NATIONAL EXAMS DECEMBER 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 *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 power generation using coal as a fuel source. 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 black-box schematic of the the FGD process and give a brief explanation of what each step in the process does.

(7) (iii) Provide the main equations that explain how photochemical smog is formed with respect to the role of nitrogen and hydrocarbons. For each equation briefly explain the main conditions that maximize smog production.

Problem 2

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 3 % sulphur is burnt in presence of stochiometric amount of oxygen. Briefly explain the formation of secondary air pollutants related to the combustion of fossil fuels.

(6) (ii) Describe one (1) biological and one (1) chemical outdoor or indoor air pollutant (2 different pollutants in a city environment). For each pollutant give the potential health impacts and describe two (2) technical strategies (2 for each pollutant) to reduce their health impacts.

(6) (iii) Consider the outdoor fugitive emission of benzene from an industrial park and describe two (2) related health and two (2) related ecological impacts associated with its release.

Problem 3

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) To prevent unnecessary damage to human health and the environment, environmental regulatory agencies such as Health Canada and Environment Canada, have established strategies to minimize the emission of air toxics from mobile sources. Identify two (2) regulated air toxics, the regulatory strategy to control these air toxics and associated relative costs with implementing engineering control measures.

(6) (ii) Identify and explain the fundamental principles of a technology used for the control of odorous emissions from a car coating factory or metal printing factory.

(6) (iii) Explain how emission trading or cap and trade may be used to achieve reduction in the emissions of pollutants.

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) Identify and describe the main difference between the three (3) primary types of air pollution emission plumes.

(8) (ii) Describe how dispersion and deposition of atmospheric pollutants is modelled using a Gaussian or Eddy diffusion model and what air pollution measurements are important to verify the model results.

(6) (iii) Consider the use of a steady state Eddy or Gaussian diffusion model and explain three (3) important limitations in its application.

Problem 5

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) Explain one (1) automatic or manual procedure to monitor SO_2 from the combustion of fossil fuels. Briefly explain the key principles involved, the advantages and limitation of the procedure.

(6) (ii) Airborne particulate matter represents a complex mixture of organic and inorganic substances. Briefly explain three (3) principal ways to characterize air pollutant particulates that are important for engineers to design control equipment.

(6) (iii) Explain two (2) key similarities in the health effects and aesthetics between the PM2.5 and PM10 categories of particulate pollutants. A total of four (4) similarities are to be provided.

Problem 6

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.*

(10) (i) Explain the overall atmospheric behaviour of one (1) gaseous pollutant (e.g., CO, SOx, NOx, etc.) by considering the basic physical and chemical interactions from emission to final sink in the environment.

(10) (ii) Comment on why electrostatic precipitators are better at removing small particles over other methods and determine the terminal electrostatic velocity (v_t) of a 10 μm unit density particle carrying 700 units of charge in an electric field of 2 kV/cm. Assume that the gas temperature is 20 °C. To solve this problem, the following equation may be used and assume C_c is 1.09.

$$v_t = \frac{n \cdot e \cdot E \cdot C_c}{3 \cdot \pi \cdot \mu \cdot d}$$

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.*

(5) (i) Calculate the expected particulate efficiency for an electrostatic precipitator serving a utility coal-fired boiler. The gas flow rate is 250,000 ACFM. The total collection plate area is 20,000 m^2. Use an effective migration velocity of 0.05 m/sec. Recall the standard Deutsch-Anderson equation:

$$\eta = 1 - e^{-\omega\left(\frac{A}{G}\right)}$$

(7) (ii) Explain two (2) important engineering design similarities between adsorption and absorption based equipment used to control gas or vapour emissions from a manufacturing process.

(8) (iii) Explain the importance of incineration temperature, combustion gas residence time and combustion air distribution in the engineering design of incineration.

Marking Scheme

1. (i) 7 (ii) 6 (iii) 7 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) 8 (iii) 6 marks, 20 marks total
5. (i) 8 (ii) 6 (iii) 6 marks, 20 marks total
6. (i) 10 (ii) 10 marks, 20 marks total
7. (i) 5 (ii) 7 (iii) 8 marks, 20 marks total