UNIVERSITI TEKNOLOGI PETRONAS

FINAL EXAMINATION
MAY 2024 SEMESTER

COURSE	**:**	**CEB3013 - ENVIRONMENTAL CHEMICAL ENGINEERING**
DATE	**:**	**12 AUGUST 2024 (MONDAY)**
TIME	**:**	**9.00 AM - 12.00 NOON (3 HOURS)**

INSTRUCTIONS TO CANDIDATES

1. Answer **ALL** questions in the Answer Booklet.
2. Begin **EACH** answer on a new page in the Answer Booklet.
3. Indicate clearly answers that are cancelled, if any.
4. Where applicable, show clearly steps taken in arriving at the solutions and indicate **ALL** assumptions, if any.
5. **DO NOT** open this Question Booklet until instructed.

Note :

i. There are **ELEVEN (11)** pages in this Question Booklet including the cover page and appendices.

ii. **DOUBLE-SIDED** Question Booklet.

1. Malaysia is now moving towards being a developed country through extensive effort that required trade-offs between the economic development and environmental quality. The rising economic development and human activities have resulted in the occurrence of urban heat island phenomenon in major cities around the country.

   a. Explain the relationship between urbanization and human activities towards urban heat island. Provide **TWO (2)** causes and **TWO (2)** correlating effects to justify your explanation.

   [8 marks]

   b. As an environmental engineer, recommend **THREE (3)** potential measures to reduce urban heat island impacts and improve urban living conditions with appropriate justification.

   [6 marks]

   c. Apart from urban heat island, air pollution is no longer an exclusively urban problem as smaller towns also experience poorer air quality as a result of urbanization. Discuss the socio-economic factors in contributing to this trend and its implications towards public health, economic development, and social equity.

   [12 marks]

2. A palm-oil based company is expanding its business line to cater for personal care products from palm oil biomass. As part of this expansion, the generation of wastewater is expected to increase and require further treatment to meet the effluent standard. For wastewater treatment, 3 sedimentation tanks with a dimensions of 8 m wide x 20 m long x 4.5 m height each are operated in parallel with a detention time of 2 hours at 70% tank capacity. **TABLE Q2** outlines the wastewater performance report of the wastewater treatment plant in the current business line and projected business operations.

TABLE Q2: Performance report for wastewater for different scenarios.

Parameter	Current	Projected
Wastewater volumetric flowrate capacity (m^3/s)	0.0174	0.029
Wastewater density (kg/m^3)	950	1,050
Overflow rate (m/s)	0.0121	0.0121
pH value	5.6	4.5
BOD_5 (mg/L)	130	165
Food-to-microorganism ratio	0.4	0.65
Mixed liquor volatile suspended solid (mg/L)	874.7	915.3
Reynold's number (Re)	$>10^4$	$>10^4$
Wastewater dynamic viscosity (Pa.s)	-	0.995×10^{-3}
Solid particle density (kg/m^3)	1,400	1,500

a. Based on the information given, determine the efficiency of BOD removal and metabolism rate based on food-to-microorganism (F/M) ratio in the projected scenario. Justify your answers accordingly.

[7 marks]

b. Assuming the ratio of mixed liquor suspended solid (MLSS) to mixed liquor volatile suspended solids (MLVSS) is 1.05 to 0.6, calculate the sludge volume index (SVI) for each tank if the sludge settlement in each tank is 30% of the effective liquid height. Based on your calculation, comment on the sludge settling performance accordingly.

[14 marks]

c. **Justify if the proposed overflow rate is sufficient to remove pollutants in the projected scenario. Assume the particles to be Type I classification with a mean diameter of 0.5 cm.**

[3 marks]

3. As part of the journey towards net zero carbon emission, the Malaysian government aims to reduce carbon intensity by 45% by 2030, against gross domestic product (GDP) levels in 2005. Apart from electricity and heat productions, the emissions of CO_2 are also greatly contributed from landfill waste emissions. Integrated Solid Waste Management (ISWM) system has been introduced as a comprehensive waste management system to reduce this problem.

a. With an aid of a flowchart, elaborate how landfills contribute to the CO_2 emissions. From a socio-environment perspective, suggest **TWO (2)** solutions to solve this problem.

[6 marks]

b. A waste-to-energy (WTE) plant is being proposed as part of the ISWM plan. The proponents of the WTE argue that recycling is unnecessary and not economical for the plant. As an environmental engineer, provide the supporting and counter arguments based on resource conservation and economic viability perspectives.

[8 marks]

c. From the life cycle assessment standpoint, explain **TWO (2)** distinct differences between linear economy and circular economy for efficient management of solid waste, particularly in terms of energy consumption and generation.

