Midterm #1

MEMS 0051 - Introduction to Thermodynamics
Summer 2020

Assigned: June 5th, 2020
Due: June 11th, 2020, 3:55 pm via Gradescope (for written) and Canvs for MATLAB code

Rules

The following listed rules, in addition, but not limited to, those listed on the syllabus, those listed on page 3, and those outlined by Pitt's Academic Integrity Policy, apply to this examination:

1. This test is open notes, open book, open lecture videos, open homework and homework solutions, open quiz and quiz solutions, and you are able to reference previous assessment materials;
2. You can direct general questions to either the MEMS 0051 Slack, or email Dr. Barry or Mr. Dosse. A general question constitutes a point of clarification with a question, for example "Is y in Problem #3 the displacement?" Specific questions about how to solve a problem, pertinent equations, related to general guidance, etc., are *not* permitted;
3. You are *not* to communicate with *any* other student about this exam. Period;
4. You are *not* to use any online resources, such as Chegg, Quora, etc., or any form of thermodynamic property calculator. Seeking external assistance in the form of posting this exam, posting questions from this exam, asking questions pertaining to the problems within the exam, etc., is in direction violation of the Academic Integrity policy.
5. Unsubstantiated results will be marked incorrect;
6. You must complete the Academic Integrity Statement and include it with your exam submission for your exam to be graded.

Problem #1

(20 pts.) Water contained with a piston-cylinder assembly undergoes a series of processes from an initial to a final state. The water is initially at 1,273 [kPa] and a temperature of 554 °C. It is cooled in a constant pressure process until it reaches a saturated vapor state. Thereafter, it is cooled in a constant volume process until the temperature reaches 137.2 °C. Lastly, it is cooled in a constant-pressure process until the temperature reaches 20 °C. Determine:

a) The overall work of this process;
b) The overall heat transfer of this process.

Problem #2

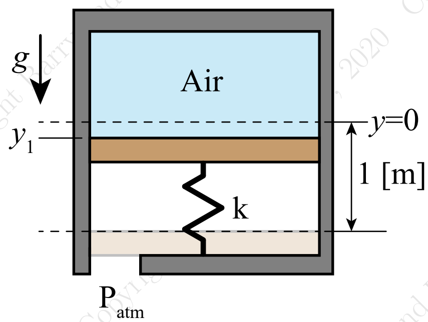
(20 pts). Consider two rigid tanks connected by a valve that is initially closed. Tank A contains water at 400 [°C] and with a specific volume of 0.25480 [m^3/kg]. Tank B contains 8.2 [kg] of water at a temperature of 110 [°C] and with a quality of 0.1. The total volume of both tanks is 3 [m^3]. The valve is now opened and the water mixes until it reaches equilibrium. If the final pressure in the tanks is approximately 600 [kPa], determine the following:

a) The initial mass, m, of water in each tank;
b) The volume, $\forall$, of each tank;
c) The initial pressure, P, temperature, T, and quality, x (if applicable) of the water in each tank;
d) The final pressure, P, temperature, T, and quality, x (if applicable) of the water after the valve is opened;
e) The heat transferred and work performed during the process.

Problem #3

(30 pts.) A piston-cylinder is filled with 0.187 [kg] of air at a pressure and temperature of 124 [kPa] and 161 [°C]. The piston is exposed to an atmospheric pressure of 100 [kPa] and is supported by a non-linear spring, i.e. a spring that does not follow Hooke's Law, as shown in the figure. The spring can be compressed a maximum of 1 [m], at which point it is pressed against the bottom of the cylinder and cannot deflect any further. The force in the spring is governed by the function $F_s = -k\sqrt{y}$, where k is the spring constant and is equal to 10 [kN/m$^{1/2}$]. The piston has an area of 0.1 [m^2], a thickness of 0.1 [m], and a density of 7,820 [kg/m^3]. In addition, the area can be considered the same on both sides of the piston. The air is first heated until it reaches a pressure of 225 [kPa]. The air is next cooled, reducing the volume, and the spring deflects upwards by 1.01 [m]. Finally, the air undergoes a polytropic process with an index of -6.77. If the net work of these processes is 1.82 [kJ], Assuming gravity is equal to 9.81 [m/s^2], determine the following:

a) The initial deflection of the spring, y_1;
b) The net heat transfer, Q_{net};
c) The final pressure, P, and temperature, T, of the air;
d) If the air can be treated as an ideal gas. Use P_c = 3,774 [kPa] and T_c = 132.41 [K] for the critical pressure and temperature, respectively.



Note: Image not drawn to scale.

Problem #4

(30 pts). A 2,500 [kg] steel forging is quenched in an 10,000 [kg] bath of oil. If the steel is initially at a temperature of 1,500 [K], and the oil is initially at a temperature of 350 [K], determine the final temperature of the system using the integral average of the specific heats. Assume there is no heat transfer to the surroundings. Note, you will have to fit the data given using "cftool" in MATLAB. You should fit the data using a polynomial fit. You will increase the order of the fit until the Adjusted R-squared value is near 0.99. Your MATLAB script must be submitted with the file name being your Pitt username, for example "MMB49.m".

The specific heat of steel and oil versus temperature are given in the table to the right:

T_{steel} [K]	C_{steel} [kJ/kg-K]	T_{oil} [K]	C_{oil} [kJ/kg-K]
273.2	1.006	313	2.271
280	1.006	323	2.42
288.7	1.006	333	2.59
300	1.006	343	2.757
320	1.007	353	2.852
340	1.009	363	2.976
360	1.01	373	3.092
380	1.012	383	3.197
400	1.014	393	3.293
500	1.03	403	3.337
600	1.054	413	3.483
700	1.075	423	3.59
800	1.099	433	3.701
900	1.121	443	3.778
1100	1.159	453	3.868
1500	1.21	463	3.91
1900	1.241	–	–

Academic Integrity Statement:

I hereby attest that I have received no assistance (from a friend, from another student, from an on-line resource, such as Chegg, etc.), and that I have provided no assistance to another student, during this exam. All the work presented within is solely my own work.

Signature: ____

Date: ____________________________