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ROSE-HULMAN
INSTITUTE OF TECHNOLOGY

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Name

ME301 – Applications of Thermodynamics

Exam 1

Sep 29, 2017

Circle section: **01** [4th Lui] **02** [5th Lui] **03** [4th Thom] **04** [5th Thom] **05** [4th Mech]

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	______/ 37
Problem 3	______/ 37
Total	______/100

PROBLEM 1 [26 points]

(a) [20 pts] Indicate whether each of the following statements is true or false.

True | False Anything that generates entropy also destroys exergy.

True | False Exergy and energy have the same dimensions.

True | False If a substance is at the same temperature as the environment (i.e., $T = T_0$) then it necessarily has no exergy.

True | False Exergy is a conserved property.

True | False "Isentropic efficiency" and "exergetic efficiency" are necessarily the same thing.

True | False Based on its definition, exergy cannot be negative.

True | False When heat is transferred into a system, it necessarily transfers entropy into the the system.

True | False When heat is transferred into a system, it necessarily transfers exergy into the the system.

True | False Exergy destruction is a consequence of the Second Law of Thermodynamics.

True | False A turbine with 101% isentropic efficiency is thermodynamically impossible.

(b) [3 pts] Heat transfer in the amount of 100 kJ is transferred to air in a rigid container. The reservoir is at T_R = 500 K and the environment are at T_0 = 300 K and P_0 = 100 kPa. How much exergy has been transferred to the air?

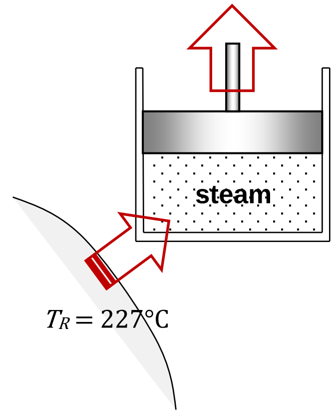
- o 100 kJ
- o -100 kJ
- o 40 kJ
- o -40 kJ
- o 20 kJ
- o Insufficient information to determine

(c) [3 pts] Power in the amount of 100 kW is transferred to air in a rigid container in a steady-state process. The environment are at T_0 = 300 K and P_0 = 100 kPa. How much exergy has been transferred to the air?

- o 100 kW
- o -100 kW
- o 66.7 kW
- o -66.7 kW
- o 33.3 kW
- o Insufficient information to determine

PROBLEM 2 [37 points]

A mass of 0.75 kg of saturated liquid steam is **initially** contained in a piston cylinder initially at P_1 = 200 kPa. Heat transfer in the amount of 990.8 kJ is added to the steam in a constant pressure process **until** the quality reaches x_2 = 0.6. The heat is transferred from a thermal reservoir maintained at T_R = 227°C while holding the pressure of the steam constant. The environment is at P_0 = 100 kPa and T_0 = 300 K.



(a) Sketch the process on *P-v* and *T-s* diagrams.

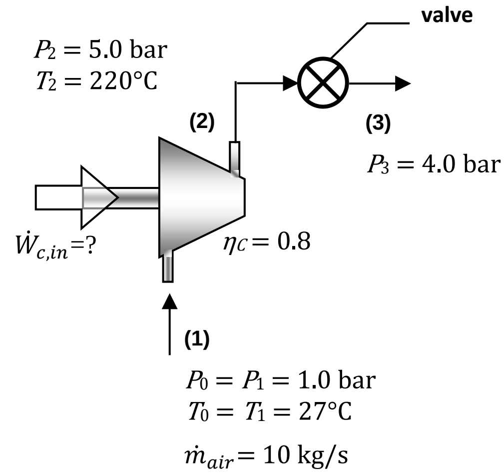
(b) Calculate the <u>work out of the steam</u> in kJ.

(c) Calculate the <u>useful work out of the steam</u> in kJ.

(d) *Using the Accounting of Exergy Equation*, find the <u>total exergy destroyed</u> in the process.

Problem 3 [37 points]

A flow of $\dot{m}_{air}$= 10 kg/s of air is compressed adiabatically in a compressor with an isentropic (adiabatic) efficiency of η_C=0.8. The exiting air is then expanded *irreversibly* through a throttle valve to a lower pressure. The valve operates adiabatically and *has no moving parts*. The apparatus and pertinent property values are shown in the diagram at the right.



Treat air as an ideal gas with variable specific heats. The environment is at P_0 = 100 kPa and T_0 = 27°C.

(a) Sketch the two-step process on a <u>*T-s* diagram</u>.

(b) Calculate <u>the compressor input power</u> in kW.

(c) Calculate the <u>exergetic efficiency of the compressor</u>.

(d) *Using any reasonable method*, find the total <u>rate of exergy destruction</u> in the valve. Remember that the valve operates adiabatically and *has no moving parts*.

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