ANNA UNIVERSITY, CHENNAI
AFFILIATED INSTITUTIONS
B. TECH. CHEMICAL ENGINEERING
REGULATIONS 2017
CHOICE BASED CREDIT SYSTEM
OPEN ELECTIVES (Offered by other Branches)

OPEN ELECTIVE I, SEMESTER V

S. No.	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1.	OCE551	Air Pollution and Control Engineering	OE	3	3	0	0	3
2.	OIT552	Cloud Computing	OE	3	3	0	0	3
3.	OEC551	Control Systems Engineering	OE	3	3	0	0	3
4.	OIC501	Basic Control Theory	OE	3	3	0	0	3
5.	OME551	Energy Conservation and Management	OE	3	3	0	0	3
6.	OCY552	Fuel Cell Chemistry	OE	3	3	0	0	3
7.	OCE552	Geographic Information System	OE	3	3	0	0	3
8.	OMD552	Hospital Waste Management	OE	3	3	0	0	3
9.	OAI552	Participatory Water Resources Management	OE	3	3	0	0	3
10.	ORO551	Renewable Energy Sources	OE	3	3	0	0	3

OPEN ELECTIVE II, SEMESTER VII

S. No.	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1.	OGI751	Climate Change and Its Impact	OE	3	3	0	0	3
2.	OME751	Design of Experiments	OE	3	3	0	0	3
3.	OCE751	Environmental and Social Impact Assessment	OE	3	3	0	0	3
4.	OAE751	Fundamentals of combustion	OE	3	3	0	0	3
5.	OEN751	Green Building Design	OE	3	3	0	0	3
6.	OME754	Industrial Safety	OE	3	3	0	0	3
7.	ORO751	Nano Computing	OE	3	3	0	0	3
8.	OML753	Selection of Materials	OE	3	3	0	0	3
9.	OML751	Testing of Materials	OE	3	3	0	0	3

OCE551　　　　　AIR POLLUTION AND CONTROL ENGINEERING　　　L T P C
　　　3 0 0 3

OBJECTIVE:
- To impart knowledge on the principle and design of control of Indoor/ particulate/ gaseous air pollutant and its emerging trends.

UNIT I　　　INTRODUCTION　　　　　　　　　　　　　　　　　7
Structure and composition of Atmosphere – Definition, Scope and Scales of Air Pollution – Sources and classification of air pollutants and their effect on human health, vegetation, animals, property, aesthetic value and visibility- Ambient Air Quality and Emission standards.

UNIT II　　　METEOROLOGY　　　　　　　　　　　　　　　　　6
Effects of meteorology on Air Pollution - Fundamentals, Atmospheric stability, Inversion, Wind profiles and stack plume patterns- Atmospheric Diffusion Theories – Dispersion models, Plume rise.

UNIT III　　　CONTROL OF PARTICULATE CONTAMINANTS　　　　　11
Factors affecting Selection of Control Equipment – Gas Particle Interaction – Working principle - Gravity Separators, Centrifugal separators Fabric filters, Particulate Scrubbers, Electrostatic Precipitators.

UNIT IV　　　CONTROL OF GASEOUS CONTAMINANTS　　　　　　11
Factors affecting Selection of Control Equipment – Working principle - absorption, Adsorption, condensation, Incineration, Bio filters – Process control and Monitoring.

UNIT V　　　INDOOR AIR QUALITY MANAGEMENT　　　　　　　10
Sources, types and control of indoor air pollutants, sick building syndrome and Building related illness- Sources and Effects of Noise Pollution – Measurement – Standards –Control and Preventive measures.

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OUTCOMES:
The students completing the course will have
- an understanding of the nature and characteristics of air pollutants, noise pollution and basic concepts of air quality management
- ability to identify, formulate and solve air and noise pollution problems
- ability to design stacks and particulate air pollution control devices to meet applicable standards.
- Ability to select control equipments.
- Ability to ensure quality, control and preventive measures.

TEXTBOOKS:
1. Lawrence K. Wang, Norman C. Pareira, Yung Tse Hung, "Air Pollution Control Engineering", Tokyo, springer science + science media LLC,2004.
2. Noel de Nevers, "Air Pollution Control Engineering", Waveland press,Inc 2017.
3. Anjaneyulu. Y, "Air Pollution and Control Technologies", Allied Publishers (P) Ltd., India 2002.

REFERENCES:
1. David H.F. Liu, Bela G. Liptak, "Air Pollution", Lweis Publishers, 2000.

2. Arthur C. Stern, "Air Pollution (Vol.I – Vol.VIII)", Academic Press, 2006.
3. Wayne T.Davis, "Air Pollution Engineering Manual", John Wiley & Sons, Inc, 2000.
4. M.N Rao and HVN Rao, "Air Pollution",Tata Mcgraw Hill Publishing Company limited,2007.
5. C.S.Rao, "Environmental Pollution Control Engineering",New Age International(P) Limited Publishers,2006.

OIT552   **CLOUD COMPUTING**   **L T P C**
                                                               3 0 0 3

OBJECTIVES:
- To learn about the concept of cloud and utility computing.
- To have knowledge on the various issues in cloud computing.
- To be familiar with the lead players in cloud.
- To appreciate the emergence of cloud as the next generation computing paradigm.

UNIT I   INTRODUCTION TO CLOUD COMPUTING   9
Introduction to Cloud Computing – Roots of Cloud Computing – Desired Features of Cloud Computing – Challenges and Risks – Benefits and Disadvantages of Cloud Computing.

UNIT II   VIRTUALIZATION   9
Introduction to Virtualization Technology – Load Balancing and Virtualization – Understanding Hypervisor – Seven Layers of Virtualization – Types of Virtualization – Server, Desktop, Application Virtualization.

UNIT III   CLOUD ARCHITECTURE, SERVICES AND STORAGE   9
NIST Cloud Computing Reference Architecture – Public, Private and Hybrid Clouds - IaaS – PaaS – SaaS – Architectural Design Challenges – Cloud Storage.

UNIT IV   RESOURCE MANAGEMENT AND SECURITY IN CLOUD   9
Inter Cloud Resource Management – Resource Provisioning Methods – Security Overview – Cloud Security Challenges – Data Security –Application Security – Virtual Machine Security.

UNIT V   CASE STUDIES   9
Google App Engine(GAE) – GAE Architecture – Functional Modules of GAE – Amazon Web Services(AWS) – GAE Applications – Cloud Software Environments – Eucalyptus – Open Nebula – Open Stack.

