SEMESTER II

Discipline: Chemical Engineering

Stream: CH2, Computer Aided Process Design

222TCH100	PROCESS MODELLING AND SIMULATION	CATEGORY	L	T	P	CREDIT
		Discipline core	3	0	0	3

Preamble:

In chemical engineering, modelling and simulation are important tools for engineers and scientists to better understand the behaviour of chemical plants. Modelling and simulation are very useful to design, to scale up and optimize pieces of equipment and chemical plants, for process control, for troubleshooting, for operational fault detection, for training of operators and engineers, for costing and operational planning, etc. A very important characteristic of modelling and simulation is its advantageous cost–benefit ratio because with a virtual chemical plant, obtained from the modelling and simulation, it is possible to predict different scenarios of operations and to test many layouts at almost no cost and in a safe way.

Pre-requisites- Nil

Course Outcomes:

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

CO 1	Summarize the methods and approaches used in Process Modelling and Simulation.
CO 2	Apply the fundamental laws of chemical engineering systems in developing mathematical models of process.
CO 3	Develop models for reactor systems.
CO 4	Develop models for separation processes.
CO 5	Develop models for distributed systems.
CO 6	Apply Simulation strategy for flow/reactor systems.

Mapping of course outcomes with program outcomes

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

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 respective College. 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

SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 222TCH100

Max. Marks: 60 Duration: 2.5 hrs.

Process Modelling and Simulation

PART – A

Answer All the Questions.

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

(5x 5 = 25)

1. Explain modelling with an example.
2. Explain equation of chemical kinetics.
3. Write the model equation of batch reactor.
4. Write the model equation of heating in open vessel.
5. Explain distributed systems with an example.

PART – B

Minimum one question from each module (Total seven questions)

Answer any five (5 x 7 = 35)

6. Explain the uses of mathematical modelling?
7. Explain the classification of modelling techniques?
8. Explain the basic modelling principles.
9. Develop the mathematical model for continuous flow tank.
10. Develop the mathematical model for steam jacketed vessel.
11. Develop the mathematical model for batch distillation.
12. Develop the simulation strategy of a gravity flow tank for the level dynamics.

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SYLLABUS

Module 1 (8hours)

Definitions and basic concepts: Definitions and basic concepts: Definition of Modelling, Simulation, Classification of modelling techniques, Basic modelling principles, Parameter estimation techniques in theoretical as well as numerical models.

Module 2 (8hours)

Fundamental laws of chemical engineering: Fundamental laws of chemical engineering, Energy equations, continuity equation, equation of motion, transport equations, equations of state, Equilibrium states and chemical kinetics, Modeling of continuous flow tank.

Module 3 (8hours)

Models of reactors: Models of reactors: Mixing with reaction - reversible reaction-steam jacketed vessel-isothermal constant and variable holdup CSTR in series-Boiling in open and closed vessel.

Module 4 (8hours)

Models of separation processes: Models of separation processes: Multicomponent flash drum- ideal binary distillation column – multicomponent distillation column, batch distillation-condensation.

Module 5 (8hours)

Distributed system modelling: Distributed system modelling: Jacketed tubular reactor - counter current liquid-liquid heat exchanger, Simulation of gravity flow tank- CSTR in series - non-isothermal CSTR- batch reactor.

Course plan

No	Topic	No. of Lectures
1	**Definitions and basic concepts (8hours)**	
1.1	Definition of Modelling, Simulation,	2
1.2	Classification of modelling techniques,	2
1.3	Basic modelling principles	2
1.4	Parameter estimation techniques in theoretical as well as numerical models.	2
2	**Fundamental laws of chemical engineering (8hours)**	
2.1	Energy equations, continuity equation,	2
2.2	Equation of motion, transport equations,	2
2.3	Equations of state, Equilibrium states and chemical kinetics,	2
2.4	Modelling of continuous flow tank	2
3	**Models of reactors (8hours)**	

3.1	Mixing with reaction - reversible reaction	2
3.2	Steam jacketed vessel	2
3.3	Isothermal constant and variable holdup CSTR in series-	2
3.4	Boiling in open and closed vessel.	2
4	**Models of separation processes (8hours)**	
4.1	Multicomponent flash drum, Condensation	2
4.2	Ideal binary distillation column	2
4.3	Multicomponent distillation column	2
4.4	Batch distillation	2
5	**Distributed system modelling (8hours)**	
5.1	Jacketed tubular reactor	2
5.2	Counter current liquid-liquid heat exchanger	2
5.3	Simulation of gravity flow tank, CSTR in series	2
5.4	Simulation of non-isothermal CSTR.	2

Reference Books

1. Denn M. M., "Process Modeling", Longman, 1986.

2. Holland C. D., "Fundamentals and Modeling of Separation Processes", Prentice Hall., 1975.

3. Luyben W. L., "Process Modeling Simulation and Control for Chemical Engineers", 2nd Ed., McGraw Hill, 1990.

4. Najim K., "Process Modeling and Control in Chemical Engineering", CRC, 1990.

5. Aris R., "Mathematical Modeling, Vol. 1: A Chemical Engineering Perspective (Process System Engineering)", Academic Press, 1999.

6. R. G. E. Franks, Modeling and Simulation in Chemical Engineering, Wiley-Interscience, New York, 1972.

222TCH002	PROCESS DESIGN II	CATEGORY	L	T	P	CREDIT
		Program Core	3	0	0	3

Preamble: This course is a continuation of Process Design I. The objective of this course is to give a foundation in the design of equipment used in process industries for the unit operations such as distillation, gas absorption, liquid extraction, evaporative cooling, and drying.

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
CO 3	Utilize proper codes & standards, empirical equations and rules of thumbs in the design of chemical engineering units
CO 4	Apply the principles of mass transfer to the design of gas-liquid contacting equipment.
CO 5	Apply the principles of mass transfer to the design of liquid -liquid contacting equipment.
CO 6	Apply the principles of heat and mass transfer to the design of equipment involving combined heat and 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			
CO 4			3	3			
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 data books 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
4. Attested copy of Sieve tray design procedure for liquid extraction from 'Mass Transfer Operations' by Robert E. Treybal, pages 532-538

Model Question paper

QP CODE: PAGES: 2

Reg No:……………______________

Name :…………….______________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 222TCH002

Marks: 60 Max Duration: 2.5 Hours

PROCESS DESIGN II

Instructions:

Apart from scientific calculators (including programmable) the following books and data books 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

4. Attested copy of Sieve tray design procedure for liquid extraction from 'Mass Transfer Operations' by Robert E. Treybal , pg 532-538

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

Module I

1. A continuous distillation column produces 24,000 kg/h of aqueous acetic acid with a concentration of 97% by weight from a feed mixture of acetic acid and water containing 60% by weight acid. The feed and reflux are at their bubble points. The distillate contains 98% by weight water. The pressure in the column is atmospheric and the reflux ratio is 1.5 times the minimum required.

VLE data at 1atm:

Temperature, ^oC		118.3	110.6	107.8	105.2	104.3	103.5	102.8
Mole fraction of water	Liquid	0.0	0.188	0.308	0.450	0.520	0.582	0.675
	Vapor	0.0	0.306	0.447	0.597	0.658	0.711	0.780
Temperature, ^oC		102.1	101.5	100.8	100.8	100.5	100.2	100
Mole fraction of water	Liquid	0.726	0.795	0.856	0.879	0.913	0.958	1.0
	Vapor	0.824	0.867	0.904	0.919	0.941	0.971	1.0

i) For a sieve tray column, calculate the number of actual trays in each section and location of feed stage for an overall tray efficiency of 64%. (10 marks)

ii) Design a segmented sieve tray and estimate pressure drop (20 marks)

OR

2. 10,000 kg/h of SO_2 bearing air is to be cleaned using water at 30^oC in a counter current absorption tower. The concentrations of SO_2 in the inlet air entering the absorber is 12% by weight and the air leaving the absorber is 1% by weight.

a) Design absorption (10 marks)

b) Design a suitable packed column (20 marks)

(30 marks)

Module II

3. An induced draft tower with wooden fills has to be designed for cooling 36,000 litres per hour in a plant. The water has to be cooled from 34 ^oC to 27 ^oC. The air conditions are: DBT = 30 ^oC and WBT = 24 ^oC. Use an air rate of 1.5 times the minimum required rate. For this operation, estimate

i. the air rate required,
ii. number of diffusion units and
iii. tower cross sectional area
iv. fan hp
v. make-up water requirement

(30 marks)

OR

4. A counter current direct heat rotary dryer is used for drying wet ore obtained from a froth floatation with 15% moisture using hot air available at 250^oC and humidity 0.012. The solid inlet temperature is 32^oC and is to be discharged at 90^oC.

Properties of ore: Bulk density = 1800 kg/m^3 of dry solid
Mean specific heat = 2400 J/kg^oC
Particle size = 200 micron

a. Calculate the air rate required
b. Estimate the drying temperature of solids.
c. Estimate dryer diameter and length
d. Evaluate percentage hold up if slope is 1 in 50.

(30 marks)

Syllabus

Module I (20 hours)

Process design of steady state isothermal binary component tray distillation columns (Sieve and valve tray): Estimation of theoretical number of stages using McCabe Thiele method – Tray design –tray efficiency - pressure drop, entrainment, downflow flooding and weeping. Process design of steady state isothermal packed bed absorption and stripping column for dilute systems without chemical reaction: Number of transfer units- height of transfer units – column diameter – packing height-liquid distribution-pressure drop.

Module II (20 hours)

Process design of mechanical draft Cooling Towers: Estimation of air quantity, tower characteristics - number of diffusion units using graphical method, water concentration, tower cross section area, fan hp, make-up water requirement.

Design of Direct heat Rotary Dryers: Estimation of air quantity, drying temperature, Number of Transfer Units, Diameter of dryer, Length, speed, slope, flight, hold up time.

Process design of sieve tray single solvent extraction columns: Number of trays, sieve tray design, height of coalesced layer, Murphree efficiency.

Computer Aided Design and Analysis of Multicomponent Distillation processes by FUG (Fenske — Underwood — Gilliland) Method.

Course plan

No	Topic	No. of Lectures
1	**Module I: (Gas-liquid Contactors)**	**20 hours**
1.1	Process design of steady state isothermal binary component tray distillation columns (Sieve and valve tray): Estimation of theoretical number of stages using McCabe Thiele method –Tray design –tray efficiency - pressure drop, entrainment, downflow flooding and weeping.	10
1.2	Process design of steady state isothermal packed bed absorption and stripping column for dilute systems without chemical reaction: Number of transfer units- height of transfer units – column diameter – packing height-liquid distribution-pressure drop	10
2	**Module II: (Combined Heat and Mass transfer, Liquid-liquid Contactors and Multi Component Distillation)**	**20 hours**
2.1	Process design of mechanical draft Cooling Towers: Estimation of air quantity, tower characteristics - number of diffusion units using graphical method, water concentration, tower cross section area, fan hp, make-up water requirement	4
2.2	Design of Direct heat Rotary Dryers: Estimation of air quantity,	4

	drying temperature, Number of Transfer Units, Diameter of dryer, Length, speed, slope, flight, hold up time.	
2.3	Process design of sieve tray single solvent extraction columns: Number of trays, sieve tray design, height of coalesced layer, Murphree efficiency	6
2.4	Computer Aided Design and Analysis of Multicomponent Distillation processes by FUG (Fenske — Underwood — Gilliland) Method.	6

Reference Books

1. Perry. R.H & Green.D.W., Chemical Engineers Handbook, Mc- Graw Hill.
2. Robert E. Treybal, Mass Transfer Operations
3. Kern D.Q., Process Heat Transfer, Tata McGraw Hill.
4. Badger & Bancharo, Introduction to Chemical Engineering, McGraw Hill
5. Coulson J.M.& Richardson J.F., Chemical Engineering, Vol.6, 3rd Edn, Butterworth-Heinemann, (Indian print)
6. McCabe W.L., Smith J.C. & Harriott P., Unit Operations in Chemical Engineering, McGraw Hill.
7. E. Ludwig, Applied Process Design for Chemical & Petrochemical Plants, Vol I, II, III, Gulf Publication, London.

222ECH005	PROCESS OPTIMIZATION	CATEGORY	L	T	P	CREDIT
		Program Elective3	3	0	0	3

Preamble:

Process Optimization is a discipline to evaluate the best possible values of process or process sub-system variables to improve its efficiency by applying analytical and numerical methods. The tools of Process Optimization are essentially useful in all the fields of Science and Engineering from basic analysis to complete design of a system. This course aims to familiarize the students with techniques, which are frequently applied to optimize process or process sub-system variables.

Pre-requisites- Nil

Course Outcomes:

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

CO 1	Discuss the basics of linear algebra and to recognize the importance and values of and Process Optimization to analyze and design any chemical process.
CO 2	Formulate Linear and non-linear Programming models to develop mathematical models of basic Chemical Engineering problems.
CO 3	Apply Linear and non-linear optimization techniques and algorithms to solve basic Chemical Engineering problems.
CO 4	Explain the concept and solve various multivariable optimization problems.
CO 5	Apply different optimization techniques in Chemical engineering process design.

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	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

SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 222ECH005

Max. Marks: 60 Duration: 150 minutes

PROCESS OPTIMIZATION

PART – A

Answer All the Questions.

(5x 5 = 25)

1. Define process optimization. Write any two chemical engineering application of optimization.
2. State Necessary and sufficient conditions for optimum of univariate unconstrained functions.
3. Decide whether the function $f(x_1, x_2) = (x_1 + 1)^4 + x_1x_2 + (x_2 + 1)^4$ is convex or concave $\forall$ x_1, $x_2 > 0$
4. Write the procedure in detail for finding the minimum of a univariate function using Golden section method
5. Find the dimensions of the biggest rectangle that can be inscribed in a right triangle with dimensions 6 cm, 8 cm and 10 cm.

PART – B

Answer any five questions (5 x 7 = 35)

6. Consider the function, $f(x) = x_1^2 + x_1x_2 + x_2^2 + 3x_1$
   a. Find the minimum/maximum of the function.
   b. Are they global or relative minimum/maximum

7. Find maximum and minimum of f(x,y) = 3x+y subjected to the constraint $x^2+y^2=10$ using Lagrange multiplier method.

8. Find the minimum of f(x) = x(x-5π) by one iteration using Quasi-Newton's method with initial point 2 and step size 0.01

9. Minimize the function $f(X) = x_1^2 + 4x_2^2$ by 2 iterations using Steepest Descent method starting from $\begin{bmatrix}-2\\-2\end{bmatrix}$.

10. Using Kuhn-Tucker conditions, find the value(s) of β for which the point $x_1^*=1$, $x_2^*=2$ will be optimal to the given problem:
    maximize $f(X) = 2x_1 + \beta x_2$ subject to

$g_1 (X) = x_1^2 - x_2^2 - 5 \leq 0$
$g_2 (X) = x_1 - x_2 - 2 \leq 0$

11. A manufacturing organization manufactures two types of products A and B. Both the products are sold at Rs.25 and Rs.20 respectively. There are 2000 resource units available every day from which the product A requires 20 units while product B requires 12 units. Both of these products require a production time of 5 minutes. Total working hours are 9 hours a day. Formulate and solve the optimization problem to maximize the profits?

12. Formulate the objective function and constrain equations to find optimum design of shell-and-tube heat exchanger.

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Syllabus

Module I (8 hours)

Linear Algebra, Scope and hierarchy of optimization, Typical chemical engineering applications of optimization. Statement of an Optimization Problem and its essential features, Classification of Optimization Problems and its essential features. unconstrained optimization problems- Analytical methods: Necessary and sufficient conditions for optimum of univariate unconstrained functions.

Module II (8 hours)

unconstrained optimization problems- Numerical methods: one dimensional gradient-free search methods (Fixed & accelerated step size, Dichotomous search, Fibonacci search, golden-section method and quadratic interpolation), One dimensional gradient search methods (Newton’s method and Quasi-Newton method).

Module III (8 hours)

Analytical methods for constrained multivariate optimization problems: Nonlinear programming with equality constraints: method of direct substitution, Lagrange multiplier method, Nonlinear programming with inequality constraints: Kuhn-Tucker conditions for local optimality, Complex method, Rosen’s gradient projection method.

Module IV (8 hours)

Numerical methods for unconstrained & constrained multivariate optimization problems: Unconstrained multivariate optimization problems: univariate search, Powell’s method, method of steepest descent, Fletcher-Reeve’s conjugate-gradient method, Newton’s method.

Constrained multivariate optimization problems: Basic concepts and graphical representation of Linear programming, graphical solution, Simplex method and two-phase simplex method**.**

Module V (8 hours)

Optimization case studies in chemical engineering: Economic considerations: Capital cost, operating cost, raw material cost, processing cost etc., Various measures of profitability. Problems solvable analytically: Minimize the capital cost of cylindrical pressure vessel with flat and closed ends, Optimum thermal insulation thickness for cylindrical pipe, Optimum intermediate concentration and time of reaction for series reaction in batch reactor, Optimum pipe diameter for an incompressible fluid. Problems solvable numerically: Optimum reflux ratio for a staged-distillation column, Fitting vapor-liquid equilibrium data using nonlinear regression, optimum design of shell-and-tube heat exchanger.

