CONFIDENTIAL

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2015/2016

COURSE NAME	:	PROCESS TECHNOLOGY
COURSE CODE	:	BNL 40203
PROGRAMME	:	4 BNL
DATE	:	DECEMBER 2015 / JANUARY 2016
DURATION	:	2 HOURS 30 MINUTES
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

THIS QUESTION PAPER CONSISTS OF **NINE (9)** PAGES

Q1 Biodiesel can be produced by converting bleached palm oil (BPO) with methanol to methyl ester under presence of a catalyst. BPO consists of triglyceride, water and free fatty acid (FFA). The chemical structure of triglyceride can be shown in **Figure Q1a**. The long chain of hydrocarbon can be modeled as palmitic acid, $R_1 = R_2 = R_3 = R = (CH_2)_{14}\text{–}CH_3$. The atomic weight of C, O, and H is 12 kg/kmol, 16 kg/kmol, and 1 kg/kmol, respectively.

(a) Calculate the molecular weight of the triglyceride, in kg/kmol

(2 marks)

(b) Write the chemical model and the molecular weight of the associated free fatty acid?

(4 marks)

Esterification and transesterification are two common processes in biodiesel production if the level of FFA is more than 1%. **Figure Q1b** shows the block flow diagram of BPO into biodiesel. The percentage composition of BPO is by weight. The amount of BPO at the feed is 1 MT.

(c) In esterification process, all FFA is converted into biodiesel($X_1 = 100\%$) under an acid catalyst according to the following stoichiometric reaction:

$$\text{FFA} + CH_3OH \longrightarrow \text{BD} + H_2O$$

(i) Write the chemical formula of the produced biodiesel (BD) and the related molecular weight.

(3 marks)

(ii) If the molar ratio of methanol to FFA is at 3:1 to be used, calculate the biodiesel produced and water generated in kilogram after esterification process, stream 3 as shown in **Figure Q1b**. Refer to **Figure Q1b** for the data given.

(4 marks)

(d) In transesterification, TG is converted to biodiesel at a conversion rate of $X_2 = 96\%$ under alkali condition. The stoichiometric reaction is as follows:

$$\mathrm{TG} + 3\mathrm{CH_3OH} \longrightarrow 3\mathrm{BD} + \mathrm{GL}$$

(i) Determine the biodiesel yield converted from this reaction in kilogram.

(4 marks)

(ii) Calculate the remaining trigyceride (TG) at the end of the process at stream 5.

(3 marks)

(iii) Determine the amount of the remaining methanol in stream 5, in kilogram, if the molar ratio of methanol to TG is 4:1 has been used.

(3 marks)

(e) Biodiesel for fuel must follow international standard in term of puritity of the product. Suggest which process technology is suitable to remove:

(i) Glycerol and the remaining catalysts

(1 mark)

(ii) Methanol and water

(1 mark)

Q2 A continuous fractionating column is to be designed to separate 40,000 kg/h of a mixture of 40% benzene (1) and 60% toluene (2) into an overhead product containing 95 % benzene and a bottom product containing 90% toluene. These percentages are by weight. A reflux ratio of 3.5 mol to 1 mol of product is to be used. The molar latent heat of benzene and toluene are 30.8 kJ/kmol and 33.3 kJ/kmol, repectively. The feed has boiling point of 95% at a pressure of 1 atm.

(a) Determine the average molecular weight and the heat of vaporization of the feed.

(4 marks)

(b) Solve the related overall mass balance equation on the entire column for feed, F, bottom product B, and top product D, in kmol.

(4 marks)

(c) Formulate the operating lines for:

(i) the rectification section

(ii) the stripping section

(iii) the feed quality line if the feed is liquid at 20 °C(c_{pL} = 134 kJ/kmol K)

(6 marks)

(d) Construct each operating line on **Figure 2**.

(4 marks)

(e) Propose the number of the theoretical plates and the position of the feed. Justify your answer.

