AREN 2110: Thermodynamics
Spring 2011
Midterm 1

Name_____

$\mu = 41.5/50$
$\sigma = 1.4$

Answer all questions. Test is open book and notes. Sign honor code statement below.

I have neither given nor received unauthorized assistance during this examination.

Signed SOLUTIONS

1. (15 points @ 3 points per question) Multiple choice. Circle THE BEST answer (only one answer per question)

   A. A tank contains pure water as a saturated liquid vapor mixture. Which pair of properties CANNOT be used to determine the complete state of the system:

   a. T and x
   b. T and P
   c. P and v
   d. T and v
   e. T and h
   e. none of the above – all pairs can be used

   B. A polytropic process with n = 0 is

   a. isothermal
   b. isobaric
   c. isochoric
   d. quasi-equilibrium
   e. adiabatic

   $PV^n = C$
   $n = 0$
   $P = C$

   C. For an ideal gas, the specific heats, c_V and c_P, are related by:

   a. $c_V \approx c_P$
   b. $c_V = c_P + R$
   c. $c_P = c_v + R$
   d. $c_P = c_v + dh/dT$
   e. $c_P = c_v + du/dT$

   D. The pressure of H_2O in a closed container is 50 kPa and the temperature is 100 °C. The water phase is:

   a. an ideal gas
   b. compressed liquid
   c. superheated vapor
   d. saturated vapor
   e. saturated liquid vapor mixture

   @ 100°C, $P_{sat} \approx 101$ kPa
   $P < P_{sat}$ means superheated vapor

   E. The specific enthalpy of air varies with:

   a. its pressure
   b. its volume
   c. its density
   d. its temperature
   e. R

   $u = u(T)$
   $h = u + Pv$, for IG $Pv = RT$
   $h = u(T) + RT$

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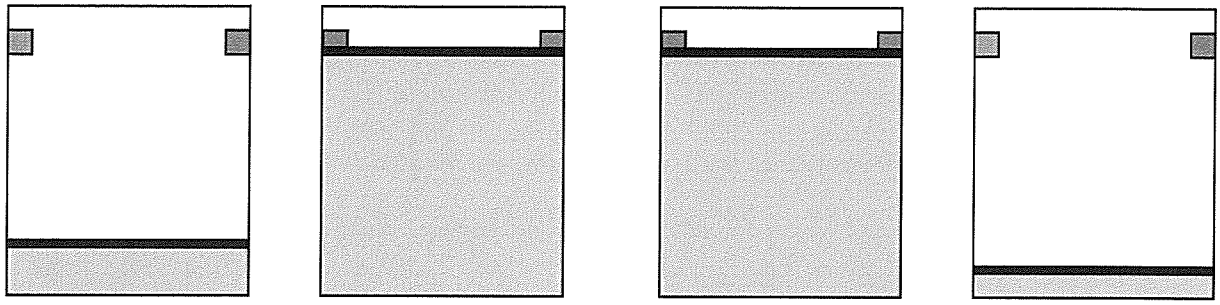
2. (35 total points). A cycle consisting of four steps is carried out in a closed system containing 2 kg R-134a, with the states as follows:



State 1 State 2 State 3 State 4

Process	Path
1→2	Isobaric
2→3	Isochoric
3→4	Isobaric
4→1	Linear

A. COMPLETE THE TABLE BELOW (14 points) Workspace on next page

State	P (kPa)	T (°C)	x	v (m^3/kg)	V (m^3)
1	240	−5.38	0.3	0.0257	0.0514
2	240	−5.38	1	0.0839	0.168
3	320	70	na	0.0839	0.168
4	320	2.46	0	0.0007772	0.00155

Useful values

R-134a Saturated liquid, saturated vapor and superheated vapor properties

T	P	v_f	v_g	v	u_f	u_g	u
(°C)	(kPa)	(m^3/kg)	(m^3/kg)	(m^3/kg)	(kJ/kg)	(kJ/kg)	(kJ/kg)
-5.38	240	0.0007620	0.0839		44.48	227.14	
70	240			0.1131			287.36
2.46	320	0.0007772	0.06360		54.92	231.52	
70	320			0.0839			286.62