                                                       TOTAL: 45 PERIODS
OUTCOMES:
On Completion of the course, the students should be able to:
- Articulate the main concepts, key technologies, strengths and limitations of cloud computing.
- Learn the key and enabling technologies that help in the development of cloud.
- Develop the ability to understand and use the architecture of compute and storage cloud, service and delivery models.
- Explain the core issues of cloud computing such as resource management and security.
- Be able to install and use current cloud technologies.

- Choose the appropriate technologies, algorithms and approaches for implementation and use of cloud.

TEXT BOOKS:
1. Buyya R., Broberg J., Goscinski A., "Cloud Computing: Principles and Paradigm", First Edition, John Wiley & Sons, 2011.
2. Kai Hwang, Geoffrey C. Fox, Jack G. Dongarra, "Distributed and Cloud Computing, From Parallel Processing to the Internet of Things", Morgan Kaufmann Publishers, 2012.
3. Rittinghouse, John W., and James F. Ransome, "Cloud Computing: Implementation, Management, And Security", CRC Press, 2017.

REFERENCES:
1. Rajkumar Buyya, Christian Vecchiola, S. ThamaraiSelvi, "Mastering Cloud Computing", Tata Mcgraw Hill, 2013.
2. Toby Velte, Anthony Velte, Robert Elsenpeter, "Cloud Computing - A Practical Approach", Tata Mcgraw Hill, 2009.
3. George Reese, "Cloud Application Architectures: Building Applications and Infrastructure in the Cloud: Transactional Systems for EC2 and Beyond (Theory in Practice)", O'Reilly, 2009.

OEC551	CONTROL SYSTEMS ENGINEERING	L	T	P	C
		3	0	0	3

OBJECTIVES:
- To introduce the components and their representation of control systems
- To learn various methods for analyzing the time response, frequency response and stability of the systems.
- To learn the various approach for the state variable analysis.

UNIT I   SYSTEMS COMPONENTS AND THEIR REPRESENTATION   9

Control System: Terminology and Basic Structure-Feed forward and Feedback control theory-Electrical and Mechanical Transfer Function Models-Block diagram Models-Signal flow graphs models-DC and AC servo Systems-Synchros -Multivariable control system

UNIT II   TIME REPONSE ANALYSIS   9

Transient response-steady state response-Measures of performance of the standard first order and second order system-effect on an additional zero and an additional pole-steady error constant and system- type number-PID control-Analytical design for PD,PI,PID control systems

UNIT III   FREQUENCY RESPONSE AND SYSTEM ANALYSIS   9

Closed loop frequency response-Performance specification in frequency domain-Frequency response of standard second order system- Bode Plot - Polar Plot- Nyquist plots-Design of compensators using Bode plots-Cascade lead compensation-Cascade lag compensation-Cascade lag-lead compensation

UNIT IV   CONCEPTS OF STABILITY ANALYSIS   9

Concept of stability-Bounded - Input Bounded - Output stability-Routh stability criterion-Relative stability-Root locus concept-Guidelines for sketching root locus-Nyquist stability criterion.

UNIT V   CONTROL SYSTEM ANALYSIS USING STATE VARIABLE METHODS   9

State variable representation-Conversion of state variable models to transfer functions-Conversion of transfer functions to state variable models-Solution of state equations-Concepts of Controllability and

Observability-Stability of linear systems-Equivalence between transfer function and state variable representations-State variable analysis of digital control system-Digital control design using state feedback.

TOTAL:45 PERIODS

OUTCOMES:
Upon completion of the course, the student should be able to:
- Identify the various control system components and their representations.
- Analyze the various time domain parameters.
- Analysis the various frequency response plots and its system.
- Apply the concepts of various system stability criterions.
- Design various transfer functions of digital control system using state variable models.

TEXT BOOK:
1. M.Gopal, "Control System – Principles and Design", Tata McGraw Hill, 4th Edition, 2012.

REFERENCES
1. J.Nagrath and M.Gopal, "Control System Engineering", New Age International Publishers, 5 th Edition, 2007.
2. K. Ogata, 'Modern Control Engineering', 5th edition, PHI, 2012.
3. S.K.Bhattacharya, Control System Engineering, 3rd Edition, Pearson, 2013.
4. Benjamin.C.Kuo, "Automatic control systems", Prentice Hall of India, 7th Edition,1995.

OIC501	BASIC CONTROL THEORY	L T P C
		3 0 0 3

OBJECTIVES:
- To understand the use of transfer function models for analysis physical systems and introduce the control system components.
- To provide adequate knowledge in the time response of systems and steady state error analysis.
- To accord basic knowledge in obtaining the open loop and closed–loop frequency responses of systems.
- To introduce stability analysis
- To introduce state variable representation of physical systems

UNIT I   SYSTEMS AND THEIR REPRESENTATION   9
Basic elements in control systems – Open and closed loop systems – Electrical analogy of mechanical and thermal systems – Transfer function – Block diagram reduction techniques.

UNIT II   TIME RESPONSE   9
Time response – Time domain specifications – Types of test input – I and II order system response – Error coefficients –Steady state error –Time response analysis.

UNIT III   FREQUENCY RESPONSE   9
Frequency response – Bode plot – Polar plot – Determination of closed loop response from open loop response - Effect of adding poles and zeros in the control loop - frequency response Analysis.

UNIT IV   STABILITY AND COMPENSATOR DESIGN   9
Characteristics equation – Routh Hurwitz criterion – controller design.

UNIT V   STATE VARIABLE ANALYSIS   9

Concept of state variables – State models for linear and time invariant Systems – Solution of state and equation in controllable canonical form – Concepts of controllability and observability –Effect of state feedback.

TOTAL : 45 PERIODS

OUTCOMES:
- Ability to understand and apply control theory to engineering problems.

TEXT BOOKS:
1. M. Gopal, 'Control Systems, Principles and Design', 4th Edition, Tata McGraw Hill, New Delhi, 2012
2. S.K.Bhattacharya, Control System Engineering, 3rd Edition, Pearson, 2013.
3. Dhanesh. N. Manik, Control System, Cengage Learning, 2012.

