat to a low-temperature reservoir? Explain.

5-13C What are the characteristics of all heat engines?

5-22C Does a heat engine that has a thermal efficiency of 100 percent necessarily violate *(a)* the first law and *(b)* the second law of thermodynamics? Explain.

5-23C In the absence of any friction and other irreversibilities, can a heat engine have an efficiency of 100 percent? Explain

5-25 An 800-MW steam power plant, which is cooled by a nearby river, has a thermal efficiency of 40 percent. Determine the rate of heat transfer to the river water. Will the actual heat transfer rate be higher or lower than this value? Why?

5-26 A steam power plant receives heat from a furnace at a rate of 280 GJ /h. Heat losses to the surrounding air from the steam as it passes Hough the pipes and other components are estimated to be about 8 GJ /h. If the waste heat is transferred to the cooling water at a rate of 145 GJ/h, determine *(a)* the net power output and *(b)* the thermal efficiency of this power plant. *Answers: (a)* 35.3 MW, *(b)* 45.4 percent

5-27 A car engine with a power output of 90 kW has a thermal efficiency *of* 28 percent. Determine the rate of fuel consumption if the value of the fuel is 44,000 kJ /kg.

5-28 A steam power plant with a power output of 150 MW consumes coal at a rate of 60 tons/h. If the energy content of the coal is 30,000 kJ/kg, determine the thermal efficiency of this plant (1 ton = 1000 kg). *Answer:* 30.0 percent

5-29 An automobile engine consumes fuel at a rate of 20 L/h and delivers 60 kW of power to the wheels. If the fuel has a heating value of 44,000 kJ/kg and a density of 0.8 g/cm^3, determine the efficiency of this engine. *Answer:* 30.7 percent

Refrigerators and Heat Pumps

5-31C What is the difference between a refrigerator and a heat pump?

5-32C What is the difference between a refrigerator and an air conditioner?

5-33C In a refrigerator, heat is transferred from a lower-temperature medium (the refrigerated space) to a higher-temperature one (the kitchen air). Is this a violation of the second law of thermodynamics? Explain.

5-34C A heat pump is a device that absorbs energy from the cold outdoor air and transfers it to the warmer indoors. Is this a violation of the second law of thermodynamics? Explain.

5-35C Define the coefficient of performance of a refrigerator in words. Can it be greater than unity?

5-36C Define the coefficient of performance of a heat pump in words. Can it be greater than unity?

5-37C A heat pump that is used to heat a house has a COP of 2.5. That is, the heat pump delivers 2.5 kWh of energy to the house for each 1 kWh of electricity it consumes. Is this a violation of the first law of thermodynamics? Explain.

5-38C A refrigerator has a COP of 1.5. That is, the refrigerator removes 1.5 kWh of energy from the refrigerated space for each 1 kWh of electricity it consumes. Is this a violation of the first law of thermodynamics? Explain.

5-41 A household refrigerator with a COP of 1.8 removes heat from the refrigerated space at a rate of 90 kJ/min. Determine *(a)* the electric power consumed by the refrigerator and *(b)* the rate of heat transfer to the kitchen air. *Answers: (a)* 0.83 kW, *(b)* 140kJ/min

5-42 An air conditioner removes heat steadily from a house at a rate of 750 kJ /min while drawing electric power at a rate of 6 kW. Determine *(a)* the COP of this air conditioner and *(b)* the rate of heat discharge to the outside air. *Answers: (a)* 2.08, *(b)* 1110 kJ /min

5-44 Water enters an ice machine at 15°C and leaves as ice at -5°C. If the COP of the ice machine is 2.4 during this operation, determine the required power input for an ice production rate of 12 kg/h. (Note that 384 kJ of energy needs to be removed from each 1 kg of water at 15°C to turn it into ice at - 5°C.)

Carnot Heat Engines

5-69C Is there any way to increase the efficiency of a Carnot heat engine other than by increasing T_H or decreasing T_L*?*

5-70C Consider two actual power plants operating with solar energy. Energy is supplied to one plant from a solar pond at 80°C and to the other from concentrating collectors that raise the water temperature to 600°C. Which of these power plants will have a higher efficiency and why?

5.71 A Carnot heat engine operates between a source at 1000 K and a sink at 300 K. If the heat engine is supplied with heat at a rate of 800 kJ / min, determine *(a)* the thermal efficiency and *(b)* the power output of this heat engine. *Answers: (a)* 70 percent, *(b)* 9.33 kW

5.73 A heat engine operates between a source at 550°C and a sink at 25°C. If heat is supplied to the heat engine at a steady rate of 1,200 kJ /min, determine the maximum power output of this heat engine.

5-77 An inventor claims to have developed a heat engine that receives 800 kJ of heat from a source at 400 K and produces 250 kJ of net work while rejecting the waste heat to a sink at 300 K. Is this a reasonable claim? Why