NATIONAL EXAMS

December 2017

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) 5 marks
		(b) 4 marks
		(c) 5 marks
		(d) 5 marks
		(e) 6 marks
2.	25 marks total	(a) 3 marks
		(b) 3 marks
		(c) 3 marks
		(d) 14 marks
		(e) 2 marks
3.	25 marks total	one question
4.	25 marks total	(a) 12 marks
		(b) 4 marks
		(c) 5 marks
		(d) 4 marks
5.	25 marks total	(a) 4 marks
		(b) 12 marks
		(c) 5 marks
		(d) 4 marks

Question (1) – 25 points

a. Transportation is the source of 60% of human-made nitrogen oxide emissions to the environment. What are two regional air pollution problems associated with oxides of nitrogen? For each of the two, write a chemical equation and provide an explanation to show how NO_X is involved. **(5 points)**

b. List four main forms (chemical species) in which nitrogen exists in the global nitrogen cycle. **(4 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? **(5 marks)**

d. Rank the following emissions of gases in terms of their global warming potential: 1.2 Tg of CO_2, 50 Gg of CH_4, or 173 Mg of PFCs. Which gas has the greatest global emission rate, by mass? [SI prefixes: tera = 10^{12}, giga = 10^9] **(5 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. 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 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 *Separation and purification processes should be a component of the design framework.* 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 are conducting a life-cycle-assessment (LCA) on the use of printed paper books versus electronic readers for a school. **(14 points)**

- **i.** What would be a good functional unit for the LCA?
- **ii.** List the stages of the product life-cycle to be considered.
- **iii.** *For each stage*, decide which of the two alternatives (paper vs reader) 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 of the two alternatives*?

e. Define any two of the following terms: **(2 points)**

- design for disassembly
- environmental purchasing policy
- reverse manufacturing
- e-waste
- 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 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) natural gas-fired power plant

Creating a table to summarize your analysis. Use the following five headings in your table: land requirement, fuel requirement, 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 drinking water treatment plant that treats surface water. Label each process and describe which pollutant(s) it removes. **(12 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 10^6 cell/mL to be reduced to 1 cell/mL if the decay coefficient is 2.4/day? Show your calculations. **(4 points)**

c. An 800-ha farm is in an area that receives 100 cm of rain each year. One-half of the rainfall percolates into an underground aquifer, the rest runs off into a stream. The farmer has a well which draws water from the aquifer for irrigation. 75% of the water from the well is lost to the atmosphere by evapotranspiration, the remainder percolates back into the ground and returns to the aquifer. How much water can the farmer extract from the aquifer on an annual basis without changing the groundwater level? [1 ha = 10,000 m^3] **(5 points)**

d. The IPAT equation is sometimes used to describe human impact on the environment. What are the three terms in the IPAT equation and how are they compiled to determine the impact? **(4 points)**

Question (5) – 25 points

a. Risk may be described in terms of likelihood and consequence. Compare the risk of living downwind of a coal-fired power plant and a nuclear power plant using these terms. **(4 points)**

b. A gasoline station attendant's job is to fill cars with gasoline. He is exposed to gasoline vapours repeatedly in his workday. Gasoline contains volatile carcinogens. Describe three ways to reduce the hazard of gasoline vapour, and three ways to reduce his exposure to the hazard. **(12 points)**

c. A 50 kg woman 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)**

d. What is the hazard quotient for a 70 kg man who drinks 2 L of water each day that contains 9 ppb of arsenic, if the reference dose is 3×10^{-4} mg/kg-d ? Is this a safe exposure? **(4 points)**