NATIONAL EXAMS DECEMBER 2019

18-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 *sources and classification of atmospheric pollutants*, *indoor and outdoor air pollutants*, *health and ecological impacts*.

(6) (i) Describe two (2) types of sources for air contaminants and two (2) different classification schemes. Give four (4) different chemicals that may be classified under each category.

(7) (ii) Identify and describe one (1) indoor air pollutant, its potential health impacts and describe two (2) potential engineering strategies to reduce its health impacts.

(7) (iii) Consider the outdoor release of lead (*Pb*) due to highway traffic 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 *meteorology* as related to *influence of solar radiation and wind fields*, *lapse rate and stability conditions* and *characteristics of stack plumes*.

(7) (i) Briefly describe stable, extremely unstable and neutral conditions in terms of typical solar radiation and wind conditions. Briefly explain how each meteorological condition may affect the pollutant dispersion in a general way.

(7) (ii) Briefly describe the significance of lapse rate and stability when considering air masses and their impact on dispersion.

(6) (iii) Five classifications of plume behaviour, which may occur under some commonly encountered meteorological conditions, include coning, looping, fanning, fumigation and lofting. Briefly describe any two (2) and state under what specific conditions these occur.

Problem 3

Provide answers to the following questions related to *dispersion and deposition modelling of atmospheric pollutants*, *Eddy and Gaussian diffusion models*, *Puff models*, *effective stack heights* and *spatial concentration distributions*.

(7) (i) Describe three (3) key differences between a Gaussian or Eddy diffusion model compared to a Puff model when trying to predict the dispersion and deposition of atmospheric pollutants. Use figures and equations as necessary.

(7) (ii) Consider the Gaussian model (below) used to determine the maximum ground level pollutant concentration. Explain three (3) important assumptions or approximations of this model and one (1) associated engineering implication.

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

(6) (iii) Briefly explain what the effective stack height represents and give a typical formula for the effective stack height (ΔH). As part of your explanation describe how any two (2) variables may affect the predicted effective stack height.

Problem 4

Provide answers to the following questions related to *control of sulphur oxides and oxides of nitrogen*, *desulphurisation*, *kinetics of NO_x formation*, *air toxics and noxious pollutants*, *mobile sources of air pollutants* and *odour control*.

(7) (i) Identify and discuss three (3) important strategies to reduce and/or control the emission of oxides of nitrogen (NO_x) during the combustion of fossil fuels. Consider both pre and post-combustion measures.

(7) (ii) Flue gas desulphurisation (FGD) plants are necessary to fulfil regulations on sulfur emission reduction. Briefly describe three (3) key design or operational principles of how a commonly used FGD is used.

(6) (iii) Identify and explain three (3) fundamental principles of a biotechnology used for the control of odorous emissions from a food production plant or animal rendering plant (e.g., cattle rendering and packaging plant for lunch meats).

Problem 5

Provide answers to the following questions related to *measurement amd monitoring techniques* as related to *characteristics of various air pollutant and particulates, health and nuisance or aesthetic considerations, particulates ($PM_{2.5}$ and PM_{10}) and gaseous pollutants (CO, SO_x, NO_x, etc.) behaviour in the atmosphere.*

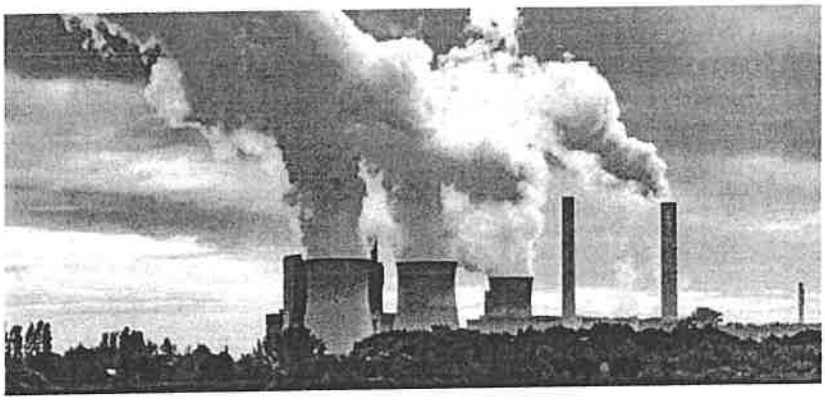
(5) (i) Explain the principle of gravimetric analysis or filter soiling method for determining ambient air particulates and provide an example of its use. Explain how instrument calibration may be performed and its importance.

(5) (ii) Explain two (2) key differences in the health effects and aesthetics between the $PM_{2.5}$ and PM_{10} categories of particulate pollutants. A total of four (4) differences are to be provided.

(5) (iii) Calculate the SO_2 concentration in flue gas when 10 moles of C_7H_{13} containing 2% sulphur is burnt in the presence of stoichiometric amount of oxygen. Briefly explain the formation of secondary air pollutants related to the combustion of fossil fuels.

(5) (iv) Calculate the terminal settling velocity of a 15 μm diameter particle with a density of 1500 kg/m^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). Make any appropriate assumptions about the air viscosity at 25 ^{o}C.

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



Problem 6

Provide answers to the following questions related to *control of particulates through collection mechanisms with consideration of efficiencies* and *emissions trading*.

(10) (i) A large diameter cyclone is being used for the removal of grain dust with particle diameters (d_{pj}) in the ranges of 1–10, 10–20, 20–50 and 50–100 μm with a corresponding % mass distribution (m/M) of 10, 30, 40 and 20%, respectively. What is the overall collection efficiency of a conventional type cyclone assuming that $d_{pc} = 6$ μm and the removal efficiency (η_j) of the particle ranges (d_{pj}) is given by the formula below. Justify any assumptions made.

$$\eta_j = \frac{1}{1 + \left(d_{pc}/d_{pj}\right)^2}$$

(10) (ii) Explain what emission trading is and how governments may use caps and carbon credits to promote reduced emissions and improve air quality. As part of your explanation include two (2) potential disadvantages in using emission trading compared to source controls.

Problem 7

Provide answers to the following questions related to *control of gases and vapours using technologies such as adsorption, absorption, combustion or incineration, photochemical reactions and the role of nitrogen and hydrocarbons in photochemical reactions*.

(6) (i) Explain two (2) important differences between adsorption and absorption control mechanisms used to control gas or vapour emissions from an industrial process.

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

(7) (iii) Explain how photochemical smog is formed with respect to the role of nitrogen and hydrocarbons. Provide equations and figures as necessary.

Marking Scheme

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

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

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

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

5. (i) 5 (ii) 5 (iii) 5 (iv) 5 marks, 20 marks total

6. (i) 10 (ii) 10 marks, 20 marks total

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