Indian Institute of Technology, Delhi
Centre for Energy Studies
2014-2015
ESL 710: Energy Ecology and Environment

Major Examinations
Duration: 120 minutes

Marks: 40
1 May 2015

Answer all questions. Section A is of 10 marks and Section B is of 30 marks. Any assumptions made are to be clearly defined or else marks will not be given.

Section A

1. a) A standard BOD test is run using seeded dilution water. In one bottle, waste sample is mixed with seeded dilution water giving a dilution of 1:30. Another bottle contains just seeded dilution water. Both bottles begin the test with DO at 9.2 mg/L. After 5d, the bottle containing waste has DO 2 mg/L while that containing seeded dilution water has DO 8 mg/L. Calculate 5d BOD of waste. If ultimate BOD of waste is 300 mg/L, find the reaction rate constant. [3]

   b) Incoming waste water with BOD_5 equal to 300 mg/L is treated in a secondary treatment plant which removes 79% BOD and in a primary treatment plant preceding removal is 35%. You are to do a BOD_5 test with a standard BOD bottle using a mixture of treated waste water and dilution water (no seed). Assuming initial DO as 9.2 mg/L

      i) What maximum volume of waste water should you put in the bottle if you want to have at least 2.5 mg/L of DO at the end of the test (filling the rest of bottle with water)?

      ii) If you make the mixture half water and half treated wastewater, what DO would you expect after 5 d? [3]

2. A receiving water body has 20 mg/L algae which are represented by the chemical formula $C_6H_{15}O_6N$, decomposition of which is represented by the following reaction.

$$C_6H_{15}O_6N + 6\,O_2 \rightarrow 6\,CO_2 + 6\,H_2O + NH_3$$

   i) Find CBOD, NBOD

   ii) What % algae removal would be needed for CBOD to become 15 mg/L. [4]

Section B

1. Write short note (one or two sentences only):
   a. What does a life table represent in population studies?
   b. What are pathogens?
   c. What names and their respective sizes are given to the mineral structure that defines the soil texture of a region?
   d. Define metabolic rate. How is it related to body mass? [5]

2. Fill in the blanks:
   a. Particles in a soil clustered together into clumps are called _____.
   b. The three layers in a thermocline formed in aquatic ecosystems are _____, _____ and _____ in order of increasing depth.
   c. The five broad groups under which an ecosystem governed by vegetation B is succeeded by one governed by vegetation A are _____, _____, _____, _____ and _____.
   d. Study of population dynamics is called _____. [5]

3. Considering that the major pollution in Delhi is caused by Particulate Matter (PM):
   a. What are the conventional classifications of PM?
   b. What are their respective implications in our ecosystem?
   c. Using a simplified analysis, estimate the settling velocity (v) of a spherical PM of density ρ and diameter d. One can consider air viscosity to be η.
   d. Find the settling velocity of a spherical droplet of water with diameter 2 μm, and estimate the residence time of such particles if they are uniformly distributed in the lower 1 km of the atmosphere and their removal rate is determined by how fast they settle in still air? [7]

4. Considering the variation of temperature of the troposphere:
   a. Derive the relation of the dry adiabatic lapse rate.
   b. When does the saturated adiabatic lapse rate occur?
   c. Are there any representative values for the two lapse rates mentioned above? If yes, state them. If not, explain why one cannot estimate it.
   d. State the conditions under which sub-adiabatic and super-adiabatic conditions occur.
   e. There are two adjacent smoke stacks. One is a short one and another is a tall one. The smaller stack shows a fanning loop whereas the taller one has a looping plume. Show the ambient atmospheric temperature profile existing in that region with respect to the dry adiabatic lapse rate. [7]

5.
   a. An unvented, portable, radiant heater, fuelled with kerosene is tested under controlled laboratory conditions. After running the heater for two hours in a test chamber with a 46 m^3 volume and an infiltration rate of 0.25 ach, the concentration of CO reaches 22.9 mg/m^3. If the air in the lab is initially clean, and the ambient CO level is negligible throughout the run, find the rate at which the heater emits CO (considering it to be a conservative pollutant). If the heater were to be used in a small room to heat 120 m^3 of space having 0.4 ach, predict the steady state concentration. Compare results with eight hour CO ambient standard of 9 ppm. Derive any relation used. Consider molecular weight of CO as 28 and 1 mole of gas occupying 24.465 lts at 1 atm and 25°C.
   b. Suppose the soil under a single story house emits 1 pCi/m2-s of radon (Ra) gas. As a worst case, assume that all of this gas finds its way through the floor and into the house. The house has 250 m^2 of floor space, an average ceiling height of 2.6 m and an air change rate of 0.9 ach Estimate the steady state concentration of Ra in the house, assuming the ambient concentration is negligible. The half-life of Ra is 3.8 days. [6]

Given the following constants:

Stefan-Boltzmann constant, $\sigma = 5.67 \times 10^{-4}$ $W/m^2\text{-}K^4$
Avagadro's number, $N_A = 0.6022 \times 10^{24}$ /mol
Boltzmann constant, $k_B = 1.38 \times 10^{-23}$ J/°K
Speed of light, $c = 3 \times 10^8$ m/s
Planck constant, $h = 6.6261 \times 10^{-34}$ J-s
$1\ m^3 = 10^3$ L
1 cal = 4.185 J
Air viscosity (η) = 0.0172 g/m-s
acceleration due to gravity (g) = $9.8 m/s^2$