Course Plan

No	Topic	No. of Lectures
1	**Linear Algebra, Introduction to Process optimization & unconstrained optimization problems -Analytical method (8 hours)**	
1.1	Scope and hierarchy of optimization.	1
1.2	Statement of an Optimization Problem and its essential features.	1
1.3	Nature and classification of mathematical functions.	1
1.4	Typical chemical engineering applications of optimization. Mathematical modelling of typical chemical engineering optimization problems.	2
1.5	Unconstrained optimization problems- Analytical methods: Necessary and sufficient conditions for optimum of univariate unconstrained functions.	3
2	**Numerical methods for unconstrained optimization problems (8 hours)**	
2.1	One dimensional gradient-free search methods (Fixed & accelerated step size)	1
2.2	Dichotomous search method	1
2.3	Fibonacci search method	2
24	golden-section method and quadratic interpolation)	2
2.5	One dimensional gradient search methods (Newton's method and Quasi-Newton method).	2
3	**Analytical methods for constrained multivariate optimization problems (8 hours)**	

3.1	Nonlinear programming with equality constraints: method of direct substitution, ,	1
3.2	Nonlinear programming with equality constraints: Lagrange multiplier method	1
3.3	Nonlinear programming with inequality constraints: Kuhn-Tucker conditions for local optimality	2
3.4	Complex method,	2
3.5	Rosen's gradient projection method.	2
4	**Numerical methods for unconstrained & constrained multivariate optimization problems (10 hours)**	
4.1	Unconstrained multivariate optimization problems: univariate search, Powell's method.	2
4.2	Constrained multivariate optimization problems: method of steepest descent	2
4.3	Fletcher-Reeve's conjugate-gradient method	2
4.4	Newton's method	1
4.5	Basic concepts and graphical representation of Linear programming, graphical solution	1
4.6	Simplex method and two-phase simplex method.	2
5	**Optimization case studies in chemical engineering (6 hours)**	
5.1	Problems solvable analytically - Minimize the capital cost of cylindrical pressure vessel with flat and closed ends, Optimum thermal insulation thickness for cylindrical pipe.	2
5.2	Optimum intermediate concentration and time of reaction for series reaction in batch reactor.	1
5.3	Optimum pipe diameter for an incompressible fluid.	1
5.4	Problems solvable numerically: Optimum reflux ratio for a staged-distillation column	1
5.5	Fitting vapor-liquid equilibrium data using nonlinear regression, optimum design of shell-and-tube heat exchanger.	1

Reference Books

1. Edgar T. F., Himmelblau D. M., Optimisation of Chemical Processes, McGraw Hill.

2. Rao S.S., Optimization: Theory and Applications, Wiley Eastern

3. M.C. Joshi and K. M. Moudgalya, Optimization: Theory and Practice, Narosa Publishing.

4. J. Nocedal and S. J. Wright, Numerical Optimization, Springer Verlag.

5. Gilbert Strang, Linear Algebra

222ECH012	ADVANCED CHEMICAL ENGINEERING THERMODYNAMICS	CATEGORY	L	T	P	CREDIT
		Program Elective 3	3	0	0	3

Preamble:

Thermodynamics plays a key role in design of process equipment's as the properties required are dictated by the principles of thermodynamics. In this course, the basic concepts of thermodynamics are reviewed along with a detailed study on thermodynamic properties of pure fluids and solutions, phase equilibria for single component and multi component systems and reaction equilibrium.

Pre-requisites- Nil

Course Outcomes:

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

CO 1	Apply thermodynamic laws, energy and entropy balance to practical situations
CO 2	Discuss the conditions for equilibrium and stability for complex systems
CO 3	Evaluate the properties of multi-phase pure materials and mixtures by selecting appropriate models.
CO 4	Solve problems involving phase equilibrium of single and multi-component systems
CO 5	Apply the knowledge of thermodynamics to design problems.

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			
CO 3			*3*	3			
CO 4			*3*	3	3		
CO 5			*3*	3	3		

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	30 %
Analyse	50 %

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

SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 222ECH012

Max. Marks: 60 Duration: 2.5 hours

ADVANCED CHEMICAL ENGINEERING THERMODYNAMICS

PART A

(Answer all questions. Each question carries 5 marks)

1	Three moles of H_2 and one mol N_2 both at 10 bar and 373 K are separately admitted, mixed and then heated to 773 K under constant volume, with increase in pressure. Calculate the entropy change in the process. Assume Cv = 21 J/mol K for the mixture.	5 marks
2	Define fugacity. Establish that fugacity and pressure are identical for an ideal gas.	5 marks
3	Discuss the importance of chemical potential. Show that the rate of change of chemical potential of a component with pressure is its partial molar volume in the solution.	5 marks
4.	Compare the application of van Laar and NRTL activity coefficient models.	5 marks
5	The system of acetone (1), acetonitrile (2) and nitromethane (3) with overall mole fractions 0.45, 0.35 and 0.2 respectively is presently at 110 kPa pressure and 80°C temperature. The pure species vapour pressures at 80°C are 195.75, 97.84 and 50.32 kPa respectively. Show that the system exists in the two phase region.	5 marks

PART B

(Answer any 5 questions. Each question carries 7 marks)

6	Elaborate the behaviour of mixtures on a molecular basis.	7 marks
7.	A 0.5m^3 rigid tank containing Hydrogen at 200°C and 400kPa is connected by a valve to another 0.5m3 rigid tank that holds Hydrogen at 500 C and 150 kPa. Now the valve is opened and the system is allowed to reach thermal equilibrium with the surroundings, which are at 150 °C. Determine the final pressure in the tank and the amount heat transferred to	7 marks

the surrounding. Take γ=1.38.

8	Determine fugacity of ammonia at 10 bar and 298 K if it follows the equation of state P(V – b) = RT with b = 3.71x10^{-5} m^3/mol. Estimate the error in fugacity if ammonia was assumed as an ideal gas at this conditions.	7 marks
9.	With a neat sketch, explain the concept of positive and negative deviations from ideality.	7 marks
10	In a binary mixture, the activity coefficient γ_1 of component 1, in the entire range of composition, is given by $R \ln \gamma_1 = A\, x_2{}^2 + B\, x_1{}^2$ where R, A and B are constants. Derive expression for the activity coefficient of component 2.	7 marks
11	A liquid mixture of benzene 60 % and toluene 40% (by mole) is totally evaporated at a constant temperature of 370 K. Calculate the initial and final pressure of the system. The vapour pressures of benzene and toluene at 370 K are 140 and 58 kPa respectively.	7 marks
12	Discuss binary and ternary liquid – liquid equilibrium diagrams.	7 marks

Syllabus

Module I (8 hours)

Classical thermodynamics: Review of the laws of thermodynamics, open and closed System, deviation from ideal gas behaviour-van der Waals, Redlich Kwong, Peng Robins and Virial equations of state, residual properties, thermodynamic diagrams – PV, PT, TS, HS diagrams, introduction to molecular thermodynamics.

Module II (8 hours)

Thermodynamic properties of pure fluids: fundamental property relations, Maxwell's equations - Gibbs energy as a generating function. Fugacity, fugacity coefficient and activity of pure fluids, Thermodynamic properties from volumetric data, fugacities at moderate and high pressures, fugacity of a pure liquid or solid

Module III (8 hours)

Multi component and multi phase equilibria: Partial molar properties - methods of estimating partial molar volume, chemical potential, fugacities in gas mixtures, concept of ideal solutions, activity in solutions, activity coefficient, Gibbs-Duhem equations, property change of mixing, excess properties.

Phase equilibria in single component and multi component systems, phase rule for non-reacting systems, Duhem's theorem.

Module 4 (8 hours)

Vapor liquid equilibria at low pressure: VLE in non-ideal solutions, positive and negative deviation from ideality, azeotropes, application of activity coefficient equations in equilibrium calculations - Wohl's expression for excess Gibbs energy, van Laar, Wilson, NRTL, UNIQUAC and UNIFAC equations for activity coefficient, molecular theories of activity coefficients, lattice models.

Module 5 (8 hours)

Vapour-liquid equilibrium at high pressures: K-value correlations, bubble point, dew point and flash calculations in multi component systems, consistency tests for equilibrium data.

Vapour-liquid-liquid equilibria - liquid-liquid equilibria - binary and ternary equilibrium diagrams, solid – liquid and solid – vapour equilibrium

Course plan

No	Topic	No. of Lectures
1	**Module I: Classical thermodynamics (8 hours)**	
1.1	Review of the laws of thermodynamics	2
1.2	Open and closed systems-isolated, intensive and extensive properties, state and path functions	1
1.3	Deviation from ideal gas behaviour-van der Waals, Redlich Kwong, Peng Robins and Virial equations of state	2
1.4	Residual properties	1
1.5	Thermodynamic diagrams –PV, PT, TS, HS diagrams,	1
1.6	Introduction to molecular thermodynamics	1
2	**Module II: Thermodynamic properties of pure fluids (8 hours)**	
2.1	Fundamental property relations, Maxwell's equations - Gibbs energy as a generating function	2
2.2	Fugacity, fugacity coefficient and activity of pure fluids.	2
2.3	Thermodynamic properties from volumetric data, fugacity at moderate and high pressures	3
2.4	Fugacity of a pure liquid or solid	1
3	**Module III: Multi component and multi phase equilibria (8 hours)**	
3.1	Partial molar properties - methods of estimating partial molar volume.	1
3.2	Chemical potential, fugacity in gas mixtures, concept of ideal solutions	1
3.3	Activity in solutions, activity coefficient, Gibbs-Duhem equations.	1
3.4	Property change of mixing, excess properties.	2

3.5	Phase equilibria in single component and multi component systems, phase rule for non-reacting systems – Duhem's theorem.	2
3.6	VLE in ideal solutions- phase diagram	1
4	**Module IV: Vapor liquid equilibria at low pressure (8 hours)**	
4.1	Non-ideal solutions, positive and negative deviation from ideality, azeotropes	2
4.2	Application of activity coefficient equations in equilibrium calculations. Wohl's expansion for excess Gibbs energy, van Laar, Wilson, NRTL, UNIQUAC and UNIFAC equations for activity coefficient.	4
4.3	Molecular theories of activity coefficients, lattice models.	2
5	**Module V: Vapour-liquid equilibrium at high pressure (8 hours)**	
5.1	K-value correlations, bubble point, dew point and flash calculations in multi component systems	2
5.2	consistency tests for equilibrium data	1
5.3	Vapour-liquid-liquid equilibria	2
5.4	Liquid-liquid equilibria - binary and ternary equilibrium diagrams	2
5.5	Solid – liquid and solid – vapour equilibrium	1

Reference Books

1. Smith J. M. & Van Ness H.V., Introduction to Chemical Engineering Thermodynamics, McGraw Hill
2. Narayanan K. V., A Textbook of Chemical Engineering Thermodynamics, Prentice-Hall of India
3. Kyle B.G., Chemical and Process Thermodynamics, Prentice-Hall of India
4. Y.V.C. Rao, Chemical Engineering Thermodynamics, Universities Press
5. Stanley I. Sandler. Chemical Engineering Thermodynamics, John Wiley & Sons
6. M. D. Koretsky. Engineering and Chemical Thermodynamics, John Wiley & sons.
7. John Prausnitz, Edmundo Gomes de Azevedo, Rudiger Lichtenthaler, Molecular Thermodynamics of Fluid-Phase Equilibria, Prentice-Hall International

222ECH013	DOWNSTREAM PROCESSING	CATEGORY	L	T	P	CREDIT
		Program Elective 3	3	0	0	3

Preamble:

The recovery and the purification of many chemical products, particularly pharmaceuticals requires several unit operations and hence involves chemical engineering principles to a great extent. This course provides a detailed study on various conventional, chromatographic and membrane-based separation and purification techniques.

Pre-requisites- Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Describe the principles that underlie major unit operations used in downstream processing.
CO 2	Integrate biological and engineering principles for intracellular product recovery and identification.
CO 3	Design and formulate effective strategies of downstream processing based on characteristics of bio molecules.
CO 4	Analyse the quality and characteristics of the purified product.

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	80 %
Analyse	20 %
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: 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

*Reg No.:*_______________ Name:__________________________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SECOND SEMESTER M.TECH DEGREE EXAMINATION, DECEMBER 2021

Course Code: 222ECH013

Course Name: DOWNSTREAM PROCESSING

Max. Marks: 60 Duration: 2.5 Hours

PART A

(Answer all questions; each question carries 5 marks)

		Marks
1	Explain electrophoresis.	5
2	Explain the mechanism of gravity settling	5
3	Explain the types of adsorbents.	5
4	Differentiate between perstraction and pervaporation	5
5	Explain dialysis and reverse osmosis.	5

PART B

(Answer any 5 questions, each question carries 7 marks)

6	List out the various cell disruption techniques and their mechanism.	7
7	Draw a neat sketch and explain the principle of the following: tubular bowl centrifuge, disc stack centrifuges	7
8	Describe aqueous two-phase extraction and reverse micellar extraction with applications	7
9	Differentiate between dead and cross flow filtration with neat sketch	7
10	Explain the basic instrumentation and working of liquid chromatography	7
11	List out various equipment used for conventional filtration and their working principles	7
12	Outline the principle, operation, merits and limitations of supercritical fluid chromatography	7

Syllabus

Module I (7 hours)

Overview of downstream process technology: Need for downstream processing, criteria for choice of recovery processes. Cell disruption: Analysis of various physical, chemical, enzymatic and mechanical methods for release of intracellular products - kinetics of bead milling and high pressure homogenization. Product identification techniques – Electrophoresis, Thin layer chromatography, High performance liquid chromatography, gas chromatography.

Module II (8 hours)

Flocculation, Foam and bubble fractionation- Principle, operation and applications. Gravity sedimentation: Mechanisms of sedimentation, Design of industrial equipments for gravity settling- thickeners, classifiers – applications in downstream processing. Centrifugal separations: Theory of centrifugal settling, ultra centrifugation. Filtration: Equipments for conventional filtration- filter media, pre-treatment methods, general filtration theory- Darcy's law, compressible and incompressible filter cakes, filtration cycle, scale up and design of filtration systems.

Module III (8hours)

Extractive separations: General principles, analysis of batch and staged extraction - differential and fractional extraction-scale up and design of extractors - reciprocating plate extraction columns, centrifugal extractors- aqueous two phase extraction and supercritical fluid extraction – theoretical principles, process, equipment and applications. *Adsorption*: Adsorption equilibrium, adsorbent types, equipment operation- adsorption column dynamics-fixed bed and agitated bed adsorption, scale up of adsorption processes- LUB method

Module IV (9 hours)

Evaporation: Factors affecting evaporation, equipments – Number of effects, short tube, long tube, falling film evaporators. *Precipitation*: Methods of precipitation, precipitate formation, Factors influencing protein solubility, design of precipitation systems. *Electrokinetic separations*: Electrophoresis – Principles and techniques. *Membrane separation processes*: Cross flow filtration – filter media- ultra filtration and microfiltration membranes, filter modules, modes of operation, concentration polarization and fouling. Equipments, principle and applications of reverse osmosis, dialysis, electro dialysis, pervaporation and perstraction

Module V (8 hours)

Chromatographic separations: Classification of techniques, elution chromatography-retention theory, band broadening effects, separation efficiency, resolution, yield and purity, discrete stage analysis, kinetic analysis- Gas and liquid chromatography- Bonded phase chromatography, Ion exchange chromatography, gel permeation chromatography, affinity chromatography- supercritical fluid chromatography - Chiral chromatography- expanded bed chromatography- simulated counter current chromatography- process scale up.

