AREN 2110: Thermodynamics
Spring 2011
Midterm 2

Name $\mu = 36.5$

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. If 10 kJ/kg heat is lost from a steam turbine generating 1 MW power from a steam flow of 20 kg/s, the enthalpy change of the steam will be:

a. -1,000 kw
b. -1,010 kw
c. -990 kw
d. -800 kw
[✓ e. -1,200 kw]

$\dot m q - \dot W = \dot m (h_2 - h_1)$

$20\frac{kg}{s}\left(-10\frac{kJ}{kg}\right) - (1000\ kW) = \dot m (h_2 - h_1)$

$\dot m (h_2 - h_1) = -200\ kW - 1000\ kW = -1200\ kW$

B. An ideal gas is compressed in an isothermal process in a closed system. The process MUST also be

[✓ a. isenthalpic]
b. isobaric
c. adiabatic
d. passive (w=0)
e. isochoric

$T_2 = T_1$

$\therefore C_p(T_2 - T_1) = h_2 - h_1 = 0$

$Q = W_b$ so c is wrong

$P_1V_1 = P_2V_2$ so b & e are wrong

$W_b = P_1V_1 \ln\left(\frac{V_2}{V_1}\right)$ d is wrong

C. A cycle receives 500 kJ net work. In turn,

a. 500 kJ heat must be added
[✓ b. 500 kJ heat must be removed]
c. the internal energy increases by 500 kJ
d. no heat is transferred
e. cannot tell from information given

$Q_{net} = W_{net} = -500 kJ$

D. Liquid water flows through an adiabatic nozzle, and the velocity at the outlet is 9 times the inlet velocity. The ratio of the inlet-to-outlet DIAMETER is:

a. ρ_2/ρ_1
b. 9
c. 0.111
[✓ d. 3]
e. 0.333

$\rho_1 V_1 A_1 = \rho_2 V_2 A_2$, $\rho_1 = \rho_2$ for liquid water

$V_1 A_1 = V_2 A_2$, $\frac{A_1}{A_2} = \frac{V_2}{V_1} = \left(\frac{D_1}{D_2}\right)^2$

$\frac{D_1}{D_2} = \sqrt{9} = 3$

E. In a closed system, heat is added to raise the temperature of an ideal gas by 100 °C. The ratio of heat added in an isobaric process to the heat added in an isochoric process is:

a. > 1
b. C_P/C_V
c. $1 + (R/C_V)$
d. $1/(1-(R/C_P))$
[✓ e. all of the above (a-d)]

$q)_P = C_p(100)$

$q)_V = C_v(100)$

$\frac{C_p}{C_v} > 1$ (a)

$\frac{q_P}{q_V} = \underset{(b)}{\frac{C_p}{C_v}} = \underset{(c)}{\frac{C_v + R}{C_v}} = \overset{(d)}{\frac{C_p}{C_p - R}}$

OR note $C_p > C_v$ and ratio $= \frac{C_p}{C_v}$
if a & b are true then all must be true

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2. (35 total points). Food is kept cold in a refrigerator by a cycle comprised of four devices (processes) in a sequence. NOTE: useful R-134a table values on LAST PAGE.

A. (16 points) Complete the table. Column values are properties at the **beginning of the process.**

Process	Device	T initial (°C)	P initial (kPa)	x initial	h initial (kJ/kg)
1→2	Evaporator heat exchanger	−26.37	100	0.415	107.32
2→ 3	Adiabatic compressor	−26.37	100	1	234.44
3→4	Condenser heat exchanger	50	1,000	na	282.74
4→ 1	Adiabatic throttling	39.37	1,000	0	107.32

$h_f < h_1 < h_g$ @ 100kPa, $x = \frac{107.32-17.28}{234.44-17.28} = 0.415$
$T_1 = T_{sat}$

The refrigerator's cold box gains 0.8 kw heat on average from the door being opened and new food being added. In addition, a fan inside the cold box rated at 0.1 kw keeps the interior air mixed. The evaporator of the refrigeration system (1→2) removes heat from the cold box to keep the temperature of the food constant at 5 °C.

