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ROSE-HULMAN
INSTITUTE OF TECHNOLOGY

Name ______________________________

ME301 – Applications of Thermodynamics

Exam 1

Oct 4, 2019

Circle section: **01** [3rd Mertz] **02** [3rd Thom] **03** [4th Thom] **04** [3rd Cloutier] **05** [4th Cloutier]

Rules:
- Closed book/notes exam.
- Help sheet allowed. (8-1/2 x 11" sheet of paper, one side, handwritten; may not contain worked out example problems)
- Maple, Excel, and MATLAB are allowed on your laptop, but nothing may be prepared before the exam.
- Either open property tables (hardcopies) or open Property Calculator Programs on your laptop.

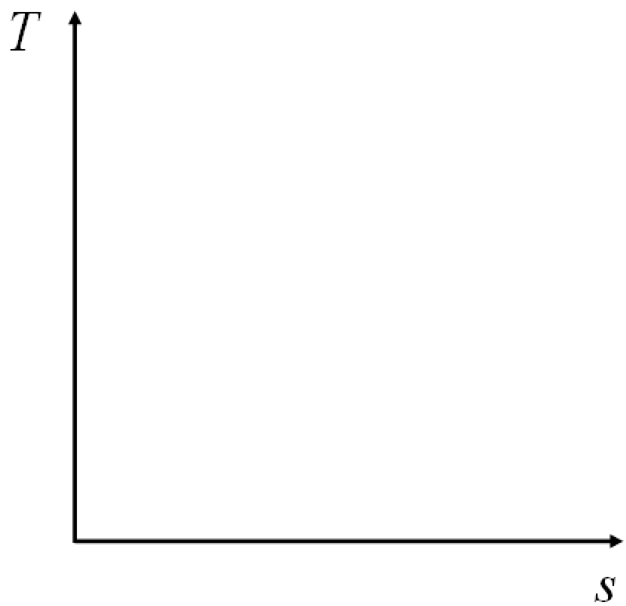
Instructions:
- Show all work for complete credit.
- Work in symbols first, plugging in numbers and performing calculations last.

Problem 1	______/ 26
Problem 2	______/ 39
Problem 3	______/ 35
Total	______/100

PROBLEM 1 [26 points]

(a) [10 pts] Water, initially a superheated vapor at a pressure P and temperature T_1, passes through a turbine and leaves at a pressure P.

1) On the T-s diagram shown below, draw the two lines of constant pressure, P and P_2.
2) On the T-s diagram shown below, draw the process from State (1) to State (2s), assuming the turbine is isentropic and that the water leaves as a saturated vapor.
3) On the T-s diagram shown below, draw the process from State (1) to State (2), assuming the turbine has an isentropic efficiency less than 1.
4) **True | False** In the case of the actual turbine (part 3), the area under the curve for Process (1) to (2) represents the heat transfer associated with Process (1) to (2).



(b) [8 pts] Answer the following True/False questions:

True | False A change in entropy can be negative.

True | False When work is produced by a system, it necessarily changes the exergy of a system.

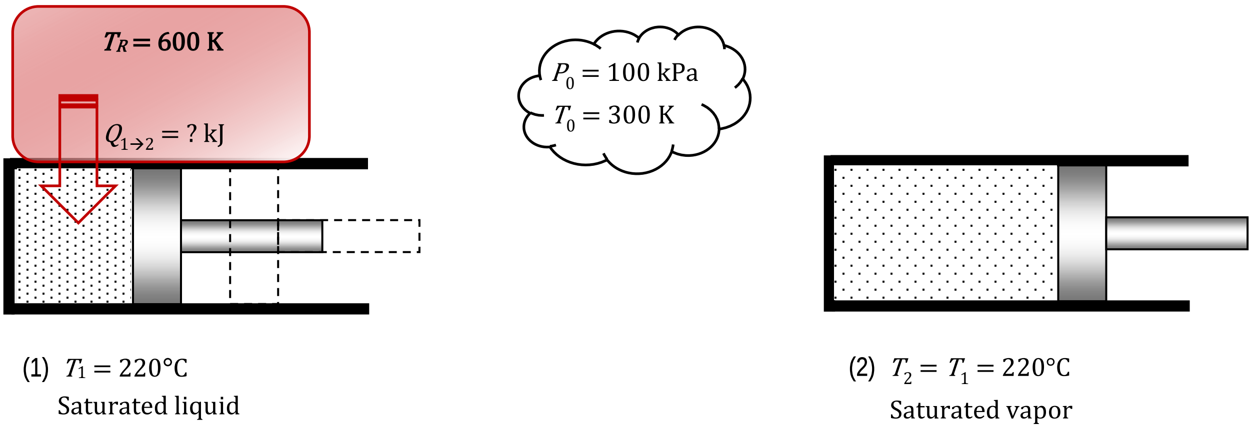
True | False If a substance is at the same temperature and pressure as its environment, then it necessarily has no exergy.