Course Plan

No	Topic	No. of Lectures
1	**Module I (7 hours)**	
1.1	Overview of downstream process technology ,Need for downstream processing, criteria for choice of recovery processes	2
1.2	Cell disruption: Analysis of various physical, chemical, enzymatic and mechanical methods for release of intracellular products- kinetics of bead milling and high pressure homogenization	3
1.3	Product identification techniques – Electrophoresis, Thin layer chromatography, High performance liquid chromatography, gas chromatography.	2
2	**Module II (8 hours)**	
2.1	Flocculation, Foam and bubble fractionation- Principle, operation and applications.	1
2.2	Gravity sedimentation: Mechanisms of sedimentation, Design of industrial equipments for gravity settling- thickeners, classifiers – applications in downstream processing.	2
2.3	Centrifugal separations: Theory of centrifugal settling, ultra centrifugation.	2
2.4	Filtration: Equipments for conventional filtration- filter media, pre-treatment methods, general filtration theory- Darcy's law, compressible and incompressible filter cakes, filtration cycle, scale up and design of filtration systems.	3
3	**Module III (8 hours)**	
3.1	Extractive separations ,General principles, analysis of batch and staged extraction - differential and fractional extraction-scale up and design of extractors - reciprocating plate extraction columns	3
3.2	Centrifugal extractors- aqueous two phase extraction and supercritical fluid extraction – theoretical principles, process, equipment and applications.	3
3.3	Adsorption: Adsorption equilibrium, adsorbent types, equipment operation- adsorption column dynamics- fixed bed and agitated bed adsorption, scale up of adsorption processes- LUB method.	2
4	**Module IV (9 hours)**	
4.1	Evaporation: Factors affecting evaporation, equipments – Number of effects, short tube, long tube, falling film evaporators	2
4.2	Precipitation: Methods of precipitation, precipitate formation, Factors influencing protein solubility, design ofprecipitation	2

	systems.	
4.3	Electrophoresis – Principles and techniques	1
4.4	Membrane separation processes: Cross flow filtration – filter media- ultra filtration and microfiltration membranes, filter modules, modes of operation, concentration polarization and fouling.	2
4.5	Equipments, principle and applications of reverse osmosis, dialysis, electrodialysis, pervaporation and perstraction	2
5	**Module V (8 hours)**	
5.1	Chromatographic separations, Classification of techniques, elution chromatography- retention theory, band broadening effects, separation efficiency, resolution, yield and purity, discrete stage analysis	2
5.2	kinetic analysis- Gas and liquid chromatography- Bonded phase chromatography, Ion exchange chromatography, gel permeation chromatography, affinity chromatography	3
5.3	supercritical fluid chromatography - Chiral chromatography- expanded bed chromatography- simulated countercurrent chromatography- process scale up.	3

Reference Books

1. Juan A. Asenjo (Ed), *Separation processes in biotechnology*, CRC
2. Satinder Ahuja (Ed), *Handbook of Separations,* Academic Press
3. Roger. H. Harrison et.al. Bioseparations Science and Engineering, Oxford University press, 2004.
4. Paul. A. Belter, E.L.Cussler, Wei-Shou Hu Bioseparations-Downstream processing for Biotechnology, John Wiley and sons, 1988
5. James.E.Bailey, David.F. OllisBiochemical engineering fundamentals, McGraw Hill.1986
6. Syed Tanveer Ahmed InamdarBiochemical engineering- Principles and concepts, Prentice Hall of India.2007
7. Richardson J.F, Harker J.H, Backhurst J.R, Coulson and Richardson’s Chemical Engineering- Vol.2: Particle technology and separation processes, Butterworth Heinemann. 2002
8. Nooralabettu Krishna Prasad. Downstream process Technology. PHI Learning Pvt Ltd, New Delhi. 2010.

9. Sivasankar B, Bio separations: Principles and Techniques, Prentice-Hall of India Pvt. Ltd., 2008.

10. Paul A Belter, EL Cussler, Wei-shou Hu, Bio separations: Downstream Processing for Biotechnology - Wiley Interscience, 1988.

222ECH003	SOLID WASTE AND HAZARDOUS WASTE MANAGEMENT	CATEGORY	L	T	P	CREDIT
		PROGRAM ELECTIVE 3	3	0	0	3

Preamble:

The quantity and hence the importance of handling solid waste and hazardous waste is ever increasing. This course provides an overview of rules and regulations regarding the solid waste and hazardous waste collection, disposal and management. The problems and issues in the collection to disposal of different categories of solid waste will be discussed in detail.

Pre-requisites- Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Discuss the regulations regarding solid waste management.
CO 2	Explain the characteristics and management of municipal and hazardous wastes.
CO 3	Apply the physico-chemical treatment methods for solid and hazardous waste.
CO 4	Apply the biological treatment methods for solid and hazardous waste.
CO 5	Describe the hazardous waste disposal methods.

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	80 %
Analyse	20 %
Evaluate	
Create	

Mark distribution

Total	**CIE**	**ESE**	**ESE**

Marks			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: 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

SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 222ECH003

Max. Marks: 60 Duration: 2.5 hours

SOLID WASTE AND HAZARDOUS WASTE MANAGEMENT

PART – A

Answer All the Questions (5x 5 = 25)

1. Elaborate the physical characteristics of MSW?
2. Explain the characteristics of hazardous waste.
3. Discuss the different physicochemical treatment processes for MSW?
4. Explain bioreactors used in municipal solid waste treatment.
5. What are the biomedical waste disposal techniques?

PART – B

Answer any five questions (5 x 7 = 35)

6. Explain the biomedical waste handling rules in detail.
7. Explain the sources and health effects of radioactive wastes.
8. Explain soil vapour extraction and chemical oxidation for the treatment of hazardous waste.
9. Explain slurry phase bioreactor in detail.
10. Explain the site selection criteria for a sanitary landfi
11. Explain the types of municipal solid wastes.
12. Explain the types of radioactive waste.

***

Syllabus

Module 1 (7 hours)

Relevant Regulations -Municipal solid waste (management and handling) rules; hazardous waste (management and handling) rules; biomedical waste handling rules; fly ash rules; recycled plastics usage rules; batteries (management and handling) rules, Municipal Solid Waste Management – Fundamentals Sources; composition; generation rates; collection of waste; separation, transfer and transport of waste; treatment and disposal options.

Module 2 (10 hours)

Hazardous Waste Management – Fundamentals Characterization of waste; compatibility and flammability of chemicals; fate and transport of chemicals; health effects. Radioactive Waste Management – Fundamentals Sources, measures and health effects; nuclear power plants and fuel production; waste generation from nuclear power plants; disposal options

Module 3 (8 hours)

Physicochemical Treatment of Solid and Hazardous Waste, Chemical treatment processes for MSW (combustion, stabilization, and solidification of hazardous wastes); physicochemical processes for hazardous wastes (soil vapour extraction, air stripping, chemical oxidation); groundwater contamination and remediation.

Modue 4 (7 hours)

Biological Treatment of Solid and Hazardous Waste Composting; bioreactors; anaerobic decomposition of solid waste; principles of biodegradation of toxic waste; inhibition; co-metabolism; oxidative and reductive processes; slurry phase bioreactor; in-situ remediation.

Module 5 (8 hours)

Biomedical waste disposal. Solidification, chemical fixation and encapsulation, incineration. Hazardous waste landfills: Site selection, design and operation – remediation of hazardous waste disposal sites.

Course Plan

No	Topic	No. of Lectures
1	**Module 1 (7 hours)**	
1.1	Relevant Regulations: Municipal solid waste (management and handling) rules; hazardous waste (management and handling) rules; biomedical waste handling rules; fly ash rules; recycled plastics usage rules	2
1.2	Municipal Solid Waste Management – Fundamentals Sources; composition; generation rates;	2
1.3	collection of waste; separation, transfer and transport of waste; treatment and disposal options	3

2	**Module 2 (10 hours)**	
2.1	Hazardous Waste Management – Fundamentals Characterization of waste.	2
2.2	compatibility and flammability of chemicals; fate and transport of chemicals; health effects	2
2.3	Radioactive Waste Management – Fundamentals Sources, measures and health effects;	3
2.4	nuclear power plants and fuel production; waste generation from nuclear power plants; disposal options	3
3	**Module 3 (8 hours)**	
3.1	Physicochemical Treatment of Solid and Hazardous Waste	2
3.2	Chemical treatment processes for MSW (combustion, stabilization and solidification of hazardous wastes)	3
3.3	physicochemical processes for hazardous wastes (soil vapour extraction, air stripping, chemical oxidation); ground water contamination and remediation	3
4	**Module 4 (7 hours)**	
4.1	Biological Treatment of Solid and Hazardous Waste	1
4.2	Composting; bioreactors; anaerobic decomposition of solid waste;	3
4.3	principles of biodegradation of toxic waste; inhibition; co-metabolism; oxidative and reductive processes; slurry phase bioreactor; in-situ remediation	3
5	**Module 5 (8 hours)**	
5.1	Biomedical waste disposal. Solidification, incineration.	2
5.2	Chemical fixation and encapsulation,	2
5.3	Hazardous waste landfills: Site selection,	1
5.4	Design and operation – remediation of hazardous waste disposal sites.	3

Reference Books

1. John Pichtel Waste Management Practices CRC Press, Taylor and Francis Group 2005.

2. LaGrega, M.D. Buckingham, P.L. and Evans, J.C. Hazardous Waste Management, McGraw Hill International Editions, New York, 1994.

3. Richard J. Watts, Hazardous Wastes - Sources, Pathways, Receptors John Wiley and Sons, New York, 1997

4. Charles A. Wentz – Hazardous Waste Management, McGraw- Hill

5. Manual on Municipal Solid Waste Management, Central Public Health and Environmental Engineering Organization, Government of India, New Delhi, 2000

6. George Tchobanoglous, Hilary Theisen and Samuel A, Vigil, Integrated Solid Waste Management, McGraw-Hill, New York, 1993

7. Vesilind, Worrell, Reihhart, Solid Waste Engineering, RCRA Orientation Manaul 2006, USEPA

22ECH014	POLYMER TECHNOLOGY	CATEGORY	L	T	P	CREDIT
		Program Elective 3	3	0	0	3

Preamble: The objective of this course is to develop the knowledge to learn about polymers, its formation and its modifications. In this course, particular emphasis will be given to polymer types, polymer characterisation, polymer processing, polymer blends and composites and polymer additives. Students will acquire the ability to understand the process technologies for fibres, plastics and rubber and gets familiar with major polymerization processes on industrial scale. After the completion of this course, students will be able to understand compounding ingredients, different processing methods and techniques used in the polymer product manufacture.

Pre-requisites- Nil

Course Outcomes:

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

CO 1	Explain the basic concepts of polymer technology and its classification
CO 2	Discuss the characterization of polymers, plastics and rubbers
CO 3	Select and explain the different processing techniques of polymers
CO 4	Analyse the importance of Polymer Blends and Composites, and of speciality polymers
CO 5	Select suitable polymer additives, synthetic fibres, plastics and rubber

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				
CO 5			3				

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	80 %
Analyse	20 %
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:

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

SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 222ECH014

Max. Marks: 60 Duration: 2.5 hours

POLYMER TECHNOLOGY

PART A

(Answer all questions, each question carries 5 marks)

1. Give the classification of polymers and explain each type of polymer.
2. Explain the principle of GPC in detail.
3. Compare calendaring and blow molding in polymer processing.
4. Explain polymer nanocomposites with examples and applications.
5. Discuss the different types of additives used in polymers.

PART B

(Answer any 5 questions, each question carries 7 marks)

6. Explain the four methods of polymerization with examples and also mention the advantages and limitations of each polymerization technique.
7. Write about any four spectroscopic characterization technique used for polymers.
8. What are the different polymer processing techniques used? Explain any two in detail.
9. Explain the properties of blends prepared by dynamic vulcanization and its technological applications.
10. Write about the use of additives to Modify Plastic Surface Properties, Additives to Modify Polymer Chain Structures and Additives to Influence Morphology and Crystallinity of Polymers.
11. Write a short note on speciality polymers and its applications.
12. Outline the production and application of the plastics: Polyester, polyethylene and Phenolics,

Syllabus

Module I (6 hours)

Introduction to Polymers:

Introduction to Polymers , Structure (linear, branched and cross-linked), General properties, Methods of Polymerisation, Bulk Polymerization, Solution Polymerization, Suspension Polymerization, Emulsion Polymerization, Advantages and limitations of each technique, Classification of polymers- On the basis of its occurrence - Natural and synthetic, On the basis of Thermal behavior -Thermo plastics and thermo setting Polymers, On basis of back bone- Organic and Inorganic, homo and co polymer, homo chain and hetero chain polymer.

Module II (9 hours)

Polymer Characterization:

Polymer Spectroscopy and Compositional Analysis - Elemental Analysis, Infrared Spectroscopy, Nuclear Magnetic Resonance of Polymers in Solution, Mass Spectrometry, Polymer Molecular Weight Measurement - Principles of GPC, Measurement of Intrinsic Viscosity, Light Scattering and its Applications in Polymer Characterization - Principles of Static and Dynamic Light Scattering, Small-Angle X-Ray Scattering, Microscopy - Transmission Electron Microscopy, Three-Dimensional Microscopy.

Module III (7 hours)

Polymer Synthesis and processing:

Step-growth polymerization, Free radical polymerization, Coordination polymerization, Copolymerization, Anionic polymerization, cationic polymerization, Polymer Rheology, Compression molding, Transfer molding, Injection molding, Blow molding, Reaction injection molding, Extrusion, Pultrusion, Calendaring, Rotational molding, Thermoforming, Rubber processing in two-roll mill, Internal mixer. Wood and natural fiber based composites (NFCs).

Module IV (9 hours)

Polymer Blends & Composites:

Preparation of polymer blends, blend characterisation techniques, specific interactions, rubber plastic blends, properties of blends prepared by dynamic vulcanization, technological application, silicone based thermoplastic elastomers, introduction to particulate and fibre filled composites, applications, function, factors influencing the performance of composites, analysis of long fibre composites, analysis of short fibre composites, composite manufacturing techniques. Speciality Polymers and Applications:High temperature and fire resistant polymers, Conducting polymers, Polymers with electrical and electronic properties, Ionic Polymers, Polymer concrete, Polymer nanocomposites.

Module V (9 hours)

Additives for Polymers:

An overview of additives, type of additives, Antioxidants, PVC Heat Stabilizers, Light Stabilizers, Flame Retardants, Plasticizers, Scavenging Agents, Additives to Enhance Processing, Additives to Modify Plastic Surface Properties, Additives to Modify Polymer

Chain Structures, Additives to Influence Morphology and Crystallinity of Polymers, Antimicrobials, Additives to Enhance Thermal Conductivity, Active Protection Additives (Smart Additives), Odor Masking, Animal Repellents, Blowing Agents.
Synthetic Fibres: Types of Fibres, Spinning Techniques, Manufacturing Technology and Applications of different types of fibres: cellulosic fibres, polyamides, acrylics, vinyls and vinylidines, fluorocarbons. Plastics: Manufacturing Technology and applications of different types of plastics: Polyester, polyethylene, Phenolics, Rubbers: Structure, properties and preparation natural rubber, synthetic rubbers: SBR, rubber compounding and reclaiming.

Course Plan

No	Topic	No. of Lectures
1	**Module I: Classification of polymers (6 hours)**	
1.1	Introduction to Polymers , Structure (linear, branched and cross-linked), General properties.	1
1.2	Bulk Polymerization, Solution Polymerization, Suspension Polymerization, Emulsion Polymerization, Advantages and limitations of each technique.	3
1.3	Classification of polymers- On the basis of its occurrence - Natural and synthetic, On the basis of Thermal behavior -Thermo plastics and thermo setting Polymers, On basis of back bone- Organic and Inorganic, homo and co polymer, homo chain and hetero chain polymer.	2
2	**Module II: Polymer Characterization (9 hours)**	
2.1	Polymer Characterization: Polymer Spectroscopy and Compositional Analysis - Elemental Analysis, Infrared Spectroscopy.	2
2.2	Nuclear Magnetic Resonance of Polymers in Solution, Mass Spectrometry.	2
2.3	Polymer Molecular Weight Measurement - Principles of GPC, Measurement of Intrinsic Viscosity, Small-Angle X-Ray Scattering, Microscopy - Transmission Electron Microscopy, Three-Dimensional Microscopy.	3
2.4	Light Scattering and its Applications in Polymer Characterization - Principles of Static and Dynamic Light Scattering.	2
3	**Module III: Polymer Synthesis and processing (7 hours)**	
3.1	Polymer Synthesis and processing: Step-growth polymerization, Free radical polymerization, Coordination polymerization, Copolymerization.	2

3.2	Anionic polymerization, cationic polymerization, Polymer Rheology, Processing: Compression molding.	1
3.3	Transfer molding, Injection molding, Blow molding, Reaction injection molding.	2
3.4	Extrusion, Pultrusion, Calendaring, Rotational molding, Thermoforming, Rubber processing in two-roll mill, Internal mixer. Wood and natural fiber based composites (NFCs).	2
4	**Module IV: Polymer Blends & Composites (9 hours)**	
4.1	Polymer Blends & Composites: Preparation of polymer blends, blend characterisation techniques, specific interactions, rubber plastic blends.	2
4.2	Properties of blends prepared by dynamic vulcanization, technological application, Ionic Polymers, Polymer concrete, Polymer nanocomposites.	2
4.3	Silicone based thermoplastic elastomers, introduction to particulate and fibre filled composites, applications, function.	1
4.4	Factors influencing the performance of composites, analysis of long fibre composites, analysis of short fibre composites, composite manufacturing techniques.	2
4.5	Speciality Polymers and Applications:High temperature and fire resistant polymers, Conducting polymers, Polymers with electrical and electronic properties.	2
5	**Module V: Additives for Polymers (9 hours)**	
5.1	Additives for Polymers: An overview of additives, type of additives, Antioxidants, PVC Heat Stabilizers, Light Stabilizers.	2
5.2	Flame Retardants, Plasticizers, Scavenging Agents, Additives to Enhance Processing, Additives to Modify Plastic Surface Properties, Additives to Modify Polymer Chain Structures.	2
5.3	Additives to Influence Morphology and Crystallinity of Polymers, Antimicrobials, Additives to Enhance Thermal Conductivity, Active Protection Additives (Smart Additives), Odor Masking, Animal Repellents, Blowing Agents.	2
5.4	Synthetic Fibres: Types of Fibres, Spinning Techniques, Manufacturing Technology and Applications of different types of fibres: cellulosic fibres, polyamides, acrylics, vinyls and vinylidines, fluorocarbons. Plastics: Manufacturing Technology and applications of different types of plastics: Polyester, polyethylene, Phenolics, Rubbers: Structure, properties and preparation natural rubber, synthetic rubbers: SBR, rubber compounding and reclaiming.	3

