Problems (Ch. 2)

1. Derive the Clausius Clapeyron equation from the Gibb's equation.

$$Tds = dh - dp/\rho \,.$$

2. Estimate the enthalpy to evaporate the water of 525°F using the Clausius Clapeyron equation and compare to the result from the steam table.

3. Find the minimum liquid superheat required for nucleate boiling from a horizontal surface in water at atmospheric pressure where.

   (a) cavities of all radii are present and the heat flux is,

$$q'' = 1.0\times10^{6}\ \mathrm{Btu/hr\ ft^2}.$$

   (b) only cavities of 1/2 mil(0.0005") radius are present

   (c) How does the result in Part (b) change as the system pressure is increased ?

4. Prob. 1-1 of Collier's book.

5. For 665.6 F water, calculate the amount of liquid superheat necessary to generate 1.68×10^{-3} in diameter bubble at 2250 psia.

6. Consider the data presented on the next three figures concerning the actual frequency distribution of departing bubbles from a platinum wire, where $F(D_b)dD_b$ is the number of bubbles leaving the surface per nucleation site per unit time with diameter between D_b and dD_b.

   1) Obtain the average departure diameter, D_b, and the average departure frequency, f, for the two heat flux

   2) Compare the frequency from the model derived in class, the Cole and Rohsennow's model and Mikic model with that of experiments. And describe the dependence of heat flux on D_b and f.

7. Derive the Rayleigh equation(Eq.5) by inserting Eq.4 into Eq.2 in Handout.

8. Plot the radius as a function of time for the isothermal and isobaric bubble dynamic model as well as the spherical bubble model of Rosenow and Mikic for the two cases below. Briefly discuss the results.

	CASE 1	CASE 2
P_{∞}	0.1831 psia	12.7 psia
T_{∞}(>Tsat)	79.1 °F	217.6 °F
R_o	0.0	0.0

9. For initially nonuniformly superheated liquid(i.e. presence of condensing heat flux), the rate equation of bubble radius was given in class as,

$$\rho_g h_{fg}\,(dR/dt) = h_f(T - T_{sat})/\sqrt{(\pi \alpha_f t)} - q''_{cond}$$

Determine the time dependent bubble radius and express with the maximum bubble radius.

10. Starting with the postulate that energy is conserved, derive the spherically symmetric liquid phase energy equation in spherical coordinates.

$$\frac{\partial T_l}{\partial t} + u_l(r)\frac{\partial T_l}{\partial r} = \frac{\alpha_l}{r^2}\frac{\partial}{\partial r}\left[r^2\frac{\partial T_l}{\partial r}\right]$$

where $u_l(r)$ is the radial velocity of the liquid phase and the subscript l, represents the liquid phase.

11. Following parameters were measured in a subcooled pool boiling test at 1 atm.

$q'' = 1.01\times10^5$ Btu/hr ft^2, T_{bulk}, T_{wall} = 98, 270 °F

Bubble departure frequency = 1000 bubbles/sec
Bubble population = 280 bubbles/cm^2
Average radius of departing bubbles bubbles = 0.01187 in

Obtain the amount of evaporative heat transfer, q''_{evap} .