B. (3 points) What is the rate at which heat must be removed from the cold box to maintain the constant temperature (kw)?

$$\dot{Q}_R + 0.8kw - (-0.1kw) = 0$$

$$\dot{Q}_R = \boxed{-0.9kw}$$

C. (3 points) What is the mass flow rate of refrigerant required (kg/s)? $\dot{W}_{12} = 0$

$$\dot{Q}_{12} = -\dot{Q}_R = 0.9kw = \dot{m}_R(h_2 - h_1)$$

$$\dot{m}_R = \frac{0.9kw}{(234.44-107.32)} = \boxed{0.0071 \frac{kg}{s}}$$

D. (4 points) What is. the power required to run the adiabatic compressor (2→3) (kw)?

$$\dot{Q} = 0$$

$$-\dot{W}_{23} = \dot{m}_R(h_3 - h_2) = 0.0071\frac{kg}{s}(282.74 - 234.44)\frac{kJ}{kg}$$

$$-\dot{W}_{23} = 0.34\ kW$$

$$\boxed{\dot{W}_{23} = -0.34\ kW}$$

E. (4 points) Heat is rejected into the kitchen air by the condenser heat exchanger (3→ 4). At what rate is heat rejected (kw)?

$$\dot{W}_{34} = 0$$

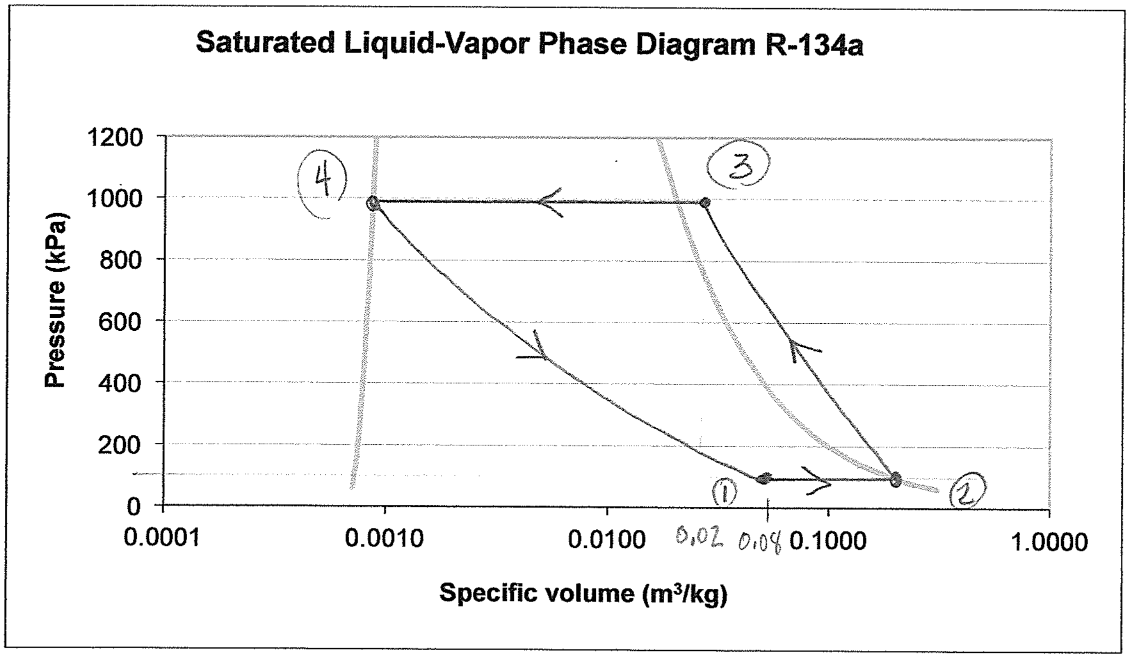
$$\dot{Q}_{34} = \dot{m}_R(h_4 - h_3) = 0.0071\frac{kg}{s}(107.32 - 282.74)\frac{kJ}{kg}$$

$$\boxed{\dot{Q}_{34} = -1.24\ kW}$$

OR $\dot{W}_{net} = \dot{Q}_{net}$, $\dot{W}_{23} = \dot{Q}_{12} + \dot{Q}_{34}$

$-0.34\ kW = +0.9\ kW + \dot{Q}_{34}$, $\boxed{\dot{Q}_{34} = -1.24\ kW}$ ✓

F. (5 points) Draw the refrigeration cycle on the P-v diagram below.



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Useful values

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

T	P	v_f	v_g	v	h_f	h_g	h
(°C)	(kPa)	(m^3/kg)	(m^3/kg)	(m^3/kg)	(kJ/kg)	(kJ/kg)	(kJ/kg)
-26.37	100	0.0007259	0.19254		17.28	234.44	
50	1,000			0.021796			282.74
39.37	1,000	0.0008700	0.020313		107.32	270.99	
50	100			0.25937			298.16

SCORE

1.__________(15)

2.__________(35)

Σ. _______________(50)