The University of Nottingham Ningbo China

DEPARTMENT OF CHEMICAL AND ENVIRONMENTAL ENGINEERING

A LEVEL 2 MODULE, 2020-2021

CHEE2052 Materials and Sustainable Processing

Time allowed THREE Hours

Candidates may complete the front cover of their answer book and sign their desk card but must NOT write anything else until the start of the examination period is announced

Answer ALL Questions

[Total 100 marks]

Only silent, self contained calculators with a Single-Line Display or Dual-Line Display are permitted in the examination.

Dictionaries are not allowed with one exception. Those whose first language is not English may use a standard translation dictionary to translate between that language and English provided that neither language is the subject of this examination. Subject specific translation dictionaries are not permitted.

No electronic devices capable of storing and retrieving text, including electronic dictionaries, may be used.

DO NOT turn examination paper over until instructed to do so

ADDITIONAL MATERIAL:

INFORMATION FOR INVIGILATORS: None

Question 1 (20 marks)

(a) Define sustainability and briefly describe how it relates to sustainable development.

[5]

(b) How would a company measure its progress towards greater sustainability? Give examples of indicators for all three of the 'pillars of sustainability'.

[8]

(c) Elaborate what we would consider a 'sustainable process', and describe the design decisions that contribute to achieving it. [7]

Question 2 (40 marks)

A new catalyst has been proposed that converts CO_2 to methanol, and a commercial scale reactor is to be built to test it further. While the process works at the moderate temperature of 200°C, a pressure of 130 bar is required. The reactor is designed as a cylindrical vessel with hemispherical ends, with an inner diameter of 1.2 m and an internal height of 3.7 m. A decision needs to be made as to whether it is preferable to use low alloy steel or a titanium alloy to build the reactor. Relevant data for both is given in Table Q2.
Note that there is a supporting formula sheet in the appendix related to this subject area.

Table Q2 - Material Properties

	Steel	Titanium
Cost per tonne / USD/t	1100	9900
Density / kg/m^3	7850	4600
Yield strength / MPa	550	1000
Ultimate strength / MPa	700	2300
Young's modulus / GPa	210	115
Fracture toughness / MPa.m$^{(1/2)}$	60	65
Poisson's ratio	0.31	0.18

a) Estimate the cost of building the reactor from each of the materials. Explain choices you made for the calculations, and clearly state the resulting total cost in USD.
If you require the design strength you may assume it here to be 0.7 times the yield strength. [15]

b) For the vessels costed in a), what is the difference in height between atmospheric and the operating pressure? [10]

c) Will both materials/vessels leak before they burst? [6]

d) Which material would you propose to use based on the calculations in a)-c). Briefly state why? [4]

e) State which other properties you may wish to consider before making a final decision, and how they could affect your decision? [5]

Question 3 (40 marks)

A community of householders and small businesses produce 30 tonnes of waste a day, which is currently collected mixed and taken to a central incinerator, where all of it except the metal is burnt for energy together with the waste from other areas in the city. The average composition of the waste collected is given in Table Q3.

Table Q3- MSW Composition

Component	Energy (as discarded)	Percentage by weight	Moisture content
	MJ/kg	%	%
Organic waste	2.5	54.9	64
Plastic	37	14.7	3
Paper	13.2	10.0	7
Textiles	5.7	2.0	13
Glass	0	6.6	1
Metal	0	3.1	2
Other	4.3	8.7	18

a) Calculate the dry composition of the waste, and the overall calorific value on a dry basis. [10]

b) How much energy is recovered from the waste per year if the incinerator has a conversion efficiency of 40% ? [3]

c) How would the answer to b) change if a new waste management system succeeded in the reduction of the organic waste by 50%, and of paper and plastic by 70% each? [7]

d) Propose two alternative ways to process the organic waste, and discuss the advantages and disadvantages of them compared with incineration and one another. [10]

e) Describe what would need to be installed and operated in order to extract the plastic from the mixed waste for recycling. Discuss the limitations of such an undertaking. [10]

Appendix Formulae for Materials

$\sigma = F / A$ $\varepsilon = dL / L$ $\sigma = E \varepsilon$ (1)

$\tau = Fs / A$ $\gamma = \tan \Theta \approx \Theta$ $\tau = G \gamma$ (2)

$\nu = - \varepsilon_{lateral} / \varepsilon$ (3)

$Gc = (\sigma^2 \pi a) / E$; $K = \sigma \sqrt{(\pi a)}$ (4)

$$\Delta\varepsilon^{pl} N_f^b = C_2 \qquad \Delta\sigma N_f^a = C_1 \qquad N_f = \int_0^{N_f} dN = \int_{a_0}^{a_f} \frac{da}{A(\Delta K)^m} \quad (5)$$

$$\varepsilon_{ss} = B\sigma^n ; \quad \frac{1}{\sigma_{n-1}} - \frac{1}{\sigma_i} = (n-1)BEt \quad (6)$$

$$\sigma_L = \frac{Pr}{2t} ; \qquad \sigma_H = \frac{Pr}{t} \quad (7)$$

a) *Cylindrical shells*

$$e = \frac{pD_i}{2f - p}$$

or

$$e = \frac{pD_o}{2f + p}$$

b) *Spherical shells*

$$e = \frac{pD_i}{4f - 1.2p}$$

or

$$e = \frac{pD_o}{4f + 0.8p} \quad (8)$$

Cylinder $V = \pi r^2 h$ (9)

Sphere $V = (4/3) \pi r^3$

END