(4 marks)

(f) If cooling water enters the condenser at 25 °C and leaves at 40 °C, determine cooling water required per hour? (c_{pW} = 4.18 kJ/kg C, ρ_w = 1000 kg/m^3)

(3 marks)

Q3 A mixture of 100 mol containing 64 mol % n-pentane and 36 mol % n-heptane is distilled under differential conditions at 101.2 kPa until 60 mol is distilled. The equilibrium data are as follows, where x and y are mole fractions of n-pentane:

x	1	0.867	0.594	0.398	0.254	0.145	0.059	0
y	1	0.984	0.925	0.836	0.701	0.521	0.271	0

(a) Sketch a schematic diagram of the simple distillation.

(4 marks)

(b) Calculate the value of y before distillation starts?

(4 marks)

(c) Plot the function $f = \dfrac{1}{y - x}$ against x on **Figure Q3**.

(4 marks)

(d) Formulate mass and component balances on the entire distillation unit.

(3 marks)

(e) Determine the average composition of the total vapor distilled? Use a simple numerical method for integration.

(6 marks)

(f) What is the composition of the liquid left, in gram?

(4 marks)

Q4 A disk turbine with six flat blades is installed centrally in a vertical baffled tank. The tank has a diameter of 2 m. The turbine is 0.67 m diameter and is positioned 0.67 m above the bottom of the vessel. The turbine blades are 134 mm wide. The vessel is filled to a depth of 2 m with an aqueous solution of 50 % NaOH at 65 °C, which has a viscosity of 12 cP and a density of 1,500 kg/m^3. The turbine impeller turns at 90 RPM.

(a) Calculate the Reynold's number.

(4 marks)

(b) Determine the motor power required.

(6 marks)

(c) Sketch flow pattern inside the vessel with and without baffles.

(6 marks)

(d) A major problem in agitator design is to scale up from laboratory to full–scale unit. List the necessary parameters in upscaling problem of agitator design.

(6 marks)

(e) Static mixers are commonly used for difficult mixing tasks. Sketch the helical element of a static mixer along with the flow direction.

(3 marks)

– END OF QUESTIONS –

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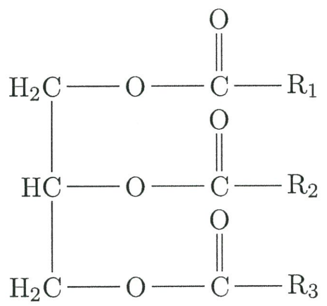

