NATIONAL EXAMS DECEMBER 2012

04-Env-A5, Air Quality and Pollution Control 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 *source and classifications of atmospheric pollutants*, *indoor and outdoor air pollutants* and *health and ecological impacts*.

(8) (i) Calculate the SO_2 concentration in flue gas when 10 moles of C_7H_{13} containing 2 % sulphur is burnt in presence of stoichiometric amount of oxygen. Briefly explain the formation of secondary air pollutants related to the combustion of fossil fuels.

(5) (ii) Describe a biological and a chemical indoor air pollutant (2 different pollutants) and their potential health impacts. Describe two (2) potential engineering remedies to reduce their health impacts (1 for each air pollutant).

(7) (iii) Consider the outdoor release of lead (*Pb*) from a mobile pollution source. Describe two (2) related health and two (2) related ecological impacts associated with its release and provide an example of a possible preventative engineering solution to both impacts.

Problem 2

Provide answers to the following questions related to *influence of solar radiation and wind fields on stack plumes*, *dispersion and deposition modelling of atmospheric pollutants* and *Eddy and Gaussian diffusion models*.

(10) (i) Identify and briefly explain under what type of stability condition(s) you can expect to see the following plume patterns: *coning*, *fanning* and *looping*. Recall Pasquill's stability criteria below where A= Extremely unstable, B= Moderately unstable, C= Slightly unstable, D= Neutral, E= Slightly stable, F= Stable.

Surface	Day solar insulation			Night cloudiness	
Wind, m/s	Strong	Moderate	Slight	Cloudy > 4/8	Clear <3/8
<2	A	A-B	B	E	F
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	E
>6	C	D	D	D	D

(10) (ii) Describe how dispersion and deposition modelling of fine particulates (e.g., PM10 from a quarry operation) is initiated (important input parameters) and conducted (necessary steps) in a Gaussian or Eddy diffusion model. You may wish to consider the Gaussian model below in your answer.

$$C_x = \left(\frac{Q}{\pi\sigma_y\sigma_z u}\right) \cdot exp\left(\frac{-H^2}{2\sigma_z^2}\right) \cdot exp\left(\frac{-y^2}{2\sigma_y^2}\right)$$

Problem 3

Provide answers to the following questions related to *measurement techniques of air pollutants*, *characteristics of various air pollutant particulates* and *health and aesthetic considerations of PM2.5 and PM10*.

(8) (i) The table below provides several monitoring methods recommended (√) for various air pollutants. Select any two (2) sampling methods and briefly explain how each works for any of the recommended air pollutants.

	particulates	SO_2	CO	NO_x	Benzene	H_2S	fluorides	O_3
Passive samplers	√	√		√	√	√	√	√
Paper tape	√					√		
Bubbler systems		√		√		√		√
NDIR			√					
Chemi-luminescence				√				√
FPD		√				√		
Fluoresence monitors		√				√		

(6) (ii) Typical control systems for particulates include inertial collectors (cyclone collectors), fabric filter collectors (baghouses), wet scrubbers, and electrostatic precipitators. Select one of these control systems and explain two (2) important particulate characteristics required to ensure a system design provides a particulate reduction efficiency of > 99 % .

(6) (iii) Explain one (1) health and one (1) aesthetic effect associated with PM2.5 and PM10 atmospheric pollutants. Briefly describe one similarity in possible engineering solutions, that apply equally to both PM2.5 and PM10, that may be applied to reduce or eliminate the associated aesthetic and health effects.

Problem 4

Provide answers to the following questions related to *air toxics*, *mobile sources of air pollutants*, *noxious pollutants and odour control* and *emission trading*.

(5) (i) The top 18 hazardous air pollutants (HAPs) found in the Lower Frazer Valley (LFV) are listed below. Explain the top two (2) recommendations you would make, as an engineering consultant to the local "LFV Health Board", to address health related issues potentially associated with the 18 HAPs.

