Vapor and Gas Power Cycles

1. A simple Rankine cycle uses water as the working fluid. The boiler operates at 6000 kPa and the condenser at 50 kPa. At the entrance to the turbine, the temperature is 450°C. The isentropic efficiency of the turbine is 94 percent, pressure and pump losses are negligible, and the water leaving the condenser is subcooled by 6.3°C. The boiler is sized for a mass flow rate of 20 kg/s. Determine the rate at which heat is added in the boiler, the power required to operate the pumps, the net power produced by the cycle, and the thermal efficiency. **(Answers: 59,660 kW, 122 kW, 18,050 kW, 30.3 percent)**

2. An ideal reheat Rankine cycle with water as the working fluid operates the boiler at 15,000 kPa, the reheater at 2000 kPa, and the condenser at 100 kPa. The temperature is 450°C at the entrance of the high-pressure and low-pressure turbines. The mass flow rate through the cycle is 1.74 kg/s. Determine the power used by pumps, the power produced by the cycle, the rate of heat transfer in the reheater, and the thermal efficiency of this system.

3. A simple ideal Rankine cycle with water as the working fluid operates between the pressure limits of 4 MPa in the boiler and 20 kPa in the condenser and a turbine inlet temperature of 700°C. Calculate the exergy destruction in each of the components of the cycle when heat is being rejected to the atmospheric air at 15°C and heat is supplied from an energy reservoir at 750°C. **Answers: 928 kJ/kg (boiler), 307 kJ/kg (condenser)**

4. Consider a steam power plant that operates on a reheat Rankine cycle. Steam enters the high-pressure turbine at 10 MPa and 500°C and the low-pressure turbine at 1 MPa and 500°C. Steam leaves the condenser as a saturated liquid at a pressure of 10 kPa. The isentropic efficiency of the turbine is 80 %, and that of the pump is 95 %. Determine the exergy destruction associated with the heat addition process and the expansion process. Assume a source temperature of 1600 K and a sink temperature of 285 K. Also, determine the exergy of the steam at the boiler exit. Take P_0 = 100 kPa. **Answers: 1289 kJ/kg, 247.9 kJ/kg, 1495 kJ/kg**

5. At the beginning of the compression process of an air-standard Otto cycle, p1 = 1 bar, T1 = 290 K, V1 = 400 cm3. The maximum temperature in the cycle is 2200 K and the compression ratio is 8. Determine **a**. the heat addition, in kJ. **b**. the net work done, in kJ. **c**. the thermal efficiency. **d**. the mean effective pressure, in bar

6. A four-cylinder, four-stroke internal combustion engine has a bore of 10 cm. and a stroke of 9 cm in. The clearance volume is 16% of the cylinder volume at bottom dead center and the crankshaft rotates at 2400 RPM. The processes within each cylinder are modeled as an air-standard Otto cycle with a pressure of 1 bar and a temperature of 16°C at the beginning of compression. The maximum temperature in the cycle is 2616°C. Based on this model, calculate the net work per cycle.

7. At the beginning of compression in an air-standard Diesel cycle, p_1 = 170 kPa, V_1 = 0.016 m^3, and T_1 = 315 K. The compression ratio is 15 and the maximum cycle temperature is 1400 K. Determine **a.** the mass of air, in kg. **b.** the heat addition and heat rejection per cycle, each in kJ. **c.** the net work, in kJ, and the thermal efficiency.

8. The world's largest diesel engine has displacement of 25 m^3 running at 200 RPM in a two-stroke cycle producing 100 000 hp. Assume an inlet state of 200 kPa, 300 K and a compression ratio of 20:1. What is the mean effective pressure and the flow rate of air to the engine?

9. A Brayton cycle produces 14 MW with an inlet state of 17°C, 100 kPa, and a compression ratio of 16:1. The heat added in the combustion is 1160 kJ/kg. What are the highest temperature and the mass flow rate of air, assuming cold air properties? Also, find the overall cycle second-law efficiency.

10. The compression ratio of an ideal dual cycle is 14. Air is at 100 kPa and 300 K at the beginning of the compression process and at 2200 K at the end of the heat-addition process. Heat transfer to air takes place partly at constant volume and partly at constant pressure, and it amounts to 1520.4 kJ/kg. Assuming variable specific heats for air, determine (a) the fraction of heat transferred at constant volume and (b) the thermal efficiency of the cycle.

11. A gas-turbine power plant operates on the simple Brayton cycle between the pressure limits of 100 and 1600 kPa. The working fluid is air, which enters the compressor at 40°C at a rate of 850 m^3/min and leaves the turbine at 650°C. Assuming a compressor isentropic efficiency of 85 percent and a turbine isentropic efficiency of 88 percent, determine (a) the net power output, (b) the back work ratio, and (c) the thermal efficiency. Use constant specific heats with cv = 0.821 kJ/kg·K, cp = 1.108 kJ/kg·K, and k = 1.35. **Answers: (a) 6488 kW, (b) 0.511, (c) 37.8 percent**

12. A gas turbine for an automobile is designed with a regenerator. Air enters the compressor of this engine at 100 kPa and 30°C. The compressor pressure ratio is 8; the maximum cycle temperature is 800°C; and the cold airstream leaves the regenerator 10°C cooler than the hot airstream at the inlet of the regenerator. Assuming both the compressor and the turbine to be isentropic, determine the rates of heat addition and rejection for this cycle when it produces 115 kW. Use constant specific heats at room temperature. **Answers: 240 kW, 125 kW**

13. 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. Determine the total exergy destruction associated with the cycle, assuming a source temperature of 2000 K and a sink temperature of 300 K. Also, determine the exergy at the end of the isentropic compression process. Account for the variation of specific heats with temperature. **Answers: 293 kJ/kg, 349 kJ/kg**

14. A gas-turbine power plant operates on the regenerative Brayton cycle between the pressure limits of 100 and 700 kPa. Air enters the compressor at 30°C at a rate of 12.6 kg/s and leaves at 260°C. It is then heated in a regenerator to 400°C by the hot combustion gases leaving the turbine. A diesel fuel with a heating value of 42,000 kJ/kg is burned in the combustion chamber with a combustion efficiency of 97 percent. The combustion gases leave the combustion chamber at 871°C and enter the turbine, whose isentropic efficiency is 85 percent. Treating combustion gases as air and using constant specific heats at 500°C, determine (a) the isentropic efficiency of the compressor, (b) the effectiveness of the regenerator, (c) the air–fuel ratio in the combustion chamber, (d) the net power output and the back work ratio, (e) the thermal efficiency, and (f) the secondlaw efficiency of the plant. Also determine (g) the second-law efficiencies of the compressor, the turbine, and the regenerator, and (h) the rate of the exergy flow with the combustion gases at the regenerator exit. **Answers: (a) 0.881, (b) 0.632, (c) 78.1, (d) 2267 kW, 0.583, (e) 0.345, (f) 0.469, (g) 0.929, 0.932, 0.890, (h) 1351 kW**