CONFIDENTIAL

# UNIVERSITI KUALA LUMPUR
## MALAYSIAN INSTITUTE OF CHEMICAL AND BIOENGINEERING TECHNOLOGY

## FINAL EXAMINATION
### OCTOBER 2025 SEMESTER

| | | |
|---|---|---|
| COURSE CODE | : | CCB 31403 |
| COURSE NAME | : | INTRODUCTION TO ENVIRONMENTAL ENGINEERING |
| PROGRAMME NAME | : | BACHELOR OF CHEMICAL ENGINEERING WITH HONOURS |
| DATE | : | 24 JANUARY 2026 |
| TIME | : | 9:00 AM – 12:00 PM |
| DURATION | : | 3 HOURS |

## INSTRUCTIONS TO CANDIDATES

1. Please read the instructions given in the question paper CAREFULLY.
2. This question paper is printed on both sides of the paper.
3. This question paper contains of FOUR (4) questions. Answer ALL questions.
4. Please write your answers on the answer booklet provided.
5. Please answer all questions in English only.

THERE ARE 6 PAGES OF QUESTIONS AND APPENDICES, EXCLUDING THIS PAGE.

**Total: 100 marks**

**Answer ALL questions.**
**Please use the answer booklet provided.**

**Question 1**

An environmental assessment is being conducted on the impact of a wastewater discharge into a freshwater river. The river flows steadily with a velocity of 1.0 m $s^{-1}$ and a volumetric flow rate of 3.0 $m^3$ $s^{-1}$ at 22°C, carrying an ultimate BOD of 10 mg $L^{-1}$. The reoxygenation rate constant of the river is 0.5 $day^{-1}$. A nearby facility discharges treated wastewater into the river at a rate of 0.5 $m^3$ $s^{-1}$, containing an ultimate BOD of 200 mg $L^{-1}$ and a temperature of 30°C. Following the mixing of both streams, the deoxygenation rate constant downstream is estimated at 0.35 $day^{-1}$, and the dissolved oxygen (DO) concentration just after mixing is measured at 3.0 mg $L^{-1}$. Assuming complete and instantaneous mixing of the two streams, examine the environmental risk to aquatic life by determining whether the DO concentration 20 km downstream will be above or below the critical threshold of 4.0 mg $L^{-1}$ required for fish survival.

(25 marks)

**Question 2**

(a) A wastewater treatment plant utilizes the activated sludge process to treat 0.75 $m^3$ $s^{-1}$ of primary effluent. The influent entering the aeration tank has a biochemical oxygen demand (BOD) concentration of 250 mg $L^{-1}$. The mixed liquor suspended solids in the aeration tank is maintained at 4.5 g $L^{-1}$, while the return activated sludge concentration is 9.0 g $L^{-1}$. The plant is designed to operate with a food-to-microorganism (F/M) ratio of 0.35 $day^{-1}$, a mean cell residence time of 12 days, and a biomass yield coefficient (Y) of 0.3.

i. Based on this information, calculate the daily mass flow rate of waste activated sludge (in kg $day^{-1}$).

(4 marks)

ii. Waste sludge produced during wastewater treatment requires additional treatments before disposal. Discuss **THREE (3)** methods for sludge stabilization.

(6 marks)

(b) An industrial facility operates a thermal power unit that consumes 3,200 metric tons of heavy fuel oil daily, with a sulfur content of 2.0% by weight. The combustion gases are released through a stack with an effective height of 220 meters. Local environmental data indicate a wind speed of 8 m $s^{-1}$ at the anemometer height. The atmospheric stability is classified as Class C, indicating slightly unstable conditions. Assuming the terrain is smooth and neglecting effects of ground reflection, estimate the maximum ground-level concentration of sulfur dioxide (in $\mu$g $m^{-3}$) at a downwind distance of 5 km from the stack.

(15 marks)

**Question 3**

(a) Hazardous waste is defined as any waste falling within the categories of waste listed in the First Schedule of the Environment Quality (Scheduled Wastes) Regulations 2005. Explain **FOUR (4)** characteristics that are used to define a hazardous waste.

(8 marks)

(b) A team of engineers is responsible for overseeing operations at a pesticide formulation plant where workers are occasionally exposed to benzene, a hazardous air pollutant classified as a known human carcinogen. To ensure workplace safety and comply with health regulations, the facility must maintain airborne benzene concentrations at levels that limit the incremental lifetime cancer risk to below the acceptable threshold of $10^{-6}$. Calculate the maximum allowable benzene concentration (in mg $m^{-3}$) in workplace air that would meet the acceptable risk criteria.

