CHE F411 – Environmental Pollution Control
Comprehensive Examination
Total Marks: 120 Duration: 180 minutes

Your name: **Date: 13/12/2023**

Important: *There are 6 question in this exam. Please READ THE QUESTIONS CAREFULLY, AND KNOW WHAT IS BEING ASKED. No electronic gadgets except non-programmable calculators are allowed. You should carry all necessary items such as pen, pencil, eraser, calculators for taking the test. Answer all questions CLEARLY, TO THE POINT and in such a way that I can understand your answers.* ***Assume any missing data and state your assumption clearly. Box your final answer. A bonus of 5 marks will be awarded for reasonably attempting all questions as per the satisfaction of the Instructor.***

PART A (CLOSED BOOK)

Q1. You are asked to design a grit chamber for a sewage treatment plant in a town comprising of 1lakh people with water consumption of **135 LPCD** (Liter per person per day). It is known that **80%** of water supplied is disposed of as sewage. Due to the land constraints, the grit chamber cannot be more than 1 m wide. The maximum sewage flow is estimated to be **2.5** times the average flow. The horizontal velocity of sewage water in grit chamber needs to be **0.2 m/s** and the retention time of water in chamber should be at least **1** minute. Additionally, you must provide **25%** additional length to accommodate inlet and outlet zones. Furthermore, a **0.3 m** free board and **0.25 m** grit accumulation zone depth should be provided additionally on top of your design depth. Under the above constraints, calculate the overall length, overall depth, surface area and cross-sectional area of grit chamber. [**15 marks**]

Q2. (a) A water flowing in the river, after receiving treated wastewater, has a temperature of **17 °C**. The first order **BOD** reaction rate constant determined in the laboratory for this mixed water had a value of **0.18** per day. Determine the fraction of maximum oxygen consumption that will occur in first five days [**5 marks**]

(b) The final **DO** in an unseeded sample of diluted sewage having an initial **DO** of **8.3 mg/L** is measured to be **2.8 mg/L** after **5 days** of incubation. The dilution factor is **33** and reaction rate constant **k** = **0.23** $\mathbf{day^{-1}}$. Determine the $\mathbf{BOD_5}$ and $\mathbf{BOD_u}$ of this wastewater. What will be **BOD** remaining after **5 days**? **[5 marks]**

(c) Determine the three-day **BOD** and ultimate first stage **BOD** for a wastewater for which the $\mathbf{BOD_5}$ at **20 °C** is **230 mg/L**. The reaction rate constant **k (base e)** = **0.23 per day**. What will be $\mathbf{BOD_3}$ at **27 °C**? Consider $\boldsymbol{\theta}$ **= 1.047** [**5 marks**]

Q3(a) Assuming both de-oxygenation and re-aeration reactions to be of first order, derive an expression for critical deficit ($\mathbf{D_c}$) and critical time ($\mathbf{t_c}$) when a waste is discharged into a stream of flowing water. The initial deficit is $\mathbf{D_o}$ and $\mathbf{k_1}$ and $\mathbf{k_2}$ represents the deoxygenation and reaeration rate constants. [**5 marks**]

(b) An industrial area disposes its effluent at the rate of **0.18** $\mathbf{m^3/sec}$ into a stream with flow rate of **1.20** $\mathbf{m^3/sec}$ at a point A. At a location fairly upstream of A, the stream has dissolved oxygen of **8.6 mg/L**, and industrial effluent has dissolved oxygen of **1.4 mg/L**. The temperatures of industrial effluent and stream water are **27°C** and **22°C**, respectively, and **5-day BOD** of **25 mg/L** and **3 mg/L**, respectively. The de-oxygenation constant has value of **0.20** per day (base e) and re-oxygenation constant of the mixture is **0.40 per day** (base e). Approximate saturation concentration of DO, at **22°C** and **23°C** is **8.73 mg/L** and **8.56 mg/L**, respectively. Determine the (a)time (b)distance and (c)magnitude of critical dissolved oxygen deficit. Consider velocity of flow after mixing at downstream of point A as **0.9 m/sec**. [**15 marks**]

