NATIONAL EXAMS

December 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

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

Question (1) – 25 marks

a. The high temperatures involved in combustion of fossil fuels produce nitrogen oxide (NO) as a by-product. Describe, using chemical equations and written explanations, how NO is involved in the formation of 1) acid rain, and 2) ground-level ozone. **(6 marks)**

b. What are the differences between ground-level ozone and stratospheric ozone in terms of their precursors, duration and effects on humans? **(6 marks)**

c. What pollutants are controlled under the Montreal Protocol? **(2 marks)**

d. Give an example of a strategy/technology for climate change *mitigation* and one for climate change *adaptation*. Give an example of a technology that achieves both effects, and explain how it does so. **(7 marks)**

e. Rank the following emissions of gases in terms of their global warming potential: 1.75 Pg of CO_2, 108 Tg of CH_4, or 12 Gg of SF_6. [SI prefixes: tera = 10^{12}, peta = 10^{15}] **(4 marks)**

Table 2.3

100-Year Global Warming Potentials (GWP) Used to Convert Mass Greenhouse Gas Emissions to Carbon Dioxide Equivalents (CO_2e)

Type of Emission	Multiplier for CO_2 Equivalents (CO_2e)
Carbon dioxide	1
Methane	25
Nitrous oxide	298
Hydrofluorocarbons (HFCs)	124–14,800 (depends on specific HFC)
Perfluorocarbons (PFCs)	7,390–12,200 (depends on specific PFC)
Sulfur hexafluoride (SF_6)	22,800

SOURCE: Values from Intergovernmental Panel on Climate Change.

Question (2) – 25 marks

a. One of the 12 Principles of Green Engineering* is *Separation and purification operations should be a component of the design framework.* 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 *System components should be designed to maximize mass, energy, and temporal efficiency.* 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 *It is better to prevent waste than to treat or clean up waste after it is formed.* 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. Is human population the only factor determining environmental impact? What are some other factors? **(3 marks)**

e. A company produces a product that requires an operation manual and it has two options: 1) provide a paper booklet, or 2) set-up and maintain an online manual. The company has contacted you to conduct a life-cycle-assessment of the two alternatives. **(7 marks)**

- **i.** What would be a good functional unit for the LCA?
- **ii.** List the stages of the manual 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.** Considering each alternative, in what stage of the LCA would you expect to find the greatest environmental impact?

f. Define any six (6) of the following terms: **(6 marks)**

- design for disassembly
- reverse manufacturing
- ecological footprint
- biological capacity
- natural capital
- cap and trade
- externalities
- intangibles

Question (3) – 25 marks

Compare the environmental impacts of installing and operating the following electricity generating technologies:

- natural gas turbine
- hydroelectric (high head systems)
- nuclear
- solar photovoltaic
- wind turbines

by creating a table to summarize your analysis. Use the following five headings in your table: land requirement, air emissions, safety and risk, initial cost, and operating cost. 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 six (6) of the following terms: **(6 marks)**
- suspended solids
- BOD
- embodied water
- hydrologic cycle
- water table
- aquitard
- vadose zone
- potentiometer

b. The processes: filtration, coagulation/flocculation and sedimentation are used in treating drinking water. List these processes in the correct order and describe what happens in each. **(4 marks)**

c. When raw sewage is discharged into a lake or river, the fecal bacteria concentration decreases by exponential decay. If the decay coefficient is 2.2/day, what would be the viable bacteria concentration after a decay period of four days, if the sewage initially contained 5×10^5 cell/mL? Show your calculations. **(4 marks)**

d. List three common methods to disinfect water or wastewater and write an advantage and disadvantage for each. **(6 marks)**

e. Calculate the future water demand, in ML/day, for a town of 3,800 inhabitants at the end of a 30-year design span. The town population is expected to grow exponentially, at a growth rate of 0.2 %/year, whereas the water demand is expected to grow linearly at 0.8 %/year from the current level of 340 L/person/day. **(5 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. Define any three (3) of the following terms: **(3 marks)**
- LD_{50}
- hazard
- exposure
- threshold
- uncertainty factor (UF)
- environmental justice

c. The following article was taken from the Ontario Ministry of Labour website. Describe 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. **(8 marks)**

Two Companies Fined a Total of $90,000 After Workers Collapse At Oil Refinery

April 21, 2015 5:15 P.M.

SARNIA, ON - Shell Canada Limited/Shell Canada Limitée and CEDA International Corporation pleaded guilty and were fined a total of $90,000 after two workers collapsed.

In early 2013, Shell hired CEDA, an Alberta-based company that provides chemical-cleaning services to industrial facilities, to clean heat exchanger tubes at Shell's Sarnia Manufacturing Centre, an oil refinery in Corunna, Ont.

On April 26, 2013, CEDA workers were at the refinery, cleaning two tubes. The tubes were placed into a vat, which was then filled with a sulfuric acid solution. Just after the acid had been added, the workers' hydrogen sulphide (H2S) monitors began sounding. They also noticed a strong smell emanating from the vat.

Two CEDA employees closest to the vat helped each other get to a safe distance. Both workers suffered dizziness, disorientation and briefly collapsed. One of the workers reportedly briefly lost consciousness. A third CEDA employee was able to leave the area. All three workers were taken to hospital and released the same day.

A Ministry of Labour investigation found that the workers were exposed to H2S gas. The scales on the tubes contained iron sulfide. When the iron sulfide came into contact with the sulfuric acid solution, a chemical reaction led to the release of H2S gas into the atmosphere.

The investigation found that although the workers were wearing personal monitors to warn of any potential release, they were not informed they might be exposed to H2S gas as a result of cleaning the tubes in an acid bath.

Shell Canada Limited/Shell Canada Limitée pleaded guilty to failing as an employer to provide information, instruction and supervision to a worker to protect the health and safety of the worker. CEDA International Corporation pleaded guilty to failing as an employer to acquaint a worker, or a person in authority over a worker, with the hazard of hydrogen sulphide.

d. Determine the concentration of arsenic in water (in µg/L) that will result in a lifetime *cancer* risk of 10^{-4} for a 50 kg woman who drinks 2.0 L/day, 350 days/year for 15 years? The slope factor for arsenic is 1.5 $(mg/kg\text{-}d)^{-1}$. **(4 marks)**

e. Arsenic also has non-carcinogenic effects (nerve damage). What is the *hazard quotient* for the woman exposed as described in part c? The reference dose for arsenic is 3.0×10^{-4} mg/kg-d ? Is this considered a safe exposure in terms of non-carcinogenic effects? **(5 marks)**