KATHMANDU UNIVERSITY
End Semester Examination
01 – January 2024

Marks Scored:

Level : B.E.
Year : IV

Course : CHEG 401
Semester : I

Exam Roll No. :

Time: 30 mins.

F. M. : 10

Registration No.:

Date :

SECTION "A"
[20Q. × 0.5 =10 marks]

Encircle the most appropriate option from each set of choices

1. What does ρv_x denote?
   a. convective flux of mass
   b. molecular flux of mass
   c. convective flux of momentum
   d. molecular flux of momentum

2. Which of the following has the greater generality than the others?
   a. shell balance
   b. equations of change
   c. equation of continuity
   d. conservation of momentum

3. What does τ_{xy} represent?
   a. x-normal stress in positive y direction
   b. y-normal stress in positive x direction
   c. flux of x momentum in positive y direction
   d. flux of y momentum in positive x direction

4. Which of the following statement is true for "shell" in a shell momentum balance?
   a. thin in the direction in which the velocity varies
   b. thin in the perpendicular direction in which the velocity varies
   c. thin in the direction in which the momentum varies
   d. thin in the perpendicular direction in which the momentum varies

5. If the gas-side velocity gradient is not too large at a liquid-gas interfacial plane of constant x, what is/are taken to be zero?
   a. only p
   b. only v
   c. τ_{xy} and v
   d. p and τ_{xy}

6. In an annual region between two coaxial circular cylinders of radii κR and R, the viscous momentum-flux distribution $\tau_{rz}(r)$ and velocity distribution $v_z(r)$ for the upward flow in a cylindrical annulus are to be estimated. What will be the boundary condition at $r = \kappa R$?
   a. v_z is finite
   b. v_z is zero
   c. τ_{rz} is finite
   d. τ_{rz} is zero

7. What does $(\nabla \cdot \rho \mathbf{v})$ represent?
   a. net rate of mass addition per unit area
   b. net rate of mass disappearing per unit area
   c. net rate of mass efflux per unit volume
   d. net rate of mass influx per unit volume

8. In the equation of change for kinetic energy, what does $-(\nabla \cdot p\mathbf{v})$ represent per unit volume?
   a. rate of work done by pressure of surroundings on the fluid
   b. rate of work done by viscous force on the fluid
   c. rate of reversible conversion of kinetic energy into internal energy
   d. rate of work done by external force on the fluid

9. In a steady flow in a long circular tube, what does $\mathbf{v} = \boldsymbol{\delta}_z v_z(r,z)$ imply?
a. no radial and axial flow
b. no tangential and radial flow
c. no axial and tangential flow
d. no axial flow only

10. What is used to calculate conductive heat-flux vector?
a. Fourier's law
b. Darcy's law
c. First law of thermodynamics
d. Prandtl number

11. To calculate work-flux vector, what convention is used?
a. the rate at which work is done by the fluid on the minus side
b. the rate at which work is done by the fluid on the positive side
c. the rate at which work is done by the fluid on the upper side
d. the rate at which work is done by the fluid on the lower side

12. At a solid-fluid interface, the normal heat-flux component is found by using:
a. conductivity
b. heat transfer coefficient
c. no-slip condition
d. continuity

13. Biot number contains the thermal conductivity of:
a. fluid
b. surrounding
c. solid
d. gas

14. In energy transport in a tubular, fixed-bed flow reactor, what is assumed in a flow through a packed bed?
a. complete mixing
b. plug flow
c. isothermal
d. isobaric

15. Mass average velocity of a binary mixture is same as:
a. v_{max} in parabolic profile
b. $\mathbf{v}$ in equation of motion
c. molar average velocity
d. convective mass flux vector

16. Total mass flux of A in binary mixture of A and B is given as:
a. $\rho_A \mathbf{v}_A$
b. $\rho_A \mathbf{v}$
c. $-\rho \mathscr{D}_{AB} \nabla \omega_A$
d. $\rho \mathbf{v}$

17. We consider a system such that A is only very slightly soluble in liquid B. What can we neglect in calculating the molar flux of A?
a. total mass flux
b. molecular flux
c. diffusive term
d. convective term

18. In diffusion with a heterogeneous chemical reaction, conversion proceeds at a finite rate because of:
a. rate of reaction
b. diffusion
c. catalytic reaction
d. convection

19. What does the Reynolds analogy neglect?
a. turbulent diffusivity
b. molecular diffusivity
c. eddy diffusivity
d. momentum transfer

20. In Chilton and Colburn J-factor analogy, when form drag is present, as in flow in packed beds or past other blunt objects, which one of the following is true?
a. $f/2 > J_H$
b. $f/2 = J_H$
c. $f/2 < J_H$
d. $f/2 < J_D$

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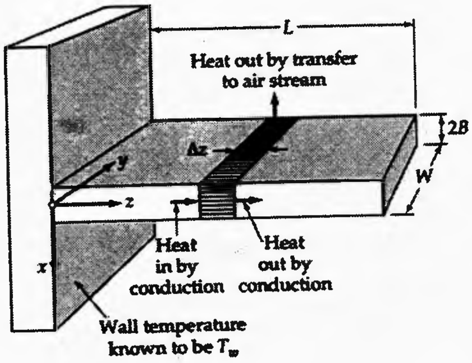
SECTION "B"

Attempt *ALL* questions. The data or information not given in the questions should be assumed properly.

