# Ph.D. Qualifying Examination
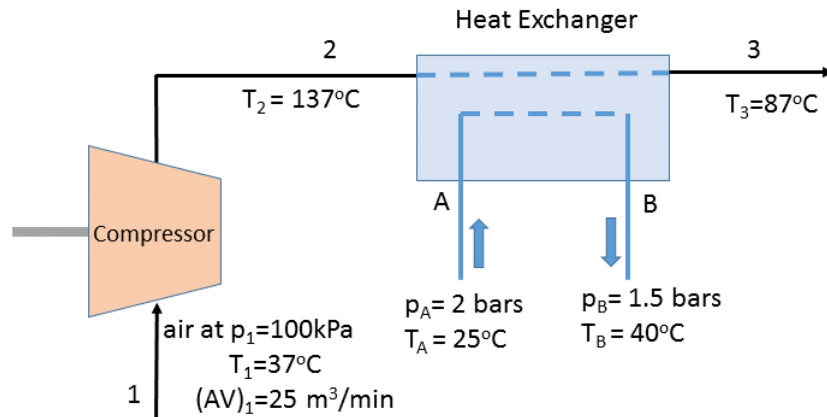
# Thermodynamics

# Spring 2017

<u>Logistics Notes:</u>

- Time allowed: 2 hours.
- Exam is open-book (one book) and closed-notes; one sheet (8.50 in.×11.00 in.) of notes is allowed.
- Calculators are allowed.
- Laptops, cell phones, and similar electronic devices are not allowed.

Problem 1

Air as an ideal gas flows at steady state through the compressor and heat exchanger shown below. Data for the various flow streams are shown in the figure. Heat transfer to the surroundings can be neglected, as can all kinetic and potential energy effects. $R_{air} = \bar{R}/M = (8.314 \text{ kJ/kmol·K})/(28.97 \text{ kg/kmol})$

a) Calculate the compressor power, in kW

b) Calculate the mass flow rate of the cooling water, in kg/s.



Heat Exchanger

2
$T_2 = 137°C$

3
$T_3 = 87°C$

A    B

Compressor

$p_A = 2$ bars    $p_B = 1.5$ bars
$T_A = 25°C$    $T_B = 40°C$

air at $p_1 = 100$kPa
$T_1 = 37°C$
1    $(AV)_1 = 25 \text{ m}^3/\text{min}$

Problem 2

In a boiler, heat is transferred from the products of combustion to the steam. The temperature of the products of combustion decreases from 1100°C to 550°C while the pressure remains constant at 0.1 MPa. The average constant-pressure specific heat of the products of combustion is 1.09 kJ/kg K. The water enters at 0.8 MPa, 150°C and leaves at 0.8 MPa, 250°C.



Control Surface

Products
1100°C
3
500°C
4
Heat Transfer

0.8 MPa
$H_2O$
150°C
1
0.8 MPa
250°C
2
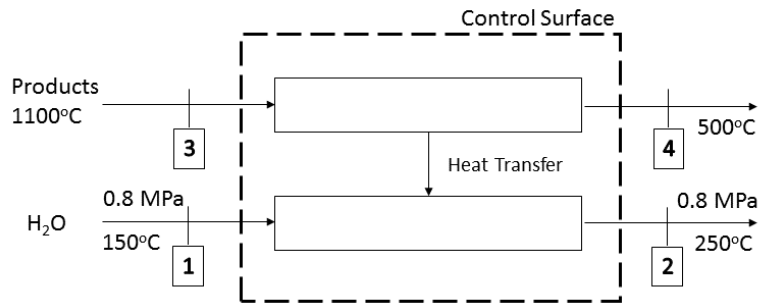
a. Draw the temperature-entropy (T-S) diagram for problem 2.

b. Determine the irreversibility for this process per kilogram of water evaporated.