REFERENCES:
1. Arthur, G.O.Mutambara, Design and Analysis of Control; Systems, CRC Press, 2009.
2. Richard C. Dorf and Robert H. Bishop, " Modern Control Systems", Pearson Prentice Hall, 2012.
3. Benjamin C. Kuo, Automatic Control systems, 7th Edition, PHI, 2010.
4. K. Ogata, 'Modern Control Engineering', 5th edition, PHI, 2012.
5. S.N.Sivanandam, S.N.Deepa, Control System Engineering using Mat Lab, 2nd Edition, Vikas Publishing, 2012.
6. S.Palani, Anoop. K.Jairath, Automatic Control Systems including Mat Lab, Vijay Nicole/ Mcgraw Hill Education, 2013.

OME551   ENERGY CONSERVATION AND MANAGEMENT   L T P C
                                                                    3 0 0 3

OBJECTIVES:
At the end of the course, the student is expected to
- understand and analyse the energy data of industries
- carryout energy accounting and balancing
- conduct energy audit and suggest methodologies for energy savings and
- utilise the available resources in optimal ways

UNIT I   INTRODUCTION   9
Energy - Power – Past & Present scenario of World; National Energy consumption Data – Environmental aspects associated with energy utilization – Energy Auditing: Need, Types, Methodology and Barriers. Role of Energy Managers. Instruments for energy auditing.

UNIT II   ELECTRICAL SYSTEMS   9
Components of EB billing – HT and LT supply, Transformers, Cable Sizing, Concept of Capacitors, Power Factor Improvement, Harmonics, Electric Motors - Motor Efficiency Computation, Energy Efficient Motors, Illumination – Lux, Lumens, Types of lighting, Efficacy, LED Lighting and scope of Encon in Illumination.

UNIT III   THERMAL SYSTEMS   9
Stoichiometry, Boilers, Furnaces and Thermic Fluid Heaters – Efficiency computation and encon measures. Steam: Distribution &U sage: Steam Traps, Condensate Recovery, Flash Steam Utilization, Insulators & Refractories

UNIT IV   ENERGY CONSERVATION IN MAJOR UTILITIES   9

Pumps, Fans, Blowers, Compressed Air Systems, Refrigeration and Air Conditioning Systems – Cooling Towers – D.G. sets

UNIT V ECONOMICS 9
Energy Economics – Discount Rate, Payback Period, Internal Rate of Return, Net Present Value, Life Cycle Costing –ESCO concept

TOTAL: 45 PERIODS

OUTCOMES:
Upon completion of this course, the students can able to analyse the energy data of industries.
- Can carryout energy accounting and balancing
- Can suggest methodologies for energy savings

TEXT BOOKS:
1. Energy Manager Training Manual (4 Volumes) available at www.energymanager training.com,a website administered by Bureau of Energy Efficiency (BEE), a statutory body under Ministry of Power, Government of India, 2004.

REFERENCES:
1. Witte. L.C., P.S. Schmidt, D.R. Brown, "Industrial Energy Management and Utilisation" Hemisphere Publ, Washington, 1988.
2. Callaghn, P.W. "Design and Management for Energy Conservation", Pergamon Press, Oxford, 1981.
3. Dryden. I.G.C., "The Efficient Use of Energy" Butterworths, London, 1982
4. Turner. W.C., "Energy Management Hand book", Wiley, New York, 1982.
5. Murphy. W.R. and G. Mc KAY, "Energy Management", Butterworths, London 1987.

OCY552	FUEL CELL CHEMISTRY	L T P C
		3 0 0 3

OBJECTIVES
- To create awareness about alternate clean fuel available.
- To familiarize the students with the concepts and chemistry of fuel cell

UNIT I INTRODUCTION 9
Overview of fuel cells: Low and high temperature fuel cells; Fuel cell thermodynamics - heat, work potentials, prediction of reversible voltage, fuel cell efficiency.

UNIT II FUEL CELL KINETICS 9
Fuel cell reaction kinetics - electrode kinetics, overvoltage, Tafel equation, charge transfer reaction, exchange currents, electro catalysis - design, activation kinetics, Fuel cell charge and mass transport - flow field, transport in electrode and electrolyte.

UNIT III CHARACTERIZATION TECHNIQUES 9
Fuel cell characterization - in-situ and ex-situ characterization techniques, i-V curve, frequency response analysis; Fuel cell modeling and system integration: - 1D model – analytical solution and CFD models.

UNIT IV RENEWABLE SOURCES 9
Balance of plant; Hydrogen production from renewable sources and storage; safety issues, cost expectation and life cycle analysis of fuel cells.

UNIT V APPLICATIONS OF FUEL CELL 9

Fuel cell power plants: fuel processor, fuel cell power section (fuel cell stack), power conditioner; automotive applications, portable applications

TOTAL: 45 PERIODS

OUTCOME

- Students will be aware of alternate energy sources and its importance of it.

TEXTBOOKS
1. Gregor Hoogers, "Fuel Cell Technology Handbook", CRC Press, 2003.
2. R.P. O'Hayre,S. Cha, W. Colella, F.B. Prinz, "Fuel Cell Fundamentals", Wiley, 2006.
3. A. J.Bard, L. R. Faulkner, "Electrochemical Methods", Wiley, 2004.

REFERENCES
1. S. Basu, "Fuel Cell Science and Technology", Springer, 2007.
2. H. Liu, "Principles of Fuel Cells", Taylor & Francis, 2006.

OCE552	GEOGRAPHIC INFORMATION SYSTEM	L T P C
		3 0 0 3

OBJECTIVES :

- To introduce the fundamentals and components of Geographic Information   System
- To provide details of spatial data structures and input, management and output processes.

UNIT I   FUNDAMENTALS OF GIS   9

Introduction to GIS - Basic spatial concepts - Coordinate Systems - GIS and Information Systems – Definitions – History of GIS - Components of a GIS – Hardware, Software, Data, People, Methods – Proprietary and open source Software - Types of data – Spatial, Attribute data- types of attributes – scales/ levels of measurements.

UNIT II   SPATIAL DATA MODELS   9

Database Structures – Relational, Object Oriented – ER diagram - spatial data models – Raster Data Structures – Raster Data Compression - Vector Data Structures - Raster vs Vector Models-TIN and GRID data models - OGC standards - Data Quality.

UNIT III   DATA INPUT AND TOPOLOGY   9

Scanner - Raster Data Input – Raster Data File Formats – Vector Data Input –Digitiser – Topology - Adjacency, connectivity and containment – Topological Consistency rules – Attribute Data linking – ODBC – GPS - Concept GPS based mapping.

UNIT IV   DATA ANALYSIS   9

Vector Data Analysis tools - Data Analysis tools - Network Analysis - Digital Education models - 3D data collection and utilisation.

