
NATIONAL EXAMS DECEMBER 2012

04-Chem-B2, Environmental Engineering

3 hours duration

NOTES

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. This is a Closed Book Exam with a candidate prepared $8\frac{1}{2}$ " x 11" double sided Aid-Sheet allowed.
3. Candidates may use one of two calculators, the Casio or Sharp approved models. Write the name and model designation of the calculator on the first inside left hand sheet of the exam work book.
4. Any five (5) questions constitute a complete paper. Only the first five (5) answers as they appear in your work book(s), will be marked.
5. Each question is worth a total of 20 marks with the section marks indicated in brackets () at the left margin of the question. The complete Marking Scheme is also provided on the final page. A completed exam consists of five (5) answered questions with a possible maximum score of 100 marks.

Problem 1

Provide answers to the following questions related to *engineering aspects of air and water pollution abatement and effluent treatment*.

- (10) (i) Briefly describe two (2) engineered air pollution control methods that can be used to reduce VOCs (e.g., benzene, methylene chloride, hexane) emissions. For each control method, briefly provide the main engineering design principle and give an example where it would be most appropriate to be used.
- (10) (ii) Eutrophication in rivers and lakes has been attributed to effluents from sewage treatment plants. Briefly explain two (2) primary causes of eutrophication and one (1) effective treatment method for each cause. In your explanation of the treatment method, provide two (2) key design parameters, two (2) operational issues and two (2) maintenance issues to ensure the long term effectiveness of the treatment system.

Problem 2

Provide answers to the following questions related to *control methods for particulates, gases and vapours*.

For the three (3) technology types ((i) to (iii) below), describe how each may be used to control the contaminant types identified. In your explanation, briefly describe the main technology principle and provide two (2) advantages, two (2) limitations and one (1) specific industrial process where each technology may be used. A table or matrix is recommended to organize your answer.

- (7) (i) Centrifugal forces based technology for particulates
- (7) (ii) Oxidation based technology for gases
- (6) (iii) Biologically based technology for odorous vapours

Problem 3

Provide answers to the following questions related to *characterization of water contaminants and their measurement, biochemical oxygen demand and flotation*.

- (8) (i) A drinking water treatment plant uses groundwater from an aquifer under the influence of surface water. Give one (1) inorganic and one (1) microbiological contaminant that typically needs to be treated for this groundwater supply. Provide two (2) treated water measurement methods (one for each contaminant type) that may be used to ensure that the water is free from the inorganic and biological contaminants identified. Briefly discuss how you would ensure that the measurement methods can be relied on to guarantee that the contaminants are sufficiently reduced.
- (ii) A BOD test is conducted at standard temperature conditions using 200 mL of secondary sewage effluent mixed with 100 mL of water. The initial DO in the mix is 7 mg/L. After 5 days, the DO is 1 mg/L and after 20 days the DO has stabilized at 0.1 mg/L. Assume that nitrification has been inhibited so that only CBOD₅ (5-day carbonaceous biochemical oxygen demand) is being measured.
- (3) (a) Calculate the 5-day CBOD of the secondary effluent in mg/L; and
- (3) (b) Estimate the ultimate CBOD in mg/L.
- (6) (iii) The hydraulic loading rate (HLR), solids loading rate (SLR) and air to solids ratios (ATS) are all critical dissolved air floatation (DAF) design parameters. Explain how the values of HLR, SLR and ATS influence the optimal performance envelope for a given DAF system.

Problem 4

Provide answers to the following questions related to *pH control*, *ion exchange*, *reverse osmosis* and the *activated sludge process*.

- (i) Explain two (2) key design principles in the application of each technology in water or wastewater treatment:
- (3) (a) pH control;
- (4) (b) ion exchange; and
- (3) (c) reverse osmosis.
- (ii) A conventional activated sludge plant is to treat $500,000 \text{ m}^3/d$ of combined residential and stormwater (its a combined sewershed). You have been asked to assist the senior process design engineer by calculating the following:
- (3) (a) The required aeration tank volume V in m^3 and the aeration tank hydraulic retention time (ϕ) in hours;
- (4) (b) the quantity of sludge to be wasted daily (Q_w) in kg/d ; and
- (3) (c) the sludge recycle ratio (Q_r/Q_o).

