NATIONAL EXAMS

May 2016

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.

4. Each question is of equal value.

Marking Scheme

1.	25 marks total	(a) 7 marks
		(b) 3 marks
		(c) 5 mark
		(d) 4 marks
		(e) 6 marks
2.	25 marks total	(a) 3 marks
		(b) 3 marks
		(c) 3 mark
		(d) 14 marks
		(e) 2 marks
3.	25 marks total	one question
4.	25 marks total	(a) 5 marks
		(b) 5 marks
		(c) 4 marks
		(d) 6 marks
		(e) 5 marks
5.	25 marks total	(a) 6 marks
		(b) 8 marks
		(c) 3 marks
		(d) 5 marks
		(e) 3 marks

Question (1) – 25 marks

a. What are the pollutants emitted by road vehicles that contribute to photochemical smog? Describe, using chemical equations and written explanations, how these pollutants create photochemical smog. What is the main toxic chemical in photochemical smog, and what are its effects on humans and plants? **(7 marks)**

b. What pollutants are controlled under the Montreal Protocol? What service function of the environment do these pollutants affect? **(3 marks)**

c. Describe the mechanism of anthropogenic global warming. In your explanation, be sure to distinguish between the actions of solar ultra-violet (UV) and infrared (IR) radiation. How does a higher concentration of greenhouse gases result in a warmer planet? **(5 marks)**

d. Rank the following emissions of gases in terms of their global warming potential: 1.2 Pg of CO_2, 50 Tg of CH_4, or 60 Gg of SF_6. [SI prefixes: tera = 10^{12}, peta = 10^{15}] **(4 marks)**

Table 7.6

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.

e. Explain the difference between climate change *mitigation* and climate change *adaptation*. Describe an example of a strategy/technology for each, and how it achieves its goal. **(6 marks)**

Question (2) – 25 marks

a. 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)**

b. One of the 12 Principles of Green Engineering* is *Embedded entropy and complexity must be viewed as an investment when making design choices on recycle, reuse or beneficial disposition.* 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 *System components should be output pulled rather than input pushed through the use of energy and materials.* 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. A newspaper has contacted you to conduct a life-cycle-assessment (LCA) of two alternatives for distributing its news: 1) news is printed on conventional newsprint paper, 2) newspaper leases electronic reading devices to subscribers, who download the news daily. **(14 marks)**

i. What would be a good functional unit for the LCA?
ii. List the four stages of the life-cycle (LC) to be considered in the assessment.
iii. List the material and energy uses in *each* stage listed in (ii) for both alternatives; decide which of the two alternatives would likely have the greatest environmental impact *in each stage.*
iv. Considering each alternative separately, in what stage of the LC would you expect to find the greatest environmental impact?

e. Define any two (2) of the following terms: **(2 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 a plant to produce 200 MW of electricity, utilizing the following generating technologies:
- wind turbines
- nuclear power plant
- solar photovoltaic farm
- natural gas turbine

Creating a table to summarize your analysis. Use the following six headings in your table: land requirement, fuel requirement, greenhouse gas emissions, health risks to local populations, initial cost, and operating cost (excluding fuel 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 five (5) of the following terms: **(5 marks)**
- suspended solids
- BOD
- embodied water
- hydrologic cycle
- water table
- aquitard
- vadose zone
- potentiometer

b. Turbidity is a parameter used to control processes in drinking water treatment plants. What does turbidity measure? How is turbidity related to microbial water quality? What processes, which are used in treating drinking water, reduce turbidity? **(5 points)**

c. When raw sewage is discharged into a lake or river, the fecal bacteria concentration decreases by exponential decay. If the viable bacteria concentration is reduced by a factor of 40,000 over a decay period of four days, what is the decay constant? Show your calculations. **(4 marks)**

d. List two commercially used methods to disinfect wastewater and write an advantage and disadvantage for each. **(6 marks)**

e. Calculate the current and future (30-year design period) water demand, in ML/day, for a town of 5,800 inhabitants. The town population is expected to grow exponentially, at a growth rate of 0.5 %/year, whereas the water demand is expected to grow linearly at 0.2 %/year from the current level of 360 L/person/day. **(5 marks)**

Question (5) – 25 marks

a. What are the two factors required to assess risk? Give an example of a situation that is high in one factor, but low in the other, and visa versa. **(6 marks)**

b. 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*. State which action that you think would be best, and why. **(8 marks)**

Paper Mill Fined $150,000 After Worker Burned in Dust Explosion at Idled Plant

January 29, 2016 4:15 P.M.

FORT FRANCES, ON - Resolute FP Canada Inc., operator of a paper mill, pleaded guilty and has been fined $150,000 after a worker was burned following an explosion of wood dust.

The paper mill, located at Mowatt Avenue and Sinclair Street in Fort Frances, was idled in 2014 but its bio mass boiler was still in operation to provide heat for the mill through the winter months. It was expected that the boiler would be idled after the winter when heating was no longer required.

The boiler was capable of running on either natural gas or bio mass. In 2008 an engineering assessment of the conveyor system for the boiler concluded that the system did not present a dust explosion hazard, owing to the particle size and moisture content of the fuel being used as bio mass.

In the days before the incident, workers had been doing a cleanup of the plant in anticipation of its closure. Up to 15 wheelbarrow loads of fine, dry wood dust that had been swept up from around the plant were dumped into the conveyor system. At that time, the boiler was running on natural gas.

On February 27, 2014, it was Resolute's intention to switch the boiler over to bio mass to burn off remaining fuel stock. On that day, a maintenance worker was checking on a plug-up of material in one of the conveyors and was near the operating controls at the head of the conveyor. The worker had cleared the plug-up and was looking into the conveyor to check whether it was going to plug up again.

As the dry wood dust that had been dumped into the conveyor was travelling on the conveyor, it was ignited by an undetermined source and a dust explosion occurred. A fireball travelled through the conveyor and out the end where the worker was standing. The worker received burns to the body.

Because the boiler system had not been designed to burn only fine, dry wood dust, but rather fuel with a certain moisture content and particle size, the protective measures of Section 63 of the Regulation for Industrial Establishments dealing with explosive hazards were not in place. That section regulates processes that could create an explosive mixture with air in industrial workplaces.

c. A 70 kg man drinks 2 L of water each day that contains 7 ppb of arsenic. Calculate his daily dose of arsenic. **(3 points)**

d. Arsenic is a carcinogen. What is the cancer risk for the man exposed for 10 years (350 days per year) as described in part c.? The slope factor for arsenic is 1.5 $(mg/kg\text{-}d)^{-1}$. Is this a safe exposure? **(5 points)**

e. Arsenic also has non-carcinogenic effects. What is the hazard quotient for the man exposed as described in part c., if the reference dose is $3x10^{-4}$ mg/kg-d ? Is this a safe exposure? **(3 points)**