NATIONAL EXAMS

May 2018

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. Any *non-communicating* calculator is permitted. This is an open 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. Indicate on the front of the exam booklet(s) which four questions were attempted, otherwise only the first four questions, as they appear in your answer book, will be marked.

4. All questions are of equal value.

Marking Scheme

1.	25 marks total	(a) 6 marks
		(b) 3 marks
		(c) 4 marks
		(d) 4 marks
		(e) 8 marks
2.	25 marks total	(a) 3 marks
		(b) 3 marks
		(c) 3 marks
		(d) 12 marks
		(e) 4 marks
3.	25 marks total	one question
4.	25 marks total	(a) 10 marks
		(b) 4 marks
		(c) 7 marks
		(d) 3 marks
		(e) 1 mark
5.	25 marks total	(a) 4 marks
		(b) 5 marks
		(c) 8 marks
		(d) 8 marks

Question (1) – 25 points

a. Explain the difference between ground-level ozone and stratospheric ozone, in terms of formation, harmful/beneficial effects, and the influence of human activities. **(6 points)**

b. What is meant by NO_X? What is the source of the nitrogen in NO_X that results from combustion? List two natural sources of NO_X? **(3 points)**

c. Describe the mechanism of anthropogenic global warming. In your explanation, be sure to distinguish between the actions of solar ultra-violet (UV) radiation and infrared (IR) radiation. How does a higher concentration of greenhouse gases result in a warmer planet? **(4 marks)**

d. Calculate the carbon dioxide equivalents of the following three emissions of gases: 0.040 Mg of CH_4, 3.36 kg of N_2O, and 43.8 kg of SF_6. Rank them in terms of their global warming potential. **(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.

e. Describe two examples of actions/technologies for climate change *mitigation* and two examples of actions/technologies for climate change *adaptation*. **(8 marks)**

Question (2) – 25 points

a. 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 points)**

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 points)**

c. Define pollution prevention and explain *two* ways in which pollution prevention can reduce operating costs in a manufacturing operation. **(3 points)**

d. Assume that you have been hired by a school board to conduct a life-cycle assessment (LCA) on the use of paper towels versus electric hand driers for a school. **(12 points)**

- **i.** What would be a good functional unit for the LCA?
- **ii.** List the *stages/phases* of the product life-cycle to be considered in a LCA.
- **iii.** For *each* stage/phase listed in (ii), decide which of the two alternatives (paper vs reader) would have the greatest environmental impact, and describe why.
- **iv.** In *what stage/phase* of the LCA would you expect to find the greatest environmental impact for *each* of the two alternatives?

e. Define any four of the following terms: **(4 points)**

- design for disassembly
- industrial ecology
- resilience
- biomimicry
- source reduction
- intangibles

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

Question (3) – 25 points

Compare the environmental, social, and economic impacts of installing and operating a plant/array to produce **200 MW** of electricity on a single site, utilizing the following generating technologies:

- wind turbines
- (one) nuclear power plant
- solar photovoltaic farm
- (one) power plant fuelled by wood pellets
- (one) coal-fired power plant

Creating a table to summarize your analysis. Use the following five headings in your table: land requirement, fuel cost, greenhouse gas emissions, health risks to local populations, and initial cost. Consider the plant itself and *any upstream processes* used to make or feed the plant. Use H, M, L (high, medium, low) ratings for each cell of the table ***and provide a brief explanation for each***.

Question (4) – 25 points

a. Draw a flow diagram to show the sequence of processes in a typical *wastewater* treatment plant that uses activated sludge secondary treatment. Label each process and describe which pollutant(s) it removes. **(10 points)**

b. Fecal bacteria in the guts of warm-blooded animals decrease when outside their hosts. 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 10^5 cell/mL to be reduced to 1 cell/mL if the decay coefficient is 3.4/day? Show your calculations. **(4 points)**

c. Dandriff Creek carries 5.5 m^3/s of water with a selenium concentration of 0.0012 mg/L. A farmer starts withdrawing 1.0 m^3/s of the creek water to irrigate her land. During irrigation, the water picks up selenium from the salts in the soil. One-half of the irrigation water goes to the ground and plants, and the other half is returned to Dardriff Creek. The irrigation run-off to the creek contains 1.0 mg/L selenium. Selenium is a conservative pollutant (does not degrade) and the farmer's field is the only source of selenium. If the farmer irrigates continuously, what will be the steady-state **concentration of selenium** in the stream (in ppm) after the run-off has mixed with the stream? Draw a diagram and show the mass balance equation(s) in your solution. **(7 points)**

d. Of the three categories of water use by humans: industry, agriculture, and drinking (domestic), which one results in the highest water use worldwide? Describe two (2) technologies that would reduce water use. **(3 points)**

e. Define any one (1) of the following terms: **(1 mark)**

- BOD
- turbidity
- aquifer

Question (5) – 25 points

a. Risk may be described in terms of likelihood and consequence. Using these terms, compare the risk of living downwind of a coal-fired power plant and living closely downriver from hydroelectric power plant. **(4 points)**

b. A 70 kg man breathes 20 m^3 of air each day containing 170 ppb of the carcinogen trichloroethylene (MW = 131.4 g/mol). The inhalation *unit risk factor* is 4.1×10^{-6} $(\mu g/m^3)^{-1}$. Is this a safe exposure? **(5 points)**

c. Arsenic is a chemical that causes cancer, and also other toxic effects. It has a reference dose of 3×10^{-4} mg/kg-d and an oral slope factor of 1.5 $(mg/kg\text{-}d)^{-1}$. Calculate the lifetime cancer risk and the hazard quotient for a 50 kg woman

consuming 2 L/d of water containing 6 ppb of arsenic in a residential exposure (350 days/year for 30 years). Are either of these exposures considered unsafe? **(8 points)**

d. Read the following report from the Ontario Ministry of Labour. Describe at least three ways that this tragedy could have been prevented, considering control at the source, control along the path, and control at the worker. State which of the three is preferred, and why. **(8 points)**

Paper Mill Fined $150,000 After Worker Burned in Dust Explosion at Idled Plant
January 29, 2016

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.