UNIT V   APPLICATIONS   9

GIS Applicant - Natural Resource Management - Engineering - Navigation - Vehicle tracking and fleet management - Marketing and Business applications - Case studies.

TOTAL: 45 PERIODS

OUTCOME:

This course equips the student to
- Have basic idea about the fundamentals of GIS.
- Understand the types of data models.
- Get knowledge about data input and topology.
- Gain knowledge on data quality and standards.
- Understand data management functions and data output

TEXT BOOKS:
1. Kang - Tsung Chang, Introduction to Geographic Information Systems, McGraw Hill Publishing, 2nd Edition, 2011.
2. Ian Heywood, Sarah Cornelius, Steve Carver, Srinivasa Raju, "An Introduction Geographical Information Systems, Pearson Education, 2nd Edition,2007.

REFERENCE:
1. Lo.C.P., Albert K.W. Yeung, Concepts and Techniques of Geographic Information Systems, Prentice-Hall India Publishers, 2006

OMD552	HOSPITAL WASTE MANAGEMENT	L T P C
		3 0 0 3

OBJECTIVES:
The student should be made to:
- Know about the healthcare hazard control and accidents
- Understand biomedical waste management
- Learn the facility guidelines, infection control and patient safety.

UNIT I   HEALTHCARE HAZARD CONTROL AND UNDERSTANDING ACCIDENTS   9
Healthcare Hazard Control: Introduction, Hazard Control: Management & Responsibilities, Hazard Analysis, Hazard Correction, Personal Protective Equipment, Hazard Control Committees, Accident Causation Theories, Accident Reporting, Accident Investigations, Accident Analysis, Accident Prevention, Workers' Compensation, Orientation, Education, and Training.

UNIT II   BIOMEDICAL WASTE MANAGEMENT   9
Biomedical Waste Management : Types of wastes, major and minor sources of biomedical waste, Categories and classification of biomedical waste, hazard of biomedical waste, need for disposal of biomedical waste, waste minimization, waste segregation and labeling, waste handling and disposal.

UNIT III   HAZARDOUS MATERIALS   9
Hazardous Materials : Hazardous Substance Safety, OSHA Hazard Communication Standard, DOT Hazardous Material Regulations, Healthcare Hazardous Materials, Medical Gas Systems, Respiratory Protection.

UNIT IV   FACILITY SAFETY   9
Introduction, Facility Guidelines: Institute, Administrative Area Safety, Slip, Trip, and Fall Prevention, Safety Signs, Colors, and Marking Requirements, Tool Safety, Electrical Safety, Control of Hazardous Energy, Landscape and Ground Maintenance, Fleet and Vehicle Safety.

UNIT V INFECTION CONTROL, PREVENTION AND PATIENT SAFETY 9

Healthcare Immunizations, Centers for Disease Control and Prevention, Disinfectants, Sterilants, and Antiseptics, OSHA Bloodborne Pathogens Standard, Tuberculosis, Healthcare Opportunistic Infections, Healthcare-Associated Infections, Medication Safety.

TOTAL : 45 PERIODS

OUTCOMES:
- After successful completion of the course, the students will be able to know the concepts of healthcare waste management, its prevention and safety.

REFERENCES:
1. Tweedy, James T., Healthcare hazard control and safety management-CRC Press_Taylor and Francis (2014).
2. Anantpreet Singh, Sukhjit Kaur, Biomedical Waste Disposal, Jaypee Brothers Medical Publishers (P) Ltd (2012).

OAI552   PARTICIPATORY WATER RESOURCES MANAGEMENT   L T P C
3 0 0 3

OBJECTIVE:
- To gain an insight on local and global perceptions and approaches on participatory water resource management

UNIT I FUNDAMENTALS: SOCIOLOGY AND PARTICIPATORY APPROACH 6

Sociology – Basic concepts – Perspectives- Social Stratification – Irrigation as a Socio technical Process - Participatory concepts– Objectives of participatory approach

UNIT II UNDERSTANDING FARMERS PARTICIPATION 10

Farmers participation –need and benefits – Comparison of cost and benefit -Sustained system performance - Kinds of participation – Context of participation, factors in the environment – WUA - Constraints in organizing FA – Role of Community Organiser – Case Studies.

UNIT III ISSUES IN WATER MANAGEMENT 9

Multiple use of water – Issues in Intersectoral Water Allocation - domestic, irrigation, industrial sectors - modernization techniques – Rehabilitation – Command Area Development - Water delivery systems

UNIT IV PARTICIPATORY WATER CONSERVATION 10

Global Challenges -Social – Economic – Environmental - Solutions –Political - Water Marketing – Water Rights -Consumer education – Success Stories Case Studies

UNIT V PARTICIPATORY WATERSHED DEVELOPMENT 10

Concept and significance of watershed - Basic factors influencing watershed development –- Principles of watershed management - Definition of watershed management – Identification of problems - Watershed approach in Government programmes –- People's participation – Entry point activities - Evaluation of watershed management measures.

TOTAL: 45 PERIODS

OUTCOMES:
The students will be able to
- Gain knowledge on various processes involved in participatory water resource management.

- Understand famers participation in water resources management.
- Aware of the issues related to water conservation and watershed development
- Get knowledge in participatory water conservation
- Understand concept , principle , approach of watershed management.

TEXTBOOKS:
1. Sivasubramaniyan, K. Water Management, SIMRES Publication, Chennai, 2011
2. Uphoff.N., Improving International Irrigation management with Farmer Participation – Getting the process Right – Studies in water Policy and management, No.11, Westview press, Boulder,CO, 1986.
3. Tideman, E.M., "Watershed Management", Omega Scientific Publishers, New Delhi, 1996.

REFERENCE:
1. Chambers Robert, Managing canal irrigation, Cambridge University Press, 1989

ORO551	RENEWABLE ENERGY SOURCES	L T P C
		3 0 0 3

OBJECTIVES:
- To get exposure on solar radiation and its environmental impact to power.
- To know about the various collectors used for storing solar energy.
- To know about the various applications in solar energy.
- To learn about the wind energy and biomass and its economic aspects.
- To know about geothermal energy with other energy sources.

UNIT I   PRINCIPLES OF SOLAR RADIATION   10
Role and potential of new and renewable source, the solar energy option, Environmental impact of solar power, physics of the sun, the solar constant, extraterrestrial and terrestrial solar radiation, solar radiation on titled surface, instruments for measuring solar radiation and sun shine, solar radiation data.

