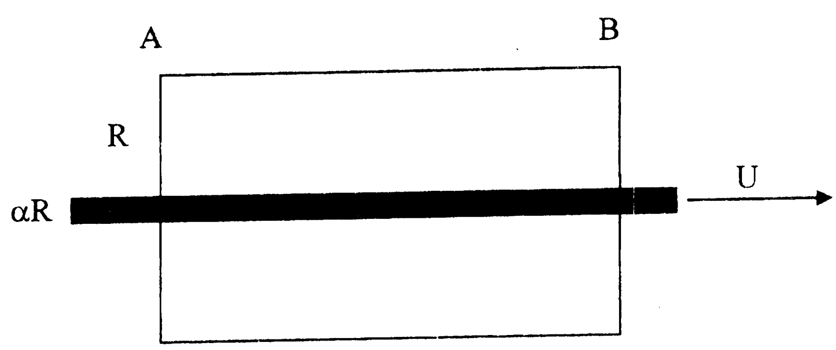
1. Consider an axial annular flow of a fluid confined between two cylinders as shown in the following figure. The inner cylinder with radius αR is moving to the right at velocity U while the outer cylinder with radius R is stationary. If ignoring the flow at both ends, the fluid flow is strictly axial laminar flow over most of the length L. Assuming the fluid is Newtonian and neglecting the gravity,
   (a) Please draw the velocity profile of the fluid flow between two cylinders. (3 %)
   (b) Obtain the velocity profile of the fluid flow. (7 %)
   (c) Derive the expression for the pressure difference between both ends. (5 %)
   (hint: begin with using the following dimensionless variables:
   $$\frac{V_z(r)}{U}=\upsilon(s),\quad \frac{r}{R}=s,\quad \frac{\Delta PR^2}{4\mu LU}=\Psi(\alpha)$$
   Which end has the higher pressure and how do you reach your answer? (2 %)
   (d) If the viscosity of the fluid is 2 Poise, L=25 cm, R=1 cm, α=0.9 and U=1 m/s, what is the pressure difference between both ends? (3 %)



$$\rho\left(\frac{\partial \upsilon_r}{\partial t}+\upsilon_r\frac{\partial \upsilon_r}{\partial r}+\frac{\upsilon_\theta}{r}\frac{\partial \upsilon_r}{\partial \theta}-\frac{\upsilon_\theta^2}{r}+\upsilon_z\frac{\partial \upsilon_r}{\partial z}\right)=-\frac{\partial P}{\partial r}+\mu\left[\frac{\partial}{\partial r}\left(\frac{1}{r}\frac{\partial}{\partial r}(r\upsilon_r)\right)+\frac{1}{r^2}\frac{\partial^2 \upsilon_r}{\partial \theta^2}-\frac{2}{r^2}\frac{\partial \upsilon_\theta}{\partial \theta}+\frac{\partial^2 \upsilon_r}{\partial z^2}\right]+\rho g_r$$

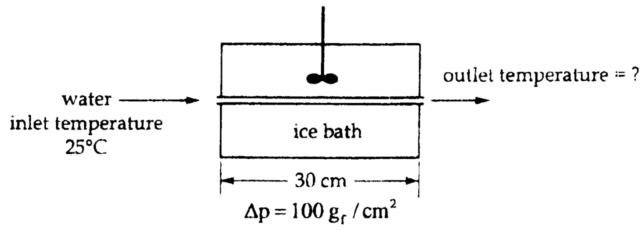
$$\rho\left(\frac{\partial \upsilon_\theta}{\partial t}+\upsilon_r\frac{\partial \upsilon_\theta}{\partial r}+\frac{\upsilon_\theta}{r}\frac{\partial \upsilon_\theta}{\partial \theta}+\frac{\upsilon_r\upsilon_\theta}{r}+\upsilon_z\frac{\partial \upsilon_\theta}{\partial z}\right)=-\frac{1}{r}\frac{\partial P}{\partial \theta}+\mu\left[\frac{\partial}{\partial r}\left(\frac{1}{r}\frac{\partial}{\partial r}(r\upsilon_\theta)\right)+\frac{1}{r^2}\frac{\partial^2 \upsilon_\theta}{\partial \theta^2}+\frac{2}{r^2}\frac{\partial \upsilon_r}{\partial \theta}+\frac{\partial^2 \upsilon_\theta}{\partial z^2}\right]+\rho g_\theta$$

