NATIONAL EXAMS MAY 2015

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*.

(8) (i) Calculate the SO_2 concentration in flue gas when 20 moles of C_7H_{13} containing 3 % sulphur is burnt in presence of stochiometric amount of oxygen. Briefly explain the formation of secondary air pollutants related to the combustion of fossil fuels and the classification of these atmospheric pollutants.

(6) (ii) Describe a biological and chemical indoor air pollutant (2 different pollutants), its potential health impacts and describe two (2) potential engineering remedies to reduce their health impacts.

(6) (iii) Consider the outdoor release of mercury (Hg) from a mobile pollution source and describe two (2) related health and two (2) related ecological impacts associated with its release.

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) Determine the plume rise from a 40 m high stack if the buoyancy flux from the source is 50 m^4/s^3 and the wind velocity is 5 m/s. The atmospheric condition is slightly unstable. State clearly any assumptions.

(6) (ii) Describe two (2) key simplifications in the modeling of the dispersion and deposition of atmospheric pollutants when using the Gaussian or Eddy diffusion model.

(8) (iii) Consider the Gaussian model (below) used to determine the maximum ground level pollutant concentration. Based on the model predictions, describe three (3) efficient ways to minimize the environmental impacts from stack emissions.

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

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 PM2.5 and PM10*.

(8) (i) Explain the principle of infrared absorption **or** gas chromatography method for determining ambient air pollutants and provide an example of its use. Explain how instrument calibration may be performed in any one of the methods.

(6) (ii) Explain the significance of particle size distribution in predicting the environmental behaviour and in devising engineering controls to minimize air particulate emissions.

(6) (iii) Explain two (2) key differences in the health effects and aesthetics between the PM2.5 and PM10 categories of particulate pollutants.

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) Identify an air toxic, from a mobile source, that may increase the chance of getting cancer or experiencing other serious health effects due to prolonged and intense exposure. Describe two (2) effective engineering strategies that may be used to reduce or eliminate this air toxic emission into the atmosphere.

(6) (ii) Identify and explain the two (2) fundamental principles of a biofilter system design used for the control of noxious odorous emissions.

(6) (iii) Explain how the emission trading principle may be applied by governments to reduce greenhouse gas emissions.

Problem 5

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

(10) (i) The pollutants of primary concern from the combustion of fossil fuels are the criteria pollutants which include nitrogen oxides (NOx), carbon monoxide (CO) and sulfur oxides (SOx). Select one (1) of these criteria pollutants and briefly explain: (a) the kinetics of formation, (b) two important combustion parameters and (c) its behaviour in the atmosphere that make this an environmental concern.

(10) (ii) Calculate the terminal settling velocity of a 20 μm diameter particle with a density of 3 g/cm^3 at 25 ^{o}C air. 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 that the following equation applies to terminal velocity (v_t) and state clearly any 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 sulfur oxides and oxides of nitrogen, desulfurisation and kinetics of NOx formation* and *the role of nitrogen and hydrocarbons in photochemical reactions*.

(7) (i) Identify and discuss two (2) important strategies to reduce or control the emission of oxides of nitrogen (NOx) during the combustion of fossil fuels. Consider both pre and post-combustion measures.

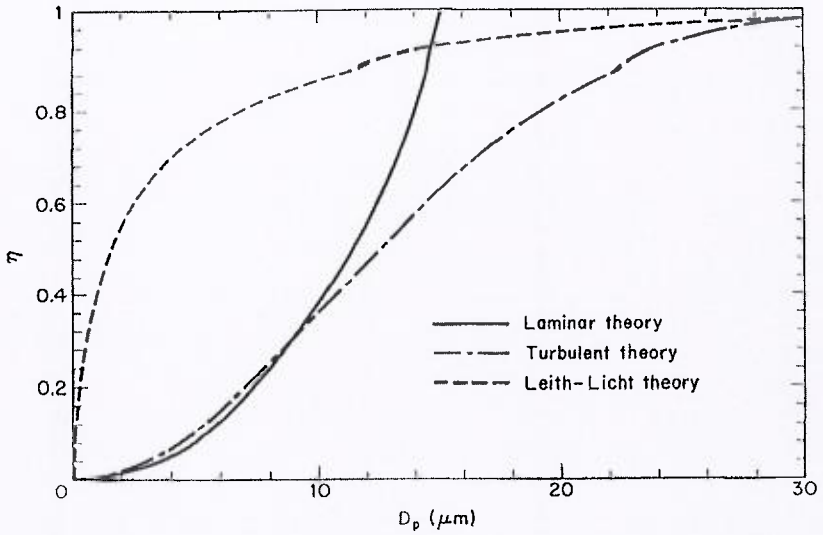
(6) (ii) Flue gas desulfurisation (FGD) plants are commonly used to fulfil regulations on sulfur emission reduction. Provide a labeled schematic and explain the basic principle of how the process works.

(7) (iii) Explain how photochemical smog is formed with respect to the role of nitrogen and hydrocarbons. Based on your explanation suggest an engineering approach to reduce smog in large cities.

Problem 7

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

(6) (i) Based on the cyclone efficiency curves (η versus D_p, below) for the three conditions (Laminar, Turbulent and Leith-Licht) explain how these curves would be applied to reduce emissions when using a cyclone system.



(6) (ii) Explain two (2) important design principles of an adsorption or absorption control equipment (**only one**) used to control gas or vapour emissions from an industrial process.

(8) (iii) Provide an example, with efficiency, of a typical design for a combustion or incineration system (**only one**) used to reduce gases or vapour emissions. In your example, provide the two (2) key design principles and important operating conditions to maximize the performance efficiency.

Marking Scheme

1. (i) 8 (ii) 6 (iii) 6 marks, 20 marks total
2. (i) 6 (ii) 6 (iii) 8 marks, 20 marks total
3. (i) 8 (ii) 6 (iii) 6 marks, 20 marks total
4. (i) 8 (ii) 6 (iii) 6 marks, 20 marks total
5. (i) 10 (ii) 10 marks, 20 marks total
6. (i) 7 (ii) 6 (iii) 7 marks, 20 marks total
7. (i) 6 (ii) 6 (iii) 8 marks, 20 marks total