SEMESTER I

Discipline: Chemical Engineering

Stream: CH2 (Computer Aided Process Design)

221TCH100	COMPUTATIONAL METHODS IN CHEMICAL ENGINEERING	CATEGORY	L	T	P	CREDIT
		Discipline Core 1	3	0	0	3

Preamble:
Most of the real-life problems are unsolvable using known analytic techniques, thus depending on numerical methods is imperative. This course focuses on the use of modern computational and mathematical techniques in chemical engineering. Statistical analysis of data is also covered.

Pre-requisites- Nil

Course Outcomes:

After the completion of the course the student will be able to

CO 1	Solve polynomial and transcendental equations using appropriate numerical techniques.
CO 2	Solve linear and nonlinear algebraic equations using appropriate numerical techniques.
CO 3	Solve ordinary differential equations using appropriate numerical techniques.
CO 4	Apply appropriate numerical techniques for polynomial interpolation, differentiation and integration.
CO 5	Solve PDE's by numerical methods
CO 6	Apply statistical methods in data analysis

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1				3			
CO 2				3			
CO 3				3			
CO 4				3	3		
CO 5				3	3		
CO 6				3			

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	70 %
Analyse	30 %
Evaluate	
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 marks

Micro project/Course based project : 20 marks

Course based task/Seminar/Quiz : 10 marks

Test paper, 1 no. : 10 marks

The project shall be done individually. Group projects not permitted. Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern: 60 marks

The end semester examination will be conducted by the university. There will be two parts; Part A and Part B.

Part A will contain 5 numerical/short answer questions with one question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions.

Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Model Question paper

QP CODE: PAGES:

Reg No: …………… Name: ……………

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
FIRST SEMESTER M.TECH DEGREE EXAMINATION, MONTH & YEAR
Course Code: 221TCH100

Marks:60 Max Duration: 2.5 Hours

COMPUTATIONAL METHODS IN CHEMICAL ENGINEERING

PART A

Answer all questions, each carries 5 marks

1. Air at 25°C and 1 atm flows through a 4 mm diameter tube with an average velocity of 50 m/s. The roughness is ε = 0.0015 mm. Make use of Newton – Raphson method to determine the friction factor using the Colebrook equation given below.

$$\frac{1}{f} = -2.0\ log\left(\frac{\varepsilon/D}{3.7} + \frac{2.51}{R_e\sqrt{f}}\right)$$

2. Use Runge–Kutta second order method to integrate
$f(x, y) = -2x^3 + 12x^2 - 20x + 8.5;\ y(0) = 1.$ Find $y(1)$ if step size, h = 0.5.

3. The following data gives the melting point of an alloy of lead and zinc, where t is the temperature in ^{0}C and P is the percentage of lead in the alloy:

p	40	50	60	70	80	90
t	184	204	226	250	276	304

Using Newton's interpolation formula, find the melting point of the alloy containing 84 percent of lead.

4. Elaborate the procedure to solve the Laplace equation numerically.

5. A book contains 500 pages. If there are 200 typing errors randomly distributed throughout the book, use the Poisson distribution to determine the probability that a page contains exactly three errors.

(5 x5 = 25)

PART B

Answer any five questions, each carries 7 marks

6. Solve the following equations by Jacobi's iteration method
   $10x-2y-3z=205; -2x+10y-2z=154; -2x-y+10z=120$

7. The concentration of salt x in a homemade soap maker is given as a function of time by $\frac{dx}{dt}=37.5-3.5x$. At the initial time, t = 0, the salt concentration in the tank is 50 g/L Using Runge-Kutta 4^{th} order method and a step size of, h = 0.75 min, determine the salt concentration after 3 minutes.

8. Find y(2) by Adam Bashforth predictor method given

x	0	0.5	1	1.5
y	2	2.636	3.595	4.968

$$y' = \frac{x+y}{2}$$

9. The velocity v (km/min) of a moped which starts from rest is given at fixed intervals of time t (min) as follows:

t	2	4	6	8	10	12	14	16	18	20
v	10	18	25	29	32	20	11	5	2	0

   Estimate approximately, the distance covered in 20 minutes.

10. Solve the equation below subject to the initial condition u(x, y, 0) = sin 2□x sin 2□y,0 ≤ x, y ≤ 1, and the conditions u(x, y, t) = 0, t > 0 on the boundaries.
    $\frac{\partial u}{\partial t}=\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}$. Obtain the solution up to one time level with h = 1/3 and α = 1/8

11. Is education level independent of gender? A random sample of 395 people were surveyed and each person was asked to report the highest education level they obtained. The data that resulted from the survey is summarized in the table below.

	High School	Bachelors	Masters	Ph.d.	Total
Female	60	54	46	41	201
Male	40	44	53	57	194
Total	100	98	99	98	395

Are gender and education level dependent at 5% level of significance? Use Ch-Square test.

12. It is desired to determine the variability of silver plating done by two companies. Independent random samples of size 12 of work of companies 1 and 2 yield standard deviation 0.035 and 0.062 respectively. Test the null hypothesis $\sigma_1^2 = \sigma_2^2$ against the alternate hypothesis $\sigma_1^2 < \sigma_2^2$ at the 0.05 level of significance.

(5 x7 = 35)

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Syllabus

Module I (7 hours)

Numerical solution of polynomial and transcendental equations - bisection method - method of false position - Newton-Raphson method; Systems of linear equations-Direct methods: Gauss Elimination, Matrix Inversion, Thomas algorithm for tridiagonal systems; Indirect methods– Jacobi, Gauss Seidel methods, Solution of system of nonlinear equations by Newton-Raphson method

Module II (7 hours)

Numerical solution of ordinary differential equations. The Taylor series method - Euler and modified Euler methods - Runge–Kutta methods (2nd order and 4th order only) - multistep methods - Milne's predictor - corrector formulas - Adam-Bashforth & Adam-Moulton formulas

Module III (8 hours)

Polynomial interpolation. Lagrange's interpolation polynomial - divided differences Newton's divided difference interpolation polynomial - finite difference operators - Gregory – Newton forward and backward interpolations - Stirling's interpolation formula - Numerical differentiation - differential formulas in the case of equally spaced points - numerical integration - trapezoidal and Simpson's rules - Gaussian integration

Module IV (8 hours)

Partial differential equations- classification, solution of elliptic, hyperbolic and parabolic partial differential equations by finite difference equations- Poisson, Laplace, Heat and Wave equations

Module V (10 hours)

Introduction to Statistics: Probability distribution: Bimodal, Poisson, Uniform, Normal, Correlation and Regression, Linear regression, Confidence limits, types of errors, testing of hypothesis based on normal, Chi-square test, F-test, Z-test, Student's T-test. Comparison of means and variances

Course Plan

No	Topic	No. of Lectures
1	**Numerical solution of polynomial and transcendental equations (7Hrs)**	
1.1	Numerical solution of polynomial and transcendental equations - bisection method - method of false position - Newton-Raphson method	2
1.2	Systems of linear equations-Direct methods: Gauss Elimination, Matrix Inversion, Thomas algorithm for tridiagonal systems	2
1.3	Indirect methods– Jacobi, Gauss Seidel methods	2
1.4	Solution of system of nonlinear equations by Newton-Raphson method	1
2	**Module II : Numerical solution of ordinary differential equations(7 hours)**	
2.1	Numerical solution of ordinary differential equations. The Taylor series method - Euler and modified Euler methods - Runge–Kutta methods (2nd order and 4th order only)	4
2.2	Multistep methods - Milne's predictor - corrector formulas - Adam-Bashforth & Adam-Moulton formulas	3
3	**Module III : Polynomial interpolation(8 hours)**	
3.1	Polynomial interpolation. Lagrange's interpolation polynomial	1
3.2	Divided differences Newton's divided difference interpolation polynomial	1
3.3	Finite difference operators - Gregory – Newton forward and backward interpolations - Stirling's interpolation formula	3
3.4	Numerical differentiation - differential formulas in the case of equally spaced points	1
3.5	Numerical integration - trapezoidal and Simpson's rules - Gaussian integration	2
4	**Module IV: Partial differential equations (8 hours)**	
4.1	Partial differential equations- classification	1

4.2	Solution of elliptic, hyperbolic and parabolic partial differential equations by finite difference equations- Poisson, Laplace, Heat and Wave equations	7
5	**Module V: Introduction to Statistics (10 hours)**	
5.1	Introduction to Statistics: Probability distribution: Bimodal, Poisson, Uniform, Normal	2
5.2	Correlation and Regression, Linear regression, Confidence limits, types of errors	2
5.3	Testing of hypothesis based on normal, Chi-square test, F-test, Z-test, Student's T-test, Comparison of means and variances	6

Reference Books

1. Steven Chapra and Raymond Canale, Numerical Methods for Engineers, 8th Edition, Mc Graw Hill.
2. Norman W. Loney, Applied Mathematical Methods for Chemical Engineers, 2nd Edition, Taylor & Francis, 2007.
3. Richard A. Johnson – Probability and Statistics for engineers (PHI)
4. Froberg C.E., Introduction to Numerical Analysis, Addison Wesley
5. Gerald C.F., Applied Numerical Analysis, Addison Wesley
6. Hildebrand F.B., Introduction to Numerical Analysis, T.M.H.

221TCH003	PROCESS DESIGN I	CATEGORY	L	T	P	CREDIT
		Program Core 1	3	0	0	3

Preamble: Before setting up a process plant, it is very important to design the process equipment involved. This course covers key elements of process design engineering, thermal and hydraulic design of process equipment such as heat exchangers, condensers, reboilers and evaporators.

Pre-requisites- Nil

Course Outcomes:

After the completion of the course the student will be able to

CO 1	Apply the basic concepts, industrial practices and theoretical relationships useful for the design of process equipment
CO 2	Utilize physicochemical properties of pure and mixed fluids for process design
CO 3	Utilize proper codes & standards, empirical equations and rules of thumbs in the design of chemical engineering units
CO 4	Utilize proper equations and codes & standards to calculate energy requirements for equipment.
CO 5	Apply the principles of heat transfer to engineering situations and the design of equipments.
CO 6	Apply the principles of heat & mass transfer to engineering situations and the design of equipments involving combined heat & mass transfer.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1			3	3			
CO 2			3	3			
CO 3			3	3	2	2	
CO 4			3	3	2	2	
CO 5			3	3			
CO 6			3	3			

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	100%
Analyse	
Evaluate	
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Micro project/Course based project : 20 marks

Course based task/Seminar/Quiz : 10 marks

Test paper, 1 no. : 10 marks

The project shall be done individually. Group projects not permitted. Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

- Question paper contains 2 numerical design questions from each module of which student shall have to answer any one from each module. Each question carries 50 marks. There can be subdivisions for the main question. Data required for design such as equilibrium data and physical properties, type of equipment, material of construction etc., in case it cannot be obtained from handbook shall be provided with the question.

Apart from scientific calculators (including programmable) the following books and databooks are permitted for the exam:

1. Steam tables
2. Perry's Handbook
3. Nomographs, charts and tables used in design taken from IS codes/ / Other editions of Handbook as directed by university

Model Question Paper

QP CODE: **PAGES: 2**

Reg No:_______________ **Name: _______________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 221TCH003

Max. Marks: 60 Duration: 2.5 hours

PROCESS DESIGN I

Instructions:

Apart from scientific calculators (including programmable) the following books and data books are permitted for the exam:

i. *Steam tables*
ii. *Perry's Handbook*
iii. *Nomographs, charts and tables used in design taken from IS codes/ / Other editions of Handbook as directed by university*
iv. *All photocopies should be attested by department faculty*

(Answer any **one** full question from each module. Each question carries 50 marks)

MODULE I

1. Aniline is to be cooled from 90 to 60°C in a double- pipe heat exchanger. For cooling, a stream of toluene amounting to 3900 kg/h at a temperature of 38°C is available. The exchanger consists of $1^1/_4$ in. Schedule 40 pipe, in 2-in. Schedule 40 pipe. The aniline flow rate is 4535 kg/h. Design the exchanger.
Properties at the mean temperature are:

Properties	Aniline	Toluene
Density, kg/m3	994	840
Viscosity, Pa.s	1.245 x10^{-3}	4.19 x 10^{-4}
Thermal conductivity, W/m.K	0.1624	0.1382
Specific heat, kJ/Kg.K	2.173	1.795

OR

2. Cumene at a flow rate of 100,000 kg/hr enters the exchanger at 50°C and leaves at 30°C. Cooling water at a rate of 95,000 kg/hr enters at 18°C is used for cooling. The tube material is Cr alloy (km = 60.5 W/m K). Fouling factors of 0.253x10^{-3} m^2 K/W for water and 0.75x10^{-4} m^2 K/W for cumene are specified. The overall heat transfer coefficient is in the range of 1000-1500 W/m^2 K. The permissible maximum pressure drop on each side is 30 kPa. Design the shell-and-tube heat exchanger by Bell's method. The properties at the mean temperatures are given.

Properties	Cumene	Water
Density, kg/m^3	847	998
Viscosity, cP	0.611	1
Thermal conductivity, W/m K	0.1201	0.598
Specific heat, J/kg K	1802	4180

MODULE II

3. A reboiler of a distillation column is required to supply 10 kg/s of toluene vapour. The column operating pressure at the bottom of the column is 1.6 bar. At this pressure, the toluene vaporizes at 127°C and can be assumed to be isothermal. Steam at 160°C is to be used for the vaporization. The latent heat of vaporization of toluene is 344,000 J/kg, the critical pressure is 40.5 bar and critical temperature is 594 K. The film coefficient (including fouling) for the condensing steam can be assumed to be 5700 W/m^2 K. Design a suitable kettle reboiler.

OR

4. A triple effect evaporator is used to produce a 50% NaOH solution from a feed containing 25% NaOH. Steam is available at 320°F, and the vapour from the last stage is condensed at 120°F. Backward feed is used. Equal amounts of water are removed in each effect, (a)what would be the concentrations in the intermediate effects, the boiling point elevation in each effect, and the net temperature differences available for heat transfer? (b) Calculate the steam consumption, the economy, and the heating surface area required, if overall heat transfer coefficients for each effects are 600, 750, 800 W/m^2 K, respectively.

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SYLLABUS

Module I (22 hours)

Introduction to Chemical Engineering Design, Goals of Engineering Design, Design Constraints, Sustainable Design, Codes and Standards for Design, Design margin and Optimum design. Process Design development: Typical Design Steps, Types of Process Design. Introduction to Process Flow diagram, Property estimation, Material and Energy Balance, Piping and Instrumentation Diagram, Selection of Process Equipment

Heat Exchanger: Classification of Exchangers, Basic design parameters, Design of Double pipe exchanger, Hairpins in series, hairpins in series-parallel, Design of Finned Double Pipe Heat Exchangers: Longitudinal fins. Fin efficiency.
Process design of Shell and Tube heat exchanger: Types of Shell and Tube exchangers, Thermal Design Considerations, Kern's method, Bell's method.

Module II (18 hours)

Process design of shell and tube exchanger for two phase heat transfer: Condenser- Types of condensers, Design of horizontal Condenser, Reboilers-Classification of reboilers, Design of Kettle reboiler.

Design of Evaporator: Types of evaporators, General design consideration of evaporator, Design of Short tube evaporator. Multiple effect evaporators-Methods of feeding of evaporators, Mass and Heat Balances in multiple effect evaporators, Boiling point rise, Enthalpy-Concentration Diagrams.