Substance*	Emissions (metric tonnes)				
	Point	Area	Onroad	Non-road	Total
PM_{10} (Respirable particulate matter less than or equal to 10 microns)	4,660.9	6,938.1	9,677.2	2,594.9	23,871.2
Ammonia (NH_3)	672.8	16,516.9	1,064.9	87.5	18,342.1
$PM_{2.5}$ (fine particulate matter less than or equal to 2.5 microns)	1,791.2	3,708.9	1,191.0	2,518.6	9,209.6
Methanol	77.1	6,329.3			6,406.4
Toluene	141.8	825.0	3,619.9	730.2	5,316.9
Acetone	81.4	4,755.8			4,837.3
Xylenes (mixed isomers)	129.6	732.4	2,021.5	580.0	3,463.5
Diesel particulate matter	8.2		440.0	2,215.8	2,663.9
Aluminum (fume or dust)	12.3	882.7	926.6	2.8	1,824.4
Iso-octane (2,2,4-trimethyl pentane)	0.35	20.3	1,284.3	240.9	1,545.9
Acetaldehyde	25.6	982.4	108.8	265.0	1,381.8
Benzene	20.5	176.2	654.3	322.0	1,173.0
n-Hexane	77.6	306.6	676.0	107.9	1,168.2
Formaldehyde	22.0	70.7	325.1	622.4	1,040.2
Ethylbenzene	7.0	54.4	552.3	152.3	766.0
Isopropyl alcohol	91.5	536.8			628.3
Methyl ethyl ketone (MEK)	101.3	418.0			519.4
n-Butyl alcohol	16.5	450.8			467.3

(5) (ii) Mobile sources are responsible for direct emissions of air toxics and contribute to precursor emissions which react to form secondary pollutants. Examples of mobile source air toxics include benzene, 1,3-butadiene, formaldehyde, polycyclic organic matter (POM), naphthalene, and diesel particulate matter. Give an example of the use of a regulatory approach to control air toxics and briefly discuss it's relative success over technology approaches.

(5) **(iii)** Briefly explain the key steps involved in designing an odour control system for VOCs emissions from a paint spray operation or similar industrial process.

(5) (iv) Provide an engineering example to show how *emission trading* may be used to reduce emissions between neighbouring countries.

Problem 5

Provide answers to the following questions related to *behaviour of gaseous pollutants (CO, SOx, NOx, etc.) in the atmosphere* and *monitoring and control of particulate emissions*.

(8) (i) A pollutant of primary concern from oil combustion includes nitrogen oxides (NOx). For NOx explain: (a) the kinetics of formation, (b) two important combustion parameters and (c) its behaviour in the atmosphere that make this an environmental concern.

(6) (ii) Briefly explain two (2) post-combustion pollution control technologies that could be implemented for gaseous emissions in a coal-fired power plant and provide the key engineering principle involved in the technology design.

(6) (iii) Calculate the terminal settling velocity of a 25 μm diameter particle with a density of 3 g/cm^3 at 55 ^{o}C air. Assume that the following equation applies to terminal velocity (v_t). Make any appropriate assumptions. Briefly explain two (2) major dfferences between cyclones and scrubbers in the method of particulate capture.

$$v_t = \frac{g\rho_p d_p^2}{18\mu_g}$$

Problem 6

Provide answers to the following questions related to *control of sulphur oxides and oxides of nitrogen, desulphurisation, kinetics of NOx formation* and *the role of nitrogen and hydrocarbons in photochemical reactions*.

(7) (i) Identify and discuss two (2) important design principles to reduce and/or control the emission of oxides of nitrogen (NOx) or sulphur oxides (SOx) during the combustion of fossil fuels. Consider one (1) different post-combustion measure for each contaminant.

(6) (ii) Flue gas desulphurisation (FGD) plants are necessary to fulfil regulations on sulfur emission reduction. Briefly describe three (3) key differences of the FGD process over the wet scrubbing process.

