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) 5 marks
		(b) 5 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) 3 marks
		(b) 5 marks
		(c) 8 marks
		(d) 4 marks
		(e) 5 marks
5.	25 marks total	(a) 4 marks
		(b) 8 marks
		(c) 2 marks
		(d) 2 marks
		(e) 5 marks
		(f) 4 marks

Question (1) – 25 marks

a. The US Environmental Protection Agency has a slogan "bad nearby, good up high."
    To what air pollutant are they referring? Explain the meaning of the slogan in terms
    of hazard and exposure. **(5 marks)**

b. Transportation is the source of 60% of human-made NO_X emissions to the
    environment. What are two secondary air pollutants 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 in its formation. **(5 marks)**

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
    Pg of CO_2, 50 Tg of CH_4, or 173 Gg of PFCs. [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.

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 *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)**

c. One of the 12 Principles of Green Engineering* is *Design of processes and systems must include integration of interconnectivity with available energy and materials flows.* 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 land developer has contacted you to conduct a life-cycle-assessment (LCA) of two alternatives for finishing the rooves of houses in a new sub-division that it is creating. Because of the style of house, the two alternatives are cedar shingles and synthetic shingles which are made of recycled plastic. The plastic shingles have a lifetime warrantee. **(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 its life-cycle would you expect to find the greatest environmental impact?

e. Define any two (2) of the following terms: **(2 marks)**
    - reverse manufacturing
    - ecological footprint
    - reuse and recycling
    - natural capital
    - cap and trade
    - externalities
    - intangibles

Question (3) – 25 marks

Compare the environmental impacts of installing and operating a single plant to produce **200 MW** of electricity, utilizing the following generating technologies:
   - wind turbines
   - (one) nuclear power plant
   - solar photovoltaic farm
   - (one) coal-fired power plant

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). 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. Define any three (3) of the following terms: **(3 marks)**
   - turbidity
   - embodied water
   - hydrologic cycle
   - water table
   - aquitard
   - vadose zone

b. BOD is a parameter monitored in wastewater treatment plants. What does BOD mean? What material in the wastewater does it measure? What are its different forms? What processes used in treating wastewater reduce BOD? **(5 points)**

c. 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. **(8 points)**

d. 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 4,000 over a decay period of three days, what is the decay constant? Show your calculations. **(4 marks)**

e. Calculate the current and future (25-year design period) water demand, in ML/day, for a town of 8,500 inhabitants. The town population is expected to grow exponentially, at a growth rate of 0.4 %/year, whereas the water demand is expected to grow linearly at 0.1 %/year from the current level of 350 L/person/day. **(5 marks)**

Question (5) – 25 marks

a. What are the two factors required to assess risk? Both of these factors are generally higher when breathing indoor air, as compared to outdoor air. Explain why, and how this affects risk. **(4 marks)**

b. The following article was taken from the Ontario Ministry of Labour website. Describe at least 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)**

Cleaning Crew Affected by Carbon Monoxide, Employer Fined $75,000
July 13, 2016

TORONTO, ON - Ground Maintenance Cleaning Contractors Inc. (GMCC Inc.), a property maintenance business, pleaded guilty and was fined $75,000 for failing to protect the health and safety of a crew of workers from exposure to carbon monoxide gas in a parking garage. One of the workers collapsed on site and later died.

The incident occurred on May 28, 2014 at a condominium building located at 15 Torrance Road in Scarborough. GMCC was hired by the condominium corporation to power wash the underground parking garage. The six workers were using four gasoline-powered washers to perform the work; the power washers emit carbon monoxide (CO) gas.

While the workers were power washing, the internal exhaust fans in the garage stopped working. The building superintendent told the GMCC Inc. supervisor that an electrician should be on site to repair the fans. Meanwhile, the workers continued to work with portable fans in use.

One worker later exited the garage and collapsed on the sidewalk. The worker was transported to hospital by ambulance and was later pronounced dead from carbon monoxide toxicity. The remaining workers were taken to hospital where they were treated for carbon monoxide exposure and released. These workers did not suffer any lasting health issues as a result of the incident.

The investigation by the Ministry of Labour revealed that the GMCC Inc. work crew and supervisor had not received any formal training on the hazards of carbon monoxide or measures that can be taken for protection from carbon monoxide poisoning. They had not received any formal health and safety training other than Workplace Hazardous Materials Information System (WHMIS), and not all of them had received that training.

Ontario Regulation 833, which covers the control of exposure to biological or chemical agents, prescribes that every employer shall take all measures reasonably necessary in the circumstances to limit the exposure of workers to hazardous biological or chemical agents in accordance with the rule that exposure to carbon monoxide shall not exceed 125 ppm at any time. The Toronto fire services' carbon monoxide measurements in the garage found that levels had reached 425 ppm.

c. How is risk assessment of carcinogens different than non-carcinogens? **(2 points)**

d. Table salt has an LD_{50} of 4,000 mg/kg. Ethanol has an LD_{50} of 10,000 mg/kg. Which is more toxic? **(2 points)**

e. A 50 kg woman breathes 20 m^3 of air each day containing 370 ppb of 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)**

f. What is the hazard quotient for a 70 kg man who drinks 2 L of water each day that contains 7 ppb of arsenic, if the reference dose is 3×10^{-4} mg/kg-d ? Is this a safe exposure? **(4 points)**