$$\rho\left(\frac{\partial \upsilon_z}{\partial t}+\upsilon_r\frac{\partial \upsilon_z}{\partial r}+\frac{\upsilon_\theta}{r}\frac{\partial \upsilon_z}{\partial \theta}+\upsilon_z\frac{\partial \upsilon_z}{\partial z}\right)=-\frac{\partial P}{\partial z}+\mu\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial \upsilon_z}{\partial r}\right)+\frac{1}{r^2}\frac{\partial^2 \upsilon_z}{\partial \theta^2}+\frac{\partial^2 \upsilon_z}{\partial z^2}\right]+\rho g_z$$

2. (a) What is the critical radius for insulation of cylinder or pipe? (5%)
   (b) The energy-transfer processes associated with the change in phase between a liquid and a vapor are more difficult to describe than the convective heat-transfer processes. Why? (6%)
   (c) Discuss the effect of liquid head and friction on capacity in tubular evaporators. (9%)

（背面仍有題目,請繼續作答）

3. Water is fed to a smooth capillary immersed in a well-stirred ice bath, as shown in the figure. The inlet temperature is 25°C and the wall temperature of the capillary is maintained at 0°C. The length (L) and inside diameter (D) of the capillary are 30 cm and 0.2 cm, respectively. In addition, the pressure drop across the capillary is 100 g_f/cm^2.



The properties of water are μ (viscosity) = 1 cp, C_p (heat capacity) = 4.184 J/g·K, k (thermal conductivity) = 0.570 W/m·K. Note that 1 cal = 4.184 J and 1 W = 1 J/sec.

(a) (7%) Estimate the average velocity of the flow if $f = 0.0791\,Re^{-1/4}$ applies, where f is the friction factor and Re is the Reynolds number.

(b) (5%) Estimate the logarithmic mean heat transfer coefficient h_{ln} if Colburn analogy applies, i.e., $j_{H,ln} = f/2$, where $j_{H,ln}$ is the Chilton-Colburn j-factor defined by

$$j_{H,ln} = \frac{Nu_{ln}}{Re\,Pr^{1/3}}$$

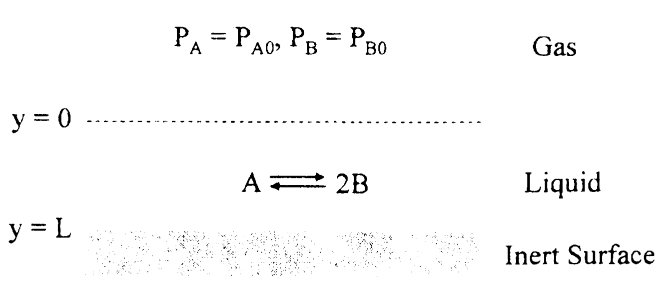
Here Pr is the Prandtl number and Nu_{ln} is the Nusselt number.

(c) (8%) Estimate the outlet temperature from the capillary.

4. (20%) A gas mixture containing different partial pressure of species A (P_A) and B (P_B) dissolves in a stagnant liquid film as shown in the figure. The solubility of gas A and gas B in the liquid is α_A and α_B respectively. In the liquid, A is converted reversibly to B following first order chemical reaction. The reaction is

$$A \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} 2B$$

At steady state, determine the flux of A in the liquid film (assume that $D_A = D_B = D$).



5. (a). A small water droplet evaporates in an air stream of temperature **T** and humidity $\mathcal{H}$. When a steady state is approached, before complete evaporation of this droplet, the temperature of the droplet is $\mathbf{T_S}$. Please derive the following equation for obtaining the $\mathbf{T_S}$: (make suitable assumption for your requirement) **(12 %)**

$$\frac{\mathcal{H} - \mathcal{H}_S}{T - T_S} = -\frac{h_y}{M_B k_y \lambda_S}$$

Where $\mathcal{H}$: the humidity of the air, M_B: molecular weight of air

$\mathcal{H}_S$: the saturation humidity at T_S,

λ_S : latent heat of water at T_S,

h_y and k_y: heat transfer and mass transfer coefficients, respectively, at gas/liquid interface

