NATIONAL EXAMS DECEMBER 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 an OPEN 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. Question 1 must be attempted and any other four (4) for a total of 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 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 how does the temperature and velocity impact the height of the plume.

(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) list and describe differences in how dispersion modelling of atmospheric pollutants is handled by Gaussian and Langrangian models.

Problem 2

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 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 4, 000 MW which consumes approximately 50,000 US tons of coal per day calculate air required for combustion due to energy generation. State all assumptions.

$$C + O_2 \text{ --> } CO_2$$

(8) (iii) Describe three (3) 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 3

Provide answers to the following quations 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}.*

(6) (i) consider a tall stack servicing coal fired kiln which emits particulates. Discuss what type of control(s) would apply on such a source, discuss and explain significance of particle size distribution.

(8) (ii) Describe three (3) measurement methods for particulate matter, for each briefly discuss merits and disadvantages.

(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) define air toxics? list three (3) air toxics and describe their sources.

(6) (ii) Describe the type of technology 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. Give examples.

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) exhaust gas leaves a lime kiln at 325 ^{0}F (162.8^{0}C) with volumetric flow rate of 50,000 SCFM (23.61m^3/s) and contains lime dust particles. The exit mass concentration (C_0) of dust measured to be 10 g/m^3 at STP. It is desired to remove 99% of the particles using a reverse-flow cleaning cycle of one per hour. Nomex bags 10 in. diameter and 15 ft long (39.09ft^2/bag) will be used. Estimate the number of bags that will be needed and the overall pressure drop across the bags.

Given: a typical gas-to-cloth ratio (u_0) of 0.7 m/min (0.01167 m/s) can be used and the dust cake constants can be assumed to be K_1=350 N min/m^3 and K_2 = 9x10^{4}s^{-1}. There are 0.0003391 ft H_2O in 1 Pa.

The maximum pressure drop across the bag is expected to be = $K_1 U_0 + K2\ c_0 U_0^2 t$

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

(6) (iii) select two gaseous pollutant (CO, SO_2, NOx) describe their behavior in the atmosphere.

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.*

(6) (i) What is smog? Describe how is it formed and from what? List sources which emit chemicals that cause smog.

(6) (ii) What is photochemical reaction? describe the roles of nitrogen and hydrocarbons in photochemical reactions.

(8) (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.*

(6) (i) select two (2) methods that can be applied to control emissions of gases and vapour;

(8) (ii) describe the following control mechanisms: adsorption, absorption, combustion and incineration. Provide example when the mechanisms would be applied.

(6) (iii) for any three (3) control mechanisms listed in (ii) list two (2) key design principles and operating conditions to maximize the performance efficiency.

Marking Scheme

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