Problems Chapter 9

Notes: 1 bar = 100 kPa, use constant specific heats unless otherwise directed.

Air Standard Cycles

9-1 An air-standard cycle is proposed which begins at an initial state of 27 °C, 1 bar, and 0.860 m^3/kg. Process 1-2 is constant-volume heating to 2 bars; process 2-3 is constant-pressure heating to 1200 K and 1.72 m^3/kg; process 3-4 is isentropic expansion to 1 bar; process 4-1 is constant-pressure cooling to the initial state. (a) Sketch pV and Ts diagrams for the cycle. (b) Determine the total amount of heat added, in kJ/kg. (c) Determine the net work output, in kJ/kg. (d) Compute the thermal efficiency. (e) What is the Carnot efficiency for a heat engine with the same maximum and minimum temperatures as the above cycle?

9-2 An air-standard cycle is proposed which begins at an initial state of 47 °C, 1.2 bars, and 0.765 m^3/kg. Process 1-2 is constant-volume heating to 2.7 bars; process 2-3 is constant-pressure heating to 1.53 m^3/kg; process 3-4 is isentropic expansion to 1.2 bars; process 4-1 is constant pressure cooling to the initial state. (a) Sketch pV and Ts diagrams for the cycle. (b) Determine the total amount of heat added, in kJ/kg. (c) Find the net work output, in kJ/kg. (d) Compute the thermal efficiency. (e) What is the Carnot efficiency for a heat engine with the same maximum and minimum temperatures as the above cycle?

9-3 A proposed air-standard cycle begins at 1 bar, 27°C, and 0.860 m^3/kg. Process 1-2 is isentropic compression to 2.75 bar; process 2-3 is constant-pressure heating to 1200 K and 1.25 m^3/kg; process 3-4 is constant-volume cooling to 1 bar; process 4-1 is constant-pressure cooling to the initial state. (a) Sketch pV and Ts diagrams of the cycle. (b) Determine the amount of heat added and the net work output, in kJ/kg. (c) Compute the thermal efficiency. (d) What is the Carnot efficiency for a heat engine with the same maximum and minimum temperatures as the above cycle?

9-4 A proposed air-standard cycle begins at 1.1 bars, 37 °C, and 0.808 m^3/kg. Process 1-2 is isentropic compression to 3.2 bars; process 2-3 is constant-pressure heating to 1050 K and 0.940 m^3/kg; process 3-4 is constant-volume cooling to 1.1 bars; process 4-1 is constant-pressure cooling to the initial state. (a) Sketch pV and Ts diagrams of the cycle. (b) Determine the amount of heat added and the net work output, in kJ/kg. (c) Compute the thermal efficiency. (d) What is the Carnot efficiency for a heat engine with the same maximum and minimum temperatures as the above cycle?

Air-standard Carnot Cycles

9-5 An air-standard Carnot cycle rejects 100 kJ/kg to a sink at 300 K. The minimum and maximum pressures in the closed cycle are 0.10 and 17.4 MPa. On the basis of the air table, determine (a) the pressure after isothermal compression, (b) the temperature of the heat supply reservoir, in degrees Kelvin, (c) the specific volume after isothermal compression and after isentropic compression, both in m^3/kg, and (d) the thermal efficiency.

9-6 An air-standard Carnot cycle for a closed system is supplied with 200 kJ/kg of heat from a source at 1000 K. The minimum and maximum pressures in the cycle are 1 and 69.3 bars. On the basis of the air table, determine (a) the pressure after isothermal heat addition, (b) the temperature of heat rejection, in degrees Kelvin, (c) the specific volume, in m^3/kg, after isothermal heat addition and after isentropic expansion, and (d) the thermal efficiency.

9-7 An air-standard Carnot cycle operates in a piston-cylinder device between temperatures of 300 and 900 K. The minimum pressure in the cycle is 0.10 MPa. Determine (1) the maximum pressure in the cycle, in MPa, and (2) the specific volume, in m^3/kg, after isentropic compression, if the heat rejection is (a) 60 kJ/kg, and (b) 40 kJ/kg.

9-8 An air-standard Carnot cycle operates between temperatures of 300 and 1100 K. The minimum pressure in the cycle is 1 bar. Determine (1) the maximum pressure in the cycle, and (2) the pressure after isothermal compression in the closed system, in bars, if the amount of heat supplied is (a) 120 kJ/kg, and (b) 150 kJ/kg.