(7 marks)

(c) A municipality operates a waste collection system using compactor trucks to serve a suburban neighbourhood. Each compactor truck has a compaction ratio of 4. The trucks travel 30 km from the collection route to a disposal site at a speed of 60 km $h^{-1}$. The total time taken for the trucks' departure and return to the garage is 50 minutes. Each trip includes a 10-minute delay. The trucks collect waste from four households per stop, with each household providing one full container of 0.25 $m^3$. It takes 20 seconds to empty each container. Additional details are given as follows:

Number of trips to the landfill per day: 3
Time between stops: 20 seconds
Unloading time at landfill: 25 minutes per trip
Worker break time per day: 40 minutes
Total working hours per day: 9 hours

Using the information provided, calculate the size (in $m^3$) the compactor truck must have to operate efficiently under the daily schedule.

(10 marks)

**Question 4**

A regional waste management authority is planning to improve its leachate treatment system at a large sanitary landfill due to increasing waste volumes and stricter environmental regulations. Two alternatives are being considered:

1. Option A involves upgrading the existing leachate treatment unit by adding a membrane filtration system. This option requires a capital investment of RM2.3 million, with annual operating costs estimated at RM520,000 and a design lifespan of 15 years.

2. Option B proposes constructing a new constructed wetland treatment system on nearby land. The initial investment would be RM3.2 million, but it offers significantly lower annual operating costs of RM280,000 and an extended lifespan of 25 years.

The authority can secure financing at an interest rate of 6% per annum. Perform a cost-effectiveness evaluation using both the present worth method and the annual cost approach to determine which alternative is the more financially viable solution for long-term leachate management.

(25 marks)

**END OF EXAMINATION PAPER**

**Appendix 1:**
**List of Equations**

$$\bar{t} = \frac{V}{Q}$$

$$\Theta_C = \frac{XV}{Q_W X_r} = \frac{K_S + S}{\mu_{\max} S}$$

$$S_0 - S = \frac{\mu_{\max} S X \bar{t}}{Y(K_S + S)}$$

$$q = \frac{S_0 - S}{X\bar{t}} = \frac{1}{\Theta_C Y} = \frac{\mu_{\max} S}{Y(K_S + S)}$$

$$C_0 = \frac{Q_S C_S + Q_P C_P}{Q_S + Q_P}$$

$$F/M = \frac{QS_0}{VX} = \frac{S_0}{\bar{t}X}$$

$$T_0 = \frac{Q_S T_S + Q_P T_P}{Q_S + Q_P}$$

$$L_0 = \frac{Q_S L_S + Q_P L_P}{Q_S + Q_P}$$

$$D = \frac{k_1 L_0}{k_2 - k_1}\left(e^{-k_1 t} - e^{-k_2 t}\right) + D_0 e^{-k_2 t}$$

$$t_C = \frac{1}{k_2 - k_1}\ln\left[\frac{k_2}{k_1}\left(1 - \frac{D_0(k_2 - k_1)}{k_1 L_0}\right)\right]$$

$$C = \frac{Q}{2\pi \bar{u}\sigma_y \sigma_z}\exp\left(-\frac{1}{2}\left[\left(\frac{y}{\sigma_y}\right)^2 + \left(\frac{z-H}{\sigma_z}\right)^2\right]\right)$$

$$D = S - C$$

$$C = \frac{Q}{2\pi \bar{u}\sigma_y \sigma_z}\exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]\left\{\exp\left[-\frac{1}{2}\left(\frac{z+H}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{z-H}{\sigma_z}\right)^2\right]\right\}$$

$$CDI = \frac{\text{Concentration} \times \text{Intake Rate} \times \text{Exposure}}{\text{Body Weight} \times 70 \times 365}$$

$$Risk = CDI \times PF$$

$$F = g r^2 v_s \left(1 - \frac{T_a}{T_s}\right)$$

$$S = \frac{g}{T_a}\left(\frac{\Delta T_a}{\Delta z} + 0.01\right)$$

$$\Delta h = 2.6\left(\frac{F}{u_h S}\right)^{1/3}$$

$$\Delta h = \frac{1.6 F^{1/3} x_f^{2/3}}{u_h}$$

$$x_f = 120 F^{0.4}$$

$$x_f = 50 F^{5/8}$$

$$\sigma_y = a x^{0.894}$$

$$\sigma_z = c x^d + f$$

$$C_R = \frac{i(1+i)^n}{(1+i)^n - 1}$$

$$C_P = \frac{(1+i)^n - 1}{i(1+i)^n}$$

$$V = \frac{V_s N}{r}$$

$$N = \frac{t_R}{n t_s}$$

$$T_t = t_1 + (2n-1)t_2 + t_3 + t_b + t_R + n t_d$$

$$t_s = \frac{d}{v} + n_c t_c$$

Molar mass Sulfur $= 32\frac{g}{mol}$

Molar mass $SO_2$ $= 64\frac{g}{mol}$

## Appendix 2:
## Oxygen Solubility in Fresh Water

| Temperature (ºC) | Dissolved Oxygen (mg/L) |
|---|---|
| 21 | 8.90 |
| 22 | 8.72 |
| 23 | 8.56 |
| 24 | 8.40 |
| 25 | 8.24 |
| 26 | 8.09 |
| 27 | 7.95 |
| 28 | 7.81 |
| 29 | 7.67 |
| 30 | 7.54 |

