ME-446 Liquid-Gas Interfacial Heat and Mass Transfer

Homework 7

Presentation by Group 7 on Thursday 6th November

Problem 1: Rohsenow's correlation

Rohsenow's correlation is commonly written in the following form (Eq. 7.30 in Van Carey):

$$\frac{q''}{\mu_l h_{lv}}\left[\frac{\sigma}{g(\rho_l-\rho_v)}\right]^{\frac{1}{2}}=\left(\frac{1}{C_{sf}}\right)^{\frac{1}{r}} Pr_l^{-\frac{s}{r}}\left[\frac{c_{pl}[T_w-T_{sat}(P_l)]}{h_{lv}}\right]^{\frac{1}{r}}$$

Rohsenow recommended $r = 0.33$ and $s = 1$. C_{sf} is suggested to be 0.0132 for water on mechanically polished stainless steel. Setting $P_l = 1\ atm$, with other thermophysical properties of water (consider using Matlab XSteam function, CoolProp library or looking for correlations in literature), write your own code to generate the boiling curve (q'' vs $T_w - T_{sat}(P_l)$ for T_w between 110°C and 130°C.

Problem 2: Bubble departure

Consider a static vapor bubble resting on a surface, neglecting the influence of the flow caused by the bubble growth. Given the apparent contact angle θ, the liquid-vapor density difference $\Delta\rho$, and the surface tension σ derive an expression that describes the volume of the bubble V_B at equilibrium.

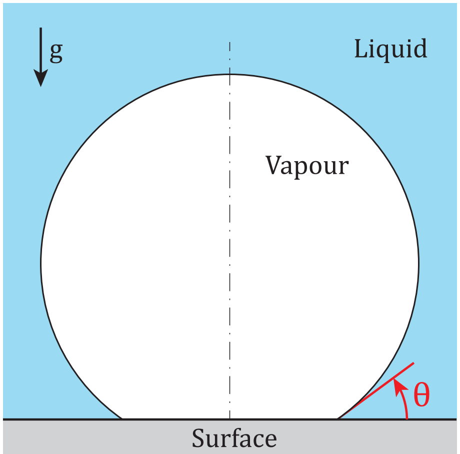

Figure 1: Schematic representation of a static vapor bubble on a surface.

Problem 3: Transient conduction in a semi-infinite solid

Consider a semi-infinite solid between $x = 0$ and $x = +\infty$ spanning half of the space, initially sitting at an isothermal state $T = T_i$ for all $x \geq 0$ and time $t < 0$. Please directly write down the solid temperature as a function of x and t ($t \geq 0$) for the following conditions, assuming you know all the necessary thermophysical properties of the solid. Comment on the timescale of the thermal response in each process assuming a certain characteristic length scale L_c representing the thermal penetration depth.

A) At time $t = 0$, set the solid surface temperature at $x = 0$ to $T_f \neq T_i$.

B) At time $t = 0$, expose the solid surface to a fluid of temperature $T_f \neq T_i$ and convective heat transfer coefficient h

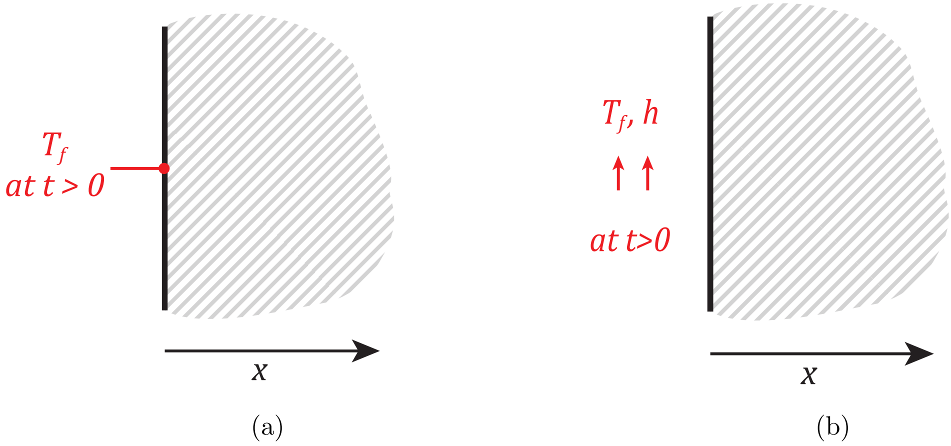

Figure 2: Scenario A, sudden shock at given temperature T_f at the surface (a). Scenario B, sudden shock at given fluid temperature and convective heat transfer coefficient h (b).

Problem 4: Hydrodynamic instabiltiy

Carefully read the pages 113 to 119 of the Van Carey book and answer the following questions with words and/or equations.

A) In Eq. 4.23, we assume and initial perturbation $\delta(x, 0) = Ae^{i\alpha x}$. And then, we consider subsequent oscillation of the interface with the functional form $\delta(x, t) = Ae^{i\alpha x} + \beta t$ with β being the unknown. Assume you now have found the expression for β as a complex number $a + ib$. Describe the condition under which the amplitude of the perturbation will grow with time.

B) If the relative velocity is zero and the liquid is on top of the vapor. We have the following expression for β (Eq. 4.53a in Van Carey).

$$\beta = \pm \left\{ \frac{(\rho_l - \rho_v) g \alpha - \sigma \alpha^3}{\rho_l + \rho_v} \right\}^{\frac{1}{2}}$$

Derive an expression for the perturbation wavelength with the fastest growth.