UNIT II   SOLAR ENERGY COLLECTION   8
Flat plate and concentrating collectors, classification of concentrating collectors, orientation and thermal analysis, advanced collectors.

UNIT III   SOLAR ENERGY STORAGE AND APPLICATIONS   7
Different methods, Sensible, latent heat and stratified storage, solar ponds. Solar Applications- solar heating/cooling technique, solar distillation and drying, photovoltaic energy conversion.

UNIT IV   WIND ENERGY   10
Sources and potentials, horizontal and vertical axis windmills, performance characteristics, Betz criteria BIO-MASS: Principles of Bio-Conversion, Anaerobic/aerobic digestion, types of Bio-gas digesters, gas yield, combustion characteristics of bio-gas, utilization for cooking, I.C.Engine operation and economic aspects.

UNIT V   GEOTHERMAL ENERGY: 9
Resources, types of wells, methods of harnessing the energy, potential in India. OCEAN ENERGY: OTEC, Principles utilization, setting of OTEC plants, thermodynamic cycles. Tidal and wave energy: Potential and conversion techniques, mini-hydel power plants, and their economics. DIRECT ENERGY CONVERSION: Need for DEC, Carnot cycle, limitations, principles of DEC.

OUTCOMES:
- Understanding the physics of solar radiation.
- Ability to classify the solar energy collectors and methodologies of storing solar energy.
- Knowledge in applying solar energy in a useful way.
- Knowledge in wind energy and biomass with its economic aspects.
- Knowledge in capturing and applying other forms of energy sources like wind, biogas and geothermal energies.

TEXT BOOKS:
1. Rai G.D. , "Non-Conventional Energy Sources", Khanna Publishers, 2011
2. Twidell & Wier, "Renewable Energy Resources", CRC Press (Taylor & Francis), 2011

REFERENCES:
1. Tiwari and Ghosal, "Renewable energy resources", Narosa Publishing House, 2007
2. Ramesh R & Kumar K.U , "Renewable Energy Technologies",Narosa Publishing House, 2004
3. Mittal K M , "Non-Conventional Energy Systems", Wheeler Publishing Co. Ltd, New Delhi, 2003
4. Kothari D.P, Singhal ., K.C., "Renewable energy sources and emerging technologies", P.H.I, New Delhi, 2010

OGI751   **CLIMATE CHANGE AND ITS IMPACT**   **L T P C**
                                                              3 0 0 3
OBJECTIVES:
- To understand the basics of weather and climate
- To have an insight on Atmospheric dynamics and transport of heat
- To develop simple climate models and evaluate climate changes using models

UNIT I   BASICS OF WEATHER AND CLIMATE: 9
Shallow film of Air– stratified & disturbed atmosphere – law – atmosphere Engine. Observation of parameters: Temperature – Humidity – Wind - Pressure – precipitation-surface – networks. Constitution of atmosphere: well stirred atmosphere – process around turbopause – in dry air – ozone – carbon Dioxide – Sulphur Dioxide– Aerosol - water. Evolution of Atmosphere. State of atmosphere: Air temperature – pressure – hydrostatic – Chemistry – Distribution – circulation

UNIT II   ATMOSPHERIC DYNAMICS: 9
Atmosphere dynamics: law – isobaric heating and cooling – adiabatic lapse rates – equation of motion - solving and forecasting. Forces – Relative and absolute acceleration – Earth's rotation *coriolis* on sphere – full equation of motion – Geostrophy;- Thermal winds –departures – small-scale motion. Radiation, convection and advections: sun & solar radiation – energy balance – terrestrial radiation and the atmosphere – Green house effect- Global warming - Global budget – radiative fluxes - heat transport. Atmosphere and ocean systems convecting & advecting heat. Surface and boundary layer – smaller scale weather system – larger scale weather system.

UNIT III   GLOBAL CLIMATE   9
Components and phenomena in the climate system: Time and space scales – interaction and parameterization problem. Gradients of Radiative forcing and energy transports by atmosphere

and ocean – atmospheric circulation – latitude structure of the circulation - latitude – longitude dependence of climate features. Ocean circulation: latitude – longitude dependence of climate features – ocean vertical structure – ocean *thermohaline* circulation – land surface processes – carbon cycle.

UNIT IV   CLIMATE SYSTEM PROCESSES   9
Conservation of motion: Force – *coriolis* - pressure gradient- velocity equations – Application – geotropic wind – pressure co-ordinates. Equation of State – atmosphere – ocean. Application: thermal circulation – sea level rise. Temperature equation: Ocean – air – Application – decay of sea surface temperature. Continuity equation: ocean – atmosphere. Application: coastal upwelling – equatorial upwelling – conservation of warm water mass.   Moisture and salinity equation: conservation of mass – moisture. Source & sinks – latent heat. Moist processes – saturation – convection – Wave processes in atmosphere and ocean.

UNIT V   CLIMATE CHANGE MODELS   9
Constructing a climate model – climate system modeling – climate simulation and drift – Evaluation of climate model simulation – regional (RCM) – global (GCM) – Global average response to warming – climate change observed to date. .

TOTAL: 45 PERIODS

OUTCOMES:
At the end of the course the student will be able to understand
- The concepts of weather and climate
- The principles of Atmospheric dynamics and transport of heat and air mass
- The develop simple climate models and to predict climate change

TEXTBOOKS:
1. Fundamentals of weather and climate (2nd Edition) Robin Moilveen (2010), Oxford University Press
2. Climate change and climate modeling, J. David Neelin (2011) Cambridge University press.

OME751	DESIGN OF EXPERIMENTS	L T P C
		3 0 0 3

OBJECTIVE:
- To impart knowledge on various types of experimental designs conduct of experiments and data analysis techniques.

UNIT I   FUNDAMENTALS OF EXPERIMENTAL DESIGNS   9
Hypothesis testing – single mean, two means, dependant/ correlated samples – confidence intervals, Experimentation – need, Conventional test strategies, Analysis of variance, F-test, terminology, basic principles of design, steps in experimentation – choice of sample size – Normal and half normal probability plot – simple linear and multiple linear regression, testing using Analysis of variance.

UNIT II   SINGLE FACTOR EXPERIMENTS   9
Completely Randomized Design- effect of coding the observations- model adequacy checking- estimation of model parameters, residuals analysis- treatment comparison methods-Duncan's multiple range test, Newman-Keuel's test, Fisher's LSD test, Tukey's test-testing using contrasts- Randomized Block Design – Latin Square Design- Graeco Latin Square Design –Applications.

