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**NATIONAL EXAMS DECEMBER 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  $8\frac{1}{2}$ " 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.
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 *source and classifications of atmospheric pollutants, indoor and outdoor air pollutants and health and ecological impacts.*

- (6) (i) Describe what is meant by primary and secondary air pollutants and give two (2) examples of each with their respective sources and classification.
- (6) (ii) Identify two (2) outdoor air pollutants and describe two (2) potential engineering remedies to reduce their health and environmental impacts.
- (8) (iii) The term “sick building syndrome” (SBS), was first employed in the 1970s. Briefly explain what situation this describes and describe two (2) related health and two (2) related ecological impacts associated with SBS.

### Problem 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.*

- (6) (i) For each of the following three (3) terms briefly explain each term and how it impacts the stack plume:
1. Briggs buoyancy flux parameter,  $F_b$  ( $\text{m}^4/\text{s}^3$ )
  2. Momentum flux parameter,  $F_m$  ( $\text{m}^4/\text{s}^2$ )
  3. Wind speed at release height,  $u_s$  (m/s)
- (6) (ii) Describe three (3) main differences between Eddy and Gaussian diffusion models and give an example of where each model is more appropriate to use.
- (8) (iii) Consider the Gaussian model (below) used to determine the maximum ground level pollutant concentration. Explain the significance of  $\sigma_y$ ,  $\sigma_z$  and  $H$  in this model, explain how each term is determined and provide two (2) assumptions used to arrive at this form of the model from the general Gaussian Plume model.

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

### Problem 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 PM<sub>2.5</sub> and PM<sub>10</sub>*.

- (8) (i) Explain the principle of gravimetric analysis for determining ambient air particulates and provide an example of its use. Explain how calibration may be performed and the importance of instrument calibration.
- (7) (ii) Explain the significance of aerodynamic diameter (considering the 0.5  $\mu\text{m}$  cutoff size) and lognormal particle size distribution in predicting their expected environmental behaviour and in devising engineering solutions to control such air particulate emissions.
- (5) (iii) Explain why the PM<sub>2.5</sub> and PM<sub>10</sub> categories of particulate pollutants have been created and how their health and aesthetic properties differ.

### Problem 4

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) People exposed to air toxics at sufficient concentrations and durations may have an increased chance of getting cancer or experiencing other serious health effects. Identify one major air toxic emitted from a mobile source and provide two (2) effective engineering strategies that may be used to reduce or eliminate this air toxic.
- (6) (ii) Identify and explain the fundamental principles of a biotechnology used for the control of odorous emissions from a food industry.
- (6) (iii) Explain what emission trading is and how governments may use a cap and carbon credits to promote reduced emissions.

### Problem 5

Provide answers to the following questions related to *behaviour of gaseous pollutants (CO, SO<sub>x</sub>, NO<sub>x</sub>, etc.) in the atmosphere and monitoring and control of particulate emissions.*

- (7) (i) The pollutants of primary concern from Liquefied Petroleum Gases (LPG) combustion are the criteria pollutants which include nitrogen oxides (NO<sub>x</sub>), carbon monoxide (CO) and sulfur oxides (SO<sub>x</sub>). Select one (1) of these criteria pollutants and briefly explain: (1) the kinetics of formation, (2) two combustion parameters that are important and (3) how it behaves in the atmosphere that make this an environmental concern.
- (6) (ii) Briefly explain how SO<sub>x</sub> are formed during the combustion of LPG and how these gaseous atmospheric emissions may be reduced by using an appropriate engineering technology. Identify the technology.
- (7) (iii) Calculate the terminal settling velocity in 20 °C air of a 5 μm diameter particle with a density of 1 g/cm<sup>3</sup> and explain why air pollution control devices that employ only gravitational settling to accomplish initial separation are limited in their use to pre-cleaners that are designed to reduce the large-particle fraction before entering fans or the primary control device. Assume the following equation (below) applies for terminal velocity ( $v_t$ ). Make any appropriate necessary assumptions.

$$v_t = \frac{g\rho_p d_p^2}{18\mu_g}$$

### Problem 6

Provide answers to the following questions related to *control of sulphur oxides and oxides of nitrogen, desulphurisation and kinetics of NO<sub>x</sub> formation and the role of nitrogen and hydrocarbons in photochemical reactions.*

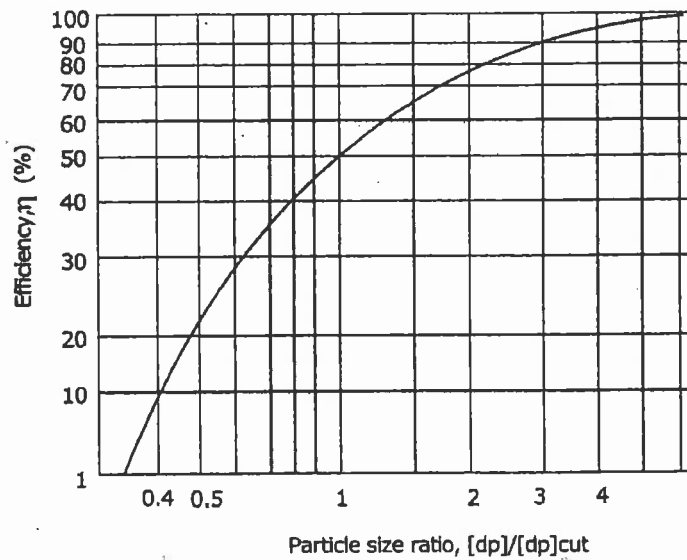
- (7) (i) Identify and discuss two (2) important strategies to reduce and/or control the emission of sulphur oxides (SO<sub>x</sub>) and oxides of nitrogen (NO<sub>x</sub>) during power generation using fossil fuels. In your discussion consider that the goals are to minimize potential health and environmental impacts.
- (6) (ii) Flue gas desulphurisation (FGD) plants have been necessary to fulfill regulations on sulphur emission reduction. Briefly describe how the wet limestone FGD process works.
- (7) (iii) Explain how nitrogen oxides react with trace hydrocarbons and hydroxyl radicals to form photochemical smog. Identify two (2) substances known to cause most of the health problems associated with photochemical smog.

### Problem 7

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

- (8) (i) A large diameter cyclone is being used for the removal of grain dust with particle diameters ( $[d_p]$ ) of 20, 40, 80 and 100  $\mu\text{m}$ . What are the collection efficiencies of these particle sizes if the cyclone has an inlet width ( $B_c$ ) of 0.3 m and an inlet gas velocity ( $v_i$ ) of 15 m/sec? Assume the particle density ( $\rho_p$ ) of 1300  $\text{kg}/\text{m}^3$ . Assume the following formula for  $[d_p]_{cut}$  applies, that  $\mu_g = 1.8 \cdot 10^{-5} \text{ kg}/(\text{m}\cdot\text{s})$  and the figure below gives the cyclone removal efficiencies.

$$[d_p]_{cut} = \sqrt{\frac{9\mu_g B_c}{2\pi v_i \rho_p}}$$



- (6) (ii) Explain how adsorption and absorption control mechanisms are used in the design of one (1) engineered system for the control of gas or vapour emissions. Select a specific gas or vapour and an engineered adsorption and/or absorption system for discussion.
- (6) (iii) Give an example of a design for a combustion and/or incineration system used to control gasses or vapour emission. Explain two (2) important parameters that influence the efficiency of the system performance.

## Marking Scheme

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