NATIONAL INSTITUTE OF TECHNOL
TIRUCHIRAPPALLI

SCHEME OF INSTRUCTION AND SYLLAE
M.TECH. CHEMICAL ENGINEERING

Effective from 2019-20
DEPARTMENT OF CHEMICAL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY TIRUCHIRAPPA

Vision /Mission for Institute

Visio

To be a university globally trusted for technical excellence where learning and res integrate to sustain society and industry.

Mission:

(1) To offer undergraduate, postgraduate, doctoral and modular programmes in mu and emerging areas.
(2) To create a converging learning environment to serve a dynamically evolving society.
(3) To promote innovation for sustainable solutions by forging global collaborations cutting-edge research.
(4) To be an intellectual ecosystem where human capabilities can develop holistically.

DEPARTMENT OF CHEMICAL ENGINEERING

VISION

To be a global leader in Chemical Engineering

MISSION

- To produce competent graduates through effective Teaching-Learning, State of t
- To foster community by providing leadership in solving societal problems for sustainab
- To serve organization and society as adaptable engineers, entrepreneurs or leaders

DEPARTMENT OF CHEMICAL ENGINEERING

M.Tech-Chemical Engineering

PROGRAMME EDUCATIONAL OBJECTIVES:

PEO1	Choose their careers as practicing chemical engineers in traditional chemical industries/Academic institutions/research organizations and as well as engagi multidisciplinary areas.
PEO2	Utilize formal and informal learning opportunities to maintain and enhance tec professional growth.
PEO3	Graduates will become effective collaborators and innovators, leading or parti address social, technical challenges.

Mapping of Departmental Mission Statements with Programme Educational Obj

Mission	PEO1	PEO2	PEO3
To produce globally competent professional chemical engineers	✓		✓
To foster process engineering knowledge through research and innovation		✓	✓
To serve organization and society as adaptable	✓	✓	✓

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ɹAMME OUTCOMES:

The Chemical Engineering post graduates are able to analyze and apply the state of art tools in addressing challenges in chemical processes.
Identify the challenges and formulate the problems, develop solutions by integration of knowledge in Mathematics/Science/Engineering.
Design system, component or process to meet the desire needs within the realistic constraints such as economic, social, political, ethical, health and safety, manufacturability and sustainability.
Use multidisciplinary knowledge in identifying solutions and to conduct systematic research.
Apply modern computational techniques in solving large scale engineering problems.
Effectively function on multidisciplinary teams
Have a knowledge on project management and finance requirements and can write
Communicate professionally to express views and to publish technical journals.
Engage in lifelong learning to improve knowledge and skill.
Attain their professional ethical responsibility for development of the society.
Use experience in applying corrective measures for continuous learning and development.

Mapping of Programme Outcomes with Programme Educationa

PEO / PO	PEO 1	PEO 2	PEO 3
PO 1		✓	✓
PO2	✓	✓	✓
PO 3		✓	✓
PO 4	✓	✓	✓
PO 5		✓	✓
PO 6	✓		✓
PO 7	✓	✓	✓
PO 8	✓		✓
PO 9	✓	✓	✓
PO 10			✓
PO 11	✓	✓	✓

CURRICULAR COMPONENTS

Category	Credits offered
Core Courses	19
Elective Courses	18
Laboratory	4
Project Work	24
Total	**65**

I Objectives

NA NSTITUTE OF TECHNOLOGY, TIRUCHIRAPPALLI-620015 DEPARTMENT

Revised Curriculum Structure and Scheme of Instruction M.TECH. Che

[The total number of credits =65]

Code	Name of the subject	Hours per week L	T	P
		SEMESTER I		
CL601	Advanced Process Control	2	1	0
CL603	Mathematical methods for chemical engineers	2	1	0
CL605	Advances in Fluidization Engineering	3	0	0
	Elective-I	3	0	0
	Elective-II	3	0	0
	Elective-III	3	0	0
CL607	Chemical Process Modelling and simulation laboratory	0	0	3
	Total Credits in Semester I			
		SEMESTER II		
CL602	Chemical Reactor Analysis and Design	3	0	0
CL604	Chemical Process Design	3	1	0
CL606	Advanced Separation Techniques	3	0	0
	Elective-IV	3	0	0
	Elective-V	3	0	0
	Elective-VI	3	0	0
CL608	Analytical Instrumentation laboratory	0	0	3
	Total Credits in Semester II			
		SEMESTER III		
CL647	PROJECT WORK	12		
	Total Credits in Semester III			
		SEMESTER IV		
CL648	PROJECT WORK	12		
	Total Credits in Semester IV			
	Total Credits in the Course			

T OF CHEMICAL ENGINEERING
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Credits
3
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S.No.	Code No.
1	**CL 611**
2	**CL 612**
3	**CL 613**
4	**CL 614**
5	**CL 615**
6	**CL616**
7	**CL 617**
8	**CL 618**
9	**CL 619**
10	**CL 620**
11	**CL 621**
12	**CL 622**
13	**CL 623**
14	**CL 624**
15	**CL 625**
16	**CL 626**
17	**CL 627**
18	**CL 628**
19	**CL 629**
20	**CL 630**
21	**CL 631**
22	**CL 632**
23	**HS 611**
24	**MT617**

List of Elective Subjects

Title
Nano Technology
Scale - up Methods
Industrial Safety and Risk Management
Bioprocess Engineering
Polymer Dynamics
Multiphase flow
Design and Analysis of Experiments
Fuel Cell Technology
Pinch Analysis and Heat Exchange Network Design
Industrial Energy Systems
Wastewater and Solid waste Treatment
Computational Fluid Dynamics
Process Optimization
Ecology for Engineers
Advanced Food Process Engineering
Bio-refinery Engineering
Air Pollution Control Equipment Design
Advanced Transport Phenomena
Electrochemical Reaction Engineering
Bio-energy
Process Intensification
Bio electrochemical Systems
Technical Communication
Surface Engineering

M. Tech. -

List of Cor

SEMESTER – I	
S.No.	**Code No.**
1.	**CL 601**
2.	**CL 603**
3.	**CL 605**
4.	**CL 607**
SEMESTER – II	
4.	**CL 602**
5.	**CL 604**
6.	**CL 606**
7.	**CL 608**

List of Elective Subjects:

S.No.	Code No.	Title
1	**CL 611**	Nano Technolo
2	**CL 612**	Scale -up Meth
3	**CL 613**	Industrial Safet
4	**CL 614**	Bioprocess Eng
5	**CL 615**	Polymer Dynan
6	**CL 616**	Multiphase flow
7	**CL 617**	Design and An
8	**CL 618**	Fuel Cell Techr
9	**CL 619**	Pinch Analysis
10	**CL 620**	Industrial Ener
11	**CL 621**	Wastewater an
12	**CL 622**	Computational
13	**CL 623**	Process Optim
14	**CL 624**	Ecology for En
15	**CL 625**	Advanced Foo
16	**CL 626**	Bio-refinery En
17	**CL 627**	Air Pollution Co
18	**CL 628**	Advanced Tran
19	**CL 629**	Electrochemica
20	**CL 630**	Bio-energy
21	**CL 631**	Process Intens
22	**CL 632**	Bio electroche
23	**HS 611**	Technical Com
24	**MT 617**	Surface Engine

Chemical Engineering
e Subjects:

Title
Advanced Process Control
Mathematical methods for chemical engineers
Advances in Fluidization Engineering
Chemical process modelling and simulation laboratory
Chemical Reactor Analysis and Design
Chemical Process Design
Advanced Separation Techniques
Analytical Instrumentation laboratory

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nology
and Heat Exchange Network Design
gy Systems
d Solid waste Treatment
Fluid Dynamics
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ontrol Equipment Design
nsport Phenomena
al Reaction Engineering
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emical Systems
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CL 601	ADVANCED PROCESS CONTROL	*3-0-0*	*3 Cre*

PRE-REQUISITE

Knowledge in chemical process dynamics and control.

COURSE LEARNING OBJECTIVES

Expose students to the advanced control methods used in industries and research. This course to take up such challenges in his profession.

COURSE CONTENT

Review of Systems: Review of first and higher order systems, closed and open loop res step, impulse and sinusoidal disturbances. Transient response. Block diagrams.

Stability Analysis: Frequency response, design of control system, process identification. PI (Ziegler-Nichols and Cohen-Coon tuning methods, Bode and Nyquist stability criterion. Process i

Special Control Techniques: Advanced control techniques, cascade, ratio, feed forward, ada predictor, internal model control, model based control systems.

Multivariable Control Analysis: Introduction to state-space methods, Control degrees of freedo analysis, Interaction, Bristol arrays, Niederlinski index - design of controllers, Tuning of mul controllers, Design of multivariable DMC and MPC.

Sample Data Controllers: Basic review of Z transforms, Response of discrete systems to various closed loop response to step, impulse and sinusoidal inputs, closed loop response of disc Design of digital controllers. Introduction to PLC and DCS.

REFERENCE BOOKS

1. D.R. Coughanour, S.E. LeBlanc, *Process Systems analysis and Control*, McGraw- H
2. D.E. Seborg, T.F. Edger, and D.A. Millichamp, *Process Dynamics and Control*, Johi 2004.
3. B.A.Ogunnaike and W.H.Ray, *Process Dynamics, Modelling and Control*, Oxford Press, 1994.
4. B.W. Bequette, *Process Control: Modeling, Design and Simulation*, PHI, 2006.
5. S. Bhanot, *Process Control: Principles and Applications*, Oxford University Press, 2008.

COURSE OUTCOME

Upon completing the course, the student will be able to

CO1	perform stability analysis and controller tuning
CO2	select and design advanced controllers that need to be used for specific problems
CO3	design controllers for interacting multivariable systems
CO4	understand the dynamic behavior of discrete time processes and design discrete controll

Mapping of Course Outcome with Programme Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	✓	✓	✓	✓						
CO2	✓	✓	✓	✓						
CO3	✓	✓	✓	✓	✓					
CO4	✓	✓	✓	✓						

dits

prepares the student

ponse. Response to

Controller tuning -
dentification.
ptive control, Smith

m analysis and
tivariable PI

s inputs. Open and
crete systems.

ill, 2nd Edition, 2009.
n Wiley and Sons, 2nd Edition,

ers

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CL 602	CHEMICAL REACTOR ANALYSIS AND DESIGN	*3-0-0*

PRE-REQUISITE

Knowledge in homogenous chemical reaction engineering, Fluid Mechanics, Heat trans

COURSE LEARNING OBJECTIVES

1. To understand the kinetics of non-catalytic chemical reaction and reactor design.
2. To understand the catalyst physical characterization of surface area, pore vc
3. To understand the kinetics of catalytic chemical reaction and reactor design.
4. To understand the kinetics of fluid -fluid Chemical reaction and reactor design.
5. To understand the operation and troubleshooting of heterogeneous reactors.

COURSE CONTENT

Analysis of Non-catalytic fluid solid reaction: Kinetics of non-catalytic fluid-p application to design.

Catalyst preparation and characterization: Catalysis - Nature of catalyses, metho factors affecting the choice of catalysts, promoters, inhibitors, and supports, catalyst s characterization of catalysts, surface area measurement by BET method, pore size d mechanism and kinetics of catalyst, deactivation.

