Problem SP27. A power-generating Brayton cycle is shown in Figure SP27. The system is operating in the mountains where the ambient temperature and pressure are 260 K and 85 kPa, respectively. The mass flow rate of air through the system is 200 kg/s. The system uses two compressors with pressure ratios of 6 and 4, respectively. The isentropic efficiency of each compressor is 85%. The air is cooled to 300 K in the heat exchanger between the compressors. The temperature at the combustor exit is 1600K. The isentropic efficiency of the turbine is 80%. The system also includes a regenerative heat exchanger with an effectiveness of 90%.

(a) Calculate the net power output and the thermal efficiency of the cycle.  
(b) Draw the T-s diagram for the cycle and label the states.

SP 28. Air at $p_i = 95$ kPa, $T_i = 310$ K with a mass flow rate of 100 kg/s enters the compressor of a power-generating gas turbine. The gas turbine system has a single stage of compression, a main combustor, a reheat combustor, and a regenerative heat exchanger. The compressor pressure ratio is 42. The isentropic efficiency of the compressor is 0.85 and the isentropic efficiency for the each turbine expansion stage is 0.90. The temperature at the exit of the first combustor is 1800 K and at the exit of the reheat combustor it is 1700 K. The ratio of the entrance to exit pressure is 7 for the high pressure turbine and 6 for the low pressure turbine. The regenerative heat exchanger effectiveness is 0.75.

(a) On a T-s diagram, label the states 1, 2s, 2, 3, 4, 5, 5s, 6, 7s, 7, and 8 and indicate the process path with arrows. 
(b) Calculate the thermodynamic efficiency and net power output for the cycle.
SP 29. Air at 10 kPa, 200 K, and 220 m/sec (state a) enters the diffuser of a turbojet engine. The pressure ratio for the compressor is 25 \( (p_2/p_1 = 25) \) and the isentropic efficiency of the compressor is 0.85. Heat is added in the constant-pressure combustor and the temperature at the turbine inlet is \( T_3 = 1500 \) K. The isentropic efficiency of the turbine is 0.85, and the magnitude of the actual turbine work is equal to the magnitude of the actual compressor work. After the turbine expansion, heat is added in the constant-pressure afterburner to bring the fluid temperature back up to 1400 K. Assume that there is no pressure drop between the turbine exit and the afterburner inlet. Assume that the flow in the nozzle and diffuser is isentropic, neglect the fluid kinetic energy except at the diffuser inlet and nozzle exit, neglect potential energy throughout.

(a) Calculate the nozzle exit velocity.
(b) Calculate the propulsive efficiency.
SP 30. Air and a pure gaseous hydrocarbon fuel represented by \( \text{C}_x\text{H}_y \) at the room temperature and 1 atm enter a steady-state combustor, giving combustion products with a dry molar analysis (water removed from products) of 8.31% \( \text{CO}_2 \), 8.31% \( \text{O}_2 \), and 83.37% \( \text{N}_2 \). It is known that the fuel might be \( \text{CH}_4 \), \( \text{C}_2\text{H}_6 \), \( \text{C}_2\text{H}_4 \), \( \text{C}_3\text{H}_8 \), or \( \text{C}_2\text{H}_2 \).

(a) Find the chemical formula for the fuel.

(b) Determine the percent of theoretical air used.