Course Plan

No	Topic	No. of Lectures
1	**Module I: (Introduction and heat exchangers) (22 hours)**	
1.1	Introduction to Chemical Engineering Design, Goals of Engineering Design, Design Constraints, Sustainable Design, Codes and Standards for Design, Design margin and Optimum design.	2
1.2	Process Design development: Typical Design Steps, Types of Process Design.	1
1.3	Introduction to Process Flow diagram, Property estimation, Material and Energy Balance, Piping and Instrumentation Diagram, Selection of Process Equipment	3
1.4	Heat Exchanger: Classification of Exchangers, Basic design parameters.	2
1.5	Design of Double pipe exchanger, Hairpins in series, hairpins in series-parallel	4

1.6	Design of Finned Double Pipe Heat Exchangers: Longitudinal fins. Fin efficiency	2
1.7	Process design of Shell and Tube heat exchanger: Types of Shell and Tube exchangers, Thermal Design Considerations.	3
1.8	Kern's method.	2
1.9	Bell's method.	3
2	**Module II (Two-phase heat transfer equipment) (18 hours)**	
2.1	Process design of shell and tube exchanger for two phase heat transfer: Condenser- Types of condensers.	2
2.2	Design of horizontal Condenser	3
2.3	Reboilers-Classification of reboilers, Design of Kettle reboiler.	4
2.4	Design of Evaporator: Types of evaporators, General design consideration of evaporator	2
2.5	Design of Short tube evaporator.	2
2.6	Multiple effect evaporators-Methods of feeding of evaporators, Mass and Heat Balances in multiple effect evaporators, Boiling point rise, Enthalpy-Concentration Diagrams.	5

Reference Books

1. Perry's Chemical Engineering Hand Book, McGrawHill.
2. D.Q. Kern, Process Heat Transfer, McGraw Hill, 1950
3. Robin Smith, Chemical Process Design and Integration, John Wiley and Sons. Ltd., New Delhi
4. McCabe and Smith, Unit Operations in Chemical Engineering, McGrawHill
5. Christie John Geankoplis, Transport Processes and Separation Process Principles, 4th Edition
6. G. Towler and R. Sinnott, Chemical Engineering Design: Principals, Practice and Economics of Plant and Process Design, Elsevier
7. J. Douglas, Conceptual Design of Chemical Processes, McGrawHill
8. L. T. Biegler, I. E. Grossmann, and A. W. Westerberg, Systematic Methods of Chemical Process Design, Prentice Hall International Series in the Physical and Chemical engineering Sciences.

221TCH004	CHEMICAL REACTOR THEORY	CATEGORY	L	T	P	CREDIT
		Program Core 2	3	0	0	3

Preamble:

Sound knowledge in Reaction Engineering is very important for Chemical Engineers. The goal of this course is to develop a critical approach to chemical reactor design. This course would enable students to gain knowledge with respect to kinetics of heterogenous reaction and catalysis. Also provide a sound knowledge in obtaining the kinetics of solid catalysed reaction and solid non catalysed reaction. This course would make the students to expertise in the design of solid catalysed and solid non-catalysed reactors.

Pre-requisites- Nil

Course Outcomes:

After the completion of the course the student will be able to

CO 1	Explain the principles of chemical kinetics of heterogenous reactions.
CO 2	Determine adsorption isotherm and surface area of catalyst.
CO 3	Obtain the kinetics of solid catalysed reactors.
CO 4	Design of solid catalysed reactors.
CO 5	Obtain the kinetics of solid non-catalysed reactors.
CO 6	Design of solid non-catalysed reactors.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1			3				
CO 2			3				
CO 3			3				
CO 4			3	3			
CO 5			3				
CO 6			3	3			

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	50
Analyse	30
Evaluate	20
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 marks

Micro project/Course based project : 20 marks

Course based task/Seminar/Quiz : 10 marks

Test paper, 1 no. : 10 marks

The project shall be done individually. Group projects not permitted. Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern: 60 marks

Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 5 marks for each question. Students shall answer all questions.

Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student shall answer any five. Each question can carry 7 marks. Total duration of the examination will be 150 minutes.

Model Question Paper

QP CODE: **PAGES:**

Reg No:_______________ **Name: _______________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 221TCH004

Max. Marks: 60 Duration: 2.5 hours

CHEMICAL REACTOR THEORY

PART – A

Answer All the Questions.

(5x5 = 25)

1. What is catalyst? Briefly explain the steps involved in solid catalyzed reactions.
2. Consider the chemical reaction A→B taking place within a flat plate shaped catalyst pellet with intrinsic reaction rate $-r_A = kC_A$. How is the isothermal effectiveness factor related to Thiele modulus for the system? In which condition the diffusion free region and strong diffusion resistance region are observed?
3. Draw the models and symbols used to describe the K-L bubbling gas fluidized bed
4. Spherical particles of a sulphide ore 2 mm in diameter are roasted in an air stream at a steady temperature. Periodically small samples of the ore are removed, crushed and analysed with the following results:

Time (min)	15	30	60
Fractional conversion	0.334	0.584	0.880

   Are these measurements consistent with a shrinking core and chemical reaction rate proportional to the area of the reaction zone? If so, estimate the time for complete reaction of the 2 mm particles, and the time for complete reaction of similar 0.5 mm particles
5. A feed consisting of 30% of 50 µm radius particles, 40% of 100 µm radius particles, and 30% of 200 µm radius particles is to be fed continuously in a thin layer onto a moving grate crosscurrent to a flow of reactant gas (Fig. 1). For the planned operating conditions the time required for complete conversion is 5, 10, and 20 minutes for the three sizes of particles. Find the conversion of solids on the grate for a residence time of 8 minute in the reactor.

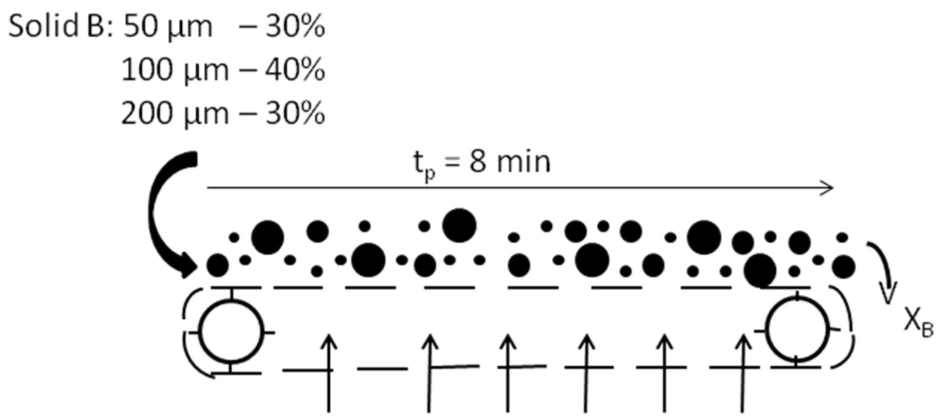

Fig. 1

PART – B

Answer any five (5 x 7 = 35)

6. Describe on Langmuir-adsorption isotherm.

7. Explain the effectiveness factor? What is the relation between Thiele modulus and effectiveness factor, if a first order isothermal reaction occurs in a spherical catalyst pellet?

8. Discuss about the spectrum of kinetic regions in a solid catalyzed reaction. How is the effect of these regions differed for porous and non-porous catalysts?

9. Discuss are the stages involved in the transition from fixed bed reactor to pneumatic conveying reactor? Briefly explain about Geldart classification of solids in bubbling fluidized bed.

10. Shrinking-Core Model is assumed for a non-catalytic fluid-spherical particle reaction. Compare the process for unchanging particle size and changing particle size.

11. Shrinking-Core Model of unchanging particle size is assumed for a non-catalytic fluid-spherical particle reaction. How is the shrinking core size related to the time if chemical reaction is the rate controlling step.

12. A stream of particle of single size are 80% converted (SCM/ ash diffusion control, uniform gas environment) on passing through a reactor. If the reactor is made twice the size but the same gas environment, same feed rate and the same flow pattern of solid, what would be the conversion of the solids? Assume that the solids are in plug flow condition.

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Syllabus

Module 1 (7 hours)

Heterogeneous process: Global rate of reaction, variables affecting heterogeneous reaction, complications involved in heterogenous system, catalysis, general characteristics, Physical and chemisorption. Adsorption isotherms-Langmuir-adsorption isotherm -Temkin isotherm. Determination of surface area of catalyst- Brunauer -Emmett-Teller (BET) method-Helium Hg method. Classification of catalyst, catalyst preparation, catalyst deactivation (No kinetics)

Module 2 (9 hours)

Solid Catalysed reactions: The rate equation-Langmuir-Hinshelwood model-surface reaction, adsorption and desorption control, Rate equation for surface kinetics, pore diffusion resistance combined with surface kinetics, Performance equation for reactors containing porous catalyst particles-plug flow-mixed flow, Experimental methods for finding the rates-Differential reactor-Integral reactor-mixed flow reactor-Recycle reactor

Module 3 (9 hours)

Experimental heterogeneous solid catalysed reactors: Packed bed catalytic reactor-various types-Staged packed bed reactors-staged mixed flow reactors-staged packed with recycle. Suspended solid reactors- Bubbling Fluidised Bed (BFB)- K-L model for BFB-first order catalytic reactions in BFB.

Module 4 (8 hours)

Solid non- catalysed reactions: Kinetics-selection of a model, Shrinking core model – Diffusion through gas film controls, Ash layer controls, chemical reaction controls, limitation of the shrinking core model, determination of the rate controlling step.

Module 5 (7 hours)

Solid non-catalysed reactor: Design- Particles of a single size plug flow of solids of uniform gas composition, mixture of particles of different but unchanging size plug flow of solids of uniform gas composition, mixed flow of particles of a single unchanging size of uniform gas composition, mixed flow of a size of mixture of unchanging size of uniform gas composition.

Course Plan

No	Topic	No. of Lectures
1	**Module-1-Heterogeneous process (7 hours)**	
1.1	Global rate of reaction, variables affecting heterogeneous reaction, complications involved in heterogenous system	1
1.2	Catalysis, general characteristics, Physical and chemisorption.	1
1.3	Adsorption isotherms-Langmuir-adsorption isotherm -Temkin isotherm.	2
1.4	Determination of surface area of catalyst- Brunauer -Emmett-Teller (BET) method-Helium Hg method.	2
1.5	Classification of catalyst, catalyst preparation, catalyst deactivation (No kinetics)	1
2	**Module 2-Solid Catalysed reactions: Kinetics (9 hours)**	
2.1	The rate equation-Langmuir-Hinshelwood model-surface reaction, adsorption and desorption control	3
2.2	Rate equation for surface kinetics, pore diffusion resistance combined with surface kinetics	2
2.3	Performance equation for reactors containing porous catalyst particles-plug flow-mixed flow	2
2.4	Experimental methods for finding the rates- Differential reactor-Integral reactor-mixed flow reactor-Recycle reactor	2
3	**Module 3- Experimental heterogeneous solid catalysed reactors (9 hours)**	
3.1	Packed bed catalytic reactor-various types	1
3.2	Staged packed bed reactors-staged mixed flow reactors-staged packed with recycle	2
3.3	Suspended solid reactors- Bubbling Fluidised Bed (BFB)	2
3.4	K-L model for BFB	2
3.5	First order catalytic reactions in BFB	2
4	**Module 4- Solid non- catalysed reactions: Kinetics (8 hours)**	
4.1	Selection of a model	1
4.2	Shrinking core model – Diffusion through gas film controls	2
4.3	Shrinking core model- Ash layer controls, chemical reaction controls	2
4.4	Limitation of the shrinking core model	1
	Determination of the rate controlling step.	2
5	**Module 5-Solid non-catalysed reactor: Design (7 hours)**	
5.1	Particles of a single size plug flow of solids of uniform gas composition	1
5.2	Mixture of particles of different but unchanging size plug flow of solids of uniform gas composition	2

5.3	Mixed flow of particles of a single unchanging size of uniform gas composition	2
5.4	Mixed flow of a size of mixture of unchanging size of uniform gas composition	2

Reference Books

1. Levenspiel Octave, “Chemical Reaction Engineering”, John Wiley & Sons, Third Edition.
2. Smith J.M, “Chemical Engineering Kinetics,” McGraw Hill
3. H Scott Fogler, “Elements of Chemical Reaction Engineering”, Prentice Hall of India, Fifth Edition.
4. James J Carberry, “Chemical &Catalytic Reaction Engineering”, Mc Graw Hill.
5. K.G Denbigh& J.C.R Turner, “Chemical Reactor Theory- An Introduction”, Cambridge University Press.

221ECH012	COMPUTATIONAL FLUID DYNAMICS	CATEGORY	L	T	P	CREDIT
		Program Elective 1	3	0	0	3

Preamble: Computational fluid dynamics is widely used in different types of industries to analyze, optimize and verify performance of flow system designs prior to fabrication. In this course, a detailed study of Computational Flow Modelling, Solution of model equations, and application in multiphase flows is included.

Pre-requisites- Nil

Course Outcomes:

After the completion of the course, the student will be able to

CO 1	Explain the major theories, approaches, and methodologies used in CFD
CO 2	Apply knowledge of basic science and engineering fundamentals to solve practical problems
CO 3	Solve the governing equations for fluid flow numerically.
CO 4	Apply turbulence models to engineering fluid flow problems.
CO 5	Describe the issues in multiphase flow modelling.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1			**3**	**3**			
CO 2	2		**3**	**3**	**3**		
CO 3			**3**	**3**	**3**		
CO 4			**3**	**3**	**3**		
CO 5			**3**	**3**	**3**		

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	70
Analyze	30
Evaluate	
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 marks

Preparing a review article based on peer-reviewed original publications (minimum 10 publications shall be referred) **: 15 marks**

Course-based task/Seminar/Data collection and interpretation **: 15 marks**

Test paper, 1 no. **: 10 marks**

Test paper shall include a minimum 80% of the syllabus.

End Semester Examination Pattern: 60 marks

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B.

Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students).Students should answer all questions.

Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry

7 marks.

Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

Total duration of the examination will be 150 minutes.

Model Question Paper

QP CODE: **PAGES:**

Reg No:_______________ **Name: _______________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 221ECH012

Max. Marks: 60 Duration: 2.5 hours

COMPUTATIONAL FLUID DYNAMICS

PART A (Answer ***all*** questions)

1.	What are the applications of CFD?	5
2.	What are the properties of discretization schemes?	5
3.	Define Peclet number. Explain its physical significance in the convection-diffusion problem.	5
4.	What is meant by staggered grid? What is the importance of staggered grid for the incompressible flow computations.	5
5.	What are the advantages and disadvantages of κ -ε model?	5

PART B (Answer ***any five*** questions)

6.	Write the governing equations used in CFD in generic form.	7
7.	Solve the set of algebraic equations using Gauss elimination and Gauss-Siedel method $-3x + y + 12z = 50$ $6x - y - z = 3$ $6x + 9y + z = 40$	7
8.	Using Taylor's series derive first-order forward difference and backward difference expression for $\frac{\partial u}{\partial x}$	7
9.	Using the Finite volume method derive the discretized equation for two-dimensional diffusion problems	7
10.	Explain false diffusion. How the false diffusion can be avoided?	7
11.	Explain the SIMPLER algorithm for the solution of incompressible fluid	7

flows.

12. Explain the terms (i) Turbulent kinetic energy and (ii) dissipation. 7

SYLLABUS

Module 1 (8 hours)

Introduction to Computational fluid dynamics. Advantages, Applications: emphasis on Chemical Engineering Applications. CFD Solution procedure. Pre-processor, solver, post-processor. Index notation of Vectors and Tensors. Methods of analysis: System and Control Volume, Differential vs Integral approach. Methods of Description: Eulerian and Lagrangian descriptions, Total derivatives. Reynolds Transport Theorem. Governing equations: Mass, Momentum, and Energy Conservation Equations, Navier Stoke equation, Generic form of conservation equations—non-dimensional forms- Phenomenological models

Module 2 (8 hours)

Classification of PDEs: Elliptic, Parabolic, and Hyperbolic. Classification of boundary conditions: Dirichlet, Neumann, Mixed and Robin boundary conditions.

Introduction to finite difference methods: Discretization methods, Taylor series and polynomial approximation methods. Solution of elliptic equations, Solution of Parabolic equations: Explicit, Implicit, and Crank- Nicholson methods. Solution of hyperbolic equations: Lax method, McCormack method

Linear algebraic equations: Elimination and Iterative methods. Properties of numerical solutions. Structured and unstructured grids.

Module 3 (8 hours)

Introduction to finite volume method: Finite volume method for one-dimensional steady-state diffusion: Numerical problems, Finite volume method for two-dimensional and three-dimensional diffusion problems. Steady one-dimensional convection and diffusion: Numerical problems: The central differencing scheme, upwind schemes, and Higher-order differencing schemes for convection-diffusion problems. Analysis of different schemes for convection-diffusion problems

Module 4 (8 hours)

Solution algorithms for pressure-velocity coupling in steady flows. Need for a special procedure. Vorticity-based methods. Representation of pressure gradient and continuity equation. 'Checker board' pressure field. Staggered grid. Momentum equations, Pressure and velocity corrections. Pressure correction equation. SIMPLE algorithm. SIMPLER algorithm.