Physical adsorption and chemical adsorption: Fluid-fluid reactions different regime application to design. Physical absorption with chemical reaction, simultaneous abs consecutive reversible reactions between gas and liquid, irreversible reactions, estima in absorption equipment.

Reaction kinetics, accounting porous nature of catalyst: Heterogeneous catalytic reacti - effectiveness factor, internal and external transport processes, non-isothermal react multiplicity of steady states, stability analysis.

Modeling of chemical reactors: Modeling of multiphase reactors - Fixed, flui reactors.

REFERENCE BOOKS

1. O. Levenspiel, Chemical *Reaction Engineering*, 3rd Edn., Wiley Eastern, New Yorl
2. J .M. Smith, *Chemical Kinetics*, 3rd Edn., McGraw Hill, New York, 1981.
3. H. Scott Fogler, *Elements of Chemical Reaction Engineering*, 4th Edn., Prentice Ha
4. J.J. Carberry, *Chemical and Catalytic Reaction Engineering*, McGraw Hill, New
5. R. Aris, *Elementary Chemical Reactor Analysis*, PHI, 1969.
6. G.F. Froment, K.B. Bischoff, Chemical *Reactor Analysis and Design*, 2nd ed., Johr Wiley, New York, 1990.

3 Credits

ɜfer, and Mass transfer.

ɔlume, and pore size.

ɔarticle reactions, various models,

ds of evaluation of catalysis,
ɜpecifications, preparation and
listribution, catalyst, poison,

ɜs, identification reaction regime,
ɜorption of two reacting cases
tion of effective interfacial area

ons
ing systems, uniqueness and

dized, trickle bed, and slurry

k, 1999.

all of India Ltd.,2008.
ɪ York, 1976.

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COURSE OUTCOME

Upon completing the course, the student will be able to

CO1	have awareness on catalyst physical properties and catalyst characterization.
CO2	acquire awareness on kinetics of catalytic and non-catalytic chemical reaction.
CO3	familiarize with the design of catalytic and non-catalytic reactor.
CO4	familiarize with operation and troubleshooting of heterogeneous reactors.

Mapping of Course Outcome with Programme Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	✓	✓	✓							
CO2	✓	✓	✓	✓		✓		✓	✓	✓
CO3	✓	✓	✓	✓	✓	✓	✓		✓	✓
CO4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

PO11
✓
✓

CL 603	Mathematical Methods for Chemical Engineers	3-0-0	3 Credits

PRE-REQUISITE

Knowledge in basic mathematics.

Course Learning Objectives

1. Analysis of experiments
2. Describe chemical engineering processes in mathematical form by employing the approp conservation principles
3. Identify if an analytical solution to the model equations

Course Content

Design and experiments, Experiments with single factor, analysis of variance, factorial design, re least square.

Development of mathematical models by first principles, Conservation principles, Mathematic chemical engineers

Analytical solution of simultaneous linear and non-linear equations, Numerical techniques for linear anc equations, linearization of non-linear equations

Numerical techniques for ordinary differential equations, initial and boundary value problems, Numerica Partial differential equations.

Books:

1. Douglas C. Montgomery, “Design and Analysis of Experiments” John Wiley, 8th Edition, 2012
2. Harold S. Mickley, Thomas S. Sherwood, Charles E. Reed, “Applied Mathematics in Chemica Tata McGraw Hill Publishing Company Limited, Second Edition, 1975.
3. Richard G. Rice & Duong D. D, “Applied Mathematics and Modelling for Chemical Engineers Sons, 1995.
4. Mark E. Davis, “Numerical Methods and Modelling for Chemical Engineers”, John Wiley & Sons, 198
5. S. K. Gupta, “Numerical Techniques for Engineers", Wiley Eastern Ltd., New York, 1995

COURSE OUTCOMES

On completion of the course, the student can

CO1 Able to analyze the data with minimum number of experiments CO2 Develop a mathematical mod processes

CO3 apply mathematics to solve the chemical engineering problems. CO4 apply numerical techniques model

Mapping of Course Outcome with Programme Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	✓	✓	✓	✓	✓						✓
CO2	✓	✓	✓	✓	✓						✓
CO3	✓	✓	✓	✓	✓						✓

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CL 604	CHEMICAL PROCESS DESIGN	*3-1-0*

PRE-REQUISITE

Students should have strong basics on Momentum, Heat and Mass transfer and Ch

COURSE LEARNING OBJECTIVES

(i) To understand process design of heat transfer equipment.
(ii) To understand process design of mass transfer equipment.
(iii) To understand process design of phase separation equipment and design various su
(iv) To get an idea on troubleshooting and operation all chemical process equipment.
(v) To get an idea on design of new chemical plant by using the studied design tools.

COURSE CONTENT

Design and sizing of Shell and Tube Heat exchangers with types and arrangements exchanger, Condensers -vertical and Horizontal.

Design and sizing of Single and Multiple Effect Evaporators-Short tube, long tube etc.

Design of storage tank and supports: horizontal storage tank, Design of Saddle, Sk
Design of Reaction vessel with and without cooling coil, Normal and High Pressure vessel, transfer equipment: Design of distillation column, Multi- component distillation with reb plate as well as packed type, cooling tower and extraction columns.

Design and sizing of drier, and Crystallizer. Design and sizing of phase separation Centrifuge, Cyclone (Hydro as well as air).

All the above design should be taught in a process Integration approach with spec conservation.

REFERENCE BOOKS

1. K.Q.Kern, *Process Heat transfer* , McGraw-Hill, 1965.
2. Coulson and Richardson, *Chemical Engineering Vol.VI* , Pergamon Press, 1983.
3. S.B.Thakore and B.I.Bhatt, *Introduction to Process Engineering and Design* , McGraw-
4. Couper, R James, *Chemical process equipment design* , Elsevier, 2012 3rd Edition.
5. Perry, *Chemical Engineer's Hand book* , McGraw-Hill, 2009.
6. McCabe and Smith, *Unit operation of Chemical Engineering* , McGraw-Hill, 2008.
7. Christie John Geankopolis, *Transport process and Separation Process* , Fourth E

COURSE OUTCOME

Upon completing the course, the student will be able to

CO1	get awareness on advances in process engineering design of many process equipment.
CO2	get exposed to process integration approach to before proceeding for design any p Equipment
CO3	have awareness on use of the design methods studies for design of a new ch
CO4	analyse and troubleshoot existing unit operation equipments in a Chemical Process plant

4 Credits

ıemical Reaction Engineering.

ɔports.

ֶs of fluids, plate type heat

irt, and Lug supports.
, Design and sizing of mass
ɔiler, Absorption tower both

equipment- filter press,

ːial material and energy

Hill, 2009.

dition, PHI, 2004.

ɔrocess
ıemical plant

Mapping of Course Outcome with Programme Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
CO2	✓	✓	✓	✓		✓		✓	✓	✓
CO3	✓	✓	✓	✓	✓	✓	✓		✓	✓
CO4	✓	✓	✓		✓		✓		✓	

PO11
✓
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✓

CL 605	ADVANCES IN FLUIDIZATION ENGINEERING	*3-0-0*	*3 Credits*

PRE-REQUISITE

Basic knowledge in Transfer operations.

COURSE LEARNING OBJECTIVES

To learn the principle, technical concepts involved in the analysis and design of Fluidized bed syste

COURSE CONTENT

Applications of fluidized beds: Introduction, Industrial application of fluidized beds, Physi and reactions.

Fluidization and analysis of different phases: Gross behavior of fluidized beds. Bubbles in dense be emulsion phase in dense bubbling beds. Flow pattern of gas through fluidized beds.

Heat and Mass transfer in fluidized bed systems: Mass and heat transfer between fluid and s conversion in bubbling beds. Heat transfer between fluidized bed and surfaces.

Elutriation and entrainment: TD and also distribution of solid in a fluidized bed. Circul Design of fluidized bed systems: design of fluidization columns for physical oper and non- catalytic reactions, three phase fluidization.

REFERENCE BOOKS

1. Diazo Kunii and O.Levenspiel, *Fluidization Engg.,* 2nd Ed., Butterworth Heinemann, 1991.
2. J. F. Davidson and Harrison, *Fluidization,* 10th Ed, Academic Press, London, 1994.
3. Jackson, R., *The Dynamics of Fluidized Particles,* Cambridge University Press, New York,
4. Fan, L.-S. and C. Zhu, *Principles of Gas-Solid Flows,* Cambridge University Press, New Y

COURSE OUTCOME

Upon completing the course, the student will be able to

CO1	evaluate the fluidization behavior.
CO2	estimate pressure drop, bubble size, TDH, voidage, heat and mass transfer rates for fluidized beds
CO3	develop model equations for fluidized beds
CO4	design gas solid fluidized bed reactors.

Mapping of Course Outcome with Programme Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	✓			✓							
CO2	✓	✓		✓							
CO3	✓	✓	✓	✓	✓						
CO4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

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'ork, 1998).

CL 606	ADVANCED SEPARATION TECHNIQUES	*3-0-0*

PRE-REQUISITE

Knowledge in equilibrium staged mass transfer separation processes.

COURSE LEARNING OBJECTIVES

1. To learn the principle and technical concepts of rate governed separation process
2. To understand the less energy intensive processes for down streaming applicatio
3. To apply the knowledge in designing process equipments.

COURSE CONTENT

Overview of separation processes, Separation factors and its dependence on p cascades and its application. Membrane Separations- membrane materials, cha polarization theory, membrane modules. Membrane Processes- Gaseous Diffus filtration, Microfiltration, Permeation, Pervaporation, Dialysis and Liquid membrane membrane contactors, modes of operational methods, fouling and preventive m membrane operations.

Sorption Separation -Principles of Chromatography and Ion exchange, chromatc theory, Band broadening and its factors, Column chromatography for gas and liquid controlling factors, scaling-up problems, Ion exchangers, equipments, kinetics and r processes, regeneration.

Ionic Separations- Theory, mechanism and equipments for electro dialysis, electrophoresis and dielectrophoresis. Design constraints of electrodialytic stack Electrokinetic methods-analytical methods of electrophoresis, electrophoretic applications, design considerations.

Thermal Separations-Thermal diffusion theory, diffusional rate equ theories, equipments and applications for gas and liquid mixtures separation. Zc diagrams, factors affecting the impurity distribution, zone heaters, Zone melting applications and design constrains.

Other Techniques-Adductive crystallization theory, extraneous agents, clathra Bubble adsorption- nature of foams, stability and drainage theory, equipments, c Lyophilisation and design controlling factors.

REFERENCE BOOKS

1. J.D. Seader, Ernest J.Henley and D. Keith Roper, *Separation process Princ* 3rd edition, John Wiley & Sons Australia, Limited, 2010.
2. H.M. Schoen, *New Chemical Engineering Separation Techniques*, Wiley Inte
3. B. Sivasankar, *Bioseparations – Principles and Techniques*, Prentice Hall of Ind
4. KaushikNath, *Membrane Separation processes*, PHI, New Delhi 2008.
5. M. Mulder, *Basic Principles of Membrane Technology*, Kluwer Academic Pul
6. Ronald W.Roussel, *Hand book of Separation Process Technology*, John W
7. C.J.King, Separation processes, Mc Graw Hill, USA, 1980.

