BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI
First Semester 2022-2023
CHE F414 Transport Phenomena
Comprehensive Examination

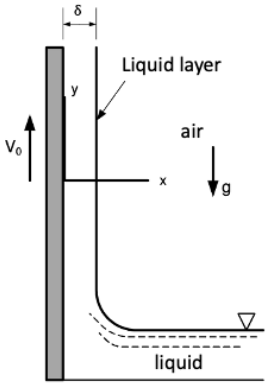
Date: 23.12.2022, 9AM-12:00PM **Duration: 180 Min.** **Total Marks: 40**

- State and justify any assumptions that you make. Nomenclature should be defined properly.

PART-B (OPEN BOOK), Total Marks 25

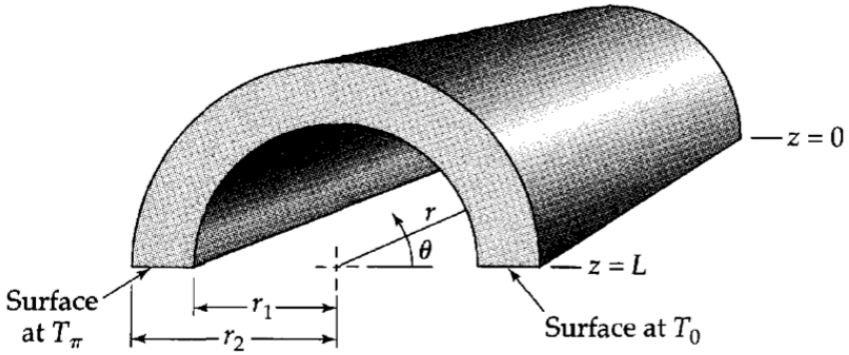
Q.1 A wide-moving belt passes through a container of a viscous liquid. The belt moves vertically upward with a constant velocity V_0 as illustrated in the figure. The belt picks up a film of fluid thickness δ and gravity tends to make the fluid drain down the belt. Assume that the flow is laminar, steady, and fully developed.

Using the shell-momentum balance approach determine an expression for
(a) momentum flux distribution and
(b) velocity distribution,
(b) the average velocity of the fluid film as it is dragged up the belt.



[5 Marks]

Q.2 Consider the schematic of the half-cylindrical shell. The curved surfaces and the end surfaces (shaded in figure) of the solid half-cylindrical shell are insulated. The surface at $\theta = 0$ of area $(r_2 - r_1)L$ is maintained at a temperature T_0 and the surface at $\theta = \pi$, also of area $(r_2 - r_1)L$ is kept at a temperature of T_{pi}. The thermal conductivity of the solid varies linearly with temperature from k_0 at $T = T_0$ to k_π at $T = T_\pi$. Using the shell balance approach, determine the expression for steady-state temperature distribution



[5 Marks]

Q.3 Consider a spherical catalyst pellet of radius R. The thermal conductivity of the catalyst is k. Because of the chemical reaction occurring within the porous pellet, heat is generated at a rate of S_c, cal/cm^3.s. Heat is lost at the outer surface of the pellet to a gas stream at constant temperature T_g, by convective heat transfer with heat transfer coefficient h. Assume that S_c is constant throughout.

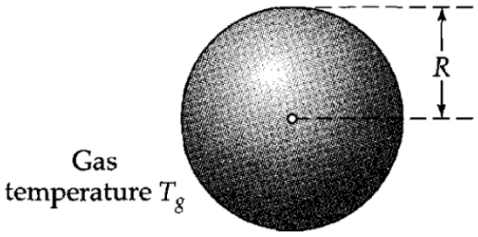
Using equations of energy,

(a) write the governing equation (explain your reasoning with postulates and assumptions),

(b) write the boundary conditions,

(c) determine the temperature profile within the catalyst.

(d) what is the maximum temperature in the catalyst?



[6 Marks]

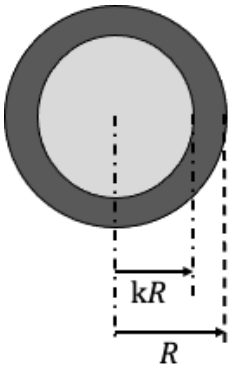
Q.4 Consider a catalyst sphere, as shown in the figure. The catalyst is inactive in the region ($0 < r < kR$) and active for a zero-order reaction ($A \rightarrow B$) in the region ($kR < r < R$). The outside bulk concentration of A and B are C_{AR} and C_{BR}, respectively. Assume no mass transfer resistance at the gas-solid boundary.

Using the shell mass balance approach,

(a) derive the governing differential equations for the concentration within the sphere.

(b) write the boundary conditions,

(c) determine the concentration profile for both the regions ($0 < r < kR$) and ($kR < r < R$).



[8 Marks]

#ALL THE BEST

BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI
First Semester 2022-2023
CHE F414 Transport Phenomena
Comprehensive Exam (Closed Book)

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PART-A (CLOSED BOOK), TOTAL MARKS 16

Q.1 (6 Marks) Answer the following questions briefly.

A. Explain the analogy between momentum transport, energy transport, and mass transport.

B. The velocity distribution for a falling film of thickness δ on a flat plate is given by: $v_z = v_{max}\left(1-\left(\frac{x}{\delta}\right)^2\right)$. Obtain the average velocity over the cross-section.

C. What is the difference between Total Time derivative and Substantial Time Derivative?

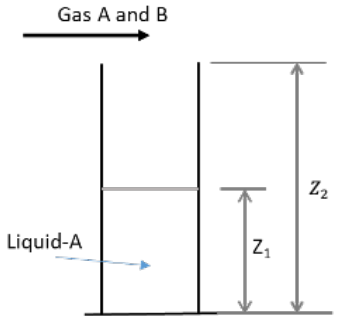
D. Write the two common boundary conditions used in Energy Transport.

E. Define total energy flux. What is the Boussinesq approximation?

F. Write expressions for the Prandtl number and Schmidt number. Write their significance.

Q.2 (5 Marks)

Liquid (A) is in a small cylindrical tube and evaporates into a large gas stream (B). The concentration of A and B may be assumed as dilute, i.e.; the convection term can be ignored. Assume the liquid level is constant in the container and species B is stationary. Obtain the expression for the concentrations of A along the z-axis.



Q.3 (5 Marks)

Consider a steady state axial flow of an incompressible liquid in an annular region between two coaxial cylinders *kR* and *R*. The cylinders are vertical, and the liquid flow is in the direction opposed to gravity. Assume laminar flow. Using shell momentum balance approach, derive an expression for velocity distribution.

#ALL THE BEST