ES 3053 **EXAM I** **February 19, 2001**

Open Books and Notes

I. 60 points

The refrigerant R-22 is contained in a piston-cylinder arrangement as given below, where the volume is 11 L when the piston reaches the stop. Initially, the R-22 is at -30°C, 150 kPa, at a volume of 10 L. Under the initial conditions, the external atmospheric pressure plus the weight of the piston combine to balance the 150 kPa R-22 pressure. A process of adding heat reversibly is then performed until the temperature is 20°C. Taking the R-22 as the system:

A. 5 points
How much R-22 (in kg) is in the device?

B. 5 points
Taking into account that the piston might hit the stop, what is the final volume?

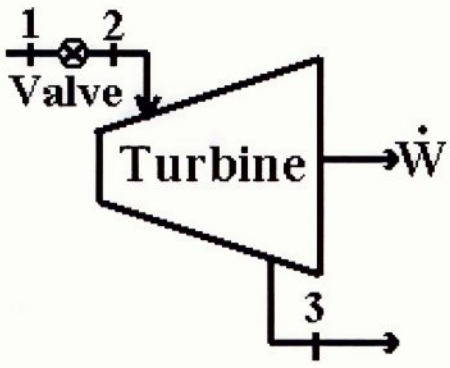
C. 10 points
What is the final pressure?

D. 20 points
How much work is done by the R-22 for this process?

E. 20 points
Neglecting KE and PE effects, how much heat is added for this process?

II. 40 points

In the figure to the right, 0.25 kg/s steam enters a valve at 1.4 MPa, 250°C (Point 1) where it is throttled to 1.2 MPa (Point 2) before entering an adiabatic turbine. The turbine produces 110 kW of power and the exhaust from the turbine is 10 kPa (Point 3). Neglecting KE and PE effects, and assuming steady-state operation:



A. 20 points
What are h (the specific enthalpy) and T (the temperature) leaving the valve (Point 2)?

B. 20 points
What are h (the specific enthalpy) and T leaving the turbine (Point 3)?

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I. A. $v = 0.14872 \ m^3/kg$ for $T = -30$, $P = 150 \ kPa$

$$m = \frac{0.010 \ m^3}{0.14872 \ m^3/kg} = 0.06724 \ kg$$

B. $m v = 0.06 \left(0.18352 \ \frac{m^3}{kg} \right)_{(20°C, 150 kPa)} \Big/ 0.06724 \Big) \times \frac{1000 \ lt}{m^3} = 12.34 \ lt$

however, stops are at 11 lt, so it hits the stop. $\therefore \quad V = 11 \ lt$

C.

P	v
150	0.18352
P_2	0.1636
200	0.1351

$$v_2 = \frac{11 \ lt}{0.06724} \times \frac{1}{1000} = 0.1636 \ \frac{m^3}{kg}$$

$$P_2 = 171.19 \ kPa$$

D. $W = \int P dV = \int_{10 lt}^{11 lt} (150 kPa)(dV) = 150 \ kPa \ (0.011 - 0.010 \ m^3)$

$$W = 0.150 \ m^3\text{-}kPa = 0.150 \ kJ$$

E. $\Delta U = Q - W$

$u_1 = 238.08 \ kJ/kg - (150 kPa \cdot 0.14872 \ m^3/kg)$

$u_1 = 215.772 \ kJ/kg$

P	h
150	270.06
171.19	h_2
200	269.27

$h_2 = 269.73$

$u_2 = 269.73 - (171.19)(0.1636)$

$u_2 = 241.72 \ kJ/kg$

$(241.72 - 215.772)(0.06724 \ kg) = Q - 0.150 \ kJ$

$Q = 1.8947 \ kJ$

II. $h_1 = 2927.22$ kJ/kJ at 1.4MPa, 250°C

A. $h_1 = h_2$ for valve since $\Delta KE = \Delta PE = 0$ & $Q = W = 0$

$h_2 = 2927.22$ kJ/kg

& $P_2 = 1200$ kPa

T	h
250	2935.01
T_2	2927.22
200	2815.90

$T_2 = 246.73°C$

B. $\dot{m}\Delta H = \dot{Q} - \dot{W}$

$0.25 \frac{kg}{sec}(H_3 - 2927.22) = 0 - 110 \frac{kJ}{sec}$

$H_3 = 2487.22$ kJ/kg @ $P = 10$kPa

⇒ saturated, $T_3 = 45.81°C$

problem doesn't ask for it, but $X_3 = 0.9593$