NATIONAL EXAMS MAY 2010

04-Env-A1, Principles of Environmental 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 *8.5in x 11in* double sided Aid-Sheet allowed.

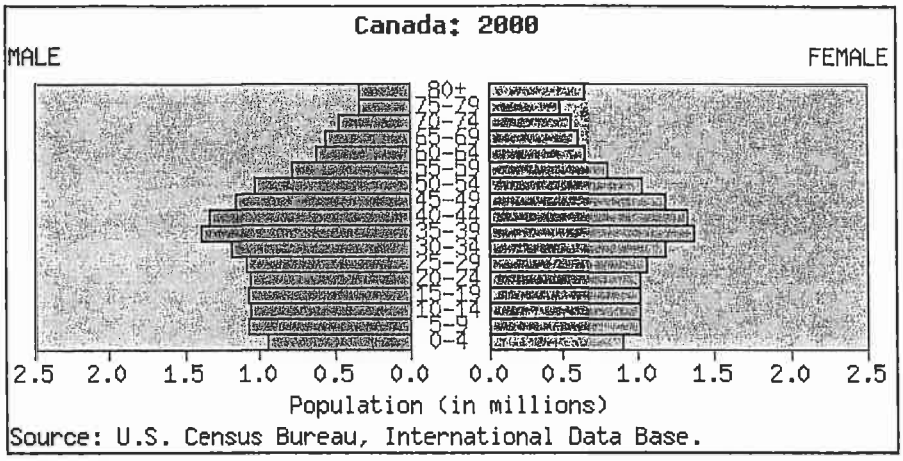
3. Candidates may use one of two calculators, the Casio or Sharp approved models. Write the name and model designation of the calculator, on the first inside left hand sheet, of the exam work book.

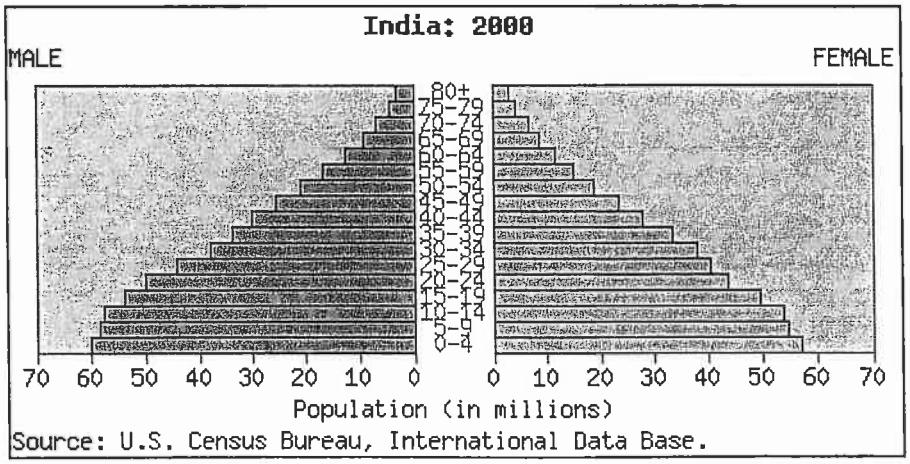
4. Any five questions constitute a complete paper. Only the first five answers, to the seven questions, as they appear in your answer book(s) will be marked.

5. Each question is worth a total of 20 marks with the section marks indicated in square brackets [ ] at the end 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.

1. Provide answers to the following questions related to population, economic growth, industrialization, urbanization and energy use as causes of environmental pollution:

   i) Briefly compare the population pyramids of Canada and India given below. In your comparison explain two (2) environmental implications, for Canada and India, over the next 25 years based on the population pyramids of the year 2000. Assume that the population of Canada was the same as India for your comparison. [7]





   ii) Provincial/territorial air toxics programs are designed to address threats to public health and the environment from toxic air pollutants, primarily from industrialization and urbanization. Briefly describe two (2) different types of industrial air toxics, an effect to the natural environment from each toxic and a possible engineering solution to reduce or eliminate the impacts of each. [7]

   iii) Energy demand is distributed amongst four broad sectors: transportation, residential, commercial, and industrial. In terms of oil use, transportation is the largest sector and the one that has seen the largest growth in demand in recent decades. Identify two (2) specific environmental impacts of increased per capita energy utilization. For each impact provide a well established technology that may be used to minimize the impact and explain the key engineering principle of each technology. [6]

