

NATIONAL EXAMS

May 2015

**11-CS-3, Sustainability, Engineering and the Environment**

3 hours duration

NOTES:

1. If a 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. An approved calculator is permitted. This is a closed book exam. Write the name and model designation of the calculator, on the first inside left hand sheet of the exam book.
3. Any four (4) questions constitute an exam paper. Only the first four questions as they appear in your answer book will be marked.

*Marking Scheme*

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|-------------------|--|
| 1. 25 marks total | (a) 7 marks<br>(b) 5 marks<br>(c) 4 mark<br>(d) 4 marks<br>(e) 5 marks                 |
| 2. 25 marks total | (a) 3 marks<br>(b) 3 marks<br>(c) 4 mark<br>(d) 2 marks<br>(e) 8 marks<br>(f) 5 marks  |
| 3. 25 marks total | one question   |
| 4. 25 marks total | (a) 4 marks<br>(b) 4 marks<br>(c) 4 marks<br>(d) 4 marks<br>(e) 4 marks<br>(f) 5 marks |
| 5. 25 marks total | (a) 5 marks<br>(b) 7 marks<br>(c) 3 marks<br>(d) 5 marks<br>(e) 5 marks                |

Question (1) – 25 marks

- a. List the main reactants and products of the following three processes: nitrogen fixation, nitrification, and denitrification. Estimate (to the nearest integer) the ratio of nitrogen fixation by humans to that performed by nature. (7 marks)
- b. Explain how  $\text{NO}_{(g)}$  is involved in the formation of ground-level ozone, using chemical equations in your answer. Why is ground-level ozone a pollutant, whereas stratospheric ozone beneficial? (5 marks)
- c. Describe the main mechanism of the global warming theory and the involvement of greenhouse gases. Be specific about the types of radiation involved (e.g. ultra-violet, visible, infrared). (4 marks)
- d. Describe the difference between climate change *mitigation* and climate change *adaptation*. Give an example of a strategy/technology for each. (4 marks)
- e. What is meant by  $\text{CO}_2$  equivalents ( $\text{CO}_2\text{e}$ )? Rank the following gases in terms of their  $\text{CO}_2$  equivalency:  $\text{CO}_2$ ,  $\text{N}_2\text{O}$ ,  $\text{SF}_6$ , and  $\text{CH}_4$ . Which of these gases currently results in the most  $\text{CO}_2\text{e}$  added to the atmosphere as a result of human activity? (5 marks)

Question (2) – 25 marks

- a. One of the 12 Principles of Green Engineering\* is *Multi-component products should strive for material unification to promote disassembly and value retention*. Give a specific example of how this principle can be used to prevent pollution. (3 marks)
- b. One of the 12 Principles of Green Engineering\* is *Targeted durability, not immortality should be a design goal*. Give a specific example of how this principle can be used to prevent pollution. (3 marks)

\*Anastas, P. and Zimmerman, J. (2003) Design Through the 12 Principles of Green Engineering. *Env. Sci. Tech.* March 1, p. 94-101.

- c. Write the IPAT equation for environmental Impact, and define the terms. (4 marks)
- d. Describe the difference between *recycling* and *reuse*. (2 marks)
- e. Assume that you are conducting a life-cycle-assessment on the use of disposable diapers versus washable cloth diapers for a baby. (8 marks)
  - i. What would be a good functional unit for the LCA?
  - ii. List the stages of the diaper life-cycle to be considered.
  - iii. Considering each *stage* listed in (ii), compare the two alternatives: decide which of the two alternatives would have the greatest environmental impact and describe why.

iv. In what stage of the LCA would you expect to find the greatest environmental impact for the disposable diapers, and for the cloth diapers?

f. Define any five of the following terms: (5 marks)

- design for disassembly
- emissions trading
- industrial ecology
- reverse manufacturing
- pollution prevention
- e-waste
- natural capital
- externalities
- intangibles

**Question (3) – 25 marks**

Compare the environmental impacts of installing and operating the following renewable energy technologies:

- hydroelectric (high head systems)
- geothermal (to produce electricity)
- solar photovoltaic
- wind turbines (to produce electricity)
- biofuel (wood chips/pellets) for building heat

by creating a table to summarize your analysis. Use the following five headings in your table: geographic availability, land requirement, life-cycle emissions, cost, and safety concerns. Use H, M, L (high, medium, low) ratings for each cell of the table *and provide a few words of explanation for each.*