Reference Books

1. *Polymer science, V. R. Gowariker, N. V. Viswanathan* and *Jayadev Sreedhar*, Halsted Press (John Wiley & Sons), New York, 1986.
2. HANDBOOK OF POLYMER SYNTHESIS, CHARACTERIZATION, AND PROCESSING, Published by John Wiley & Sons, Inc., Hoboken, New Jersey Enrique Saldivar-Guerra, Eduardo Vivaldo-Lima.
3. O. Olabisi, I.W. Robeson, and M.T. Shaw, Polymer-polymer Miscibility Academic Press, New York, 1979
4. L. A. Utracki, Polymer Alloys and Blends, Hanser, New York, 1989
5. Gupta R K and Anil Kumar, " Fundamentals of Polymer Engineering", 2nd Ed., Marcel Dekkar (2003) 5. Fried J R "Polymer Science and Technology" PHI
6. P.K. Mallick, Composites Engineering Handbook, CRC Press, 1997

222ECH015	INDUSTRIAL POLLUTION CONTROL	CATEGORY	L	T	P	CREDIT
		Program Elective 3	3	0	0	3

Preamble:

The issue of industrial pollution is to be emphatically addressed for the welfare of future generations. Environmental pollution resulting from phenomenal industrial growth is to be monitored with extreme care and caution. This course, essentially deals with the technology and techniques to reduce the dangerous levels of pollutants in the atmosphere. The objective of this course is to understand the important issues of industrial pollution and its abatement principles

Pre-requisites- Nil

Course Outcomes:

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

CO 1	Describe the environmental Acts in India
CO 2	Design suitable treatment process for wastewater.
CO 3	Discuss on water pollution control techniques in industries.
CO 4	Selection and design of air pollution control devices.
CO 5	Suggest measures for handling and management of solid wastes.
CO 6	Explain the features of environment management systems.

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	
CO 2	3		3			3	
CO 3	3		2			3	
CO 4	3		3			3	
CO 5	3		3			3	
CO 6	3		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:

Continuous Internal Evaluation: **40marks**
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
Testpaper,1no. :10marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination: 60marks
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 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: 2**

Reg No:______________

Name :______________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 222ECH015

Max. Marks: 60 **Duration: 2.5 Hours**

INDUSTRIAL POLLUTION CONTROL

PART A

(Answer all questions, each question carries 5 marks)

1. Explain Air pollution Acts in India.
2. Name the unit operations and unit processes involved in conversion of polluted water to potable standards.
3. Discuss the sources and characteristics of waste water from textile industry.
4. Explain the principle and working of cyclone separator with neat diagram.
5. Explain general guidelines of environmental impact assessment.

(5x5=25 marks)

PART B

(Answer any five questions, each question carries 7 marks)

6. Name and explain the physical water quality parameters of concern to environmental engineers. Explain.
7. List out and explain Different unit operations and unit processes involved in conversion of polluted water to potable standards.
8. An activated sludge plant is designed to reduce 90% of influent BOD of 250 mg/L. Compute (a) net sludge (solids) produced per day, (b) mean cell residence time, (hydraulic retention time), and (d) the F/M ratio for the assumed design data given below.
   1) Wastewater flow = 2 MLD
   2) Volume of the aeration tank = 500 m^3
   3) MLVSS in the aeration tank = 2500 mg/L

4) Kinetic coefficients, $Y = 0.5$ and $kd = 0.08$ d

9. Explain the waste generation points, waste water characteristics and treatment scheme for the petroleum refinery industry.

10. A multi- tray settling having 8 trays, including the bottom surface, handles 6 m^3/s of air at 20 °C . The trays are spaced 0.25 m apart and the chamber is to be 1m wide and 4 m long. What is the minimum particle size of density 2000 kg/m^3 that can be collected with 100% efficiency? What will be the efficiency of the settling chamber if 50µm particles are to be removed? Laminar flow condition within the chamber and presence of no dust initially on trays may be assumed. Viscosity of air at 20 °C is 1.81×10^{-5} kg/m.s.

11. Explain any two methods of disposal of solid wastes.

12. Describe in detail about environmental audit.

(5x7=35 marks)

Syllabus

Module I (7 hours)

Introduction- Types of pollution. Pollution control aspects, Need of environmental legislations and environmental Acts in India. Functions of central and state pollution control boards. Sources, Sampling and Analysis of Wastewater: Origin of wastewater, classification and characterization of wastewater. Physical and chemical characteristics. BOD, COD and their importance. Types of water pollutants and their effects.

Module II (9 hours)

Wastewater Treatment; Classification of different treatment methods into physico-chemical and biochemical techniques, Physico-chemical methods, General concept of primary treatment, Liquid-solid separation, Design of a settling tank, Neutralization and flocculation, Disinfection, Biological methods, Concept of aerobic digestion, Design of activated sludge process, Concept of anaerobic digestion. Different unit operations and unit processes involved in conversion of polluted water to potable standards.

Module III (7 hours)

Water pollution control in industries : Norms and standards of treated water. Origin, characteristics, and treatment methods in typical industries-petroleum refinery, pulp and paper, distillery, and textile processing, tannery indusrty, dairy industry, fertilizer industry, chlor-alkali industries, nuclear power plant wastes, thermal power plant wastes.

Module IV (9 hours)

Air Pollution Control: Sampling of pollutants. Methods of estimation of air pollutants. Control methods for particulates and gaseous pollutants. Control equipment like gravitational settling chambers, Cyclone separators, fabric filters, ESP. Concepts of control of gaseous emissions by absorption, adsorption, chemical transformation and combustion. Origin, control methods, and equipment used in typical industries- metallurgical industries, and cement industries.

Module V (8 hours)

Solid Waste Treatment: Analysis and quantification of hazardous and non-hazardous wastes, Treatment and disposal of solid wastes, Land filling, Leachate treatment, Incineration. Environmental Management System: Environment impact assessment, its concept and constituents, Environmental audit, ISO-14000 system.

Course Plan

No	Topic	No. of Lectures
1	**Introduction (7 hours)**	
1.1	Types of pollution. Pollution control aspects, Need of environmental legislations and environmental Acts in India. Functions of central and state pollution control boards.	2
1.2	Sources, Sampling and Analysis of Wastewater: Origin of wastewater	1
1.3	classification and characterization of wastewater.	2
1.4	Physical and chemical characteristics. BOD, COD and their importance. Types of water pollutants and their effects.	2
2	**Wastewater Treatment (9 hours)**	
2.1	Classification of different treatment methods into physico-chemical and biochemical techniques, Physico-chemical methods	2
2.2	General concept of primary treatment, Liquid-solid separation, Design of a settling tank, Neutralization and flocculation	2
2.3	Disinfection, Biological methods, Concept of aerobic digestion, Design of activated sludge process, Concept of anaerobic digestion.	3
2.4	Different unit operations and unit processes involved in conversion of polluted water to potable standards.	2
3	**Water pollution control (7 hours)**	
3.1	Norms and standards of treated water. Origin, characteristics, and treatment methods in typical industries-petroleum refinery, pulp	3

	and paper.	
3.2	distillery, and textile processing, tannery industry, dairy industry, fertilizer industry	2
3.3	Chlor-alkali industries, nuclear power plant wastes, thermal power plant wastes.	2
4	**Air Pollution Control (9 hours)**	
4.1	Sampling of pollutants. Methods of estimation of air pollutants. Control methods for particulates and gaseous pollutants.	3
4.2	Control equipment like gravitational settling chambers, Cyclone separators, fabric filters, ESP.	2
4.3	Concepts of control of gaseous emissions by absorption, adsorption, chemical transformation and combustion.	2
4.4	Origin, control methods, and equipment used in typical industries- metallurgical industries, and cement industries.	2
5	**Solid waste management and environmental management system (8 hours)**	
5.1	Solid Waste Treatment: Analysis and quantification of hazardous and non-hazardous wastes,	2
5.2	Treatment and disposal of solid wastes, Land filling, Leachate treatment, Incineration.	2
5.3	Environmental Management System: Environment impact assessment, its concept and constituents, Environmental audit, ISO-14000 system	4

References:

1. Nelson &Nemerow, Industrial Water pollution-Origin, Characteristics and treatment, Addison, Wesley Publishing Co.
2. Gerard Kiely,Environmental Engineering, McGraw Hill
3. Rao M.N. & Rao H, Air Pollution, Tata McGraw Hill
4. Sincero A.P.& Sincero G.A., Environmental Engineering, A Design Approach, Prentice Hall of India
5. Rao C.S., Environmental Pollution Control Engineering, New Age Int. Pub.
6. Mahajan S.P., Pollution Control in Process Industries, Tata McGraw Hill

222ECH016	ADVANCED PROCESS CONTROL	CATEGORY	L	T	P	CREDIT
		Program Elective 4	3	0	0	3

Preamble:

Process control has become increasingly important in the process industries. Due to the consequence of stringent environmental and safety regulations, rapidly changing economic conditions and global competition the control strategies are advancing. This course would enable students to gain knowledge on transient response of open and closed loop systems, stability analysis, design of controllers, modern control strategies, multiloop control systems, state space analysis techniques and digital control using z transforms.

Pre-requisites- Nil

Course Outcomes:

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

CO 1	Explain the concepts of linear feedback control theory
CO 2	Analyze the stability of systems and design controllers
CO 3	Apply the advancements in control strategies to practical situations
CO 4	Describe the State space and multivariable systems
CO 5	Explain the basic concepts of digital control
CO 6	Simulate control systems using software

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	3		
CO 4				3			
CO 5				3			
CO 6	3			3		3	

Assessment Pattern

Bloom's Category	**End Semester Examination**
Apply	60 %
Analyse	30 %
Evaluate	10 %

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

SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 222ECH016

Max. Marks: 60 Duration: 2.5 hours

ADVANCED PROCESS CONTROL

PART – A

Answer All the Questions.

(5x 5 = 25)

1. Derive the expression for response of a first order system $G(s) = \frac{2}{4\,s+1}$ to a ramp input. Sketch the response and input in the same figure.

2. Define stability and explain how it is related to characteristic equation of a system. Check for stability if the system with characteristic equation given by
$s^4 + 8s^3 + 2s^2 + 11s + 5 = 0$

3. Discuss the implementation of feed forward control for a distillation column.

4. Explain the different characteristics of control valves. Discuss the role of valve positioner.

5. Compare the reconstruction using zero order and first order hold elements.

PART – B

Answer any five (5 x 7 = 35)

6. A step change of magnitude 4 is introduced into a system having transfer function $(s) = \frac{10}{s^2+1.6\,s+4}$. Determine gain, overshoot, period of oscillation, maximum value and ultimate value of response.

7. Explain the significance of a time integral performance criteria. Distinguish between IAE and ITAE

8. A process has the transfer function $G(s) = \frac{e^{-0.2s}}{(10s+1)(2s+1)}$. (i) Using Bode stability criteriaon determine (i) proportional gain Kc for sustained oscillation. (ii) using half the value of this Kc, determine gain margin and phase margin.

9. Design a Smith predictor controller for the process $(s) = \frac{e^{-0.3s}}{(10s+1)(4s+1)(2s+1)}$. Explain the working with a block diagram.

10. Explain relative gain array analysis. In a distillation column, the reflux rate R and steam rate S are used to control the distillate composition X_D and bottom product composition X_B. The steady state gain matrix is determined by conducting experiment as $\begin{bmatrix} -0.002 & 0.001 \\ 0.002 & 0.003 \end{bmatrix}$. Calculate RGA and determine best pairing.

11. Determine the closed loop response of a first order discrete time system to a unit step input.

12. Determine the pulse transfer function for the system of a first order system operating in series with an integrator. Obtain the discrete time step response of the system to a unit step input.

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Syllabus

Module I: Modeling and dynamics of systems (8 hours)

Importance of modelling in process control, general modelling principles, degrees of freedom, models for stirred tank heating process with constant and variable holdups, model of double pipe heat exchanger, characteristics of under damped second order step response, Performance criteria of controllers — the error performance indices.

Module II: Closed loop stability and controller tuning (8 hours)

Different modes of controllers - P, PI, PID, closed loop transfer functions and block diagrams, characteristic equation, stability analysis, Routh Hurwitz criteria, Bode diagrams, Bode stability criteria, Process identification, Process reaction curve, First order plus time delay model, Skogestad's half rule for approximation of higher order transfer functions, Zeigler – Nichols and Cohen – Coon tuning methods, relay auto- tuning

Module III: Advanced control strategies (8 hours)

Advanced control strategies, Cascade control, Feed forward control, and ratio control, Smith predictor control, Adaptive control, selective control, inferential control.

Introduction to Model predictive control, internal model control, PLC and SCADA.

Module IV: State space representation and multivariable systems (8 hours)

State space representation- Modelling in state space, correlation between transfer functions and state space equations, solution of state space models.

Bbasics of multivariable control systems - Process interactions and control loop interactions, pairing of controlled and manipulated variables in 2x2 systems, relative gain array analysis, decoupling control systems.

Control valves – construction, characteristics, sizing and valve positioners.

Module V: Digital control systems (8 hours)

Sampled data control systems - Discrete time feedback control systems, Sampling continuous signals, Reconstruction of continuous signals from discrete time values, Zero order and first order holds, Basic review of Z transforms, Properties of z-transforms, inversion of z-transforms, difference equations, Response of open loop discrete systems to step and impulse inputs, the Pulse transfer function, transient response of first order closed loop sampled data system to step input, Stability concepts of discrete time systems – stability regions in s and z planes.

Course plan

No	Topic	No. of Lectures
1	**Modeling and dynamics of systems (8 hours)**	
1.1	Importance of modelling, general modelling principles, degrees of freedom, models for stirred tank heating process with constant and variable hold ups, and double pipe heat exchanger	4
1.2	Dynamics of first order system	1
1.3	Dynamics of second order systems, characteristics of second order under-damped step response.	2
1.4	Performance criteria of controllers — the error performance indices	1
2	**Closed loop stability and controller tuning (8 hours)**	
2.1	Different modes of controllers - P, PI, PID, closed loop transfer functions, closed loop transfer function from block diagram	1
2.2	Stability Analysis, Routh Hurwitz criteria, Bode diagrams, Bode stability criteria	3
2.3	Process identification, Process reaction curve, First order plus time delay model, Skogestad's half rule for approximation of higher order transfer functions	1
2.4	Zeigler – Nichols and Cohen – Coon tuning methods, relay auto-tuning, Implementation of closed loop control system in MATLAB	3
3	**Advanced control strategies (8 hours)**	
3.1	Cascade control	2
3.2	Feed forward control, and ratio control	2
3.3	Smith predictor	1
3.4	Adaptive control, selective control, inferential control	1
3.5	Introduction to Model predictive control, internal model control, PLC and SCADA	2
4	**State space representation and multivariable systems (8 hours)**	
4.1	Modeling in state space, correlation between transfer functions and state space equations, solution of state space models	3
4.2	Process interactions and control loop interactions, pairing of controlled and manipulated variables in 2x2 systems, relative gain array analysis, decoupling control systems	3
4.3	Control valves – construction, characteristics, sizing and valve positioners	2
5	**Digital control systems (8 hours)**	
5.1	Discrete time feedback control systems, Sampling continuous signals, Reconstruction of continuous signals from discrete time values, Zero order and first order holds	2

5.2	Basic review of Z transforms, Properties of z-transforms, inversion of z-transforms, difference equations	2
5.3	Response of open loop discrete systems to step and impulse inputs, the Pulse transfer function, transient response of first order closed loop sampled data system to step input.	3
5.4	Stability concepts of discrete time systems – stability regions in s and z planes	1

Reference Books

1. Dale E. Seborg, Thomas F. Edgar and Duncan A. Mellichamp, Process Dynamics and Control, John Wiley & Sons Inc. Second Edition.
2. Stephanopoulos G., Chemical Process Control, An Introduction to Theory and Practice, Prentice Hall of India
3. Coughanowr D.P., Process Systems Analysis and Control, McGraw Hill
4. Katsuhiko Ogata, State space analysis of control systems, Prentice Hall of India
5. Kuo,B.C, Analysis and synthesis of sampled data control systems, Prentice –Hall
6. C.A. Smith and A.B. Corripio. 'Principle and Practice of Automatic Process Control', 3" ed., John Wiley and Sons, 2005
7. W.L. Luyben, Process modeling, Simulation and Control for Chemical Engineers, McGraw Hill.
8. Eckman D.P., Principles of Industrial Process Control, John Wiley & Sons Inc, NY (1946)
9. Harriot P., Process Control, Tata McGraw Hill
10. Ceaglske N.H., Automatic Process Control for Chemical Engineers, John Wiley & Sons, NY, 1956

222ECH011	PROCESS SAFETY MANAGEMENT	CATEGORY	L	T	P	CREDIT
		Program Elective 4	3	0	0	3

Preamble:

The course is intended to introduce the basic requirements in Occupational Health and Safety Analysis (OSHA) standard of United States Department of Labour, Process Safety Management of highly hazardous chemicals, the need of process safety, and the tools used to implement PSM. It covers the 14 elements required by OSHA standard.

