NATIONAL EXAMS

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.

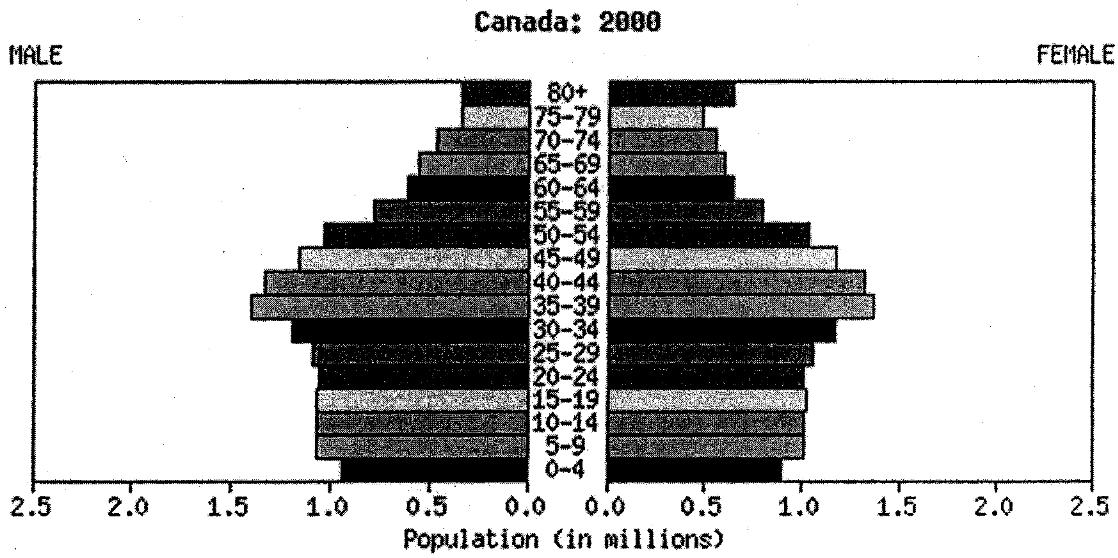
5. Each question is worth a total of 20 marks with the section marks indicated in square brackets [ ] at the end of the question. The complete Marking Scheme is also provided on the final page. A completed exam consists of five (5) answered questions with a possible maximum score of 100 marks.

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

   i) Briefly describe two (2) different types of pollutants, caused by industrialization, an effect to the natural air environment from each type of toxic emission (i.e., emissions to the airshed or watershed) and a possible engineering solution ('hard' or 'soft' engineering solution) to minimize the impacts of each type of pollutant. [7]

   ii) Identify two (2) specific environmental water impacts (i.e., surface water or ground-water) caused by increased energy use. For each impact, provide a well-established general technology that may be used to minimize the impact and explain the key engineering principle of each technology. [6]

   iii) Canada in 2000 showed the following population pyramid (below). Briefly explain the important characteristic of this type of population distribution and two (2) main factors that will contribute to environmental pollution over the next 25-years. Provide two (2) engineering measures, related to energy use that may be implemented over the next 25-years to ensure energy sustainability for Canada. **Note** that although Canada has a large land mass the core of the population is concentrated in large cities near large water bodies and a large part of our energy resources are in high demand all over the world. [7]



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 steel manufacturing plant uses a dedicated coal burning power plant that produces 10,000 MW of electrical power with an efficiency of 35 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. Use the specific heat of water as 5000 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 ($pH < 2$) in the lake and how the carbonate system works to buffer the pH change. In your description, consider using appropriate equations and schematics. **[6]**

   iii) Consider unsteady and non-uniform water flow in a conduit or channel where flow or depth varies with both time and location. Explain what engineering principles, methods and/or equations you would use to predict the future performance of this system given knowledge of the complete current state of the system (e.g., time, position, velocity and channel/conduit conditions). **[6]**

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 explain the major benefits and challenges associated with incineration over landfilling of residuals associated with the solid waste management (SWM) practices. Residuals are materials left over after reusing, recycling and reducing measures are exhausted. **Note** that these residuals need to be handled in an environmentally responsible manner and in a sustainable approach. **[10]**

   ii) An environmental impact assessment (EIA) is important to identify the critical environmental issues during the construction of a new power plant located on the shore of a large lake near a heavily populated municipality. Briefly describe four (4) steps you would take as an engineer having been asked to conduct an EIA for the above facility. In your description, identify a situation where environmental ethics would play an important role during the EIA. **[10]**

4. Assume that you are the consulting engineer hired by the owners to help them resolve issues related to the scenarios described in (i) to (iii). For each scenario, provide good engineering advice to the owners, based on your understanding of air toxics, sustainable development, life cycle analysis, principles of environmental quality objectives, standards and guidelines:

   i) Particulates (e.g., PM10) are being discharged due to a high rate of industrial production and the need to meet strict ambient air standards imposed by the environmental regulators. **[7]**

   ii) Mining of industrial metals (e.g., copper, iron) to meet a high industrial demand while ensuring a sustainable development for future generations. **[7]**

   iii) Implementing the principles of life cycle analysis to ensure a generic pharmaceutical production plant remains profitable and environmentally "green". **[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 (*S*)-water (*W*) environment are directly related to their equilibrium partitioning coefficient (K_d) which is often estimated by the following equation. Explain the meaning and significance of the three (3) terms in the equation below: **[6]**

$$K_d = \alpha \cdot f_{OC} \cdot K_{OW}$$

   ii) A steady-state equilibrium exists between ammonia and ammonium in a sewage polishing lagoon at 25°C and a pH of 9. Given that 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 that the equilibrium ionization constant is 2×10^{-5} at 25 °C. **[6]**

   iii) The water contaminant nitrite (NO_2^-) 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 four (4) 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 99 % of the *Escherichia coli* was inactivated using a $C \cdot t_c$ value of 30 min·mg/L. Determine the reaction rate constant *k*, corresponding to a free chlorine concentration of 3 mg/L. **[3]**

   b) Approximately what percentage of *Escherichia coli* organisms would be inactivated at a free chlorine concentration of 0.5 mg/L and a contact time of 50 minutes? **[5]**

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

   iii) Consider a water treatment plant or wastewater treatment plant and briefly explain the key function associated with the following: (1) primary sedimentation, (2) pH control, 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) remedial engineering solutions to alleviate the thermal impacts from effluent being discharged from a cooling tower of a power plant to a cold water fishery stream. **[5]**

   ii) Briefly describe two (2) noise reduction strategies useful to ensure that the necessary decibel reductions within a typical residential neighbourhood located within 50m from an adjacent busy 5-lane highway. **[5]**

   iii) Briefly explain how global warming may be caused by greenhouse gas emissions and give one (1) engineering technology that may be used to reduce emissions and explain what system you would put in place to measure the effectiveness of your solution. **[5]**

   iv) Briefly explain how acid precipitation is formed from the burning of fossil fuels and provide one (1) engineering solution to reduce the formation of acid rain. **[5]**

Marking Scheme

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May, 2013

1. (i) 7 (ii) 6 (iii) 7 marks; 20 marks total
2. (i) 8 (ii) 6 (iii) 6 marks; 20 marks total
3. (i) 10 (ii) 10 marks; 20 marks total
4. (i) 7 (ii) 7 (iii) 6 marks; 20 marks total
5. (i) 6 (ii) 6 (iii) a) 4 b) 4 marks; 20 marks total
6. (i) a) 3 b) 5 (ii) 6 (iii) 6 marks; 20 marks total
7. (i) 5 (ii) 5 (iii) 5 (iv) 5 marks; 20 marks total