9-9 A Carnot heat engine which produces 10 kJ of work for one cycle has a thermal efficiency of 50 percent. The working fluid is 0.50 kg of air, and the pressure and volume at the beginning of the isothermal expansion are 7 bars and 0.119 m^3, respectively. Find (a) the maximum and minimum temperatures for the cycle, in degrees Kelvin, (b) the heat and work for each of the four processes, in kJ/cycle, and (c) the volume at the end of the isothermal expansion process and at the end of the isentropic expansion process, in m^3.

Compression ratio and mean effective pressure

9-10 For the data in Prob. 9-5, determine the compression ratio and the mean effective pressure for a reciprocating device.

9-11 For the data in Prob. 9-6, determine the compression ratio and the mean effective pressure for a reciprocating device.

9-12 For the data in Prob. 9-7, determine the compression ratio and the mean effective pressure for a reciprocating device if the heat rejection is (a) 60 kJ/kg, and (b) 40 kJ/kg.

9-13 For the data in Prob. 9-8, determine the compression ratio and the mean effective pressure for a reciprocating device if the amount of heat supplied is (a) 120 kJ/kg, and (b) 150kJ/kg.

Otto cycle

9-14 The compression ratio of an Otto cycle is 8:I. Before the compression stroke of the cycle begins, the pressure is 0.98 bar and the temperature is 27 °C. The amount of heat added to the air per cycle is 1332 kJ/kg. On the basis of the air-standard cycle and using constant heat capacities, determine (a) the pressure and temperature at the end of each process of the cycle, (b) the theoretical thermal efficiency, and (c) the mean effective pressure for the cycle, in bars.

9-15 Same as Prob. 9-14, except that the amount of heat added is 1188 kJ/kg.

9-16 The air at the beginning of the compression stroke of an air-standard Otto cycle is at 0.095 MPa and 22 °C, and the cylinder volume is 2800 cm^3. The compression ratio is 9, and 4.3 kJ are added during the heat-addition process. Using constant heat capacities, determine (a) the temperature and pressure after the heat-addition and expansion processes, (b) the thermal efficiency, and (c) the mean effective pressure, in MPa.

9-17 Same as Prob. 9-16, except that the amount of heat added is 3.54 kJ.

9-18 An air-standard Otto cycle operates with a compression ratio of 8.55, and at the beginning of compression the air is at 0.98 bar and 32 °C. During the heat-addition process the pressure is tripled. Using constant heat capacities, determine (a) the temperatures around the cycle, in degrees Kelvin, (b) the thermal efficiency of the cycle, and (c) the thermal efficiency of a Carnot engine operating between the same overall temperature limits.

9-19 Consider an air-standard Otto cycle that has a compression ratio of 8.3 and a heat addition of 1310 kJ/kg. If the pressure and temperature at the beginning of the compression process are 0.095 MPa and 70 °C, determine (a) the maximum pressure and temperature for the cycle, (b) the net work output, in kJ/kg, (c) the thermal efficiency, and (d) the mean effective pressure, in MPa.

9-20 Same as Prob. 9-19, except that the amount of heat added is 1213 kJ/kg.

9-21 Reconsider the Otto cycle in Prob. 9-14. Determine (a) the closed-system availability of the air at the end of isentropic expansion, in kJ/kg, if T_0 = 27 °C and P_0 = 0.98 bar, and (b) the ratio of this availability quantity to the net work output of the cycle.

9-22 Reconsider the Otto cycle in Prob. 9-16. Determine (a) the closed-system availability of the air at the end of isentropic expansion, in kJ/kg, if T_0 = 22 °C and P_0 = 0.095 MPa, and (b) the ratio of this availability quantity to the net work output of the cycle.

9-23 Reconsider the Otto cycle in Prob. 9-19. Determine (a) the closed-system availability of the air at the end of isentropic expansion, in kJ/kg, if T_0 = 7 °C and P_0 = 0.095 MPa, and (b) the ratio of this availability quantity to the net work output of the cycle.

Diesel cycle

9-24 An air-standard Diesel cycle operates with a compression ratio of 16.7 and a cutoff ratio of 2. At the beginning of compression the air temperature and pressure are 37 °C and 0.10 MPa, respectively. Determine (a) the maximum temperature in the cycle, in degrees Kelvin, (b) the pressure after isentropic expansion, in MPa, and (c) the heat input per cycle, in kJ/kg.

