NATIONAL EXAMS

December 2014

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

1.	25 marks total	(a) 3 marks
		(b) 2 marks
		(c) 5 mark
		(d) 4 marks
		(e) 4 marks
		(f) 4 marks
		(g) 3 marks
2.	25 marks total	(a) 3 marks
		(b) 3 marks
		(c) 3 mark
		(d) 2 marks
		(e) 8 marks
		(f) 6 marks
3.	25 marks total	one question
4.	25 marks total	(a) 6 marks
		(b) 7 marks
		(c) 4 marks
		(d) 5 marks
		(e) 3 marks
5.	25 marks total	(a) 5 marks
		(b) 8 marks
		(c) 2 marks
		(d) 5 marks
		(e) 5 marks

Question (1) – 25 marks

a. List the main reactants and products of the following three processes: nitrogen fixation, nitrification, and denitrification. **(3 marks)**

b. Define eutrophication. **(2 marks)**

c. What is the major anthropogenic source of $NO_{(g)}$? Explain how NO 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)**

d. What is another secondary pollutant (aside from O_3) associated with oxides of nitrogen? Write a sentence or two of explanation to show how this problem is caused by NO. **(4 marks)**

e. 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)**

f. Describe the difference between climate change *mitigation* and climate change *adaptation*. Give an example of a strategy/technology for each. **(4 marks)**

g. What is meant by CO_2 equivalents (CO_2e)? Rank the following gases in terms of their CO_2 equivalency: CO_2, N_2O, SF_6, CH_4, and hydrofluorocarbons (HFCs). Which of these gases currently results in the most CO_2e added to the atmosphere as a result of human activity? **(3 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 *Performance metrics should include designing for performance in commercial "afterlife".* Give a specific example of how this principle can be used to prevent pollution. **(3 marks)**

c. 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.

d. Define the terms in the IPAT equation for environmental impact. **(2 marks)**

e. Assume that you are conducting a life-cycle-assessment on the use of single use zinc-alkaline batteries versus rechargeable nickel-metal hydride batteries for a camera manufacturing company. **(8 marks)**

   i. What would be a good functional unit for the LCA?
   ii. List the stages of the life-cycle to be considered.
   iii. For each stage, 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 each alternative?

f. Define any four of the following terms: **(6 marks)**
   - design for disassembly
   - industrial ecology
   - reverse manufacturing
   - pollution prevention
   - intrinsic hazard
   - intangibles

Question (3) – 25 marks

Compare the following types of renewable energy technologies:
- hydroelectric (high head systems)
- geothermal for electricity
- solar photovoltaic
- wind turbines for 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, emissions, cost, and safety concerns. Use 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 of the following terms: **(6 marks)**

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

b. Draw a flow diagram to show the sequence of processes in a typical drinking water treatment plant that treats surface water. Label each process and describe which pollutant(s) it removes. **(7 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 $2x10^7$ cell/mL to be reduced to 10 cell/mL, if the decay coefficient is 2.3/day? Show your calculations. **(4 marks)**

d. Calculate the future water demand, in ML/day, for a town of 5,000 inhabitants at the end of a 20-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 350 L/person/day. **(5 marks)**

e. Of the three categories of water use by humans: industry, drinking and irrigation, which one results in the greatest worldwide water use? Describe two technologies that would reduce water use. **(3 marks)**

Question (5) – 25 marks

a. Compare the health risk in living downwind of a coal-fired power plant versus a nuclear 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. Describe two ways to limit or eliminate the *hazard* in this situation and two ways to reduce the *exposure*. **(8 marks)**

A 43-year old, self-employed male sandblaster died of carbon monoxide poisoning at his outdoor work station.

The victim was working alone and wearing personal protective equipment that included a NIOSH-approved Type CE sandblasting helmet. The helmet was supplied with breathing air by a manifold from a diesel-powered, oil-lubricated rotary screw compressor. This compressor also provided the sandblasting air. The equipment was old (circa 1970) and in very poor condition. Between the manifold and helmet were an in-line lubricator, a polycarbonate particulate filter, and a freestanding carbon filter.

Testing of the breathing air produced from this system showed that it contained in excess of 960 ppm of carbon monoxide. The CSA standard Z180.1-M85 "Compressed Breathing Air" recommends a maximum concentration of 5 ppm carbon monoxide. Also present were more than 3900 ppm of carbon dioxide, 55.5 ppm of methane, various hydrocarbons, and an unacceptable odour. The recommended maximum levels of carbon dioxide and methane are 500 ppm and 25 ppm, respectively. The oxygen content of the sample was deficient as well.

There are two potential sources of carbon monoxide in breathing air from this type of system.
1. Oil lubricants in air compressors may break down at high temperatures and produce dangerous carbon monoxide levels.
2. The compressor intake may draw air that is contaminated by exhaust emissions from the diesel engine or another nearby source.

c. Explain the statement "exposure to a single molecule of a carcinogen will result in a risk of cancer". **(2 marks)**

d. What is the cancer risk for a 70 kg man who drinks 2.0 L/day of water containing 0.5 μg/L (micrograms per litre) of arsenic, 350 days/year for 30 years? The slope factor for arsenic is 1.5 $(mg/kg\text{-}d)^{-1}$? 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 3.0×10^{-4} mg/kg-d ? Is this considered a safe exposure in terms of non-carcinogenic effects? **(5 marks)**