Module 5 (8 hours)

Turbulence modeling. Need for turbulence modelling. Closure problem. Reynolds averaged Navier Stokes equation. Turbulent flow calculations, RANS, Large eddy simulation, Direct numerical simulation. k-ε two-equation turbulence model,

Multiphase flow modeling in CFD, Classification of multiphase flow, Industrial examples, Examples for multiphase reactors, Multiphase flow modeling approaches Eulerian-Lagrangian approach, Eulerian – Eulerian Approach, Volume of fluid approach,

Course Plan

No	Topic	No. of Lectures
1	**Module 1 (8 hrs)**	
1.1	Introduction to Computational fluid dynamics. Advantages, Applications: emphasis on Chemical Engineering Applications. CFD Solution procedure. Pre-processor, solver, post-processor.	1
1.2	Index notation of Vectors and Tensors: Stress tensor, Alternating tensor, gradient, divergence and curl	1
1.3	Methods of analysis: System and Control Volume, Differential vs Integral approach. Methods of Description: Eulerian and Lagrangian descriptions, Total derivatives.	1
1.4	Reynolds Transport Theorem: Derivation	1
1.5	Mass conservation equation	1
1.6	Momentum conservation equation and Energy equation	1
1.7	Navier Stokes equation, Generic form	1
1.8	Non-dimensional forms, Phenomenological models	1
2	**Module 2 (8 hrs)**	
2.1	Classification of PDEs: Elliptic, Parabolic, and Hyperbolic. Equilibrium, Propagation, and Eigen problems. Range of influence and domain of dependence. Classification of boundary conditions: Dirichlet, Neumann, Mixed and Robin boundary conditions.	1
2.2	finite difference methods: Derivation of first, second and mixed derivatives	1
2.3	Solution of elliptic equations, Difference equation formulation	1
2.4	Solution of parabolic equation: Explicit method, stability criterion (Derivation not required)	1
2.5	Solution of parabolic equation: Implicit and semi-implicit method:	1
2.6	Solution of hyperbolic equations: Lax method, McCormack method, Stability criterion (Derivation not required)	1
2.7	Solution of linear equations, Elimination and iterative methods	1

2.8	Thomas algorithm, Properties of numerical solutions, types of grids	1
3	**Module 3 (8 hours)**	
3.1	Introduction to finite volume method: Finite volume method for one-dimensional steady-state diffusion: Numerical problems	2
3.2	Finite volume method for two-dimensional and three-dimensional diffusion problems.	1
3.3	Steady one-dimensional convection and diffusion: Numerical problems:	1
3.4	The central differencing scheme, upwind schemes	2
3.5	Higher-order differencing schemes for convection-diffusion problems	1
3.6	Analysis of different schemes for convection-diffusion problems	1
4	**Module 4 (8 hours)**	
4.1	Solution algorithms for pressure-velocity coupling in steady flows. Need for a special procedure.	1
4.2	Vorticity stream function formulation	1
4.3	Representation of pressure gradient and continuity equation. 'Checker board' pressure field. Staggered grid and collocated grid	1
4.4	Momentum equations, Pressure and velocity corrections. Pressure correction equation.	2
4.5	SIMPLE algorithm.	1
4.6	SIMPLER algorithm.	1
4.7	Numerical problems	1
5	**Module 5 (8 hours)**	
5.1	Turbulence modeling. Need for turbulence modelling. Closure problem.	1
5.2	Reynolds averaged Navier Stokes equation.	1
5.3	Turbulent flow calculations, RANS, Large eddy simulation, Direct numerical simulation.	1
5.4	k-ε two-equation turbulence model	1
5.5	Multiphase flow modeling in CFD, Classification of multiphase flow	1
5.6	Industrial examples, Examples for multiphase reactors such as bubble column reactors, fluidized bed reactors, CSTR	1
5.7	Multiphase flow modelling approaches Eulerian-Lagrangian approach, Eulerian – Eulerian Approach, Volume of fluid approach	2

Reference Books

1. H. Versteeg, W, Malalasekra, An Introduction to Computational Fluid Dynamics: The Finite volume method, Pearson
2. John D Anderson, Computational Fluid Dynamics: The Basics with Applications, McGraw-Hill
3. Suhas V. Patankar, Numerical Heat Transfer and Fluid Flow, CRC Press
4. S. C. Chapra, R. P. Canale, Numerical Methods for Engineers, McGraw-Hill
5. Anderson, D. A; Tarmeheil, J. C; Pletcher, R. H., Computational Fluid Mechanics and Heat transfer, Taylor and Francis
6. Ferziger, J. H and Peric, M., Computational methods for Fluid Mechanics, Springer
7. Bird, R. B; Stewart, W. E and Lightfoot, E. N, Transport Phenomena, John Wiley
8. T J Chung, Computational Fluid Dynamics, Cambridge
9. Jiyuan Tu, Computational Fluid Dynamics: A Practical Approach, Butterworth-Heinemann

221ECH004	DESIGN AND ANALYSIS OF EXPERIMENTS	CATEGORY	L	T	P	CREDIT
		Program Elective1	3	0	0	3

Preamble: Explore innovative strategies for constructing and executing experiments including factorial and fractional factorial designs. The identification of the objectives of the experiment and the practical considerations governing the design form the heart of the subject matter and serve as the link between the various analytical techniques. The learning about design and analysis of experiments is best achieved by the planning, running, and analyzing of a simple experiment.

Pre-requisites- Nil

Course Outcomes:

After the completion of the course the student will be able to

CO 1	Explain various statistical methods of analysis of data.
CO 2	Investigate the logic of hypothesis testing, analysis of variance and the detailed analysis of experimental data.
CO 3	Describe the general theory of factorial design and blocking
CO 4	Discuss and apply regression analysis techniques to develop suitable models.
CO 5	Apply response surface methodology and explain its basic underpinnings.

Mapping of course outcomes with program outcomes

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**
CO 1	2		3				
CO 2	3			3		2	
CO 3			3	3			
CO 4			3			3	
CO 5	2			3		3	

Assessment Pattern

Bloom's Category	**End Semester Examination**
Apply	50
Analyse	30
Evaluate	20
Create	-

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 marks

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred): 15 marks

Course based task/Seminar/Data collection and interpretation: 15 marks

Test paper, 1 no.: 10 marks

Test paper shall include minimum 80% of the syllabus. End Semester Examination Pattern:

End Semester Examination Pattern: 60 marks

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B.

Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions.

Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example, if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

Total duration of the examination will be 150 minutes.

Model Question paper

QP CODE: **PAGES:**

Reg No:_______________ **Name: _______________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

221ECH004: DESIGN AND ANALYSIS OF EXPERIMENTS

Max. Marks: 60 Duration: 150 minutes

PART – A

Answer All the Questions.

(5x 5 = 25)

1. What is meant by design of experiments?

2. Write a short note on estimation of the model parameters

3. Give two advantages of factorial designs

4. What is scaled residuals in regression model diagnostics

5. Briefly describe the method of steepest ascent in Response surface methodology

PART – B

Answer any five (5 x 7 = 35)

6. The viscosity of a liquid detergent is supposed to average 800 centistokes at 25^0C. A random sample of 16 batches of detergent is collected, and the average viscosity is 812. Suppose we know that the standard deviation of viscosity is σ = 25 centistokes

(a) State the hypotheses that should be tested

(b) Test these hypotheses using α = 0.05. List your conclusions.

(c) Find the P value for the test in part b.

(d) Find a 95 % confidence interval on the mean.

7. The effective life of insulating fluids at an accelerated load of 35 kV is being studied. Test data have been obtained for four types of fluids. The results were as follows

Fluid type	Life in hr at 35 kV load					
1	17.6	18.9	16.3	17.4	20.1	21.6
2	16.9	15.3	18.6	17.1	19.5	20.3
3	21.4	23.6	19.4	18.5	20.5	22.3
4	19.3	21.1	16.9	17.5	18.3	19.8

(a) Is there any indication that the fluids differ? Use $\alpha = 0.05$
(b) Which fluid would you select given that the objective is long life
(c) Analyse the residuals from this experiment. Is the basic analysis of variance assumptions satisfied?

8. Suppose that you are planning to run an experiment with three treatment factors, where the first factor has two levels and the other two factors have three levels each. Write out the coded form of the 18 treatment combinations. Assign 36 experimental units at random to the treatment combinations so that each treatment combination is assigned two units.

9.A bacteriologist is interested in the effects of two culturing media and two different times on the growth of a particular virus. She performs six replicates of 2^2 design making the runs in random order. Analyse the bacterial growth data that follow and draw the appropriate conclusions.

Time	Culture Medium			
	1		2	
12	21	22	25	26
	23	28	24	25
	20	26	29	27
18	37	39	31	34
	38	38	29	33
	35	36	30	35

10. The tensile strength of a paper product is related to the amount of hardwood in the pulp. Ten samples are produced in the pilot plant, and the data obtained are shown in the following table

Strength	% Hardwood	Strength	% hardwood
160	10	181	20
171	15	188	25
175	15	193	25
182	20	195	28
184	20	200	30

(a) Fit a liner regression model relating strength to percent hardwood
(b) Test the model in part (a) for significance of regression
(c) Find a 95 % confidence interval on the parameter β_1

11. An experimenter has run a Box-Behnken design and has obtained the results below, where the response variable is the viscosity of a polymer

Level	Temperature	Agitation rate	Pressure	X_1	X_2	X_3
High	200	10.0	25	+1	+1	+1
Middle	175	7.5	20	0	0	0
Low	150	5.0	15	-1	-1	-1

Run	X_1	X_2	X_3	Y1
1	-1	-1	0	535
2	+1	-1	0	580
3	-1	+1	0	596
4	+1	+1	0	563
5	-1	0	-1	645
6	+1	0	-1	458
7	-1	0	+1	350
8	+1	0	+1	600
9	0	-1	-1	595
10	0	+1	-1	648
11	0	-1	+1	532
12	0	+1	+1	656
13	0	0	0	653
14	0	0	0	599
15	0	0	0	620

(a) Fit the second order model

(b) Perform the canonical analysis. What type of surface has been found?

(c)

12. Explain the properties rotatability, orthogonal blocking, and orthogonality of central composite design (CCD).

Syllabus

Module 1 INTRODUCTION TO DOE (8 hrs)

Introduction to the role of experimental design, Basic statistical concepts, sampling and sampling distribution, Hypothesis Testing, Inference about the difference in means and variances

Module 2 ANALYSIS OF VARIANCE (ANOVA) (9 hrs)

Analysis of variance (ANOVA) -one-way classification of ANOVA, Analysis of fixed effects model, Estimation of model parameters, Comparison among treatment means, Random effects model; randomized designs and paired comparison designs, The randomized complete block design.

Module 3 FACTORIAL DESIGN (8 hrs)

Factorial design of experiments; two-factor factorial design, Analysis of fixed effects model, General factorial design, Analysis of 2k and 3k factorial designs

Module 4 REGRESSION ANALYSIS (8 hrs)

Regression analysis— Simple and multiple linear regression, Estimation of parameters in linear regression models, Hypothesis testing in multiple regression, Confidence intervals in multiple regression

Module 5 RESPONSE SURFACE METHODOLOGY (8 hrs)

Response surface methodology- Introduction, Method of steepness ascent, Response surface designs for first-order models, Response surface designs for second-order models.

Course Plan

No	Topic	No. of Lectures
1	**Module I (7 hours)**	
1.1	Introduction to the role of experimental design	1
1.2	Basic statistical concepts, sampling and sampling distribution	2
1.3	Hypothesis Testing	2
1.4	Inference about the difference in means and variances	2
2	**Module II (9 hours)**	
2.1	Analysis of variance (ANOVA) ,One-way ANOVA	2
2.2	Analysis of fixed effects model, Estimation of model parameters	2
2.3	Comparison among treatment means	2
2.4	Random effects model; randomized designs and paired comparison designs	2

2.5	The randomized complete block design.	1
3	**Module III (8 hours)**	
3.1	Factorial design of experiments; two-factor factorial design	2
3.2	Analysis of fixed effects model	2
3.3	General factorial design	2
3.4	Analysis of 2k and 3k factorial designs	2
4	**Module IV (8 hours)**	
4.1	Regression analysis— Simple and multiple linear regression	2
4.2	Estimation of parameters in linear regression models	2
4.3	Hypothesis testing in multiple regression	2
4.4	Confidence intervals in multiple regression	2
5	**Module V (8 hours)**	
5.1	Response surface methodology- Introduction	2
5.2	Method of steepness ascent	2
5.3	Response surface designs for first-order models.	2
5.4	Response surface designs for second-order models.	2

Reference Books

1. "Design and analysis of experiments" by D.C. Montgomery, 8th edition John Wiley and sons, New York.
2. "Applied Statistics and Probability for Engineers", by D.C. Montgomery and G.C. Runger, 5th edition John Wiley and sons, New York.
3. "Design and analysis of experiments" by Klaus Hinkelmann, 2 nd Edn. Wiley, New York.
4. "Introduction to Probability models" by Sheldon M. Ross, 10 th Edn, Elsevier, USA.
5. "Response surface methodology" byR. H. Myers, D.C. Montgomery, C. M. Anderson- Cook, 2 nd .Edn, John Wiley and sons, New York.

221ECH013	PRINCIPLES AND PRACTICES OF PROCESS EQUIPMENT AND PLANT DESIGN	CATEGORY	L	T	P	CREDIT
		Program Elective1	3	0	0	3

Preamble:

The course is expected to provide a gap filling process to the design courses included in the curriculum of the program. Along with design, the course focuses on the basic calculations, the internals, accessories and methodologies included in economical plant operation. The content will primarily cover the design and construction aspects of typical mass transfer systems like tray and packed towers, heat transfer systems, reactors and fluid moving systems and their safety.

Pre-requisites- Nil

Course Outcomes:

After the completion of the course the student will be able to

CO 1	Explain the fundamental and advanced concepts of process engineering
CO 2	Design and analyze flow system and accessories
CO 3	Discuss the constructional details and design heat and mass transfer processes
CO 4	Select and design reactors suitable for the specific applications
CO 5	Conduct safety and hazard analysis of process systems
CO 6	Use proper codes and standards, empirical equations and rules of thumbs in the design of process equipment.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1			3	3			
CO 2			3	3			
CO 3			3	3			
CO 4			3	3	2		
CO 5			3	3			
CO 6	3		3	3	3	3	

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	70

Analyse	30
Evaluate	
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 marks

Preparing a review article based on peer reviewed Original publications (minimum 10 publications shall be referred) : 15 marks

Course based task/Seminar/Data collection and interpretation : 15 marks

Test paper, 1 no. : 10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern: 60 marks

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B.

Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students).Students should answer all questions.

Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

Total duration of the examination will be 150 minutes.

Model Question Paper

QP CODE: **PAGES:**

Reg No:______________ **Name: ______________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 221ECH013

Max. Marks: 60 Duration: 2.5 hours

PRINCIPLES AND PRACTICES OF PROCESS EQUIPMENT AND PLANT DESIGN

PART – A

Answer all questions.

(5x 5 = 25)

1. Discuss the steps involved in implementation of a chemical plant project from idea to operation.

2. A centrifugal pump is drawing methanol from an underground tank at 1 atm. Vertical distance between centreline of pump and free surface of liquid in the tank is 3 m. Maximum operating temperature is 50^{o}C. The vapour pressure and density of methanol at are 400 Torr and 785 kg/m^3, respectively. Friction loss in suction line is 1 m of liquid column. Calculate $(NPSH)_A$ of centrifugal pump.

3. With the help of neat sketch, compare the different types of baffles used in heat exchangers.

4. Compare the advantages and disadvantages of batch and continuous flow reactors.

5. Explain the concepts of intrinsic and extrinsic safety with example for each.

PART – B

Answer any five questions (5 x 7 = 35)

6. Sketch and explain the P&ID diagram for obtaining high purity distillate from a distillation column.

7. Discuss on process intensification equipments and methods.

8. Design an orifice meter for the situation given below.
   Fluid : water, Flow rate : 100,000 kg/h
   Pipe : 154 mm ID (6” schedule 40 pipe)
   Operating temperature : 32^{o}C, Density : 995 kg/m^3
   Viscosity of water at 32^{o}C : 0.765 mPa s
   Manometric fluid: Mercury (density : 13516 kg/m^3)

9. Detail the internals required for a packed bed distillation column.

10. A heat recovery problem consists of two streams given in Table below.

Stream	Type	Supply temperature (°C)	Target temperature (°C)	Enthalpy change (MW)
1	Hot	100	40	12
2	Cold	10	150	7

Steam is available at 180ºC and cooling water at 20ºC.

a. For a minimum permissible temperature difference (ΔTmin) of 10ºC, calculate the minimum hot and cold utility requirements.

b. What are the hot and cold stream pinch temperatures?

c. If the (ΔTmin) is increased to 20ºC, what will happen to the utility requirements?