COURSE OUTCOME

Upon completing the course, the student will be able to

3 Credits

ses.
ns.

process variables, Theory of
aracterization, concentration
sion, Reverse osmosis, ultra-
es. Design controlling factors of
easures and economics of

graphic techniques, Retention
mixtures separation, design
mass transport, commercial

electro- coagulation,
s, variants of electrodialysis.
mobility factors, commercial

uations, phenomenological
one melting- theory, equilibrium
processes, commercial

tes and adducts, equipments,
commercial applications,

ciples ,

rscience, New York, 1972.
ia Pvt. Ltd, New Delhi, 2005.

blishers, London, 1996.
iley, New York, 1987.

CO1	have awareness about conventional and non-conventional separation processes.
CO2	acquire sufficient knowledge in less energy intensive processes for separation of components.
CO3	apply the methodologies for various industrial down streaming and bio- process applications.
CO4	analyze the design constraints of process equipments in industrial applications.

Mapping of Course Outcome with Programme Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	✓	✓								
CO2	✓	✓		✓		✓		✓	✓	✓
CO3	✓	✓	✓	✓	✓	✓	✓		✓	✓
CO4	✓	✓	✓		✓				✓	

PO11
✓
✓

CL 607	CHEMICAL PROCESS MODELLING AND SIMULATION LABORATORY	*0-0-3*	*2 Credits*

PRE-REQUISITE

Knowledge in modelling of Chemical Processes.

COURSE LEARNING OBJECTIVES

1. To implement the numerical techniques to solve the problems of engineering interest.
2. To use computational tools and commercial packages to solve process simulation problems.

LIST OF EXPERIMENTS

Simulation will be carried out for the design and estimation of following using ASPEN PLU

1. Physical and thermodynamic property estimations
2. Mass and Energy balances
3. Design of reactors
4. Design of distillation column
5. Design of heat exchangers
6. Design of absorbers

REFERENCE BOOKS

1. Edgar, T.F. and Himmelblau, D.M., *Optimization of Chemical Processes* , McGraw-Hill Book C
2. Jana A.K., *Chemical Process Modeling and Computer Simulation,* PHI, 2008.
3. Jana A.K., *Process Simulation and Control using ASPEN,* PHI, 2009

COURSE OUTCOME

At the end of the course, students will be able to

CO1	implement the numerical techniques to solve the problems of engineering interest.
CO2	use computational tools and commercial packages to solve process simulation problems.

Mapping of Course outcome with Programme Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	✓	✓	✓	✓	✓		✓	✓	✓	✓
CO2	✓	✓	✓	✓	✓	✓		✓		✓

JS/MATLAB software

:o., 2008.

PO11
✓
✓

CL 608	ANALYTICAL INSTRUMENTATION LABORATORY	*0-0-3*	*2 Credits*

PRE-REQUISITE: None

COURSE LEARNING OBJECTIVES

1. To provide various techniques and methods of analysis in Chemical Process systems.
2. To understand the principles and apply the theory of instrumental analysis.
3. To emphasize the safe use of Chemical Instrumentation

LIST OF EXPERIMENTS

1. Verification of Beer-Lambert's Law using UV spectrophotometer.
2. pH measurements for liquid samples
3. Analysis of IR spectrum of samples
4. Analysis of Heavy metal elements in water samples.
5. Analysis of thermal degradation of solid samples.
6. Elemental analysis of solid samples
7. Determination of surface area of particulates.

REFERENCE BOOKS

1. G.W.Ewing, *Instrumental Methods of Analysis* , McGraw Hill, 1992.
2. H.H.Willard, L.L.Merritt, J.A.Dean, F.A.Settle, *Instrumental Methods of Analysis* , CBS publishi distribution, 1995.
3. Robert D.Braun, *Introduction to Instrumental Analysis* , McGraw Hill, Singapore, 1987.
4. R.S.Khandpur, H*andbook of Analytical Instruments* , McGraw Hill, 2003.

COURSE OUTCOME

On completion of the course, the students will be able to

CO1	acquire the practical knowledge of handling analytical instruments.
CO2	apply the principles and concepts of analytical instrumentation in Process industries.
CO3	troubleshoot to solve the problems in Chemical process systems.

Mapping of Course outcome with Programme outcomes

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO1**
CO1	✓	✓			✓					✓	
CO2	✓	✓	✓	✓					✓	✓	✓
CO3	✓	✓	✓						✓	✓	

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CL 611	NANOTECHNOLOGY	*3-0-0*	*3 Credits*

PRE-REQUISITE: None

COURSE LEARNING OBJECTIVES

1. To learn the basics of nanotechnology.
2. To understand the structure, properties, manufacturing and applications of nanomaterials.
3. To know the classification and fabrication methods of nanomaterials.
4. To know the characterization methods for nanomaterials (optical, electrical, AFM, SEM, TEI nanoindentation).

COURSE CONTENT

Supramolecular Chemistry: Definition and examples of the main intermolecular forces use chemistry. Self-assembly processes in organic systems. Main supramolecular structures.

Physical Chemistry of Nanomaterials: Students will be exposed to the very basics of nai nanomaterials that exhibit unique properties will be introduced.

Methods of Synthesis of Nanometerials- Equipment and processes needed to fabricate n structures such as bio-chips, power devices, and opto-electronic structures. Bottom-up molecular level) and top-down (breakdown of microcrystalline materials) approaches.

Biologically-Inspired nanotechnology, basic biological concepts and principles that may lea of technologies for nano engineering systems. Coverage will be given to how life has evolve molecular nanoscale engineered devices, and discuss how these nanoscale biotechnologies ar their functions than most products made by humans.

Instrumentation for nanoscale characterization. Instrumentation required for cha properties on the nanometer scale materials. The measurable properties and resoluti technique, with an emphasis on measurements in the nanometer range.

REFERENCE BOOKS

1. Jean-Marie Lehn, *Supramolecular Chemistry* , Wiley VCH, 1995.
2. Jonathan Steed and Jerry Atwood, *Supramolecular Chemistry* , John Wiley & Sons, 2004.
3. Jacob Israelachvil, *Intermolecular and Surface Forces* , Academic Press, London, 1992.
4. Chris Binns, *Introduction to Nanoscience and Nanotechnology* , Wiley, 2010.

COURSE OUTCOME

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

CO1	understand the physical chemistry of the nanomaterials.
CO2	identify the basic, emerging principles and concepts that impact nanotechnology.
CO3	formulate the processes for fabrication of nano devices.
CO4	defend the characterization of nanomaterials using various instruments.

Mapping of Course Outcome with Programme Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	✓				✓				✓	

CO2		✓		✓	✓			✓		
CO3	✓			✓	✓				✓	✓
CO4	✓				✓				✓	

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CL 612	SCALE -UP METHODS	*3-0-0*	*3 Credits*

PRE-REQUISITE

Knowledge on basics of unit operations.

COURSE LEARNING OBJECTIVES

To learn the step-by-step process for developing a successful scaling up strategy.

COURSE CONTENT

Principals of Similarity, Pilot Plants & Models: Introduction to scale-up methods, pilot plants, models ar similarity, Industrial applications.

Dimensional Analysis and Scale-Up Criterion: Dimensional analysis, regime concept, similari scale up methods used in chemical engineering.

Scale-Up of Mixing and Heat Transfer Equipment: Typical problems in scale-up of mixing equipment ar equipment

Scale-Up of Chemical Reactors: Kinetics, reactor development & scale-up techniques for chemic Scale-Up of Distillation Column & Packed Towers: Scale-up of distillation columns and packed t continuous and batch processes

REFERENCE BOOKS

1. Johnstone and Thring, *Pilot Plants Models and Scale-up methods in Chemical Engg.* , New York, 1962.
2. Marko Zlokarnik, *Dimensional Analysis and Scale-up in Chemical Engg* ., Springer Verlag, Berlin, Ge
3. Donald G.Jordan, *Chemical Process Development* (Part 1 and 2), Interscience Publish

COURSE OUTCOME

Upon completing the course, the student will be able to

CO1	know the industrial applications of scale up methods.
CO2	perform dimensional analysis of chemical engineering problems and can be able to establish a scale up criterion.
CO3	solve problems in scale-up of mixing equipment and heat transfer equipment**.**
CO4	solve scale-up of chemical reactors, distillation columns and packed column.

Mapping of Course Outcome with Programme Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO1
CO1	✓	✓	✓								
CO2	✓	✓	✓	✓		✓		✓	✓	✓	
CO3	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
CO4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

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CL 613	INDUSTRIAL SAFETY AND RISK MANAGEMENT	*3-0-0*

COURSE OVERVIEW

This course is intended to understand the principles of industry safety and its level industries.

Course objectives

To distinguish, analyze by core engineering knowledge, design and operations to en plant

To provide knowledge on risk, hazard and their assessment techniques in Industry

COURSE OUTCOMES (CO)

1. Identify the potential hazards and hazardous conditions associated with the processe process industries.
2. Apply engineering fundamentals to the analysis and prediction of performance un
3. Perform PHA analysis of chemical processes and evaluate the safety performance
4. Work effectively in teams to develop problem solving skills and to prepare and present a

Process Safety Management; Responsibility; OSHA and EPA Regulations, Properties Industrial Hygiene, Vaporization Rates; Dilution; Ventilation, Source Modeling: Leak Gases; Flashing and Boiling; Two Phase Flow, Toxic and Flammable Release and Disp Fires and Explosions; Flammability, MOC; Explosions, Detonations, Blast Damag Inerting and Purging; Static Electricity; Ventilation

Chemical Process Safety: Decomposition & Runaway Reactions, Initiating factors Reactive Reaction Hazard; Tools for evaluating thermal explosion, steps to Reduce Reactive Hazard Process Plant Design: Flow Diagrams; Piping and Instrumentation Diagram, Control Systen Layout: Passive protection, Active Protection, Emergency Shutdown System, Safety Integrit Techniques. Relief Systems; Relief Sizing for Liquid, Gas, and Two-Phase Flow; Dust Explo Hazard Identification & Risk Assessment: The Process of Risk Management Hazarc (Risk Assessment, Risk Matrix), Risk Control Implementation, Action and Recommenda Techniques: Quantitative, Qualitative Safety Review, Process / System Checklists, Dow What-If Analysis, HAZOP. Reliability, Probability Distribution, Demand and Failure, Fault Tı Cut Set Identification, Event Tree Analysis.

Tutorial

Accident Investigations – nuclear and other chemical process plants, Student Presentations Reports–Case Studies, Design Problems, Quantitative Methods, etc.

Textbooks, reference books Website addresses, journals, etc

1. *Sam Mannan, Frank P. Lees, “Lees' Loss Prevention in the Process Industries: Hazard and Control”, 4th Edition, Butterworth-Heinemann, 2005.*
2. *H.H. Fawcett & W. S. Wood, “Safety and Accident Prevention in Chemical Operation", 2nd Ed, Wiley Interscience, 1982.*

3 Credits

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nder unsafe conditions.

a professional project report.
of Toxic Materials;
kage Rates of Liquids and
ersion Modeling
e, Protection and Prevention;

Chemical Hazard, Assessing
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n, Alarms, Chemical Plant
ty Level, Inherent Safety
osions
d Identification, Evaluation
ation Hazard Evaluation
Fire and Explosion Index,
ree Analysis (FTA), Minimal

s of Term Project

Identification, Assessment

3. Guide for Safety in the Chemical Laboratory Second edition 1977, Manufacturing Ch Van Nostrand Reinhold Company, New York.