[8 marks]

d. Waste reduction hierarchy plays an important role in waste landfill management. Propose **TWO (2)** strategies to implement 3R effectively.

[4 marks]

4. In an effort to reduce electricity consumption in their daily operations, a pulp and paper factory for the production of bleached paper located at Gambang normally begins pulping process from 8:00 PM to 6:00 AM. During the pulping process, the stack releases 1,500 g/s of SO_2 into the atmosphere on a low cloudy night, with a wind speed of 3.1 m/s. An inversion layer exists several kilometres from the stack with a plume rise of 30 m. The mean atmospheric condition and stack parameters are outlined in **TABLE Q4**.

TABLE Q4: Information on the atmospheric conditions and stack parameters.

Atmospheric conditions	
Pressure (kPa)	98.0
Temperature (°C)	24.3
Stack conditions	
Height (m)	60.0
Diameter (m)	1.8
Stack effluent velocity (m/s)	8.8
Stack effluent temperature (°C)	250

a. Based on the given atmospheric conditions, describe the effect of inversion layer towards air pollutant dispersion. Justify your description with an appropriate diagram.

[8 marks]

b. According to Ambient Air Quality Standard 2020, the daily concentration limit of SO_2 is 80 μg/m^3. Evaluate whether the concentration of SO_2 at a point of 3 km downwind and 0.3 km perpendicular to the plume centerline meets the allowable concentration limit of SO_2. The molecular weight of SO_2 is given as 64.07 g/mol.

[12 marks]

c. Provide **ONE (1)** solution to minimize the emissions of SO_2 with a proper example.

[4 marks]

– END OF PAPER –

APPENDIX I – STABILITY CLASS

Surface wind speed (at 10 m) (m/s)	Day[a]			Night[a]	
	Incoming solar radiation				
	Strong	Moderate	Slight	Thinly overcast or ≥ 1/2 Low cloud	≤ 3/8 Cloud
<2	A	A–B	B	—	—
2–3	A–B	B	C	E	F
3–5	B	B–C	C	D	E
5–6	C	C–D	D	D	D
>6	C	D	D	D	D

[a]The neutral class, D, should be assumed for overcast conditions during day or night. Note that "thinly overcast" is not equivalent to "overcast."

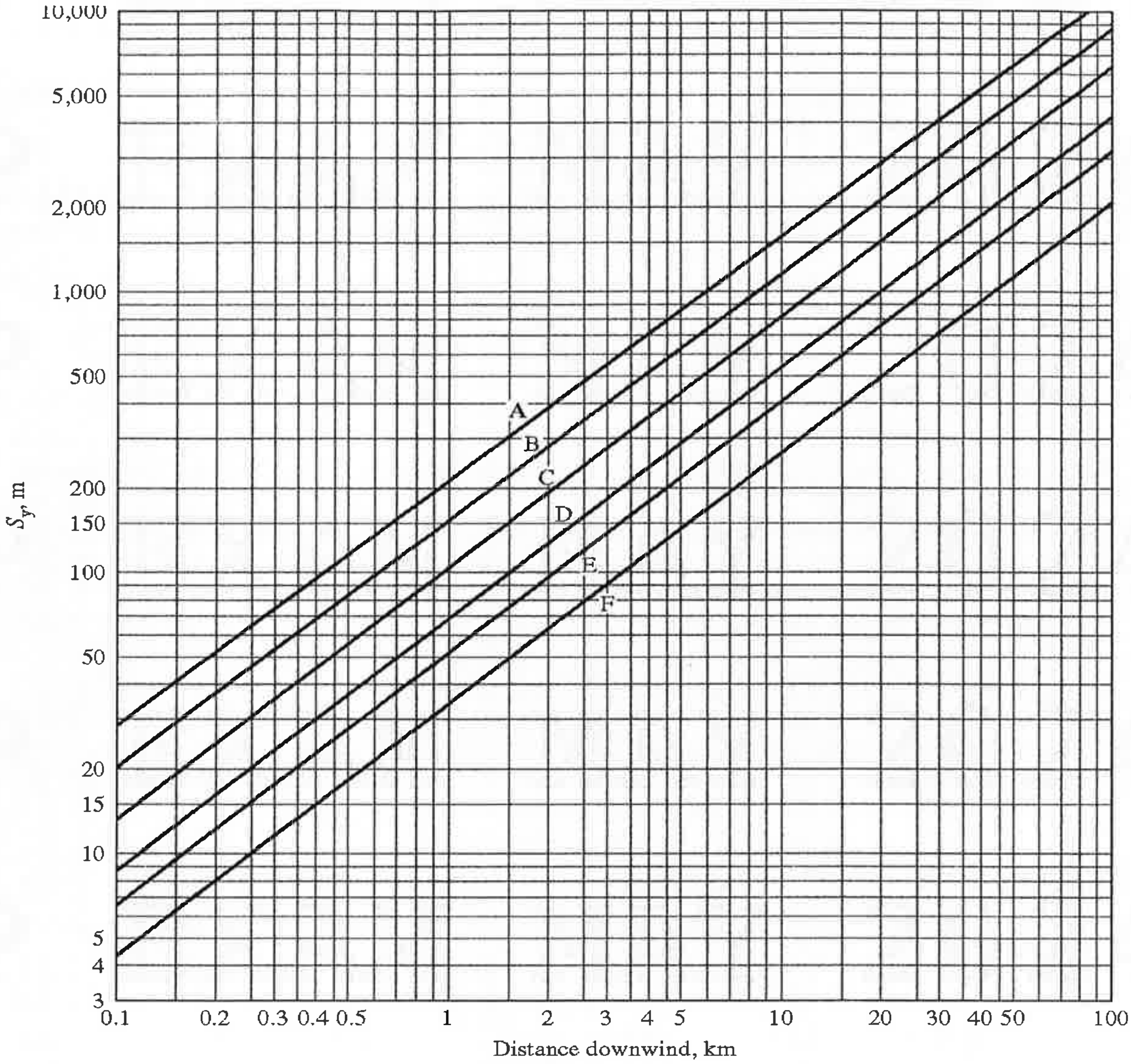
Notes: Class A is the most unstable and class F is the most stable class considered here. Night refers to the period from one hour before sunset to one hour after sunrise. Note that the neutral class, D, can be assumed for overcast conditions during day or night, regardless of wind speed.