11. A stoichiometric mixture of nitrogen and hydrogen is to be reacted at 1 bar by the reaction $3H_2 + N_2 \longleftrightarrow 2NH_3$. Assuming ideal gas behaviour (R = 8.3145 $kJ\cdot K^{-1}\cdot kmol^{-1}$), calculate equilibrium constant, equilibrium conversion of hydrogen and composition of the reaction products at equilibrium at 300 K. Standard free energy of formation data for ammonia synthesis is −16,223 kJ/kmol.

12. Discuss the general considerations needed in site selection and plant layout.

Syllabus

Module I: 9 hours

Process Engineering: Generalized approach to chemical plant design, preparation of operating instructions manual, Green engineering, Energy recovery, Process integration and pinch technology, process intensification, block diagram, PFD and P&ID, typical control systems.

Module II: 6 hours

Design of flow systems: Process design of piping, economic pipe diameter, valve sizing, power requirement for pumping liquids, design and selection of centrifugal pumps, design of orifice meter and rotameter.

Module III: 10 hours

Heat and Mass Transfer systems: Shell and tube heat exchanger construction details, tube side and shell side heat transfer and pressure drops, Heat Exchanger Network analysis

Interphase mass transfer, phase equilibrium, flash distillation, fractionation, Column Internals, practical issues in designing distillation processes, minimum reflux and total reflux conditions, sieve tray design, Bubble Cap design, valve tray design, Tower and tower internals for Packed columns, multicomponent distillation - key components

Module IV: 9 hours

Reactor design: Reactor classification based on - Mode of operation, Phases present, Reactor geometry and mixing arrangements, Thermal operation and Idealized flow arrangement. Real reactors approximating ideal CSTR and PFR, rate limiting step, reactor design – equations for homogeneous and heterogeneous systems, design deliverables, additional volume requirements, pros and cons of different reactor geometry, design parameters and features of various reactors, scale up, bioreactors.

Module V: 6 hours

Safety and Loss Prevention: Intrinsic and extrinsic safety, hazards, Dow fire and explosion index, Safety Checklists, Hazard and operability studies, Hazard analysis

General considerations in site selection and plant layout, environmental considerations.

Note: The students are expected to do the detailed design of equipment / plant as projects manually/using software.

Course Plan

No	Topic	No. of Lectures
1	**Process Engineering (9 hours)**	
1.1	Generalized approach to chemical plant design, research and pilot plant studies, preparation of operating instructions manual	1 hour
1.2	Block diagram, PFD and P&ID	2 hours
1.3	Green engineering, Energy recovery, Process intensification – equipment and methods, micro reactors, cavitation reactors, reactive distillation	2 hours
1.4	Supercritical fluids and applications	1 hour
1.5	Process integration and pinch technology	1 hour
1.5	Typical control systems.	2 hours
2	**Design of flow systems (6 hours)**	
2.1	Process design of piping: optimum pipe diameter, pressure drop, economic pipe diameter, valve sizing, power requirement for pumping liquids	2 hours
2.2	Design and selection of centrifugal pumps	2 hours
2.3	Design of orifice meter and rotameter.	2 hours
3	**Heat and Mass Transfer systems (10 hours)**	
3.1	Shell and tube heat exchanger construction details	1 hour
3.2	Tube side and shell side heat transfer and pressure drops	1 hour
3.3	Heat Exchanger Network analysis	1 hour
3/4	Interphase mass transfer, phase equilibrium, flash distillation, fractionation	2 hours
3.5	Column Internals, practical issues in designing distillation processes, minimum reflux and total reflux conditions	2 hours
3.6	sieve tray design, Bubble Cap design, valve tray design and comparison	2 hours
3.7	Tower and tower internals for Packed columns, multicomponent distillation - key components	1 hour
4	**Reactors (9 hours)**	
4.1	Reactor classification based on - Mode of operation, Phases present, Reactor geometry and mixing, Thermal operation and Idealized flow arrangement.	2 hours
4.2	Real reactors approximating ideal CSTR and PFR	2 hours
4.3	Rate limiting step, reactor design – equations for homogeneous and heterogeneous systems, design deliverables, additional volume requirements	2 hours
4.4	Pros and cons of different reactor geometry, design parameters and features of various reactors	2 hours
4.5	Scale up, bioreactors	1 hour

5	**Safety and Loss Prevention (6 hours)**	
5.1	Intrinsic and extrinsic safety, hazards, Dow fire and explosion index	2 hours
5.2	Hazard and operability studies, Hazard analysis	2 hours
5.3	General considerations in site selection and plant layout, environmental considerations	2 hours

Reference Books

1. Introduction to process engineering and design, Shuchen B Takore, Bharat I Bhatt, McGraw Hill Education (India) Pvt. Ltd., Chennai, 2017

2. Chemical engineering design, principles, practice and economics of plant and process design, Gavin Towler, Ray Sinnott, Elsevier, 2008

3. Chemical Process Design and Integration, Robin Smith, John Wiley and Sons. Ltd., New Delhi

4. Process equipment and plant design Principles and practices, Subhabrata Ray, Gargi Das, Elsevier, 2020

5. Chemical Engineering design, Coulson and Richardson’s Chemical Engineering Series, Volume 6, R K Sinnot, Elsevier.

6. Product & Process Design Principles, Warren D. Seider, J . D. Seader and Daniel R. Lewin, Wiley Publication.

7. Robert E. Treybal, Mass Transfer Operations, McGraw Hill

8. Kern D.Q., Process Heat Transfer, Tata McGraw Hill

9. Perry’s Chemical Engineer’s handbook, McGraw Hill.

221ECH014	ENERGY ENGINEERING AND MANAGEMENT	CATEGORY	L	T	P	CREDIT
		Program Elective 1	3	0	0	3

Preamble:

This course provides a comprehensive knowledge of different sources of renewable energy, solar energy tapping, biomass conversion, fuel cells, and energy conservation. It also focuses on fundamental principles to design biomass conversion technology and solar energy equipment. Basics of energy auditing and conservation measures employed in process industries also will be addressed in the course.

Pre-requisites- Nil

Course Outcomes:

After the completion of the course the student will be able to

CO 1	Explain the working principle of various solar energy systems
CO 2	Develop awareness of using biomass as energy resources and capability to do basic design of bio gas plant.
CO 3	Discuss the advances and applications of different renewable energy sources
CO 4	Illustrate the significance and procedure for energy conservation and audit
CO 5	Suggest measures to improve energy conservation and management in process industries

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1			3	3	3		
CO 2	2		3	3	3		
CO 3			3	3	2		
CO 4			3	3	3		
CO 5			3	3	3		

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	60 %
Analyse	20 %
Evaluate	10 %
Create	10 %

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 marks

Preparing a review article based on peer reviewed original publications (minimum 10)

publications shall be referred) : 15 marks
Course based task/Seminar/Data collection and interpretation : 15 marks
Test paper, 1 no. : 10 marks
Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern: 60 marks

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B.
Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions.
Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry
7 marks.
Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example, if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.
Total duration of the examination will be 150 minutes.

Model Question Paper

QP CODE: **PAGES:**

Reg No:_______________ **Name: _______________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 221ECH014

Max. Marks: 60 Duration: 2.5 hours

ENERGY ENGINEERING AND MANAGEMENT

PART – A

Answer All the Questions.

(5x 5 = 25)

1. Bring out the necessity of energy conservation and list its various aspects?
2. Identify the applications and advantages of flat plate collector.
3. List the usable forms of biomass, their composition and fuel properties
4. Explain the merits and demerits of fuel cell
5. Elaborate on steam economy in chemical plants

PART – B

Answer any five questions (5 x 7 = 35)

6. Describe Enegry Audit and its different types.
7. With a neat sketch explains the working of a fixed dome type biogas plant.
8. Explain pumped hydro-electric energy storage system with a schematic diagram.
9. Illustrate electrical energy loss and conservation measures in steel industry.
10. Explain the different types of solar collectors.
11. Explain the working principle of OTEC with a neat sketch
12. Identify the necessity of energy conservation and explain its various aspects

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Syllabus (40 hrs)

Module I: Solar energy (6 hrs)

Energy management using non-conventional energy sources- Indian scenario of energy resources and consumption. Energy management using RRR principle. Solar energy: – Production and transfer of solar energy – Sun-Earth angles –Availability and limitations of solar energy – Measuring techniques and estimation of solar radiation – Solar thermal collectors – General description and characteristics – Flat plate collectors – Heat transfer processes – Short term and long-term collector performance – Solar concentrators – Design, analysis and performance evaluation.

Module II: Biomass energy (6 hrs)

Energy from biomass – Sources of biomass – Different species – Conversion of biomass into fuels – Energy through fermentation – Pyrolysis, gasification and combustion – Aerobic and anaerobic bio-conversion – Properties of biomass – Biogas plants – Types of plants – Design and operation – Properties and characteristics of biogas. .

Module III : Non-conventional Energy sources (6 hrs)

Introduction and advances in non-conventional energy sources- Wind energy, small hydropower, nuclear power plants. Hydel power plants, Tidal Energy, wave energy, Ocean Thermal energy conversion, Magneto hydrodynamics, hydrogen energy, fuel cells.

Module IV : Energy Audit (10 hrs)

Energy Audit Concepts: Need of Energy audit – Types of energy audit – Energy management (audit) approach – understanding energy costs – Bench marking – Energy performance – Matching energy use to requirement – Maximizing system efficiencies -Optimizing the input energy requirements -Duties and responsibilities of energy auditors- Energy audit instruments – Procedures and Techniques.

Module V: Energy Management in Industries (12 hours)

Principles and Objectives of Energy Management: Design of Energy Management Programmes – Development of energy management systems -Importance – Indian need of Energy Management – Duties of Energy Manager – Preparation and presentation of energy audit reports – Monitoring and targeting, some case study and potential energy savings in industries- Energy management calculations using softwares.
Energy conservation in distillation columns, heat exchangers, dryers, furnaces, boilers, Electrical Energy conservation industries.

Course plan

No	Topic	No. of Lectures
1	**Solar Energy (6 hours)**	
1.1	Energy management using non-conventional energy sources- Indian scenario of energy resources and consumption. Energy management using RRR principle	1
1.2	Solar energy: – Production and transfer of solar energy - Sun-Earth angles –Availability and limitations of solar energy	1
1.3	Measuring techniques and estimation of solar radiation –	1
1.4	Solar thermal collectors – General description and characteristics – Flat plate collectors –	1
1.5	Heat transfer processes – Short term and long-term collector performance	1
1.6	Solar concentrators – Design, analysis and performance evaluation	1
2	**Biomass Energy (6 hours)**	
2.1	Energy from biomass – Sources of biomass – Different species – Conversion of biomass into fuels	1
2.2	Energy through fermentation – Pyrolysis, gasification and combustion.	1
2.3	Aerobic and anaerobic bio-conversion	1
2.4	Properties of biomass – Biogas plants – Types of plants	1
2.5	Design and operation of Biogas plants – Properties and characteristics of biogas	2
3	**Non-conventional Energy sources (6 hours)**	
3.1	Advances and challenges in non-conventional energy sources-	1
3.2	Wind energy, small hydropower	1
3.3	Nuclear power plants. Hydel power plants	1
3.4	Tidal Energy, wave energy	1
3.5	Ocean Thermal energy conversion	1
3.6	Magneto hydrodynamics, hydrogen energy, fuel cells	1
4	**Energy Audit (10 hours)**	
4.1	Energy Audit Concepts: Need of Energy audit – Types of energy audit	2
4.2	Energy management (audit) approach – understanding energy costs – Bench marking–– Energy performance	2
4.3	Matching energy use to requirement – Maximizing system efficiencies	2
4.4	Optimizing the input energy requirements -Duties and responsibilities of energy auditors	2
4.5	Energy audit instruments – Procedures and Techniques.	2
5	**Energy Management in Industries (12 hours)**	
5.1	Principles and Objectives of Energy Management: Design of	2

	Energy Management Programmes – Development of energy management systems -Importance	
5.2	Indian need of Energy Management – Duties of Energy Manager – Preparation and presentation of energy audit reports	2
5.3	Monitoring and targeting, some case study and potential energy savings in industries	2
5.4	Energy management calculations using softwares	1
5.5	Energy conservation in distillation columns,	1
5.6	Energy conservation heat exchangers, dryers	1
5.7	Energy conservation furnaces, boilers,	1
5.8	Electrical energy conservation in industries	2

Reference Books

1. Mittal.K.M, Non-conventional energy systems, Wheeler Publishing Co.
2. Rao.S and Parulekar, Energy technology, Khanna Publishers.
3. Bansal.N.K and Kleeman, Renewable energy sources and conversion technologies, Tata-McGraw Hill.
4. Sukhatme.S.P.Solar energy, Tata-McGraw Hill.
5. G.N. Tiwari: Solar Energy-Fundamentals, Design, Modelling and Applications, Narosa Publishers, 2002
6. J.A. Duffie and W.A. Beckman: Solar Energy Thermal Processes, J. Wiley, 1994
7. A.A.M. Saigh (Ed): Solar Energy Engineering, Academic Press, 1977
8. 3. F. Kreith and J.F. Kreider: Principles of Solar Engineering, McGraw Hill, 1978
9. Reddy, A.K.N and Goldemberg, Energy for a sustainable world, Tata-McGraw Hill.
10. K.M. Mittal: Non-conventional Energy Systems-Principles, Progress and Prospects, Wheeler Publications, 1997
11. Murphy, W. R., Energy Management, Elsevier, 2007.
12. Smith, C. B., Energy Management Principles, Pergamum, 2007
13. Handbook of Energy Audit, Sonal Desai, Mcgraw Hill Education Private Ltd.,

221ECH015	PROJECT ENGINEERING AND ECONOMICS OF PROCESS PLANTS	CATEGORY	L	T	P	CREDIT
		Program Elective1	3	0	0	3

Preamble:

The project engineering and economics and management of chemical industries is one of the key areas where Chemical Engineers need to concentrate. This course focuses on project management and economic analysis of engineering projects, giving insights on tools used for planning and scheduling, cost estimation, profitability analysis and taking decision among alternatives. The basic purpose of this course is to provide a sound understanding of concepts and principles of project engineering and economics, and to develop proficiency with methods for making rational decisions regarding problems likely to be encountered in professional practice.

Pre-requisites: Nil

Course Outcomes:

The COs shown are only indicative. For each course, there can be 4 to 6 COs.

After the completion of the course the student will be able to

CO 1	Apply the concept of front end engineering design, process engineering and detailed engineering in process plant projects
CO 2	Develop the ability for planning and scheduling the projects as well as the methodology for procurement operation.
CO 3	Apply the concept of time value of money and depreciation in project economics
CO 4	Apply the different tools for cost estimation and methods for profitability analysis
CO 5	Apply the concept of break even and minimum cost analysis in process plant projects

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	2		3	3	3	2	3
CO 2	2		3	3	3	2	3
CO 3	2		3	3	3	2	3
CO 4	2		3	3	3	2	3
CO 5	2		3	3	3	2	3

Assessment Pattern

Bloom's Category	End Semester Examination

Apply	30%
Analyse	30%
Evaluate	30%
Create	10 %

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 marks

Preparing a review article based on peer reviewed Original publications (minimum 10 publications shall be referred) : 15 marks

Course based task/Seminar/Data collection and interpretation : 15 marks

Test paper, 1 no. : 10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern: 60 marks

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B.

Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students).Students should answer all questions.

Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

Total duration of the examination will be 150 minutes.

Model Question Paper

QP CODE: **PAGES:**

Reg No:_______________ **Name: _______________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 221ECH015

Max. Marks: 60 Duration: 2.5 hours

PROJECT ENGINEERING AND ECONOMICS OF PROCESS PLANTS

PART – A

Answer All the Questions.

(5x 5 = 25)

1. Explain the role of project Engineer in process plant projects
2. What are the uses of codes and standards? Distinguish between two
3. What is unacost? Obtain the relationship between present value and unacost
4. What is meant by NPV and DCFRR? Compare the use of two criteria for profitability analysis
5. With neat diagram explain the economic production chart for 100% capacity

PART – B

Answer any five (5 x 7 = 35)

6. What is TEFR? Discuss the details to be included in TEFR

7. Discuss the important network techniques used for planning and scheduling of projects

8. A heat exchanger costs Rs 1,50,000 and its operating cost is 20,000/year and lasts 6 years. Another heat exchanger costs Rs 2,35,000 with a salvage value of Rs 25,000 at the end of 8 years. Its operating cost is Rs 10,000. Which one is economical and by how much?

