ME 3310 Thermodynamics I Homework Handout #9: 9-13, 9-37E, 9-48, 9-81, 9-82, 9-133, 9-134

9–12 An air-standard cycle is executed within a closed piston-cylinder system and consists of three processes as follows:

1-2 V = *constant* heat addition from 100 kPa and 27°C to 700 kPa

2-3 Isothermal expansion until $V_3 = 7V_2$

3-1 P = *constant* heat rejection to the initial state

Assume air has constant properties with c_v = 0.718 kJ/kg·K, c_p = 1.005 kJ/kg·K, R = 0.287 kJ/kg·K, and k = 1.4.

(*a*) Sketch the *P*-*v* and *T*-*s* diagrams for the cycle.

(*b*) Determine the ratio of the compression work to the expansion work (the back work ratio).

(*c*) Determine the cycle thermal efficiency.

Answers: (*b*) 0.440, (*c*) 26.6 percent

9–13 An air-standard cycle with variable specific heats is executed in a closed system and is composed of the following four processes:

1-2 Isentropic compression from 100 kPa and 22°C to 600 kPa

2-3 v = *constant* heat addition to 1500 K

3-4 Isentropic expansion to 100 kPa

4-1 P = *constant* heat rejection to initial state

(*a*) Show the cycle on P-v and T-s diagrams.
(*b*) Calculate the net work output per unit mass.
(*c*) Determine the thermal efficiency.

9–15 An air-standard cycle is executed in a closed system with 0.5 kg of air and consists of the following three processes:

1-2 Isentropic compression from 100 kPa and 27°C to 1 MPa

2-3 P = *constant* heat addition in the amount of 416 kJ

3-1 $P = c_1 v + c_2$ heat rejection to initial state (c_1 and c_2 are constants)

(*a*) Show the cycle on P-v and T-s diagrams.
(*b*) Calculate the heat rejected.
(*c*) Determine the thermal efficiency.

Assume constant specific heats at room temperature.
Answers: (*b*) 272 kJ, (*c*) 34.7 percent

9–16E An air-standard cycle with variable specific heats is executed in a closed system and is composed of the following four processes:

1-2 v = *constant* heat addition from 14.7 psia and 80°F in the amount of 300 Btu/lbm

2-3 P = *constant* heat addition to 3200 R

3-4 Isentropic expansion to 14.7 psia

4-1 P = *constant* heat rejection to initial state

(*a*) Show the cycle on P-V and T-s diagrams.
(*b*) Calculate the total heat input per unit mass.
(*c*) Determine the thermal efficiency.

Answers: (*b*) 612 Btu/lbm, (*c*) 24.2 percent

9–33 An ideal Otto cycle has a compression ratio of 8. At the beginning of the compression process, air is at 95 kPa and 27°C, and 750 kJ/kg of heat is transferred to air during the constant-volume heat-addition process. Taking into account the variation of specific heats with temperature, determine (*a*) the pressure and temperature at the end of the heat-addition process, (*b*) the net work output, (*c*) the thermal efficiency, and (*d*) the mean effective pressure for the cycle. *Answers:* (*a*) 3898 kPa, 1539 K, (*b*) 392.4 kJ/kg, (*c*) 52.3 percent, (*d*) 495 kPa

9–35 Repeat Problem 9–33 using constant specific heats at room temperature.

9–36E A six-cylinder, four-stroke, spark-ignition engine operating on the ideal Otto cycle takes in air at 14 psia and 105°F, and is limited to a maximum cycle temperature of 2400°F. Each cylinder has a bore of 3.5 in, and each piston has a stroke of 3.9 in. The minimum enclosed volume is 9.8 percent of the maximum enclosed volume. How much power will this engine produce when operated at 2500 rpm? Use constant specific heats at room temperature.

9–37E A spark-ignition engine has a compression ratio of 8, an isentropic compression efficiency of 85 percent, and an isentropic expansion efficiency of 95 percent. At the beginning of the compression, the air in the cylinder is at 13 psia and 60°F. The maximum gas temperature is found to be 2300°F by measurement. Determine the heat supplied per unit mass, the thermal efficiency, and the mean effective pressure of this engine when modeled with the Otto cycle. Use constant specific heats at room temperature. *Answers:* 247 Btu/lbm, 47.5 percent, 49.0 psia

9–46 An air-standard Diesel cycle has a compression ratio of 16 and a cutoff ratio of 2. At the beginning of the compression process, air is at 95 kPa and 27°C. Accounting for the variation of specific heats with temperature, determine (*a*) the temperature after the heat-addition process, (*b*) the thermal efficiency, and (*c*) the mean effective pressure. *Answers:* (*a*) 1725 K, (*b*) 56.3 percent, (*c*) 675.9 kPa

9–47 Repeat Problem 9–46 using constant specific heats at room temperature.

