



## **FACULTY OF SCIENCE AND ENGINEERING**

**ACADEMIC YEAR 2020/2021**

**APRIL/MAY ASSESSMENT PERIOD**

**Module Code: SE4011**

**Module Title: Materials Processing and Manufacture**

**Level: 4**

**Component: Take Home Assessment**

**Release time and date: 9.30am on 11<sup>th</sup> May 2021**

**Submission deadline: 9.30am on 12<sup>th</sup> May 2021**

### **INSTRUCTIONS TO CANDIDATES:**

**Answer all TEN questions.**

**Each question is worth 10 marks. A formula sheet and conversion factors are supplied.**

**Use of calculators is permitted subject to University regulations.**

## Dimensions, Units and Conversions

1. a) State the dimensions of the following quantities, using fundamental variables (i.e. mass, M, length, L and so on)

- i) work
- ii) dynamic viscosity
- iii) energy

[3 marks]

b) This is a quote from Doran (2013):

*Properly constructed equations representing general relationships between physical variables must be dimensionally homogeneous.*

What does the term 'dimensionally homogeneous' mean?

[2 marks]

c) The pressure,  $P$ , at the base of a vertical column of liquid of density  $\rho$ , and height  $h$ , is called the hydrostatic pressure and is given by

$$P = P_o + \rho gh$$

where  $P_o$  is the pressure exerted at the top of the column and  $g$  is the acceleration due to gravity.

Demonstrate that the equation is dimensionally homogeneous. Show all your working.

[5 marks]

## Risk Management

2. a) If a purged vessel is left full of hot steam with all its valves closed, what might happen to the vessel when the steam condenses? Explain your answer.

[2 marks]

b) There are four strategies for managing process risk: inherent, passive, active and procedural. Explain the approach used in TWO of them.

[4 marks]

c) What is meant by the following terms in the 'lines of defence' approach to process safety?

i) Substitution

[2 marks]

ii) Attenuation

[2 marks]

## Reactors

3. a) The design equation for a continuous stirred tank reactor is:

$$V = \frac{F_{A0}X}{-r_A}$$

Identify each of the parameters,  $V$ ,  $F_{A0}$ ,  $X$  and  $r_A$ .

[4 marks]

- b) If a reactor does not operate adiabatically, then its design must include provision for heat transfer. Describe, with the aid of a diagram, ONE way in which the contents of a batch reactor may be heated or cooled.  
[4 marks]
- c) Give ONE disadvantage and ONE advantage of an ideal plug flow reactor.  
[2 marks]

## Design and Analysis of Processing Systems

4. a) Would a batch or a continuous process be more appropriate in each of the following cases? Explain your answers.
- i) When small product throughput is required.  
[2 marks]
- ii) When equipment needs to be designed and optimised for a single or small number of operating conditions.  
[2 marks]
- iii) When a varying market demand dictates finished product availability.  
[2 marks]
- b) The process flow diagram (PFD) contains the bulk of the chemical engineering information necessary for the design of a chemical process.
- List FOUR pieces of information that are expected to be shown on a typical PFD.  
[4 marks]

## Membranes

5. a) State TWO well-established, large-scale membrane separation processes and give an industrial example for each one. [4 marks]
- b) Explain what the following terms mean when applied to a membrane:-  
i) selectivity  
ii) flux [2 marks]
- c) What TWO generic factors affect the extent (or rate) of membrane fouling? [2 marks]
- d) Suggest TWO ways in which you might reduce membrane fouling? [2 marks]

## Material Balances

6. a) Write in words the Conservation Equation. [2 marks]
- b) State what is meant by steady-state and a transient system. [2 marks]
- c) A distillation column is fed with a stream of ethanol, propanol and butanol flowing at a total rate of  $1000 \text{ kg h}^{-1}$  and containing 26 wt% ethanol. The top product consists of 80% of the ethanol and 40% of the propanol contained in the feed. All of the  $330 \text{ kg h}^{-1}$  of butanol in the feed ends up in the bottom product. Calculate the bottom product component mass flow rates. [6 marks]

## Fluid Flow and Mixing

7. a) A solution of sodium hydroxide of density  $1650 \text{ kg m}^{-3}$  and dynamic viscosity  $50 \text{ mN s m}^{-2}$  flows in a pipe with a 3 cm internal radius. You have been asked to recommend a value for the linear flow velocity to ensure turbulent flow in the pipe. What flow velocity would you recommend and why? [3 marks]
- b) Linseed oil at a temperature of 293 K is being transferred to a holding tank via a pipeline with an internal diameter of  $\frac{1}{2}$ ". The flow rate of the oil is  $0.25 \text{ kg s}^{-1}$ . Assume the density of linseed oil at 293 K is  $936 \text{ kg m}^{-3}$ . Calculate the linear velocity of the linseed oil in  $\text{m s}^{-1}$ . [4 marks]
- c) The impeller Reynolds number  $Re_i$  is used to characterise fluid flow in stirred tanks and is given by the equation

$$Re_i = \frac{N_i D_i^2 \rho}{\mu}$$

Define the parameters  $\mu$ ,  $N_i$  and  $D_i$ .