9. An equipment costs Rs 5,45,000 with a salvage value of Rs 10,000 after 7 years. Calculate the annual depreciation and book value at the end of 3^{rd} and 6^{th} years by i) declining balance method ii) sum of years digit method

10. Discuss the techniques used for cost estimation

11. Designs of 4 four heat exchangers are available for heat saving. Select the suitable design. Plant demands 16% rate of return

Design	I	II	III	IV
Initial investment, Rs	2,50,000	4,00,000	5,00,000	6,50,000
Operating cost, Rs/Year	7500	7500	7500	7500
Fixed charge % of initial investment, Rs/Year	10	10	10	10
Value of heat saved, Rs/Year	1,00,000	1,40,000	1,60,000	2,00,000

12. A firm manufactures a product A and sells at a rate of P metric tons per day. The cost per metric ton produced is C (in rupees) = 50+0.1P+9000/P. The selling price per metric ton is Rs. 300. Determine i) The production level giving the minimum cost per metric ton ii)The production level which maximizes the profit per day iii) The production level at which profit is zero

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Syllabus

Module I: Scope of project engineering (7 hours)

Classification of Projects, different stages of chemical engineering projects, the role of project engineer, TEFR, Conceptual process design, Front End Engineering Design (FEED), Process engineering, Flow diagrams, plot plans, Detailed engineering.

Module II: Planning and scheduling of projects (7 hours)

Bar chart and network techniques, Procurement operations, Contracts and contractors, Project financing, statutory sanctions, Scope of piping engineering, pipe sizing technique, Codes and standards, Piping design, Thermal insulation, safety in plant design, Plant constructions, start up and commissioning.

Module III: Time value of money and equivalence (9 hours)

Equations used in economic analysis - compound interest, effective interest and continuous interest, Unacost - capitalized cost, cost comparison with equal and unequal duration of service life, depreciation and taxes - nature of depreciation, methods of determining depreciation - straight line - declining balances methods, double declining balance, sum of years digits methods, sinking fund, units of production methods.

Module IV: Cost Estimation and profitability analysis (9 hours)

Cost indices , material cost indices, labour cost indices , William's six tenth factor , location index, techniques of cost estimates: - conference techniques , comparison techniques graphic relationship , tabular relationship, unit rate techniques , lang factor method , hand factor method, Chilton method , miller method, Peter's and Timmerhaus ratio factor method, Profitability analysis: :mathematical methods for profitability evaluation, payout time without interest, return on average investment , Return on original investment, net present value , net present value index , DCF rate of return, incremental analysis (return on additional investment).

Module V: Breakeven and minimum cost analysis (8 hours)

Variable cost and fixed cost, Break even analysis, economic production chart for 100% capacity, economic production chart for above 100% capacity and dumping, Non-linear economic production chart- analysis.

Course Plan

No	Topic	No. of Lectures
1	**Module I: Scope of project engineering** (7 hours)	
1.1	Classification of Projects, different stages of chemical engineering projects	1
1.2	The role of project engineer	1
1.3	TEFR	1
1.4	Conceptual process design, Front End Engineering Design (FEED)	1
1.5	Process engineering	1
1.6	Flow diagrams, plot plans	1
1.7	Detailed engineering	1
2	**Module II: Planning and scheduling of projects (7 hours)**	
2.1	Bar chart and network techniques	1
2.2	Procurement operations	1
2.3	Contracts and contractors	1
2.4	Project financing, statutory sanctions	1
2.5	Scope of piping engineering, pipe sizing technique, Codes and standards, Piping design	1
2.6	Thermal insulation, safety in plant design,	1
2.7	Plant constructions, start up and commissioning	1
3	**Module III: Time value of money and equivalence (9 hours)**	
3.1	Equations used in economic analysis - compound interest, effective interest and continuous interest	2
3.2	Unacost - capitalized cost	1
3.3	cost comparison with equal and unequal duration of service life	2
3.4	depreciation and taxes - nature of depreciation	1
3.5	methods of determining depreciation - straight line - declining balances methods	1
3.6	double declining balance, sum of years digits methods	1

3.7	sinking fund, units of production methods	1
4	**Module IV: Cost Estimation and profitability analysis (9 hours)**	
4.1	Cost indices, material cost indices, labour cost indices, William's six tenth factor, location index	2
4.2	techniques of cost estimates: - conference techniques, comparison techniques graphic relationship, tabular relationship	1
4.3	unit rate techniques, lang factor method , hand factor method	1
4.4	Chilton method, miller method, Peter's and Timmerhaus ratio factor method	1
4.5	Profitability analysis:: mathematical methods for profitability evaluation	1
4.6	payout time without interest, return on average investment, Return on original investment	1
4.7	net present value, net present value index , DCF rate of return	1
4.8	incremental analysis (return on additional investment)	1
5	**Module V: Breakeven and minimum cost analysis (8 hours)**	
5.1	variable cost and fixed cost, Break even analysis	2
5.2	economic production chart for 100% capacity	2
5.3	economic production chart for above 100% capacity and dumping	2
5.4	Non-linear economic production chart- analysis	2

Reference Books

1. . Ernest E. Ludwig, Applied project engineering and management, Gulf Pub. Co., (1988)
2. Jelen F.C., Cost and Optimisation Engineering, McGraw Hill
3. Peters & Timmerhaus, Plant Design & Economics for Chemical Engineering, McGraw Hill
4. Rase & Barrow, Project Engineering of Process Plants, John Wiley
5. Schweyer, Process Engineering Economics, McGraw Hill

221ECH016	HAZARD AND RISK ASSESSMENT	CATEGORY	L	T	P	CREDIT
		Program Elective 1	3	0	0	3

Preamble:

The subject aims to impart students with knowledge and skill for hazard identification and evaluation, modelling fire, explosion and toxic gas release and layer of protection analysis.

Pre-requisites: Nil

Course Outcomes:

After the completion of the course the student will be able to

CO 1	Determine the individual and societal risk of hazardous chemical installations.
CO 2	Describe the various basic hazard analysis techniques such as Fault tree- event tree analysis, HAZOP and FMECA.
CO 3	Describe the various advanced hazard analysis techniques such as Bow-tie analysis, barrier management and QRA
CO 4	Develop the model for fire, explosion & toxic gas release.
CO 5	Describe and implement the layer of protection analysis

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	3		3	3	3	3	3
CO 2	3		3	3	3	3	3
CO 3	3		3	3	3	3	3
CO 4	3		3	3	3	3	3
CO 5	3		3	3	3	3	3

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	70 %
Analyse	20 %
Evaluate	10 %
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration

100	40	60	2.5 hours

Evaluation Pattern:

Continuous Internal Evaluation: 40 marks

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred) : 15 marks

Course based task/Seminar/Data collection and interpretation : 15 marks

Test paper, 1 no. : 10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination: 60 marks

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B.

Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question. Students should answer all questions.

Part B will contain 7 questions with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example, if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.
Total duration of the examination will be 150 minutes.

Model Question Paper

QP CODE: PAGES:

Reg No:_______________ Name: ______________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 221ECH016

Max. Marks: 60 Duration: 2.5 hours

HAZARD AND RISK ASSESSMENT

PART – A

Answer All the Questions.

(5x 5 = 25)

1. Define and explain the terms 'Hazard and Risk'
2. Give the steps of failure modes, effects, and criticality analysis (FMECA)
3. Comment on Bow-tie analysis
4. Explain in detail the steps in pool fire modelling.
5. How will you compare LOPA with Hazop and FTA?

PART – B

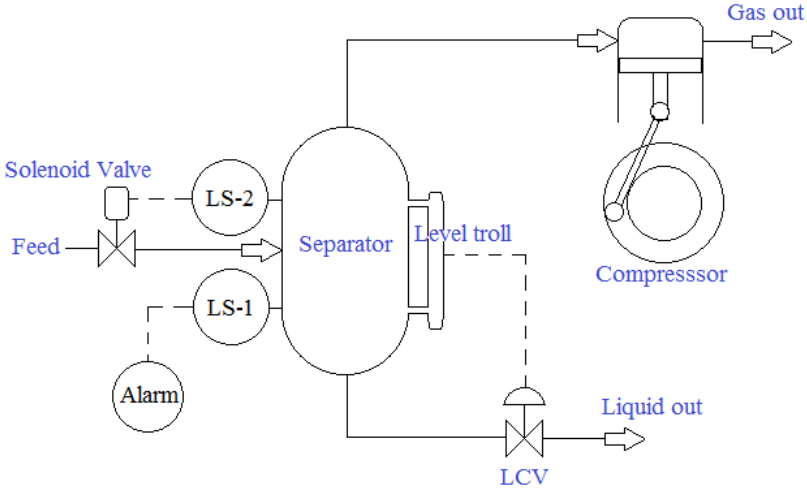
Answer any five (5 x 7 = 35)

6. Discuss in detail the concept of risk tolerability and acceptability.
7. Discuss in detail the influence of risk target setting and risk perception in risk assessment.
8. Liquid part available is the gaseous streams are important to remove before compression to avoid explosion of the compressor piston. In normal working, the level is 50% and properly controlled by the level control system (Components involved: Level troll to measure level and LCV to control level by regulating the outlet liquid flowrate). In case of its failure, level can increase. A high-level alarm is set to alarm at 60% level (Components involved: Level switch-1 and alarm light indicator). The operator can take remedial measures once the alarm is received. In case of its failure, the level can further increase. So, a shutdown system is designed to initiate shutdown of the plant by closing the solenoid valve in the feed line when the level reaches 80% (Components involved: Level switch-2 and solenoid valve).
9. The failure rates of the components involved are tabulated below.

Components	Failure rate

	(faults/year)
Level troll	0.15
LCV	0.12
Level Switch-1	0.14
Alarm light	0.044
Level Switch-2	0.14
Solenoid valve	0.42

10. Conduct a Fault Tree Analysis and find the probability of happening the top event of explosion of the compressor piston.



Explain in detail the steps of Quantitative Risk Assessment

Discuss the assumptions taken for developing the Gaussian Dispersion Model. What are the advantages and limitations of this model?

11. List and comment on five examples of Safeguards which are usually considered as IPLs for LOPA
12. What are Passive IPLs and Active IPLs? Explain with examples

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Syllabus

Module I: Risk estimation and reduction (8 hours)

Risk estimation and reduction: Hazard and risk, Risk estimation, Presentation and perception of risk, Individual risk and societal risk, Risk estimation, Risk representations and Risk targets, Tolerability and acceptability, Risk reduction methods

Module II: Basic hazard analysis techniques (8 hours)

Basic hazard analysis techniques: Preliminary hazard analysis: Checklist, what-if analysis, Fault tree analysis- case studies, Event tree analysis- case studies, HAZOP analysis- case studies, Failure modes, effects, and criticality analysis (FMECA)- case studies, Reliability, Introduction to Availability and Maintainability Study (RAMS)

Module III: Advanced hazard analysis techniques (8 hours)

Advanced hazard analysis techniques: Hazard Identification, Bow- tie analysis, Barrier management, Quantitative Risk Assessment

Module IV: Fire and explosion (8 hours)

Fire and Explosion: Modelling of fire, Explosion and toxic gas dispersion, Case studies, Detailed analysis and application of these models, Safe distances between plant items, Software applications

Module V: Layer of protection analysis (8 hours)

Layer of protection analysis: Implementation of LOPA, Benefits and limitations of LOPA, Estimation of consequence and severity for LOPA analysis, developing scenario for LOPA, initiating event and their frequency, Independent Protection Layer (IPL) and its characteristics, Risk decision using LOPA, Introduction to Safety integrity level (SIL)

Course Plan

No	Topic	No. of Lectures
1	**Risk estimation and reduction (8 hours)**	
1.1	Hazard and risk	1
1.2	Risk estimation	1
1.3	Presentation and perception of risk	1
1.4	Individual risk and societal risk	1
1.5	Risk estimation	1
1.6	Risk representations and Risk targets	1
1.7	Tolerability and acceptability	1
1.8	Risk reduction methods	1
2	**Basic hazard analysis techniques (8 hours)**	
2.1	Preliminary hazard analysis: Checklist, what-if analysis	1
2.2	Fault tree analysis- case studies	1
2.3	Event tree analysis- case studies	1

2.4	HAZOP analysis- case studies	2
2.5	Failure modes, effects, and criticality analysis (FMECA)- case studies	2
2.6	Reliability, Availability and Maintainability Study (RAMS)- introduction	1
3	**Advanced hazard analysis techniques (8 hours)**	
3.1	Hazard Identification	2
3.2	Bow- tie analysis	2
3.3	Barrier management	2
3.4	Quantitative Risk Assessment	2
4	**Fire and explosion (8 hours)**	
4.1	Modelling of fire	1
4.2	Explosion and toxic gas dispersion	1
4.3	Case studies	1
4.4	Detailed analysis and application of these models	2
4.5	Safe distances between plant items	1
4.6	Software applications	2
5	**Layer of protection analysis (8 hours)**	
5.1	Implementation of LOPA	1
5.2	Benefits and limitations of LOPA	1
5.3	Estimation of consequence and severity for LOPA analysis	1
5.4	Developing scenario for LOPA	1
5.5	Initiating event and their frequency	1
5.6	Independent Protection Layer (IPL) and its characteristics	1
5.7	Risk decision using LOPA	1
5.8	Safety integrity level (SIL)- introduction	1

Reference Books:

1. Daniel A Crowl& Joseph F Louvar, Chemical Process Safety, Second Edition, Prentice-Hall.
2. Lees' Loss Prevention in Process Industries, 3rd edition, Elsevier, 2005.
3. Ian T. Cameron and Reghuraman, Process System Risk Management, Vol. 6, Elsevier Academic press, 2005.
4. Safety in process plant design by G.L.Wells, John Wiley& Sons.
5. Guidelines for Evaluating the Characteristics of Vapor Cloud Explosions, Flash Fires, and BLEVEs. CCPS/AIChE, 1994
6. Layer of Protection Analysis: Simplified process risk assessment. CCPS/AIChE, New York, 2001.
7. Guidelines for Chemical Process Quantitative Risk Analysis. 2nd Edition, CCPS/AIChE, New York, 2000.
8. Guideline for Hazard Evaluation Procedures. 2nd edition, CCPS/AIChE, New York,1992.
9. Trevor Kletz, Hazop and Hazan- Identifying and Assessing Process Industry Hazards, 4th Edition, Institution of Chemical Engineers, UK

221ECH011	PROCESS INTEGRATION	CATEGORY	L	T	P	CREDIT
		Program Elective 2	3	0	0	3

Preamble:

The subject aims to impart students with knowledge and skill on systematic methods for the material and energy integration to conserve material and energy requirements in chemical process industries.

Pre-requisites- Nil

Course Outcomes:

After the completion of the course the student will be able to

CO 1	Solve the heat integration problems by finding the minimum utility requirement and optimum use of the utilities.
CO 2	Estimate various targets for the selection the best HEN.
CO 3	Choose and integrate a reactor properly in a HEN
CO 4	Integrate distillation column properly in a HEN
CO 5	Target and design a water management facility of single contaminant

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	3		1	3	3		
CO 2	3		1	3	3		
CO 3	3		1	3	3		
CO 4	3		1	3	3		
CO 5	3		3	3	3	3	

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	60 %
Analyse	20 %
Evaluate	10 %
Create	10 %

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 marks

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred) : 15 marks
Course based task/Seminar/Data collection and interpretation : 15 marks
Test paper, 1 no. : 10 marks
Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern: 60 marks

The end semester examination will be conducted by the respective College. There will be two parts: Part A and Part B.

Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions.

Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example, if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %. Total duration of the examination will be 150 minutes.

Model Question Paper

QP CODE: PAGES:

Reg No:_______________ Name: _______________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 221ECH011

Max. Marks: 60 Duration: 2.5 hours

PROCESS INTEGRATION

PART – A

Answer All the Questions.