4. Daniel A. Crowl & Joseph F. Louvar, "Chemical Process Safety, Fundamentals with Edition, Prentice Hall, Inc. ISBN 0-13-018176-5.

COURSE OUTCOME

On completion of the course, the students will be familiar with

CO1	accident prevention and Hazard analysis techniques.
CO2	identification of process safety responsibilities.
CO3	the psychological approach to process safety.
CO4	legislations pertaining to safety in chemical industries

Mapping of Course Outcome with Programme Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	✓	✓	✓	✓	✓	✓	✓	✓		
CO2	✓		✓	✓		✓		✓	✓	✓
CO3	✓			✓		✓				✓
CO4	✓	✓	✓	✓		✓	✓		✓	

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CL 614	BIOPROCESS ENGINEERING	*3-0-0*	*3 Credits*

PRE-REQUISITE

Knowledge in Biochemical Engineering and Reaction Engineering

COURSE LEARNING OBJECTIVES

To understand the principles, stoichiometry, kinetics, modeling and instrumentation of biologi employed in industrial fermentation

COURSE CONTENT

Introduction: Fermentation Processes General requirements of fermentation processes- An o and anaerobic fermentation processes and their application in industry - Medium requiremen processes - examples of simple and complex media Design and usage of commercial industrial fermentation. Sterilization: Thermal death kinetics of micro-organisms - Batch and Sterilization of liquid Media- Filter Sterilization of Liquid Media and Air.

Enzyme Technology, Microbial Metabolism: Enzymes: Classification and Properties-Applied enzym Kinetics of enzyme catalytic Reactions-Metabolic pathways - Protein synthesis in cells.

Stoichiometry and kinetics of Substrate Utilization And Biomass And Product Formation: Sto microbial growth, Substrate utilization and product formation-Batch and Continuous culture, Fe Bioreactor and Product Recovery Operations: Operating considerations for bioreactors for suspens immobilised cultures, Selection, scale-up, operation of Bioreactors-Mass Transfer in heteroge reaction systems; Oxygen transfer in submerged fermentation processes; oxygen uptake rate determination of oxygen transfer rates and coefficients; role of aeration and agitation in oxygen t transfer processes in Biological systems. Recovery and purification of products.

Introduction to Instrumentation and Process Control in Bioprocesses: Measurement of physic parameters in bioreactors- Monitoring and control of dissolved oxygen, pH, impeller speed an stirred tank fermenter.

REFERENCE BOOKS

1. M.L. Shuler and F. Kargi, *Bio-process Engineering*, 2nd Edition, Prentice Hall of India, New Delhi. 2002.
2. J.E. Bailey and D.F. Ollis, *Biochemical Engineering Fundamentals*, 2nd McGraw Hill, Publishing Co. New York, 1985.
3. P.Stanbury A. Whitakar and S.J.Hall, *Principles of Fermentation Technology,* 2ndEdn., Elsevier-Pergamon Press, 1995.

COURSE OUTCOME

On completion of the course, the students will be able to

CO1	get knowledge on fermentation processes and its characteristics
CO2	understand the concepts of enzyme kinetics.
CO3	define stoichiometry of the fermentation processes.
CO4	understand the working principle of bioreactor and product recovery operations and its monito instruments

Mapping of Course Outcome with Programme Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	P(
CO1	✓	✓					✓	✓	✓	✓	
CO2	✓	✓		✓		✓				✓	

CO3	✓	✓	✓	✓	✓		✓	✓			
CO4	✓	✓	✓	✓	✓	✓		✓	✓		

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CL 615	POLYMER DYNAMICS	*3-0-0*	*3 Credit*

PRE-REQUISITE: None

COURSE LEARNING OBJECTIVES

To provide an opportunity for post graduate students to develop skills, strategies and me understand the basic principles dynamics of polymers in solution through various models.

COURSE CONTENT

Polymer Melts and Solution: Description Viscosity of Polymer Melts and Solution: Viscosity of Co and Melts, Effect of Branching on Viscosity, Elasticity and Visco- elasticity, Maxwell Model for phenomena in polymeric liquids, Brownian Motion, Smoluchowski and Langevin Equatior Cross- Correlation functions, Response Function, Fluctuation Dissipation Theorem, Interacti Oseen Tensor, microscopic basis of visco elasticity.

Dilute Solutions: Elastic Dumbell Model and bead-rod-spring model for polymer chain, the Models

Visco-elasticity and Birefringence. Semidilute and Concentrated Solutions and melts: Effect Entanglement Effect, Tube Model and Reptation Model, Network theories, Linear Visco-elasticit Non-Linear Visco-elasticity, Dynamics of Rigid Rodlike Polymers.

REFERENCE BOOKS

1. M. Doi and S. F. Edwards, *Theory of Polymer Dynamics* , Clarendon Press, Oxford, 1986.
2. R. B. Bird, R. C. Armstrong, O. Hassager, *Dynamics of Polymeric Liquids* , 2nd Edition vols. Sons, NY, 1987.
3. R. G. Larson, *Structure and Rheology of Complex Fluids* , Oxford University Press, 1999.

COURSE OUTCOME

On completion of the course, the student will have ability

CO1	to understand the flow behavior of polymer melts and solutions.
CO2	to describe polymer dynamics in dilute and semi-dilute solutions.
CO3	to review and distinguish between the models for polymer solutions..

Mapping of Course Outcome with Programme Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	✓		✓							
CO2	✓	✓		✓	✓				✓	
CO3	✓	✓		✓	✓	✓	✓	✓		

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CL 616	MULTIPHASE FLOW	3-0-0	3 Cred

PRE-REQUISITE

Transfer operations at undergraduate level.

COURSE LEARNING OBJECTIVES

The course will give a general introduction to the underlying concepts of multiphase flows and model such flows under different conditions. The course opens with real life examples of such fl process industries with multiphase contactors.

COURSE CONTENT

Two phase flow: Gas/Liquid and Liquid/liquid systems: Flow patterns in pipes, analysis o situations,

Prediction of holdup and pressure drop or volume fraction, Bubble size in pipe flow, Loc parameters, Bubble column and its design aspects, Minimum carryover velocity. holdup ratios, p transport velocities and their prediction.

Flow patterns - identification and classification - flow pattern maps and transition - mo balance - homogeneous and separated flow models -correlations for use with homogeneous an - void fraction and slip ratio correlations - influence of pressure gradient - empirical treatmen drift flux model - correlations for bubble, slug and annular flows

Introduction to three phase flow, Dynamics of gas-solid liquid contactors (agitated vessels, pack bed, pneumatic conveying, bubble column, trickle beds), Flow regimes, pressure drop, mass and heat transfer, reactions, Applications of these contactors

Measurement techniques in multiphase flow: Conventional and novel measurement te systems (Laser Doppler anemometry, Particle Image Velocimetry)

REFERENCE BOOKS

1. Clift, R., Weber, M.E. and Grace, J.R., *Bubbles, Drops, and Particles*, Academic Pre
2. Y. T. Shah, *Gas-Liquid-Solid reactors design*, McGraw Hill Inc, 1979.
3. Fan, L. S. and Zhu, C., *Principles of Gas-solid Flows*, Cambridge University Press, 1998.
4. Govier, G. W. and Aziz. K., *The Flow of Complex Mixture in Pipes*, Van Nostrand R 1972.
5. Wallis, G.B.,*One Dimensional Two Phase Flow*, McGraw Hill Book Co., New York, 1969.
6. Crowe, C. T. Sommerfeld, M. and Tsuji, Y., Multiphase *Flows with Droplets and Particles*,
7. Kleinstreuer, C., *Two-phase Flow: Theory and Applications*, Taylor & Francis, 2003.

COURSE OUTCOME

Upon completing the course, the student will be able to

CO1	analyze, characterize the multiphase systems and appreciate the role of structure in multi flows and the role it plays in obtaining engineering solutions.
CO2	understand the assumptions may be made to simplify multiphase flows and when they might be employed.
CO3	understand the limitations of modelling multiphase flow.
CO4	obtain answers to engineering problems involving multiphase flow .

Mapping of Course Outcome with Programme Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	✓	✓		✓	✓					
CO2	✓	✓	✓	✓	✓					
CO3	✓	✓	✓	✓	✓					
CO4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

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CL 617	DESIGN AND ANALYSIS OF EXPERIMENTS	3-0-0	

PRE-REQUISITE: None

COURSE LEARNING OBJECTIVES

To give competences in the field of applied statistical methods for work concerning plar experiments, regression analysis, optimization of processes and multivariate analysis

COURSE CONTENT

Statistics, Simple Comparative Experiments, Experiments of a single factor, analysis of varianc Randomized blocks, Latin squares, The 2^k factor design, Blocking and confounding
Two level fractional Factorial design, Three level and mixed level factorial and fractiona Fitting regression methods, LS method, Robust parameter design, Experiment with random fa Response surfaces, EVOP, Multivariate data analysis

REFERENCE BOOKS

1. Douglas C. Montgomery, *Design and Analysis of Experiments*, Wiley, 6th Edition.
2. Zivorad R. Lazic, *Design of Experiments in Chemical Engineering: A Practical Guide* Inc.
3. Robert L. Mason, Richard F. Gunst, James L. Hess, *Statistical Design and Analysis of Experiments: With Applications to Engineering and Science*, Jhon Wiley &Sons Inc

COURSE OUTCOME

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

CO1	plan experiments according to a proper and correct design plan.
CO2	analyze and evaluate experimental results (statistically), according to chosen experimenta (ANOVA, regression models).
CO3	use fundamentals such as hypothesis testing, degrees of freedom, ANOVA, fractional des other design methods/techniques and so on.
CO4	know the fundamentals of multivariate analysis and chemometric methods (PCA and PLS simple applications.

Mapping of Course Outcome with Programme Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	✓	✓					✓	✓		
CO2	✓	✓		✓				✓		
CO3	✓		✓	✓	✓	✓		✓	✓	✓
CO4	✓		✓	✓	✓	✓	✓	✓	✓	

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CL 618	FUEL CELL TECHNOLOGY	*3-0-0*	*3 Credi*

PRE-REQUISITE: None

COURSE LEARNING OBJECTIVES

To understand about fuel cells, their working principle, Types, Design and performance analys

COURSE CONTENT

Basic principles, classifications, heat of reactions, enthalpy of formation of substances, substances, Efficiency, power, heat due to entropy change and internal ohmic heating.

Nernst equation and open circuit potential, pressure and temperature effect -Stoichiometric co reactants utilization - Mass flow rate calculation - voltage and current in parallel and ser potentials and polarizations - Activation polarization - Tafel equation and exchange curre conductivity, catalysts, Temperature and humidification effect, electro-osmotic Drag effect.

PEM Fuel Cell components: Anode and Cathode materials, catalysts, membrane, Fuels Fuel cell stacks - Rate of mass transfer of reactants and products - water managemen and gas removal- Bipolar plates- flow distribution

– Heat and water removal from the stack.

Fuel cell systems analyze: Energy systems, power- Train or Drive-Train Analysis – PEN Powered Bus- Flow Sheet and conceptual Design-Detailed Engineering Designs

REFERENCE BOOKS

1. James Larminie and Andrew Dicks, *Fuel Cell Systems Explained*, 2nd Edition, John W
2. FranoBarbir, *PEM Fuel Cells Theory and Practice*, Elsevier Academic Press, 2005.
3. GregorHoogers, *Fuel Cell Technology,* Handbook, SAE International, 2003.
4. B Viswanathan and M AuliceScibioh, Fuel *Cell Principles and Applications*, Univer

COURSE OUTCOME

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

CO1	know the basics and working principles of the fuel cell technology.
CO2	select the suitable materials for electrode, catalyst, membrane for the fuel cells.
CO3	understand the pressure drop and velocity distribution in single cell as well as stack.
CO4	design and stack making process for real field applications.

