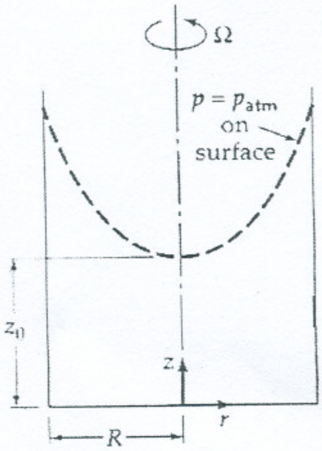
1. (25%) Briefly express the followings (a) adsorption, absorption, leaching, distillation, extraction and crystallization in terms of multiphase separation/ purification processes, (b) rotameter, thermocouple and Bourdon gauge and (c) sketch recycle steam, purge steam and bypass steam in a flowchart of the process and explain the purpose(s) of the steams.

2. (10%) Why does a golf ball have dimples (凹面/凹洞)? Please explain it in terms of aerodynamics.

3. (15%) A liquid of constant density (ρ) and viscosity (μ) is in a cylindrical container of radius R as shown in the Figure on the right. The container is caused to rotate about its own axis at an angular velocity Ω and the fluid is a Newtonian fluid. The cylinder axis is vertical, so that $g_r = 0$, $g_\theta = 0$, $g_z = -g$, in which g is the magnitude of the gravitational acceleration. Please (a) express the equation of the velocity distribution $\upsilon_\theta(r)$, (b) express the pressure (p) at all points within the liquid and (c) find the shape of the free surface of the liquid when steady state has been established. (assume: $\upsilon_\theta = \upsilon_\theta(r)$, $\upsilon_r=0$, $\upsilon_z=0$ and $p=p(r, z)$)



Equation of Continuity $\dfrac{\partial \rho}{\partial t} = -(\nabla \cdot \rho \mathbf{v})$

Cylindrical coordinates (r, θ, z):

$$\frac{\partial \rho}{\partial t} + \frac{1}{r}\frac{\partial}{\partial r}(\rho r v_r) + \frac{1}{r}\frac{\partial}{\partial \theta}(\rho v_\theta) + \frac{\partial}{\partial z}(\rho v_z) = 0$$

Equation of Motion for a Newtonian fluid with constant μ and ρ

Cylindrical coordinates (r, θ, z):

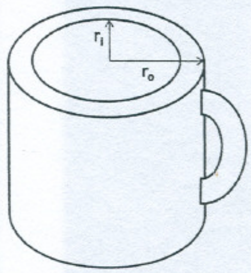
$$\rho\left(\frac{\partial v_r}{\partial t} + v_r\frac{\partial v_r}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_r}{\partial \theta} + v_z\frac{\partial v_r}{\partial z} - \frac{v_\theta^2}{r}\right) = -\frac{\partial p}{\partial r} + \mu\left[\frac{\partial}{\partial r}\left(\frac{1}{r}\frac{\partial}{\partial r}(r v_r)\right) + \frac{1}{r^2}\frac{\partial^2 v_r}{\partial \theta^2} + \frac{\partial^2 v_r}{\partial z^2} - \frac{2}{r^2}\frac{\partial v_\theta}{\partial \theta}\right] + \rho g_r$$

$$\rho\left(\frac{\partial v_\theta}{\partial t} + v_r\frac{\partial v_\theta}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_\theta}{\partial \theta} + v_z\frac{\partial v_\theta}{\partial z} + \frac{v_r v_\theta}{r}\right) = -\frac{1}{r}\frac{\partial p}{\partial \theta} + \mu\left[\frac{\partial}{\partial r}\left(\frac{1}{r}\frac{\partial}{\partial r}(r v_\theta)\right) + \frac{1}{r^2}\frac{\partial^2 v_\theta}{\partial \theta^2} + \frac{\partial^2 v_\theta}{\partial z^2} + \frac{2}{r^2}\frac{\partial v_r}{\partial \theta}\right] + \rho g_\theta$$

$$\rho\left(\frac{\partial v_z}{\partial t} + v_r\frac{\partial v_z}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_z}{\partial \theta} + v_z\frac{\partial v_z}{\partial z}\right) = -\frac{\partial p}{\partial z} + \mu\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial v_z}{\partial r}\right) + \frac{1}{r^2}\frac{\partial^2 v_z}{\partial \theta^2} + \frac{\partial^2 v_z}{\partial z^2}\right] + \rho g_z$$

4. CCU convenient store would like to launch a new coffee cup, which will maintain the temperature of hot coffee. This project is assigned to you, a chemical engineer who leads a design team.
   (a) (10%) Please write down the energy balance equation, boundary conditions and assumptions, based on the shape of a regular mug shown in the following Figure.
   (b) (10%) Calculate the minimum thickness of the mug.

   Thermal conductivity of the mug, k (W/m.K); convection heat transfer coefficient of the air, h ($W/m^2.K$); the temperature of the coffee inside the cup, T_i; room temperature, T_∞; inner radius of the mug, r_i; outer radius of the mug, r_o.



CCU mug.

5. (10%) CCU is building an energy efficient Engineering Building in order to decrease the use of electricity. Based on your knowledge of heat transfer process, please give few key factors that can assist us to design this green architecture and explain why.

6. (a) (10%) What is the physical origin of mass diffusion process? What is fick's law? Name few driving forces for mass diffusion.
   (b) (10%) Steam reforming of hydrocarbons is the major process used to produce hydrogen. In situ hydrogen removal from the reactor shifts the equilibrium to a higher conversion. Pd membrane is usually used for this hydrogen separation process. Assume a simple mass diffusion mechanism, please calculate the steady-state molar diffusion flux for hydrogen through thin Pd membrane (30 μm). The molar concentration of hydrogen at one side of the membrane is 2 $kmol/m^3$, while the concentration of hydrogen at the other side of the membrane is negligible. The binary diffusion coefficient for hydrogen in Pd is 4×10^{-12} m^2/s. (10 pts)