(5 x 5 = 25)

1. Pinch technology converts a draft PFD to a modified PFD. Explain the steps in detail.
2. Discuss the rules for stream splitting for design of single pinch networks
3. Comment about the appropriate placement of various types of reactors in a HEN
4. List and explain the four important heuristics for distillation sequencing
5. What is meant by limiting water profile in water conservation pinch problem. Explain with the help of a diagram

PART B

Answer any five (5 x 7 = 35)

6. For the problem given below, use the approach of Problem table algorithm to find the heat capacity flowrates of the hot utility and cold utility, assuming ΔT_{min}= 10°C

Type	T_S, °C	T_T, °C	CP (kW/°C)
Hot-1	250	40	0.15
Hot-2	200	80	0.25
Hot Utility	240	239	
Cold-1	20	180	0.2
Cold-2	140	230	0.3
Cold Utility	20	30	

7. For the problem table cascade given below, calculate the furnace efficiency if the theoretical flame temperature of combustion is 800°C., Given: ΔT min= 10 °C, Atmospheric temperature= 25 °C

Cascade heat flow, MW	Temperature, ^{o}C
21.9	440
29.4	410
23.82	131
1.8	130
0	40
15	30

8. Find the minimum number of units for the problem mentioned below

Type	T_S, ^{o}C	T_T, ^{o}C	CP ($kW/^{o}C$)
Hot-1	55	80	12
Hot-2	40	120	8.75
Hot Utility	290	300	90
Cold-1	150	100	8
Cold-2	145	45	10
Cold Utility	50	25	20

9. What is meant by 'temperature cross' and temperature approach' in heat exchangers? How can it influence the 'number of shells targeting' in an HEN?

10. Explain in detail the choices for heat management in reactors

11. Using the Underwood Equations, determine the best distillation sequence, in terms of overall vapour load, to separate the mixture of alkanes in the table given below into relatively pure products. The recoveries are to be assumed to be 100%. Assume the ratio of actual to minimum reflux ratio to be 1.2 and all columns are fed with a saturated liquid. Neglect pressure drop across each column. Determine the rank order of the distillation sequences on the basis of total vapour load for:

Component	Flowrate (kmol/h)	NBP (K)	Relative Volatility
Propane	45.4	231	5.78
i-butane	136.1	261	2.98
n-butane	226.8	273	2.36

12. Consider the four processes involving a single contaminant with the following limiting water profile data. Cin and Cout stands for the concentrations of the contaminant in the inlet and outlet water streams respectively. Mw denotes the mass flowrate of water. Find the minimum freshwater requirement and the % savings due to integration.

Process	Cin	Cout	Mw

	(ppm)	(ppm)	(kg/h)
P1	0	200	20,000
P2	150	300	50,000
P3	200	300	20,000
P4	200	600	40,000

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Syllabus

Module I (8 Hours)

Energy targeting methods of Heat Exchanger Networks: The idea of PI, Composite curve method, Problem table algorithm, Grand composite curve, Optimal selection of utilities

Module II (8 Hours)

Targeting of Heat Exchanger Network: Number of units targeting, Number of shells targeting, Area targeting, Cost targeting, Grid diagram, Stream splitting design for single pinch networks

Module III (8 Hours)

Integration of Reactor systems: Choice of Idealized reactor model and reactor performance, Reactor configurations: Temperature Control, Choice of Reactors, Heat Integration characteristics of reactors, Appropriate placement of reactors

Module IV4 (8 Hours)

Integration of Distillation systems: Distillation sequencing, Heat Integration characteristics of Distillation column, Appropriate placement of distillation column, Various configurations for heat integration of distillation column

Module V (8 Hours)

Water System Design: Primary, Biological and Tertiary Treatment Processes, Targeting and Design of Maximum Water Reuse for Single Contaminants, Process Changes for Reduced Water Consumption, Targeting and Design of Minimum Wastewater Treatment Flowrate for Single Contaminants, Regeneration of Wastewater

Course Plan

No	Topic	No. of Lectures
1	**Energy targeting methods of heat exchanger networks (8 hours)**	
1.1	The idea of PI	1
1.2	Composite curve method	2
1.3	Problem table algorithm	2
1.4	Grand composite curve	2
1.5	Optimal selection of utilities	1
2	**Targeting of heat exchanger network (8 hours)**	
2.1	Number of units targeting	1
2.2	Number of shells targeting	2
2.3	Area targeting	2
2.4	Cost targeting	1
2.5	Grid diagram	1
2.6	Stream splitting design for single pinch networks	1
3	**Integration of reactor systems (8 hours)**	
3.1	Choice of Idealized reactor model and reactor performance	1
3.2	Reactor configurations: Temperature Control	2
3.3	Choice of Reactors	2
3.4	Heat Integration characteristics of reactors	2
3.5	Appropriate placement of reactors	1
4	**Integration of distillation systems (8 hours)**	
4.1	Distillation sequencing	2
4.2	Heat Integration characteristics of Distillation column	2
4.3	Appropriate placement of distillation column	2
4.4	Various configurations for heat integration of distillation column	2
5	**Water system design (8 hours)**	
5.1	Primary, Biological and Tertiary Treatment Processes	2
5.2	Targeting and Design of Maximum Water Reuse for Single Contaminants	2
5.3	Process Changes for Reduced Water Consumption	1
5.4	Targeting and Design of Minimum Wastewater Treatment Flowrate for Single Contaminants	2
5.5	Regeneration of Wastewater	1

Reference Books:

1. R. Smith, Chemical Process: Design and Integration, 1st Edition, Wiley,2005.
2. Kemp I.C., "Pinch Analysis and Process Integration: A User Guide on Process Integration for the Efficient Use of Energy", 2nd Ed., Butterworth-Heinemann. 2007
3. Shenoy U.V., "Heat Exchanger Network Synthesis", Gulf Publishing. 1995.
4. El-Halwagi M.M., "Process Integration", 7th Ed., Academic Press. 2006
5. Linnhoff, B. Townsend D. W., Boland D., Hewitt G. F., Thomas B.E.A., Guy A. R. and Marsland R. H., "A User's guide on process integration for efficient use of energy", Inst. Of Chemical Engineers, London (1982).

221ECH017	MODERN METHODS OF INSTRUMENTATION AND ANALYSIS	CATEGORY	L	T	P	CREDIT
		Program Elective 2	3	0	0	3

Preamble: This course aims at providing a sound knowledge on modern analytical instruments used in scientific research. The course deals with basic concepts of various modem instrumentation techniques such chromatography, spectroscopy, and thermal analysis, XRD, SEM, TEM etc. used in chemical analysis.

Pre-requisites- Nil

Course Outcomes:

After the completion of the course the student will be able to

CO 1	Explain the principles of differential scanning calorimetry (DSC), thermogravimetric analysis (TGA) and differential thermal analysis.
CO 2	Describe the principles UPS, XP, XRD, SEM, and TEM.
CO 3	Apply modern instrumentation and classical techniques, to design experiments
CO 4	Explain the qualitative and quantitative methods of Spectroscopic analysis.
CO 5	Compare the concepts involved in different spectroscopic techniques and select appropriate method for analysis.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	2		3			2	
CO 2	2		3			2	
CO 3	3	2	2	2		2	
CO 4	2		3				
CO 5	2		3				

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	60 %
Analyse	20 %
Evaluate	20 %
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 marks

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred) : 15 marks

Course based task/Seminar/Data collection and interpretation : 15 marks

Test paper, 1 no. : 10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern: 60 marks

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B.

Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions.

Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example, if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

Total duration of the examination will be 150 minutes.

Model Question Paper

QP CODE: **PAGES:**

Reg No:_______________ **Name: ______________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 221ECH017

Max. Marks: 60 Duration: 2.5 hours

MODERN METHODS OF INSTRUMENTATION AND ANALYSIS

PART – A

Answer All the Questions.

(5x 5 = 25)

1. What are the different factors affecting the choice of analytical method
2. Write briefly about electron capture detector
3. Explain the advantages of DSC over DTA
4. Write about different applications of X-ray
5. Explain the correlation of mass spectra with molecular structure.

PART – B

Answer any five (5 x 7 = 35)

6. Explain the principle, instrumentation and applications of Differential thermal analysis
7. Write the principle, instrumentation, and applications of HPLC.
8. Explain the laws of absorption. Derive the mathematical expression of beer-Lambert's law. Give its limitations
9. Discuss the principle behind IR spectroscopy?
10. Explain working principle and instrumentation of Auger electron microscopy-principle,
11. Compare the similarity in instrumentation of SEM & TEM.
12. Describe the principle and any two types of ionization methods of mass spectroscopy.

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Syllabus

Module I **9hours**

Basic functions of instrumentation, Classification of instrumental techniques, factors affecting choice of analytical method – interferences - data handling. Principles, instrumentation and applications of differential scanning calorimetry (DSC), thermogravimetric analysis (TGA) and differential thermal analysis (DTA).

Module II **10 hours**

Principles of chromatography, Classification of chromatography, Principle, Instrumentation - description of equipment and different parts, columns, carrier gas, stationary phase, instrumentation, sample injection. Applications. Detectors- thermal conductivity detectors, flame ionization detectors, thermionic emission detector and electron capture detector, nitrogen-Phosphorous detector,

Module (3) **7 hours**

General feature of spectroscopy, interaction of radiation with matter. UV-Visible spectroscopy: Introduction, Theory, Laws, Instrumentation associated with UV-Visible spectroscopy, Choice of solvents and solvent effect and Applications of UV Visible Spectroscopy. IR spectroscopy: Theory, Modes of Molecular vibrations, Sample handling, Instrumentation of Dispersive and Fourier – Transform IR Spectrometer, Factors affecting vibrational frequencies and applications of IR spectroscopy.

Module (4) **6hours**

Introduction to scanning electron microscopy, transform electron microscopy. Electron spectroscopy: Introduction, principle of Ultraviolet photoelectron spectroscopy (UPS) and X-ray photoelectron spectroscopy (XPS), types of peaks, chemical shifts, Instrumentation, Applications, Auger electron microscopy-principle, instrumentation and applications

Module (5) **8hours**

Mass spectroscopy- instrumentation ionization methods, mass analysis, correlation of mass spectra with molecular structure. X-ray absorption, Diffraction, fluorescence spectroscopy: Introduction, Instrumentation, X-ray absorption, Diffraction and fluorescence methods and its applications.

Course plan

No	Topic	No. of Lectures
1	**Module I (9hours)**	
1.1	Basic functions of instrumentation, Classification of instrumental techniques.	1
1.2	factors affecting choice of analytical method – interferences - data handling	1
1.3	Introduction to thermogravimetry	1
1.4	DSC-working principle & instrumentation	1
1.5	DTA-working principle & instrumentation	1
1.3	TGA- working principle & instrumentation	1
1.4	Applications advantages & disadvantages of DSC, DTA., TGA	1
2	**Module II (10 hours)**	
2.1	Principles of chromatography, Classification in chromatography,	1
2.2	Principle, Instrumentation - description of equipment and different parts, columns, carrier gas, stationary phase	1
2.3	Instrumentation, sample injection, Applications	1
2.4	Detectors - thermal conductivity detectors, flame ionization detectors, thermionic emission detector	1
2.5	Electron capture detector, nitrogen-Phosphorous detector	1
2.6	HPLC instrumentation, mobile phase delivery system, sample introduction	1
2.7	narrow bore column, short fast column, guard column and in-line filters	1
2.8	Separation columns – standard column, temperature control, isocratic and gradient elution	1
2.9	detectors —UV visible photometers and spectrometers, electrochemical detectors. High pressure liquid chromatography applications	2
3	**Module III (7 hours)**	
3.1	General feature of spectroscopy, interaction of radiation with matter.	1
3.2	UV-Visible spectroscopy: Introduction, Theory, Laws, Instrumentation associated with UV-Visible spectroscopy,	2
3.2	Choice of solvents and solvent effect and Applications of UV Visible Spectroscopy	1
3.2	IR spectroscopy: Theory, Modes of Molecular vibrations, Sample handling, Instrumentation of Dispersive and Fourier – Transform IR Spectrometer,	2
3.3	Factors affecting vibrational frequencies and Applications of IR spectroscopy	1
4	**Module IV (6 hours)**	
4.1	Working principle &instrumentation SEM	1
4.2	Working principle &instrumentation TEM	1

4.3	Electron spectroscopy: Introduction, principle of Ultraviolet photoelectron spectroscopy (UPS) and X-ray photoelectron spectroscopy (XPS), types of peaks, chemical shifts	2
4.4	Instrumentation, Applications, Auger electron microscopy-principle, instrumentation and applications	2
5	**Module V (8 hours)**	
5.1	Mass spectroscopy- instrumentation ionization methods, mass analysis, correlation of mass spectra with molecular structure.	2
5.2	X-ray absorption- Introduction, Instrumentation & applications	2
5.3	X-Diffraction- Introduction, Instrumentation & applications	2
5.4	X- fluorescence spectroscopy- Introduction, Instrumentation & applications	2

Reference Books

1. J. Mendham, J.D. Barnes, R.C. Denny& M.J.K.Thomas, Vogel's Textbook of Quantitative Chemical Analysis.
2. Gurdeep.R Chatwal, Sham Anand, Instrumental Methods of Chemical Analysis, Himalaya Publishing.
3. Hobart.H. Williard, Lynne.L. Merritt, John.A. Dan, Frank.A. Settle, Instrumental Methods of Analysis, CBS Publishers & Distributors
4. Introduction to instrumental analysis by R. D. Broun, Mc Graw Hill (1987)

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221ECH018	NOVEL SEPERATION PROCESS	CATEGORY	L	T	P	CREDIT
		Program Elective 2	3	0	0	3

Preamble:

Separation techniques are critical unit operations in most of the chemical, fertilizer, petrochemical, pharmaceutical and other process plants. The separation processes, like, membrane-based techniques, chromatographic separations, surfactant based separations and super critical fluid extractions are gaining importance in modern process plants. The present course is designed to emphasize on these novel separation processes.

Pre-requisites- Nil

Course Outcomes:

After the completion of the course the student will be able to

CO 1	Discuss the fundamentals of advanced separation processes.
CO 2	Apply chemical engineering principles to explain separation based on adsorption and ion exchange.
CO 3	Analyze various separation techniques based on separation factors.
CO 4	Develop fundamental understanding of external field and surfactant-based separation process.
CO 5	Select appropriate separation process for a specific application

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	2		3	3			
CO 2	2		3	3			
CO 3	2		3	3			
CO 4	2		3	3			
CO 5	2		3	3			

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	60 %
Analyse	40 %
Evaluate	
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Preparing a review article based on peer reviewed original publications (minimum 10

Publications shall be referred) : 15 marks
Course based task/Seminar/Data collection and interpretation : 15 marks
Test paper, 1 no. : 10 marks
Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern: The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B.
Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions.
Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.
<u>Note:</u> The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example, if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.
Total duration of the examination will be 150 minutes.

Model Question paper

QP CODE: **PAGES:**

Reg No:_______________ **Name: _______________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 221ECH018

Max. Marks: 60 Duration: 2.5 hours

NOVEL SEPARATION PROCESS

PART – A

Answer All the Questions.

One question from each module, having 5 marks for each question.

(5x 5 = 25)

1. Explain the significance on W_{min} (Minimum isothermal work) for separation process.
2. Calculate the osmotic pressure of a solution containing 0.1 gm mol KCl/1000 gm water at 25C, given that density of water at 25C is 997 Kg/m^3.
3. Describe how the Resolution of liquid chromatography column is calculated.
4. Write the applications of Foam separation.
5. Explain the mass transfer aspects in Pervaporation process.

PART – B

Minimum one question from each module (Total seven questions)

Answer any five (5 x 7 = 35)

6. Explain in detail about how the energy requirement for different separation process is calculated.
7. Explain about the solution diffusion model in connection with Reverse Osmosis.
8. A cellulose acetate membrane is being used for a desalination system using RO. The pure water flux is 100 l/m^2 hr at a hydrostatic pressure differential of 100 bar. A 4% NaCl solution is to be desalinated at an operating pressure difference of 90 bar. Salt rejection is 98% and the osmotic pressure of 3% NaCl is 17.62 bar. The polarization modulus is taken to be unity. Calculate the water and salt flux.
9. Explain the theory and applications of immuno chromatography.
10. Sketch a pervaporation system is designed to break the ethanol – water azeotrope.
11. What is the basic principle of Zone melting. Explain its significance in Industries
12. What are the factors that are important in supercritical fluid extraction and foam Separation.

Syllabus

Module I: Overview of Separation Processes (7 hours)

Characteristics and selection of separation process, factors influencing the choice of separation process, inherent separation factor. Recent advances in separation techniques based on size, surface properties, ionic properties and other special characteristics of substances. Rate based versus equilibrium separation processes, Energy requirements of separation processes. Selection and economics of separation process.