Mapping of Course Outcome with Programme Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1									✓	
CO2	✓	✓	✓	✓	✓		✓	✓		
CO3	✓	✓		✓	✓	✓	✓	✓		
CO4	✓	✓	✓	✓	✓	✓	✓	✓		✓

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CL 619	PINCH ANALYSIS AND HEAT EXCHANGER NETWORK DESIGN	*3-0-0*	*3 C*

PRE-REQUISITE

Basics of Heat Transfer, Mathematics, Process Design

COURSE LEARNING OBJECTIVES

Understanding Pinch concept, Application to Process Heat Exchange Networking, Ide
Minimization in the Process, Retrofitting Concepts and Setting up Targets for Energy Minimizati

COURSE CONTENT

Basics: Thermodynamical review of the process, Pinch concept, significance of pinch, pin
representation, Threshold problems, capital cost implication of the pinch.

Targeting: Heat exchanger networks, energy targeting, area targeting, unit targeting, shell targe
super targeting, and continuous targeting.

Pinch Methodology: Problem representation, temperature enthalpy diagram, simple match matri
Temperature interval diagram.

Pinch Design and Optimization: Networks for maximum energy recovery, Pinch design meth
the pinch, cp table, the tick of heuristic, case studies, optimization of heat exchanger netw
minimum area network, Sensitivity analysis.

Energy and Resource Analysis of various processes: Batch process, flexible process, dis
evaporation process, reaction process, process using mass separating agent. Heat pipes and H

REFERENCE BOOKS

1. V. UdayShenoy, Heat Exchanger network synthesis, Gulf Publishing Co, USA, 1995.
2. D.W. Linnhoff et al., User Guide on Process Integration for the efficient use of Energy, Instit
Engineers, U.K., 1994.
3. James M.Douglas, Conceptual Design of Chemical Process, McGraw Hill, New York, 1988.
4. Anil Kumar, Chemical Process Synthesis and Engineering Design, Tata McGraw Hill New D

COURSE OUTCOME

After completion of this course, the student should be able to

CO1	understand the pinch concept and process thermodynamics.
CO2	identify minimum energy targets.
CO3	identify different choices and constraint during heat exchange networking.
CO4	apply strategies for retrofitting existing process plant, integration of energy demands of multiple processes.

Mapping of Course Outcome with Programme Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	✓	✓	✓	✓	✓				✓	
CO2	✓	✓	✓	✓	✓				✓	✓
CO3	✓	✓	✓	✓	✓				✓	✓
CO4	✓	✓	✓	✓	✓				✓	✓

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CL 620	INDUSTRIAL ENERGY SYSTEMS	*3-0-0*

PRE-REQUISITE

Knowledge in thermodynamics, heat transfer and heat exchanger process design.

COURSE LEARNING OBJECTIVES

To learn the process integration methods and to understand the technical anc industrial process systems.

COURSE CONTENT

Introduction to industrial process energy systems: concepts, heat balanc heating vs central heating systems; illustrating example from the pulping industry

Energy conversion technologies in industrial energy systems: overview of technolc thermodynamics for process utility boilers, heat pumps, steam turbine c gas turbine CHP. Energy conversion performance of such systems for given en parameters, and given industrial process heat load characteristics

Process integration: Basics of process integration methodologies with emphasis temperature, minimum process heating and cooling requirements, compos curves, targeting for minimum number of heat
exchanger units, and heat exchanger surface area costs).

Design of heat exchanger networks for maximum heat recovery. Process in efficiency energy conversion technologies (heat pumps and combined heat a intensive thermal separation operations (distillation, evaporation). Energy effi evaluation of process integration measures. Process integration methodologies industrial energy systems.

Economics of energy conversion in industrial energy systems: characteristics and power (CHP) units (performance, investment costs). Influence of operatin Optimization of size and various design parameters based on process integration identifying the cost- optimal mix of technologies for satisfying a process heat dem over the course of the year.
Greenhouse gas emissions consequences of energy efficiency measures in from industrial energy systems. Optimization of industrial
energy systems considering future costs associated with greenhouse gas emissio

REFERENCE BOOKS

1. D.W. Linnhoff et al., *User Guide on Process Integration for the efficient use of* Engineers, U.K., 1994.
2. Richard E. Putman, Industrial *Energy Systems: Analysis, Optimization, and C*
3. Anil Kumar, *Chemical Process Synthesis and Engineering Design*, Tata I
4. Francis M. Vanek, Louis D. Albright, Largus T. Angenent, *Energy Systems En*
Implementation, 2nd Edition, Mc-Graw Hill, 2012.

3 Credits

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ombined heat and power (CHP) and
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principles. Methodology for
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industry. Greenhouse gas emissions

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Energy, Institution of Chemical

ontrol, ASME Press, 2004.
McGraw Hill New Delhi, 1977.
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COURSE OUTCOME

On completion of the course, the student can

CO1	understand the different technologies and heat distribution configurations for various indu systems.
CO2	optimize the process parameters and investment cost using process integration methods
CO3	understand the design a heat exchanger network for maximum heat recovery for a given
CO4	identify opportunities for integration of high-efficiency energy conversion technologies an intensive thermal separation operations (distillation, evaporation) at an industrial process
CO5	identify the cost-optimal mix of technologies for an industrial process heat demand.

Mapping of Course Outcome with Programme Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	✓	✓	✓				✓		✓	
CO2	✓	✓	✓				✓	✓	✓	
CO3	✓	✓	✓		✓		✓	✓	✓	
CO4	✓	✓	✓		✓		✓		✓	
CO5	✓	✓	✓		✓		✓	✓	✓	

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CL 621	WASTEWATER AND SOLID WASTE TREATMENT	*3-0-0*

PRE-REQUISITE: None

COURSE LEARNING OBJECTIVES

Expose students to the waste management overview, treatment of liquid wast train the students in different waste management techniques.

COURSE CONTENT

Water Pollutants, Effects, Monitoring and Quality standards: Pollution of \ pollutants on environment and health, monitoring water pollution, water pollutio standards, monitoring, compliance with standards,
Latest norms for effluent treatment.

Water Pollution Sources, Analysis and Methods of control: Water pollution so pollutants - Wastewater sampling and analysis. Treatment of water- pollution: BOI reduction – Fundamentals of Anaerobic
digestion and Aerobic digestion.

Wastewater Treatment Plant Design: Physical unit operations: Screeni sedimentation etc., Chemical Unit Processes: chemical precipitation, disinfe Biological unit processes: Aerobic suspended - growth treatment processes, aer processes, anaerobic suspended - growth treatment processes, anaerobic attachec

Advanced Wastewater and Water Treatment: Carbon adsorption - Ion e Nutrient (nitrogen and phosphorus) removal - Design of plant for
treatment and disposal of sludge.

Solids Waste and Landfill Management: Sources and classification - methods of soli (natural) - Accelerated composting with industrial sludge - Landfill technology - solid waste - Toxic-waste management,
Incineration of industrial waste, Design aspects, economics.

Hazardous Waste Management and Risk Assessment: Types of hazardous Wastes and radioactive waste treatment and disposal methods. Risk assessment.

REFERENCE BOOKS

1. C.S. Rao, *Environmental Pollution Control Engineering*, Wiley 2nd Edition, N 2006.
2. S.P. Mahajan, *Pollution Control in Process Industries*, Tata McGraw Hill, Ne
3. Sincero and G.A. Sincero, *Environmental Engineering: A Design Approach,*
4.Tchbanoglous and F.L. Burton, *Metcalf and Eddy's Wastewater Treatment-Di* publishing Co Ltd, N. Delhi.

3 Credits

:e streams. This course prepares to

water and soil, effect of
n laws and minimum national

urces and classification of water
D, COD of wastewater and its

ing, Flow equalization,
ction, colour removal by adsorption
obic attached-growth treatment
d-growth treatment processes.

xchange - Membrane processes -

id waste disposal - Composting
- Methods adopted for municipal

-Health effects - Nuclear fission

lew Age International Publishers,

ew Delhi, 1985
PHI, New Delhi,1996.
sposal And Reuse (Third Ed.), TMH

COURSE OUTCOME

Upon completing the course, the student will be able to

CO1	Understand waste management and its concepts.
CO2	get the concepts of recycling of metals and polymeric materials.
CO3	identify the treatment of liquid waste streams - mechanical, biological and chemical metho industrial and municipal cases; anaerobic digestion; production of bio-gas; dewatering an
CO4	Classify solid wastes separation, management by incineration, composting and landfilling

Mapping of Course Outcome with Programme Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	✓	✓	✓	✓					✓	
CO2	✓	✓	✓	✓					✓	
CO3	✓	✓	✓	✓	✓				✓	
CO4	✓	✓	✓	✓					✓	

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CL 622	COMPUTATIONAL FLUID DYNAMICS	*3-0-0*	*3 Credits*

PRE-REQUISITE

Knowledge in fluid mechanics and solving partial differential equations using iterative methods.

COURSE LEARNING OBJECTIVES

1. To understand the theory of governing equations representing fluid flow behavior.
2. To solve fluid flow problems involving diffusion and convection phenomena using Finite volur

COURSE CONTENT

Conservation Laws of Fluid Motion and Boundary Conditions: Governing equations of fluid flow a Equations of state, Navier-Stokes equations for a Newtonian fluid, Classification of physical b Classification of fluid flow equations, Auxiliary conditions for viscous fluid flow equations.

Turbulence and its Modelling: Transition from laminar to turbulent flow, Effect of turbulence on tir Stokes equations, Characteristics of simple turbulent flows, Free turbulent flows, Flat plate bounc flow, Turbulence models, Mixing length model, The k-e model, Reynolds stress equation models equation models.

The Finite Volume Method for Diffusion Problems: Introduction, one-dimensional steady sta dimensional diffusion problems, three-dimensional diffusion problems discretised equations fc

The Finite Volume Method for Convection-Diffusion Problems: Steady one-dimensional co diffusion, the central differencing scheme, Properties of discretisation Schemes-Conservativ Transportiveness, Assessment of the central differencing scheme for convection-diffusion p differencing scheme, the hybrid differencing scheme, The power-law scheme, Higher order diffe convection-diffusion, Quadratic upwind differencing scheme.

The Finite Volume Method for Unsteady Flows and Implementation of Boundary Conditions: One unsteady heat conduction, Discretisation of transient convection-diffusion equation, Solution proc flow calculations, Implementation of Inlet, outlet and wall boundary conditions, constant pressure

REFERENCE BOOKS

1. H. K. Versteeg and W. Malalasekera, *An introduction to computational fluid dynamics: the finit* Longman scientific & technical publishers, 1995.

