NATIONAL EXAMS

May 2019

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 Casio or Sharp 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. 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) 8 marks
		(b) 4 marks
		(c) 6 marks
		(d) 5 marks
		(e) 2 marks
2.	25 marks total	(a) 3 marks
		(b) 3 marks
		(c) 3 marks
		(d) 4 marks
		(e) 12 marks
3.	25 marks total	one question
4.	25 marks total	(a) 8 marks
		(b) 4 marks
		(c) 2 marks
		(d) 6 marks
		(e) 4 mark
		(f) 1 mark
5.	25 marks total	(a) 2 marks
		(b) 4 marks
		(c) 11 marks
		(d) 8 marks

Question (1) – 25 marks

a. The Unites States Environmental Protection Agency has an expression about ozone: "bad nearby, good up high". What are the two kinds of ozone to which they are referring? Explain the difference between the two types, in terms of formation, harmful/beneficial effects, and the influence of human activities. **(8 marks)**

b. What is the difference between a *primary* air pollutant and a *secondary* air pollutant? Give one example of each. **(4 marks)**

c. What are the two main types of acid that make up acid rain? What is the main source of each? List two effects of acid rain. **(6 marks)**

d. Calculate the carbon dioxide equivalents of the following three emissions of gases: 23.4 tonnes of CO_2, 0.932 Mg CH_4, 78.8 kg of N_2O, and 932 g of SF_6. Rank them in terms of their global warming potential. **(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. Describe one example of actions/technologies for climate change *mitigation* and one example of actions/technologies for climate change *adaptation*. **(2 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 *Design for unnecessary capacity or capability should be considered as a design flaw. This includes engineering "one size fits all" solutions.* 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 *Multi-component products should strive for material unification to promote disassembly and value retention (minimize*

material diversity). Give a specific example of how this principle can be used to prevent pollution. **(3 marks)**

d. Aluminum is one of the raw materials used by a factory to make bodies for computers. The factory purchases 100 tonnes of raw materials per year and 91 tonnes end up in the finished products that leave the factory every year. The difference ends up leaving the factory as pollution: particular matter exhausted through the stack, turnings collected from the shop floor and thrown out, or in the wastewater. Draw and label a diagram to show the mass balance of aluminum for the factory. Draw and label another diagram to show the mass balance if pollution prevention measures were implemented to reduce the pollution by half, while maintaining the same production. **(4 marks)**

e. 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 marks)**

- **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?

*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 marks

Compare the environmental, social, and economic impacts of installing and operating a plant/array/windfarm to produce **200 MW** of electricity, 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

Create a table to summarize your analysis. Use the following five headings in your table: initial cost, fuel cost, greenhouse gas emissions, health risks to local populations, and land requirement. 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 marks

a. Draw a flow diagram to show the sequence of processes in a typical *drinking water* treatment plant. Include the following processes (listed here in alphabetic order): coagulation/flocculation, disinfection, filtration, grit chamber, screens, and sedimentation. Label each process and describe which pollutant(s) it removes. **(8 marks)**

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 $\left[\frac{dX}{dt} = -k_d X\right]$. How many days would it take for a viable bacteria concentration of 10^6 cell/mL to be reduced to 10 cell/mL if the decay coefficient is 2.9/day? Show your calculations. **(4 marks)**

c. Turbidity is a parameter used to control processes in drinking water treatment plants. What is turbidity? How is turbidity related to microbial water quality? **(2 marks)**

d. Conserville, a town of 7,500 inhabitants, wants ensure that its total water consumption does not increase. The town population is expected to grow exponentially at a growth rate of 1.5%/year. The town will implement conservation measures to *reduce* its per capita water consumption linearly from its current value of 204 L/person·day. What rate of decrease of per capita water consumption must it achieve so that the total water consumption at the end of 20 years is the same as it is now? **(6 marks)**

e. The "IPAT" equation attempts to quantify the Impact of humans on the natural environment such that I = f (P, A, T). What do the P, A and T stand for? What is the form of the equation (*i.e.* write the function). **(4 marks)**

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

- virtual water
- aquifer
- coliform
- groundwater

Question (5) – 25 marks

Equations for this question:

$ppb = \frac{C \cdot R \cdot T}{MW \cdot P}$ where C = concentration ($\mu g/m^3$)

$Average\ Daily\ Dose\ (ADD) = \frac{C \cdot IR \cdot EF \cdot ED}{BW \cdot AT}$

where C = concentration (mg/L)
IR = intake rate (L/day)
BW = body weight (kg)
AT = averaging time (days) = lifetime (70 years) for carcinogens
= actual exposure (days) for non-carcinogens

Risk = ADD*(slope factor) [acceptable risk is 10^{-4}]

Hazard Quotient = ADD/(reference dose) [acceptable HQ<1]

Table 6.14

Land Uses and Examples of Exposure Assessment Associated with Each Use The EPA publishes an *Exposure Factors Handbook* (EPA, 2011b) that provides more detail on specific values used in exposure assessment (EPA/600/R-09/052F, 2011).

Land Use	Examples of This Land Use	Example IR for Drinking Water; Air Inhalation, and Soil Ingestion	Example Exposure Frequency (EF) (days per year) and Exposure Duration (ED) (years)
Residential (primary activity is residential)	**Single-family dwellings, condominiums, apartment buildings**	**Children drink** 1 L/day **Adults drink** 2 L/day **Adults inhale** 20 m^3/day **Children age 1–6 consume** 200 mg soil/day **Adults consume** 100 mg soil/day	**For drinking water** EF: 350 days/year ED: 30 years **For air inhalation** EF: 350 days/year ED: 30 years **For soil ingestion** ED: 6 years for children 1–6 ED: 24 years for adults EF: 350 days for children and adults
Industrial (primary activity is industrial, or zoning is industrial)	Manufacturing, utilities, industrial research, and development, petroleum bulk storage	Adults drink 1 L/day Adults inhale 10 m^3/day	For drinking water EF: 245 days/year ED: 21 year For air inhalation EF: 245 days/year ED: 21 years For soil ingestion ED: 21 years for adults EF: 245 days for children and adults
Commercial (use is a business or is intended to house, educate, or provide care for children, the elderly, the infirm, or other sensitive subpopulations)	Day-care centers, educational facilities, hospitals, elder-care facilities and nursing homes, retail stores, professional offices, warehouses, gas stations, auto services, financial institutions, government buildings	Adults drink 1 L/day Adults inhale 10 m^3/day	For drinking water EF: 245 days/year ED: 21 years For air inhalation EF: 245 days/years ED: 21 years For soil ingestion ED: 21 years for adults EF: 245 days for children and adults

*Recall that the average weight for a male, female, and child are 70 kg, 50 kg, and 10 kg, respectively.

a. Define the terms hazard and exposure as they relate to risk. **(2 marks)**

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? **(4 marks)**

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 an average man consuming water containing 6 µg/L of arsenic in a *residential* exposure. Are either of these exposures considered unsafe? **(11 marks)**

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 marks)**

Worker's Permanent Injury Results in $75,000 Fine for London-Area Company
October 25, 2018 4:00 P.M.

Convicted: Coldstream Concrete Ltd., a company that manufactures precast concrete products for the construction industry.

- Two workers were working in the business's heavy precast yard, moving three-sided concrete culverts from the bed of a trailer on to the ground using a gantry straddle crane and spreader beam.
- The crane had recently been inspected and found to be in good working order.
- One worker operated the crane from the cab, and the other was on the ground, rigging the culverts to the crane.
- The crane operator moved a 23,000-kilogram culvert from the trailer and set it down on the ground. The worker on the ground needed the culvert raised again in order to remove a metal date plate attached to the bottom of the culvert. The operator raised the culvert about five feet and, while it was suspended, the worker on the ground reached underneath and started to chisel the date plate away.
- While doing so, the worker heard a cracking noise and was knocked to the ground by the culvert.
- The worker knocked to the ground suffered a permanent injury as a result.
- Later examination of the crane showed it had suffered an unexpected and catastrophic failure.
- In particular, the examination determined that a pin in the roller chain link connecting the crane's hoist transmission drive socket to the hoist drum socket assembly had failed. This caused the hoist drum to rotate freely and the part of the culvert which had been supported by one end of the crane to fall to the ground.