NATIONAL EXAMS MAY 2013

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 *behaviour of gaseous pollutants (HCl, CO, SOx, NOx, etc.) in the atmosphere* and *monitoring and control of particulate emissions.*

(8) (i) The pollutants of primary concern from oil combustion are the criteria pollutants which include nitrogen oxides (NOx), hydrogen chloride (HCl) and sulfur oxides (SOx). Select one (1) of these criteria pollutants and briefly explain: (a) the kinetics of formation, (b) two important combustion parameters and (c) its behaviour in the atmosphere that make this an environmental concern.

(7) (ii) Briefly explain how NOx are formed during the combustion of coal by a power plant. Provide an example of the use of a technology to reduce these gaseous atmospheric emissions *during pre or post-combustion.*

(5) (iii) Calculate the terminal settling velocity of a 25 μm diameter particle with a density of 3 g/cm^3 at 20 ^{o}C air. Explain why air pollution control devices that employ only gravitational settling to accomplish initial separation are limited in their use to pre-cleaners that are designed to reduce the large-particle fraction before entering fans or the primary control device. Assume that the following equation applies to terminal velocity (v_t). Make any appropriate assumptions.

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

Problem 2

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) Compare a typical **passive** and **active sampler** used for detecting ambient air pollutants and provide a situation where each type of sampler is most appropriate.

(6) (ii) Explain the significance of terminal settling velocity and particle size distribution in predicting the environmental behaviour and in devising engineering solutions to control air particulate emissions.

(6) (iii) Recently a comprehensive report on PM pollution identified sulfate and organic matter as the two main contributors to the annual average PM10 and PM2.5 mass concentrations. Explain two (2) key differences in the health effects and aesthetics between the PM2.5 and PM10 categories of particulate pollutants. A total of four (4) differences are to be provided and you may use a table to summarize your answer.

Problem 3

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_7H_{13} containing 5% 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.

(6) (ii) Describe a biological and chemical indoor air pollutant (2 different pollutants), their potential health impacts and describe two (2) potential engineering solutions to reduce their health impacts.

(6) (iii) Consider a continuous atmospheric emission of lead (Pb) in an aerosol form within a municipal boundary. Describe two (2) health and two (2) ecological potential impacts associated with this continuous Pb emission.

Problem 4

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 stable, very unstable and slightly unstable conditions in terms of solar radiation, cloud cover and/or wind conditions. Briefly explain how each condition may affect the stack plume behaviour.

(6) (ii) Describe how different source types (i.e., point, line or areal) are handled or approximated in a Gaussian or Eddy diffusion model predictions of resultant ground level concentration of contaminants.

(8) (iii) Consider the Gaussian model (below) used to determine the maximum ground level pollutant concentration. For three (3) important source or environmental conditions, explain the effect on the calculated maximum ground level concentration.

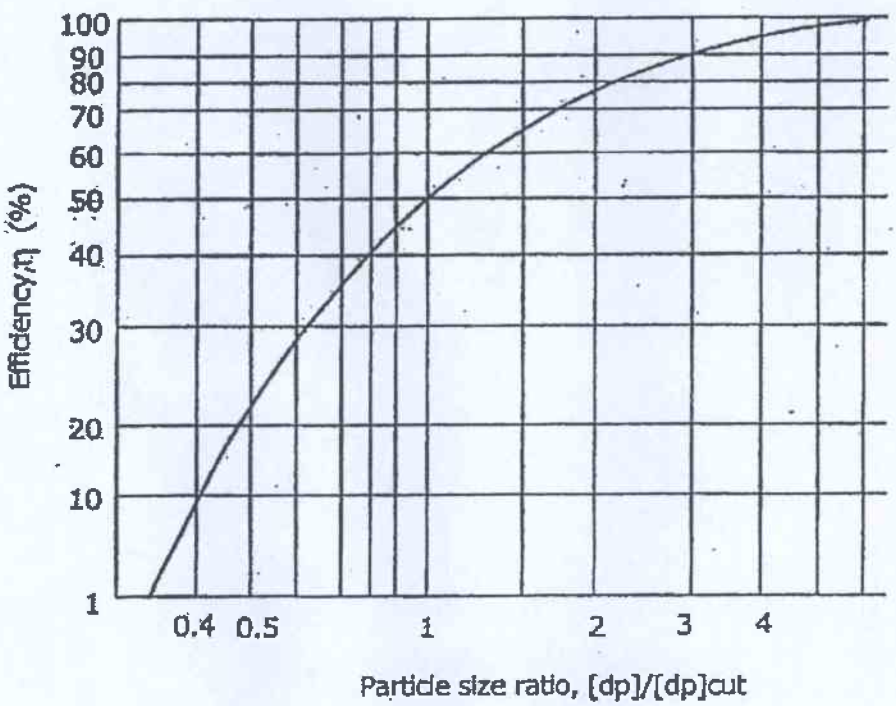
$$C_x = \left(\frac{Q}{\pi\sigma_y\sigma_z u}\right) \cdot exp\left(\frac{-H^2}{2\sigma_z^2}\right) \cdot exp\left(\frac{-y^2}{2\sigma_y^2}\right)$$

Problem 5

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, *moderately efficient* cyclone is being used for the removal of grain dust with particle diameters ($[d_p]$) of 5, 10, 15 and 20 microns. What are the collection efficiencies of these particle sizes if the cyclone has an inlet width (B_c) of 0.4 m and an inlet gas velocity (v_i) of 20 m/sec? The particle density (ρ_p) is 1200 kg/m^3. Assume that the following formula for $[d_p]_{cut}$ applies, $\mu_g = 1.8{\cdot}10^{-5}$ kg/(m·s) and the figure below gives the cyclone removal efficiencies.

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



(6) (ii) Explain two (2) important differences between combustion and incineration control mechanisms used to control 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 and important operating conditions to maximize the performance efficiency.

Problem 6

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) People exposed to air toxics at sufficient concentrations and durations may have an increased chance of getting cancer or experiencing other serious health effects. Consider benzene or polycyclic organic matter (POM) emitted from a mobile source and provide two (2) effective engineering strategies that may be used to reduce this air toxic.

(6) (ii) Identify and explain the fundamental principles of a physical-chemical based technology used for the control of noxious pollutants or odorous emissions from a food industry.

(6) (iii) Provide an example of emission trading at the international level and how governments may use caps and carbon credits to promote reduced emissions.

Problem 7

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) Compare two (2) important strategies to reduce and/or control the emission of oxides of nitrogen (NOx) during the combustion of fossil fuels. Use a matrix to provide both advantages and costs associated with each strategy.

(6) (ii) Flue gas desulfurisation (FGD) plants are necessary to fulfil regulations on sulfur emission reduction. Explain two (2) important engineering principles that control the effectiveness of the FGD process.

(7) (iii) Explain two (2) environmental conditions necessary for the formation of photochemical smog and provide a reason to explain why each condition is necessary.

Marking Scheme

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