Pre-requisites: Nil

Course Outcomes:

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

CO 1	Explain importance of PSM and the basic requirements in PSM standards
CO 2	Explain the element required by OSHA standard: Process Safety Information
CO 3	Explain the element required by OSHA standard: Process Hazard Analysis
CO 4	Explain the elements required by OSHA standard: Operating Procedures, Employee Participation, Training, Contractors, Pre-start-up Review
CO 5	Explain the elements required by OSHA standard: Mechanical Integrity, Hot work Permit, Management of Change, Incident Investigation, Emergency Planning and Response, Compliance Audits and Trade Secrets

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

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. 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

SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 222ECH011

Max. Marks: 60 Duration: 2.5 hours

PROCESS SAFETY MANAGEMENT

PART – A

Answer all questions.

(5 x 5 = 25)

1. What are the benefits of an effective PSM program?
2. List the characteristics of chemicals to be expressed as a part of process safety information for PSM
3. Distinguish between fault tree analysis and event tree analysis
4. What is the importance of pre-start-up review in PSM?
5. How can the mechanical integrity of emergency shutdown systems be tested and ensured?

PART – B

Answer any five questions (5 x 7 = 35)

6. Write a short note on the 14 elements of OSHA for PSM
7. List the classes of industries for which PSM is applicable. Explain why PSM is not applicable for some classes of industries
8. What are the common materials of construction in use in Chemical Process Industries? Explain the characteristics of the materials considered for the selection for some requirements.
9. What are important diagrams in Chemical Process Industries? Distinguish them.
10. When is Failure Modes and Effects Analysis (FMEA) selected as a Process Hazard Analysis technique?
11. What are the activities for which the operating procedures to be clearly stated for PSM? Explain the activities
12. Give an example for an accident in history resulted from poor 'management of change'. Explain the incident in detail.

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Syllabus

Module I (8 Hours)

Introduction to PSM: Introduction to Process Safety Management (PSM), Benefits of an effective PSM program, PSM standards, Basic requirements in PSM standards, 14 elements of OSHA, Tools used to implement PSM standards, Industries applicable

Module II (8 Hours)

Process Safety Information: Hazards of chemicals in the processes: Toxicity, Permissible exposure limits, Physical data, Reactivity data, Corrosivity data, Thermal and chemical stability data, hazardous effects of inadvertent mixing of different materials, Materials of construction, Electrical classification, Material and energy balances, Safety systems, Diagrams: Block Diagram, Process Flow Diagram (PFD) and Piping and Instrumentation diagram (P&ID)

Module III (8 Hours)

Process Hazard Analysis: Introduction to the PHA techniques: Checklist, What-if analysis, Hazard and Operability study (HAZOP), Failure Modes and Effects Analysis (FMEA), Fault tree analysis and event tree analysis, Bow-tie analysis, Quantitative Risk Assessment (QRA)

Module IV (8 Hours)

Other elements required by OSHA standard-1: Operating Procedures: Initial start-up, Normal operations, Temporary operations, Emergency shutdown, Emergency operations, Normal shutdown, Start-up, Employee participation and training: Initial training, Refresher training, Employer responsibilities, Contractors: contractor employer responsibilities, Pre-start-up Review.

Module V (8 Hours)

Other elements required by OSHA standard-2: Mechanical Integrity, Pressure vessels and storage tanks, Piping systems, Relief and vent systems and devices, Emergency shutdown systems, Controls, Pumps, Hot work Permit, Management of Change, technical basis for the proposed change, impact of the change on employee safety and health, modifications to operating procedures, necessary time period for the change, authorization requirements for the proposed change, Incident Investigation, Emergency Planning and Response, Compliance Audits, Trade Secrets

Course Plan

No	Topic	No. of Lectures
1	**Introduction to PSM (8 hours)**	
1.1	Introduction to Process Safety Management (PSM)	1
1.2	Benefits of an effective PSM program	1
1.3	PSM standards	1
1.4	Basic requirements in PSM standards	2
1.5	14 elements of OSHA	1
1.6	Tools used to implement PSM standards	1
1.7	Industries applicable	1
2	**Process safety information (8 hours)**	
2.1	Hazards of chemicals in the processes: Toxicity, Permissible exposure limits, Physical data, Reactivity data, Corrosivity data, Thermal and chemical stability data, hazardous effects of inadvertent mixing of different materials	2
2.2	Materials of construction	1
2.3	Electrical classification	1
2.4	Material and energy balances	1
2.5	Safety systems	1
2.6	Diagrams: Block Diagram, Process Flow Diagram (PFD) and Piping and Instrumentation diagram (P&ID)	2
3	**Process hazard analysis (8 hours)**	
3.1	Introduction to the PHA techniques: Checklist	1
3.2	What-if analysis	1
3.3	Hazard and Operability study (HAZOP)	1
3.4	Failure Modes and Effects Analysis (FMEA)	1
3.5	Fault tree analysis and event tree analysis	1
3.6	Bow-tie analysis	1
3.7	Quantitative Risk Assessment (QRA)	2
4	**Other elements required by OSHA standard-1 (8 hours)**	
4.1	Operating Procedures: Initial start-up, Normal operations, Temporary operations, Emergency shutdown, Emergency operations, Normal shutdown, Start-up	4
4.2	Employee participation and training: Initial training, Refresher training, Employer responsibilities	1
4.3	Contractors: contractor employer responsibilities	1
4.4	Pre-start-up Review	2
5	**Other elements required by OSHA standard-2 (8 hours)**	

5.1	Mechanical Integrity, Pressure vessels and storage tanks, Piping systems, Relief and vent systems and devices, Emergency shutdown systems, Controls, Pumps	2
5.2	Hot work Permit	1
5.3	Management of Change, technical basis for the proposed change, impact of the change on employee safety and health, modifications to operating procedures, necessary time period for the change, authorization requirements for the proposed change	2
5.4	Incident Investigation	1
5.5	Emergency Planning and Response	1
5.6	Compliance Audits, Trade Secrets	1

Reference Books:

1. Introduction to Process Safety Management, OSHA Academy, United States Department of Labor
2. Alexis M. Herman, Charles N. Jeffress, Process Safety Management, OSHA-3132, U.S. Department of Labor
3. Process Safety Management Guide, 4th Edition, Canedian Society for Chemical Engineers
4. Gary Whitmore, Process Safety Management General Awareness Training,
5. Accident Prevention Manual for Industrial Operations", N.S.C.Chicago, 1982
6. Heinrich H.W. "Industrial Accident Prevention" McGraw-Hill Company, New York, 1980.
7. Krishnan N.V. "Safety Management in Industry" Jaico Publishing House, Bombay, 1997.
8. John Ridley, "Safety at Work", Butterworth & Co., London, 1983.
9. Blake R.B., "Industrial Safety" Prentice Hall, Inc., New Jersey, 1973.

222ECH017	NANOTECHNOLOGY	CATEGORY	L	T	P	CREDIT
		Program Elective 4	3	0	0	3

Preamble:

Nanotechnology has gained great importance during recent decades. It is a highly interdisciplinary science and is projected as the technology with the ability to change all fields of modern life.

The course will provide an overview over Nanotechnology. It will show that the nano regime is so different from other regimes because, both classical and quantum effects can be active thus leading to unique properties of nano materials and devices. Production of nano particles and applications of nanotechnology will be dealt with in the course.

Pre-requisites- Nil

Course Outcomes:

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

CO 1	Demonstrate a working knowledge of nanoscience/nanotechnology principles and applications
CO 2	Summarize the methods for synthesis of different nanoparticles
CO 3	Describe the methods of characterization of nanomaterials
CO 4	Explain nanofabrication principles and techniques used to build novel nanomaterials and assemblies of nanomaterials.
CO 5	Discuss the applications of nanomaterials and nanotechnology

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	3			3	2		
CO 3				3	3		
CO 4	2			3	3	2	
CO 5					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

SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 222ECH017

Max. Marks: 60 Duration: 2.5 hours

NANOTECHNOLOGY

PART – A

Answer All the Questions.

(5x 5 = 25)

1. What are semiconducting materials? How they are important in nanotechnology?
2. Explain the preparation and applications of gold nanoparticles,
3. Discuss the principle of AFM.
4. Explain on the role of photoresists in nanolithography
5. Discuss the safety issues with nanoscale powders.

PART – B

Answer any five (5 x 7 = 35)

6. Define nanotechnology? Bring out the importance and applications of nanotechnology in human life.
7. Distinguish between top down and bottom-up approaches with suitable examples.
8. Explain the sol-gel method of nanosynthesis.
9. Describe the process of chemical vapour deposition. List its applications.
10. Discuss the principle, working and applications of TEM.
11. Explain the concepts of nanolithography and soft lithography.
12. Discuss the production and applications of quantum dots.

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Syllabus

Module I: General Concepts in Nanotechnology (8 hours)

Introduction to nanotechnology, nanoscale, electromagnetic spectrum, top down and bottom-up approach, particle size, electronic structure of solids - semiconductors, optical absorption in solids, quantum effects.

Module II: Nanomaterials (8 hours)
Nanomaterials - preparation and properties of nanomaterials - gold and silver, different types of nano-oxides - $A1_20_3$, TiO_2 and ZnO. Sol-gel methods, physical vapour deposition, chemical vapour deposition, self-assembly, preparation of graphene, Carbon nanotubes.

Module III: Characterization Techniques (8 hours)
Different types of characterization techniques like SEM, AFM, TEM, STM, XRD, HRTEM, HRSEM, ICP, SAXS.

Module IV: Micro and nanofabrication techniques (8 hours)
Micro and nanofabrication techniques, Photolithography, E-beam, FIB. Nanolithography, soft lithography, photoresist materials. Introduction to MEMS, NEMS and nanoelectronics. Introduction to bio nanotechnology and nanomedicines.

Module V: Applications of nanotechnology (8 hours)
High performance materials - Nanocomposites, nanofillers, polymer nanocomposites, nano clays, nanowires, nanotubes, nanoclusters, dendrimers, quantum dots. Smart materials, zeolites, self-assembly of materials, safety issues with nanoscale powders.

Course Plan

No	Topic	No. of Lectures
1	**General Concepts in Nanotechnology (8 hours)**	
1.1	Introduction to nanotechnology, nanoscale, electromagnetic spectrum	2
1.2	Top down and bottom-up approaches	2
1.3	Particle size, electronic structure of solids - semiconductors	2
1.4	Optical absorption in solids, quantum effects	2
2	**Nanomaterials (8 hours)**	
2.1	Preparation and properties of nanomaterials - gold and silver	2
2.2	Different types of nano-oxides - $A1_2O_3$, TiO_2 and ZnO.	2
2.3	Sol-gel methods, self-assembly	1
2.4	Physical vapour deposition and chemical vapour deposition	1
2.5	Preparation and properties of grapheme and Carbon nanotubes	2
3	**Characterization Techniques (8 hours)**	

3.1	SEM, HRSEM	2
3.2	TEM, HRTEM	2
3.3	AFM, STM	2
3.4	XRD, ICP, SAXS	2
4	**Micro and nanofabrication techniques (8 hours)**	
4.1	Photolithography, E-beam, FIB	2
4.2	Nanolithography, soft lithography, photoresist materials	2
4.3	Introduction to MEMS, NEMS and nanoelectronics	2
4.4	Introduction to bio nanotechnology and nanomedicines	2
5	**Applications of nanotechnology (8 hours)**	
5.1	High performance materials - Nanocomposites, nanofillers	2
5.2	Polymer nanocomposites, nano clays, nanowires, nanotubes, nanoclusters, dendrimers, quantum dots and - applications	4
5.3	Smart materials, zeolites, self-assembly of materials, safety issues with nanoscale powders.	2

Reference Books

1. B.S. Murty, P. Shankar, Baldev Raj, B B Rath, James Murday, Textbook of Nanoscience and Nanotechnology, .
2. T Pradeep, Nano: The essentials – Understanding nanoscience and nanotechnology, Tata McGraw-Hill Publishing Company Limited, Newdelhi.
3. Said Salaheldeen Elnashaie, Firoozeh Danafar and Hassan Hashemipour Rafsanjani, Nanotechnology for Chemical Engineers, Springer.
4. Poole C P and Owens F J, Introduction to Nanoscience and Nanotechnology, ***Wiley.***
5. Cao G, Nanostructures and Nanomaterials: Synthesis, Properties and Applications, ACS Publications.
6. Bhushan, Handbook of Nanotechnology, Springer–Springer,2007
7. K K Chattopadhyay and A N Banerjee, Introduction to Nanoscience and Nanotechnology, PHI.
8. Sulabha K Kulkarni, Nanotechnology: Principles and Practices, Springer.
9. Carl C. Koch. Noyes, Nano-structured materials: Processing, properties and Potential Applications, William Andrew Publishing New York.
10. Hari Singh Nalwa, "Nanostructured Materials and Nanotechnology", Academic Press.

222ECH018	PROCESS EQUIPMENT DESIGN	CATEGORY	L	T	P	CREDIT
		Program Elective4	3	0	0	Discuss

Preamble:

Mechanical design of equipment addresses the stress and strain produced in different parts of the equipment such as pressure vessels, head, supports, etc. due to operating conditions of the process. The success and failure of the process depends on how perfectly stress and strain are considered while designing. This course focuses on design of tall vertical vessels, and flanges.

Pre-requisites- Nil

Course Outcomes:

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

CO 1	Discuss the basic concepts of process design development
CO 2	Use software tool for the design of internal pressure vessels and external pressure vessels
CO 3	Design supports for vertical vessels and horizontal vessels
CO 4	Design tall vessels with heads and closures
CO 5	Design flanges

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	
CO 2			3	3	3	3	
CO 3			3	3	3	3	
CO 4			3	3	3	3	
CO 5			3	3	3	3	

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	20 %
Analyse	40 %
Evaluate	40 %
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 of 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. The question paper will contain 4 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 2. Each question can carry 30 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

SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 222ECH018

Max. Marks: 60 Duration: 2.5 hours

PROCESS EQUIPMENT DESIGN

Use of relevant IS Codes is permitted

Answer ***two*** questions

1. A process vessel is to be designed for the maximum operating pressure of $500kN/m^2$. The vessel has the nominal diameter of 1.2m and tangent to tangent length of 2.4m. The vessel is made of IS 2002 1962 grade 2B quality steel having allowable design stress value of $118MN/m^2$ at working temperature. The corrosion allowance is suggested to be 2mm for the life span expected for the vessel. The vessel is to be fabricated according to class 2 of IS specification which stipulates the weld joint efficiency of 0.85. (30)

(a) What would be the std. plate thickness to fabricate this vessel?

(b) If a spherical vessel having the same diameter and thickness is fabricated with the same quality steel, what maximum internal pressure the sphere will withstand safely?

OR

2. a) A vessel is to operate at an internal pressure of $10kg/cm^2$.The vessel has a hemispherical head and conical bottom with apex angle of 60^o. Using the following data, Estimate the minimum standard plate thickness required for fabrication of shell, hemispherical head and conical bottom. (20)

The given data are :

The internal diameter of vessel=3m; Allowable stress of the material= $1020kg/cm^2$; Welded joint efficiency: 85%; C=0.5 and Corrosion allowance =2mm

b) A spherical vessel having inside diameter 2m operating at vacuum of 200mmHg.and 250^oC is used for the process. Carbon steel is used for the manufacture. Design the vessel. (10)

3. A tall vertical vessel 1.5m in diameter and 13m. in height is to be provided skirt support. Weight of a vessel with all its attachments is 80,000kg. The (30)

diameter of skirt is equal to the diameter of the vessel. Height of the skirt is 2.2m. Wind pressure acting over the vessel is 100kg/m^2. The coefficient due to wind force, k_1=0.7 for cylindrical vessel; Seismic coefficient c=0.08; Permissible tensile stress of skirt material =960kg/cm^2; Permissible Compressive stress is 1/3 of yield stress of material. Yield stress of material is 2400kg /cm^2 . Estimate the thickness of the support. Size of the base plate for a wide range of overturning moment 15662.5kg/cm and vertical thrust of 52090kg. Allowable stress on bulk material =1400kg/cm^2; Allowable stress on concrete=50kg/cm^2; Allowable building stress for bearing ring =1400kg/cm^2; Base ring projection beyond column outside diameter =10cm.

