NATIONAL EXAMS MAY 2014

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 100 moles of C_7H_{13} containing 5 % 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.

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

(6) (iii) Consider the outdoor release of Arsenic(As) from an industrial 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 *control of gases and vapour emissions to the atmosphere* and *control mechanisms including adsorption, absorption, combustion and incineration.*

(6) (i) Explain the use of a packed tower, spray chamber or venturi scrubber (select only one) to control the emissions of two (2) typical gas or vapour contaminants from an asphalt and concrete batch plant.

(8) (ii) Explain the application, by example, of two (2) different control devices (one based on combustion and the other on absorption) used to control gas or vapour emissions from an industrial process. Two (2) separate examples are to be provided.

(6) (iii) Provide an example of a typical design for an incineration system used to reduce gases or vapour emissions from an industrial facility. In your example, provide a simple schematic and explain three (3) key design principles and important operating conditions to maximize the performance efficiency.

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) Select one (1) measurement technique from the following and explain how it is used to measure the corresponding chemical: Ultraviolet fluorescence method used to measure SO_2; chemiluminescence analyzer for NO_x; radiometric method for particulate fractions up to PM_{10} or coulometric method to measure SO_2 and NO_2 concentrations.

(6) (ii) Explain which particle properties (e.g., cohesion, adhesion, particle surface resistivity, density or shape) help engineers to select cyclones, fabric filters and electrostatic precipitators. For each technology identify briefly explain the most important particulate characteristics that affects the emission from each control device.

(6) (iii) Explain two (2) key sources of PM2.5 in the environment, two (2) aesthetic effects and two (2) health effects all associated with PM2.5 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) Give two (2) major air toxics from mobile sources and explain the key principles in using two (2) different appropriate technologies that would be effective at reducing concentrations of these air toxics in the air shed.

(6) (ii) Describe one (1) appropriate odour technology that can be used to control industrial odorous emissions caused by hydrogen sulfide or VOCs. In your description explain the odour control mechanism involved and important issues of operation and maintenance to ensure the control equipment remains effective.

(6) (iii) Explain how emission trading of greenhouse gasses, between neighboring countries applied on a global scale, may or may not, effectively reduce or reverse the greenhouse effect. Choose a pro or con position and provide a well supported scientific argument in favor of your choice.

Problem 5

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) Consider the Pasquill-Gifford (PG) Stability Classification and describe what meteorological conditions occur during class A (extremely unstable) atmospheric conditions. Briefly explain how this conditions affects the stack plume behaviour and how it can be predicted.

(6) (ii) Describe how dispersion and deposition modelling of atmospheric pollutants are useful at predicting the fate of atmospheric pollutants. Briefly describe one (1) such model, provide two (2) key underlying assumptions and two (2) associated limitations of using such models in real applications.

(8) (iii) Given a factory emits 20 g/s of SO_2 at a height H with a wind speed (μ) of 5 m/s; at 1 km downstream σ_y and σ_z are 30 m and 20 m, respectively. Consider the Gaussian model (below) and calculate the SO_2 concentration at a point 60 m to the side and 20 m below the centerline of the plume.

$$C(x,y,z) = \frac{Q}{2\pi\mu\sigma_y\sigma_z} exp\left(-\frac{1}{2}\left[\frac{y^2}{\sigma_y^2} + \frac{(z-H)^2}{\sigma_z^2}\right]\right)$$

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) Determine the stoichiometric fuel/air mass ratio and product gas percent composition during the complete combustion of octane (C_8H_{18}) in air with octane containing 2% sulphur. Assume a 4:1 molar ratio of nitrogen (N_2) to oxygen (O_2) in the air. Make any reasonable assumptions necessary.

(6) (ii) Provide a simple schematic and briefly explain how a Flue gas desulfurisation (FGD) process works to effectively reduce sulfur emissions

(7) (iii) Explain two (2) key functions of nitrogen and hydrocarbon compounds (*two (2) key function for each type of compounds*) in the formation of photochemical smog.

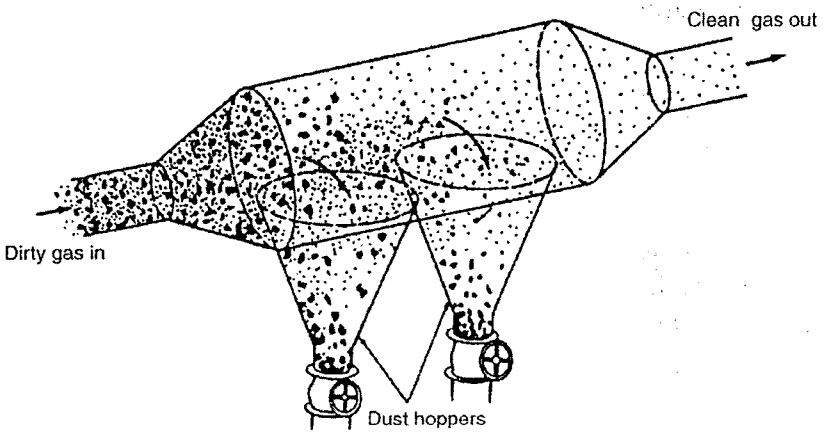
Problem 7

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*.

(7) (i) Briefly explain how SO_x pollutants are formed during the combustion of coal by a power plant. Provide an example of the use of a technology to reduce these gaseous atmospheric emissions during pre or post-combustion.

(6) (ii) From the list of five (5) monitoring systems explain how any two (2) of these technologies are applied to measure PM concentrations: (1) light scattering; (2) beta attenuation; (3) probe electrification; (4) light extinction and (5) optical scintillation.

(7) (iii) Briefly explain two (2) key design principles and two (2) important operational factors of gravity settlers (example below) that influence the removal efficiency of particulate emissions.



Marking Scheme

1. (i) 8 (ii) 6 (iii) 6 marks, 20 marks total

2. (i) 6 (ii) 8 (iii) 6 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) 6 (ii) 6 (iii) 8 marks, 20 marks total

6. (i) 7 (ii) 6 (iii) 7 marks, 20 marks total

7. (i) 7 (ii) 6 (iii) 7 marks, 20 marks total