Open Electives offered by Chemical Engineering Department (R22)

B.E. / B.TECH. I to VIII SEMESTERS

(Inline with AICTE Model Curriculum with effect from AY 2022-23)

(R–22 Regulation)

CHAITANYA BHARATHI INSTITUTE OF TECHNOLOGY (A)

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Department of Chemical Engineering

List of Open electives offered to other departments in R 22 Scheme

S.no	Course Code	Course Name
1.	22CHO01	Fuel Cells and Batteries
2.	22CHO02	Fundamentals of Nano Science and Nano Technology
3.	22CHO03	Industrial Pollution Control
4	22CH O04	Environmental and Sustainable Development
5.	22CH O05	Material Science and Engineering
6.	22CH O06	Safety and Hazard Management

22CHO01 **FUEL CELLS AND BATTERIES**
(Open Elective)

Instruction	3L Periods per week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Course Objectives: This course helps the students to:

1. Create awareness about alternate clean fuel available.
2. Evaluate the concepts and chemistry of fuel cell
3. Examine the details of fuel used in fuel cell technology
4. Explain the application of fuel cell in different sectors
5. Evaluate the fuel cell system balance plant and future opportunities

Course Outcomes: At the end of course, students will be able to

1. Apply know-how of thermodynamics, electrochemistry and principle of fuel cell
2. Understand the different types of fuel cell
3. Understand the components of hydrogen-based fuel cell
4. Explain the application of fuel cell in transport, stationary and portable sector
5. Understand the impact of this technology in a global and societal context

CO-PO-PSO Matrix

	PO1	PO 2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
CO1	3	3	3	-	-	3	-	-	-	1	2		
CO2	3	3	3	-	-	2	-	-	-	1	2		
CO3	3	3	3	-	-	2	-	-	-	1	2		
CO4	3	3	3	-	-	2	-	-	-	1	2		
CO5	3	3	3	-	2	3	-	-	-	1	2		

UNIT - I

Introduction: Electrochemical Systems and Fuel Cell, Fuel Cell Fundamentals and Basic Concepts, Fuel Cell Degradation, Fuel Cell Operation, Types Of Fuel Cell And Its Applications: Direct Carbon Fuel Cell, Solid Oxide Fuel Cell, Polymer Electrolyte Fuel Cell, Alkaline Fuel Cell, Phosphoric Acid Fuel Cell, Molten Carbonate FuelCell, Fuel Cell Thermodynamics - Heat, Work Potentials, Prediction of Reversible Voltage, Fuel Cell Efficiency.

UNIT – II

Fuels and Fuel Processing: Introduction, Feedstock for H_2 production: Natural gas, Liquefied petroleum gas, Liquidhydrocarbon Fuels: Gasoline and Diesel, Alcohols- Methanol and Ethanol, Ammonia, Biomass, Fuel processing for fuel cell applications: Desulfurization, fuel reforming, water gas shift reaction, Carbon monoxide Removal.

UNIT – III

Fundamental and Components of Portable Hydrogen Fuel Cell: Introduction, PEM Fuel cell Components and their properties: Membrane, Electrode, Gas diffusion layer, Bipolar plates, Stack design principles, system design, performance analysis, current/voltage, voltage efficiency and power density, ohmic resistance, direct methanol and other non-hydrogen fuel cells, biofuel cell

UNIT – IV

Application of Fuel Cell: Hydrogen fuel cell use in transport, stationary Fuel cell characterization: - in-situ and ex- situ characterization techniques, i-V curve, frequency response analyses; Fuel cell modelling and system integration: 1D model - Analytical solution and CFD models.

UNIT – V:

Balance of plant and commercialization issues, Future Opportunities, obstacles and challenges

associated in fuel cellsystems, impact of this technology in a global and societal context

Text Books

1. Nigel M. Sammes ,Fuel Cell Technology, Reaching Towards Commercialization, Springer London, 2006.
2. David A Berry, Dushyant Shekhawat, J.J. Spivey, Fuel Cells: Technologies for Fuel Processing, , Elsevier Science, 2011.

Suggested Readings

1. Shigenori Mitsushima, Viktor Hacker Fuel Cells and Hydrogen, From Fundamentals to Applied Research, Elsevier Science, 2018.

