EXAM 2

INSTRUCTIONS

- This is a closed book and closed notes exam. Answer as many questions as you can in the allotted time. Do not hesitate to ask questions if you do not understand a problem statement. For your own benefit, please write clearly and legibly. Maximum credit for each problem is indicated below. To receive full credit for a problem, you must follow instructions, show all work, and write the answers in the appropriate boxes.

- For Problems 1 and 2, significant credit will be given if you start with the basic equation(s), list all assumption(s), and illustrate the method by which you propose to solve the problem correctly. Some parts of Problem 3 will be given no partial credit.

- Do not write on the back of any page. Material on the back of a page may not be graded. If additional pages are needed, ask for additional pages. Insert the extra pages in their proper order and staple them to the exam.

- The use of PDAs, Blackberry-type devices, cell phones, laptop computers, or any other sources of communication (wireless or otherwise) are strictly prohibited during examinations. Doing so is cheating. If you bring a cell phone or other communication devices to the examination, they must be turned off prior to the start of the exam, placed in your backpack, and the backpack stored below your seat, and only picked up as you leave the examination room for the final time. They are not to be turned on again until after you have exited the examination room. Otherwise it will be considered a form of cheating and treated as such.

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Problem 1: (20 points)

Given:
A rigid, insulated tank having total volume of 2 m³ is initially divided into two equal chambers as shown below. Chamber A contains 2 kg of liquid A which has specific heat of 2.0 kJ/kg-K and is initially at a temperature of 100°C and a pressure of 1 atm. Chamber B contains 3 kg of liquid B which has specific heat of 5.0 kJ/kg-K and is initially at a temperature of 50°C and a pressure of 1 atm. The partition dividing the two liquids is removed and the liquids are allowed to come to an equilibrium temperature during a constant pressure process at 1 atm. Assume that the two liquids completely mix in each other.

Find:
Determine the final temperature (°C) inside the tank.

Final temperature inside the tank = °C

You must indicate system on the above sketch and apply the first law of thermodynamics to receive complete credit.

Assumptions:

Basic Equations:
Problem 2: (40 points)

Given:
Air (mass flow rate $\dot{m}_{air,\text{main}}$) passing through a gas turbine, heat exchanger, and nozzle is shown below. Air exiting the turbine stage is heated inside a heat exchanger using another stream of air (mass flow rate $\dot{m}_{air,\text{HEX}} = 18.9 \frac{\text{kg}}{\text{s}}$). The velocity of air exiting the heat exchanger and entering the nozzle is negligibly small. The pressures and temperatures of air at various points within the system are indicated below. Assume that air can be considered ideal gas at these conditions. Do not interpolate; use the closest values for properties of air from appropriate table. You must show appropriate control volumes for each component.

Find:
(a) Determine the mass flow rate of air ($\dot{m}_{air,\text{main}}$) (kg/s) passing through the turbine-heat exchanger-nozzle system.

(b) What is the temperature of air ($T_3$) (K) at the inlet of the nozzle?

(c) Calculate the velocity (m/s) of air at the exit of the nozzle.
Assumptions:
Turbine

Heat Exchanger

Nozzle

Basic Equations:
Turbine

Heat Exchanger

Nozzle

Solution:
Problem 2 Solution (continued):
Problem 3: (40 points)

Write your answers in the boxes provided for each question. Only the answers written in the boxes will be graded. For Problem 3 only, you do not have to list assumptions; however, you must show work (basic equations and calculations to support your answers) to receive full credit.

(a) Water exits a pump at 15 bar and 75°C.

(a1) What is the specific volume (m³/kg) of water at the pump exit?
(2 points)

(a1) v = m³/kg

(a2) What is the specific internal energy (kJ/kg) of water at the pump exit?
(2 points)

(a2) u = kJ/kg

(a3) What is the specific enthalpy (kJ/kg) of water at the pump exit?
(2 points)

(a3) h = kJ/kg

(b) A particular gas has molecular weight of 10 kg/kmol. The critical pressure and critical temperature of the gas are known to be 0.6 MPa and 515.5 K, respectively. Indicate by circling one of the answers below whether the gas should be considered “ideal gas” when its pressure is 0.51 MPa and its temperature is 541.3 K. You must provide justification to receive any credit.
(5 points)

(b) Yes  No  Can’t decide
(c) For the gas described in part (b), indicate by circling one of the answers below, the closest value of the specific volume of the gas \((\text{m}^3/\text{kg})\) when its pressure is 0.51 MPa and its temperature is 541.3 K. You must show work with an appropriate equation to receive any credit.

(5 points)

\[(c) \quad 0.42 \quad 0.62 \quad 0.82 \quad 1.02\]

(d) Air flows through a single-inlet, single-exit device at steady state. The specific volume at the exit is twice the specific volume at the inlet. The area at the exit is twice the area at the inlet.

(d1) What happens to mass flow rate of air from inlet to exit?
(2 points)

(d1) increases decreases remains the same

(d2) What happens to velocity of air from inlet to exit?
(2 points)

(d2) increases decreases remains the same

(d3) What happens to volumetric flow rate of air from inlet to exit?
(2 points)

(d3) increases decreases remains the same
(e) For a particular ideal gas, the specific heat at constant volume is known to be 25 kJ/kg-K. The specific heat ratio \(k\) of this ideal gas is 1.4. Answer the following questions.

(e1) Calculate the specific heat at constant pressure (kJ/kg-K) for this ideal gas.
\[
\text{(e1) Specific heat at constant pressure} = \text{kJ/kg-K}
\]

(2 points)

(e2) 2 kg of the above ideal gas is heated at constant volume inside a piston-cylinder device from 300 K to 500 K. Assuming changes in kinetic and potential energy are negligible, determine the amount of heat transfer (kJ) to the gas during the constant volume process. You must apply energy balance to receive full credit.
\[
\text{(e2) Heat transfer to the gas during constant volume process} = \text{kJ}
\]

(3 points)

(e3) 2 kg of the same ideal gas is heated at constant pressure inside a piston-cylinder device from 300 K to 500 K. Assuming changes in kinetic and potential energy are negligible, determine the amount of heat transfer (kJ) to the gas during the constant pressure process. You must apply energy balance to receive full credit.
\[
\text{(e3) Heat transfer to the gas during constant pressure process} = \text{kJ}
\]

(5 points)
(f) R134a enters a throttling valve as saturated liquid at 2 bar. The refrigerant exits the throttling valve at 1 bar. Determine the change in temperature (°C) of R134a from inlet to exit.

(5 points)

(f) Change in temperature of R134a from inlet to exit = °C

(g) Air (Z = 1) enters a throttling valve at 2 bar and 27°C. Air exits the throttling valve at 1 bar. Determine the change in temperature (°C) of air from inlet to exit.

(3 points)

(g) Change in temperature of air from inlet to exit = °C