## Appendix 3:
## Constants for Dispersion Coefficient

| | | $x \leq 1$ km | | | $x \geq 1$ km | | |
|---|---|---|---|---|---|---|---|
| Stability | $a$ | $c$ | $d$ | $f$ | $c$ | $d$ | $f$ |
| A | 213 | 440.8 | 1.941 | 9.27 | 459.7 | 2.094 | −9.6 |
| B | 156 | 106.6 | 1.149 | 3.3 | 108.2 | 1.098 | 2.0 |
| C | 104 | 61.0 | 0.911 | 0 | 61.0 | 0.911 | 0 |
| D | 68 | 33.2 | 0.725 | −1.7 | 44.5 | 0.516 | −13.0 |
| E | 50.5 | 22.8 | 0.678 | −1.3 | 55.4 | 0.305 | −34.0 |
| F | 34 | 14.35 | 0.740 | −0.35 | 62.6 | 0.180 | −48.6 |

*Note:* The computed values of $\sigma$ will be in meters when $x$ is given in kilometers.

## Appendix 4:
## Wind Profile Exponent ($p$) for Rough Terrain $\left(\frac{\overline{u}}{u_a}\right) = \left(\frac{H}{z_a}\right)^p$

| Stability Class | Description | Exponent $p$ |
|---|---|---|
| A | Very unstable | 0.15 |
| B | Moderately unstable | 0.15 |
| C | Slightly unstable | 0.20 |
| D | Neutral | 0.25 |
| E | Slightly stable | 0.40 |
| F | Stable | 0.60 |

For smooth terrain, multiply $p$ by 0.6

## Appendix 5:

### Toxicity Data for Selected Potential Carcinogens

| Chemical | Category | Potency Factor Oral Route $(mg/kg\text{-}day)^{-1}$ | Potency Factor Inhalation Route $(mg/kg\text{-}day)^{-1}$ |
|---|---|---|---|
| Arsenic | A | 1.75 | 50 |
| Benzene | A | $2.9 \times 10^{-2}$ | $2.9 \times 10^{-2}$ |
| Benzol(a)pyrene | B2 | 11.5 | 6.11 |
| Cadmium | B1 | — | 6.1 |
| Carbon tetrachloride | B2 | 0.13 | — |
| Chloroform | B2 | $6.1 \times 10^{-3}$ | $8.1 \times 10^{-2}$ |
| Chromium VI | A | — | 41 |
| DDT | B2 | 0.34 | — |
| 1,1-Dichloroethylene | C | 0.58 | 1.16 |
| Dieldrin | B2 | 30 | — |
| Heptachlor | B2 | 3.4 | — |
| Hexachloroethane | C | $1.4 \times 10^{-2}$ | — |
| Methylene chloride | B2 | $7.5 \times 10^{-3}$ | $1.4 \times 10^{-2}$ |
| Nickel and compounds | A | — | 1.19 |
| Polychlorinated biphenyls (PCBs) | B2 | 7.7 | — |
| 2,3,7,8-TCDD (dioxin) | B2 | $1.56 \times 10^{5}$ | — |
| Tetrachloroethylene | B2 | $5.1 \times 10^{-2}$ | $1.0 - 3.3 \times 10^{-3}$ |
| 1,1,1-Trichloroethane (1,1,1-TCA) | D | — | — |
| Trichloroethylene (TCE) | B2 | $1.1 \times 10^{-2}$ | $1.3 \times 10^{-2}$ |
| Vinyl chloride | A | 2.3 | 0.295 |

## Appendix 6:

### Exposure Factors Recommended for Risk Assessment

| Land Use | Exposure Pathway | Daily Intake | Exposure Frequency, Days/Year | Exposure Duration, Years | Body Weight, kg |
|---|---|---|---|---|---|
| Residential | Ingestion of potable water | 2 L (adult)<br>1 L (child) | 350 | 30 | 70 (adult)<br>15 (child) |
| | Ingestion of soil and dust | 200 mg (child)<br>100 mg (adult) | 350 | 6<br>24 | 15 (child)<br>70 (adult) |
| | Inhalation of contaminants | 20 $m^3$ (adult)<br>12 $m^3$ (child) | 350 | 30 | 70 |
| Industrial and commercial | Ingestion of potable water | 1 L | 250 | 25 | 70 |
| | Ingestion of soil and dust | 50 mg | 250 | 25 | 70 |
| | Inhalation of contaminants | 20 $m^3$ (workday) | 250 | 25 | 70 |
| Agricultural | Consumption of homegrown produce | 42 g (fruit)<br>80 g (veg.) | 350 | 30 | 70 |
| Recreational | Consumption of locally caught fish | 54 g | 350 | 30 | 70 |