Online Resources

1. https://archive.nptel.ac.in/courses/103/102/103102015/#

22CHO02 FUNDAMENTALS OF NANO SCIENCE AND NANO TECHNOLOGY

(Open Elective)

Instruction	3(3L+0T) Hours per week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Course Objectives This course aims to give some understanding on

1. The introduction and classification of nanoscience and nanomaterials
2. Explain the unique properties of nanomaterials.
3. The various synthesis routes of nanomaterials
4. The tools required for the characterization of nanomaterials.
5. The applications of nanomaterials.

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

1. Explain the types of nanomaterials and classify them.
2. Understand various defects, and the effect of nano dimensions on the material behavior.
3. Discuss the bottom up and top-down synthesis of nanomaterials.
4. Explain the characterization of nanomaterials using various techniques.
5. Enlist and explain various applications of nanomaterials in diversified fields and areas.

CO-PO-PSO Matrix

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
1	2	1	1	-	-	1	-	-	-	-	2		
2	2	1	1	-	-	1	-	-	-	-	2		
3	2	1	1	-	-	1	-	-	-	-	2		
4	2	1	1	-	-	1	-	-	-	-	2		
5	2	1	1	-	-	1	-	-	-	-	2		

Unit I: Introduction

History and scope, classification of nanostructured materials, Fascinating nanostructures, applications of nanomaterials

Unit II: Unique properties of nanomaterials

Microstructure and defects in nanocrystalline materials – dislocations, Twins, stacking faults and voids, Grain boundaries, triple junctions and disclinations.

Effect of nano-dimensions on materials behavior – Elastic properties, magnetic properties, electrical properties, optical properties, thermal properties, and mechanical properties.

Unit III: Synthesis Routes

Bottom-up approaches – PVD, CVD, sol-gel process, wet chemical synthesis and self-assembly.

Top-down approaches – mechanical alloying, nanolithography.

Unit IV: Tools to Characterize Nanomaterials

Scanning electron microscopy, transmission electron microscopy, x-ray diffraction, atomic force microscopy, nanoindentation

Unit V: Applications of Nanomaterials

Nano-electronics, Micro- and Nano-electromechanical systems (MEMS/NEMS), Nano sensors, Nano catalyst, Food and Agriculture Industry, Cosmetics and Consumer Goods, Structure and Engineering, Automotive Industry, Water Treatment and the Environment, Nano-medical Applications, Textiles, Paints, Energy, Defense and Space Applications.

Textbooks:

1. Murty BS, Shankar P, Baldev Raj, Rath BB, James Murday. Textbook of Nanoscience and Nanotechnology. Bangalore: Springer; 2013.
2. Introduction to Nanotechnology – Charles P. Poole, Jr., and Frank J. Owens, Wiley India Edition, 2012.

Suggested Readings:

1. Nano: The Essentials by T. Pradeep, Mc Graw- Hill Education.
2. Nanomaterials, Nanotechnologies and Design by Michael F. Ashby, Paulo J. Ferreira, and Daniel L. Schodek
3. Transport in Nano structures- David Ferry, Cambridge University press 2000.
4. Nanofabrication towards biomedical application: Techniques, tools, Application, and impact – Ed. Challa S., S. R. Kumar, J. H. Carola.
5. Carbon Nanotubes: Properties and Applications- Michael J. O'Connell.
6. Electron Transport in Mesoscopic systems - S. Dutta, Cambridge University press.

Online Resources:

1. Nanotechnology, Science and Applications by Prof. Prathap Haridoss, IIT Madras https://onlinecourses.nptel.ac.in/noc22_mm33/preview
2. Introduction to Nanoscience and Nanotechnology, Prof. Dr. Swapna Nair, Central University of Kerala https://onlinecourses.swayam2.ac.in/cec24_cy03/preview

22CHO03

INDUSTRIAL POLLUTION CONTROL

(Open Elective)

Instruction	3 Hours per week
Duration of SEE	3 Hrs
CIE	40 Marks
SEE	60 Marks
Credits	3

Course Objectives: This course will help the students to understand the:

1. Effects of pollution on environment and ecosystems
2. Types and sources of pollution
3. Measurement of air and water pollution
4. Different methods and equipment used in pollution abatement
5. Management practices in solid and hazardous wastes.