Name_____

(1) sat. mixture $(x=0.3)$, $T = T_{sat}$ @ 240 kPa $= -5.38\,^{\circ}C$

$v_1 = 0.3(v_g - v_f) + v_f$ @ 240 kPa $= 0.3(0.0839 - 0.000762) + 0.000762$

$= 0.0257\ m^3/kg$

$V_1 = 2(0.0257) = 0.0514\ m^3$

(2) isobaric $P_2 = P_1$, $x = 1$, $T_2 = T_{sat} = T_1$ sat. vapor

$v_2 = v_g = 0.0839\ m^3/kg$

$V_2 = 2(0.0839) = 0.168\ m^3$

(3) isochoric $v_3 = v_2 = 0.0839 > v_g$ @ 320 kPa $\Rightarrow$ superheated

table: $T = 70\,^{\circ}C$

(4) isobaric, $P = 320$ kPa, $v_4 = v_f$ @ 320 kPa $= 0.0007772\ m^3/kg$

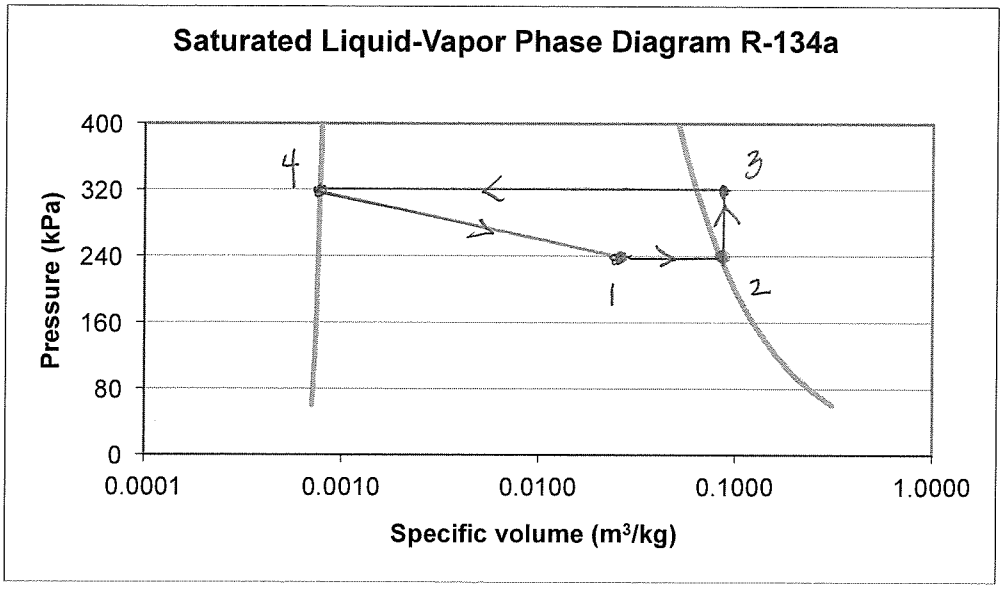
$x = 0$

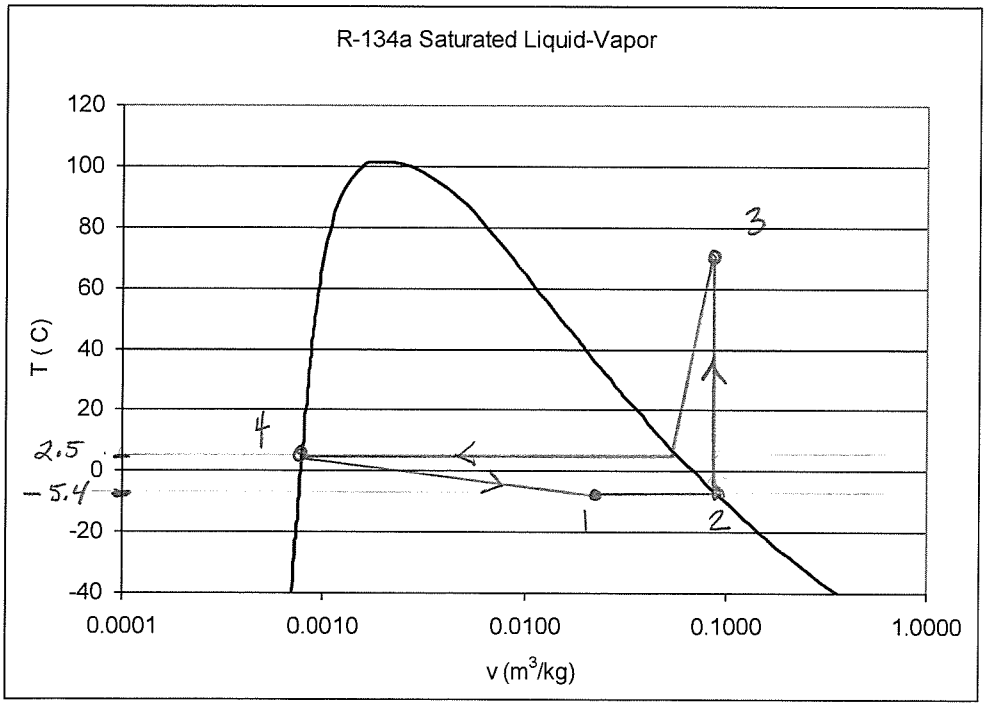
sat. liquid $T = T_{sat}$ @ 320 kPa $= 2.46\,^{\circ}C$

$V_4 = 2(0.0007772) = 0.00155\ m^3$

Name_____

B. (8 points) DRAW THE CYCLE ON THE P-v and T-v diagrams, below





Name_____

C. (2 points) Does the cycle have net work output or net work input?

from P-V diagram: Area (3→4) is negative W_b >
Area (4→1 + 1→2) is positive. | so net WORK INPUT |

D. (6 points) COMPLETE THE TABLE BELOW, including the correct sign convention for work

Process	boundary work (kJ)
1→2	28 (+)
2→3	0
3→4	−53.3

$W_{12} = P_1(V_2 - V_1) = 240kPa(0.168 - 0.0514)m^3$
$= 28kJ$ (+)

$W_{23} = 0$ (isochoric)

$W_{34} = 320kPa(0.00155 - 0.168)m^3$
$=$

E. (5 points) Find the heat transferred for the process between states 2 and 3, in kJ.

$Q_{23} = m(u_3 - u_2)$

$u_2 = u_g @ 240kPa$
$= 227.14 \frac{kJ}{kg}$

$u_3 = 286.62 \frac{kJ}{kg}$

$Q_{23} = 2kg(286.62 - 227.14)\frac{kJ}{kg}$
$= |119kJ|$
heat input

Name_____

SCORE

1._____(15)

2._____(35)

Σ._____(50)