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Student ID Number-----------------------------

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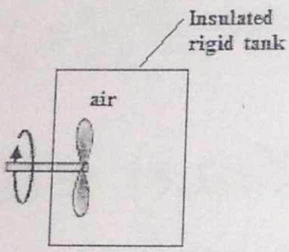
Cankaya University
Faculty of Engineering
Mechanical Engineering Department
ME 211 Thermodynamics I
Midterm Exam I
Closed Notes Closed Book
Spring 2015
Solution
Prof.Dr.Nevzat Onur and Dr.Ekin Yapici

a) Do either problem 1 or 2
b) Do problems 3 and 4

1) **In a rigid insulated container of volume 0.8 m^3, 2.5 kg of air is filled. A paddle wheel is fitted in the container and it transfers energy to the contained air at a constant rate of 12 W for a period of 1 hr. There is no change in the potential or kinetic energy of the system. Determine the energy transfer by work to the air per kg of air.**



$\forall = 0.8\,m^3 \quad m = 2.5\,kg \quad \dot{W} = 12\ watt$

$W = \left(12\,\frac{J}{s}\right)(3600\,s) = -43200\,J$

$\cancel{Q}^{0} - W = m(u_2 - u_1)$

insulated

$\Longrightarrow \Delta u = -\frac{W}{m} = -\frac{(-43200)}{2.5} = 17280\ J/kg = 17.28\ \frac{kJ}{kg}$

2) The internal energy of a certain gas is given by the following equation

$$u = 3.56\, pv + 84$$

where u is given in kJ/kg, p is in kPa, and v is in m^3/kg.

A system composed of 3 kg of this gas expands from an initial pressure of 500 kPa and a volume of 0.22 m^3 to a final pressure 100 kPa in a process in which pressure and volume are related by $pv^{1.2}$ = constant.

If the expansion is quasi-static, find Q, ΔU, and W for the process.

$$u = 3.56\, pv + 84 \qquad (v:\ m^3/kg)$$

$$\Delta u = u_2 - u_1 = 3.56\, P_2 v_2 - 3.56\, P_1 v_1 = 3.56(P_2 v_2 - P_1 v_1)$$

$$m = 3\ kg$$

$$\Delta U = m \Delta u = 3.56(P_2 V_2 - P_1 V_1) \qquad (V:\ m^3)$$

$$P_2 V_2^{1.2} = P_1 V_1^{1.2} \Rightarrow V_2 = V_1 (P_1/P_2)^{1/1.2} = 0.22\left(\frac{500}{100}\right)^{\frac{1}{1.2}} = 0.841\ m^3$$

$$\Delta U = (3.56)(1 \times 0.841 - 5 \times 0.22) \times 10^5$$

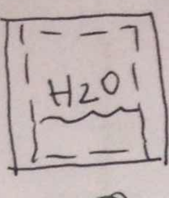
$$= -92.204\ kJ$$

$$W = \int_1^2 p\, dV = c \int_1^2 \frac{dV}{V^{1.2}} = \frac{P_2 V_2 - P_1 V_1}{1 - 1.2}$$

$$= \frac{(1 \times 0.841 - 5 \times 0.22)10^5}{1 - 1.2} = 1.295 \times 10^5\ J = 129.5\ kJ$$

$$Q = \Delta U + W = -92.204 + 129.5 = 37.296\ kJ$$

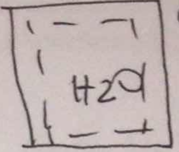
3)A closed, rigid tank contains 2 kg of water initially at 80°C and a quality of 0.6. Heat transfer occurs until the tank contains only saturated vapor at a higher pressure. Kinetic and potential energy effects are negligible. For the water as the system, determine the amount of energy transfer by heat, in kJ.



$m = 2\,kg$

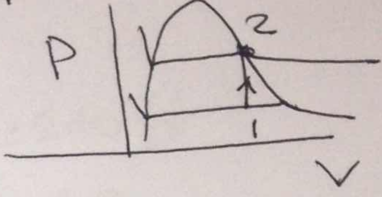
$T_1 = 80°C$

$x_1 = 0.6$



(1) Sat. liquid vapor mixture

(2) sat. vapor $x_2 = 1$



$\Delta U = Q - W^{\nearrow 0} \Rightarrow Q = m(u_2 - u_1)$

$u_1 = u_f + x_1 u_{fg} = 334.86 + 0.6(2482.2 - 334.86)$

$= 1623.26\ kJ/kg$

$v_1 = v_f + x_1 v_{fg} = 1.0291 \times 10^{-3} + 0.6(3.407 - 1.0291 \times 10^{-3})$

$= 2.0446\ m^3/kg$

Rigid container

$v_2 = v_1 = 2.0446\ m^3/kg$

$x_2 = 1$

v	u	T
2.365	2494.5	89.95
2.0446		93.5
2.087	2498.8	

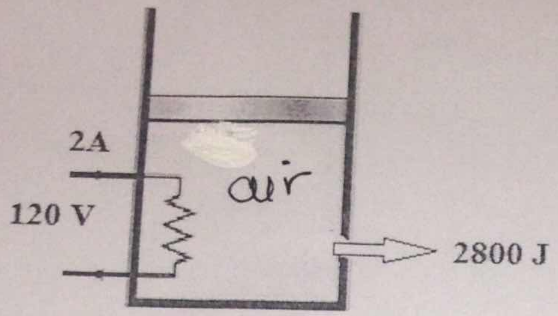
$T \cong 93.5°C$

$u_2 \cong 2498.8\ kJ/kg$

I think good estimate

$Q = (2)(2498.8 - 1623.26) \cong 1751.1\ kJ$

4) A piston– cylinder device initially contains 0.5 m^3 of air at 400 kPa and 27° C. An electric heater within the device is turned on and is allowed to pass a current of 2 A for 5 min from a 120- Volts source. Air expands at constant pressure, and a heat loss of 2800 J occurs during the process. Determine the final temperature of air using tables. Show the process on a $p-\forall$ diagram. Hint: $\dot{W} = VI$ (Watts) ,I =current (A),V=voltage (Volts)



$\forall = 0.5\ m^3$ $\quad Q - W = \Delta U$

$P_1 = 400\ kPa$

$T_1 = 300K$

$\dot{W} = IV = (2A)(120V) = 240\ W = 240\ J/s$

$W = (240\ \frac{J}{s})(5\ min)(\frac{60s}{min}) \cong 72\ kJ$

$$m = \frac{P_1 \forall}{R T_1} = \frac{(500\ kN/m^2)(0.5\ m^3)}{(0.287\ \frac{kN.m}{kg\,K})(300\ K)} = 2.32\ kg$$

$Q - W_b - W_e = U_2 - U_1$

$W_b = \int_1^2 p\, d\forall = p(\forall_2 - \forall_1) = P_2\forall_2 - P_1\forall_1$

$Q - W_e = U_2 - U_1 + P_2\forall_2 - P_1\forall_1 = H_2 - H_1$

$= m(h_2 - h_1)$

$$\Rightarrow h_2 = \frac{Q - W_e}{m} + h_1 = \frac{-2800 - (-72)}{2.32} + 300.19$$

$= 330\ kJ/kg$

$\rightarrow T_2 \cong 330K$