1. An incompressible Newtonian fluid is in laminar flow in a narrow slit formed by two parallel walls a distance 2B apart. It is understood that $B \ll W$ and $B \ll L$, so that "edge effects" are unimportant.
   a. Make a shell momentum balance and obtain the velocity distributions. [6]
   b. What is the ratio of the average velocity to the maximum velocity for this flow? [2]

2. Fins are used to increase the area available for heat transfer between metal walls and poorly conducting fluids such as gases. A simple rectangular fin is shown in figure below. The wall temperature is T_w and the ambient air temperature is T_a. Perform shell energy balance to get temperature profile. [8]



Take the solution of $\frac{d^2\Theta}{d\zeta^2} - N^2\Theta = 0$ as:

$$\Theta(\zeta) = C_1 \cosh N\zeta + C_2 \sinh N\zeta$$

$$\cosh(x \pm y) = \cosh x \cosh y \pm \sinh x \sinh y$$

$\Theta(\zeta) = \frac{T(z) - T_a}{T_w - T_a}$ = dimensionless temperature difference

$\zeta = \frac{z}{L}$ = dimensionless distance

$N^2 = \frac{hL^2}{kB}$ = dimensionless heat-transfer coefficient

3. In studying the rate of leaching of a substance *A* from solid particles by a solvent *B*, we may postulate that the rate-controlling step is the diffusion of *A* from the particle surface through a stagnant liquid film of thickness δ ($z = 0$ to $z = \delta$) out into the main stream. The molar solubility of *A* in *B* is c_{A0}, and the concentration in the main stream is $c_{A\delta}$.
   a. Obtain a differential equation for c_A as a function of z by making a mass balance on *A* over a thin slab of thickness Δz. Assume that $\mathscr{D}_{AB}$ is constant and that *A* is only slightly soluble in *B*. Neglect the curvature of the particle. [5]
   b. Find the equation of the rate of leaching per unit area. [3]

4. In the portion of the annulus in Couette viscometer, the fluid moves in a circular pattern. Simplify the following components of the equation of motion for this system by providing reasonable postulates for the velocity and pressure. [6]

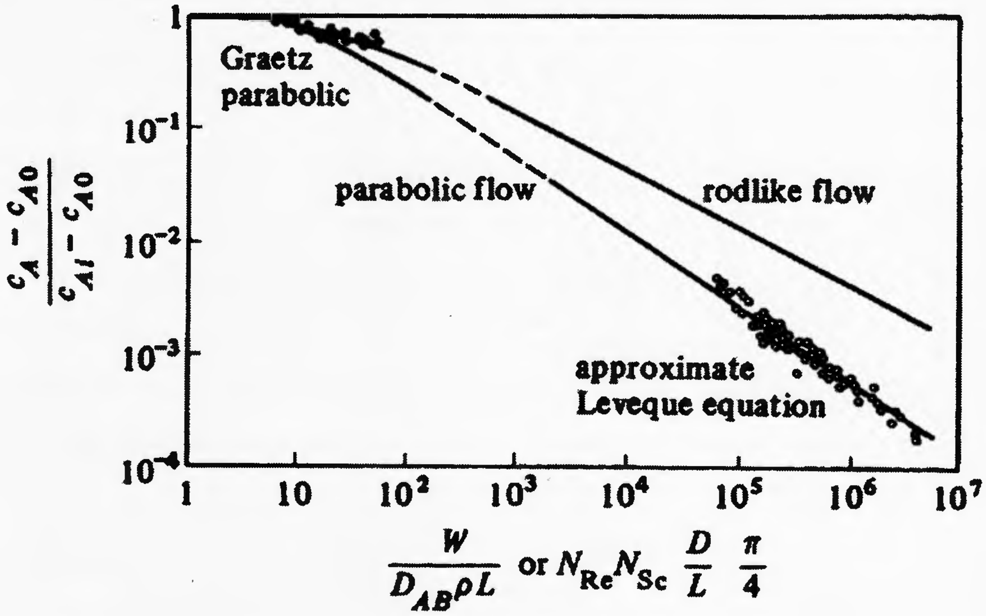
$$\rho\left(\frac{\partial v_r}{\partial t}+v_r\frac{\partial v_r}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_r}{\partial \theta}+v_z\frac{\partial v_r}{\partial z}-\frac{v_\theta^2}{r}\right)=-\frac{\partial p}{\partial r}+\mu\left[\frac{\partial}{\partial r}\left(\frac{1}{r}\frac{\partial}{\partial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

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

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

5. Pure water at 26.1°C is flowing at a velocity of 0.0305 m/s in a tube having an inside diameter of 6.35 mm. The tube is 1.829 m long, with the last 1.22 m having the walls coated with benzoic acid. Assuming that the velocity profile is fully developed, calculate the average concentration of benzoic acid at the outlet. The solubility of benzoic acid in water is 0.02948 kg mol/m^3.

$\mu = 8.71\times 10^{-4}$ Pa·s; $\rho = 996$ kg/m^3; $\mathscr{D}_{AB} = 1.245 \times 10^{-9}$ m^2/s. Use the graph below as well. [6]



6. Briefly explain: [2 × 2=4]

a. Equation of motion in vector/tensor notation

b. Local mass average velocity for a mixture of two chemical species