Module II: Separation by Adsorption Techniques (9 hours)

Separation by Adsorption Techniques, their mechanism, types and choice of adsorbents, normal adsorption techniques. Types of chromatography, Elution chromatography: Principles and Retention theory, Band broadening and separation efficiency. Affinity chromatography and immuno chromatography. Types of equipment and commercial processes, recent advances and process economics. Ion exchange: Basics of Ion exchange, Ion exchange resins, Binary ion exchange equilibrium, Ion movement theory, Applications.

Module III: Membrane based Separations (8 hours)

Classification, structure and characteristics of membranes, Types and choice of membranes, Plate and frame, tubular, spiral wound and hollow fiber membrane and their relative merits. Commercial, pilot plant and laboratory membrane permeators involving Dialysis, Reverse osmosis, Nano filtration, Ultra filtration, Micro filtration and Donnan dialysis and their application. Economics of membrane operations, Ceramic membranes.

Module IV: External field induced and Surfactant Based Separations (8 hours)

External field induced membrane separation processes for colloidal particles, Fundamentals of various colloid separations. Coupling of membrane separation and electrophoresis. Electric and magnetic field separations. Surfactant based separation processes, Liquid membranes-fundamentals and application, Micelles enhanced separation processes, Fundamentals of surfactants at surfaces and in solutions, Liquid membrane permeation, foam separations, micellar separations.

Module V: Other separation techniques (8 hours)

Super Critical Fluid Extraction: Physicochemical principles, thermodynamics, process synthesis and application, Separations involving Lyophilization, Pervaporation and permeation techniques for solids, liquids and gases, Separations involving Lyophilization, Pervaporation and permeation techniques for solids, liquids and gases, Zone melting, adductive crystallization, Industrial viability and examples.

Course Plan

No	Topic	No. of Lectures
1	**Module I: Overview of Separation Processes (7 hours)**	
1.1	Characteristics and selection of separation process, factors influencing the choice of separation process, inherent separation factor.	2 hrs
1.2	Recent advances in separation techniques based on size, surface properties, ionic properties and other special characteristics of substances.	2 hrs
1.3	Rate based versus equilibrium separation processes, Energy requirements of separation processes.	2 hrs
1.4	Selection and economics of separation process.	1 hr
2	**Module II: Separation by Adsorption Techniques (9 hours)**	
2.1	Separation by Adsorption Techniques, their mechanism, types and choice of adsorbents, normal adsorption techniques.	2 hrs
2.2	Types of chromatography, Elution chromatography: Principles and Retention theory, Band broadening and separation efficiency.	2 hrs
2.3	Affinity chromatography and immuno chromatography. Types of equipment and commercial processes, recent advances and process economics.	2 hrs
2.4	Ion exchange: Basics of Ion exchange, Ion exchange resins, Binary ion exchange equilibrium, Ion movement theory, Applications	3 hrs
3	**Module III: Membrane based Separations (8 hours)**	
3.1	Classification, structure and characteristics of membranes. Types and choice of membranes, Plate and frame, tubular, spiral wound and hollow fiber membrane and their relative merits.	3 hrs
3.2	Commercial, pilot plant and laboratory membrane permeators involving Dialysis, Reverse osmosis, Nano filtration, Ultra filtration, Micro filtration and Donnan dialysis and their application.	4 hrs
3.3	Economics of membrane operations, Ceramic membranes.	1 hr
4	**Module IV: External field induced and Surfactant Based Separations (8 hours)**	
4.1	External field induced membrane separation processes for colloidal particles, Fundamentals of various colloid separations.	2 hr
4.2	Coupling of membrane separation and electrophoresis. Electric and magnetic field separations.	2 hrs
4.3	Surfactant based separation processes, Liquid membranes-fundamentals and application, Micelles enhanced separation processes.	2 hrs
4.4	Fundamentals of surfactants at surfaces and in solutions. Liquid	2 hrs

	membrane permeation, foam separations, micellar separations.	
5	**Module V: Other separation techniques (8 hours)**	
5.1	Super Critical Fluid Extraction: Physicochemical principles, thermodynamics, process synthesis and application.	3 hrs
5.2	Separations involving Lyophilization, Pervaporation and permeation techniques for solids, liquids and gases.	3 hrs
5.3	Zone melting, adductive crystallization, Industrial viability and examples.	2 hrs

Reference Books

1. Kaushik Nath, Membrane separation Processes, PHI Pvt. Ltd., 2008

2. King, C.J, Separation Processes, Tata McGraw Hill Publishing Co., Ltd., 2013

3. Richard W. Baker, Membrane Technology and applications Second Edition, 2004.

4. Seader, J D, and Ernest J Henley. *Separation Process Principles*. New York, Wiley, 1998.

221ECH019	ADVANCED TRANSPORT PHENOMENA	CATEGORY	L	T	P	CREDIT
		Program Elective 2	3	0	0	3

Preamble:

In undergraduate level chemical engineering, students gain basic knowledge in momentum, heat and mass transfer. This course on advanced transport phenomena would help the students to meet the requirement of industry and research. This course would enable students to solve simple industrial problems in transport processes. It also acts as a foundation for courses such as computational flow modelling.

Pre-requisites- Nil

Course Outcomes:

After the completion of the course the student will be able to

CO 1	Demonstrate vector and tensor operations
CO 2	Solve industrial problems involving isothermal steady state momentum transfer in simple geometries using shell momentum balance and equations of change
CO 3	Obtain analytical solutions of selected simple engineering steady state problems of heat transfer using shell energy balance and equations of change
CO 4	Analyze simple steady state diffusion problems using shell mass balance

Mapping of course outcomes with program outcomes

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**
CO 1	3		3				
CO 2			3	3			
CO 3			3	3			
CO 4			3	3			

Assessment Pattern

Bloom's Category	**End Semester Examination**
Apply	60 %
Analyse	40 %
Evaluate	
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Preparing a review article based on peer-reviewed original publications (minimum 10 publications shall be referred) **: 15 marks**

Course-based task/Seminar/Data collection and interpretation **: 15 marks**

Test paper, 1 no. **: 10 marks**

Test paper shall include a minimum 80% of the syllabus.

End Semester Examination Pattern:

There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question. Part B will contain 7 questions with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Model Question Paper

Reg No.:________________ Name:___________________________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M.TECH DEGREE EXAMINATION, MONTH and YEAR

Course Code: 221ECH019

ADVANCED TRANSPORT PHENOMENA

Max. Marks: 60 Duration: 2.5 hours

Use of Photostat copies of the complex equations of the following in soft-bound form duly attested by the concerned faculty and Head of the Department of the institution shall be permitted in the Universityexamination hall.

1. Tables containing Equation of continuity and equation of motion in rectangular, cylindrical andspherical coordinate.

2. Tables containing Equations of the components of the stress tensor for Newtonian fluids in rectangular, cylindrical and spherical coordinate.

3. Tables containing Equation of energy in terms of momentum fluxes and transport properties in rectangular, cylindrical and spherical coordinate.

PART A

*Answer **all** questions, each carries **5 marks**.*

1	Define the terms (i) tensor (ii) unit tensor (iii) symmetric tensor	(5)
2	Write vector form of equation of motion. Explain significance of each term involved in it. What is the physical law underlying in the equation?	(5)
3	Sketch the velocity and shear stress distribution for the upward flow through a cylindrical annulus. Mark the surface of zero shear stress.	(5)
4	What are the assumptions used in transpiration cooling through two concentric porous spherical shells. Clearly mention the boundary conditions that can be applied.	(5)
5	Prove that the sum of the molar diffusion fluxes relative to the molar average velocity is zero in any mixture.	(5)

PART B

Answer any five full questions, each carries 7 marks.

6	State and explain integral theorems for vectors and tensors	(7)
7	Two immiscible liquids A and B flow between two parallel horizontal plates of length L and width W. The channel is half-filled with a more viscous dense fluid A and a less viscous light fluid B. Gravity may be considered unimportant, so that the pressure is essentially only a function of the horizontal distance, x. Clearly state the boundary and interfacial conditions, and hence derive expressions for the velocity profiles in the two layers. Also sketch the velocity profiles and the shear-stress distribution between the upper and lower phases.	(7)
8	A fluid of constant density and viscosity is in a cylindrical container of radius R. The container is caused to rotate about its own axis (vertical) at an angular velocity Ω. Find the shape of the free surface at steady state.	(7)
9	A thermocouple in a cylindrical well is exposed to a gas stream. Estimate the true temperature of the gas stream, if the temperature indicated by the thermocouple is 500 K, wall temperature is 350 K, heat transfer coefficient of the gas stream is 120 W/m^2K, thermal conductivity of the well wall is 60 W/m K, and thickness of the well wall is 2 mm and length of well is 6 cm.	(7)
10	A fluid with density ρ, viscosity μ is placed between two very long vertical walls at a distance 2B apart. The heated wall is maintained at T2 and cooled wall at T1. The system is closed at top and bottom. The temperature is function of one coordinate only. Develop the expression for the temperature profile and velocity distribution between the plates.	(7)
11	Starting from fundamentals, derive the equation of continuity.	(7)
12	Diffusivity of a gas pair O_2-CCl_4 is determined by observing the steady state evaporation of CCl_4 into a tube containing O_2. The distance between CCl_4 liquid level and the top of the tube is 17.1cm. The total pressure on the system is 755 mmHg and temperature is 273 K. The vapour pressure of CCl_4 at that temperature is 33 mmHg. The cross-sectional area of diffusion tube is 0.82 cm^2. It is found that 0.0208 cm^3 of CCl_4 evaporate in a 10 hr period after steady state has been achieved. (i)What will be diffusivity of gas pair CCl_4-O_2. Given that density of CCl_4=1.59 g/cm^3. (ii)Sketch the concentration profile of components.	(7)

Syllabus

Module 1 (7 hours)

Vector and tensor algebra: Geometric and analytical view point operations on vectors. Tensors: second order tensor, mathematical operations of second order tensor. Integral Theorems: Divergence theorem, curl theorem, Liebnitz rule. Kinematics: Eulerian & Lagrangian representations, relationship between Eulerian and Lagrangian viewpoints. Coordinate systems and time derivative.

Module 2 (8 hours)

Shell momentum balances and velocity distributions in laminar flow: shell momentum balances and boundary conditions. Application of shell balance to simple flow systems: Derivation of Hagen-Poiseuille equation, Buckingham Reiner equation, flow of two adjacent immiscible fluids between pair of horizontal plates. Derivation of continuity equation. Derivation of equation of motion in rectangular coordinates, Navier Stoke's equation and Euler equation with significance of each terms, transport equation in curvilinear coordinates (derivation not desired).

Module 3 (7 hours)

Application of transport equations to solve steady flow problems:- Flow of a falling film, flow through annulus, flow through narrow slit, tangential annular flow, cone and plate viscometer , shape of surface of a rotating liquid and simple flow problems.

Module 4 (10 hours)

Shell energy balance: - Boundary conditions, application of shell balances to fixed bed flow reactor, cooling fins with insulated tip condition, heat transfer by free convection between two vertical plates. Equations of energy in rectangular coordinates (derivation not desired), energy equations in curvilinear coordinates (derivation not desired), application to steady state heat transfer problems: - tangential flow in annulus with viscous heat generation, transpiration cooling.

Module 5 (8 hours)

Definitions of concentrations, velocities and mass fluxes. Shell mass balances: Boundary conditions, diffusion through a stagnant gas film, diffusion with homogeneous and heterogeneous chemical reaction, diffusion into a falling liquid film (gas absorption), diffusion and reaction in a spherical droplet. Derivation of equation of continuity for binary mixtures in rectangular coordinates in mass and molar units, general study of equation of continuity in curvilinear coordinates (derivation not desired). use ofequations of change to solve problems involving simultaneous heat and mass transport.

Course plan

No	Topic	No. of Lectures
1	**Module 1(7 hours)**	
1.1	Vector and tensor algebra: Geometric and analytical view point operations on vectors.	2
1.2	Tensors: second order tensor, mathematical operations of second order tensor.	2
1.3	Integral Theorems: Divergence theorem, curl theorem, Liebnitz rule.	1
1.4	Kinematics: Eulerian & Lagrangianre presentations, relationship between Eulerian and Lagrangian viewpoints.	1
1.5	Coordinate systems and time derivative.	1
2	**Module 2 (8 hours)**	
2.1	Shell momentum balances and velocity distributions in laminar flow: shell momentum balances and boundary conditions.	1
2.2	Application of shell balance to simple flow systems: Derivation of Hagen-Poiseuille equation, Buckingham Reiner equation, flow of two adjacent immiscible fluids between pair of horizontal plates.	4
2.3	Derivation of continuity equation	1
2.4	Derivation of equation of motion in rectangular coordinates, Navier Stoke's equation and Euler equation with significance of each terms, transport equation in curvilinear coordinates (derivation not desired)	2
3	**Module 3 (7 hours)**	
3.1	Application of transport equations to solve steady flow problems:- Flow of a falling film	2
3.2	Flow through annulus	1
3.3	Flow through narrow slit	1
3.4	Tangential annular flow	1
3.5	Shape of surfaceof a rotating liquid	1
3.6	Cone and plate viscometer	1
4	**Module 4 (10 hours)**	
4.1	Shell energy balance: - Boundary conditions, application of shell balances to fixed bed flow reactor	2
4.2	Cooling fins with insulated tip condition	2
4.3	Heat transfer by free convection between two vertical plates	2
4.4	Equations of energy in rectangular coordinates (derivation not desired), energy equations in curvilinear coordinates (derivation not desired) , application to steady state heat transfer problems:- tangential flow in annulus with viscous heat generation	2
4.5	Transpiration cooling	2
5	**Module 5 (8 hours)**	
5.1	Definitions of concentrations, velocities and mass fluxes. Shell mass	2

	balances: Boundary conditions, diffusion through a stagnant gas film	
5.2	Diffusion with homogeneous and heterogeneous chemical reaction	2
5.3	Diffusion into a falling liquid film (gas absorption)	1
5.4	Diffusion and reaction in a spherical droplet.	1
5.5	Derivation of equation of continuity for binary mixtures in rectangular coordinates in mass and molar units, general study of equation of continuity in curvilinear coordinates (derivation not desired). use ofequations of change to solve problems involving simultaneous heat and mass transport.	2

Reference Books

1. Bird R.B., Stewart W.C and Lightfoot F.N, Transport phenomena, John Wiley & Sons.
2. Theodore L, Transport Phenomena for Engineers by, International text book Company, U.S.A
3. Geankoplis, Transport processes and unit operations, 3rd, , PHI, 1997.
4. Welty, Wicks and Wilson, Fundamentals of Heat, Momentum and Mass Transfer, John Wiley.
5. John C Slattery, Momentum, Energy and Mass transfer in continua, McGraw Hill, Co.
6. Robert S. Brodkey and Harry C Hersing, Transport Phenomena a Unified approach, McGraw Hill Book Co.
7. Bennet C U and Myers J E, Momentum, Heat and Mass Transfer, Tata McGraw Hill Publishing Co.

221ECH020	HETEROGENEOUS CATALYSIS AND CATALYTIC PROCESSES	CATEGORY	L	T	P	CREDIT
		PROGRAM ELECTIVE 2	3	0	0	3

Preamble:

Heterogeneous catalysis plays a very important and defining role in most of the chemical industry. This course starts with basics of catalysis and goes deeper into various aspects of catalytic preparation and characterization techniques. The topics will also include study of reaction mechanism and kinetics of the heterogeneous catalytic reactions. Effect of external and internal transport processes on reaction rates will be discussed. Catalyst deactivation which is the main problem faced in heterogeneous catalytic process will be covered in detail. Various actual industrial catalytic processes and new developments in catalysis will be covered.

Pre-requisites- Nil

Course Outcomes:

After the completion of the course the student will be able to

CO 1	Explain various catalysts and the role of catalyst in chemical reactions
CO 2	Analyse heterogeneous reactions and kinetics in catalytic processes
CO 3	Knowledge of preparation of catalyst and support
CO 4	Understanding of characterisation of catalysts
CO 5	Applications of heterogeneous catalysis in industry and new developments in catalysis

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	3		1				
CO 2			3				
CO 3			3				
CO 4	3		**3**				
CO 5			2	3	3		

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	50 %
Analyze	50 %
Evaluate	

Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Preparing a review article based on peer-reviewed original publications (minimum 10 publications shall be referred) **: 15 marks**

Course-based task/Seminar/Data collection and interpretation **: 15 marks**

Test paper, 1 no. **: 10 marks**

Test paper shall include a minimum 80% of the syllabus.