9-25 An engine operates on the theoretical Diesel cycle with a compression ratio of 16 : 1, and fuel is injected for 10 percent of the stroke. The pressure and temperature of the air entering the cylinder are 0.98 bar and 17 °C, respectively. Determine (a) the cutoff ratio, (b) the temperature, in degrees Kelvin, at the end of the compression process and at the end of the heat-addition process, (c) the pressure after isentropic expansion, in kPa, and (d) the heat input, in kJ/kg.

9-26 The intake conditions for an air-standard Diesel cycle operating with a compression ratio of 15 : 1 are 0.95 bar and 17 °C. At the beginning of the compression stroke the cylinder volume is 380 L, and 7.5 kJ of heat are added to the gas during the constant-pressure heating process.
(a) Calculate the pressure and temperature at the end of each process of the cycle.
(b) Determine the thermal efficiency and the mean effective pressure of the cycle.

9-27 A Diesel air-standard cycle has a compression ratio of 15 : 1. The pressure and temperature at the beginning of compression are 1 bar and 17 °C, respectively. If the maximum temperature of the cycle is 2250 °C, determine (a) the cutoff ratio, (b) the thermal efficiency, and (c) the mean effective pressure, in kPa.

9-28 An air-standard Diesel cycle is supplied with 1490 kJ/kg of heat per cycle. The pressure and temperature at the beginning of compression are 0.095 MPa and 27 °C, respectively, and the pressure after compression is 4.33 MPa. Determine (a) the compression ratio, (b) the maximum temperature in the cycle, in degrees Kelvin, (c) the cutoff ratio, and (d) the pressure after isentropic expansion, in MPa.

9-29 Reconsider the Diesel cycle in Prob. 9-24. Determine (a) the closed system availability of the air at the end of isentropic expansion, in kJ/kg, if T_0 = 17°C and P_0 = 0.10 MPa, and (b) the ratio of this availability quantity to the net work output of the cycle.

9-30 Reconsider the Diesel cycle of Prob. 9-26. Determine (a) the closed system availability of the air at the end of isentropic expansion, in kJ/kg, if T_0 = 17 °C and P_0 = 0.95 bar and (b) the ratio of this availability quantity to the net work output of the cycle.

Dual Cycle

9-31 An air-standard dual cycle operates with a compression ratio of 15:1. At the beginning of compression the conditions are 17 °C, 0.95 bar, and 3.80 L. The amount of heat added is 6.3 kJ, of which one-third is added at constant volume and the remainder at constant pressure. Determine (a) the pressure after the constant-volume heat-addition process, (b) the temperature before and after the constant-pressure heat-addition process, in degrees Kelvin, (c) the temperature after isentropic expansion, and (d) the thermal efficiency.

9-32 An air-standard dual cycle operates with a compression ratio of 14 : 1. At the beginning of the isentropic compression the conditions are 27 °C and 0.96 bar. The total heat addition is 1480 kJ/kg, of which one-fourth is added at constant volume and the remainder at constant pressure. Determine (a) the temperatures at the end of each process around the cycle, in degrees Kelvin, (b) the thermal efficiency, and (c) the mean effective pressure.

9-33 Same as Prob. 9-31, except that the heat addition is 6.0 kJ, of which 30 percent is added at constant volume.

9-34 Same as Prob. 9-32, except that the heat addition is 1530 kJ/kg, of which one-third is added at constant volume.

Ideal Open Gas Turbine Cycle

9-35 A gas turbine power plant operates on an air-standard cycle between pressure limits of 0.10 MPa and 0.60 MPa. The inlet-air temperature is 22 °C, and the air enters the turbine at 747 °C. Determine (a) the net work output and the heat input, in kJ/kg, and (b} the thermal efficiency if the cycle is ideal.

9-36 A gas-turbine power plant operates on an air-standard cycle between pressure limits of 1 and 6.4 bars. The inlet-air temperature is 22 °C, and the temperature limitation on the turbine is 807 °C. Calculate (a) the net work output, in kJ/kg, and (b} the thermal efficiency if the cycle is ideal.

