CHEMICAL ENGINEERING 070004

Time : 3 hours

Full Marks: 200

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Instructions :

- (1) Answer all questions following the directions.
- (2) The figures in the margin indicate full marks for the questions.

MATHEMATICS

(Marks: 40)

1. Solve the following differential equation :

$$x(1-x^2)\frac{dy}{dx} + (2x^2 - 1)y = x^3$$

2. Find the eigenvalues and eigenvectors of the matrix :

$$A = \begin{bmatrix} 1 & -2 \\ -5 & 4 \end{bmatrix}$$

3. If $A = \begin{bmatrix} 2 & 1 & 3 \\ 3 & 1 & 2 \\ 1 & 2 & 3 \end{bmatrix}$, then show that

$$A(adj A) = (adj A)A = |A|I$$

4. If $z(x+y) = x^2 + y^2$, then show that

$$\left(\frac{\partial z}{\partial x} - \frac{\partial z}{\partial y}\right)^2 = 4\left(1 - \frac{\partial z}{\partial x} - \frac{\partial z}{\partial y}\right)$$

5. Obtain the Fourier series for the function $f(x) = x^2$, $-\pi < x < \pi$. Hence show that

$$\frac{1}{1^2} + \frac{1}{2^2} + \frac{1}{3^2} + \frac{1}{4^2} + \dots = \frac{\pi^2}{6}$$

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6. If $\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$, then show that

Soli Marks : 200

div
$$\vec{r} = 3$$
 and curl $\vec{r} = \vec{0}$

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- 7. Find all the values of $(1+i)^{1/3}$ and obtain their product.
- 8. Assume that on the average one telephone number out of fifteen called between 2 p.m. and 3 p.m. on weekdays is busy. What is the probability that if six randomly selected telephone numbers are called (a) not more than three and (b) at least three of them will be busy?

PROCESS CALCULATIONS AND THERMODYNAMICS

(Marks : 30)

- **9.** 1000 kg of mixed acid of composition $40\% H_2SO_4$, $45\% HNO_3$ and $15\% H_2O$ is to be produced by strengthening waste acid of composition $30\% H_2SO_4$, $36\% HNO_3$ and $34\% H_2O$ by weight. Concentrated sulphuric acid of strength 95% and concentrated nitric acid containing 80% are available for this purpose. How many kilograms of spent acid and concentrated acids are to be mixed together?
- **10.** Recycling of the fluid stream is an important operation in chemical processing. Explain with a suitable example.
- 11. Propane is burned with excess air to ensure complete combustion. If 55 kg of CO_2 and 15 kg of CO are obtained when propane is completely burned with 500 kg of air, determine the kg of propane burnt and the percentage of excess air required.
- **12.** What do you mean by intensive and extensive properties? Explain with examples.
- 13. State and explain the second law of thermodynamics. A 40 kg steel casting $(C_p = 0.5 \text{ kJ/ kgK})$ at a temperature of 723.15 K is quenched in 150 kg of oil $(C_p = 2.5 \text{ kJ/ kgK})$ at 298.15 K. If there are no heat losses, what is the change in entropy of the steel casting, oil and the both? 2+4=6

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14. Show that for an ideal gas in out the matter per silver could be all state .81

small copilian with an inside $\left(\frac{36}{\sqrt{5}}\right)_T = 0$ and to con $0 = \frac{36}{\sqrt{56}}$

What do you mean by degrees of freedom? How many degrees of freedom each of the following systems have?

Or

- (a) Liquid water in equilibrium with its vapour
- (b) Liquid water in equilibrium with a mixture of water vapour and nitrogen
- (c) A liquid solution of alcohol in water in equilibrium with its vapour

FLUID MECHANICS AND MECHANICAL OPERATIONS

(Marks: 30)

- 15. State the different laws of size reduction. It is desired to crush 100 tons/hour of phosphate rock from a feed size where 80% is less than 4 inch to a product where 80% is less than 1/8 inch. The work index is 2.74. Calculate the power required.
- **16.** Explain with neat sketch, the working principle of an equipment used for the separation of a gas-solid mixture.
- 17. How does free settling differ from hindered settling? Show that the maximum spherical particle diameter of density ρ_s obeying Stokes' law range and settling under gravity in a fluid of density ρ and viscosity μ is given by

$$D_{p_{\text{max}}} = \left[\frac{36\mu^2}{\rho(\rho_s - \rho)g}\right]^{1/3}$$

Or

Explain with neat sketch, the concept of hydrodynamic boundary layer. Why is it important in fluid mechanics?