2. John D. Anderson, *Computational fluid dynamics: The Basics with A* McGraw-Hill, Inc.New York, 1995.

3. Vivek V. Ranade, *Computational flow modeling for Chemical Reactor Engineering*, Academi 2002

COURSE OUTCOME

Upon completing the course, the student will be able to

CO1	impart knowledge on theory of governing equations representing fluid flow behavior
CO2	understand the concept of turbulence and its modeling
CO3	solve steady state diffusion and convection fluid flow problems using Finite volume method
CO4	solve unsteady state fluid flow problems using finite volume method

Mapping of Course Outcome with Programme Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10

CO1	✓	✓					✓	✓	✓	✓
CO2	✓	✓		✓		✓				✓
CO3	✓	✓	✓	✓	✓		✓	✓		
CO4	✓	✓	✓	✓	✓	✓		✓	✓	

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dary layer and pipe
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ate diffusion, two-
ɔr diffusion problems.
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eness, Boundedness,
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erencing schemes for

e-dimensional
cedures for unsteady
boundary condition.

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c Press, San Diego,

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CL 623	PROCESS OPTIMIZATION	3-0-0	3 Credit

PRE-REQUISITE

Knowledge in applied mathematics and basic chemical engineering process principles

COURSE LEARNING OBJECTIVES

1. To understand the concepts and origin of the different optimization methods.
2. To get a broad picture of the various applications of optimization methods used in Chemical E
3. Optimize the different methods in industry for design and production of products, both econor

COURSE CONTENT

Functions of single variable and multi-variable, Classical optimization methods, Linear Prog Transportation problems,

Non-linear programming, constrained and unconstrained optimization methods, Multi- o Quadratic and Geometric Programming: Quadratic and geometric programming problems, Grey box modeling, Artificial Intelligence in Optimization: ANN based optimization, Genetic algor Application of the above optimization techniques to chemical engineering processes: e heat exchanger, distillation column, liquid liquid extraction process by using computer packa Aspen plus etc.,

REFERENCE BOOKS

1. T.F. Edgar and D.M. Himmelblau, *Optimization Techniques for Chemical Engineers*, Mc 1985.

2. S.S.Rao, *Engineering Optimization Theory and Practice*, Third edition, New Age Interna India.

3. K. Deb, *Optimization Techniques*, Wiley Eastern, 1995.

4. R.Panneerselvam, *Operation Research*, Second edition, PHI,New Delhi, India.

5. Prem Kumar Gupta and D.S.Hira, *Problems in Operations Research (Principles and S* company Ltd. New Delhi, India.

COURSE OUTCOME

Upon completing the course, the student will be able to

CO1	Selection of the appropriate optimization technique to the process
CO2	acquire sufficient knowledge for chemical engineering applications, where optimal decisio to be taken in the presence of trade-offs between two or more conflicting objectives.
CO3	implement the theory and applications of optimization techniques in a Comprehensive ma solving linear and non-linear, geometric, quadratic programming
CO4	identify, formulate and solve a practical engineering problem of their interest by applying c modifying an optimization technique.

Mapping of Course Outcome with Programme Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10

CO1	✓	✓	✓	✓	✓					
CO2	✓	✓	✓	✓	✓					
CO3	✓	✓	✓	✓	✓					

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calculus of variations.
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evaporator, reactor,
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CL 624	ECOLOGY FOR ENGINEERS	*3-0-0*

PRE-REQUISITE: None

COURSE LEARNING OBJECTIVES

The course aims at giving substantial and functional knowledge on ecology, ecosyst materials from biological systems to the industry in a society adapting towards sustainal

COURSE CONTENT

Ecosystem Concepts: Levels of biological organization; Native Species; Keystone Spec thresholds; Ecological resilience; Disturbances – Natural disturbances/ Human-induced fragmentation;
Ecosystem management Concepts: Coarse and fine filter approach; Risk – inherent as Adaptive management; Ecosystem based management (EBM); Protected area.

Ecological principles: Protection of species and species sub-divisions to conserve habitat – to conserve species; Large areas vs Small areas in accommodating spe strength; Disturbances – influence on populations, communities and ecosystems; Influe freshwater and marine ecosystems

Terrestrial Biomass: Biomass classification schemes – Holdredge scheme, Whittak system; Equatorial, Tropical, Subtropical, Mediterrnaean, Warm temperate, Nem Polar; and Aquatic Biomes – Freshwater biomes, marine biomes – Marine habitat t seeps, Benthic Zone, Pelagic Zone, Abyssal, Hadal (ocean trench);

Ecosystem services: Carbon Cycle – Estimation of Carbon Sources and distributi of Energy Consumption and Balance of Energy associated with ecosystem.

Sustaining biological resources for society's consumption – Moving from Water Problem Availability of resources; Access to resources; Theory of Change and Impact Path

Valuation of nature and ecosystem services: The general concepts of value; Instrumental/ Use Value – Direct Use Value, Indirect Use Value; Intrinsic or Non-use/ P Value, Bequest Value; Values in the concept of governance; Values in the concept

REFERENCE BOOKS

1. G. Tyler Miller, Jr, Scott E. Spoolman, *Living in the Environment* , International Stud
Brooks/Cole, 2008.
2. Martin Beniston, *Assessing the impact of climate change on mountain*
15559, 2013.
3. Balmansee, *Sustainability of water resource systems in India: Role of value i*
4. Allen, T.F.H., Bandurski B.L., King A.W. 1992, *The ecosystem approach: theo*
International Joint Commission United States and Canada, Washington D.C. (U
5. Daly H.E., and Farley J., *Ecological Economics: Principles and Applications,*
Island Press, 2004
6. Hanley, N., and Spash. *Cost Benefit Analysis and the Environment* . Edward Elgar,
7. Millennium Ecosystem Assessment Reports *(http://www.maweb.org/en/Index.aspx*
student reports, handouts from lectures and exercises.

3 Credits

em services and provision of raw
bility.

ies; Population viability/
disturbances; Connectivity/

ɔect of decision making;

gene diversity; Maintaining
ecies; Connections – nature and
nce of climate – terrestrial,

:es's biome-type, Walter
ıoral, Continental, Boreal and
ypes – Hydrothermal vents, Cold

on; Energy Cycle – Estimation

ıs to Water Solutions;
ıways;

Total Economic Value;
assive Value – Existence
of social -Ecological Systems.

ent Edition, Seventeenth edition,

water resources , STOTEN

'n Urban Lake Governance.
ɔry and ecosystem integrity,
SA).

1998.
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COURSE OUTCOME

After completion of this course, the student should be able to

CO1	describe fundamental ecological principles .
CO2	identify and describe the major biomes of the world .
CO3	explain how the productivity of biological systems and ecosystem services affect and are affected by activities in society.
CO4	explain how industry could be transformed to enable sustainable use of natural capital.
CO5	describe valuation of nature from different ethical perspectives.

Mapping of Course Outcome with Programme Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	✓	✓	✓	✓		✓					
CO2	✓		✓	✓							
CO3	✓	✓	✓	✓		✓					
CO4	✓		✓	✓			✓	✓		✓	
CO5	✓	✓		✓					✓	✓	✓

CL 625	ADVANCED FOOD PROCESS ENGINEERING	*3-0-0*	*3 Credits*

PRE-REQUISITE

Knowledge in basic principles and applications of Unit Operations.

COURSE LEARNING OBJECTIVES

To understand the various process methods involved in converting raw materials into quality f emphasize the methods and procedures involved in food canning technology.

COURSE CONTENT

Food Process Engineering - Fundamentals: Raw material and the Process-Geometric, Functior properties of the raw material, Mechanization and the raw material, cleaning - contaminants in food ra function of cleaning and c leaning methods, sorting and Grading of Foods.

Unit Operations in Food Processing: Fluid flow, thermal process calculations, refrigeration, evaporatio dehydration operations in food processing. Heat processing of foods - modes of heat transfer ir processing of foods.

Food Canning Technology: Fundamentals of food canning technology, Heat sterilization of canned f metal, glass and flexible packaging, Canning procedures for fruits, vegetables, meats, poultry ar produces.

Separation and Mixing Process In Food Industries: Conversion operations. Size reduction of solids mixing and emulsification, filtration and membrane separation, centrifugation, crystalliza Food Biotechnology: Food Biotechnology. Dairy and cereal products. Beverages and food ingredien corn syrup. Single cell protein.

REFERENCE BOOKS

1. R.T. Toledo, *Fundamentals of Food Process Engineering*, AVI Publishing Co., New York, 1

2. Paul Singh, R. and Dennis R Heldman, *Introduction to Food Engineering,* Third edition. Academic 2004.

3. J.M. Jackson & B . M . Shinn, Fundamentals of Food Canning Technology, AVI Publishing Co.,

4. J.G. Bernnan, J. R. Butters, N.D. Cowell & A. E. V. Lilley, Food *Engineering Operations*, Science, New York, 1976.

COURSE OUTCOME

After completion of this course, the student should be able to

CO1	identify appropriate processing, preservation, and packaging method
CO2	understand the various causes of food deterioration and food poisoning
CO3	select suitable unit operation equipment, separation methods and conveying system
CO4	understand biological basics and food processing.

Mapping of Course Outcome with Programme Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	✓		✓								
CO2	✓					✓			✓		
CO3	✓	✓	✓	✓	✓					✓	

CO4	✓	✓	✓	✓							✓

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press, London,

New York, 1978.
2^{nd} Edn., Applied

CL 626	BIOREFINERY ENGINEERING	*3-0-0*	*3 Credits*

PRE-REQUISITE: None

COURSE LEARNING OBJECTIVES

To impart basics and working knowledge of converting bio based feedstock to fuels and ot chemicals in an economical and sustainable way.

COURSE CONTENT

Introduction: Evolution of bio refinery (current energy consumption, conventional fossil fuel basec challenges, scope of bio refinery); renewable feedstock and their availability.

Basic biomass properties (cell wall, plant anatomy, fiber morphology); chemistry of basic ca oxidation & reduction reactions of monosaccharides); chemistry of polysaccharides (structure ar cellulose, addition & substitution reactions); chemistry of lignin (structure and properties, isolat Pulping technology (mechanical & chemical pulping, Sulfate process (Kraft pulping)); bioma (dilute acid pretreatment, steam explosion pretreatment, Ammonia fiber explosion pretreatme Biochemical conversion of lignocelluloses to alcohol (enzymatic hydrolysis, microbial ferm digestion); Thermo chemical conversion of biomass to liquid fuels (gasification, pyrolysis)

Residues of bio fuel industry & their value-added processing, economics of bio refineries, enviror refineries, life-cycle analysis.

REFERENCE BOOKS

1. Robert C. Brown, Biorenewable Resources: Engineering New Products from Agriculture, Wile 2003.
2. Samir K. Khanal, Anaerobic Biotechnology for Bioenergy production: Principles and Applicati Publishing, 2008.
3. EeroSjöström's Wood Chemistry-Fundamentals and Applications, Second Edition, Aca
4. Monica EK; Goran Gellerstedt; Gunnar Henriksson, Wood Chemistry and Wood E Stockholm: KTH, 2007.

COURSE OUTCOME

On completion of the course, the students will be able to

CO1	know the overview of world energy situation, refinery and biorefinery concept.
CO2	familiarize themselves with the unit processes/operations involved in biofuel producti apply energy balances and thermodynamics in biomass conversion.
CO3	perform the techno-economic analysis of various biofuel conversion technologies.
CO4	understand the role of bio refinery engineering in facing the societal challenges.