"Strong" incoming solar radiation corresponds to a solar altitude greater than 60° with clear skies; "slight" insolation corresponds to a solar altitude from 15° to 35° with clear skies. Table 170, Solar Altitude and Azimuth, in the Smithsonian Meteorological Tables, can be used in determining solar radiation. Incoming radiation that would be strong with clear skies can be expected to be reduced to moderate with broken (5/8 to 7/8 cloud cover) middle clouds and to slight with broken low clouds.

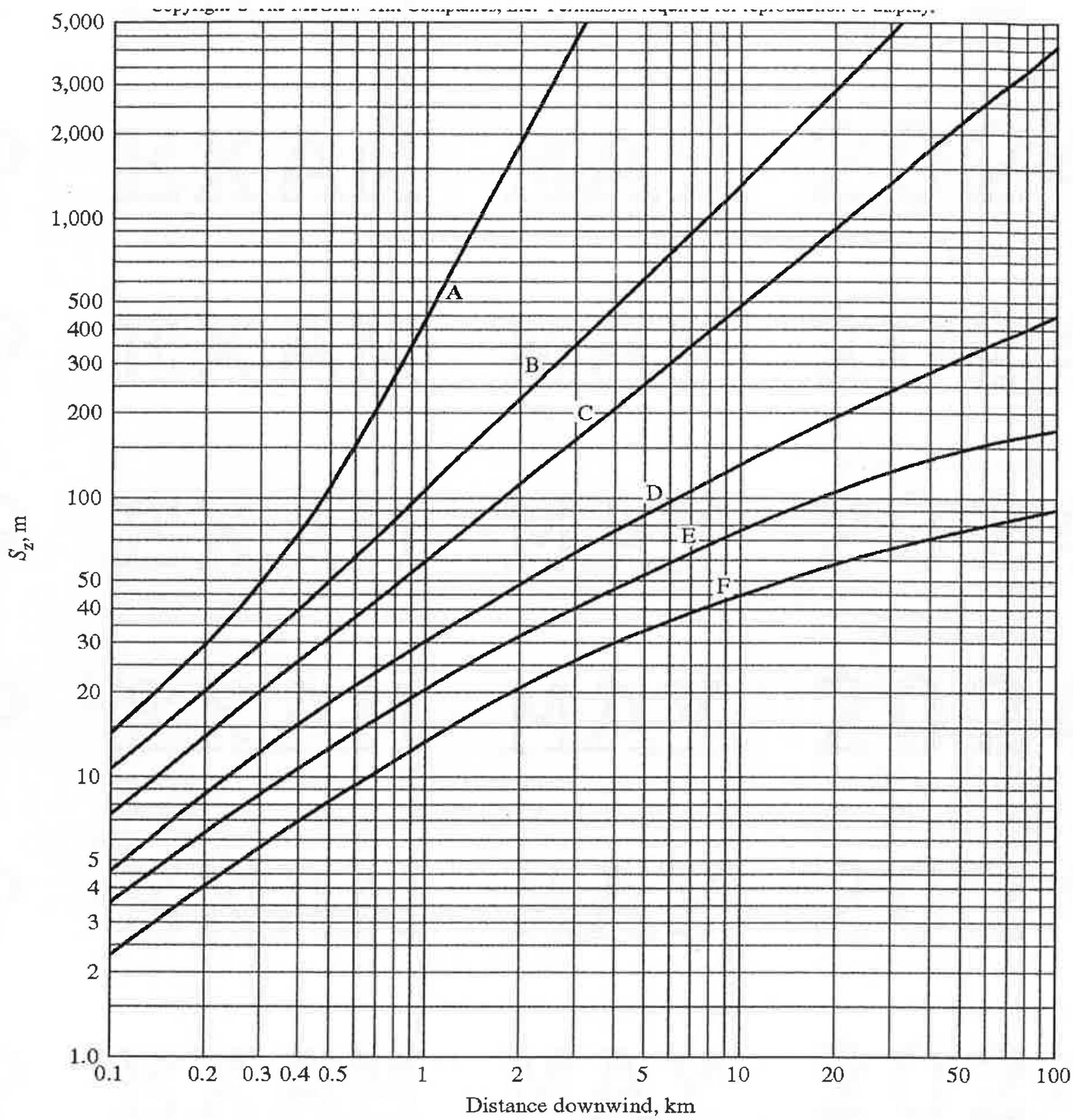
(*Source:* Turner, 1967.)