(b). If the air temperature is 140 °F with a percentage humidity of 30%, determine the droplet temperature from the attached humidity chart. Please explain why this chart can be used and draw a simple figure to show how you find the answer from this chart? **(4%)**

(c). If the air of problem (b) was fed into an adiabatic chamber containing sufficient amount of water droplets. In which, the humidity of the air was increased to a saturated condition. Please determine the temperature and humidity of the air leaving from the chamber. Describe how you obtain the answer **(4%)**

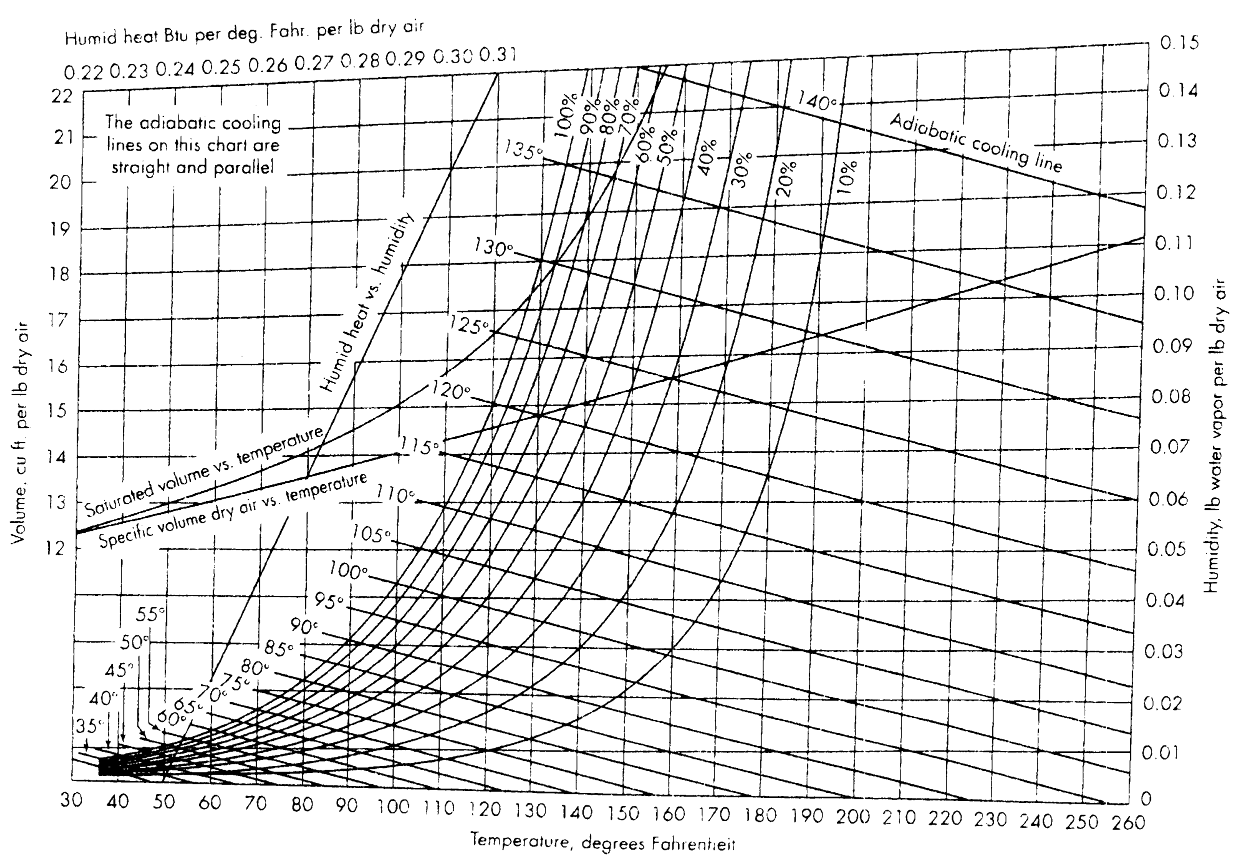


FIGURE
Humidity chart. Air-water at 1 atm.