Use the following process information:

- Influent BOD_5 and $TSS = 200 \text{ mg}/L$;
- effluent BOD_5 and $TSS = 15 \text{ mg}/L$;
- yield coefficient, $Y = 0.6$;
- decay rate, $k_d = 0.04 \cdot d^{-1}$;
- average MLSS in the aeration tank, $X = 4,000 \text{ mg}/L$;
- waste MLSS from the clarifier, $X_w = 8,000 \text{ mg}/L$; and
- mean cell residence time, $\phi_c = 12 \text{ days}$;

Problem 5

Provide answers to the following questions related to *sources and dispersion of atmospheric pollutants*.

A large coal fired power plant producing 500 GW of power releases sulfur dioxide (SO_2) during its operation. The SO_2 is released from a 50 m stack at a rate of 25 g/min. The average wind speed is 15 m/s, with strong solar radiation.

- (10) (i) What is the distance downwind of the plume centerline emission point at which the predicted SO_2 ground-level concentration falls to about $5 \mu\text{g}/\text{m}^3$;
- (10) (ii) Provide three (3) possible engineering measures that may be used to reduce the ground level SO_2 concentration and compare each method in terms of the life cycle considerations and recommend the preferred option.

Assume an estimate of the dispersion parameters is provided by the following equations:

$$\sigma_y = a \cdot x^{b-c \cdot \ln(x)}$$

$$\sigma_z = d \cdot x^{e-f \cdot \ln(x)}$$

The variables to calculate the moderated unstable dispersion parameters are taken from the appropriate stability class given in the table below:

Stability Class	a	b	c	d	e	f
A	150	1.2	-0.006	200	2.4	0.5
B	110	1.2	-0.005	110	1.1	0.04
C	120	1.2	-0.004	65	1.0	0.02
D	45	1.2	-0.003	45	0.8	-0.04
E	35	1.2	-0.003	15	0.6	-0.07

Problem 6

Provide answers to the following questions related to *photochemical reactions, noxious pollutants and odour control*.

Photochemical smog has been identified as one of the primary causes of urban air pollution resulting in respiratory problems among the general population and thousands of asthma attacks among the more susceptible in our cities.

- (6) (i) Briefly explain the formation of smog in terms of the necessary physical atmospheric conditions and chemical reactions;
- (7) (ii) Briefly describe the design of an engineering process to reduce the release of chlorinated hydrocarbons or similar noxious pollutants by 99.9%. Identify all the assumptions you need to make to arrive at your answer; and
- (7) (iii) Identify an effective physical-chemical based engineered odour control technology and briefly explain its design principle, operational and maintenance requirements.

Problem 7

Provide answers to the following questions related to *contaminant soil remediation and measurement techniques* as applied to environmental engineering.

- (5) (i) Provide an example and explain one (1) appropriate technology that may be used in soil remediation when soil contamination from light hydrocarbons has impacted a deep groundwater aquifer used as a drinking water source;
- (5) (ii) Briefly explain two (2) main differences between the application of bioremediation and physical-chemical based remediation technologies; and
- (10) (iii) Define and discuss the importance of sensitivity (S), reliability (R) and accuracy (A) in measurement techniques as applied to instrumentation used to measure: (1) influent or effluent wastewater quality parameters; or (2) raw water or finished water quality parameters as related to drinking water. *Do only part (1) or (2)*.

Marking Scheme

1. (i) 10 (ii) 10 marks, 20 marks total
2. (i) 7 (ii) 7 (iii) 6 marks, 20 marks total
3. (i) 8 (ii) (a) 3, (b) 3 (iii) 6 marks, 20 marks total
4. (i) (a) 3, (b) 4, (c) 3 (ii) (a) 3, (b) 4, (c) 3 marks, 20 marks total
5. (i) 10 (ii) 10 marks, 20 marks total
6. (i) 6 (ii) 7 (iii) 7 marks, 20 marks total
7. (i) 5 (ii) 5 (iii) 10 marks, 20 marks total