

Qualifying Examination Fall 2016

Thermodynamics

Logistics Notes:

- Duration: 2.5 hours.
- Open book (the textbook provided during the exam).
- Calculator is allowed.
- Laptops, cell phones, and similar electronic devices are not allowed.
- State your assumptions.

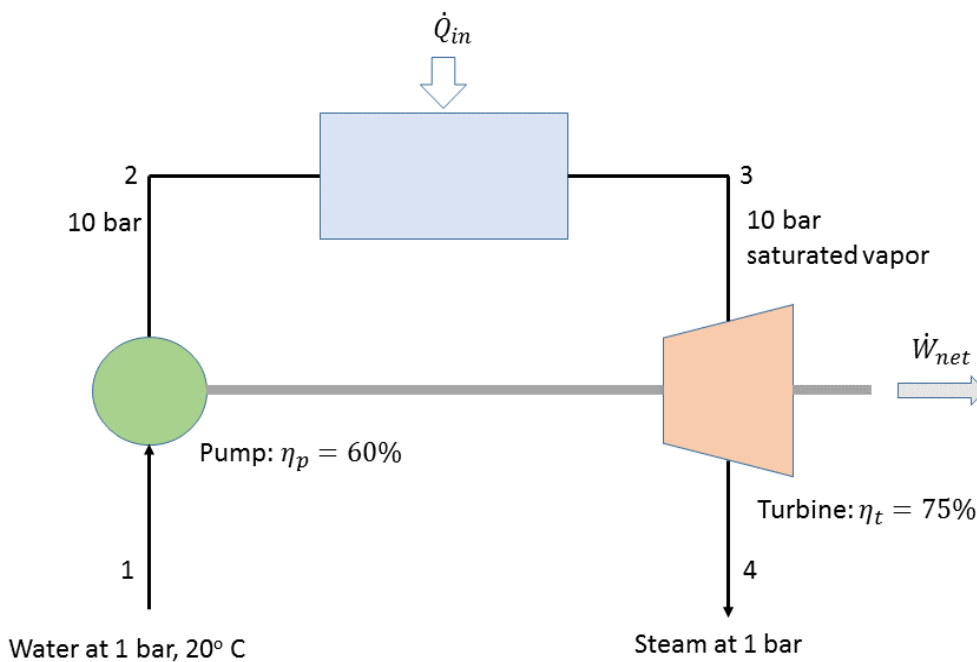
Problem 1

(30 points) Air enters a compressor operating at steady state at 1.5 bar, 30°C with a volumetric flow rate of 2 m³/min and is compressed to 4 bar, 165°C. The power input is 3.5 kW. The ambient temperature is 25°C. Employing the ideal gas model and ignoring kinetic and potential energy effects, obtain the following results:

- a) Determine the heat transfer rate, in kW, and the change in specific entropy from inlet to exit in kJ/kg·K.
- b) Calculate the rate of entropy production, in kW/K.
- c) If the daily cost of exergy destruction is \$0.1 per kW·h, determine the daily cost to operate the compressor.
- d) Comment on a possibility of such a compressor.

Problem 2

(40 points) Three devices are operating at steady state: a pump, a boiler, and a turbine as shown in Figure 2. The turbine provides the power required to drive the pump and also supplies power to other devices. For adiabatic operation of the pump and turbine, and ignoring kinetic and potential energy effects, determine, in kJ per kg of water steam flowing a) work required by the pump, b) the net work developed by the turbine, and c) the heat transfer to the boiler (η_p and η_t are isentropic efficiencies of the pump and the turbine, respectively).



Problem 3

(30 points) 3 kg of air within a piston-cylinder assembly execute a Carnot power cycle with maximum and minimum temperatures of 650K and 320K, respectively. The heat transfer to the air during the isothermal expansion is 70 kJ. At the end of the isothermal expansion, the pressure is 600 kPa and the volume is 0.5 m³. Assuming the ideal gas model for the air, determine:

- a) the thermal efficiency;
- b) the pressure and volume at the beginning of the isothermal expansion;
- c) The heat transfer to the air during the isothermal compression;
- d) The entropy changes during each stage of the cycle;
- e) Sketch the cycle on p-V and S-T diagrams and show the cycle work on each diagram.