NATIONAL EXAMS MAY 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 x 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.

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) One method of effectively dealing with particulate emissions is being able to classify them by their source and characteristics. Briefly explain how this method is used by engineers to select appropriate engineering solutions to control particulate air pollutants. **[5]**

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, institutional or industrial structures. **[5]**

iii) Describe a legislative approach used by regulators to reduce outdoor air pollutants from fixed or mobile sources. Give an advantage and a disadvantage of this regulatory strategy over engineered control measures. **[5]**

iv) Briefly describe the ecological and health impacts associated with motor vehicle traffic in urban environments. Include the effects of temperature (i.e., summer versus winter) 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) Identify and briefly explain four (4) factors affecting the atmospheric dispersion of a plume of contaminated air. The factors can be any one of meteorological, process related, operational or design in nature. **[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 importance of any three (3) parameters in the equation below by describing their function. **[5]**

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

iii) Briefly describe the following transport mechanisms and provide one example where each transport mechanism can be used to explain an environmental phenomenon:

a) Dispersion **[3]**
b) Turbulent diffusion **[3]**
c) Hydrodynamic dispersion **[3]**

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) Air pollutant measurement techniques include gravimetric methods, light-scattering monitors, electro-chemical monitors, pump and filter, bag collection and lab analysis methods. Select any two (2) methods, briefly explain how each works, provide an example of its use giving an advantage and a limitation in comparison to the other method selected. **[6]**

ii) Briefly explain why PM < 10 microns are of particular concern when considered in conjunction with other toxic air pollutants. **[4]**

iii) Stratospheric ozone depletion has been identified as a global concern. Briefly explain the key cause of stratospheric ozone depletion and the potential damaging effects that may result. **[4]**

iv) 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 an engineering strategy that may help to reduce the health and aesthetic impacts for urban commuters. **[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) Certain gaseous pollutants such as SOx and NOx 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 10 Gigajoules per hour is firing heavy fuel oil with a sulphur content of 2.5% by weight and an efficiency of 80%. Given:

- 1 litre of Heavy fuel yields 42,000 kilojoules and weighs 0.97 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 electrostatic precipitators 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, control mechanisms including adsorption, absorption, combustion and incineration:

i) The Canadian Environmental Protection Act defined several substances emitted during the combustion of fossil fuels as toxic. Environment Canada therefore initiated a "Strategic Options Process" to examine the impact and potential need for controlling the emissions of these contaminants, such as nickel, arsenic, hexavalent chromium and cadmium. Briefly describe an engineering or regulatory strategy that may accelerate the reduction or elimination of air toxics emissions. Give an advantage and a disadvantage of your plan. **[5]**

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 0.90. 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. **[5]**

iii) Certain gaseous pollutants in air streams are often removed by sorption onto a liquid stream. Explain how sulphur dioxide (SO2) may be effectively removed using this method. In your explanation, provide some of the fundamental chemistry and process design considerations.**[5]**

iv) Recent emission standards for incinerators require that the total particulates concentration in the incinerator stack discharge gas shall not exceed 180 mg/m^3, based on a monthly average, corrected to 11% 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. **[5]**

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 important issues related to chemistry, system process control, reagent/feed preparation, waste handling/disposal and operation and maintenance. [7]

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 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 two (2) different engineering technologies typically used to reduce or eliminate environmental impacts associated with volatile organic compound (VOC) emissions. In your description, provide the key engineering principle associated with each technology. [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 measure that may be applied to reduce these emissions. Provide two (2) advantages and two (2) limitations of your measure. [5]

iii) Provide an example of an active or passive engineered process to reduce or eliminate 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, that will assist in maintaining a cap on greenhouse-gas emissions. [5]

Marking Scheme

04-Env-A1 Principles of Environmental Engineering

May 2009

1. i) 5 ii) 5 iii) 5 iv) 5 marks; 20 marks total

2. i) 6 ii) 5 iii) a) 3 b) 3 c) 3 marks; 20 marks total

3. i) 6 ii) 4 iii) 4 iv) 6 marks; 20 marks total

4. i) 6 ii) 7 iii) 7 marks; 20 marks total

5. i) 5 ii) 5 iii) 5 iv) 5 marks; 20 marks total

6. i) 6 ii) 7 iii) 7 marks; 20 marks total

7. i) 5 ii) 5 iii) 5 iv) 5 marks; 20 marks total