9-37 A gas-turbine power plant operates on an air-standard cycle between pressure limits of 1 bar and 6 bars. The inlet-air temperature to the compressor is 17 °C, and the inlet-air temperature to the turbine is 1080 K. Calculate (a) the net work output, in kJ/kg, (b) the heat input, and (c) the thermal efficiency if the cycle is ideal.

9-38 A stationary gas-turbine power plant has maximum and minimum cycle temperatures of 827 and 27 °C, and a pressure ratio of 5.2:1. Find (a) the ratio of compressor work to turbine work, (b) the thermal efficiency, and (c) the mass flow rate of air required, in kg/min, for a net power output of 1000 kW.

9-39 The pressure ratio of an air-standard Brayton cycle is 4.5, and the inlet conditions to the compressor are 0.10 MPa and 27 °C. The turbine is limited to a temperature of 827 °C, and the mass flow rate is 4 kg/s. Determine (a) the compressor and turbine work, in kJ/kg, (b) the thermal efficiency, (c) the net power output, in kilowatts, and (d) the volume flow rate at the compressor inlet, in m^3/min. (e) If the heat addition is accomplished by the complete combustion of a fuel with a heating value of 42,900 kJ/kg, estimate the fuel-air ratio used in the combustor, in kg/kg.

9-40 The pressure ratio of an air-standard Brayton cycle is 6:1, and the inlet conditions are 1.0 bar and 17 °C. The turbine is limited to a temperature of 1000 K, and the mass flow rate is 3.5 kg/s. Determine (a) the compressor and turbine work, in kJ/kg, (b) the thermal efficiency, (c) the net power output, in kilowatts, and (d) the volume flow rate at the compressor inlet, in m^3/min. (e) If the heat addition is accomplished by the complete combustion of a fuel with a heating value of 44,000 kJ/kg, estimate the fuel-air ratio used in the combustor, in kg/kg.

9-41 If the sink temperature T_0 is the same as the compressor-inlet temperature, then determine the steady-flow availability of the turbine exhaust stream, in kJ/kg, for the Brayton cycle described in (a) Prob. 9-35, (b) Prob. 9-36, (c) Prob. 9-37 and (d) Prob. 9-38. Also, calculate the percent increase in net work output if this availability could be completely converted into work output.

9-42 Prove that the maximum net work for a simple Brayton cycle, for fixed compressor and turbine-inlet temperatures, occurs when $T_2 = (T_1 \bullet T_3)^{1/2}$ if the specific heats are constant.

9-43 Show that the pressure ratio which yields the largest net work for a simple Brayton cycle with fixed compressor and turbine inlet temperatures is given by $P_2/P_1 = (T_3/T_1)^n$, where $n = k/[2(k - 1)]$ and k is a constant.

Non-ideal Simple Gas Turbine Power Cycle

9-44 Using the data of Prob. 9-35, calculate the heat input and the thermal efficiency if the compressor and turbine adiabatic efficiencies are 84 and 87 percent, respectively.

9-45 Using the data of Prob. 9-36, calculate the required quantities if the adiabatic efficiencies of the compressor and turbine are 82 and 85 percent, respectively.

9-46 Using the data of Prob. 9-37, calculate the required quantities if the compressor and turbine adiabatic efficiencies are 82 and 85 percent, respectively.

9-47 Using the data of Prob. 9-38, calculate the required quantities if the adiabatic efficiencies of the compressor and turbine are 81 and 86 percent, respectively.

9-48 Using the data of Prob. 9-39, calculate the required quantities if the compressor and turbine adiabatic efficiencies are 83 and 86 percent, respectively.

9-49 Using the data of Prob. 9-40, calculate the required quantities if the compressor and turbine adiabatic efficiencies are 84 and 88 percent, respectively.

9-50 A gas-turbine power cycle operates with a pressure ratio of 12:1. The compressor and turbine adiabatic efficiencies are 85 and 90 percent, respectively. The compressor-inlet temperature is 22 °C, and the turbine-inlet temperature is 1027 °C. For a mass flow rate of 1 kg/s, find the power generated by the cycle. Now, double the pressure ratio and find the power output in this latter case, in kilowatts.

9-51 Air enters a gas-turbine power plant at 17 °C and 1 bar. The compressor and turbine both operate with a pressure ratio of 8, and the adiabatic efficiencies of each are 80 and 85 percent, respectively. Gases enter the combustor at 887 °C, and the mass flow rate is 10 kg/s. Determine what percent of the total output of the turbine may be used to drive devices other than the compressor.

