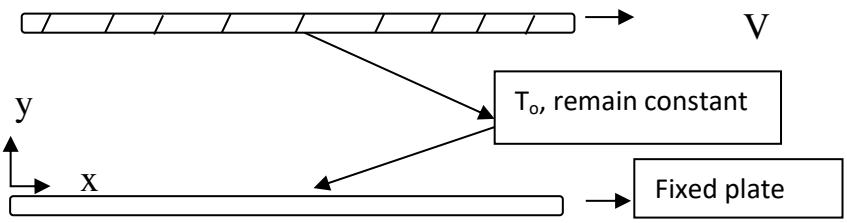
CLL 110 Max Marks: 40, Max Time: 2hrs: 9.00-11.00 AM

After you have finished answering all questions, you are required to submit the scanned copy of your answers as a single pdf file. 20 minutes of extra time is given for this post-examination operation. Once you have created a single pdf file of your answers, please upload this file to the folder 'Major' on Moodle. No submissions will be accepted after 11.20 am.

Q1.Determine the velocity profile for a power-law fluid flowing in a horizontal pipe under steady, laminar flow conditions. The length of the pipe is L and at z = 0, pressure, $p = p_0$, while at z = L, pressure, $p = p_L$. Use equation of motion to solve the problem. Also, determine the average velocity as well as the shear stress at the wall.
(8)

Q2. Determine the critical radius of insulation, R_c , for an insulated long pipe. Before the insulation is applied, the radius of the pipe is R_0 and the pipe is maintained at constant temperature of T_0. A fluid at temperature T_a surrounds the insulated pipe and the thermal conductivity of the insulation is k. The outside heat transfer coefficient under these conditions is h_a. Discuss your result in detail. Show 'heat lost' profile as a function of the thickness of the insulation for the cases where $R>R_c$, and $R<R_c$.
(8)

Q3. A Newtonian fluid (lubricant) as shown below lubricates a sliding bearing. Both plates of the bearing are maintained at a constant temperature T_o. The bearing lubricant is expected to heat up due to viscous dissipation and it is important to ensure that the recommended maximum lubricant operation temperature is not exceeded. The bottom plate is fixed while the top plate moves with a velocity 'V'. Find the velocity and temperature distribution, and the maximum temperature and its location. The gap between the two plates of the bearing is 'H' and the density and viscosity are expected to be constants in the involved temperature range. The thermal conductivity of the lubricant is a function of temperature is given by, $k= \frac{1}{A+B\,T}$, where 'A' and 'B' are constants.
(8)



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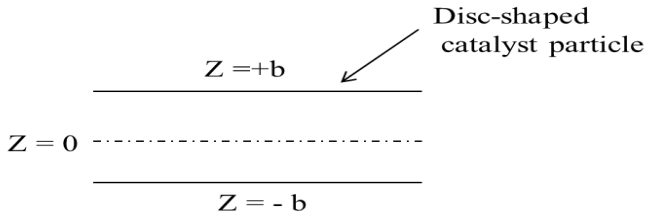
Q4. A spherical vessel of radius 100 cm is half filled with methanol at 27°C. A small circular hole of radius 10 cm is cut on top of this vessel from where the methanol is lost to air by evaporation. Determine the rate of loss of methanol in gm/sec for following data.

P = pressure = 760 mm Hg
Diffusion coefficient of methanol in air = 0.1 cm^2/sec and
Vapor pressure of methanol at 27°C = 160 mm Hg

You may assume that negligible methanol is present in the air outside the vessel and that methanol behaves like an ideal gas.
(8)

Q5. A first order reaction A → B is taking place inside a circular disc shape porous catalyst particle. The thickness of the disc is 2b, and the concentration of *A* at both end of disc is C_{As}. Neglect the variation of concentration in *r* and θ direction and curvature of disc.



If the rate of reaction R_A is given by

$$R_A = -k_1'' \, a \, C_A,$$

where 'a' is surface area of the catalyst per unit volume of the catalyst particle, determine the rate of conversion of A into the product B. Also, determine the effectiveness factor for this particle.
(8)