FIGURE Q1a

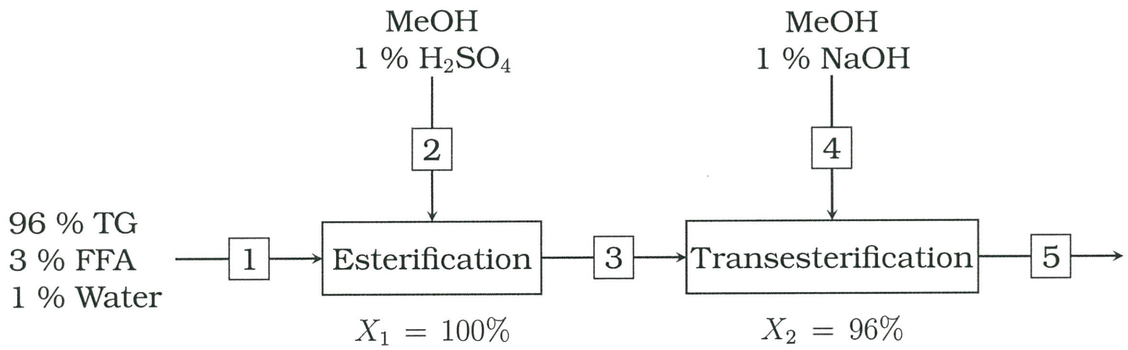

FIGURE Q1b

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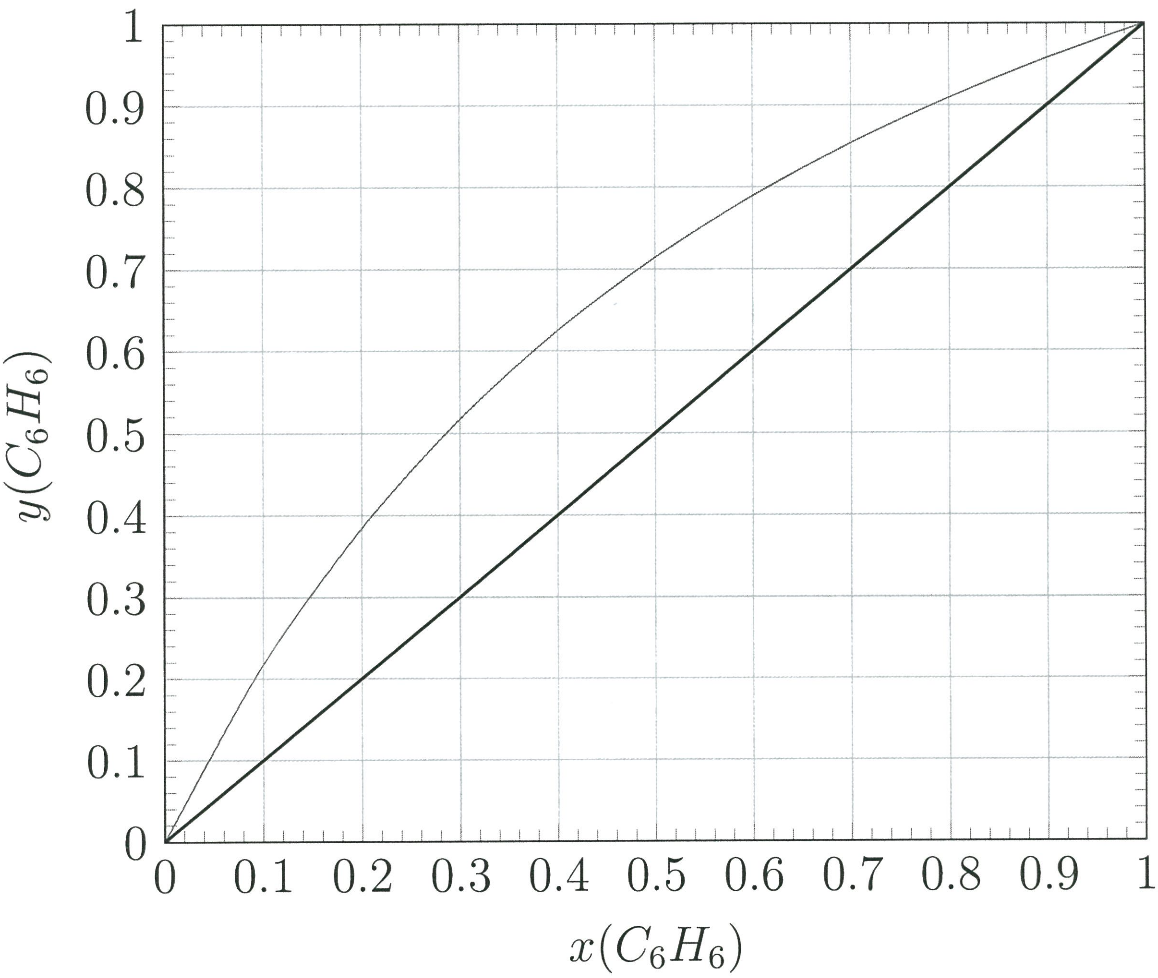

