ENCH 501 Transport Phenomena University of Calgary Name A. Kyi

Quiz #3 / Time Allowed: 40 minutes Only a "cheat sheet" is allowed. October 13, 2015 AJ

Q. 1 (5 points)

Identify the types of motion prevalent in the following:

1 – Translation, **2** – Linear Deformation, **3** – Angular deformation, **4** – Rotation

Check all the appropriate boxes (There are no part marks for each one.)

	1	2	3	4	
1. Blowing wind	✓		✓	✓	
2. Gas flow at high rates through a uniform-diameter, straight pipe	✓	✓	✓	✓	← eddies
3. Water flowing at a slow rate in a straight uniform-diameter tube	✓		✓		
4. Water draining from a full kitchen sink suddenly unplugged	✓				← no rotation, pure translation (path curved) - spiral
5. Air flow during inhalation (as you breathe)	✓		✓	✓	
6. A drop of water falling through the air	✓				
7. Waves crashing on the seashore	✓		✓	✓	
8. Mushroom cloud from detonating an explosion from blasting rock	✓	✓	✓	✓	
9. Flow out of the exhaust pipe of a running vehicle	✓	✓	✓	✓	← cooling + shrinking
10. Water in a beaker placed at the centre of a slowly rotating turn-table	✓				↑ solid body rotation

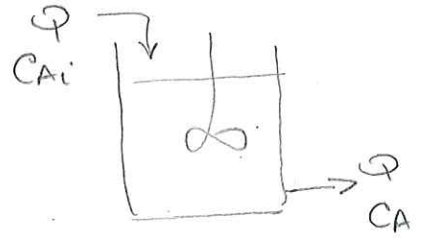
Q. 2 (5 pts)

A batch reactor is a cylindrical tank with a diameter of D m. It is filled to a volume ∀. The level of the liquid above the bottom of the tank is maintained constant. At time t = 0, a solution containing substance A at a concentration C_{Ai} kg/m^3 flows at a rate Q m^3/s into the reactor from the top of the tank. There was no substance A initially in the tank that is always well stirred. Substance A reacts in the tank and it is removed at a rate proportional to its concentration C_A within the tank at any time (a first –order reaction). Per unit volume, the rate of disappearance of A is $k_1 C_A$. A solution flows out of the tank at the same volume rate as the feed from time t = 0.

Derive an expression for the mass of A in the tank as a function of time, t.

Show all important steps.

Q. 2.



At $t = 0$ $C_A = 0$ in tank.

Control volume – liquid in tank.

Balance – mass of A in tank → A.

Input + Gen = Output + Accum.

$$Q C_{Ai} - k_1 C_A V = Q C_A + \frac{d(V C_A)}{dt} \quad ; \; V = \text{const.}$$

$$\frac{dC_A}{dt} = -\left(k_1 + \frac{Q}{V}\right) C_A + \frac{Q}{V} C_{Ai}$$

Group constants, ∴

$$\frac{dC_A}{dt} = -\alpha C_A + \beta \quad \text{with} \quad t = 0, \; C_A = 0$$

Let $Y = \beta - \alpha C_A$, $dY = -\alpha \, dC_A$

$$-\frac{1}{\alpha}\frac{dY}{dt} = Y \quad \text{or} \quad \frac{dY}{Y} = -\alpha \, dt$$

Integrate $t = 0$, $C_A = 0$ or $Y = \beta$

$$\int_{\beta}^{\beta - \alpha C_A} \frac{dY}{Y} = -\alpha \int_0^t dt \quad \text{or} \quad \ln Y \Big|_{\beta}^{\beta - \alpha C_A} = -\alpha t$$

$$\ln\left(\frac{\beta - \alpha C_A}{\beta}\right) = -\alpha t \quad \text{or} \quad 1 - \frac{\alpha}{\beta} C_A = e^{-\alpha t}$$

$$\therefore \; C_A = \frac{\beta}{\alpha}\left(1 - e^{-\alpha t}\right)$$

Mass of A, $A = C_A V = \frac{\beta V}{\alpha}\left(1 - e^{-\alpha t}\right)$

Total A in tank $A = \left(\frac{Q C_{Ai} V}{k_1 V + Q}\right)\left(1 - e^{-\left(k_1 + \frac{Q}{V}\right)t}\right)$ kg

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