NATIONAL EXAMS DECEMBER 2009

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 8.5*in* x 11*in* 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.

3. Any five questions constitute a complete paper. Only the first five answers, to the seven questions, as they appear in your answer book(s) will be marked.

4. Each question is worth a total of 20 marks with the section marks indicated in square brackets [ ] at the end 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.

1. Provide answers to the following questions related to sources and classifications of atmospheric pollutants, indoor and outdoor air pollutants and health and ecological impacts.

   i) Classify the following three (3) atmospheric pollutants by their source, key characteristic and provide an appropriate engineering method to control their production or emissions: VOCs, PM_{10} and CFCs. Use a tabular format or matrix to answer this question. **[6]**

   ii) Aerosols can be significant indoor air pollutants. Identify three (3) different types of aerosols, their source and elimination by passive or engineering approaches in residential or industrial structures. [6]

   iii) Briefly describe the four (4) ecological or health impacts associated with incineration of municipal solid waste within an urban environment. [8]

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

   i) Briefly explain how solar radiation and wind fields can affect the atmospheric dispersion of a plume of sulphur dioxide (SO_2) from a 100 m fly ash stack. [6]

   ii) The Gaussian plume diffusion model is commonly used to predict the ground level concentration of a pollutant at some distance x from the source (C_x). Explain the effect of H, σ_y and u on C_x. [7]

$$C_x = \frac{Q}{\pi \sigma_y \sigma_z u} e^{-1/2\left[\frac{H}{\sigma_z}\right]^2} e^{-1/2\left[\frac{y}{\sigma_y}\right]^2}$$

   iii) Compare and contrast Eddy and Gaussian diffusion models by providing three (3) commonalities and three (3) differences in their use or application. [7]

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

   i) Explain, by using an example, how any two (2) of the following methods are used in measuring air pollutants: ultraviolet fluorescence method, chemiluninescence analyzer, radiometric method, gas chromatography and ultraviolet absorption photometry. [**8**]

   ii) Briefly explain why PM2.5 particulates are of particular concern when considered in conjunction with other toxic air pollutants. [**6**]

   iii) It has been identified in an urban study that furnaces and dirty ductwork may be a significant source of PM2.5 and PM10 particulates in buildings. Identify two (2) health and two (2) aesthetic impacts and provide an engineering strategy that may reduce or eliminate the health and aesthetic impacts for office workers. [**6**]

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

   i) SOx and NOx emissions are known to contribute to the production of acid rain. Describe two (2) effects of acid rain and give two (2) engineering solutions to minimize the formation of acid rain. **[6]**

   ii) An industrial heater rated at 20 Gigajoules per hour is firing heavy fuel oil with a sulphur content of 3% by weight and an efficiency of 90%. Given:

   - 1 litre of Heavy fuel yields 40,000 kilojoules and weighs 0.95 kilograms
   - Atomic weights: S = 32, O = 16

   Estimate the emission rate of sulphur dioxide from this heater in (in grams per second). Clearly state any assumptions. **[7]**

   iii) Briefly describe the use of baghouse fabric filters (dust collectors) to control particulate matter emissions from an industrial operation. Provide two (2) advantages and two (2) limitations of this process and give an example of where it is most appropriate to use. **[7]**

5. Provide answers to the following questions related to control of gasses and vapour emissions to the atmosphere by adsorption, absorption, combustion and incineration::

   i) Briefly describe an engineering and regulatory strategy that may accelerate the reduction or elimination of lead toxics emissions from mobile sources. Give three (2) advantages and three (2) disadvantages of both the engineering and regulatory strategy. Use a matrix or table to provide your answer. [**8**]

   ii) Assuming lignite ($CH_{0.9}O_{0.2}N_{0.02}S_{0.01}$) is used as a fuel burned in air at an equivalent ratio of 0.80. Determine the total amount of exhaust gas produced per mole of carbon combusted. Assume that combustion is complete and that the nitrogen in the lignite is all emitted as NO_2. **[6]**

   iii) Certain gaseous pollutants in air streams are often removed by sorption onto a liquid stream. Explain how sulphur dioxide (SO_2) may be effectively removed using this method. In your explanation, provide two (2) fundamental chemistry and process design considerations. **[6]**

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

   i) A dominant source of nitrous oxide (NOx) emissions is due to power plants based on combustion of fossil fuels. Identify and explain the key engineering principles associated with the design and operation of an engineering technology used to reduce NOx formation or emissions. [**6**]

   ii) Briefly explain a gas-phase desulphurisation technology used to remove NO_x and H_2S from the air emission streams. In your explanation, include two (2) important issues related to chemistry and two (2) system process control issues. [**8**]

   iii) Give an example of an organic atmospheric compound that undergoes photochemical reaction to form reactive radicals that contribute to the formation of smog. In your example show the most significant chemical reactions. [**6**]

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

   i) Briefly describe three (3) different engineering technologies typically used to reduce or eliminate environmental impacts associated with volatile organic compound (VOC) emissions. **[5]**

   ii) A significant amount of air pollutants come from automotive emissions due to incomplete combustion of compounds in gasoline. Explain one (1) engineering or regulatory strategy that may be applied to reduce these emissions. Provide two (2) advantages and two (2) limitations of your selected strategy. **[5]**

   iii) Provide an example of an active or passive engineered process to reduce or eliminate noxious air pollutants and odours from screening operation of a sewage treatment plant (STP). Note that the sewage is typically septic when it reaches the STP. **[5]**

   iv) Provide an example to show how emission trading would work between countries who share a large trade of both raw materials and manufactured goods and how this may assist in maintaining a cap on greenhouse-gas emissions. **[5]**

Marking Scheme

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December 2009

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