[3 marks]

## Manufacturing

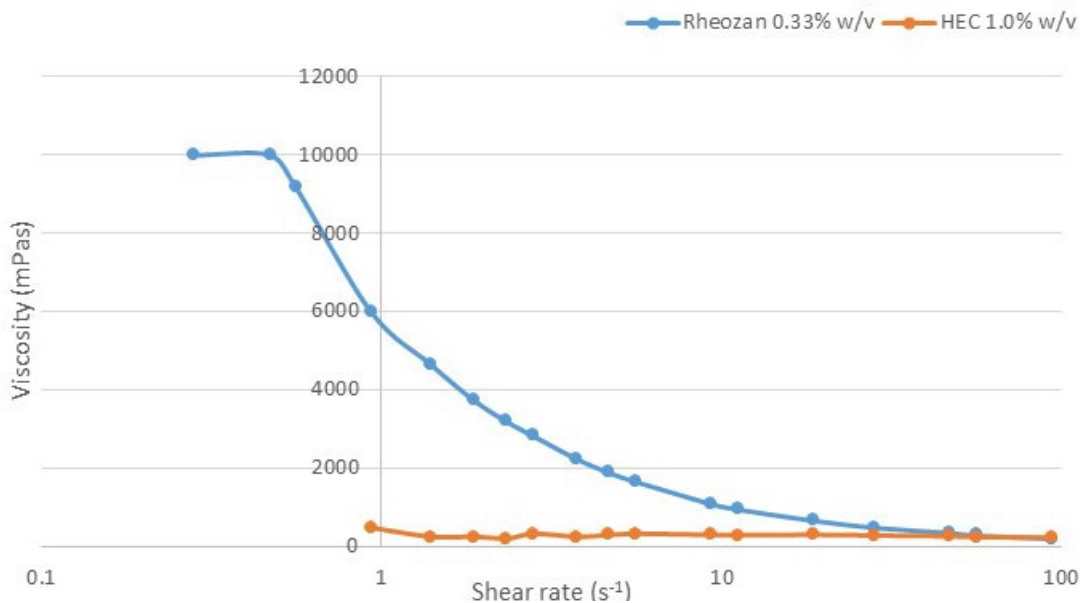
8. There are four main layout types for manufacturing: fixed position, cell, functional, and product. Choose TWO of the layout types. For each one
- a) Describe the characteristics of the layout: [6 marks]
- b) Discuss ONE advantage and ONE disadvantage of using that layout. [4 marks]

## Rheology

9. a) Describe the characteristics of a Bingham plastic, and explain why these characteristics are desirable in toothpaste, a well-known Bingham Plastic. [4 marks]

Using a Brookfield DVII Viscometer, the rheological behaviour of two fluids has been determined and is shown in Figure Q9. The fluids are 1.0% w/v hydroxyethyl cellulose and 0.33% w/v 'Rheozan' solution in tap water at 25° C.

Figure Q9 Viscosity of Polymeric material @ 25 deg c



- b) What kind of fluid rheological behaviour is being exhibited by:
- 1.0% w/v hydroxyethyl cellulose (HEC) solution? Explain your answer. [2 marks]
  - 0.33% w/v 'Rheozan' at a shear rate  $>1 \text{ s}^{-1}$ ? Explain your answer. [2 marks]
- c) What would you expect the effect of increasing temperature to be on the viscosity of the HEC 1.0 w/v solution? Explain your answer. [2 marks]

## Sustainability

10. a) A chemical process may be made more sustainable by minimising the use of energy. State TWO other ways in which a process may be made more sustainable.

[2 marks]

- b) Burning a biofuel derived from purpose-grown biomass crops (such as ethanol derived from sugar cane or corn) releases carbon dioxide, but that carbon was originally withdrawn by the biomass from the atmosphere during the process of photosynthesis. Hence the net emission of carbon dioxide to the atmosphere is often taken to be zero (carbon neutral) over the short term. But this analysis considers only the photosynthesis and combustion stages of the process. Give TWO further aspects which could be included in an assessment of sustainability over the entire process. Briefly explain your answers.

[4 marks]

- c) Several parameters are used to quantify the degree of utilisation of materials and the generation of waste in industrial processing. An example is the E-factor, which is defined as

$$\text{E-factor} = \frac{\text{mass of waste}}{\text{mass of product}}$$

where 'waste' is all the material generated by the process except the product.

Use of the E-factor as a measure has been criticised. What is the drawback of using the E-factor?