Course Outcomes: After the completion of this course, students will be able to

1. Differentiate the types of wastes generated in an industry, their effects on living and non-living things
2. Understand the effect of climate changes, atmospheric dispersion of air pollutants, and operating principles.
3. Understand working principles of particulate control devices.
4. Quantify wastewater and Assess treatment technologies for wastewater
5. Select treatment methodologies for hazardous and E-waste

CO-PO-PSO Matrix

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
CO1	2	1	1	1	1	2	1	1	1	1	2		
CO2	2	2	2	2	1	2	1	1	1	1	2		
CO3	2	2	1	1	1	2	1	1	1	1	2		
CO4	2	1	2	1	1	3	1	1	1	1	2		
CO5	2	2	2	2	1	3	1	1	1	1	2		

UNIT- I: Introduction

Definition and types of pollution. Effects of pollution on environment and ecosystems - global warming - greenhouse effect. Laws and standards for pollution. Sources, types, characteristics and effects of air pollutants, liquid effluents, solid wastes industries.

UNIT- II: Air Pollution

Meteorological aspects of pollution dispersion, Temperature lapse rates, Turbulence and stability of atmosphere. Indoor air pollution - smoke and hydrocarbons. Richardson Number, Plume raise, plume behavior and characteristics, effective stack height.

UNIT III: **Air Pollution General Control Methods and Equipment:**

Removal of sulphur dioxide, oxides of nitrogen and carbon, organic vapors from gaseous effluents. Removal of particulate matter - principle and working of settling chambers cyclone separators solid traps, fabric and fiber filters, electro-static precipitators.

UNIT IV: Introduction to water pollution –Origin of wastewater, types of water pollutants and their effects., Determination of organic matter, Determination of inorganic substances, Physical characteristics, Bacteriological measurement, Zero liquid discharge, wastewater treatment methods – RO, UF, Grey water recycling.

UNIT –V: Solid and Hazardous Waste

Solid waste management: Sources and classification, Public health aspects, Methods of collection, Disposal Methods,. Hazardous waste management: Definition and sources, Hazardous waste classification, Treatment methods, Disposal methods. E-waste: Sources, environmental and social issues, management practices.

Text Books

1. C.S.Rao, "Environmental Pollution Control Engineering", 3rd Ed, New Age International, 2018.
2. S.C. Bhatia, " Solid And Hazardous Waste Management ", Atlantic Publishers, 2021

Suggested Reading:

1. Metcalf and Eddy, "Wastewater Engineering: Treatment and Reuse", 4th Ed, MGH publishing, 2004.
2. M.N Rao and H.V.N Rao, "Air Pollution", Tata McGraw- Hill Publishing Company Limited, New Delhi, 2000.
3. Lakshmi Raghupathy, "Introduction to E-Waste Management" TERI Press,
4. Peavy, H.S., Rowe, D.R. and Technobanolous, G., "Environmental Engineering", McGraw Hill, 1985.

Online resources:

1. Basic Environmental Engineering and Pollution Abatement

   https://archive.nptel.ac.in/courses/103/107/103107215/

22CH O04 **ENVIRONMENTAL AND SUSTAINABLE DEVELOPMENT**

(Open Elective)

Instruction	3(3L+0T) Hours per week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Course Objectives: This course will help the students:

1. To have an increased awareness on issues in areas of sustainability
2. To understand the role of engineering & technology within sustainable development
3. To know the methods, tools and incentives for sustainable product service system development
4. To establish a clear understanding of the role and impact of various aspects of engineering decisions on environmental, societal and economic problems.
5. To communicate results related to their research on sustainable engineering

Course Outcomes: At the completion of this course, students will be able to:

1. Understand the concept of sustainable engineering and its significance in addressing contemporary environmental challenges.
2. Explore the 4R concept of solid waste management and examine various tools and methodologies to assess and mitigate the environmental impacts of engineering activities.
3. To be aware of the principles and requirements of environmental management standards and their application in promoting environmental sustainability.
4. Analyze the challenges and opportunities associated with promoting sustainable habitats such as sustainable cities, sustainable transport, sustainable sources of energy conventional and sustainable materials for green buildings
5. Understand and evaluate the industrial processes through the principles of industrial ecology and industrial symbiosis.

CO-PO-PSO Matrix

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
CO1	2	1	3	1	1	3	2	1	1	1	3		
CO2	2	2	3	2	1	3	2	1	1	1	3		
CO3	2	1	3	1	2	3	2	1	2	1	3		
CO4	3	1	3	3	1	3	2	2	1	1	3		
CO5	3	3	3	1	2	3	2	1	1	2	3		

UNIT I

Introduction of sustainability- Need and concept of Sustainable Engineering, Social-environmental and economic sustainability concepts, Sustainable development and challenges, Sustainable Development Goals, Environmental acts and protocols – Clean Development Mechanism (CDM).