End Semester Examination Pattern:

There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question. Part B will contain 7 questions with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Model Question Paper

QP CODE: **PAGES:**

Reg No:_______________ **Name: _______________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 221ECH020

Max. Marks: 60 Duration: 2.5 hours

HETEROGENEOUS CATALYSIS AND CATALYTIC PROCESSES

PART A (Answer ***all*** questions**)**

1.	What do you mean by a rate determining step in catalysis?	5
2.	What are the causes of deactivation of catalyst?	5
3.	Write note on selection of support for catalyst	5
4.	Explain principle of XRD	5
5.	What is green catalysis?	5

PART B (Answer ***any five*** questions**)**

6.	Explain adsorption isotherms	7
7.	Write note on organo metallic catalysts and dual function catalysts	7
8.	Briefly describe CVD process	7
9.	List various techniques used for characterization of catalysts. Explain any one technique.	7
10.	Write note on surface area measurement by BET	7
11.	Describe fluidized bed reactor with the help of a neat sketch.	7
12.	Explain any two applications for industrial catalysis	7

Syllabus

Module 1 (8 hours)

Introduction to catalysis, scope and importance, basic concepts. Heterogeneous catalytic processes, types of heterogeneous reactions, rate determining steps, reaction kinetics, Langmuir, Hinshelwood kinetics, Michaelis, Menten kinetics, Thermodynamics of adsorption, Physical adsorption and chemisorptions. Adsorption isotherms.

Module 2 (8 hours)

Solid catalysis, types of catalysts, transition metal catalyst, organo metallic catalyst, dual function catalyst, Zeolite, active sites, promoters, modifiers, catalyst deactivation, sintering, thermal degradation, inhibition, poisoning - poisoning of metallic catalysts, poisoning of nonmetallic catalysts, poisoning of bifunctional catalysts, coke formation on catalysts, metal deposition on catalysts. Regeneration of deactivated catalyst.

Module 3 (8 hours)

Catalyst preparative methods – supported catalysts – precipitation, adsorption, ion exchange, reductive deposition, Chemical Vapor Deposition, preparation and applications of zeolite catalysts, preparation and structure of supports, selection of right support.

Module 4 (7 hours)

Catalyst Characterisation- surface area measurements, BET theory, Pore size distribution, Porosimetry, Chemisorption techniques, Static and dynamic methods, Crystallography and surface analysis techniques – XRD, NMR. Characterization of zeolite catalyst

Module 5 (8 hours)

Industrial processes involving heterogeneous solid catalysts – Haber process, contact process for sulfuric acid preparation, catalytic processes in petroleum industry (overview) – catalytic cracking of gas oil.

New development in solid catalysis, monolith catalysts, nanocatalysts, Fuel cell catalysts, Environmental catalyst – fluidized bed, trickle bed, introduction and basic concept of green catalysis

Course Plan

No	Topic	No. of Lectures
1	**Module 1 (8 hours)**	
1.1	Introduction to catalysis, scope and importance, basic concepts	2
1.2	Heterogeneous catalytic processes, types of heterogeneous reactions, rate determining steps	2
1.3	Langmuir, Hinshelwood kinetics, Michaelis, Menten kinetics	2
1.4	Thermodynamics of adsorption, Physical adsorption and chemisorptions. Adsorption isotherms	2
2	**Module 2 (9 hours)**	
2.1	Solid catalysis, types of catalysts, transition metal catalyst, organo metallic catalyst, dual function catalyst, Zeolite	2
2.2	active sites, promoters, modifiers	1
2.3	catalyst deactivation, sintering, thermal degradation, inhibition	2
2.4	poisoning of metallic catalysts, poisoning of non metallic catalysts, poisoning of bifunctional catalysts	2
2.5	coke formation on catalysts, metal deposition on catalysts. Regeneration of deactivated catalyst.	2
3	**Module 3 (8 hours)**	
3.1	Catalyst preparative methods – supported catalysts – precipitation, adsorption, ion exchange, reductive deposition	2
3.2	Chemical Vapor Deposition	1
3.3	preparation and applications of zeolite catalysts	2
3.4	preparation and structure of supports	2
3.5	selection of right support	1
4	**Module 4 (7 hours)**	
4.1	Catalyst Characterisation- surface area measurements, BET theory	1
4.2	Pore size distribution, Porosimetry	1
4.3	Chemisorption techniques	1
4.4	Static and dynamic methods	2
4.5	Crystallography and surface analysis techniques – XRD, NMR	2
5	**Module 5 (8 hours)**	
5.1	Industrial processes involving heterogeneous solid catalysts	2
5.2	New development in solid catalysis, monolith catalysts	1
5.3	nanocatalysts, Fuel cell catalysts	1
5.4	Environmental catalyst – fluidized bed, trickle bed	2
5.5	introduction and basic concept of green catalysis	2

Reference Books

1. J. M. Smith, Chemical Engineering Kinetics, Mc, Graw Hill, 1981
2. Thomas and Thomas, Introduction to Heterogeneous Catalysis, Academic Press, London, 1967
3. B. Viswanathan, S. Sivasanker , A.V. Ramaswamy, "Catalysis : Principles & Applications" CRC Press.
4. H. S. Fogler, "Elements of Chemical reaction engineering" Prentice – Hall of India
5. Diazo Kunii, and Octave Levenspiel, Fluidization Engineering, Butterworth-Heinemann
6. C. H. Bartholomew and R. J. Farrauto "Fundamentals of Industrial catalytic Processes", Wiley- VCH
7. Rothenberg G, Catalysis: Concepts and green applications, Wiley Publications, 2008

221ECH021	BIOCHEMICAL ENGINEERING	CATEGORY	L	T	P	CREDIT
		Program Elective 2	3	0	0	3

Preamble:

Biochemical engineering, also known as bioprocess engineering amalgamates the facts from both chemical engineering and biological engineering. It mainly deals with the design, construction, and advancement of unit processes that involve biological organisms or organic molecules. This subject has various applications in the areas of biofuels, pharmaceuticals, agriculture, food sciences, biotechnology and water treatment processes.

This course would enable students to gain a basic knowledge on application of the biological processes to design a bioreactor for bioprocess industries and Analysis of various bio separation processes

Pre-requisites- Nil

Course Outcomes:

After the completion of the course the student will be able to

CO1	Apply basic knowledge of energy and material balances for understanding the metabolic pathways within the cell
CO2	Interpret kinetics of enzyme catalyzed reactions
CO3	Apply stoichiometric principles in bioreactors and bioprocess
CO4	Describe design and operation of a fermentation process and use of sensors
CO5	Describe various product recovery and purification processes in bioprocesses

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1			3	3			
CO 2			3	3			
CO 3			3	3			
CO 4			3	3			
CO 5			3	3			

Assessment Pattern

Bloom's Category	End Semester Examination

Apply	50
Analyse	30
Evaluate	20
Create	-

Mark distribution

Total Marks	**CIE**	**ESE**	**ESE Duration**
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 marks

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred): 15 marks

Course based task/Seminar/Data collection and interpretation: 15 marks

Test paper, 1 no.: 10 marks

Test paper shall include minimum 80% of the syllabus. End Semester Examination Pattern:

End Semester Examination Pattern: 60 marks

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B.

Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions.

Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry

7 marks.

Note: The marks obtained for the ESE for an elective course shall not exceed 20%

over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example, if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

Total duration of the examination will be 150 minutes.

Model Question Paper

Reg No.:________________ Name:___________________________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M.TECH DEGREE EXAMINATION, MONTH and YEAR

Course Code: 221ECH021

BIOCHEMICAL ENGINEERING

Max. Marks: 60 Duration: 2.5 hours

PART – A

Answer All the Questions.

(5x 5 = 25)

1. Describe bioleaching? Give the names of two bioleaching agents
2. Explain lock and key enzyme hypothesis
3. Plot Monod Growth kinetics
4. Distinguish physical and chemical sensors
5. Explain the principle of electrophoresis

PART – B

Answer any five (5 x 7 = 35)

6. Describe the Kreb's cycle with a neat diagram. (7)
7. Explain the functions of carbon catabolism. (7)
8. Illustrate the effect of competitive inhibitors on the rate expression of a biochemical reaction. (7)
9. Describe the three methods used for evaluation Michaelis -Menten parameters with suitable plots. (7)
10. Explain different Mixing patterns in non-ideal bioreactors. (7)
11. Explain plant cell reactor technology. (7)
12. Explain solvent extraction used in the biochemical product recovery operations. (7)

Syllabus

Module 1 ENERGETICS OF THE CELL (7 hours)

Metabolic reaction coupling: ATP, ADP and NAD. Oxidation and reduction- Coupling via NAD. Embden-Meyerhof pathway (EMP), Pentose phosphate cycle, Respiration - TCA cycle). An understanding of biochemical processes like photosynthesis, biosynthesis, carbon catabolism, biosorption, bioleaching and bioremediation

Module 2 ENZYME KINETICS (9 hours)

Kinetics of enzymes – catalysed reactions, Michaelis-Menten kinetics for different types of enzyme catalysed reactions. Solution of problems on above reactions for estimating step constants of Michaelis-Menten equation. Substrate activation and inhibition, Enzyme activation and inhibition, Enzyme specificity and enzyme specificity hypotheses

Module 3 BIOREACTORS (8 hours)

Growth of cells in a batch process-phases of growth. Monod growth kinetics. Ideal batch reactors- fed-batch reactor, CSTR, PFR, Non- ideal reactors. Multi-phase bioreactors –packed bed type, bubble column bioreactor, fluidized bed type, trickle bed type Mixing patterns and RTD in non-ideal bioreactors.

Module 4 FERMENTATION AND BIOSENSORS (8 hours)

Fermentation technology, medium formulation, design and operation of a typical aseptic, aerobic fermentation process. Different configurations for fermenters. Animal and plant cell reactor technology. Physical and chemical sensors, gas analysis sensors, On-line sensors and offline sensors for cell properties.

Module 5 PRODUCT RECOVERY OPERATIONS (8 hours)

Upstream and downstream processing, product recovery operations-filtration, centrifugation, sedimentation, solvent extraction, extraction using two-phase systems, sorption and precipitation. Purification processes like reverse osmosis, ultra-filtration, electrophoresis, dialysis

Course plan

1	**Module I (7 hours)**	
1.1	Metabolic reaction coupling: ATP, ADP and NAD	1
1.2	Oxidation and reduction- Coupling via NAD	1
1.3	Embden-Meyerhof pathway (EMP), Pentose phosphate cycle	1
1.4	Respiration - TCA cycle	1
1.5	Photosynthesis, Biosynthesis	1
1.6	Carbon catabolism, biosorption	1
1.7	Bioleaching and bioremediation	1
2	**Module II (9 hours)**	
2.1	Simple enzyme kinetics with one or two substrates	1
2.2	Derivation of Michaelis - Menten Kinetics	1
2.3	Estimating step constants of MM Eqn	2
2.4	Description of Substrate activation and inhibition	1
2.5	Description of Enzyme activation and inhibition	1
2.6	Derivation of competitive inhibition	1
2.7	Derivation of uncompetitive inhibition	1
2.8	Enzyme specificity and enzyme specificity hypotheses	1
3	**Module III (8 hours)**	
3.1	Growth cycle in batch cultivation - (lag, exponential, stationery and death phase)	1
3.2	Monod growth kinetics	1
3.3	Ideal batch reactors- fed-batch reactor, CSTR, PFR	2
3.4	Non- ideal reactors. Multi-phase bioreactors –packed bed type, bubble column bioreactor	1
3.5	Fluidized bed type, Trickle bed type	1
3.6	Mixing patterns and RTD in non-ideal bioreactors	2
4	**Module IV (8 hours)**	
4.1	Introductions to Fermentation technology	1
4.2	Design and operation of a typical aseptic, aerobic fermentation process	2
4.3	Different configurations for fermenters	1
4.4	Animal and plant cell reactor technology.	1
4.5	Physical and chemical sensors, gas analysis sensors	1
4.6	On-line sensors for cell properties	1
4.7	Offline sensors for cell properties	1
5	**Module V (8 hours)**	
5.1	Introduction to Upstream and downstream processing in bioprocesses,	1

5.2	Product recovery operations	1
5.3	Filtration, centrifugation	1
5.4	Sedimentation, solvent extraction	1
5.5	Extraction using two-phase systems	1
5.6	Sorption and precipitation	1
5.7	Reverse osmosis, ultra-filtration	1
5.8	Electrophoresis, dialysis	1

Reference Books

1. James E. Bailey and David F. Ollis., "Bio-chemical Engineering Fundamentals". Mc Graw Hill International Editions.
2. D G Rao., "Introduction to Biochemical Engineering", Tata Mc Graw Hill.
3. Michael L Shuler and Frikret Khargi., "Bioprocess Engineering Basic Concepts" PHI Publications.
4. Aiba, Humphrey, Millis, Biochemical engineering, 2nd Edn., Academic Press
5. Biochemical Engineering by H. W.Blanch & D.S. Clark, Marcel Dekker, Inc., 1997.
6. Bioprocess Engineering principles Paulin M Doran ISBN-978-0-12-220851-5
7. Donald Wise, Bioinstrumentation and Biosensors, Pearson education
8. Levenspiel O, chemical reaction engineering, 3rd Edn., Wiley Eastern

221LCH001	COMPUTER AIDED DESIGN LAB	CATEGORY	L	T	P	CREDIT
		LAB	0	0	2	1

Preamble:

This lab aims to impart the students with basic knowledge and skills for using Commercial chemical process simulators and interpret the simulated results.

Pre-requisites- Nil

Course Outcomes:

After the completion of the course, the student will be able to

CO 1	Use commercial process simulation software tools for the analysis of process equipment.
CO 2	Select an appropriate property package, operation or a group of operations to simulate a unit operation, a unit process or part of the process plant.
CO 3	Employ the utility of the software tools in solving real time chemical engineering problems.
CO 4	Perform dynamic simulation of an operation or a small portion of a process plant to predict the variation of operating parameters on a servo or regulator problem of process control.
CO 5	Use and interpret results from a commercial process simulation software package.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1			3	3	3		
CO 2			3	3	3		
CO 3			3	3	3		
CO 4			3	3	3		
CO 5			3	3	3		

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	30 %

Analyze	70 %
Evaluate	
Create	

Internal Continuous Assessment: (MaximumMarks-100)

Practical Records/Outputs : 40 marks

Regular class viva voce : 20 marks

End semester exam : 40 marks

Number of Experiment to be performed

At least 10 experiments must be performed from the experiments listed below.

List of experiments

1. **Equations of state**: To study the effect of temperature and pressure on molar volume of a gas using various equations of state with the help of DWSIM/Unisim etc.
2. **Phase equilibrium**: Analysis of vapour-liquid equilibrium with the help of DWSIM/Unisim etc.
3. **Chemical Reaction equilibrium**: Study of various possibilities of finding the product composition in an equilibrium reaction using DWSIM/Unisim etc.
4. **Mass Balances**: Study of material balance of chemical processes involving recycle/purge of material streams using DWSIM/Unisim etc.
5. **Simulation of Mass Transfer Equipment**: Steady-state simulation of shortcut/ rigorous distillation column using process simulators such as DWSIM/Unisim etc.
6. **Simulation of Mass Transfer Equipment**: Steady-state simulation of absorption column using process simulators such as DWSIM/Unisim etc.
7. **Simulation of Mass Transfer Equipment**: Steady-state simulation of liquid- liquid extraction column using process simulators such as DWSIM/Unisim etc.
8. **Simulation of Chemical Reactors**: Steady-state simulation of a Plug Flow Reactor/ Mixed Flow Reactor using suitable example in process simulators such as DWSIM/Unisim etc.
9. **Simulation of process**: Steady-state simulation of a typical chemical plant involving heat exchangers/ coolers/ heaters using process simulators such as DWSIM/Unisim etc.
10. **Simulation of process**: Steady-state simulation of a typical chemical plant involving

pumps/ compressors using process simulators such as DWSIM/Unisim etc.

11. **Simulation of process**: Steady-state simulation of a typical chemical plant involving a reactor and a mass transfer operation using process simulators such as DWSIM/Unisim etc.
12. **Dynamic simulation**: Dynamic simulation of a process part involving flow/level/temperature/pressure control.