Qualifying Examination Fall 2019

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 for each problem.

Problem 1
(50 points)
An inventor claims to have developed a device requiring no work or heat transfer input, yet able to produce hot and cold air streams at steady state. The device has one input and two exits. Air enters the device at $T = 20^0C$ and pressure of 3 bar and leaves the device at $T = 60^0C$ through one of the exits and at $T = 0^0C$ through the other exit. Pressure at both exits is the same: 2.7 bar. The ideal gas model can be used for the air. Heat losses through the device walls and kinetic and potential energy effects can be neglected. Evaluate this claim.

Problem 2
(35 points)
A quantity of water within a piston-cylinder assembly executes a Carnot power cycle. During isothermal expansion, the water is heated from saturated liquid at 50 bar until it is a saturated vapor. The vapor then expands adiabatically to a pressure of 5 bar while doing 364.31 kJ/kg of work.

a. Sketch the cycle on p-v coordinates.
b. Evaluate the heat transfer per unit mass and work per mass for each process, in kJ/kg.
c. Evaluate the thermal efficiency.

Problem 3:
(15 points)
At steady state, a 750-MW power plant receives energy by heat transfer from combustion of fuel at an average temperature of 317 °C. As shown in Fig. 1, the plant discharges energy by heat transfer to a river whose mass flow rate is 1.65 x 105 kg/s. Upstream of the power plant the river is at 17 °C. Determine the increase in the temperature of the river, T, traceable to such heat transfer, in °C, if the thermal efficiency of the power plant is the Carnot efficiency of a power cycle operating between hot and cold reservoir at 317 °C and 17 °C, respectively.

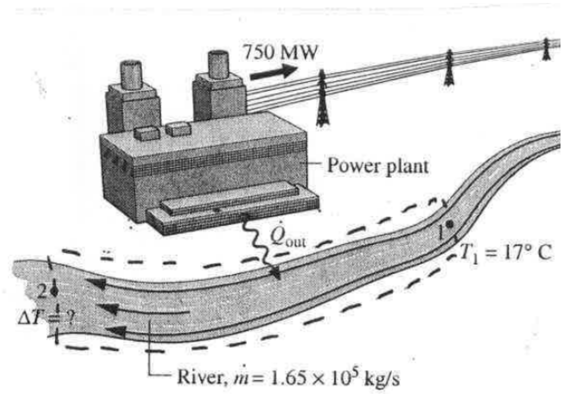

Fig. 1 Power plant discharging energy to a river