2. Provide answers to the following questions related to material and energy balance for engineering systems under steady state and unsteady state conditions.

   i) A power plant, with an output of 10,000 MW, converts fuel energy into electrical energy with an efficiency of only 25 percent. The other part of the energy content of the fuel is rejected to the environment as waste heat. About 25 percent of the waste heat goes up the smokestack and the rest is taken away by cooling water that is drawn from a nearby river with a flow of 100 m^3/s and a temperature of 10 °C. Estimate the elevated temperature of the stream just downstream from the cooling water discharge point. Assume that the specific heat of water as 4000 J/(kg · °C). **[8]**

   ii) Consider the carbonate system in a fresh water lake including the air-water-limestone interphase. Briefly describe the response of the lake to an acid spill in the lake and how the carbonate system works to buffer the pH change. In your description consider using relevant equations and schematics. **[6]**

   iii) Briefly describe the following transport mechanisms and provide one example where each transport mechanism can be used to explain an environmental phenomenon:

      a) Diffusion in 1-dimension of an instantaneous point release **[3]**
      b) Advection in 2-dimensions of an instantaneous point release **[3]**

3. Provide answers to the following questions related to the application of technical and non-technical environmental principles of solid waste management, environmental impact assessment and environmental ethics:

   i) Briefly describe four (4) solid waste management (SWM) practices normally adopted in industrialised countries as part of a SWM hierarchy. In your description prioritize each practice from the most to the least environmentally significant (in terms of benefits or impacts) practice. **[10]**

   ii) An environmental impact assessment (EIA) is important to identify the critical environmental issues during the construction of a new sewage treatment plant, water treatment plant or landfill site to serve a regional municipality. Briefly describe four (4) steps you would take as an engineer having been asked to conduct an EIA for any one of the above facilities. In your description identify a situation where environmental ethics would play an important role during the EIA. **[10]**

4. Provide an answer to the following questions related to air toxics, sustainable development, life cycle analysis, principles of environmental quality objectives, standards and guidelines:

   For each set of terms use one (1) example to briefly explain the use of the terms as applied to solving environmental engineering problems. *Note that it may be convenient to use a table to answer these questions.*

   i) Air toxic pollutants and ambient concentration benchmarks **[7]**

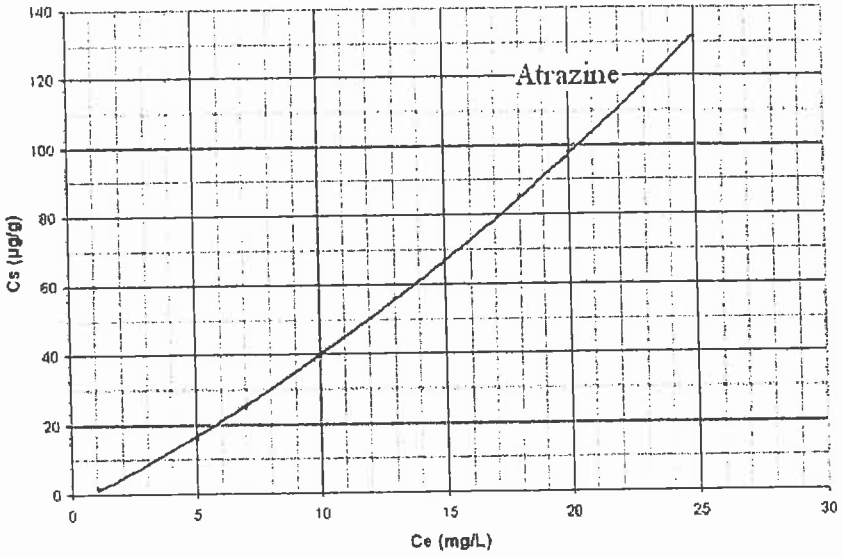
   ii) Sustainable development and life cycle analysis **[7]**

   iii) Drinking water quality standards and water treatment plants design guidelines **[6]**