UNIT III   FACTORIAL DESIGNS   9

Main and Interaction effects - Two and three factor full factorial designs- Fixed effects and random effects model - Rule for sum of squares and Expected Mean Squares- 2^K Design with two and three factors- Yate's Algorithm- fitting regression model- Randomized Block Factorial Design - Practical applications.

UNIT IV   SPECIAL EXPERIMENTAL DESIGN   9

Blocking and Confounding in 2^K Designs- blocking in replicated design- 2^K Factorial Design in two blocks- Complete and partial confounding- Confounding 2^K Design in four blocks- Two level Fractional Factorial Designs- one-half fraction of 2^K Design, design resolution, Construction of one-half fraction with highest design resolution, one-quarter fraction of 2^K Design

UNIT V   TAGUCHI METHODS   9

Design of experiments using Orthogonal Arrays, Data analysis from Orthogonal experiments- Response Graph Method, ANOVA- attribute data analysis- Robust design- noise factors, Signal to noise ratios, Inner/outer OA design.

TOTAL: 45 PERIODS

OUTCOME:

- Able to apply experimental techniques to practical problems to improve quality of processes / products by optimizing the process / product parameters.

TEXT BOOK:

1. Krishnaiah K, and Shahabudeen P, "Applied Design of Experiments and Taguchi Methods", PHI, India, 2011.

REFERENCES:

1. Douglas C. Montgomery, "Design and Analysis of Experiments", John Wiley & sons, 2005
2. Phillip J. Ross, "Taguchi Techniques for Quality Engineering", Tata McGraw-Hill, India, 2005.

OCE751	ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT	L T P C
		3 0 0 3

OBJECTIVE:

- To impart the knowledge and skills to identify, assess and mitigate the environmental and social impacts of developmental projects

UNIT I   INTRODUCTION   9

Impacts of Development on Environment – Rio Principles of Sustainable Development- Environmental Impact Assessment (EIA) – Objectives – Historical development – EIA Types – EIA in project cycle –EIA Notification and Legal Framework.

UNIT II   ENVIRONMENTAL ASSESSMENT   9

Screening and Scoping in EIA – Drafting of Terms of Reference,Baseline monitoring, Prediction and Assessment of Impact on land, water, air, noise, flora and fauna - Matrices – Networks – Checklist Methods - Mathematical models for Impact prediction.

UNIT III   ENVIRONMENTAL MANAGEMENT PLAN   9

Plan for mitigation of adverse impact on water, air and land, water, energy, flora and fauna – Environmental Monitoring Plan – EIA Report Preparation – Public Hearing-Environmental Clearance

UNIT IV SOCIO ECONOMIC ASSESSMENT 9

Baseline monitoring of Socio economic environment – Identification of Project Affected Personal – Rehabilitation and Resettlement Plan- Economic valuation of Environmental impacts – Cost benefit Analysis-

UNIT V CASE STUDIES 9

EIA case studies pertaining to Infrastructure Projects – Roads and Bridges – Mass Rapid Transport Systems - Airports - Dams and Irrigation projects - Power plants.

TOTAL: 45 PERIODS

OUTCOMES:

The students completing the course will have ability to
- carry out scoping and screening of developmental projects for environmental and social assessments
- explain different methodologies for environmental impact prediction and assessment
- plan environmental impact assessments and environmental management plans
- evaluate environmental impact assessment reports

TEXTBOOKS:

1. Canter, R.L, "Environmental impact Assessment ", 2nd Edition, McGraw Hill Inc, New Delhi,1995.
2. Lohani, B., J.W. Evans, H. Ludwig, R.R. Everitt, Richard A. Carpenter, and S.L. Tu, "Environmental Impact Assessment for Developing Countries in Asia", Volume 1 – Overview, Asian Development Bank,1997.
3. Peter Morris, Riki Therivel "Methods of Environmental Impact Assessment", Routledge Publishers,2009.

REFERENCES:

1. Becker H. A., Frank Vanclay,"The International handbook of social impact assessment" conceptual and methodological advances, Edward Elgar Publishing,2003.
2. Barry Sadler and Mary McCabe, "Environmental Impact Assessment Training Resource Manual", United Nations Environment Programme,2002.
3. Judith Petts, "Handbook of Environmental Impact Assessment Vol. I and II", Blackwell Science New York, 1998.
4. Ministry of Environment and Forests EIA Notification and Sectoral Guides, Government of India, New Delhi, 2010.

OAE751	FUNDAMENTALS OF COMBUSTION	L T P C
		3 0 0 3

OBJECTIVE:

- To make the student understand the fundamentals of combustion and to teach them combustion in different regions like basic flame to gas turbine engines to rocket engines and finally how it is done in supersonic speeds.

UNIT I INTRODUCTION TO COMBUSTION 9

Thermo-chemical equations –Heat of formation –Activation energy -Multi-step reactions - Heat of

reaction -first order, second order and third order reactions – Calculation of adiabatic flame temperature

UNIT II   BASICS OF CHEMICAL KINETICS AND FLAMES   9
Premixed flames –Diffusion flames –measurement of burning velocity – various methods –Effect of various parameters on burning velocity – flame stability –Deflagration – Detonation – Rankine-Hugoniot curve –Radiation by flames.

UNIT III   COMBUSTION IN GAS TURBINE ENGINES   9
Combustion in gas turbine combustion chambers -Recirculation – combustion efficiency, Factors affecting combustion efficiency-Fuels used for gas turbine combustion chambers – combustion stability –Flame holder types.

UNIT IV   COMBUSTION IN ROCKETS   9
Solid propellant grain types – types of solid propellant burning in rocket combustion chambers – basic mechanism of composite propellant combustion – solid propellant burn rate laws – criterion for stable combustion - combustion in liquid rocket engines – single fuel droplet combustion model – combustion in hybrid rockets.

UNIT V   SUPERSONIC COMBUSTION   (Qualitative Treatment only)   9
Introduction – supersonic combustion controlled by diffusion, mixing and heat convection – Analysis of reactions and mixing processes - supersonic burning with detonation shocks .

TOTAL: 45 PERIODS

OUTCOMES:
- The student will be in a position to understand the detailed mechanism of Aerospace Vehicles and Aircraft Engines.
- The student will be able to analyse and impart the combustion processes that occur in Aircraft Engines and Rocket Vehicles.