I6-52 If the sink temperature T_0 is the same as the compressor-inlet temperature, then determine two-stage compression and expansion are used with a regenerator effectiveness of (a) 60 percent, and (b) 70 percent. The compressor and turbine efficiencies are given in Prob. 9-46. Intercooling and reheating are ideal.

9-77 A gas turbine cycle operates with two stages of compression and two stages of expansion. The pressure ratio across each stage is 2. The inlet temperature is 22 °C to each stage of compression and 827 °C to each stage of expansion. The compressor and turbine efficiencies are 78 and 84 percent, respectively, and the regenerator has an effectiveness of 70 percent. Determine (a) the compressor and turbine work, in kJ/kg, (b) the thermal efficiency, and (c) the temperature of the air stream leaving the regenerator and entering the atmosphere, in degrees Celsius.

9-78 Reconsider Prob. 9-77, and calculate the same required quantities, except that the compressor and turbine efficiencies are now 81 and 86 percent, respectively, and the regenerator effectiveness is now 75 percent.

9-79 A gas-turbine cycle operates with two-stage compression and expansion. The pressure ratio across each stage of compression is 2.0, and the compressor efficiency is 81 percent. The compressor inlet temperature is 22 "C, but intercooling reduces the temperature only to 37 °C before the air enters the second stage. The inlet temperature to each stage of expansion is 827 °C, but a pressure drop between the compressor and turbine reduces the expansion pressure ratio of 1.9:1 across each turbine stage, which has an adiabatic efficiency of 86 percent. The regenerator effectiveness is 75 percent. Determine (a) the compressor work, (b) the turbine work, (c) the heat removed in the intercooler, (d) the thermal efficiency, (e) the temperature of the air stream leaving the regenerator and entering the combustor, and (f) the stream availability of the fluid leaving the regenerator and entering the environment, which has a temperature of 22 °C.

9-80 A gas-turbine power plant employs two-stage compression and expansion, with intercooling, reheating, and regeneration. The temperature at the outlet of the compressor second stage is 390 K, and the combustor-inlet temperature is 750 K. The turbine-inlet temperature is limited to 1180 K. (a) Determine the gross maximum work output from the two-stage turbine if the overall pressure ratio is 6:1. (b) Determine the regenerator effectiveness.

Turbojet Cycles

9-81 Rework Example 9-10 in the text under the following conditions: (1) the actual pressure rise in the diffuser is 92 percent of theoretical, (2) the compressor efficiency is 82 percent, (3) the turbine efficiency is 86 percent and (4) the nozzle efficiency is 95 percent. Determine (a) the pressure and temperature throughout the cycle, (b) the compressor work, and (c) the exit-jet velocity, in m/s.

9-82 The airspeed of a turbojet aircraft is 300 m/s in still air at 0.25 bar and 220 K. The compressor pressure ratio is 9, and the maximum temperature in the cycle is 1320 K. Assume ideal performance of the various components. Determine (a) the temperatures and pressures throughout the cycle, (b) the compressor work required, in kJ/kg, and (c) the exit-jet velocity, in m/s.

9-83 Rework Prob. 9-82 under the following conditions: (1) the actual pressure rise in the diffuser is 90 percent of the isentropic value, (2) the compressor and turbine adiabatic efficiencies are 83 and 87 percent, respectively, and (3) the nozzle efficiency is 96 percent. Determine the quantities specified in Prob. 9-82.

9-84 The airspeed of a jet aircraft is 280 m/s in still air at 0.050 MPa and 250 K. The pressure ratio across the compressor is 11, and the maximum cycle temperature is 1360 K. Assume ideal performance of the various components. Determine (a) the compressor work, in kJ/kg, (b) the pressure at the turbine outlet, in MPa, and (c) the exit-jet velocity in m/s.

9-85 Rework Prob. 9-84 under the following conditions: (1) the actual pressure rise in the diffuser is 92 percent of the isentropic value, (2) the compressor and turbine efficiencies are 84 and 87 percent, respectively, and (3) the nozzle efficiency is 94 percent.

9-86 Reconsider Example 9-10. Determine (a) the total thrust, in Newtons, (b) the specific work required, in kJ/kg, and (c) the propulsive efficiency, if the mass flow rate of air is 60 kg/s.

