NATIONAL EXAMS DECEMBER 2014

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 $8\frac{1}{2}'' \times 11''$ 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 100 moles of C_8H_{17} containing 3% sulphur is burnt in the presence of stoichiometric amount of oxygen. Briefly explain the formation of secondary air pollutants related to the combustion of fossil fuels.

(6) (ii) Describe 2 different types of indoor air pollutants, their potential health impacts and briefly explain two (2) engineering methods to reduce their potential health impacts.

(6) (iii) Consider the outdoor release of VOCs (e.g., formaldehyde, toluene, pesticides, select only one) from an industrial operation and describe two (2) health and two (2) ecological 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*.

(6) (i) Describe Pasquill stability classes 'A' and 'F' in terms of solar radiation, wind conditions and night time cloud cover. Briefly explain how each of the two (2) stability classes will impact the stack plume behaviour.

(6) (ii) Describe how dispersion and deposition modelling of atmospheric pollutants is handled in the Box, Lagrangian or Gaussian diffusion model (choose one only).

(8) (iii) Briefly explain: (1) the cause of inversion layers; and (2) the effect of inversion layers on the Gaussian plume model (below) predictions of the maximum ground level pollutant concentration. You may use diagrams to assist with the explanation.

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

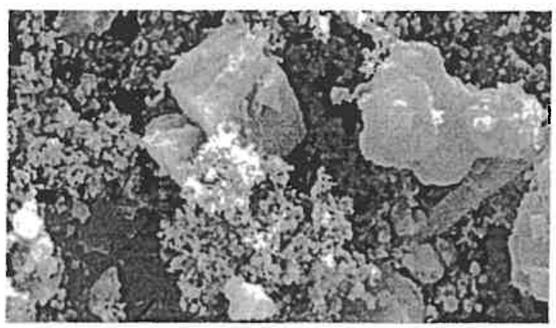
Problem 3

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* $PM_{2.5}$ *and* PM_{10}.

(8) (i) Explain three (3) key differences between passive and active measurement techniques and two (2) conditions (for each method) where each technique is most appropriate.

(6) (ii) Explain the significance of aerodynamic diameter to particulate pollutants and give one (1) example of its use in engineered systems used to control air pollution.

(6) (iii) Explain two (2) key differences in the health effects and aesthetics between the $PM_{2.5}$ and PM_{10} categories of particulate pollutants. A total of four (4) differences are to be provided. The diagram below is a micrograph of PM_{10} particulates sampled at a traffic monitoring site.



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*.

(8) (i) Examples of toxic air pollutants include dioxins, benzene, arsenic, beryllium, mercury and vinyl chloride. Select any two (2) toxics, identify the potential health effect and give an example of an effective engineering strategy that may be used to reduce the air toxic effect.

(6) (ii) Identify and explain the process design of a biotechnology that may be used for the control of odorous emissions from a food industry.

(6) (iii) Explain what emission trading is and how it may be used to promote reduced emissions between international neighbours.

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) The types of air pollutant emission sources are commonly characterized as either point, line, area or volume sources. Briefly explain when the use of each type is most appropriate to characterize atmospheric emissions.

(7) (ii) Briefly explain how NOx are formed during the combustion of natural gas by a power plant and provide an example of the use of a post-combustion technology to reduce these gaseous atmospheric emissions.

(5) (iii) Briefly explain how opacity monitoring of stack emissions may be used to control particulate emissions.

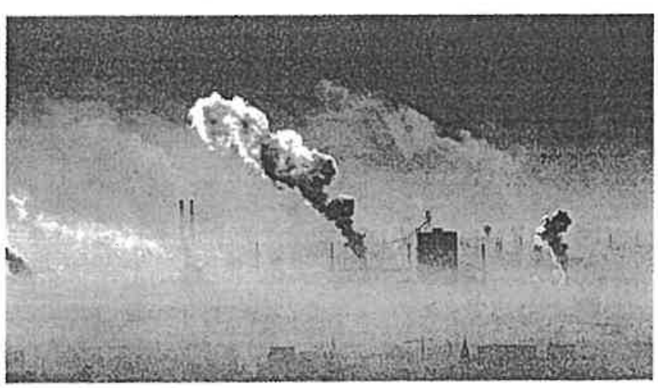
Problem 6

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

(7) (i) Identify and discuss two (2) important strategies to reduce and/or control the emission of oxides of suphur (SOx) during the combustion of fossil fuels. Consider both pre and post-combustion measures.

(6) (ii) Flue gas desulfurisation (FGD) plants are necessary to fulfil regulations on sulfur emission reduction. Provide a simple schematic and briefly describe how a commonly used FGD plant works.

(7) (iii) Explain the role of nitrogen and hydrocarbons in the formation of smog.

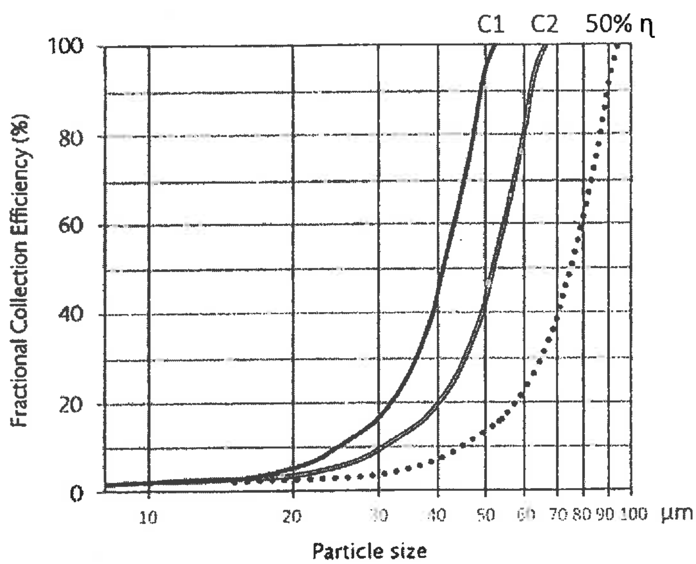


Problem 7

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.*

(6) (i) A large diameter cyclone is being used for the removal of grain dust with particle diameters ($[d_p]$) of 20, 40, 60 and 80 μm. What are the collection efficiencies of these particle sizes if the cyclone has an inlet width (B_c) of 0.3 m and an inlet gas velocity (v_i) of 25 m/sec? The particle density (ρ_p) is 1100 kg/m^3. Assume that the following formula for $[d_p]_{cut}$ applies, $\mu_g = 1.9{\cdot}10^{-5}$ kg/(m·s) and the figure below (use the 50% η curve) gives the cyclone removal efficiencies.

$$[d_p]_{cut} = \sqrt{\frac{9\mu_g B_c}{2\pi v_i \rho_p}}$$



(6) (ii) Provide one (1) example of the use of adsorption system to control gas or vapour emissions from an industrial process. Include a labeled schematic showing the process.

(8) (iii) Provide an example, with efficiency, of a typical design for an incineration system used to reduce gases or vapour emission. In your example, provide the key design principles and important operating conditions to ensure an efficiency of 99.9%.

Marking Scheme

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