[2 marks]

- d) Suggest an alternative parameter which addresses the problem identified in Part c), and explain how that parameter is calculated.

[2 marks]

**END OF QUESTIONS**

**Conversion sheet SE4011 May-June 2020 Exam Paper**

<b><u>Quantity</u></b>	<b><u>Equivalent values</u></b>
Mass	1 kg = 1000 g = 0.001 metric ton = 2.20462 lb <sub>m</sub> = 35.27392 oz 1 lb <sub>m</sub> = 16 oz = 5 x 10 <sup>-4</sup> ton = 453.593 g = 0.453593 kg
Length	1 m = 100 cm = 1000 mm = 10 <sup>6</sup> microns (μm) = 10 <sup>10</sup> angstroms Å = 39.37 in. = 3.2808 ft = 1.0936 yd = 0.0006214 mile 1 ft = 12 in. = 1/3 yd = 0.3048 m = 30.48 cm
Volume	1 m <sup>3</sup> = 1000 L = 10 <sup>6</sup> cm <sup>3</sup> = 10 <sup>6</sup> mL = 35.3145 ft <sup>3</sup> = 219.97 imperial gallons = 264.17 gal = 1056.68 qt 1 ft <sup>3</sup> = 1728 in. <sup>3</sup> = 7.4805 gal = 0.028317 m <sup>3</sup> = 28.317 L = 28 317 cm <sup>3</sup>
Force	1 N = 1 kg·m s <sup>-2</sup> = 10 <sup>5</sup> dynes = 10 <sup>5</sup> g·cm s <sup>-2</sup> = 0.22481 lb <sub>f</sub> 1 lb <sub>f</sub> = 32.174 lb <sub>m</sub> ·ft s <sup>-2</sup> = 4.4482 N = 4.4482 x 10 <sup>5</sup> dynes
Pressure	1 atm = 1.01325 x 10 <sup>5</sup> N m <sup>-2</sup> (Pa) = 101.325 kPa = 1.01325 bar = 1.01325 x 10 <sup>6</sup> dynes cm <sup>-2</sup> = 760 mm Hg at 0°C (torr) = 10.333 m H <sub>2</sub> O at 4°C = 14.696 lb <sub>f</sub> in <sup>-2</sup> (psi) = 33.9 ft H <sub>2</sub> O at 4°C = 29.921 in. Hg at 0°C
Energy	1 J = 1 N·m = 10 <sup>7</sup> ergs = 10 <sup>7</sup> dyne·cm = 2.778 x 10 <sup>-7</sup> kW·h = 0.23901 cal = 0.7376 ft·lb <sub>f</sub> = 9.486 x 10 <sup>-4</sup> Btu
Power	1 W = 1 J/s = 0.23901 cal s <sup>-1</sup> = 0.7376 ft·lb <sub>f</sub> s <sup>-1</sup> = 9.486 x 10 <sup>-4</sup> Btu s <sup>-1</sup> = 1.341 x 10 <sup>-3</sup> hp

Example: The factor to convert grams to lb<sub>m</sub> is  $\left(\frac{2.20462 \text{ lb}_m}{1000 \text{ g}}\right)$

## SE4011 Formulae Sheet

$$\text{density, } \rho = \frac{\text{mass}}{\text{volume}}$$

$$\text{equation of continuity } \rho_1 A_1 u_1 = \rho_2 A_2 u_2$$

$$F = \mu A \frac{u}{y}, \text{ where } \mu \text{ is viscosity}$$

$$\text{impeller tip speed} = \pi D_i N_i$$

$$\text{impeller Reynolds number, } Re_i = \frac{N_i D_i^2 \rho}{\mu}$$

$$\text{kinematic viscosity, } \nu = \frac{\mu}{\rho}$$

$$\text{mass flowrate, } \dot{m} = \frac{m}{t}$$

$$\text{Power Number, } N_p = \frac{P}{\rho D_i^5 N_i^3}$$

$$\text{pressure, } P = \frac{F}{A} \quad \text{absolute pressure, } P = P_o + P_g$$

$$\text{Reynolds number, } Re = \frac{ud\rho}{\mu}$$

$$\text{specific gravity, s.g.} = \frac{\rho}{\rho_{ref}}$$

$$\text{temperature } T (^{\circ}\text{F}) = 1.8 \times T(^{\circ}) + 32 \text{ and } T (\text{K}) = T(^{\circ}\text{C}) + 273$$

$$\text{volumetric flow rate, } Q = u_{\text{mean}} A$$

**Formulae continued overleaf...**

Reactor design equations:

batch: 
$$t = N_{A0} \int_0^X \frac{dX}{-r_A V}$$

CSTR/WMR: 
$$V = \frac{F_{A0} X}{-r_A}$$

PFR: 
$$V = F_{A0} \int_0^X \frac{dX}{-r_A}$$