Stability class	a	$x \le 1$ km			$x > 1$ km		
		c	d	f	c	d	f
A	213	440.8	1.941	9.27	459.7	2.094	−9.6
B	156	100.6	1.149	3.3	108.2	1.098	2
C	104	61	0.911	0	61	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	0.74.0	−0.35	62.6	0.18	−48.6

APPENDIX II – HORIZONTAL DISPERSION COEFFICIENT



APPENDIX III – VERTICAL DISPERSION COEFFICIENT



APPENDIX IV – GENERAL MATHEMATICAL EQUATIONS

Dispersion Model

$$X_{(x,y,0,H)} = \left[\frac{E}{\pi S_y S_z u}\right]\left[exp\left[-\frac{1}{2}\left(\frac{y}{S_y}\right)^2\right]\right]\left[exp\left[-\frac{1}{2}\left(\frac{H}{S_z}\right)^2\right]\right]$$

where

$X_{(x,y,0,H)}$ = downwind concentration at ground level, g/m^3

E = emission rate of pollutant, g/s

s_y, s_z = plume standard deviations, m

μ = wind speed, m/s

x,y,z, and H = distances, m

Holland's Formula

$$\Delta H = \frac{v_s d}{u}\left[1.5 + \left(2.68 \times 10^{-2}(P)\left(\frac{T_s - T_a}{T_s}\right)d\right)\right]$$

where

ΔH = plume height, m

d = stack diameter, m

u = wind speed, m/s

P = pressure, kPa

T_s = stack temperature, K

T_a = air temperature, K

Horizontal and vertical dispersion coefficient correlation

$S_y = ax^{0.894}$

$S_z = cx^d + f$

$S_z = 0.47(L - H)$ (for inversion case)

Settling velocity for Type I particles

$$v_s = \left[\frac{4g(\rho_s - \rho)d}{3C_d \rho}\right]^{\frac{1}{2}}$$

where

Re >10^4, then C_D = 0.4

Re <0.5, then C_D = 24/Re

0.5 < Re < 10^4, then C_D = (24/Re) + (3/$Re^{1/2}$) + 0.34

Settling velocity for spherical particles under laminar conditions

$$v_s = \frac{g(\rho_s - \rho)d^2}{18\mu}$$

where

μ = dynamic viscosity, Pa.s

g = gravitational force, 9.81 m/s^2

d = diameter of particles, m

C_D = drag coefficient

ρ = density of wastewater, kg/m^3

ρ_s = density of solid particle, kg/m^3

Food-to-microorganism ratio

$$\frac{F}{M} = \frac{QS_0}{VX}$$

where

Q = volumetric flowrate, m^3/s

S_0 = soluble BOD_5 entering the aeration tank, mg/L

V = volume of aeration tank, m^3

X = mixed liquor volatile suspended solids in aeration tank, mg/L

Sludge volume index (SVI)

$$SVI = \frac{V_{set} \times 10^3}{MLSS}$$

where

V_{set} = volume of settled sludge in tank, mL

MLSS = mixed liquor suspended solids, mg/L