FIGURE Q2

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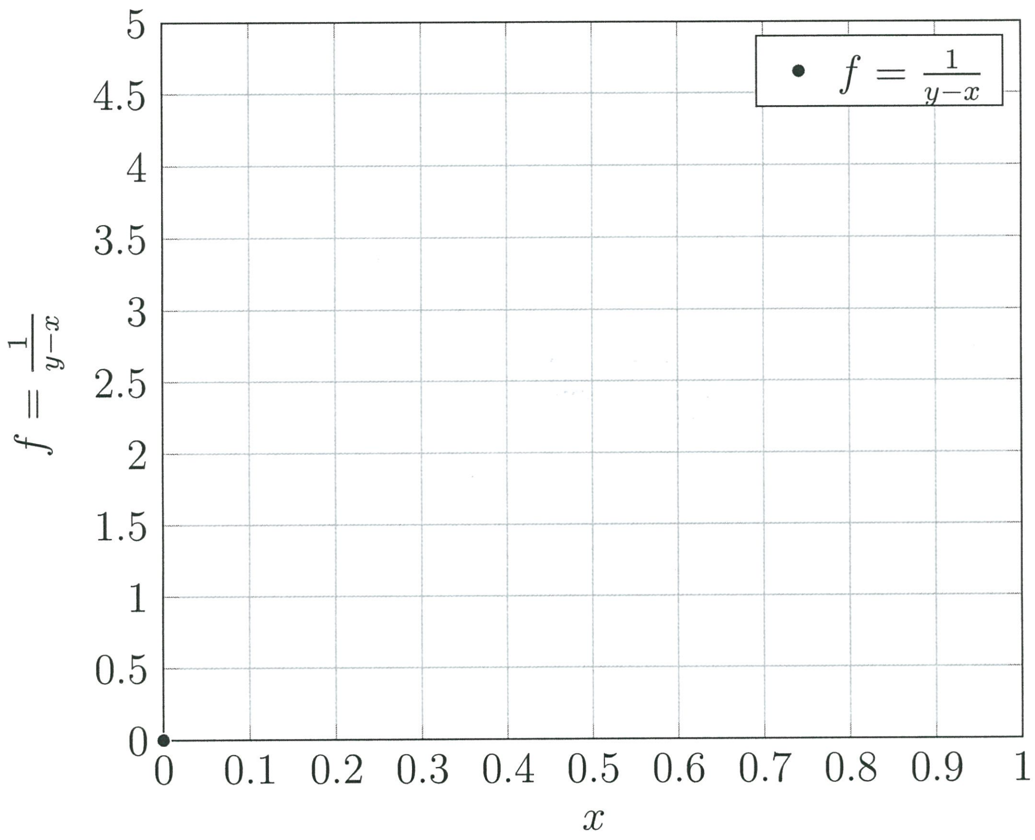

FIGURE Q3

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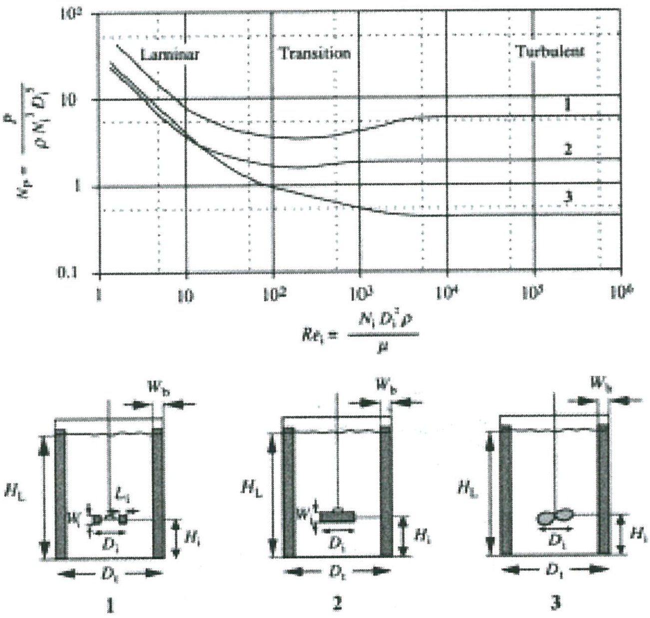

FIGURE Q4

TABLE Q4

Type of impeller	K_L	K_T
Propeller, three blades		
Pitch, 1.0	41	0.32
Pitch, 1.5	48	0.87
Turbine		
Six–blade disk ($S_3 = 0.25, S_4 = 0.2$)	65	5.75
Six–pitched blades ($45°, S_4 = 0.2$)	-	1.63
Four–pitched blades ($45°, S_4 = 0.2$)	44.5	1.27
Flat paddle, two blades ($S_4 = 0.2$)	36.5	1.70
HE–3 impeller	43	0.28
Helical ribbon	52	-
Anchor	300	0.35