TEXT BOOK:
1. Sharma, S.P., and Chandra Mohan, "Fuels and Combustion", Tata Mc. Graw Hill Publishing Co., Ltd., New Delhi, 1987.

REFERENCES:
1. Beer, J.M., and Chiierar, N.A. "Combustion Aerodynamics", Applied Science Publishers Ltd., London, 1981.
2. Chowdhury, R., Applied Engineering Thermodynamics, Khanna Publishers, New Delhi, 1986.
3. Loh, W.H.T., "Jet, Rocket, Nuclear, Ion and Electric Propulsion: Theory and Design, Springer Verlag, New York, 1982.
4. Mathur, M.L. and Sharma, R.P., "Gas Turbine, Jet and Rocket Propulsion", Standard Publishers & Distributors, Delhi, 2nd edition 2014.
5. Sutton,G.P., Rocket Propulsion Elements, John Wiley, 1993.

OEN751   GREEN BUILDING DESIGN   L T P C
                                                                       3 0 0 3

UNIT I   ENVIRONMENTAL IMPLICATIONS OF BUILDINGS   9

Energy use, carbon emissions, water use, waste disposal; Building materials: sources, methods of production and environmental Implications. Embodied Energy in Building Materials: Transportation Energy for Building Materials; Maintenance Energy for Buildings.

UNIT II IMPLICATIONS OF BUILDING TECHNOLOGIES EMBODIED ENERGY OF BUILDINGS 9
Framed Construction, Masonry Construction. Resources for Building Materials, Alternative concepts. Recycling of Industrial and Buildings Wastes. Biomass Resources for buildings.

UNIT III COMFORTS IN BUILDING 9
Thermal Comfort in Buildings- Issues; Heat Transfer Characteristic of Building Materials and Building Techniques. Incidence of Solar Heat on Buildings-Implications of Geographical Locations.

UNIT IV UTILITY OF SOLAR ENERGY IN BUILDINGS 9
Utility of Solar energy in buildings concepts of Solar Passive Cooling and Heating of Buildings. Low Energy Cooling. Case studies of Solar Passive Cooled and Heated Buildings.

UNIT V GREEN COMPOSITES FOR BUILDINGS 9
Concepts of Green Composites. Water Utilisation in Buildings, Low Energy Approaches to Water Management. Management of Solid Wastes. Management of Sullage Water and Sewage. Urban Environment and Green Buildings. Green Cover and Built Environment.

TOTAL: 45 PERIODS

TEXT BOOKS:
1. K.S.Jagadish, B. U. Venkataramareddy and K. S. Nanjundarao. Alternative Building Materials and Technologies. New Age International, 2007.
2. Low Energy Cooling For Sustainable Buildings. John Wiley and Sons Ltd, 2009.
3. Sustainable Building Design Manual. Vol 1 and 2, Teri, New Delhi, 2004.

REFERENCES:
1. Osman Attmann Green Architecture Advanced Technologies and Materials. McGraw Hill, 2010.
2. Jerry Yudelson Green building Through Integrated Design. McGraw Hill, 2009.
3. Fundamentals of Integrated Design for Sustainable Building By Marian Keeler, Bill Burke

OME754 **INDUSTRIAL SAFETY** **L T P C**
3 0 0 3

OBJECTIVES :
- To impart knowledge on safety engineering fundamentals and safety management practices.

UNIT I INTRODUCTION 9
Evolution of modern safety concepts – Fire prevention – Mechanical hazards – Boilers, Pressure vessels, Electrical Exposure.

UNIT II CHEMICAL HAZARDS 9
Chemical exposure – Toxic materials – Ionizing Radiation and Non-ionizing Radiation - Industrial Hygiene – Industrial Toxicology.

UNIT III   ENVIRONMENTAL CONTROL   9

Industrial Health Hazards – Environmental Control – Industrial Noise - Noise measuring instruments, Control of Noise, Vibration, - Personal Protection.

UNIT IV   HAZARD ANALYSIS   9

System Safety Analysis –Techniques – Fault Tree Analysis (FTA), Failure Modes and Effects Analysis
(FMEA), HAZOP analysis and Risk Assessment

UNIT V   SAFETY REGULATIONS   9

Explosions – Disaster management – catastrophe control, hazard control ,Safety education and training - Factories Act, Safety regulations Product safety – case studies.

TOTAL : 45 PERIODS

OUTCOMES:

- Students must be able to identify and prevent chemical, environmental mechanical, fire hazard through analysis and apply proper safety techniques on safety engineering and management.

TEXT BOOK:

1. John V.Grimaldi, "Safety Management", AITB S Publishers, 2003.

REFERENCES:

1. Safety Manual, "EDEL Engineering Consultancy", 2000.
2. David L.Goetsch, "Occupational Safety and Health for Technologists", 5th Edition, Engineers and Managers, Pearson Education Ltd., 2005.

ORO751   **NANO COMPUTING**   **L T P C**
                                                3 0 0 3

OBJECTIVES:
The student should be made to:

- Learn nano computing challenges
- Be familiar with the imperfections
- Be exposed to reliability evaluation strategies
- Learn nano scale quantum computing
- Understand Molecular Computing and Optimal Computing

UNIT I   NANOCOMPUTING-PROSPECTS AND CHALLENGES   9

Introduction - History of Computing - Nanocomputing - Quantum Computers – Nanocomputing Technologies - Nano Information Processing - Prospects and Challenges - Physics of Nanocomputing: Digital Signals and Gates - Silicon Nanoelectronics - Carbon Nanotube Electronics - Carbon Nanotube Field-effect Transistors – Nanolithography.

UNIT II   NANOCOMPUTING WITH IMPERFECTIONS   9

Introduction - Nanocomputing in the Presence of Defects and Faults - Defect Tolerance - Towards Quadrillion Transistor Logic Systems.

UNIT III   RELIABILITY OF NANOCOMPUTING   9

Markov Random Fields - Reliability Evaluation Strategies - NANOLAB - NANOPRISM - Reliable Manufacturing and Behavior from Law of Large Numbers.

UNIT IV   NANOSCALE QUANTUM COMPUTING   9

Quantum Computers - Hardware Challenges to Large Quantum Computers - Fabrication, Test, and Architectural Challenges - Quantum-dot Cellular Automata (QCA) - Computing with QCA - QCA Clocking - QCA Design Rules.