9–48 An ideal Diesel cycle has a compression ratio of 17 and a cutoff ratio of 1.3. Determine the maximum temperature of the air and the rate of heat addition to this cycle when it produces 140 kW of power and the state of the air at the beginning of the compression is 90 kPa and 57°C. Use constant specific heats at room temperature.

9–52E An air-standard Diesel cycle has a compression ratio of 18.2. Air is at 120°F and 14.7 psia at the beginning of the compression process and at 3200 R at the end of the heat-addition process. Accounting for the variation of specific heats with temperature, determine (*a*) the cutoff ratio, (*b*) the heat rejection per unit mass, and (*c*) the thermal efficiency.

9–53E Repeat Prob. 9–52E using constant specific heats at room temperature.

9–57 A four-cylinder two-stroke 2.4-L diesel engine that operates on an ideal Diesel cycle has a compression ratio of 22 and a cutoff ratio of 1.8. Air is at 70°C and 97 kPa at the beginning of the compression process. Using the cold-air-standard assumptions, determine how much power the engine will deliver at 3500 rpm.

9–80E A simple ideal Brayton cycle with air as the working fluid has a pressure ratio of 10. The air enters the compressor at 520 R and the turbine at 2000 R. Accounting for the variation of specific heats with temperature, determine (*a*) the air temperature at the compressor exit, (*b*) the back work ratio, and (*c*) the thermal efficiency.

9–81 A gas-turbine power plant operates on the simple Brayton cycle with air as the working fluid and delivers 32 MW of power. The minimum and maximum temperatures in the cycle are 310 and 900 K, and the pressure of air at the compressor exit is 8 times the value at the compressor inlet. Assuming an isentropic efficiency of 80 percent for the compressor and 86 percent for the turbine, determine the mass flow rate of air through the cycle. Account for the variation of specific heats with temperature.

9–82 Repeat Problem 9–81 using constant specific heats at room temperature.

9–88 An aircraft engine operates on a simple ideal Brayton cycle with a pressure ratio of 10. Heat is added to the cycle at a rate of 500 kW; air passes through the engine at a rate of 1 kg/s; and the air at the beginning of the compression is at 70 kPa and 0°C. Determine the power produced by this engine and its thermal efficiency. Use constant specific heats at room temperature.

9–91E A gas-turbine power plant operates on a simple Brayton cycle with air as the working fluid. The air enters the turbine at 120 psia and 2000 R and leaves at 15 psia and 1200 R. Heat is rejected to the surroundings at a rate of 6400 Btu/s, and air flows through the cycle at a rate of 40 lbm/s. Assuming the turbine to be isentropic and the compresssor to have an isentropic efficiency of 80 percent, determine the net power output of the plant. Account for the variation of specific heats with temperature. *Answer:* 3373 kW

9–129E A turbojet is flying with a velocity of 900 ft/s at an altitude of 20,000 ft, where the ambient conditions are 7 psia and 10°F. The pressure ratio across the compressor is 13, and the temperature at the turbine inlet is 2400 R. Assuming ideal operation for all components and constant specific heats for air at room temperature, determine (*a*) the pressure at the turbine exit, (*b*) the velocity of the exhaust gases, and (*c*) the propulsive efficiency.

9–130E Repeat Problem 9–129E accounting for the variation of specific heats with temperature.

9–132 A pure jet engine propels an aircraft at 240 m/s through air at 45 kPa and −13°C. The inlet diameter of this engine is 1.6 m, the compressor pressure ratio is 13, and the temperature at the turbine inlet is 557°C. Determine the velocity at the exit of this engine's nozzle and the thrust produced. Assume ideal operation for all components and constant specific heats at room temperature.

9–133 A turbojet aircraft is flying with a velocity of 280 m/s at an altitude of 9150 m, where the ambient conditions are 32 kPa and −32°C. The pressure ratio across the compressor is 12, and the temperature at the turbine inlet is 1100 K. Air enters the compressor at a rate of 50 kg/s, and the jet fuel has a heating value of 42,700 kJ/kg. Assuming ideal operation for all components and constant specific heats for air at room temperature, determine (*a*) the velocity of the exhaust gases, (*b*) the propulsive power developed, and (*c*) the rate of fuel consumption.

9–134 Repeat Prob. 9–133 using a compressor efficiency of 80 percent and a turbine efficiency of 85 percent.