**Question (4) – 25 marks**

a. Define any four (4) of the following terms: (4 marks)

- turbidity
- BOD
- watershed
- embodied water
- water footprint
- hydrologic cycle

b. Describe what happens in the coagulation/flocculation and sedimentation processes used to treat drinking water? Why are these processes important in improving the microbiological quality of water? (4 marks)

- c. When raw sewage is discharged into a lake or river, the fecal bacteria numbers decrease by exponential decay. How many days would it take for a viable bacteria concentration of  $4 \times 10^7$  cell/mL to be reduced to 10 cell/mL, if the decay coefficient is 2.5/day? Show your calculations. (4 marks)
- d. List two (2) common methods to disinfect drinking water and write an advantage and disadvantage for each. (4 marks)
- e. Define any four (4) of the following terms: (4 marks)
- water table
  - aquitard
  - aquifer
  - vadose zone
  - potentiometer
  - Darcy's Law
- f. Calculate the future water demand, in ML/day, for a town of 5,000 inhabitants at the end of a 30-year design span. The town population is expected to grow exponentially, at a growth rate of 1.2 %/year, whereas the water demand is expected to grow linearly at 0.6 %/year from the current level of 340 L/person/day. (5 marks)

**Question (5) – 25 marks**

- a. Compare the health risk in living 1 km downwind of a coal-fired power plant versus living on the shore of a river less than 1 km downstream of a large hydroelectric power plant. In each situation, rate (high/medium/low) the relative magnitude of the two risk factors: consequence and likelihood. How is a value for risk evaluated? (5 marks)
- b. The following article was taken from the Ontario Ministry of Labour website. Suggest three actions that could have been taken to prevent this tragedy, consisting of a way to control the hazard at the source, a method to control the exposure 'along the path', and finally, a way to control the exposure at the worker(s). State which action that you think would be best, and why. (7 marks)

**Prokleen Washing Services (Oakville) Inc. fined \$60,000 for health and safety violation**

BURLINGTON, ON, June 7 /CNW/ - Prokleen Washing Services (Oakville) Inc., an Aurora, Ont.-based cleaning company which owns and operates an industrial establishment in Oakville that specializes in the cleaning of tanker trucks, was fined \$60,000 on June 6, 2006 for a violation of the Occupational Health and Safety Act that resulted in chemical burns to two employees.

On May 16, 2005, two workers were on the outside of a tank cleaning the inside when one of the workers decided to enter the tank to clean some dirty spots. The worker climbed inside and proceeded to use a chemical cleaner without putting on any protective equipment such as

respiratory equipment, coveralls, gloves, safety glasses, hardhat, five-point harness and lifeline. All of this equipment was available for the worker's use at the workplace. The cleaner emitted strong fumes and the worker inside the tank soon became disoriented and fell down unconscious in the tank, knocking over the pail of cleaner. When yells from the second worker, who was outside, failed to awaken the first worker, who was inside, the second worker called out "man down" and entered the tank. The second worker wore no respiratory equipment, but tried to refrain from breathing while attempting to get the first worker into a five-point harness for extrication from the tank. The second worker then fell unconscious too.

Other workers managed to remove the second worker who suffered chemical burns to the face, right arm and buttock, abdomen and chest. Firefighters extricated the first worker who received chemical burns to the legs, buttocks and back. The incident occurred at the company's tanker truck cleaning facility at 2378 Royal Windsor Drive in Oakville.

- c. Explain the statement "exposure to a single molecule of a carcinogen will result in a risk of cancer". What is meant by a "threshold" dose for non-carcinogens? (3 marks)
- d. What is the *cancer* risk for a 50 kg woman who drinks 2.0 L/day of water containing 0.5 µg/L (micrograms per litre) of arsenic, 350 days/year for 15 years? The slope factor for arsenic is  $1.5 \text{ (mg/kg-d)}^{-1}$ . Is this considered a safe exposure in terms of cancer risk? (5 marks)
- e. Arsenic also has non-carcinogenic effects (nerve damage). What is the *hazard quotient* for the woman exposed as described in part d., if the reference dose is  $3.0 \times 10^{-4} \text{ mg/kg-d}$ ? Is this considered a safe exposure in terms of non-carcinogenic effects? (5 marks)