UNIT V   QCADESIGNER SOFTWARE AND QCA IMPLEMENTATION   9

Basic QCA Circuits using QCA Designer - QCA Implementation - Molecular and Optical Computing: Molecular Computing - Optimal Computing - Ultrafast Pulse Shaping and Tb/sec Data Speeds.

TOTAL: 45 PERIODS

OUTCOMES:

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

- Discuss nano computing challenges.
- Handle the imperfections.
- Apply reliability evaluation strategies.
- Use nano scale quantum computing.
- Utilize Molecular Computing and Optimal Computing.

TEXT BOOK:

1. Sahni V. and Goswami D., Nano Computing, McGraw Hill Education Asia Ltd. (2008), ISBN (13): 978007024892.

REFERENCES:

1. Sandeep K. Shukla and R. Iris Bahar., Nano, Quantum and Molecular Computing, Kluwer Academic Publishers 2004, ISBN: 1402080670.
2. Sahni V, Quantum Computing, McGraw Hill Education Asia Ltd. 2007.
3. Jean-Baptiste Waldner, Nanocomputers and Swarm Intelligence, John Wiley & Sons, Inc. 2008, ISBN (13): 978-1848210097.

OML753	SELECTION OF MATERIALS	L T P C
		3 0 0 3

OBJECTIVES:

- The subject exposes students to the basics parameter for selection of materials and different classes of materials, manufacturing processes and their properties , applications of materials.

UNIT I   ENGINEERING MATERIALS   9

Introduction – classification of engineering materials – selection of materials for engineering purposes –selection of materials and shape –classification metal and alloys, polymers, ceramics and glasses, composites, natural materials,-non metallic materials- smart materials - physical, metrical properties of metals

UNIT II   MATERIAL PROPERTIES   9

Mechanical properties – fatigue strength – fracture Toughness - Thermal Properties - Magnetic Properties - Fabrication Properties –electrical , optical properties - Environmental Properties , Corrosion properties –shape and size - Material Cost and Availability– failure analysis

UNIT III   MANUFACTURING PROCESSING AND ECONOMIC ANALYSIS   9

Interaction of Materials Selection, Design, and Manufacturing Processes - Production Processes and Equipment for Metals - Metal Forming, Shaping, and Casting - Plastic Parts Processing - Composites Fabrication Processes - Advanced Ceramics Processing – surface treatment - Resource -The Price and Availability of Materials

UNIT IV   MATERIALS SELECTION CHARTS AND TESTING   9

Ashby material selection charts-Testing of Metallic Materials - Plastics Testing - Characterization and Identification of Plastics - Professional and Testing Organizations - Ceramics Testing - Nondestructive Inspection.

UNIT V   APPLICATIONS AND USES   9

Selection of Materials for Biomedical Applications - Medical Products - Materials in Electronic Packaging - Advanced Materials in Sports Equipment - Materials Selection for Wear Resistance - Advanced Materials in Telecommunications - Using Composites - Manufacture and Assembly with Plastics, fiber and Diamond Films.

TOTAL : 45 PERIODS

OUTCOMES:
- Understand different types of availability materials
- Easy and effective way to select required materials
- Ability to identify the material properties

TEXT BOOKS:
1. Ashby, M. F. Materials selection in mechanical design, 3rd edition. Elsevier, 2005.
2. Ashby, M. F. and Johnson, K. Materials and design – the art and science of material selection in product design. Elsevier, 2002.

REFERENCES:
1. Charles, J. A., Crane, F. A. A. and Furness, J. A. G. Selection and use of engineering materials, 3rd edition. Butterworth-Heinemann, 1997
2. Handbook of Materials Selection. Edited by Myer Kutz2002 John Wiley & Sons, Inc., NewYork.

OML751	TESTING OF MATERIALS	L T P C
		3 0 0 3

OBJECTIVE:
- To understand the various destructive and non destructive testing methods of materials and its industrial applications.

UNIT I   INTRODUCTION TO MATERIALS TESTING   9

Overview of materials, Classification of material testing, Purpose of testing, Selection of material, Development of testing, Testing organizations and its committee, Testing standards, Result Analysis, Advantages of testing.

UNIT II   MECHANICAL TESTING   9

Introduction to mechanical testing, Hardness test (Vickers, Brinell, Rockwell), Tensile test, Impact test (Izod, Charpy) - Principles, Techniques, Methods, Advantages and Limitations, Applications. Bend test, Shear test, Creep and Fatigue test - Principles, Techniques, Methods, Advantages and Limitations, Applications.

UNIT III   NON DESTRUCTIVE TESTING   9

Visual inspection, Liquid penetrant test, Magnetic particle test, Thermography test – Principles, Techniques, Advantages and Limitations, Applications. Radiographic test, Eddy current test, Ultrasonic test, Acoustic emission- Principles, Techniques, Methods, Advantages and Limitations, Applications.

UNIT IV   MATERIAL CHARACTERIZATION TESTING   9

Macroscopic and Microscopic observations, Optical and Electron microscopy (SEM and TEM) - Principles, Types, Advantages and Limitations, Applications. Diffraction techniques, Spectroscopic Techniques, Electrical and Magnetic Techniques- Principles, Types, Advantages and Limitations, Applications.

UNIT V   OTHER TESTING   9

Thermal Testing: Differential scanning calorimetry, Differential thermal analysis. Thermo-mechanical and Dynamic mechanical analysis: Principles, Advantages, Applications. Chemical Testing: X-Ray Fluorescence, Elemental Analysis by Inductively Coupled Plasma-Optical Emission Spectroscopy and Plasma-Mass Spectrometry.

TOTAL: 45 PERIODS

OUTCOMES:
- Identify suitable testing technique to inspect industrial component
- Ability to use the different technique and know its applications and limitations

TEXT BOOKS:
1. Baldev Raj, T.Jayakumar, M.Thavasimuthu "Practical Non-Destructive Testing", Narosa Publishing House, 2009.
2. Cullity, B. D., "Elements of X-ray diffraction", 3rd Edition, Addison-Wesley Company Inc., New York, 2000.
3. P. Field Foster, "The Mechanical Testing of Metals and Alloys" 7th Edition, Cousens Press, 2007.

REFERENCES:
1. Metals Handbook: Mechanical testing, (Volume 8) ASM Handbook Committee, 9th Edition, American Society for Metals, 1978.
2. ASM Metals Handbook, "Non-Destructive Evaluation and Quality Control", American Society of Metals, Metals Park, Ohio, USA.
3. Brandon D.G., "Modern Techniques in Metallography", Von Nostrand Inc. NJ, USA, 1986.