5. Provide answers to the following questions related to contaminant partitioning in water with solids, chemistry of species in equilibrium and reactor material balances:

i) The mobility and fate of organic chemicals in the soil-water environment are directly related to their equilibrium partitioning coefficient (K_d) at which can be defined by the equation below. From the plot of the equilibrium partitioning of Atrazine in a soil-water mixture and equation provided below, estimate the K_d and n value. **[6]**

$$K_d = \frac{C_S}{C_e^{1/n}}$$



ii) A steady-state equilibrium exists between ammonia and ammonium in a sewage polishing lagoon at 25°C and a pH of 9. Given the total ammonia-nitrogen (TAN) concentration is 20 mg/L, calculate the percentage of ammonia-nitrogen (NH_3-N) and ammonium-nitrogen (NH_4^+-N) present in the lagoon. Assume the equilibrium ionization constant is 2×10^{-5} at 25 °C. **[6]**

iii) The water contaminant hydrogen sulphide (H_2S) undergoes first-order decay with rate constant k.

a) Calculate the mean residence time (as a function of k) in a completely mixed flow reactor (CMFR) to achieve a 99% removal (i.e., $C_{out}/C_{in} = 0.01$, where C_{out} is the steady-state outlet concentration for a constant inlet concentration C_{in}). **[4]**

b) If the single reactor is replaced with two (2) CMFRs of the same total volume in series, what is the total mean residence time (as a function of k) required to achieve the same 99% removal? **[4]**

6. Provide answers to the following questions related to disinfection reaction kinetics, environmental ecology and water or wastewater treatment principles:

i) In answering questions (a) and (b), consider Chick's and Watson Law expressions:

Chick's Law: $\frac{N(t_c)}{N(0)} = e^{-k \cdot t_c}$

Watson Law: $C \cdot t_c = \alpha$

where $N(t_c)$ = number of viable organism remaining after time t_c
$N(0)$ = number of viable organism initially present
k = the reaction rate constant (min^{-1})
C = disinfectant concentration (mg/L)
α = constant for a given disinfection objective (min·mg/L)

a) It was shown that 90 % of the Norwalk virus was inactivated using a $C \cdot t_c$ value of 50 min·mg/L. Determine the reaction rate constant k, corresponding to a free chlorine concentration of 1 mg/L. **[3]**

b) Approximately what percentage of Norwalk virus organisms would be inactivated at a free chlorine concentration of 2 mg/L and a contact time of 15 minutes? **[5]**

ii) A basic phenomenon of environmental ecology is the conservation or cycling of carbon through plants, organisms and environmental systems. Briefly describe the main components of the Carbon Cycle and its role in sustaining life. In your description, include two (2) important carbon species and two (2) important carbon sinks that support life on earth. **[6]**

iii) Select a typical water treatment plant or wastewater treatment plant and briefly explain the key function associated with the following: (1) coagulation and flocculation, (2) disinfection, and (3) filtration. In your explanation you may use diagrams, equations or narrative. **[6]**

7. Provide answers to the following questions related thermal pollution, noise pollution, greenhouse gas effects and acid precipitation:

i) Briefly describe two (2) potential adverse impacts and two (2) corresponding remedial solutions to alleviate the thermal impacts on biological fresh water systems. **[5]**

ii) Briefly describe two (2) noise reduction strategies useful to ensure the necessary decibel reductions within a typical residential neighbourhood from an airport. **[5]**

iii) Briefly describe how global warming may be impacted by the reduction in the emission of greenhouse gasses. In your description, provide two (2) engineering measures that may be used to reduce emissions giving an advantage and a disadvantage of each engineering measure. **[5]**

iv) Briefly provide two (2) engineering solutions to reduce the production of acid precipitation from the burning of fossil fuels containing sulphur and nitrogen compounds. In your explanation give an advantage and a disadvantage of each engineering solution. **[5]**