OR

4. A ring type flange with a plain face for a heat exchanger shell is required to be designed to the following specification: (30)
Design pressure: kg/cm^2, Design temperature: 150^{o}C, Shell outside diameter: 80 cm, Shell thickness: 10mm, gasket material: asbestos composition, Gasket ID : 84 cm, gasket width: 1.6 cm, gasket factor: 2.75 (m), Seating stress: 260 kg/cm2, 32 bolts of 19mm are to be used, Permissible stress –bolt material: 950 kg/cm^2 ,flange material: 950 kg/cm^2 .Check whether the gasket is sufficiently wide keep away from crushing. Calculate the minimum thickness of the flange.

SYLLABUS

Module 1 (22 hours)

Introduction to codes. Factors influencing the design of vessels, Criteria in vessel design, Design of cylindrical, spherical vessels under internal pressure.

Selection and design of closures –Flat plate, Conical, Elliptical, Tori spherical and Hemispherical dished closures for cylindrical vessels, Design of cylindrical vessels with formed closures operating under external pressure.

Module 2 (18 hours)

Design of Tall vertical vessels

Design of supports for vertical vessels - Skirt supports, Lug supports

Design of horizontal vessels with Saddle supports

Design of Flanges.

Course Plan

No	Topic	No. of Lectures
1	**Module 1 (22 hours)**	
1.1	Introduction to codes.	1
1.2	Factors influencing the design of vessels	2
1.3	Criteria in vessel design	2
1.4	Design of cylindrical vessels under internal pressure	3
1.5	Design of spherical vessels under internal pressure	3
1.6	Selection and design of closures	3
1.7	Flat plate and Conical closures for cylindrical vessels	4
1.8	Elliptical, Torispherical and Hemispherical dished closures for cylindrical vessels	4
2	**Module 2 (18 hours)**	
2.1	Design of Tall vertical vessels	3
2.2	Design of supports for vertical vessels - Skirt supports	4
2.3	Design of supports for vertical vessels - Lug supports	4
2.4	Design of horizontal vessels with Saddle supports	3
2.5	Design of Flanges.	4

Reference Books

1. Lloyd E. Brownell,and Edwin H.Young., Process Equipment Design, Wiley Eastern.
2. B.C Bhattacharya, Introduction to Chemical Equipment Design, CBS Publishers & Distributors, New Delhi.
3. B.C. Bhattacharyya and C.M. Narayanan, “Computer Aided Design of Chemical Process Equipment, Ist Edn., New Central Book Agency (P) Ltd., New Delhi, 1992.
4. M.V Joshi & Mahajan V.V., Process Equipment Design, 3rd Edn, Mac-Milan & Co India.
5. IS Codes

222ECH019	BIOMASS CONVERSION AND BIOREFINERY	CATEGORY	L	T	P	CREDIT
		Program Elective 4	3	0	0	3

Preamble:

This course discusses the different types of renewable energy feed stocks and the basic knowledge needed to convert into fuels, power, heat, and value-added chemicals. The world energy scenario, different types of renewable feedstocks and basic knowledge needed to convert it into fuel, power, heat and value-added chemicals

Pre-requisites- Nil

Course Outcomes:

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

CO 1	Explain the world energy situation, and refinery and biorefinery concept
CO 2	Identify potential biomass feedstocks including energy crops
CO 3	Evaluate the existing and emerging biomass to energy technologies
CO 4	Determine potential solutions for energy needs and problems by incorporating the bioenergy technologies being explored.
CO 5	Identify various biomass valorisation routes and commodities.

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		3	
CO 5			3	3		3	

Assessment Pattern

Bloom's Category	**End Semester Examination**
Apply	20 %
Analyze	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 **: 10 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

SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 222ECH019

Max. Marks: 60 Duration: 2.5 hours

BIOMASS CONVERSION AND BIOREFINERY

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

1.	What are the various sources of biomass? Mention the advantages of biomass energy.	5
2.	Write a note on gasification reaction.	5
3.	Explain in detail about biomass purification.	5
4.	Write a note on pentose derived products	5
5.	Explain the importance of biorefinery for bio-based industries.	5

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

6.	What are the economic and social challenges related to biomass?	7
7.	Explain the mechanism of biomass gasification.	7
8.	Explain in detail about fundamentals of biogas technology.	7
9.	Give a detailed account of factors affecting biooil and biochar production.	7
10.	Give a detailed account of ABE fermentation pathway and kinetic.	7
11.	Explain in detail about the synthesis, properties application and advantages of Poly lactic acid.	7
12.	Give a detailed account of different types of biorefinery.	7

Syllabus

Module I (8 hours)

World energy scenario, consumption pattern, fossil fuel depletion and environmental issues. Biomass Availability and abundance, photosynthesis, composition and energy potential, virgin biomass production and selection, waste biomass (municipal, industrial, agricultural and forestry) availability, abundance and potential, biomass as energy resources: dedicated energy crops, annual crops (maize, sorghum sugar beet, hemp), perennial herbaceous crops (sugarcane, switchgrass, miscanthus), short rotation woody crops (poplar, willow), oil crops and their biorefinery potential, microalgae as feedstock for biofuels and biochemical, enhancing biomass properties for biofuels, challenges in conversion.

Module II (8 hours)

Barriers in lignocellulosic biomass conversion, pretreatment technologies such as acid, alkali, autohydrolysis, hybrid methods, role of pretreatment in the biorefinery concept. Physical and Thermal Conversion Processes: Types, fundamentals, equipments and applications; thermal conversion products, commercial success stories, Microbial Conversion Process: Types, fundamentals, equipments and applications, products, commercial success stories

Module III (8 hours)

Hydrogen, Methane and Methanol: Biohydrogen generation, metabolic basics, feedstocks, dark fermentation by strict anaerobes, facultative anaerobes, thermophilic microorganisms, integration of biohydrogen with fuel cell; fundamentals of biogas technology, fermenter designs, biogas purification, methanol production and utilization.
Diesel from vegetable oils, microalgae and syngas; transesterification; FT process, catalysts; biodiesel purification, fuel properties. Biooil and Biochar: Factors affecting biooil, biochar production, fuel properties, biooil upgradation.

Module IV (8 hours)

Bioethanol and Biobutanol: Corn ethanol, lignocellulosic ethanol, microorganisms for fermentation, current industrial ethanol production technology, cellulases and their role in hydrolysis, concepts of SSF and CBP, advanced fermentation technologies, ABE fermentation pathway and kinetics, product recovery technologies.Organic Commodity Chemicals from Biomass: Biomass as feedstock for synthetic organic chemicals, lactic acid, polylactic acid, succinic acid, propionic acid, acetic acid, butyric acid, 1,3-propanediol, 2,3-butanedioil, PHA

Module V (8 hours)

Biorefinery- Basic concept, biorefinery feedstocks , properties cost and availability of biorefinery feedstocks,, Biorefinery types (based on platforms, products, feedstock, processes) and their features - C6 sugar platform biorefinery, Syngas platform biorefinery,

C6 & C5 sugar and syngas platform biorefinery, SWOT (Strength, Weakness, Opportunities and Threat) analysis on a biorefinery, evaluating biorefinery performance.
Biorefinery types

(based on platforms, products, feedstock,
processes) and their features -
C6 sugar platform biorefinery,
Syngas platform biorefinery, C6 & C5 sugar and syngas
platform biorefinery,
Biorefinery types

(based on platforms, products, feedstock,
processes) and their features -
C6 sugar platform biorefinery,
Syngas platform biorefinery, C6 & C5 sugar and syngas
platform biorefinery,

Course Plan

No	Topic	No. of Lectures
1	**Module I (8 hours)**	
1.1	World energy scenario, consumption pattern, fossil fuel depletion and environmental issues.	1
1.2	Biomass Availability and abundance, photosynthesis, composition and energy potential, virgin biomass production and selection,	1
1.3	Waste biomass (municipal, industrial, agricultural and forestry) availability, abundance and potential,	1
1.4	Biomass as energy resources: dedicated energy crops, annual crops (maize, sorghum sugar beet, hemp),	1
1.5	Perennial herbaceous crops (sugarcane, switchgrass, miscanthus), short rotation woody crops (poplar, willow),	1
1.6	Oil crops and their biorefinery potential,	1
1.7	Microalgae as feedstock for biofuels and biochemical,	1
1.8	Enhancing biomass properties for biofuels, challenges in conversion.	1
2	**Module II (8 hours))**	
2.1	Barriers in lignocellulosic biomass conversion,	1
2.2	Pretreatment technologies such as acid, alkali, autohydrolysis, hybrid methods, Role of pretreatment in the biorefinery concept.	2
2.3	Physical and Thermal Conversion Processes: Types, fundamentals, equipments and applications;	2
2.4	thermal conversion products, commercial success stories,	1

2.5	Microbial Conversion Process: Types, fundamentals,	1
2.6	Equipments and applications, products, commercial success stories	1
3	**Module III (8 hours)**	
3.1	Hydrogen, Methane and Methanol: Biohydrogen generation, metabolic basics, feedstocks, dark fermentation by strict anaerobes,	1
3.2	Facultative anaerobes, thermophilic microorganisms, integration of biohydrogen with fuel cell;	1
3.3	Fundamentals of biogas technology, fermenter designs, biogas purification, methanol production and utilization.	2
3.4	Diesel from vegetable oils, microalgae and syngas; transesterification; FT process, catalysts; biodiesel purification, fuel properties.	2
3.5	Biooil and Biochar: Factors affecting biooil, biochar production, fuel properties, biooil upgradation,	2
4	**Module IV (8 hours)**	
4.1	Bioethanol and Biobutanol: Corn ethanol, lignocellulosic ethanol, microorganisms for fermentation, current industrial ethanol production technology,	2
4.2	cellulases and their role in hydrolysis, concepts of SSF and CBP, advanced fermentation technologies,	1
4.3	ABE fermentation pathway and kinetics, product recovery technologies.Organic Commodity	1
4.4	Chemicals from Biomass: Biomass as feedstock for synthetic organic chemicals, lactic acid, polylactic acid, succinic acid, propionic acid,	2
4.5	acetic acid, butyric acid, 1,3-propanediol, 2,3-butanedioil, PHA	2
5	**Module V (8 hours)**	
5.1	Biorefinery- Basic concept, biorefinery feedstocks	1
5.2	Biorefinery types (based on platforms, products, feedstock, processes) and their features	2
5.3	C6 sugar platform biorefinery, Syngas platform biorefinery,	2
5.4	C6 & C5 sugar and syngas platform biorefinery,	1
5.5	SWOT (Strength, Weakness, Opportunities and Threat) analysis on a biorefinery, evaluating biorefinery performance.	2

Reference Books

1. Jhuma Sadhukhan, KokSiew Ng, Elias Martinez Hernandez, Biorefineries and Chemical Processes: Design, Integration and Sustainability Analysis, John Wiley & Sons, 2013.
2. Paul R. Mahmoud M. El-Halwagi, Integrated Biorefineries: Design, Analysis, and optimization, CRC Press, 2013.
3. Chinnappan Baskar, Shikha Baskar, Ranjit S. Dhillon (Eds), Biomass Conversion: The Interface of Biotechnology, Chemistry and Materials Science, Springer, 2012.

4. Shang-Tian Yang, Hesham El-Ensashy, NutthaThongchul, Bioprocessing Technologies in Biorefinery for Sustainable Production of Fuels, Chemicals and Polymers. John Wiley & Sons, 2013.
5. Ashok Pandey, Rainer Höfer, Mohammad Taherzadeh, Madhavan Nampoothiri, Christian Larroche (Eds), Industrial Biorefineries& White Biotechnology, Elsevier, 2015.
6. Pratima Bajpa, Biomass to Energy Conversion Technologies,The Road to Commercialization 1st Edition - October 22, 2019

222ECH020	ADVANCED HEAT AND MASS TRANSFER	CATEGORY	L	T	P	CREDIT
		Program Elective 4	3	0	0	3

Preamble:

The analysis of the phenomena of heat and mass transfer is important in engineering design applications. Heat and mass transfer processes are modelled by similar mathematical equations in the case of diffusion and convection. It is thus more efficient to consider them jointly. Besides, heat and mass transfer must be jointly considered in some cases like humidification and drying. This course also explains how to solve engineering problems involving conduction, convection, diffusion mass transfer, interphase mass transfer, simultaneous heat and mass transfer.

Pre-requisites- Nil

Course Outcomes:

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

CO 1	Analyze various modes of heat transfer in multi-dimensions.
CO 2	Solve engineering problems involving conduction and convection heat transfer
CO 3	Develop and solve boundary layer equations for various cases of heat transfer
CO 4	Analyze and solve mass transfer cases involving multi-component diffusion
CO 5	Understand the interphase mass transport involving multi component systems
CO 6	Apply the knowledge of heat and mass transfer to design problems

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	3		
CO 3			3	3	3		
CO 4			3	3			
CO 5			3	3			
CO 6			3	3	3		

Assessment Pattern

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

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.
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

SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: 222ECH020

Max. Marks: 60 Duration: 2.5 hours

ADVANCED HEAT AND MASS TRANSFER

PART – A

Answer All the Questions.

(5x 5 = 25)

1. Describe the importance of boundary conditions and give any two boundary conditions used in heat transfer.
2. Sketch thermal and hydrodynamic boundary layer for flow over a flat plate. How do you predict the relative thickness of both?
3. Explain Knudsen diffusion
4. Describe two resistance theory in interphase mass transfer
5. What is the need for analogy? List assumptions involved in formulation of analogical expressions.

PART – B

Answer any five (5 x 7 = 35)

6. Differentiate between lumped and distributed systems. Derive temperature profile for unsteady state heat conduction using lumped parameter analysis.
7. An aluminium fin (k = 200 W/m K) 3 mm thick and 7.5 cm long protrudes from a wall at 300 ^{0}C. The ambient temperature is 50 ^{0}C with h = 10 W/m^2 K. Compute the heat loss from the fin. Also calculate its efficiency.
8. Water flows with a mean velocity of 2m/s inside a circular pipe of inside diameter 5 cm. Pipe wall is maintained at a constant temperature of 100^{0}C by condensing steam on the outer side. Bulk mean temperature of water is 60^{o}C and properties of water at this temperature are ρ = 985 kg/m^3, Pr = 3.02, μ = 4.71 x 10-4 kg/ms, k = 0.651 W/m^{0}C, μ at 100^{0}C = 2.82 x 10^{-4} kg/ms. Calculate heat transfer coefficient by (a) Colburn equation (b) Dittus – Boelter equation (c) Sieder Tate equation.

9. A long thin tube contains liquid A and the top end of the tube is open. Gas B is flowing past the tube, at the open end. If liquid A evaporates into gas B, develop an expression for concentration profile $\frac{x_B}{x_{B1}} = \left(\frac{x_{B2}}{x_{B1}}\right)^{\frac{z-z_1}{z_2-z_1}}$, x_B is mole fraction of B, z_1 is liquid level in the tube and z_2 is the length of the tube.

10. Derive relationship between individual mass transfer coefficients and overall coefficient in transfer of a solute present in gas phase to liquid phase. Equilibrium relation can be taken as straight line with slope 'm'. How can you simplify the expression if the solute in gas phase is readily soluble in the liquid phase?

11. Nitrogen gas at 290 K and 101.3 kPa is passed across a plastic sheet to remove excess styrene. The sheets are 0.75 m long and nitrogen flow at a velocity of 10 m/s. Diffusivity of styrene vapour in nitrogen at this condition is 7×10^{-6} m^2/s. Determine the average mass transfer coefficient assuming laminar flow condition.

12. Develop an expression for concentration for a dimerization reaction, $2A \rightarrow A_2$ in catalytic reactor. Assume the reaction occurring at the catalyst surface is instantaneous and the process is diffusion controlled. List all the assumptions used.

Syllabus

Module I (9 hours)

Introduction: Mechanisms of heat transfer – conduction, Fourier's law of conduction, Convection, Newton's law of cooling, Radiation. Stefan Boltzmann law of thermal radiation, combination of all modes of heat transfer (concept). Role of boundary conditions, types of boundary conditions.

Derivation of one-dimensional heat conduction equation (Cartesian coordinates), three dimensional heat conduction equation (no derivation). Heat source systems – plane wall with heat source, cylinder with heat source. Transient conduction – lumped and distributed systems, derivation for lumped capacity model. One dimensional conduction and convection through rectangular fin – very long fin, fin with insulated end, fin of finite length with heat loss from end.