UNIT II

Economic and social factors affecting sustainability, Effects of pollution from natural sources, Solid waste-sources, impacts, 4R (Reduce, Reuse, Recycling, Recover) concept, Ozone layer depletion, Global warming, Tools used to ensure sustainability in engineering activities such as environmental management systems and environmental impact assessment studies.

UNIT III

Global, Regional and Local environmental issues, Carbon credits and Carbon trading, Carbon foot print, Environmental management standards, ISO 14000 series, Life cycle Analysis (LCA)-scope and goal, Procedures of EIA (Environment Impact Assessment) in India.

UNIT IV

Basic concept of sustainable habitat-Sustainable cities, Sustainable transport, Sustainable sources of energy conventional and renewable sources, Green Engineering: Green buildings, Green materials for sustainable design, Methods for increasing energy efficiencies of buildings**.**

UNIT V

Technology and sustainable development, Sustainable urbanization, Industrialization and poverty reduction, Social and Technological change, Industrial processes-material selection, Pollution prevention, Industrial ecology, Industrial symbiosis.

Text book:

1. Rag R. L., Introduction to Sustainable Engineering, 2nd Ed, PHI Learning Pvt Ltd, 2016.
2. Allen D. T and Shonnard D. R., Sustainability Engineering Concepts, Design and Case Studies, 1 st Ed, Prentice Hall, 2011.

Suggested Reading

1. Bradley A. S, Adebayo A. O and Maria. P., Engineering Applications in Sustainable Design and Development, 1st Ed, Cengage Learning, 2016.
2. Krishna R. Reddy, Claudio Cameselle, Jeffrey A. Adams., Sustainable Engineering,1st Ed, Wiley, 2019.

Online resources:

1. Sustainable Engineering concepts and Life cycle analysis
   https://archive.nptel.ac.in/courses/105/105/105105157/
2. Sustainable Energy Technology
   https://onlinecourses.nptel.ac.in/noc23_me138/preview

22CHO05 **MATERIAL SCIENCE AND ENGINEERING**
(Open Elective)

Instruction	3 L Hours per week
Duration of SEE	3Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Course Objectives: This course helps the students to understand the

1. Introduction to different types of engineering materials and alloys
2. Alloying elements and factors for material selection
3. Significant properties of engineering materials
4. Specific requirements of materials for high and low temperature applications.
5. Possible and latest alternatives available for standard engineering materials.

Course outcomes: Upon completing this course, students will be able to:

1. Classify different engineering materials as ferrous and non-ferrous alloys.
2. Compare mechanical and thermal properties of engineering materials
3. Select materials for high and low temperature applications.
4. Identify new or alternate materials for development and operation of process industry.
5. Understand the significance and applications of Biomaterials

CO, PO and PSO Correlation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
CO1	2	3	3	3	2	1	0	-	-	-	-		
CO2	3	3	3	3	3	2	1	-	-	-	-		
CO3	3	3	3	3	3	3	1	-	-	-	-		
CO4	3	3	3	3	3	3	1	-	-	-	-		
CO5	3	3	3	3	3	3	2	-	-	-	-		

UNIT-I Introduction to Engineering Materials: Classification – metals, non-metals, alloys; Criteria for material selection. Ferrous metals and alloys - types of steels like mild, carbon and stainless steel, common grades of steel – 304 and 316; Non-Ferrous metals and alloys of Aluminium, Copper and Nickel;

UNIT-II General Properties of Engineering Materials: Mechanical Properties: Stress-strain diagram, Elastic, Plastic, Anelastic and Viscoelastic behavior. Creep, Fatigue and Fracture strengthening mechanisms; **Thermal Properties:** Conductivity, Expansion, Protection, Diffusivity, Stresses and Shock resistance;

UNIT-III Materials for High and Low Temperature Applications: Classification, advantages, general properties and applications of engineering materials like Refractories, Ceramics, Super alloys, Composites

UNIT-IV New materials: Nano-materials: carbon nanotubes, fullerene, nanosensors; **Nanocomposites,** role of reinforcement-matrix interface strength on composite behaviour
Smart materials: Piezoelectrics, shape memory alloys, Magneto-strictive, electro-rheological materials, 3D printing.

UNIT-V Biomaterials: Biomaterials: Biocompatibility, advantages, properties, uses, Types - Nearly inert, surface active, resorbable.

