NATIONAL EXAMS
MAY 2010

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 *8.5in x 11in* 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 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.

5. 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) One method of effectively dealing with VOCs is being able to classify them by their source and characteristics. Provide two (2) fundamental sources, two (2) sinks and two (2) pathways in the atmosphere for two (2) selected VOCs. **[5]**

   ii) Aerosols can be significant indoor air pollutants. Identify two (2) different types of aerosols, their source and possible elimination by engineering approaches in residential, institutional or industrial structures. Select only one location. **[5]**

   iii) Describe a regulatory approach that may be used to reduce indoor air pollutants from enclosed areas. Give an advantage and a disadvantage of this regulatory strategy over a site specific engineered control measure. **[5]**

   iv) Briefly describe one (1) ecological and one (1) health impact associated with motor vehicle traffic in urban environments. Include the effects of solar radiation (i.e., night versus day) on these impacts. **[5]**

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) Explain and compare two (2) main differences between a *buoyant plume* and a *dense gas plume*. **[4]**

   ii) Briefly explain how solar conditions and wind fields affect the stability conditions which influence the movement of stack plumes. **[4]**

   iii) Identify and briefly explain two (2) factors affecting the atmospheric dispersion of a plume of contaminated air. The factors must be process related, operational or design in nature. **[6]**

   iv) 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 importance of any three (3) parameters in the equation below by describing their function. **[6]**

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

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 how CO and PM may be monitored accurately in ambient outdoor conditions using any two (2) viable methods. Briefly explain how each monitoring method works, provide an example of its use giving an advantage and a limitation in comparison to the other method selected. [6]

   ii) The *aerodynamic diameter* is a commonly used term to characterize the size of particulates. Briefly explain the meaning of the term and its usefulness in air quality pollution control of aerosols from a primary source. Use an example to facilitate your explanation. [6]

   iii) It has been identified in an urban study that road dust is a significant source of PM2.5 and PM10 particulates. Identify two (2) health and two (2) aesthetic impacts and provide one (1) engineering strategy and one (1) regulatory approach that may help to reduce these impacts for commuters using public transportation. [8]

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 :

   v) Briefly describe two (2) engineering control methods that may be used to control VOC emissions. For each method, briefly provide two (2) advantages and two (2) limitations of the method and an example of where it is most appropriate to use that particular method. **[8]**

   vi) Calculate SO_2 concentration in flue gas when one mole of C_7H_{13} containing 1 % sulphur is burnt in the presence of a stochiometric amount of oxygen. **[6]**

   vii) Briefly explain the use of electrostatic precipitators to control particulate matter emissions from an industrial operation. In your explanation provide two (2) key process design conditions and two (2) operational conditions necessary to ensure optimum efficiency. **[6]**

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

   i) Major sources of greenhouse gases include home heating and cooling, electricity consumption, and transportation. Select one source and explain how a technical and a non-technical control method, have been combined, to reduce emissions to the atmosphere. [7]

   ii) Recent emission standards for incinerators require that the total particulates concentration in the incinerator stack discharge gas shall not exceed 100 $\mu g/m^3$, based on a monthly average, corrected to 10% oxygen. Explain the key operating parameters that you would need to control in the operation of the incinerator to ensure that you comply with the total particulates emission requirements. **[6]**

   iii) New large plants use double conversion double absorption (DCDA) process realizing above 99 percent efficiency in the production of sulphuric acid. A 500 T/d DCDA sulphuric acid plant burns 200 T/d of sulphur in the manufacturing process. Flue gas containing 300 ppm SO_2 is discharged at the rate of 35 Nm^3/s. What is the percent recovery of sulfur in the product? **[7]**

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) The dominant source of sulphur oxides emissions in steel making is due to the burning of high-sulphur fossil fuels and blast furnace slag. Identify and explain the key engineering principles associated with the design and operation of an engineering technology used to reduce sulphur oxides emissions. [6]

   ii) Briefly explain a gas-phase desulphurisation technology used to remove SO_x and H_2S from the air emission streams. In your explanation, include the key system process control, the reagent/feed preparation, waste handling/disposal with the principle operation and maintenance factor. [7]

   iii) Explain how nitrogen oxides (NOx), volatile organic compound (VOCs) and sunlight contribute to the formation of photochemical smog. In your example show the most significant chemical reactions and briefly explain why they are significant. [7]

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 the key engineering principles associated with two (2) different engineering technologies known to be effective at reducing emissions of volatile organic compound (VOCs) or other air toxics. **[6]**

   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 measure that may be applied to reduce these emissions. [4]

   iii) Provide an example of a passive engineered process to reduce noxious air pollutants and odours from a pumping station that receives sewage from a large sewershed. Note that the sewage is typically septic when it reaches the pumping station. **[5]**

   iv) Provide an example to show how emission trading would work between municipalities, located along the Canadian and United States border, Briefly how this may assist in maintaining a cap on greenhouse-gas emissions. [5]