Q4 (a). Derive an expression for the height of absorption tower (**Z**) as shown below. **G** is the total air flowrate, **y** is the mole fraction of gaseous pollutant in air, $\mathbf{K_y}$ is the overall gas side mass transfer coefficient, and **a** is the interfacial area per tower volume. [**10 marks**]

$$Z = \frac{G}{K_y a (1-y)_{lm}} \int_{y_2}^{y_1} \frac{(1-y)_{lm}\, dy}{(1-y)(y-y^*)}$$

(b). Determine the height of a packed tower that is used to reduce the conc. of NH_3 in air from **0.1 kg/m³** to **0.005 kg/m³** given the following data. Assume that the contacting systems are dilute and operating and equilibrium lines are straight over the tower height. [**10 marks**]

Incoming liquid is water free of NH_3
Density of air at operating temperature: **1.185 kg/m³**
Operating pressure **101.325 kPa**
Henry's law constant = **5.522**
H_G = **0.444m**; H_L = **0.325m**
Liquid flow rate = **10 kg/s**
Gas flow rate = **10 kg/s**
The following equations may be useful.

$$H_{OG} = H_G + \left(\frac{mG}{L}\right)H_L \quad , \quad N_{OG} = \frac{y_1 - y_2}{[y-y^*]_{lm}} \quad , \quad Z = \frac{G}{K_y a(1-y)_{lm}} \int_{y_2}^{y_1} \frac{(1-y)_{lm}\,dy}{(1-y)(y-y^*)}$$

$$[y-y^*]_{lm} = \frac{[y-y^*]_1 - [y-y^*]_2}{\ln\frac{[y-y^*]_1}{[y-y^*]_2}} \quad , \quad \frac{1}{K_y} = \frac{1}{k_y} + \frac{m}{k_x}$$

$$H_G = \frac{\alpha(G')^\beta}{(L')^\gamma}\sqrt{Sc_G} \qquad Sc_G = \left(\mu_G / \rho_G D_G\right)$$

$$H_L = \phi\left(\frac{L'}{\mu_L}\right)^\eta \sqrt{Sc_L} \qquad Sc_L = \left(\mu_L / \rho_L D_L\right)$$

PART B (OPEN BOOK)

Q5. A conventional activated sludge process (ASP) to treat soluble wastewater from bottle washing plant containing a soluble organic waste having a **COD** of **500 mg/L**. From extensive laboratory studies for untreated wastewater the **BOD_5/COD** ratio was found to be **0.60**. The average flow rate of effluent is **1.0 MLD** (MLD=million liters per day), which is to be treated in ASP so that effluent **BOD_5** should be less than **20 mg/L**. Consider following conditions are applicable

- Return sludge concentration = **6400 mg/L**
- MLVSS = **2000 mg/L**
- Mean cell residence time **θ_c = 8 days**
- Y = **0.50 kg cells/ kg substrate (BOD) consumed**, K_d = **0.06 day⁻¹**.

Determine the following: (a)Volume of the aeration tank (b)Sludge stream wasting rate from the recycle line (c)Mass of sludge wasted per day (d)Sludge recycle ratio (e) hydraulic retention time (f) Specific substrate utilization rate (g) F/M ratio **[25 marks]**

Q6. Settling column test was performed with discrete suspension with initial concentration of solids of 1000 **mg/l**. The following observations were made. An ideal settling tank was fed with the above water and hydraulic loading rate was **0.2 m³/m²s**. Find the percentage removal expected in accordance with ideal settling theory. [**20 marks**]

Samples collected at		
Depth	Time	Concentration of solids
25 cm	0 min 50 s	800 mg/l
25 cm	4 min 10 s	300 mg/l
25 cm	8 m 20 s	100 mg/l
50 cm	2 min 5 s	650 mg/l
50 cm	3 min 20 s	500 mg/l
50 cm	41 min 40 s	50 mg/l

END OF QUESTION PAPER