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2+4=6

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- **18.** State Hagen-Poiseuille equation for flow of a fluid in a circular tube. A small capillary with an inside diameter of $2 \cdot 22 \times 10^{-3}$ m and a length of 0.317 m is being used to continuously measure the flow rate of a liquid having density of 875 kg/m³ and $\mu = 1 \cdot 13 \times 10^{-3}$ Pa.s. The pressure drop reading across the capillary during flow is 0.0655 m water (density 996 kg/m³). What is the flow rate in m³/s? 2+6=8
- Name few flowmeters widely used in industry. Explain the working principle of any one of them.

MASS TRANSFER

(Marks : 19)

20. State and explain the Fick's law of molecular diffusion. Ammonia gas A is diffusing through a uniform tube 0.10 meter long containing N₂ gas B at 1.013×10^5 Pa pressure and 298 K counter-currently. At point 1, $P_{A1} = 1.013 \times 10^4$ Pa and at point 2, $P_{A2} = 0.507 \times 10^4$ Pa. The diffusivity $D_{AB} = 0.230 \times 10^{-4}$ m²/s. Calculate the flux of ammonia at steady state.

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- **21.** With the help of a diagram, derive the material and energy balance equations for different sections of a continuous distillation column.
 - Or

What are the basic criteria for the selection of solvent and stripping medium in absorption?

22. Give the physical significance of the following dimensionless groups in mass transfer :

(a) Sherwood number

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(b) Schmidt number

What are their equivalent numbers in heat transfer?

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CHEMICAL REACTION ENGINEERING

(Marks: 21)

23. Name the different types of ideal reactors. Derive the performance equation of a mixed-low reactor for homogeneous reaction. 1+5=6

Or

Explain the different steps involved in a heterogeneous catalytic reaction. 6

24. Draw the typical concentration-time curves for the following first order reactions :

(i)
$$A \rightarrow R \rightarrow S$$

Or

Explain the following terms related to non-ideal flow :

- (a) Residence time distribution (RTD)
- (b) F curve and C curve
- **25.** Liquid A decomposes by first-order kinetics, and in a batch reactor 50% of A is converted in a 5-minute run. How much longer would it take to reach 75% conversion?
- 26. At 500 K, the rate of a bimolecular reaction is ten times the rate at 400 K. Find the activation energy of this reaction.

INSTRUMENTATION AND PROCESS CONTROL

(Marks: 20)

27. What do you mean by time constant of an instrument? Give the salient points how you would evaluate this parameter in a graphical mode.

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28. A thermometer having a time constant of 0.5 minute is used to measure temperature of a bath which increases linearly at the rate of 0.1 °C/min. Find the difference between the bath temperature and the temperature indicated by the thermometer at t = 0.05 min.

It is desired to measure the temperature of a furnace that operates in the range of 1000°F–5000°F. Select a suitable instrument for the above purpose and explain its working principle.

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Or

- **29.** With the help of a neat sketch, explain the concept of a feedback control system.
- **30.** What are the characteristics of P, PI and PID controllers? Mention one application of each.

Or

What is transfer function? Derive the transfer function for a first-order system.

PLANT DESIGN AND ECONOMICS

(Marks : 10)

- 31. In what ways, the design of storage tank (for liquid storage) is different from the design of pressure vessel? What are the parameters that are evaluated in the design of a storage tank?
 3+2=5
- **32.** What do you understand by the law of supply and demand? What are the factors influencing them?

Or

What is break-even point (BEP)? What is the main objective of determining BEP and what assumptions are made in the determination of BEP relationship?

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HEAT TRANSFER

(Marks: 15)

33. What is the total rate of heat loss per hour from a 0.5 m by 0.5 m by 1 m container having 5 cm thick walls of an insulated material of thermal conductivity $K = 0.04 \text{ W} / (\text{m}^{\circ}\text{C})$ for a temperature difference of 30 °C between inside and outside? Neglect the thermal resistances for heat transfer coefficient at the inside and outside surfaces.

Or

Name the different types of heat exchangers used in chemical industries. Explain the concept of extended surface heat exchanger.

- **34.** Define view factor and radiocity. Determine the view factors F_{12} and F_{21} for an enclosure formed by two concentric spherical surfaces. The outer surface has an area A_2 and inner one has an area A_1 . 2+3=5
- **35.** What is Colburn J_H factor? Explain how heat transfer coefficient can be determined with the help of J_H factor. 5

CHEMICAL TECHNOLOGY

(Marks: 15)

- **36.** What are the major engineering problems associated with urea production?
- **37.** Discuss very briefly the manufacturing of white sugar touching the following points :
 - (a) Raw materials
 - (b) Clarification process
 - (c) Byproducts utilization

Or

What is black liquor? How is black liquor converted to white liquor?

38. What do you mean by synthetic fibre? Give examples (at least two) along with their uses.

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