Sterling Cycle

9-87 A Stirling cycle operates with air, and at the beginning of isothermal expansion the state is 447 C and 8 bars. The minimum pressure in the cycle is 2 bar, and at the end isothermal compression the volume is 60 percent of the maximum volume. Determine the thermal efficiency of the cycle and the mean effective pressure.

9-88 A Stirling cycle operates with air, and at the beginning of isothermal compression the state is 77 C and 2 bar. The maximum pressure is 6 bars, and during the isothermal expansion the volume increases by 40 percent. Determine the thermal efficiency and the mean effective pressure of the cycle.

English Unit Problems

9-9E A Carnot heat engine which produces 10 Btu of work for one cycle has a thermal efficiency of 50 percent. The working fluid is 1.0 Ib_m of air, and the pressure and volume at the beginning of the isothermal expansion are 100 psia and 4.0 ft^3, respectively. Find (a) the maximum and minimum temperatures for the cycle, in degrees Rankine, (b) the heat and work for each of the four processes, in Btu/cycle, and (c) the volume at the end of the isothermal expansion process and at the end of the isentropic expansion process, in ft^3.

Compression ratio and Mean Effective Pressure

9-10E For the data in Prob. 9-5E, determine the compression ratio and the mean effective pressure for a reciprocating device.

9-11E For the data in Prob. 9-6E, determine the compression ratio and the mean effective pressure for a reciprocating device.

9-12E For the data in Prob. 9-7E, determine the compression ratio and the mean effective pressure for a reciprocating device if the heat rejection is (a) 30 Btu/lb_m, and (b) 20 Btu/lb_m.

9-13E For the data in Prob. 9-8E, determine the compression ratio and the mean effective pressure for a reciprocating device if the heat supplied is (a) 80 Btu/lb_m, and (b) 70 Btu/lb_m.

Otto cycle

9-14E The compression ratio of an Otto cycle is 8:1. Before the compression stroke of the cycle begins, the pressure is 14.5 psia and the temperature is 80 °F. The heat added to the air per cycle is 840 Btu/lb_m of air. On the basis of the air-standard cycle, determine (a) the pressure and temperature at the end of each process of the cycle, (b) the theoretical thermal efficiency, and (c) the mean effective pressure for the cycle, in lbf/in^2.

9-15E Same as Prob. 9-14E, except that the amount of heat added is 792 Btu/lb_m.

9-16E The air at the beginning of the compression stroke of an air-standard Otto cycle is at 14 psia and 68 F, and the cylinder volume is 0.20 ft^3. The compression ratio is 9, and 8.80 Btu are added during the heat-addition process. Determine (a) the temperature and pressure after the heat-addition and expansion processes, (b) the thermal efficiency, and (c) the mean effective pressure, in psia.

9-17E Same as Prob. 9-16E, except that the amount of heat added is 8.30 Btu.

9-18E An air-standard Otto cycle operates with a compression ratio of 8.50, and at the beginning of compression the air is at 14.5 psia and 90 °F. During the heat-addition process the pressure is tripled. Determine (a) the temperatures around the cycle, in degrees Rankine, (b) the thermal efficiency of the cycle, and (c) the thermal efficiency of a Carnot engine operating between the same overall temperature limits.

9-19E Consider an air-standard Otto cycle that has a compression ratio of 9.0 and a heat addition of 870 Btu/lb_m. If the pressure and temperature at the beginning of the compression process are 14.0 psia and 40 °F, determine (a) the maximum pressure and temperature for the cycle, (b) the net work output, in Btu/lb_m, (c) the thermal efficiency, and (d) the mean effective pressure, in psia.

9-20E Same as Prob. 9-19E, except that the amount of heat added is 750 Btu/lb_m.

9-21E Reconsider the Otto cycle in Prob. 9-14E. Determine (a) the closed-system availability of the air at the end of isentropic expansion, in Btu/lb_m, if T_0 = 80 °F and P_0 = 14.5 psia, and (b) the ratio of this availability quantity to the net work output of the cycle.

9-22E Reconsider the Otto cycle in Prob. 9-16E. Determine (a) the closed-system availability of the air at the end of isentropic expansion, in Btu/lb_m, if T_0 = 80 °F and P_0 = 14.0 psia, and (b) the ratio of this availability quantity to the net work output of the cycle.