

Student Code Number: _____

Ph.D. Qualifying Exam

Thermodynamics

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Directions: Work all six problems. Problems are equally weighted. Each student is allowed one book and five sheets of notes.

Problem 1

A turbo-charger is often used to increase the power output of an internal combustion engine. A turbo-charger consists of a compressor that increases the energy of the air coming into the engine, mechanically tied to a turbine that is driven by the engine exhaust. The work output of the turbine is used as the work input for the compressor or

$$W_{\text{comp}} = -W_{\text{turb}}$$

Air enters the compressor side at 290 K and 100 kPa. If air enters the turbine side of the turbo-charger at 430 K and 400 kPa and leaves at 100 kPa, determine

- (a) the work of the turbine (in kJ/kg) (40%)
- (b) the exit temperature and pressure for the compressor (60%)

Problem 2

An adiabatic tank of compressed air with volume 100 m^3 at 600 kPa and 500 K is attached to an ideal turbine that exhausts to a pressure of 100 kPa . Air is allowed to flow through the turbine until the conditions in the tanks become 350 kPa and 350 K .

- (a) How much shaft work can be produced by this system? (90%)
- (b) What is the average temperature of the exhaust during the process? (10%)

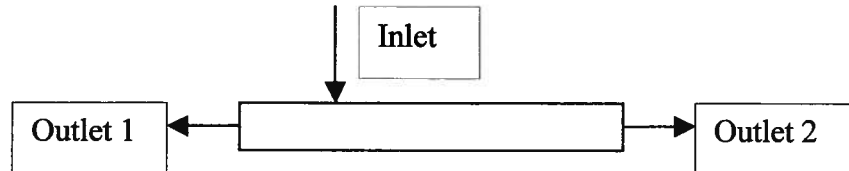
Problem 3

Consider a steam power plant operating on the Rankine cycle with two open feedwater heaters. Steam enters the turbine at 17.5 MPa and 800°C and 15 kg/s. Steam is extracted at 2 MPa (Open Feedwater Heater #2) and 1 MPa (Open Feedwater Heater #1) to supply the two open feedwater heaters. The exhaust of the turbine (goes to the condenser) is at 0.05 MPa.

- (a) Sketch a layout of the power plant. (25%)
- (b) Determine the power output (in kW) of the turbine. (75%)

Problem 4

An adiabatic tube, measuring 1 m in length and 15 cm in diameter, has compressed air introduced tangentially, at a point along its midsection. The inlet air is at 600 kPa and 20 °C. There are no moving parts or chemical reactions inside the tube. You are told that 2 g/s of air exits at one end with a pressure of 1 atm and temperature of 0 °C. Air exits from the other end at 1 atm and 60 °C. Is this possible? Use appropriate calculations to justify your answer.



Problem 5

Two moist air streams, one at $1200 \text{ m}^3/\text{hr}$, $50 \text{ }^\circ\text{C}$, $\Phi = 20\%$ and 1 atm and the other at $300 \text{ m}^3/\text{hr}$, $20 \text{ }^\circ\text{C}$, $\Phi = 90\%$ and 1 atm , enter a chamber and mix with each other. Saturated liquid water at 30°C either enters and is sprayed into the mixture or condenses and leaves. The new moist air mixture leaves the chamber at $30 \text{ }^\circ\text{C}$, $\Phi = 60\%$ and 1 atm .

- a) How much saturated liquid water enters or leaves the chamber? (50%)
- b) What is the heat transferred to or from the chamber? (50%)

Problem 6

A mixture of butane and 180% theoretical air enters a combustion chamber at 298 K and 300 kPa. The products of combustion exit the chamber at 1200 K and 300 kPa. Assume complete combustion. Calculate the heat transferred from the combustion chamber, per kilomole of butane.