Mapping of Course Outcome with Programme Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1		✓		✓				✓	✓	
CO2	✓	✓	✓	✓	✓	✓		✓		
CO3	✓		✓	✓	✓	✓		✓		✓

CO4		✓	✓						✓	✓

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l refinery and its

arbohydrate (structure,
nd properties of
ion and application)
ass pretreatment
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nmental impact of bio

ey-Blackwell Publishing,

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demic Press, 1993.
Biotechnology,

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CL 627	AIR POLLUTION CONTROL EQUIPMENT DESIGN	*3-0-0*	*3 Cr*

PRE-REQUISITE

Knowledge in various methods of air pollution and their control measures.

COURSE LEARNING OBJECTIVES

To design equipment based on the application of air pollution treatment and various methods of (control equipment.

COURSE CONTENT

Air Pollutant Sources, Effects and Clean Air Acts: Pollution of air: Sources and effects of air pollu environment and living systems, Monitoring air pollution, Air pollution Laws and Minimum nationa Air Pollutant Formation, Dispersion, Analysis: Formation of pollutants through large-scale c fuels, mineral processing, automobiles in urban areas and at source minimization of relea aspects of air pollutant dispersion. Chemical reactions in a contaminated atmosphere, urba rain Air sampling and measurement, Analysis of air pollutants.

Air Pollution Control Methods for Particulates Removal: Control Methods -Source Corr Particulate emission control: Dry techniques industrial dust collectors, cyclone and multiclone sep electrostatic precipitators, relative merits and demerits, choice of equipments, design aspects techniques wet dust collection, wet cyclone, empty scrubber, column (packed) scrubber, v suitability, merits and demerits, design aspects and economics.

Control of Specific Gaseous Pollutants: Cleaning of Gaseous effluents – Control of sulphur dioxic methods - Control of nitrogen oxides in combustion products - Control of release of carbon mono to the atmosphere.

REFERENCE BOOKS

1. Y.B.G. Verma, H. Brauer, Air *Pollution Control Equipments*, Springer, Verlag Berlin,19
2. M.N. Rao and H.V.N. Rao, *Air Pollution*, Tata McGraw Hill, New Delhi, 1993.
3. Rao C.S., *Environmental Pollution Control Engineering*, 2nd Edition, New Age International F
4. A. P. Sincero and G.A. Sincero, *Environmental Engineering: A Design Approach*, Prentice N.Delhi.1996.

COURSE OUTCOME

On completion of the course, the students will be able to

CO1	identify the pollution of air and effects of air pollutants.
CO2	acquire sufficient knowledge for control of air pollution at source level and control of spec gaseous pollutants.
CO3	design suitable equipment based on the application of air pollution treatment.
CO4	get exposed on causes of air pollution and its control.

Mapping of Course Outcome with Programme Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	✓	✓							✓	
CO2	✓	✓	✓	✓	✓	✓		✓	✓	✓

CO3	✓	✓	✓	✓	✓	✓	✓	✓	✓	
CO4	✓	✓				✓			✓	

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design of air pollution

tants on physical
l standards.
ombustion of fossil
se - Meteorological
an air pollution, acid

ection methods -
parators, bag filters,
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entury scrubber,

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xide and hydrocarbons

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Publishers, 2006.
Hall of India pvt Ltd,

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CL 628	ADVANCED TRANSPORT PHENOMENA	*2-1-0*

PRE-REQUISITE

UG Courses on Momentum, Heat and Mass transfer, Reaction Engineering, PDEs, OD

COURSE LEARNING OBJECTIVES

1. The course reviews the fundamentals of momentum, mass and energy balances as analysis.
2. The Focus will be to develop physical understanding of principles discussed engineering applications.
3. The course will accustom the students in advanced topics of transport phenomena different Chemical Engineering applications.
4. The student will be exposed to classic and current literature in the field.

COURSE CONTENT

Introduction to concepts and definitions, Newtonian and non-Newtonian Fluid Mo method and Equations of changes for fluid flow problems (Flow over flat plate, thc fluidized beds)

Turbulent Flow - Equation of changes, phenomenological theories, Turbulent flow in clo different velocity distributions, Boundary layer theory: Equation of changes, Blasius E karman Integral momentum method, Boundary layer separation.

Application of Shell balance and Equations of changes for temperature distributions in conduction, Combination of heat transfer resistance,

Different method of analysis for Multidimensional Steady and Unsteady state hea transfer co-efficient, Heat transfer during Laminar and Turbulent flow in closed

Application of Shell balance method and Equations of changes for mass transfer proble for isothermal and non-isothermal mixtures, Multi component systems, with more th in turbulent flow

Convective mass transfer and correlation, interphase mass transfer, Macroscopic balar Mass transfer with chemical reactions.

Dimensional analysis in fluid dynamics, convection heat transfer, Boiling and Condensa transfer in Liquid metals, Empirical correlation for high Prandtl Number of flui and heat transfer.

REFERENCE BOOKS

1. R. Byron Bird, Warren E. Stewart and Edwin N. Lightfoot, Transport Phen John Wiley & Sons, 2007.
2. John C Slattery, Advanced Transport Phenomena Cambridge University Press, 19
3. J.R.Welty, C. E. Wicks and R. E. Wilson, G. L Rorrer, Fundamentals of Momentum Edition, 2008.
4. C. O. Bennet and J. O. Meyers, Momentum, Heat and Mass transfer, McGraw Hill,
5. H. Schlichting and K. Gersten, Boundary-Layer Theory, 8th edition, Springer, 2004.

3 Credits

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s well as vector and tensor

and with emphasis on chemical

fundamentals and applications to

dels, Review of Shell balance
ugh pipes, packed bed and

osed conduits and analysis of
Exact solution method, von

heat flow problems. Steady state

at conduction, Convection heat
conduits.
ems, Concentration distributions
an one independent variable and

nce for multi component system,

ation heat transfer, Heat
ids, Analogy between momentum

omena, Revised second Edition,

99.
, Heat and Mass transfer, 5th

1995.

COURSE OUTCOME

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

CO1	set up and solve differential momentum, heat, and mass balances for 1-D steady state problems and quasi-steady-state problems occurring in laminar and turbulent flows terms of vector and tensor fluxes with physical understanding using shell balance & Equations of changes.
CO2	formulate a mathematical representation of velocity, temperature and concentration profiles ir momentum, heat and mass transfer respect ively at different operating conditions at differe scales.
CO3	carry out dimensional analysis and correlate them for transfer operations and its applications.

Mapping of Course Outcome with Programme Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	✓	✓		✓	✓			✓	✓		✓
CO2	✓	✓		✓	✓			✓	✓		✓
CO3	✓	✓		✓	✓			✓	✓		✓

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CL 629	ELECTROCHEMICAL REACTION ENGINEERING	*3-0-0*

PRE-REQUISITE

Thermodynamics, Mass transfer, Chemical Reaction Engineering

COURSE LEARNING OBJECTIVES

To familiarize in the aspects of current-voltage relationships & estimation of mass transfer coef systems model

COURSE CONTENT

A general view of electrolytic processes; current-voltage relationships in electrolytic reactors; th plateau; mass & energy balance, and efficiency in electrochemical reactors; The estim transport coefficients at commonly occurring electrodes; The estimation of mass tra enhanced convection conditions.

A general view of plug flow model of electrolytic reactors: plug flow model of electrochemical re plate reactor; Plug flow model under constant mass flux conditions; PFM analysis with ele and real electrochemical reactors. General view of simple CSTER systems; CSTER in cas of batch electrochemical reactors, CSTER analysis of semi-continuous electrochemical re electrolyte recycling; Batch reactor combined with electrolyte recycling.

General aspects of thermal behavior in electrochemical reactor; Thermal behavior under estimation of heat losses; the thermal behavior under PFR conditions; Thermal behavior c reactors.

Convective diffusion equation and migration effects –derivation of convective diffusion eq and limitation – migration effects – Electroneutrality conditions – supporting electrolyte ef Nernst layer model – Estimation of true limiting current.

General aspects of dispersion models-tracer input signal/output signal - axial dispersion in elec axial dispersion and reactor performance - axial dispersion analysis via tank-in-series mod optimization of electrochemical reactor

– elementary process optimization – IBL formula – optimization of electro refining process – Ja optimization of a general electrolytic process – The Beck formula.

REFERENCE BOOKS

1. Scott K, *Electrochemical Reaction Engineering* , Plenum Press, New York, 1991.
2. Goodridge F, Scott K, *Electrochemical Process Engineering* , Plenum Press, New York, 19
3. T.Z.Fahidy, *Principles of Electrochemical Reactor Analysis* , Elsevier, 1985
4. D.J. Pickett, *Electrochemical Reactor Design* , Elsevier Scientific Publishing Company,

COURSE OUTCOME

3 Credits

ficient, PFR & CSTR

ne limiting current
nation of mass
nsport coefficients under

eactors employing parallel
ectrolyte recycling PFM
scades; CSTER analysis
eactors; CSTER analysis of

CSTER conditions; The
of batch electrochemical

quation theory – scope
fect – fundamental of

trochemical reactors -
el - general notions on

skula formula –

95.

New York, 1979.

On completion of the course, the student can

CO1	understand kinetics of single and multiple electrochemical reaction
CO2	understand mass transport process in the electrochemical system
CO3	design electrochemical reactors.
CO4	analyze electrochemical design models, thermal behavior of reactors and electrochemical reactors.

Mapping of Course Outcome with Programme Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	✓	✓		✓					✓	
CO2	✓	✓		✓				✓	✓	
CO3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
CO4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

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✓

CL 630	BIOENERGY	3-0-0	3 Cre

PRE-REQUISITE: None

COURSE LEARNING OBJECTIVES

Gain a comprehensive understanding of the principle of generation of energy from biomass.

COURSE CONTENT

Biomass characteristics & preparation: Biomass sources and classification. Chemical con properties of biomass. Energy plantations. Size reduction, Briquetting of loose biomass, Drying handling of biomass.

Biogas technology: Feedstock for producing biogas. Aqueous wastes containing bio matter, animal residues sugar rich materials. Microbial and biochemical aspects and c parameters for biogas production. Kinetics and mechanism. Dry and wet fermentation. rural Application-High rate digestors for industrial waste water treatment.

Pyrolysis and thermo chemical conversion: Thermo-chemical conversion of ligno-cellulose bio safe disposal of hazardous waste. Biomass processing for liquid fuel production. Pyrolysis of bion regime, effect of particle size, temperature, and products obtained.

Gasification of biomass: Thermochemical principles: Effect of pressure, temperature and of introdu oxygen. Design and operation of Fixed and Fluidised Bed Gasifiers. Safety aspects.

Combustion of biomass and cogeneration systems: Combustion of woody biomass-theory, calculati equipments. Cogeneration in biomass processing industries.

Case studies: Combustion of rice husk, Use of bagasse for cogeneration.

REFERENCE BOOKS

1. A.Chakraverthy, *Biotechnology and Alternative Technologies for Utilisation of Biomass or Agric* Oxford & IBH publishing Co., New Delhi, 1989.
2. K.M.Mital, *Biogas Systems: Principles and Applications*, New Age International Publi
3. P.VenkataRamana and S.N.Srinivas, *Biomass Energy Systems*, Tata Energy Resea Delhi, 1996.
4. D.L. Klass and G.M. Emert, *Fuels from Biomass and Wastes*, Ann Arbor Science publ. Inc. Mic
5. Khandelwal K.C. and Mahdi, *Bio-gas Technology*, Tata McGraw-Hill pub. Co. Ltd., New Delhi,
6. O.P. Chawla, *Advances in bio-gas Technology*. I.C.A.R., New Delhi. 1970.