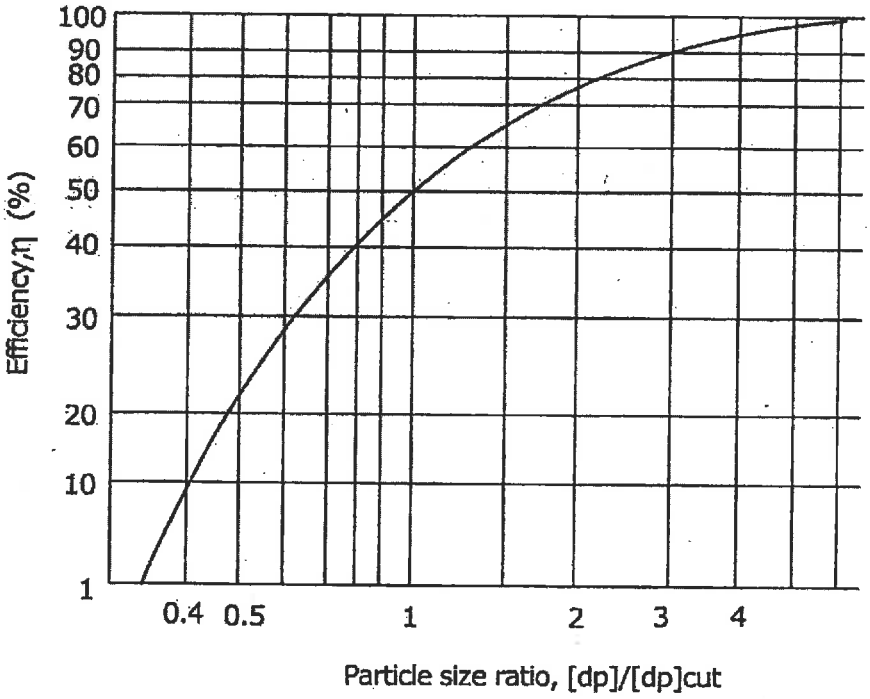
(7) (iii) Explain how photochemical smog is formed with respect to the role of nitrogen and hydrocarbons. In addition, briefly explain the conditions which increase smog production and why.

Problem 7

Provide answers to the following questions related to *control of gases and vapour emissions to the atmosphere* and *control mechanisms including adsorption, absorption, combustion and incineration.*

(7) (i) A large diameter cyclone is being used for the removal of grain dust in the range of 8 to 100 μm diameter. What are collection efficiencies over this range if the cyclone has an inlet width of 0.3 m, an inlet gas velocity (v_i)of 20 m/s? Assume the particle density of 1200 kg/m^3, use the efficiency curve (below) and estimate the efficiency for 10, 20, 40 and 80 μm diameter particles.

$$[d_p]_{cut} = \sqrt{\frac{8\mu_g B_c}{1.8\pi v_i \rho_p}}$$



(5) (ii) Explain two (2) important design differences between combustion and incineration control mechanisms used to reduce gas or vapour emissions from an industrial process.

(8) (iii) Provide an example, with efficiency, of a typical design for an adsorption or absorption system used to reduce gases or vapour emission. In your example, provide the key design principles, safety factors and important operating conditions to maximize the performance efficiency.

Marking Scheme

1. (i) 8 (ii) 5 (iii) 7 marks, 20 marks total

2. (i) 10 (ii) 10 marks, 20 marks total

3. (i) 8 (ii) 6 (iii) 6 marks, 20 marks total

4. (i) 5 (ii) 5 (iii) 5 (iv) 5 marks, 20 marks total

5. (i) 8 (ii) 6 (iii) 6 marks, 20 marks total

6. (i) 7 (ii) 6 (iii) 7 marks, 20 marks total

7. (i) 7 (ii) 5 (iii) 8 marks, 20 marks total