Module II (8 hours)

Forced and free convection, dimensionless numbers in forced and free convection, expressions for heat transfer coefficient (no derivation) – free convection and forced convection through tubes, Boundary layer over flat plate – hydrodynamic and thermal boundary layer, Prandtl number and relative thicknesses of hydrodynamic and thermal boundary layer, boundary layer thickness, approximate and exact analysis of thermal boundary layer.

Module III (8 hours)

Fick's first and second law of diffusion, steady state molecular diffusion in gases, diffusion of A through stagnant B, pseudo steady state diffusion, diffusion in multicomponent mixtures, molecular diffusion in liquids, diffusivity in porous solids – Knudsen diffusion, unsteady state diffusion – basic diffusion equation

Module IV (9 hours)

Theories of mass transfer – film theory, penetration theory, surface renewal theory, film-penetration, boundary layer theory (no derivation). Interphase mass transfer, two resistance theory, local and overall mass transfer coefficients, gas phase and liquid phase controlled systems

Module V (6 hours)

Analogy between momentum, heat and mass transfer, Reynolds, Prandtl, Chilton-Colburn and von-Karman analogical expressions. Simultaneous diffusion and chemical reaction: homogeneous and heterogeneous reactions, simultaneous heat and mass transfer: condensation of hot vapour on solid surface in presence of non-condensable gas, steady state binary thermal diffusion in a two-bulb apparatus.

Course plan

No	Topic	No. of Lectures
1	**Modes of heat transfer (9 hours)**	
1.1	Mechanisms of heat transfer – conduction, Fourier's law of conduction, Convection, Newton's law of cooling, Radiation. Stefan Boltzmann law of thermal radiation, combination of all modes of heat transfer (concept).	1
1.2	Role of boundary conditions, types of boundary conditions.	1
1.3	Derivation of one-dimensional heat conduction equation (Cartesian coordinates),	1
1.4	three-dimensional heat conduction equation (no derivation) in Cartesian, cylindrical and spherical coordinates	1
1.5	Heat source systems – plane wall with heat source, cylinder with heat source.	1
1.6	Transient conduction – lumped and distributed systems, derivation for lumped capacity model, Biot number, Fourier number	2
1.7	One dimensional conduction and convection through rectangular fin – very long fin, fin with insulated end, fin of finite length with heat loss from end.	2
2	**Convection (8 hours)**	
2.1	Forced and free convection, dimensionless numbers in forced and free convection	1
2.2	expressions for heat transfer coefficient (no derivation) – free convection and forced convection through tubes	2
2.3	Boundary layer formation over flat plate – hydrodynamic and thermal boundary layer	1
2.4	Prandtl number and relative thicknesses of hydrodynamic and thermal boundary layer, boundary layer thickness	1
2.5	approximate and exact analysis of thermal boundary layer.	3
3	**Diffusional mass transfer (8 hours)**	
3.1	Fick's first and second law of diffusion, steady state molecular diffusion in gases	2
3.2	diffusion of A through stagnant B, pseudo steady state diffusion	2
3.3	diffusion in multicomponent mixtures	1
3.4	molecular diffusion in liquids	1
3.5	diffusivity in porous solids – Knudsen diffusion	1
3.6	unsteady state diffusion – basic diffusion equation	1

4	**Convective transport and interphase mass transfer (9 hours)**	
4.1	Theories of mass transfer – film theory, penetration theory, surface renewal theory, film-penetration, boundary layer theory (no derivation)	3
4.2	Interphase mass transfer, two resistance theory, local and overall mas transfer coefficients	3
4.3	Gas phase and liquid phase-controlled systems	3
5	**Analogies and Simultaneous heat and mass transfer (6 hours)**	
5.1	Analogy between momentum, heat and mass transfer, Reynolds, Prandtl, Chilton-Colburn and von-Karman analogical expressions	2
5.2	Simultaneous diffusion and chemical reaction: homogeneous and heterogeneous reactions	2
5.3	Smultaneous heat and mass transfer: condensation of hot vapour on solid surface in presence of non-condensable gas	1
5.4	Steady state binary thermal diffusion in a two-bulb apparatus	1

Reference Books

1. Bird et al., *Transport phenomena*, John Wiley & Sons
2. Wetty J.R et al., *Fundamentals of momentum, heat and mass transfer*, John Wiley & Sons
3. Ozisik M Necati, *Heat transfer, A Basic Approach*
4. K V Narayanan and B Lakshmikutty, *Mass Transfer theory and applications*, CBS publishers.
5. Robert E Treybal, Mass Transfer Operations, Mc GrawHill

INTERDISCIPLINARY ELECTIVE

222ECH038	WASTE TO ENERGY	CATEGORY	L	T	P	CREDIT
		INTERDISCIPLINARY ELECTIVE	3	0	0	3

Preamble:

This course discusses the production of energy from different types of wastes using technologies through different routes, via thermal, biological and chemical. This course aims to update the knowledge of students in the area of waste utilization for energy production through newer technologies

Pre-requisites- Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Understand and analyse the characteristics of wastes and need of waste to Energy conversion of technologies
CO 2	Understand the use of incineration technology for waste to energy conversion and analyse its environmental impact
CO 3	Understand the basic chemistry, schemes and use of gasification as a method of waste to Energy conversion and compare the same with other technologies
CO 4	Explain the mechanism, types and use of pyrolysis as a waste to energy conversion technology and analyse this method for conversion of plastic
CO 5	Understand the concept, chemistry, and use of biochemical and chemical routes of waste to energy conversion and also gain knowledge on the use of algae for wastewater treatment

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	
CO 2	3		3	3	3	3	
CO 3	3		3	3	3	3	
CO 4	3		3	3	3	3	
CO 5	3		3	3	3	3	
CO 6	3		3	3	3	3	

Assessment Pattern

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

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

SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

222ECH038: WASTE TO ENERGY

Max. Marks: 60 Duration: 150 minutes

PART A

Answer All the Questions.

One question from each module, having 5 marks for each question **(5x5= 25 marks)**

1. Discuss the classification of solid wastes.
2. Discuss the environmental impact of incineration and their solution.
3. Compare gasification with incineration.
4. Discuss different types of pyrolysis and their product distribution.
5. Discuss the mechanism and pathways for anaerobic digestion.

PART B

Minimum one question from each module (Total seven questions)

Answer any five **(5x7= 35 marks)**

6. What are the parameters to be checked to find out the suitability of waste for energy conversion? Explain.
7. The composition of flue gas (dry basis) from an incinerator is as follows: 12.3% CO_2 , 5.1% O_2 , and the rest is nitrogen. From these data, calculate a) The weight ratio of hydrogen to carbon in the waste b) The percent carbon and hydrogen in the dry waste c) The percent excess air used d) The moles of exhaust gas discharged from the unit per kilogram dry waste burnt.

8. A dry MSW has the following composition on mass basis: C: 40 %, H: 5 %, O: 30 % and Ash:25 %. Determine the stoichiometric oxygen requirement for the combustion of the MSW. Assume the ash as inert and average molecular weight of ash is 56. If the ratio of nitrogen to oxygen in air is 4:1 (v/v), determine the stoichiometric requirement of air.
9. A fast pyrolysis plant handles 1TPD MSW and produces gas, char and liquor. Operating temperature and pressure of the reactor are 788^{o}C and 1 atm., respectively. The gas composition (vol %) is H_2 - 37.16, CO- 35.50), CH_4 - 11.10, CO_2- 16.3). The mass % of production of gas, char and oil are 30, 25 and 45 respectively. Determine

the product distribution with individual components of gas and the rate of hydrogen production assuming 90 % separation efficiency for hydrogen.

10. Discuss the conversion of plastic to fuel through pyrolysis.
11. In a high-rate biogas plant food waste is anaerobically digested to produce biogas. The slurry contains 8 % of solid food grains. The elemental composition of the food grains on dry basis is C: 58%, H:8%, O:26%, N:8% (mass basis). Around 80 % of the food grains are converted to biogas and all the converted hydrogen forms methane. If the flowrate of the slurry is 4500 litre per day, calculate the rate of biogas (CO_2 + CH_4) production.
12. Explain the process of wastewater treatment using algae.

SYLLABUS

Module 1 (7 hours)

Wastes- Classification and characteristics: Definition of wastes and their classification, Important quality parameters of different types of wastes, Waste suitable for energy production, Solid wastes and their classification, Wastewater and their classification. Need of energy production from wastes, present status of WTE technologies.

Characterization of solid wastes: Physical, Chemical, Proximate and ultimate analysis, Fusing point of ash, Lignocellulosic composition, Leaching properties, Energy content: Heating value, Characterization of wastewater.

Module 2 (8 hours)

Incineration: Definition and scope for application, Mechanism, Air requirement, Performance factors and staged combustion, Advantages and disadvantages, Preferable feedstocks characteristics for incineration, Process flowsheet, Incinerators parts and their types/working, Environmental impact and operational issues

Module 3 (8 hours)

Gasification: Definition and Basic chemistry of gasification, Gasification reaction schemes and steps, Syngas production and efficiency and Factors influencing gasification, Advantages of gasification, Typical process flowsheet and Utilization schemes for gasification products, Syngas conditioning and clean up, Gasifier types, Gasifiers for biomass and wastes, Comparison between incineration and gasification

Module 4 (8 hours)

Pyrolysis: Definition of pyrolysis, mechanism, Types of pyrolysis, Operating conditions and end product distribution, Use of pyrolysis products, Properties of bio-oil and need of its upgradation, Catalytic pyrolysis, Pyrolysis reactors, Utilization of pyro char and gases

Options for management of plastic wastes and recycling through pyrolysis, Pyrolysis process types and their variables, Common steps for converting waste plastics to fuels

Module 5 (9 hours)

Energy production through biochemical and chemical routes: Anaerobic digestion for biogas production: Mechanism of anaerobic digestion, Microorganisms for anaerobic digestion, Pathways for anaerobic digestion, Pre-treatment of lignocellulosic biomass and wastes, Type of anaerobic digestion process, Kinetics of methane formation, Anaerobic digester and their types, Operation of anaerobic digester, Impurities in biogas and their impacts

Fermentation: Production of ethanol from different feedstocks and pre-processing steps, microorganisms and product recovery, Ethanol production through gasification route

Transesterification: Organic wastes for transesterification, Production of bio-oil from oil seeds and its major composition

Wastewater treatment using Algae

Reference Books

1. Rogoff, M.J. and Screve, F., "Waste-to-Energy: Technologies and Project Implementation", Elsevier Store.
2. Young G.C., "Municipal Solid Waste to Energy Conversion processes", John Wiley and Sons.
3. Harker, J.H. and Backhusrt, J.R., "Fuel and Energy", Academic Press Inc.
4. EL-Halwagi, M.M., "Biogas Technology- Transfer and Diffusion", Elsevier Applied Science.
5. Hall, D.O. and Overeed, R.P.," Biomass - Renewable Energy", John Willy and Sons.
6. Mondal, P. and Dalai, A.K. eds., 2017. *Sustainable Utilization of Natural Resources*. CRC Press.

Course Plan

No	Topic	No. of Lectures
1	**Module 1: Wastes- Classification and characteristics (7hrs)**	
1.1	Definition of wastes and their classification	1
1.2	Important quality parameters of different types of wastes, Waste suitable for energy production	1
1.3	Solid wastes and their classification	1
1.4	Wastewater and their classification	1
1.5	Need of energy production from wastes, present status of WTE technologies	1
1.6	Characterization of solid wastes – Physical – Chemical, Proximate and ultimate analysis, fusing point of ash, Lignocellulosic composition, Leaching properties, Energy content: Heating value	1
1.7	Characterization of wastewater	1
2	**Module 2: Incineration (8hrs)**	
2.1	Definition and scope for application	1
2.2	Mechanism, Air requirement,	1
2.3	Performance factors and staged combustion	1
2.4	Advantages and disadvantages, Preferable feedstocks characteristics for incineration	1
2.5	Process flowsheet	1
2.6	Incinerators parts and their types/working	2
2.7	Environmental impact and operational issues	1
3.0	**Module 3: Gasification (8hrs)**	
3.1	Definition and Basic chemistry of gasification	1
3.2	Gasification reaction schemes and steps	1
3.3	Syngas production and efficiency and Factors influencing gasification	1

3.4	Advantages of gasification	1
3.5	Typical process flowsheet and Utilization schemes for gasification products	1
3.6	Syngas conditioning and clean up	1
3.7	Gasifier types, Gasifiers for biomass and wastes	1
3.8	Comparison between incineration and gasification	1
4	**Module 4: Pyrolysis (8 hrs)**	
4.1	Definition of pyrolysis, mechanism,	1
4.2	Types of pyrolysis	1
4.3	Operating conditions and end product distribution	1
4.4	Use of pyrolysis products, Properties of bio-oil and need of its upgradation	1
4.5	Catalytic pyrolysis, Pyrolysis reactors, Utilization of pyro char and gases	1
4.6	Options for management of plastic wastes and recycling through pyrolysis	1
4.7	Pyrolysis process types and their variables,	1
4.8	Common steps for converting waste plastics to fuels	1
5	**Module 5: Energy production through biochemical and chemical routes (9 hrs)**	
5.1	Anaerobic digestion for biogas production: Mechanism of anaerobic digestion, Microorganisms for anaerobic digestion, Pathways for anaerobic digestion	1
5.2	Pre-treatment of lignocellulosic biomass and wastes, Type of anaerobic digestion process,	1
5.3	Kinetics of methane formation, Anaerobic digester and their types	1
5.4	Operation of anaerobic digester, Impurities in biogas and their impacts	1
5.5	Fermentation: Production of ethanol from different feed stocks and pre-processing steps	1
5.6	microorganisms and product recovery, Ethanol production through gasification route	1
5.7	Transesterification: Organic wastes for transesterification	1
5.8	Production of bio-oil from oil seeds and its major composition	1
5.9	Wastewater treatment using Algae	1

222ECH039	NANOMATERIALS AND NANOTECHNOLOGY	CATEGORY	L	T	P	CREDIT
		INTERDISCIPLINARY ELECTIVE	3	0	0	3

Preamble:

Nanotechnology has emerged as an important and exciting area in science and engineering. It provides promises in many technological advancements with wide range of application fields. The course gives a basic introduction to chemical and physical principles in the synthesis of nanomaterials. It also covers different methods for synthesis, properties, applications and characterization of nanoscale materials.

Pre-requisites- Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Understand the concepts of nanotechnology and apply the basic principles of Physics and Chemistry in Nanotechnology.
CO 2	Explain synthesis, properties and applications of nanomaterials and nanocomposites.
CO 3	Apply nanotechnology in biological fields and acquire the knowledge about drug delivery, biosensors, nanomedicine and therapeutic applications.
CO 4	Develop understanding about various characterisation techniques applied to nanomaterials.
CO 5	Understand the applications of nanotechnology in energy sector, catalysis and electronics.

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	60%
Analyse	15%
Evaluate	15%
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

SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

222ECH039: NANOMATERIALS AND NANOTECHNOLOGY

Max. Marks: 60 Duration: 2.5 hrs

PART – A

Answer All the Questions.

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

(5x 5 = 25)

1. What is quantum confinement effect?
2. Write down the various steps in CVD process.
3. What are biosensors?
4. Explain the principle of thermogravimetric analysis.
5. What are the applications of nanolithography?

PART – B

Minimum one question from each module (Total seven questions)

Answer any five (5 x 7 = 35)

6. Write a note on pioneers who contributed for the propagation of the ideas of nanotechnology.
7. Describe the synthesis, properties and applications of carbon nano tubes.
8. What is targeted drug delivery? What are the applications of nanomaterials in cancer treatment?
9. Describe the principle and operation of SEM using a ray diagram
10. Describe photolithography using a neat diagram.
11. Explain the application of nanomaterials in energy conversion and storage.
12. What is CVD? Describe the classification of CVD processes. What are the various steps involved in a CVD process?

****

SYLLABUS

Module 1 (8 hours)

Introduction and general properties: Introduction to Nanotechnology - History of nanotechnology, Pioneers in the field of nanotechnology, Classification of nanomaterials: Zero-, one-, two- and three-dimensional nano-structured materials. Electromagnetic spectrum, particle size and its significance, Physics of nanomaterials - Size effect on thermal, electrical, electronic, mechanical, optical and magnetic properties of nanomaterials- surface area and aspect ratio- band gap energy- quantum confinement size effect, Chemistry of nanomaterials - Ionic properties of nanomaterials, electronic phenomenon in nanostructures.

