Indian Institute of Technology, Delhi
Centre for Energy Studies

ESL 330: Energy, Ecology and Environment

Major Examination
Duration: 120 minutes

Marks: 50
18 Nov. 2017

Answer all questions

1. a) i. What is leaf area index?
   ii. Define net primary productivity.
   iii. Draw a mass balance diagram. [1+1+1]
   b) Write at least four pollutant emission factors from an IC engine other than the air to fuel ratio. [2]

2. a) Give a diagrammatical representation (Life cycle) for the following isolated population of the field grasshopper, using the following available information. In 2008 the population had 250 females and 280 males over an area of 1000 m^2. In a year this population reproduces 580 adults with an equal probability of males and females and has hatched out of 1825 pods containing a total of 20075 eggs. It is also known that the probabilities of survival to the subsequent Instar stages (I, II, III, IV) are 7.9%, 72%, 76%, and 76% respectively and the probability of survival of the parents are 0.1% of the male and 0.5% for the female. [3]
   b) An indoor "tractor pull" competition resulted in a CO concentration of 436 ppm. What percent COHb would result for a spectator who is exposed to one hour at the level? How long would it take to reach 10 percent COHb, which is a level at which most people will experience dizziness and headache? [3]
   c) What hydrocarbon, RH, reacting with the OH* radical in "RH + OH* → R* + H_2O", would produce formaldehyde, HCHO, in "RO* + O_2 → HO_2* + R' CHO". [2]
   d) Plants absorb 340000 kcal/m^2/yr sunlight incident on a community in the region. The absorbed light results in a net plant production of 8833 kcal/m^2/yr and evapotranspiration of 11977 kcal/m^2/yr. The herbivores consume 3368 kcal/m^2/yr of plant mass and additional intake of 536 kcal/m^2/yr from other sources respiring 1760 kcal/m^2/yr of it. 1478 kcal/m^2/yr die of natural causes with the remaining eaten up by the carnivores, provide a net production of 37 kcal/m^2/yr for this higher tropic level with respiration of the former level amounting to 216 kcal/m^2/yr. Estimate the trophic efficiencies for the producers, primary and secondary consumers of this food chain. [2]

3. a) Define air exchange rate per hour (or ach) of a building. Discuss wind-driven and stack-driven infiltration, and how these affect radon pollution inside a building. [1+3]
   b) Considering a simple, one box building model and ignoring any mechanical infiltration show that the general solution for the pollutant concentration inside can be derived as,

$$C(t) = \left[\frac{S/V + C_o n}{n + K}\right]\left[1 - e^{-(n+K)t}\right] + C(0)e^{-(n+K)t}$$

   $C(0)$ = Initial pollutant concentration of the building, S = Source emission rate, n = number of air changes per hour, C_o = Ambient concentration, K = Pollutant decay rate, V = Volume of conditioned space in the building.
   Plot the above equation ($C(t)$ *vs* t) under the conditions that there is no ambient pollutant concentration, no initial concentration and the pollutant is conservative. [3+1]
   c) In a 300 m^3 home the only source of CO is the gas range and the ambient CO concentration is always zero. Suppose there is no CO in the home at 6 PM, but then an oven and two burners are on for one hour. Assume that the air is well mixed in the house; estimate the CO concentration in the

home at 7 PM and again at 10 PM. Given the CO emission rate for gas range, Oven: 1900 mg/hr, One burner: 1840 mg/hr. [2]

4. a) Distinguish between the carbonaceous oxygen demand (CBOD) and the nitrogenous oxygen demand (NBOD). Why the standard five day BOD test is not affected by nitrification? [3]
b) A BOD test is to be run on a sample of wastewater that has a five day BOD of 230 mg/L. If the initial DO of a mix of distilled water and wastewater is 8.0 mg/L, and the test requires a decrease in DO of at least 2.0 mg/L with at least 2.0 mg/L of DO remaining at the end of the five days, what range of dilution factors (P) would produce acceptable results? In 300 mL bottles, what range of wastewater volumes could be used? [2]
c) Derive the Streeter-Phelps oxygen sag equation to find out the dissolve oxygen deficit (D) at a downstream distance x measured from a point source where wastewater is instantaneously mixed with river water that is flowing with uniform speed u. Assume waste and water is uniformly mixed and no dispersion along the flow. Given D_0 is the initial deficit, L_0 is the ultimate BOD of the mixture of stream-water and wastewater, k_d is deoxygenation rate constant and k_r is reaeration rate constant. Derive the solution again for a special case where $k_r = k_d$. [3+2]

5. a) Discuss how thermal stratification can lead the hypolimnion of a eutrophic lake to become anaerobic during summer. [2]
b) Define hydraulic gradient of an unconfined aquifer with necessary diagram.
Three monitoring wells, each located at the vertex of an equilateral triangle. The distance between any pair of wells is 300 m. The head at each well, referenced to some common datum, is as follows: well 1, 100 m; well 2, 100.3 m; well 3, 100.3 m. Sketch the well field and find the magnitude and direction of the hydraulic gradient. [1+2]
c) Use Darcy's law to derive an equation which can estimate the height of water table h at a radial distance r from the centre of a pumping well in an unconfined aquifer. Consider the pumping rate constant and pumping has been steady for a long enough time that equilibrium condition is reached.
A fully penetrating well of 0.30 m diameter, has been pumping at the rate of 6000 m^3/day for a long enough time that steady state condition have been reached. An observation well located 30 m from the pumped well has been drawn down by 1.0 m and another well at 100 m is drawn down by 0.50 m. The aquifer is unconfined and 30.0 m thick.
i. Determine the hydraulic conductivity K.
ii. Estimate the drawdown at the well.
iii. The slope of the water table at the well boundary. [2+3]

6. Write the most appropriate answer.
a) The value of dry adiabatic lapse rate is (i) 1^0C/ km (ii) 10^0C/ km (iii) 10^0C/ m.
b) If the ambient temperature cools more rapidly with altitude than the dry adiabatic lapse rate, the atmosphere is said to be (i) stable (ii) unstable (iii) neutrally stable.
c) Radiation temperature inversion builds up as the morning sun rises and breaks up as the evening progresses. The statement is (i) true or (ii) false.
d) In a sedimentation basin or clarifier for a particle to reach the basin floor, its settling velocity (i) must be equal to or greater than the critical settling velocity, (ii) must be equal to or lower than the critical settling velocity, (iii) must be exactly equal to the critical settling velocity.
e) Flocculation is a (i) physical process (ii) chemical process (iii) bio-chemical process. [5]

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