NATIONAL EXAMS
MAY 2011

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) Explain what SPM and NOx refer to and identify 2-potential industrial sources for each SPM and NOx. **[4]**

   ii) Sulfur dioxide (SO_2) is common atmospheric pollutant resulting from combustion processes. Calculate the amount of SO_2 emitted when 2-moles of 2-ethyl hexane (C_6H_{12}), having a 2% sulphur content, is burned in the presence of a stochiometric amount of oxygen. **[6]**

   iii) Identify a major indoor air pollutant, give the source(s) and potential health impacts. Also describe one (1) engineering process or strategy to reduce the pollutant concentration in the indoor air. Give one (1) advantage and one (1) limitation of the engineering process. **[6]**

   iv) Briefly describe one (1) ecological and one (1) health impact potentially associated with pollutants generated from cement manufacturing plants. **[4]**

2. 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.

   i) Briefly explain how solar conditions and wind fields affect the plume rise (ΔH). In your explanation consider appropriate equations, figures and/or logical arguments. **[4]**

   ii) Provide three (3) important criteria that dispersion and deposition models of atmospheric pollutants should have and briefly explain why these criteria are important. **[6]**

   iii) Provide two (2) key differences between Eddy and Gaussian diffusion models and provide one (1) condition where the use of each model is most appropriate. **[4]**

   iv) Explain any two (2) limitations associated with the Gaussian plume model (below) when predicting ground level concentrations and give two (2) corrections that can be made by the modeller to overcome these limitations. **[6]**

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

3. 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.

   i) From 1900 to 1970 the emission of six criteria pollutants including particulate matter (PM10), sulphur dioxide, carbon monoxide, nitrogen dioxide, ozone, and lead, increased significantly. Explain how any two (2) criteria pollutants can be measured in ambient air. Provide an advantage and a limitation of each method. **[6]**

   ii) Briefly explain why settling velocities and aerodynamic diameters of PM are important characteristics to consider in determining engineering control strategies for various air pollutant particulates. **[6]**

   iii) It has been shown that wear from tires largely impacts the particle concentration and contribute to poor environmental air quality due to high levels of PM2.5 concentration that exceed 50 $\mu g/m^3$ for more than 35 days per year in large cities. Briefly explain two (2) types of related health hazards, (2) aesthetic hazards and one (1) regulatory method to help reduce such health and aesthetic effects. **[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.

   i) Briefly describe two (2) engineering control methods that may be used to control NOx emissions to the atmosphere from an industrial source. For each control method, contrast and/or compare any two (2) advantages and two (2) limitations and for each method give one (1) example where it is most appropriate to be used. **[8]**

   ii) Briefly explain how to monitor and control an electrostatic precipitator to gain its maximum removal efficiency. In your explanation, identify two (2) key parameters that would need to be monitored and controlled. **[6]**

   iii) Briefly explain the use of cyclone 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 removal efficiency of particulates. **[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 CO_2 and NOx come from transportation and electricity production. Select one (1) source and explain how one (1) technical and one (1) non-technical control method could be combined to reduce emissions to the atmosphere. [7]

   ii) Recent emission standards for spray scrubbers require that the total particulates concentration in the stack discharge gas shall not exceed 250 $\mu g/m^3$, based on a 24-hour average. Explain how you would control two (2) key operating parameters of the scrubber to ensure that you comply with the 24-hour particulate emission requirement. **[8]**

   iii) Consider an electrostatic precipitator and calculate the drift velocity V_e of a 2 μm particle with a +2 units of charge in an electrostatic field of 200 V/cm. Recall that one equation for the electrostatic drift velocity V_e, is given by: **[5]**

$$V_e = \frac{q \cdot E \cdot C_c}{3\pi \cdot \mu \cdot d_p}$$

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) Identify three (3) broad options for controlling SO_2 emissions and provide one (1) example of each option. [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 two (2) key system process controls, one (1) reagent/feed preparation method and one (1) waste handling/disposal method. [6]

   iii) Explain how nitrogen oxides (NOx), volatile organic compounds (VOCs) and sunlight contribute to the formation of photochemical smog. Provide the important equations in your explanation. [8]

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) Identify two (2) major air toxics common in a large city and briefly describe one (1) engineering technology (for each toxic) that may be a viable option at reducing them. In your description, include one (1) operation and one (1) maintenance issue associated with the technology to ensure its lasting performance. **[6]**

   ii) A significant amount of air pollutants come from mobile diesel combustion sources. Explain one (1) engineering and one (1) regulatory measure that may be applied to reduce these emissions. **[4]**

   iii) Provide an example of a passive engineered system to reduce noxious air pollutants and/or odours from fugitive emissions from an indoor wood burning stove. Propose two (2) measures to ensure the system remains effective. **[5]**

   iv) Briefly explain how emission trading works or doesn't work to effectively cap greenhouse-gas emissions between neighbouring countries that rely heavily on coal burning electricity generation. **[5]**

MARKING SCHEME

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

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

3. i) 6 ii) 6 iii) 8 marks; 20 marks total

4. i) 8 ii) 6 iii) 6 marks; 20 marks total

5. i) 7 ii) 8 iii) 5 marks; 20 marks total

6. i) 6 ii) 6 iii) 8 marks; 20 marks total

7. i) 6 ii) 4 iii) 5 iv) 5 marks; 20 marks total