Faculté de génie
Génie mécanique

uOttawa
L'Université canadienne
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Faculty of Engineering
Mechanical Engineering

Name____________________________ ID Number______________

MCG2130 - THERMODYNAMICS I

Midterm Examination | Time: 80 minutes
1 November 2010 | Page 1 of 2
Prof. W. Hallett | Version A

Closed book. Put your name on this question paper and hand it in with your exam booklet. **If you do not hand in the question paper your exam will not be marked.** In each problem, state any assumptions you need to make.

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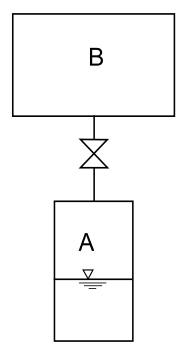
1. (3 marks) Sketch a T-v diagram showing the compressed liquid, saturation, and superheated vapour regions. Draw and label on the diagram (a) the saturated liquid and saturated vapour lines; (b) a line of constant pressure; (c) the critical point.

2. (9 marks total) In a Diesel engine cylinder, air is initially at P_1 = 100 kPa, V_1 = 20 litres, and T_1 = 20°C. It is then compressed in a polytropic process (given by PV^n = constant, where n = 1.3), to a final volume of $V_2 = V_1 / 16$.
(a) (3 marks) Determine the final pressure and temperature.
(b) (2 marks) Show that the work done in a polytropic process is $W_{12} = (P_2V_2 - P_1V_1) / (1 - n)$.
(c) (3 marks) Calculate the work done and the heat transfer in this process.
(d) (1 mark) Sketch this process on a P-v diagram, showing lines of constant temperature.
Properties data are given on the other side of the paper.

3. (12 marks total) A tank A of volume V_A = 0.01 m^3 initially contains ammonia at a temperature of T_{A1} = 20°C and a quality x_{A1} = 0.2. It is connected through a valve to tank B of volume V_B = 0.05 m^3. Tank B is initially empty. The valve is then opened, and ammonia vapour allowed to flow into tank B until A and B are at a uniform final state. During this process the temperature remains constant.
(a) (4 marks) Find the total mass of ammonia in the system, and the initial volume of liquid in tank A.
(b) (4 marks) Determine the final state of the ammonia (pressure or quality, whichever is appropriate).
(c) (4 marks) Calculate the work and the heat transfer.
Properties data are given on the other side of the paper.



Total marks for this paper: 24

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Universal gas constant: $\bar{R}$ = 8.314 kJ/kmol K. Specific gas constant for air: R = 0.287 kJ/kg K.

Specific Heats for Air as a Function of Temperature

T - K	c_{P0} - kJ/kg K	c_{V0} - kJ/kg K	$k = c_P/c_V$
300	1.007	0.720	1.40
400	1.011	0.724	1.40
500	1.029	0.742	1.39
600	1.053	0.766	1.37
700	1.078	0.791	1.36
800	1.101	0.814	1.35
900	1.122	0.835	1.34
1000	1.141	0.854	1.34

Saturation Tables for Ammonia

Temperature	Saturation Pressure	Specific Volume m³ / kg			Internal Energy kJ / kg		
°C	kPa	v_f	v_{fg}	v_g	u_f	u_{fg}	u_g
-30	119.5	0.001476	0.9619	0.9634	44.08	1244.8	1288.9
-20	190.2	0.001504	0.6218	0.6233	88.76	1210.7	1299.5
-10	290.9	0.001534	0.4166	0.4181	134.0	1175.2	1309.2
0	429.6	0.001566	0.2876	0.2892	179.7	1138.3	1318.0
10	615.2	0.001600	0.2038	0.2054	225.0	1099.7	1325.7
20	857.5	0.001638	0.1476	0.1492	272.9	1059.3	1332.2
30	1167.0	0.001680	0.1088	0.1105	320.5	1016.9	1337.4
40	1554.9	0.001725	0.0814	0.0831	368.7	972.2	1341.0

Superheat Table for Ammonia

Temp °C	400kPa (-1.89°C)		Temp C	600kPa (9.28°C)		Temp C	800kPa (17.85°C)		Temp C	1000kPa (24.9°C)	
	v (m³/kg)	u (kJ/kg)		v (m³/kg)	u (kJ/kg)		v (m³/kg)	u (kJ/kg)		v (m³/kg)	u (kJ/kg)
Sat	0.3094	1316.4									
0	0.3123	1320.2	Sat	0.2104	1325.2						
10	0.3270	1339.9	10	0.2112	1326.7	Sat	0.1596	1330.9			
20	0.3413	1359.1	20	0.2215	1347.9	20	0.1614	1335.8	Sat	0.1285	1334.9
30	0.3552	1377.7	30	0.2315	1368.2	30	0.1695	1358.0	30	0.1321	1347.1
40	0.3688	1396.1	40	0.2412	1387.8	40	0.1772	1379.0	40	0.1387	1369.8

Solutions to MCG2130 Midterm Exam - Fall 2010

Version A

2. (a) $P_2 = P_1 (V_1 / V_2)^n = 3676$ kPa,

$T_2 = P_2 V_2 / m R$, and $m = P_1 V_1 / R T_1 = 0.0238$ kg, so $T_2 = 673$ K.

(b) $W_{12} = \int P \, dV = \int P_1 V_1^n V^{-n} dV = P_1 V_1^n [V^{(1-n)} / (1-n)]$
$= [P_1 V_1^n V_2^{(1-n)} - P_1 V_1^n V_1^{(1-n)}] / (1-n)$
$= [P_2 V_2 - P_1 V_1] / (1-n)$

(c) $W_{12} = - 8.65$ kJ.

$Q_{12} = W_{12} + m (u_2 - u_1) = W_{12} + m c_{V0} (T_2 - T_1)$, assuming constant specific heat.

Evaluate c_{V0} at $(T_2 + T_1) / 2$, get $c_{V0} = 0.739$ kJ / kg K, and $Q_{12} = -1.97$ kJ.

3. (a) $m_{A1} = m = V_A / v_{A1}$, and $v_{A1} = v_{f1} + x_{A1} v_{fg1}$.

Ammonia: Evaluating at 20°C, $v_{f1} = 0.001638$ m^3/kg, $v_{fg1} = 0.1476$ m^3 / kg,
$v_{A1} = 0.0312$ m^3 / kg, m = 0.321 kg.

$V_{fA1} = (1 - x_{A1}) m v_{f1} = 0.000421$ m^3

(b) $v_2 = (V_A + V_B) / m = 0.187$ m^3 / kg $> v_{g1}$, therefore superheated.

Interpolating in the superheat tables at 20°C, $P_2 = 715$ kPa, $u_2 = 1342.3$ kJ/kg.

(c) $Q_{12} = W_{12} + m(u_2 - u_1)$

$W_{12} = 0$, $u_1 = u_{f1} + x_{A1} u_{fg1} = 272.9 + x_{A1} \cdot 1059.3 = 484.8$ kJ/kg.

and $Q_{12} = 274.8$ kJ.