COURSE OUTCOME

On completion of the course, the students will be familiar with

CO1	availability of biomass feed stocks and their potential attributes to biofuels production.
CO2	evaluation of methodologies for biomass preparation.
CO3	concepts of the second and third generation of bioenergy, and the conversion processes of bio feedstock to biofuels.

Mapping of Course Outcome with Programme Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10

CO1				✓		✓			✓	
CO2	✓	✓							✓	
CO3	✓	✓	✓	✓		✓			✓	

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CL 631	PROCESS INTENSIFICATION	*3-0-0*	*3 Crec*

PRE-REQUISITE

Unit operations at undergraduate level.

COURSE LEARNING OBJECTIVES

To gain the scientific background, techniques and applications of intensification in the pro

COURSE CONTENT

Introduction: Process Intensification (PI) Applications, The philosophy and opportunities of Pr Main benefits from process intensification, Process-Intensifying equipment, Process intensific Techniques for PI application.

Process Intensification through micro reaction technology: Effect of miniaturization on unit reactions, Implementation of Micro-Reaction Technology, From basic properties to technic Inherent Process restrictions in miniaturized devices and their potential solutions, Micro-fabricatic operation devices - Wet and Dry Etching processes.

Scales of mixing, Flow patterns in reactors, mixing in stirred tanks: Scale up of mixing, Heat trans intensified equipment, Chemical Processing in High-Gravity Fields Atomizer, Ultrasound at High intensity inline mixer reactors, Static mixers, Ejectors, Tee mixers, Impinging jets, Rotor principles of static Mixers- Applications of static mixers, Higee reactors.

Combined chemical reactor heat exchangers and reactor separators: Principles of operation; App absorption, Reactive distillation, Applications of RD processes, Fundamentals of Process M Extraction Case Studies, Absorption of NOx- Coke Gas Purification.

Compact heat exchangers: Classification of compact heat exchangers, Plate heat exc exchangers, Flow pattern, Heat transfer and pressure drop, Flat tube-and-fin heat exchange exchangers, Phase-change heat transfer, Selection of heat exchanger technology, Feed/effluer Integrated heat exchangers in separation processes, Design of compact heat exchanger - exa Enhanced fields: Energy based intensifications, Sono-chemistry, Basics of cavitation, (Flow over a rotating surface, Hydrodynamic cavitation applications, Cavitation reactor desig and mass transfer, The Rotating Electrolytic Cell, Microwaves, Electrostatic fields, Sonocrystalli separations, Supercritical fluids.

REFERENCE BOOKS

1. Stankiewicz, A. and Moulijn, (Eds.), Re-engineering the Chemical Process Plants, Proce Marcel Dekker, 2003.

2. Reay D., Ramshaw C., Harvey A., Process Intensification, Butterworth Heinemann, 2008.

COURSE OUTCOME

On completion of the course, the students will be familiar with

CO1	process intensification in industrial processes
CO2	implementation of methodologies for process intensification.
CO3	scale up issues in the chemical processes
CO4	process challenges using intensification technologies

Mapping of Course Outcome with Programme Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	✓	✓				✓			✓	
CO2	✓	✓		✓	✓				✓	✓
CO3	✓	✓	✓						✓	
CO4	✓	✓	✓	✓					✓	

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CL 632	BIOELECTROCHEMICAL SYSTEMS	*3-0-0*	*3 Credits*

COURSE LEARNING OBJECTIVES

To understand the basics, working principle, Types, components, Design and performance analy Bioelectrochemical system

Course Content:

Basics of Bioelectrochemical System: Energy needs, Energy and the challenge of global climate Bioelectricity generation using a BES, BES technologies for wastewater treatment, Renewable generation using BES. Exoelectrogens: Introduction, Mechanisms of electron transfer, BES known exoelectrogenic strains, Community analysis, BES as tools for studying exoelectrogens, Nernst Equation and open circuit potential, voltage and current measurement, maximum voltage thermodynamic relationships, anode and cathode potentials, role of communities in setting anod voltage generation by fermentative bacteria. Calculating power, Coulombic and energy efficiency losses, Measuring internal resistance, Chemical and electrochemical analysis of reactor.

BES components: Anode, Cathode materials, catalysts, membrane, architecture, Fuels for BES.

BES stack: Kinetics of mass transfer, Boundaries on rate constants and bacterial charac Maximum power from a monolayer of bacteria, Maximum rate of mass transfer to a biofilm, M reactor volume, Stacked MFCs, Metal catholytes, Towards a scalable MFC architecture.

Various types of BES: Microbial Electrolysis Cell, Microbial Desalination Cell, Algae assisted MFC, Ca MFC, Microbial remediation cells, Microbial solar cell, MEC-based systems for chemical productio systems for chemical production, MDC-based systems for water desalination and beneficial reuse.

References

1. Microbial Fuel Cells, Bruce E. Logan, John Wiley & Sons Inc., 2007.
2. Microbial Electrochemical and Fuel Cells: Fundamentals and Applications, 1st Edition, Keith S Yu, Woodhead Publishing, 2015
3. Microbial Electrochemical Technology Sustainable Platform for Fuels, Chemicals and Remedi in Biomass, Biofuels and Biochemicals, Edited by S. Venkata Mohan, Sunita Varjani and Ashok P 2018 ISBN: 978-0-444-64052-9
4. Microbial Fuel Cell: A Bioelectrochemical System that Converts Waste to Watts, Edited by Debabra Springer, Cham, 2018.

Course Outcomes

On completion of the course, the student will understand

CO1	Basics, working principles, types, wastewater treatment using Bio electrochemical system.
CO2	Selection of anode and cathode electrode, catalyst, membrane for the Bio electrochemical system.
CO3	Design and scalable process of Bio electrochemical system for real time application

Mapping of Course Outcome with Programme Outcomes

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	√	√	√				√	√	√		

CO2				√	√	√	√	√		√	√
CO3	√		√	√	√	√	√	√			

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HS 611	TECHNICAL COMMUNICATION	*3-0-0*

Objectives:

The objective of the course is

- To develop the professional and communicational skills of learners in a technical en
- To enable students acquire functional and technical writing skills.
- To enable students acquire presentation skills to technical and non-technical audien

Course Description:

This course intends to focus on the discourse of technical communication to make stud components and practices within the field. This course concentrates on advanced writin Principles and procedure of technical writing; to analyzing audience and purpose, organ graphic aids, and writing such specialized forms as abstracts, technical reports, propos

Learning Outcome:

Learners will be able to:

- Communicate to multiple professional audiences clearly and effectively through both
- Identify weaknesses in their own writing and apply appropriate revision processes to
- Analyze rhetorical aspects of audience, purpose, and context to communicate techni written, oral, and visual media.
- Recognize structures or genres typically used in science and engineering, understan them, and the organizational and stylistic conventions characteristic of them, and apply tasks.

Course Content Communication:

Concepts, goals and levels of communication - Barriers to effective communication - P Significance of technical communication - Demonstration and evaluation of Scientific Re Writing and Talking about workplace relationships, Gender Issues, Stereotypes, Biases,

Oral Communication:

Tools and skills of communication - Presentation skills and Use of PowerPoint Slides, P Prepared Speech - Body language and Nonverbal Cues - Interview techniques - Discus Podcasts and Webcasts -

Written Communication:

Effective Writing - Coherence and Cohesion - Report Writing - Drafting Proposals, Res technical / software manuals - Reader Perspective - Two pass approach to reading pap Nonverbal cues in Writing - literature survey and organization - Ethics and Plagiarism

Developing Listening Skills:

Kinds of Listening- Developing effective listening skills; Barriers to effective listening ski Retention of facts, data & figures - Role of speaker in listening, Difference between note

Technology and Communication:

Telephone etiquette - Effective email messages - Editing skills - Visual Aids, Presentati Software - Document Processing Software - Elements of style in technical writing - Role communication - Library and Reference skills.

3 Credits

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ls - Listening Comprehension -
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References:

1. Andrea J. Rutherford. (2007). *Basic Communication Skills for Technology* . New Delhi: Pea
Asia.
2. R.C. Sharma and Krishnamohan.(2011).*Business Correspondence and Report Writing* .Ne
Hill.
3. Whitesides, George M. (2004) Whitesides Group: Writing a Paper 302224, Advanced Mate
(2004)
4. David Lindsay. (1995). *A Guide to Scientific Writing* . Macmillan.
5. Alley, Michael (2003) The Craft of Scientific Presentations, Springer.
6. Strunk Jr., William; E. B. White, (1999). The Elements of Style, Fourth Edition, Longman; 4
7. L.J. Gurak & J.M. Lannon (2010). *Strategies for Technical Communication in the Workplac*
Pearson Education, Inc.

Monippally, M. M., Pawar, B.S. (2010) Academic Writing: A Guide for Management Students a
Response Books.

8. V.R. Narayanaswami (2005). *Strengthen Your Writing* , 3rd ed. Hyderabad: Orient Longma

Course Outcome:

Learners will be able to:

CO1	Communicate to multiple professional audiences clearly and effectively through verbal modes
CO2	Identify weaknesses in their own writing and apply appropriate revision proces communication
CO3	Analyse rhetorical aspects of audience, purpose, and context to communicate techni effectively in written, oral, and visual media.
CO4	Recognize structures or genres typically used in science and engineering, understan that produce them, and the organizational and stylistic conventions characteristic of them, and apply this knowledge to their own

Mapping of Course Outcome with Programme Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1							✓	✓	✓	✓
CO2							✓	✓	✓	✓
CO3							✓	✓	✓	✓
CO4							✓	✓	✓	✓

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MT 617	SURFACE ENGINEERING	3-0-0

COURSE OBJECTIVE:

To analyse the various concepts of surface engineering and comprehend the design

COURSE CONTENT

Introduction tribology, surface degradation, wear and corrosion, types of wear, roles (overview of different forms of corrosion, introduction to surface engineering, importanc Chemical and electrochemical polishing, significance, specific examples, chemical phosphating, chromating, chemical colouring, anodizing of aluminium alloys, thermochen practices

Surface pre-treatment, deposition of copper, zinc, nickel and chromium - principles a electrocomposite plating, electroless plating of copper, nickelphosphorous, nickel-boron; electroless composite plating; application areas, properties, test standard quality deposits.

Definitions and concepts, physical vapour deposition (PVD), evaporation, sputtering, ic process capabilities, chemical vapour deposition (CVD), metal organic CVD, plasma ass applications

Thermal spraying, techniques, advanced spraying techniques - plasma surfacing, DGun anc processes, laser surface alloying and cladding, specific industrial applications, tests for corrosion behaviour.

TEXT BOOKS

1. *Sudarshan T S, 'Surface modification technologies - An Engineer's guide', Marcel Dekker*
2. *Varghese C.D, 'Electroplating and Other Surface Treatments - A Practical Guide', TMH, 1*

COURSE OUTCOMES:

Upon completion of the course, the student will be able to:

1. Define different forms of processing techniques of surface engineering materials
2. Know the types of Pre-treatment methods to be given to surface engineering
3. Select the Type of Deposition and Spraying technique with respect to the application
4. Study of surface degradation of materials
5. Asses the surface testing methods and Comprehend the degradation properties

3 Credits

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nd practices, alloy plating,

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