Text Books

1. Materials Science and Engineering an Introduction, William D. Callister, Jr. 5thEd., John Wiley and Sons, Inc. 2002.

Suggested Readings:

1. Fundamentals of Smart Materials, Mohsen Shahinpoor, The Royal Society of Chemistry Publishing, U.K, 2020.
2. B. S. Mitchell An Introduction to Materials Engineering and Science for Chemical and Materials Engineers, John Wiley & Sons, 2004.
3. S. Upadhyaya and A. Upadhyaya, Material Science and Engineering, Anshan Publications, 2007.

Online Resources:

1. Nature And Properties of Materials, by Prof. Bisakh Bhattacharya, Department of Mechanical Engineering IIT Kanpur
   https://archive.nptel.ac.in/courses/112/104/112104203/

22CHO06 **SAFETY AND HAZARD MANAGEMENT**
(Open Elective)

Instruction	3Hours per week
Duration of SEE	3 Hours
SEE	60 Marks
CIE	40 Marks
Credits	3

Course Objectives: This course will help the students to understand the

1. Importance of safety culture in process industry.
2. Disregard for ethical decision making based on numerous case studies.
3. Interaction and implementation of trade-offs concept in chemical plant operation.
4. Examples of problems that can occur with inadequate process design, improper process modification.
5. Different case studies related to industrial processes

Course outcomes: At the completion of this course, students will be able to

1. Analyze chemical incidents and possible consequences to plant facilities, workers, and the general public.
2. Evaluate effect of chemical hazards and risks of toxicants.
3. Understand the safety aspects and safety audit norms for chemical process plant
4. Analyze fire and explosion hazards.
5. Integrate safety concepts into chemical plant design.

CO-PO-PSO Matrix

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
CO1	3	2	3	2	-	-	-	-	-	1	1		
CO2	3	3	2	1	-	-	-	-	-	-	-		
CO3	3	3	2	1	-	-	-	-	-	-	-		
CO4	3	3	3	1	-	-	-	-	-	1	1		
CO5	3	3	2	1	-	-	-	-	-	-	-		

Unit-I: Introduction:
Safety program, engineering ethics, concept of loss prevention, accident and loss statistics, acceptable risks, nature of accident process, inherent safety. Case studies of major disasters: Chernobyl disaster, Bhopal disaster, recent oil spills.

UNIT – III: Toxicology and Industrial Hygiene:
Toxic materials and their properties, toxicants entry route, dose versus response, models for dose and response curves, threshold limit values, Effects of toxic Agents, Industrial hygiene anticipation and identification, industrial hygiene evaluation, hygiene control.

UNIT – II: Hazard identification and Risk Assessment:
Process hazards checklists, hazard survey, hazards and operability studies (HAZOP), safety reviews, other methods, review of probability theory, event tree, and fault tree, QRA, OSHA and LOPA, Risk assessment procedures.

UNIT – IV: **Fires and explosions:**
Definition of fire, fire triangle, Classification of fires as Class-A, B, C and D, causes of fire and preventive fire and explosion hazards, methods types of explosions, explosion index, explosion-proof equipment and instruments, Fire extinguishers: Portable fire extinguishers applications and their uses..

UNIT – V: Emergency preparation and accident investigation:
On-site and off-site emergency plan and infrastructure, learning from accidents, layered investigation, equipment aiding in diagnosis. Safety audit: Introduction, essentials, requirements, programs and procedures.

Text Books

1. D. A. Crowl and J.F. Louvar, "Chemical Process Safety", Prentice Hall, New Delhi, 2011.
2. Howard H. Fawcett and W. S. Wood, "Safety & Accident prevention in chemical operations", 2nd Ed., John Wiley and Sons Inc, 1982.

Suggested Reading:

1. Coulson and Richadson, “Chemical Engineering Design”, 3rd ed., Vol 6, TMH, 1999.
2. Fulekar M.H, “Industrial Hygiene and Chemical Safety”, I.K. International Publisher, 2006.
3. Sanders R.E., “Chemical Process Safety: Learning from case Histories”, Butterworth-Heinemann (Elsevier) pub, 2005.

Online Resources:

1. Chemical Process Safety, by Prof. Shishir Sinha, Department of Chemical Engineering IIT Roorkee https://archive.nptel.ac.in/courses/103/107/103107156/
2. Industrial Safety Engineering, by Prof. Jhareswar Maiti, Department of Industrial & Systems Engineering IIT Kharagpur https://archive.nptel.ac.in/courses/110/105/110105094/
3. Safety And Risk Analytics, Prof. Jhareswar Maiti, Department of Industrial & Systems Engineering IIT Kharagpur https://archive.nptel.ac.in/courses/110/105/110105160/