NATIONAL EXAMS MAY 2016

04-Env-A5, Air Quality and Pollution Control Engineering

3 hours duration

NOTES

1. If doubt exists as to the interpretation of any questions, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is a Closed Book Exam

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) Describe two (2) different types of outdoor air pollutants, their source of origin, their potential health impacts and briefly explain engineering methods, one per pollutant, to reduce their potential health impacts.

(6) (ii) For a typical plant 2,200 MW which consumes approximately 21,000 US tons of coal per day calculate air required for combustion due to energy generation. State all assumptions.

(6) (iii) Describe two (2) different types of indoor air pollutants, their potential health impacts and briefly explain two (2) related health and two (2) related ecological impacts associated with each.

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.*

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

(8) (i) Consider the Gaussian Plume model (above) used to determine pollutant concentration.

a) simplify the equation to calculate maximum ground level pollutant concentration. Show all work and assumption(s).

b) explain significance of effective stack height, provide two (2) factors that contribute to it.

c) describe two (2) assumptions behind the Gaussian Plume model, provide examples.

d) a local industry emits air pollutants through a tall stack, describe what happens to the plume at a distance away from the facility at night time and how would it change by lunch time. Describe the atmospheric conditions in terms of solar insolation and Pasquill Stability Classes.

(6) (ii) chose two (2) distinct type of plume behavior and for each draw a simple diagram (i.e. side view), describe the behavior in terms of distance away from the stack and dispersion. Describe potential problems with the dispersion. Assume, for prevailing wind speed u>> 0 m/s.

Distinct type of plume behaviors: Fumigation, Trapping, Lofting, Fanning, Coning, Looping

(6) (iii) Describe how dispersion and deposition modelling of atmospheric pollutants is handled any two (2) of the following models: Lagrangian, Eulerian, Gaussian or Box diffusion model.

Problem 3

Provide answers to the following equations related to *measurement techniques of air pollutants, characteristics of various air pollutant particulates and health and aesthetic considerations of $PM_{2.5}$ and PM_{10}.*

(8) (i) A 75 m long kiln at a cement plant operates 24 hr per day, year around, and is fired with 20 tons/hr of petroleum coke. What type of kiln emissions would be expected to exhaust through a 100 m stack at 20 m/s and well above ambient temperature? A large baghouse and electrostatic precipitator are used to control the emissions of what contaminant(s)? Explain the significance of particle size distribution in predicting the environmental behavior and in devising engineering controls to minimize air particle emissions.

(6) (ii) Describe what technique(s) can be used to measure the air pollutants within the stack.

(6) (iii) Describe two (2) key differences in the health effects and aesthetics between the $PM_{2.5}$ and PM_{10} 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) Consider a heavy industrial urban area with access to water and rail to transport materials, a local airport and high local population. List at least three (3) mobile sources that emit air toxics that cause emissions of air pollutants.

(6) (ii) Describe the type of biotechnology that can be used for the control of emissions from food industry with a process that releases pet food like odour. List two (2) fundamental principles of the design.

(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 *behavior of gaseous pollutants (CO, SO_x, NO_x, etc) in the atmosphere and monitoring and control of particulate emissions.*

(8) (i) Using equation below, calculate the terminal settling velocity of a 30 μm diameter particle with a density of 4 g/cm^3 at 25 ^{0}C. Explain limitation of a control device that employs only gravitational settling to accomplish initial separation. Describe potential solution(s) to this limitation.

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

(6) (ii) List and briefly describe monitoring techniques of stack emissions, one for emissions of particulate and one for emissions of SO_x.

(6) (iii) The air dispersion models can simulate emissions as point, line, area or volume sources. Select only two (2) sources. For each briefly explain each modelling source and provide real life example where the dispersion can be applied.

Problem 6

Provide answers to the following questions related to *control of sulphur oxides and oxides of nitrogen, desulphurization and kinetics of NO_x formation and the role of nitrogen and hydrocarbons in photochemical reactions.*

(8) (i) Describe what is smog, when does it occur and what causes it. Explain the role of nitrogen and hydrocarbons in the formation of smog. Based on your explanation suggest an engineering approach to reduce smog in large urban areas.

(6) (ii) List and discuss two (2) strategies to reduce and/or control the emission of SO_x during combustion of fossil fuels.

(6) (iii) Provide a simple schematic and briefly describe how a commonly used Flue Gas Desulfurization plant works.

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.*

(8) (i) Explain two (2) design principles of an adsorption and absorption control equipment used to control gas or vapor emissions from an industrial process.

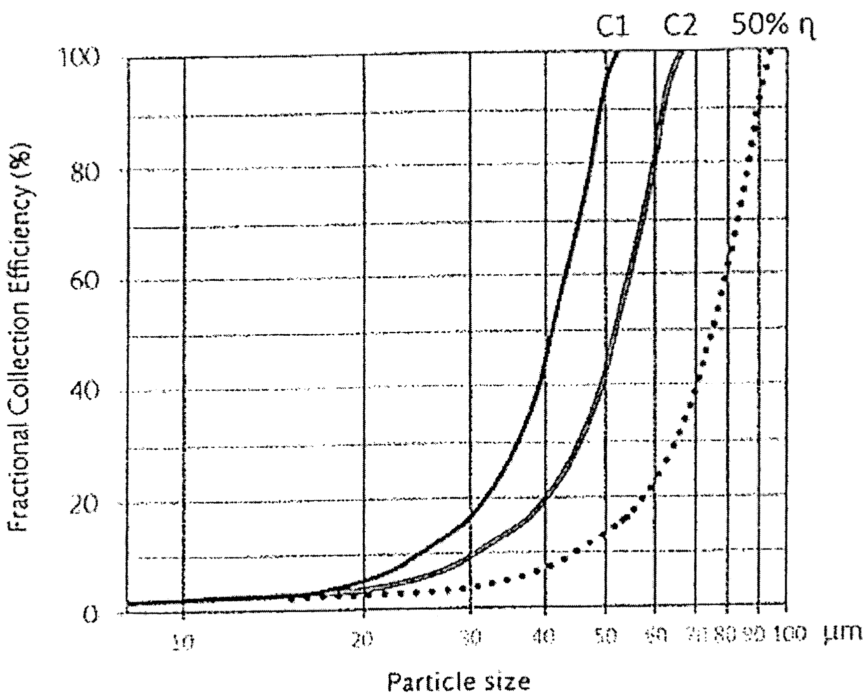
(6) (ii) A large diameter cyclone is being used for the removal of grain dust with particle diameters $(d_p) of\ 20, 40, 60\ and\ 80\ \mu m.$ What are the collection efficiencies of these particle seizes if the cyclone has an inlet width (B_c) of 0.5 m and an inlet gas velocity (v_i) of 30 m/s?

Given:

The particle density (ρ_p) is 1300 kg/m^3.

Assume that the following formula for $[d_p]_{cut}$ applies, μ_g= 1.9x10^{-5} kg/(m x s) and the figure below (use the 50 % efficiency curve) gives the cyclone removal efficiencies.

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



(6) (iii) Provide an example when an incineration system can be used to reduce gases or vapor emissions and provide why it would apply in that scenario. List two (2) key design principles and operating conditions to maximize the performance efficiency. List and describe what the incineration of waste materials results in.

Marking Scheme

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