

Student # _____

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Ph.D. Qualifying Exam in Heat Transfer

- One open book.
- Answer all questions.
- All questions carry the same weight.

Exam prepared by

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Problem 1:

A home pressure cooker employs a pressure regulator to limit the internal gauge pressure to 99 kPa. A sufficient quantity of water is added to the pressure cooker before cooking begins to insure that saturation conditions prevail while cooking is in progress. Suppose that when the operating pressure is first reached, the pressure cooker contains 0.25 kg of a mixture of liquid water and water vapor and that the volume of the cooker is 0.004 m^3 . Determine:

- a. the temperature at which cooking occurs,
- b. the mass of liquid and the mass of vapor present when the operating pressure is reached, and
- c. the maximum allowable heat transfer rate to the cooker if the final mass of liquid in the cooker at the end of 20 min is required to be equal to one-half of the initial mass of liquid.

Problem 2:

A rigid tank initially contains 0.5 kg of steam at 800 kPa and 280 °C. It is connected through an insulated valve to a steam supply line that is capable of supplying steam at a constant condition of 1.4 MPa and 280 °C. The valve is opened so that the supply of steam flows slowly into the tank until the pressure and temperature inside are 1.2 MPa and 280 °C. Determine

- a) the final mass of steam in the tank and
- b) the amount of heat transfer to or from the steam in the tank during the process.

Problem 3:

Nitrogen enters a turbine at 600 kPa and 1000 K and exhausts at a pressure of 100 kPa. During this process the work output of the turbine per unit mass of nitrogen is 380 kJ/kg. Heat loss from the nitrogen in the turbine is 40 W/kg to the surroundings at 298 K. For negligible changes in kinetic and potential energies of the nitrogen, determine:

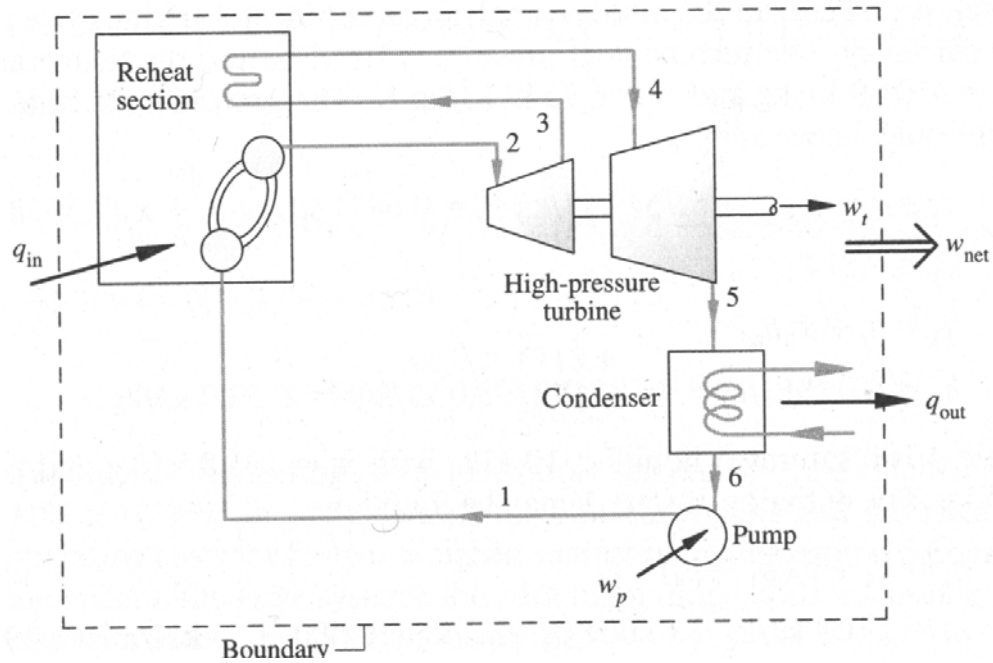
- a. the irreversibility associated with the process and
- b. the reversible work.

Problem 4:

One kg water at 500 °C and 1 kg saturated water vapor both at 200 kPa are mixed in a constant pressure and adiabatic process. Find the final temperature and the entropy generation for the process.

Problem 5:

Consider an ideal reheat Rankine cycle, shown below, with a steam generator pressure of 10 MPa, temperature of both turbine inlets 550 °C, reheat pressure (entry to low pressure turbine) 1 MPa, and a condenser pressure of 10 kPa. Determine the cycle efficiency and compare it to an ideal Rankine cycle without reheat.



Problem 6:

An adiabatic air compressor is to be powered and driven by a direct-coupled (through a shaft) adiabatic steam turbine that is also driving a generator. Steam enters the turbine at 12.5 MPa and 500 °C at a rate of 25 kg/s and exits at 10 kPa and a quality of 0.92. Air enters the compressor at 98 kPa and 295 K at a rate of 10 kg/s and exits at 1 MPa and 620 K. Determine (i) net power developed by the steam turbine, (ii) net power consumed by the compressor and (iii) net power delivered to the generator by the turbine.

