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National Exams December 2014

**04-Chem-A5, Chemical Plant Design and Economics**

3 hours duration

**NOTES:**

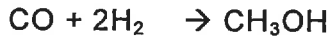
1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. This is a CLOSED BOOK EXAM.
3. Any non-communicating calculator is permitted.
4. FIVE (5) questions constitute a complete exam paper. The questions are of equal value. The candidate may answer any five of the six questions. Only the first five questions as they appear in the answer book(s) will be marked.
5. Most questions require an answer in essay format. Clarity and organization of the answer are important. Some of the questions require calculations – Please show all your steps.

### Question 1 Process Design

(20 marks)

Prepare in the form of a flow sheet, an outline showing the sequence of steps in the complete development of plant for producing methanol ( $\text{CH}_3\text{OH}$ ) from a gas mixture containing CO and hydrogen in stoichiometric amount (that is  $\text{H}_2$  to CO ratio is 2 to 1)

Let's assume the following simple catalytic chemical reaction for the synthesis of methanol:



This reaction occurs at high pressure, say 80 bar and high temperature  $180^\circ\text{C}$  with the presence of a catalyst in slurry form.

A detailed analysis of the points to be considered at each step should be included and the outline should take the project from the initial conceptual idea to the stage where the plant is fully operational.

Boiling Points of the following Gaseous Compounds at 1 atm<sup>1</sup>:

$\text{CH}_3\text{OH}$ :	$65^\circ\text{C}$
$\text{H}_2$ :	$-253^\circ\text{C}$
$\text{N}_2$ :	$-196^\circ\text{C}$
$\text{O}_2$ :	$-183^\circ\text{C}$

<sup>1</sup> Data for  $\text{H}_2$ ,  $\text{N}_2$  and  $\text{O}_2$  extracted from T.M. Duncan and J.A. Reimer (Chemical Engineering Design and Analysis: An Introduction; Ambridge University Press, 1998.)

### Question 2 Cost Estimation

(20 marks)

(a) There are five types of investments needed to build a new plant:

- (i) Battery limits investment
- (ii) Utility investment
- (iii) Off-site investment
- (iv) Engineering fees
- (v) Working capital

Explain in a concise manner, the meaning and importance of each of the above five types of investments that comprise the total capital investment for building a new plant.

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(b) Let us assume that the total capital investment required for building a 24 metric tone per day cement plant is \$50 million. If this plant has a working capital of \$ 1 million and can operate for 360 days per year, how much should be the selling price of the kg of cement to have a turnover ratio of 1.0?

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**Question 3 Depreciation****(20 marks)**

- (a) There are several methods for determining the amount of capital depreciation. Explain in a concise manner two of these methods and list a few of the advantages and disadvantages for each of them.

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- (b) A pump was purchased for \$20,000. If it is depreciated by 4% using the sinking fund method, what would be its annual depreciation charge if the book value of the property after 8 years is the same as if it had been depreciated at \$2000 per year by the straight line method?

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**Question 4 Interest and Investment Costs****(20 marks)**

- (a) Explain in a concise manner the difference between a compounded and a simple interest rate.

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- (b) A loan of \$10,000 was taken to purchase a pressure relief valve at a 4% simple annual interest rate for 5 years. If no interest was paid during those 5 years and the loan was extended for 10 additional years at a new, effective, compound-interest at an annual rate of 6%. What is the total amount owed at the end of 15 years, if no intermediate payments were made?

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**Question 5 Project Risk and Profitability Assessment****(20 marks)**

- (a) Explain in a concise manner two factors that can seriously affect the profitability of a chemical processing plant.

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- (b) When evaluating the feasibility of a plant design project, there are several potential risk factors. List 2 potential risk factors and what you would do to mitigate their impacts.

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- (c) An ethanol manufacturing plant required a fixed capital investment of \$50 million dollars. If it is estimated that the working capital will amount 20% of the total investment and the annual depreciation costs are estimated to be 5% of the fixed capital cost. Calculate, what would be (i) the standard percent return on the total investment and (ii) the minimum payout period, if the annual profit margin from this plant is \$5 million.

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**Question 6 Health and safety and Environmental Issues (20 marks)**

- (a) There are several design optimization methods. Explain briefly and concisely the difference between optimum economic design and optimum operation design.  
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- (b) Three major hazards in processing plants are fire, explosion and toxic release. Explain briefly and in a concise manner what you would do to mitigate their risk factor and how would you do that?  
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- (c) In many chemical plants, there boilers to produce steam, heat and power. Explain in a concise manner, what actions you'd take to prevent these boilers from polluting the environment?  
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