True | False A reversible process yields no exergy destruction.

(c) [8 pts] Air flows through a turbine with an exergetic efficiency of 65% and a mass flow rate of 1 kg/s. If the air's specific flow exergy decreases by 300 kJ/kg as it travels through the turbine, determine the power produced by the turbine in kW.

PROBLEM 2 [39 points]

A mass of m=0.3 kg of steam (water) is contained in a piston-cylinder. Initially a saturated liquid at 220°C, heat transfer is added to the water until it becomes a saturated vapor via a constant temperature process. The heat transfer comes from a reservoir maintained at 600 K. The temperature and pressure of the surroundings (environment) are 300 K and 100 kPa, respectively.



(a) Show the process and the two states on a P-v diagram. Be sure to include the vapor dome and lines of constant temperature.

(b) Find the compression/expansion work out of the water and the heat transfer into the water in kJ.

(c) Find the useful work out of the water in kJ.

(d) Using the accounting of exergy (i.e., *not* the accounting of entropy) find the exergy destroyed in the process in kJ.

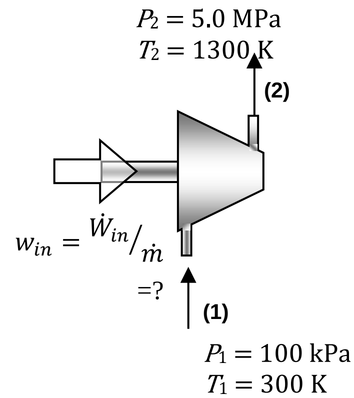
Problem 3 [35 points]

An adiabatic compressor compresses air with a temperature and pressure of 300 K and 100 kPa to a pressure and temperature of 5 MPa and 1300 K, respectively. Treat air as an ideal gas with variable specific heats and $R_{air} = 0.287$ kJ/kg-K. Find

(a) the power per unit mass flow rate needed to compress the air in kJ/kg,

(b) the issentropic efficiency of the compressor, and

(c) the rate of entropy generation per unit mass flow rate in the compressor in kJ/kg-K.



Length

1 ft = 12 in = 0.3048 m = 1/3 yd
1 m = 100 cm = 1000 mm = 39.37 in = 3.2808 ft
1 mile = 5280 ft = 1609.3 m

Mass

1 kg = 1000 g = 2.2046 lbm
1 lbm = 16 oz = 0.45359 kg
1 slug = 32.174 lbm

Temperature Values

(T/K) = (T/°R) / 1.8
(T/K) = (T/°C) + 273.15
(T/°C) = [(T/°F) – 32]/1.8
(T/°R) = 1.8(T/K)
(T/°R) = (T/°F) + 459.67
(T/ °F) = 1.8(T/°C) + 32

Temperature Differences

$(\Delta T/^\circ R) = 1.8(\Delta T/K)$

$(\Delta T/^\circ R) = (\Delta T/^\circ F)$

$(\Delta T/K) = (\Delta T/^\circ C)$

Volume

1 m^3 = 1000 L = 10^6 cm^3 =10^6 mL = 35.315 ft^3
= 264.17 gal
1 ft^3 = 1728 in^3 = 7.4805 gal = 0.028317 m^3
1 gal = 0.13368 ft^3 = 0.0037854 m^3

Volumetric Flow Rate

1 m^3/s = 35.315 ft^3/s = 264.17 gal/s
1 ft^3/s = 1.6990 m^3/min = 7.4805 gal/s
= 448.83 gal/min

Force

1 N = 1 kg·m/s^2 = 0.22481 lbf
1 lbf = 1 slug·ft/s^2 = 32.174 lbm·ft/s^2
= 4.4482 N

Pressure

1 atm = 101.325 kPa = 1.01325 bar
= 14.696 lbf/in^2
1 bar = 100 kPa = 10^5 Pa
1 Pa = 1 N/m^2 = 10^{-3} kPa
1 lbf/in^2 = 6.8947 kPa = 6894.7 N/m^2 ;
[lbf/in^2 = "psi"]

Energy

1 J = 1 N·m = 1 Pa·m^3
1 kJ = 1000 J = 737.56 ft·lbf = 0.94782 Btu
1 Btu = 1.0551 kJ = 778.17 ft·lbf
1 ft·lbf = 1.3558 J

Energy Transfer Rate

1 kW = 1 kJ/s = 737.56 ft·lbf/s = 1.3410 hp = 0.94782 Btu/s
1 Btu/s = 1.0551 kW = 1.4149 hp
= 778.17 ft·lbf/s
1 hp = 550 ft·lbf/s = 0.74571 kW
= 0.70679 Btu/s

Specific Energy

1 kJ/kg = 1000 m^2/s^2
1 Btu/lbm = 25037 ft^2/s^2
1 ft·lbf /lbm = 32.174 ft^2/s^2