CM

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**Name**

**Circle section:** **01** [10 am, Lui] **02** [11 am, Lui]
**03** [10 am, Thom] **04** [11 am, Thom]
**05** [11 am, Danesh]

# *ME301 – Applications of Thermodynamics*

## *Exam 1*

*Sep 30, 2022*

**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 (from your textbook) 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** | ______/ 28 |
| **Problem 2** | ______/ 36 |
| **Problem 3** | ______/ 36 |
| **Total** | ______/100 |

## PROBLEM 1 [28 points]

For (a) through (c), assume the temperature and pressure of the surroundings are $T_0$=300 K and $P_0$=100 kPa, respectively.

(a) [4 pts] Heat transfer in the amount of $Q$=100 kJ is transferred from a thermal reservoir at $T_R$= 400K to a closed system. How much exergy has been transferred from the reservoir to the system with the heat transfer?

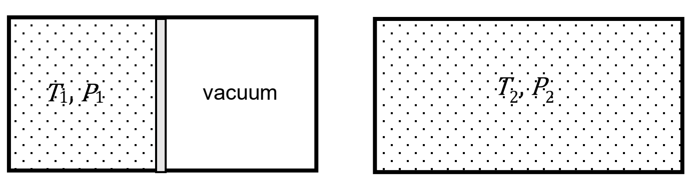
- 0 kJ
- 25 kJ
- 75 kJ
- 100 kJ
- Cannot be determined

(b) [2 pts] Electrical work in the amount $W$=100 kJ is transferred to a closed system of fixed volume. How much exergy has been transferred to the system?

- -100 kJ
- 0 kJ
- 50 kJ
- 100 kJ
- Cannot be determined

(c) [4 pts] Compression/expansion work in the amount of $W$=100 kJ of leaves a closed system. The system volume increases by 0.5 m$^2$ during the expansion. How much exergy has been transferred out of the system?

- -100 kJ
- 0 kJ
- 50 kJ
- 100 kJ
- Cannot be determined




Air at temperature and pressure $T_1$ and $P_1$ initially occupies half of a rigid (i.e., non-deformable), adiabatic container. A partition separates the air from a vacuum. The partition is removed so that the air fills the entire container at a final temperature and pressure of $T_2$ and $P_2$. Take your system to be the entire container before and after the process.

(d) [2 pts] The heat transfer into the system is

- $Q_{in,12} < 0$
- $Q_{in,12} = 0$
- $Q_{in,12} > 0$
- Cannot be determined

(e) [3 pts] The work into the system is

- $W_{in,12} < 0$
- $W_{in,12} = 0$
- $W_{in,12} > 0$
- Cannot be determined

(f) [3 pts] The change internal energy of the system is

- $U_2 - U_1 < 0$
- $U_2 - U_1 =$
- 0
- $U_2 - U_1 > 0$
- Cannot be determined

(g) [2 pts] The entropy generation of the system is

- $S_{gen} < 0$
- $S_{gen} = 0$
- $S_{gen} > 0$
- Cannot be determined

(h) [8 pts] Indicate whether each of the following states are sometimes, always, or never true.

i. For a system undergoing a finite time process, the destroyed exergy is sometimes | always | never the same as $T_0 S_{gen}$.

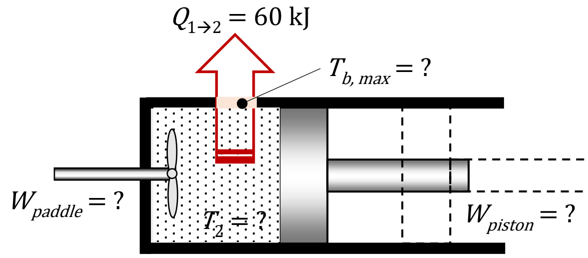
ii. The exergy of a closed system sometimes | always | never decreases.

iii. A substance with no kinetic and potential energy that is at the same temperature and pressure as the surroundings sometimes | always | never has no exergy

iv. The power out of a turbine at steady-state is sometimes | always | never the same as the useful power out.

## PROBLEM 2 [36 points]

0.1 kg of air ($R$=0.287k J/kg·K) is contained in a piston-cylinder device and subjected to work from a paddle wheel. Initially, the air is at $P_1$=300 kPa and $T_1$=450 K. It is then gradually compressed by the piston in a constant-pressure process such that its volume becomes one-half of its initial value. During this process, 60 kJ of heat is removed from the air through a boundary as shown.




Model air as an ideal gas with variable specific heats.

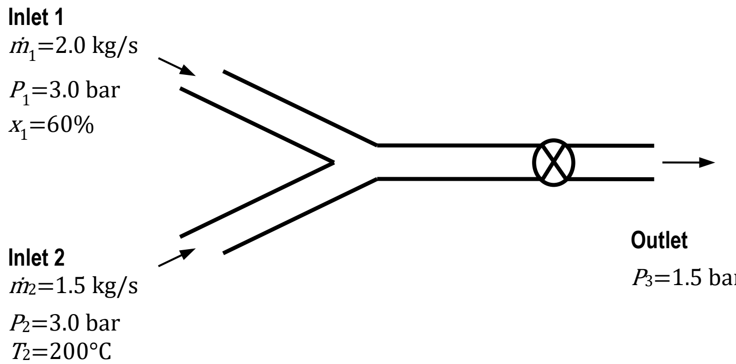
Determine:

(a) the final temperature $T_2$ of the air, in K;
(b) the work done on the air by the piston, in kJ;
(c) the work done on the air by the paddle wheel, in kJ;
(d) and the maximum boundary temperature at which the heat can be removed while this process would still be *possible*, in K.

## Problem 3 [36 points]

A flow of $\dot{m}_1$=2.0 kg/s of a saturated water mixture with quality of $x_1$=60% and $P_1$=3.0 bar (Inlet 1) is mixed with $\dot{m}_2$=1.5 kg/s of superheated water vapor at $P_2$=3.0 bar and $T_2$=200°C (Inlet 2). The mixture stream is then throttled to a pressure of $P_3$=1.5 bar through a valve.

Assume the entire process is adiabatic. Use $T_0$ = 25°C and $P_0$ = 101.325 kPa.




(a) Determine the specific flow exergy of the saturated water mixture at Inlet 1 in kJ/kg.

(b) Determine the mixture temperature at the exit in °C.

(c) Determine the rate of exergy destruction for the mixing-throttling process in kW. Use the Accounting of Exergy.

(d) Clearly identify the two inlet states and the one exit state on a $T$–$s$ diagram, relative to the two-phase dome with properly labeled isobars.

**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 $ft^2/s^2$