CM

ROSE-HULMAN
INSTITUTE OF TECHNOLOGY

Name

ME301 – Applications of Thermodynamics

Exam 1

Sep 28, 2018

Circle section: **01** [6th Cloutier] **02** [5th Thom] **03** [6th Thom] **04** [5th Lui] **05** [6th Lui]

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.

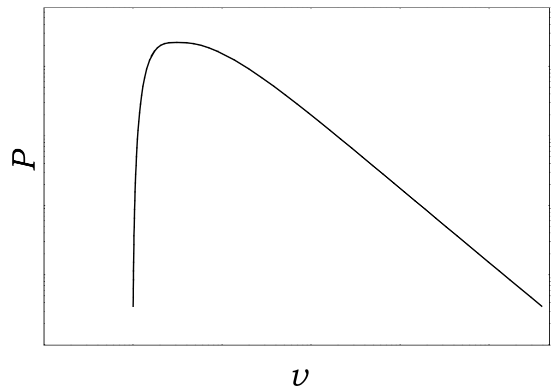
Instructions:

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

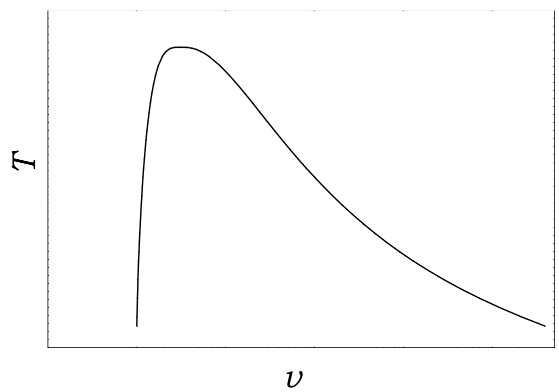
Problem 1	______/ 25
Problem 2	______/ 40
Problem 3	______/ 35
Total	______/100

PROBLEM 1 [25 points]

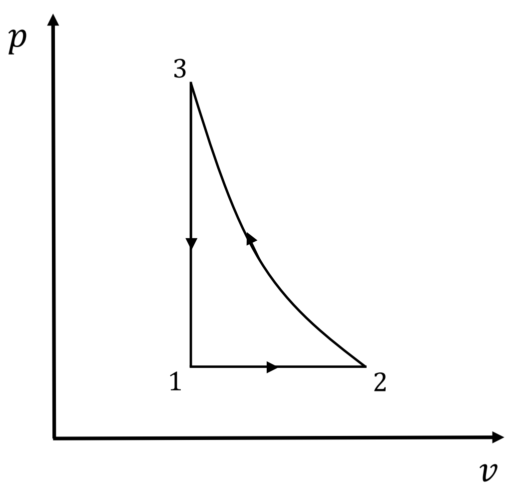
(a) [3 pts] Below is a *P*-*v* diagram showing the vapor dome. Draw two lines of constant temperature on the plot labeled T_1 and T_2, where $T_1 > T_2$.



(b) [3 pts] Below is a *T*-*v* diagram showing the vapor dome. Draw two lines of constant pressure on the plot labeled P_1 and P_2, where $P_1 > P_2$.



(c) [3 pts] Circle the correct answer. Which process shown below has the largest magnitude of work?



a) Process 1 → 2

b) Process 2 → 3

c) Process 3 → 1

d) Insufficient information to conclude

(d) [3 pts] Circle the correct answer. Water, initially a saturated liquid, is heated at a constant pressure until it becomes a saturated vapor. During this process:

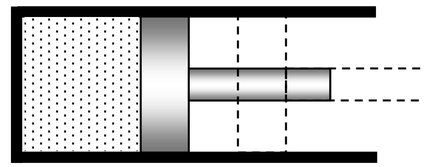
- The temperature will remain constant
- The temperature will not remain constant
- There is insufficient information to determine the temperature's behavior

(e) [8 pts] 0.4 kg of air in a closed piston-cylinder, initially at a pressure of 250 kPa and a specific volume of $0.75\,\frac{\text{m}^3}{\text{kg}}$, expands in a constant pressure process until its volume doubles. Calculate the useful work done (in kJ) by the air during this process. The environment is at $P_0 = 100$ kPa and $T_0 = 25°$C.

(f) [5 pts] Determine the magnitude and direction of exergy transfer by 50 kJ of heat transfer out of a system crossing a system boundary at 30°C. The temperature and pressure of the environment are 25°C and 100 kPa, respectively.

PROBLEM 2 [40 points]

3.0 kg of a water initially at a temperature of 200°C and a pressure of 3.0 bar is kept in a closed piston-cylinder. It undergoes a gradual expansion to a final pressure of 1.0 bar and a final volume of 2.5 times its original value without any leakage. The total heat transfer from the water during the expansion is measured to be 50 kJ at an average boundary temperature of 30°C. The environment is at 25°C and 1.0 bar.

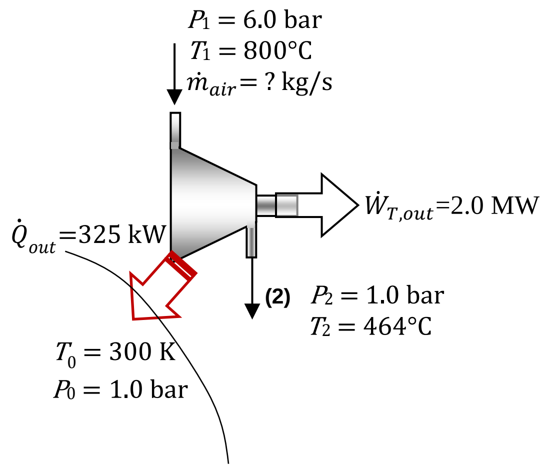


(a) Sketch the process path on a *P*–*v* diagram. Clearly label your states relative to the two-phase dome.
(b) Determine the final volume and temperature of the water, in m^3 and °C, respectively.
(c) Determine the work done by the water during the expansion, in kJ.
(d) Determine the entropy generation during the expansion, in kJ/K.

Problem 3 [35 points]

A steady-state turbine takes an unknown mass flow rate of air and expands it from 6.0 bar and 800°C to 1.0 bar and 464°C. The turbine produces 2000 kW of power and rejects 325 kW of heat transfer to the surroundings at T_0=300 K. Modeling air as an ideal gas with variable specific heats,

(a) find the required mass flow rate of air in kg/s,
(b) the drop in specific flow exergy of the air, $a_{f,1}$- $a_{f,2}$, in kJ/kg, and
(c) the total rate of exergy destruction for the turbine in kW.



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

$(T/K) = (T/{}^{o}R) / 1.8$
$(T/K) = (T/{}^{o}C) + 273.15$
$(T/{}^{o}C) = [(T/{}^{o}F) - 32]/1.8$
$(T/{}^{o}R) = 1.8(T/K)$
$(T/{}^{o}R) = (T/{}^{o}F) + 459.67$
$(T/{}^{o}F) = 1.8(T/{}^{o}C) + 32$

Temperature Differences

$(\Delta T/{}^{o}R) = 1.8(\Delta T/K)$
$(\Delta T/{}^{o}R) = (\Delta T/{}^{o}F)$
$(\Delta T/K) = (\Delta T/{}^{o}C)$

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 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