GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Spring Quarter 1995

THERMODYNAMICS
EXAM AREA

Assigned Number **(DO NOT SIGN YOUR NAME)**

-- Please sign your name on the back of this page --

Ph.D. Prelims
Thermodynamics
Spring 1995

(1) In our laboratory, a tank having inside volume V, initially contains water occupying volume v (v<V). The remainder of the tank volume contains air. The tank is provided with an air vent of diameter d. The rate of inflow of water is $\dot{m}_w$ as measured by a suitable flow device.

- Draw a schematic that best represents this descriptive data and information.
- State the principle you plan to use in determining mass flow rate of air being vented, in this arrangement.
- Derive an expression for mass flow rate of air being vented.
- Draw a sketch depicting air venting rate as a function of time, as the tank gets filled up. $(0 \leq v \leq V)$.

(2) Using Clapeyron's equation $[(dP/dT)_{sat}] = [h_{fg}/(Tv_{fg})$ estimate the value of latent heat of water at 70°C and compare it with actual value. For your information, a portion of property data is appended here.

Saturated water–Temperature table

Temp. °C T	Sat. press. kPa P_{sat}	Specific volume m³/kg: Sat. liquid v_f	Specific volume m³/kg: Sat. vapor v_g	Internal energy kJ/kg: Sat. liquid u_f	Internal energy kJ/kg: Evap. u_{fg}	Internal energy kJ/kg: Sat. vapor u_g	Enthalpy kJ/kg: Sat. liquid h_f	Enthalpy kJ/kg: Evap. h_{fg}	Enthalpy kJ/kg: Sat. vapor h_g	Entropy kJ/(kg · K): Sat. liquid s_f	Entropy kJ/(kg · K): Evap. s_{fg}	Entropy kJ/(kg · K): Sat. vapor s_g
50	12.349	0.001 012	12.03	209.32	2234.2	2443.5	209.33	2382.7	2592.1	0.7038	7.3725	8.0763
55	15.758	0.001 015	9.568	230.21	2219.9	2450.1	230.23	2370.7	2600.9	0.7679	7.2234	7.9913
60	19.940	0.001 017	7.671	251.11	2205.5	2456.6	251.13	2358.5	2609.6	0.8312	7.0784	7.9096
65	25.03	0.001 020	6.197	272.02	2191.1	2463.1	272.06	2346.2	2618.3	0.8935	6.9375	7.8310
70	31.19	0.001 023	5.042	292.95	2176.6	2469.6	292.98	2333.8	2626.8	0.9549	6.8004	7.7553
75	38.58	0.001 026	4.131	313.90	2162.0	2475.9	313.93	2321.4	2635.3	1.0155	6.6669	7.6824
80	47.39	0.001 029	3.407	334.86	2147.4	2482.2	334.91	2308.8	2643.7	1.0753	6.5369	7.6122
85	57.83	0.001 033	2.828	355.84	2132.6	2488.4	355.90	2296.0	2651.9	1.1343	6.4102	7.5445
90	70.14	0.001 036	2.361	376.85	2117.7	2494.5	376.92	2283.2	2660.1	1.1925	6.2866	7.4791

With the aid of above equation demonstrate that as we proceed towards critical point, as expected, h_{fg} - values decrease.

(3) A complex heat to work energy conversion system uses R-134a as its working fluid and operates in a steady state at 60 Hz on a modified Ericsson cycle. This system dissipates available energy internally at a constant rate of 200 W under all conditions applicable to this problem. If the system receives heat at the rate of 500 W from a 300 C source and 200 W from a 200 C source, what is the maximum allowable sink temperature for the system to produce 100 W of shaft power. T_{sink} = _______ C

If operating at the maximum possible efficiency at the calculated sink temperature, what is the rate at which heat is rejected to the sink? $\dot{Q}_{sink}$ = _______ W

(4) The system shown below is used for producing fresh water from salt water. The conditions are as shown in the figure. Assume that properties of salt water are the same as for pure water, and that the pump is reversible and adiabatic.

a. Determine the ratio (m_7/m_1); i.e., the fraction of salt water purified.

b. Determine the pump work input per mass of pure water produced, w_P.