Module 2 (8 hours)

Synthesis methods: Top down approach – size reduction techniques like milling and machining, Bottom up approach - Sol-gel methods, Chemical vapour deposition, Physical Vapour Deposition, Wet chemical synthesis, Laser ablation methods, Synthesis, properties and applications of nanomaterials like gold, silver and different types of nano-oxides like Al_2O_3, TiO_2, ZnO and SiO_2 , Special nano-materials - synthesis, properties and applications – fullerenes, graphene, graphite, Synthesis, properties and applications of carbon nano-tubes, nano wires, nano rods, nanofluids, nanoclusters

Module 3 (8 hours)

Nanocomposites and Bio-nanotechnology: Matrix materials- Basics of Metal matrix, Ceramic Matrix nanocomposites, Polymer Matrix nanocomposites - Nano-reinforcements, nanofillers- nano-clays, Introduction to bio-nanotechnology- Nanomedicine, Drug delivery, Therapeutic applications, Applications of biosensors, Future of Bio-nanotechnology.

Module 4 (8 hours)

Characterisation techniques: Scanning Electron Microscopy (SEM) - Energy Dispersive X-ray Spectroscopy (EDS) - Transmission Electron Microscopy (TEM) - Atomic Force Microscopy (AFM), Scanning Probe Microscopy (SPM) - Scanning Tunnelling Microscopy (STM), UV-visible spectroscopy, Raman spectroscopy, Nuclear Magnetic Resonance Spectroscopy (NMR), Fourier Transform Infrared Spectroscopy (FTIR), X-Ray Diffraction (XRD), Dynamic Light Scattering (DLS), Thermogravimetric analysis (TGA), Differential Thermal Analysis (DTA), Differential Scanning Calorimetry (DSC).

Module 5 (8 hours)

Applications in energy, catalysis and electronics: Nanotechnology for sustainable energy, nanotechnology enabled renewable energy technologies, Application of nanomaterials in catalysis, Nanoelectronics - Introduction to Micro Electro Mechanical Systems (MEMS), Nano Electro Mechanical Systems (NEMS), Nanomanipulation – STM based atomic manipulations, Nanolithography, soft lithography, Scanning Probe Lithography, photolithography, E-beam Lithography, Focused ion beam lithography, Dip-pen Lithography.

Textbooks

1. Joel I. Gersten, ―The Physics and Chemistry of Materials, Wiley, 2001 2. G. Cao, Nanostructures & Nanomaterials: Synthesis, Properties & Applications, Imperial College Press, 2004.
2. S Zhang, L. Li and Ashok Kumar, Materials Characterization Techniques, CRC Press (2008).
3. T. Pradeep, Nano: The Essentials, McGraw-Hill (India) Pvt Limited, 2008.
4. Nanocomposite science and technology, Pulikel M. Ajayan, Wiley-VCH 2005.
5. C. M. Niemeyer, C. A. Mirkin, ―Nanobiotechnology: Concepts, Applications and Perspectives, Wiley – VCH, (2004)
6. J. Twidell and T. Weir, Renewable Energy Resources, E & F N Spon Ltd, London, (1986)
7. Nanotechnology in Catalysis Volumes 1 and 2, Bing Zhou, Sophie Hermans, Gabor A. Somorjai , Springer Science & Business Media, 05-Sep-2007.
8. W.R.Fahrner, Nanotechnology and Nanoelectronics–Materials, Devices, Measurement Techniques, Springer-Verlag Berlin, Germany (2006).

Reference Books

1. K.W. Kolasinski, ―Surface Science: Foundations of Catalysis and Nanoscience, Wiley, 2002.
2. S. Edelstein and R. C. Cammarata, ―Nanomaterials: Synthesis, Properties and Applications, Institute of Physics Pub., 1998.
3. S.Yang and P.Shen: ―Physics and Chemistry of Nanostructured Materials,Taylor & Francis, 2000.
4. Z L Wang (Ed.), Characterization of Nanophase materials, Willet-VCH (2000).
5. Guo, Jinghua (Ed.), X-rays in Nanoscience - Spectroscopy, Spectro-microscopy, and Scattering Techniques, John Wiley &Sons (2010).
6. Handbook of Nanoscience, Engineering and Technology, Kluwer publishers, 2002.
7. David S Goodsell, "Bio-nanotechnology, John Wiley & Sons, (2004).
8. Zheng Cui, Nanofabrication, Principles, Capabilities and Limits, Springer Science + business media, New York (2008).

Course Plan

No	Topic	No. of Lectures
1	**Introduction and general properties (8 hours)**	
1.1	Introduction to Nanotechnology - History of nanotechnology, Pioneers in the field of nanotechnology.	2
1.2	Classification of nanomaterials: Zero-, one-, two- and three-dimensional nano-structured materials. Electromagnetic spectrum, particle size and its significance.	2
1.3	Physics of nanomaterials - Size effect on thermal, electrical, electronic, mechanical, optical and magnetic properties of nanomaterials- surface area and aspect ratio- band gap energy- quantum confinement size effect.	2
1.4	Chemistry of nanomaterials - Ionic properties of nanomaterials, electronic	2

	phenomenon in nanostructures	
2	**Synthesis methods (8 hours)**	
2.1	Top-down approach – size reduction techniques like milling and machining.	1
2.2	Bottom-up approach - Sol-gel methods, Chemical vapour deposition, Physical Vapour Deposition, Wet chemical synthesis, Laser ablation methods	2
2.3	Synthesis, properties and applications of nanomaterials like gold, silver and different types of nano-oxides like Al_2O_3, TiO_2, ZnO and SiO_2	1
2.4	Special nano-materials - synthesis, properties and applications – fullerenes, graphene, graphite	2
2.5	Synthesis, properties and applications of carbon nanotubes, nano wires, nano rods, nanofluids, nanoclusters	2
3	**Nanocomposites and Bio-nanotechnology (8 hours)**	
3.1	Matrix materials- Basics of Metal matrix, Ceramic Matrix nanocomposites	2
3.2	Polymer Matrix nanocomposites - Nano-reinforcements, nanofillers- nano-clays	2
3.3	Introduction to bio-nanotechnology- Nanomedicine, Drug delivery, Therapeutic applications	2
3.4	Applications of biosensors, Future of Bio-nanotechnology	2
4	**Characterisation techniques (8 hours)**	
4.1	Scanning Electron Microscopy (SEM) - Energy Dispersive X-ray Spectroscopy (EDS) - Transmission Electron Microscopy (TEM) - Atomic Force Microscopy (AFM), Scanning Probe Microscopy (SPM) - Scanning Tunnelling Microscopy (STM)	2
4.2	UV-visible spectroscopy, Raman spectroscopy, Nuclear Magnetic Resonance Spectroscopy (NMR), Fourier Transform Infrared Spectroscopy (FTIR)	2
4.3	X-Ray Diffraction (XRD), Dynamic Light Scattering (DLS)	2
4.4	Thermogravimetric analysis (TGA), Differential Thermal Analysis (DTA), Differential Scanning Calorimetry (DSC)	2
5	**Applications in energy, catalysis and electronics (8 hours)**	
5.1	Applications: Nanotechnology for sustainable energy, nanotechnology enabled renewable energy technologies	2
5.2	Application of nanomaterials in catalysis.	2
5.3	Nanoelectronics - Introduction to Micro Electromechanical Systems (MEMS), Nano Electromechanical Systems (NEMS)	2
5.4	Nanomanipulation – STM based atomic manipulations, Nanolithography, soft-lithography, Scanning Probe Lithography, photolithography, E-beam Lithography, Focused ion beam lithography, Dip-pen Lithography.	2

222ECH040	PROCESS SAFETY ENGINEERING	CATEGORY	L	T	P	CREDIT
		INTERDISCIPLINARY ELECTIVE	3	0	0	3

Preamble: This course aims to learn about the different types of process safety strategies to improve the overall safety standards, various hazards in process plant like fire, explosions and the ways to prevent fire and explosions, toxicology studies and industrial hygiene.

Pre-requisites- Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Identify various types of hazards and risks in a chemical industry.
CO 2	Perform risk analysis by applying various risk assessment techniques.
CO 3	Demonstrate an understanding of issues related to the practical application of safety and risk management.
CO 4	Apply chemical engineering principles for prevention of hazards.
CO 5	Apply the concept of inherent safety and reliability in the process safety.

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	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.

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

SECOND SEMESTER M. TECH DEGREE EXAMINATION, MONTH & YEAR

222ECH040: PROCESS SAFETY ENGINEERING

Max. Marks: 60 Duration: 150 minutes

PART – A

Answer All the Questions.

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

(5x 5 = 25)

1. Explain the significance of entropy risk model in process safety.
2. How do we calculate the RPN. Discuss the significance of RPN in process safety.
3. Recommend a suitable procedure for the calculation of over pressure due to an explosion.
4. Write the salient features of LOPA.
5. Justify the significance of Inherent safety in process plant with suitable examples.

PART – B

Minimum one question from each module (Total seven questions)

Answer any five (5 x 7 = 35)

6. How do we calculate the Business interruption (BI) using the Dow F&EI.
7. Estimate LFL, UFL and limiting oxygen concentration (LOC) of Butane using empirical equations.
8. A liquid storage tank is filled by pump P1. It has a level indicator LI, a level alarm LA and a trip LT at successively higher levels. The pump discharge line to the storage tank has independent shut off valves V1 and V2, both of which are operator actuated. LI is simply an indicator; LA has an audible alarm and LT automatically trips the pump in case of a very high level. Draw a fault tree for the top event Tank overflows. Estimate the probability of overflow using the following data.

Event	Description	Probability
A	Valve V1 stuck open	0.01
B	Valve V2 stuck open	0.01
C	Level indicator LI fails flow	0.01
D	Level alarm LA fails	0.0005
E	Pump trip fails	0.005
H	Operator fails to respond to LI	0.03
K	Operator fails to respond to LA	0.01

9. Determine the evaporation rate from a 10m dia pool of pentane at an ambient temperature of 296 K. The pool is on wet sand and the solar energy input rate is 642 J/m^2 s.

Wind speed	4.9m/s
Molecular weight	72
Heat of vaporisation	27 kJ/mol
V.P at ambient temperature	0.652 bar abs.
Kinematic Viscosity of air	1.5×10^{-5} m^2/s
Diffusivity of air	7.1×10^{-6} m^2/s

10. Determine the concentration in PPM, 500m downwind from a 0.1 Kg/s ground release of a gas. The gas has a molecular weight of 30. Assume a temperature of 298 K, a pressure of 1 atmosphere, F stability with a 2m/s wind speed. The release occurs in rural area. Assume σy=19.52m, σz=6.96m.
11. Develop an onsite emergency plan in connection with the leakage of ammonia from a storage tank. Assume suitable assumptions.
12. Explain the concept of inherent safety. Describe the various tools for assessing inherent process safety.

SYLLABUS

Module 1 (8 hours)

Special Hazards of Chemicals: Introduction to process safety engineering, strategies for process safety engineering, Process safety management, safety integrity level, Toxicity, Flammability, Explosions, Ionising radiation, Runaway Reactions, Hazard survey – Inventory analysis, Dow Fire and Explosion Index, Mond Fire, Explosion and Toxicity Index, Chemical exposure index, Review of major industrial accidents- Bhopal, Flixborough disasters.

Module 2 (8 hours)

Techniques for Hazard Identification: Hazard and Operability Study, Preliminary Hazard Analysis, What if Analysis- methodology and application in industrial scenario, Fault tree Analysis, Event Tree Analysis- methodology and application in industrial scenario, Failure Modes and Effects Analysis, Criticality and risk priority number, Bow –tie analysis, Examples.

Module 3 (9 hours)

Consequence Analysis and Quantitative Risk Assessment: Consequences of chemical accidents, Procedure for Quantitative risk assessment. Source modelling, Models for fire-pool fire modelling, Fire ball modelling, Models for explosion- TNT model, model for toxic gas dispersion, Individual and Societal Risk, F-N curves, Probit functions.

Module 4 (7 hours)

Preventive and protective measures: Elements of Emergency Planning, Electrical area classification, Explosion prevention and protection, Industrial hygiene, Flame arresters, Flare systems, Reasons for human error, Techniques for assessing human error, The basic steps for LOPA risk assessment. Security in process industries.

Module 5 (8 hours)

Inherent Safety and Process Reliability: The concept of inherent safety, Tools for inherent process safety, Inherent safety indices, Assessment of Process hazards in early design stages, the concept of process intensification, Basic principles of reliability engineering, Ways of improving process reliability, Security vulnerability analysis (SVA)- concepts only.

Reference Books

1. Crowl, D. and Louvar, J.F., “Chemical Process Safety: Fundamentals with applications”, Prentice Hall, 2011
2. Guidelines for Hazard Evaluation Procedures Centre for Chemical Process Safety, AIChE, 1992.
3. Sam Mannan, Lees' Loss Prevention in the Process Industries: Hazard Identification, Assessment and Control, 4th edition, 2012.
4. K S N Raju, Chemical Process Industrial Safety, McGraw Hill Education.

Course Plan

No	Topic	No. of Lectures
1	**Special Hazards of Chemicals (8 hrs)**	
1.1	Introduction to process safety engineering, strategies for process safety engineering, Process safety management, safety integrity level.	2
1.2	Toxicity, Flammability, Explosions, Ionising radiation, Runaway Reactions	3
1.3	Hazard survey – Inventory analysis, Dow Fire and Explosion Index, Mond Fire, Explosion and Toxicity Index, Chemical exposure index.	2
1.4	Review of major industrial accidents- Bhopal, Flixborough disasters.	1
2	**Techniques for Hazard Identification (8 hrs)**	
2.1	Hazard and Operability Study, Preliminary Hazard Analysis, What if Analysis- methodology and application in industrial scenario.	3
2.2	Fault tree Analysis, Event Tree Analysis- methodology and application in industrial scenario.	3
2.3	Failure Modes and Effects Analysis, Criticality and risk priority number, Bow –tie analysis, Examples.	2
3	**Consequence Analysis and Quantitative Risk Assessment (9 hrs)**	
3.1	Consequences of chemical accidents, Procedure for Quantitative risk assessment. Source modelling	3
3.2	Models for fire- pool fire modelling, Fire ball modelling.	2
3.3	Models for explosion- TNT model, model for toxic gas dispersion.	2
3.4	Individual and Societal Risk, F-N curves, Probit functions.	2
4	**Preventive and protective measures (7 hrs)**	
4.1	Elements of Emergency Planning, Electrical area classification, Explosion prevention and protection.	2
4.2	Industrial hygiene, Flame arresters, Flare systems	2
4.3	Reasons for human error, Techniques for assessing human error.	1
4.4	The basic steps for LOPA risk assessment. Security in process industries.	2
5	**Inherent Safety and Process Reliability (8 hrs)**	
5.1	The concept of inherent safety, Tools for inherent process safety, Inherent safety indices	3
5.2	Assessment of Process hazards in early design stages, The concept of process intensification.	2
5.3	Basic principles of reliability engineering, Ways of improving process reliability.	2
5.4	Security vulnerability analysis (SVA)- concepts only	1

222LCH001	DESIGN, SIMULATION, AND INSTRUMENTAL ANALYSIS LAB	CATEGORY	L	T	P	CREDIT
		LAB	0	0	2	1

Preamble:

This lab aims to provide the students with the fundamental knowledge of programming and computation in MATLAB and measurement and analysis of process variables by using modern instruments.

Pre-requisites: Nil

Course Outcomes:

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

CO 1	Employ the utility of the software tools in solving real-time chemical engineering problems.
CO 2	Use and interpret results from a commercial process simulation software package
CO 3	Operate sophisticated laboratory instruments used for chemical analysis
CO 4	Explain and select an analytical method and instrument meeting their use objectives
CO 5	Demonstrate proficiency in data analysis and interpretation

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				
CO 3				3	3		
CO 4				3	3		
CO 5			3				

Assessment Pattern

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

Continuous Internal Evaluation Pattern:

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

Design and Simulation Lab

1. Vector and Matrix computations in MATLAB/ Scilab
2. Numerical Simulation of Linear and Non-linear equations in MATLAB/ Scilab
3. Numerical Differentiation and Integration in MATLAB/ Scilab
4. Numerical Simulation of Ordinary Differential Equations in MATLAB/ Scilab
5. Numerical Solution of Partial Differential Equation in MATLAB/ Scilab
6. Curve Fitting in MATLAB/ Scilab
7. Numerical Optimization (Constrained and unconstrained) in MATLAB/Scilab
8. Numerical simulation of flow problems using CFD software ANSYS/OpenFoam

Instrumental Analysis Lab

9. UV-Visible spectrophotometer
10. Fourier Transform Infrared spectroscopy
11. Atomic absorption spectrophotometer.
12. Thermogravimetric analyzer
13. High-performance liquid chromatography

References

1. Pallab Ghosh, Numerical, symbolic and statistical computing for Chemical Engineers using MATLAB, Prentice Hall of India
2. Kenneth J. Beers, Numerical Methods for Chemical Engineering, Applications in MATLAB ®
3. G H Jeffery, Vogel's Textbook of Quantitative Chemical Analysis, Longman Scientific Technical