M.Tech Degree (Full Time) Programme

in

INDUSTRIAL SAFETY
(Specialisation: HSE Management)

SCHEME OF EXAMINATION & SYLLABUS

SCHOOL OF ENGINEERING
COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY
COCHIN – 682 022

JULY 2018

M.Tech Degree (Full Time) Programme in Industrial Safety

(Specialisation: HSE Management)

SEMESTER I

Course Code	Course Name	Hours/Week			Credits
		L	T	P	
18-455-0101	Statistical and Computational Methods	3	1	0	4
18-455-0102	Environmental Engineering and Management	3	1	0	4
18-455-01**	Elective I	3	1	0	3
18-455-01**	Elective II	3	1	0	3
18-455-0109	HSE Laboratory	0	0	3	1
18-455-0110	Seminar I	0	0	3	1
18-455-0111	Research Methodology and IPR	2	1	0	2
Total		14	5	6	**18**

SEMESTER II

Course Code	Course Name	Hours/Week			Credits
		L	T	P	
18-455-0201	Hazard Analysis and Risk Assessment	3	1	0	4
18-455-0202	Occupational Health and Hygiene	3	1	0	4
18-455-02**	Elective III	3	1	0	3
18-455-02**	Elective IV	3	1	0	3
18-455-0209	Fire Engineering Laboratory	0	0	3	1
18-455-0210	Seminar II	0	0	3	1
18-455-0211	Internship	0	0	3	2
Total		12	4	9	**18**

SEMESTER III

Course Code	Course Name	Hours/Week			Credits
		L	T	P	
18-455-03**	Elective V	3	1	0	3
18-455-03**	Elective VI	3	1	0	3
18-455-0307	Dissertation – Phase I	0	0	20	12
Total		6	2	20	**18**

SEMESTER IV

Course Code	Course Name	Hours/Week			Credits
		L	T	P	
18-455-0401	Dissertation – Phase II	0	0	30	18
Total		0	0	30	**18**

***Electives must be selected from the following list for the corresponding semester*

Total credits for the M.Tech programme = 72

ELECTIVES I & II (Semester I)

18-455-0103	Industrial Safety Management – Concepts and Practices
18-455-0104	Reliability Engineering
18-455-0105	Industrial Noise and Vibration Control
18-455-0106	Corrosion and Surface Engineering
18-455-0107	Remote Sensing and Geographic Information System
18-455-0108	Food Safety and Sanitation

ELECTIVES III & IV (Semester II)

18-455-0203	Construction Safety and Fire Engineering
18-455-0204	Health, Safety and Environmental Laws
18-455-0205	Hazard Control in Manufacturing
18-455-0206	Pipeline Engineering
18-455-0207	Disaster Preparedness and Emergency Planning
18-455-0208	Ecological Engineering

ELECTIVES V & VI (Semester III)

18-455-0301	Fluid Power Safety
18-455-0302	Human Factors Engineering
18-455-0303	HSE Management in Hydrocarbon Industry
18-455-0304	Fire Modelling
18-455-0305	Environmental Impact Assessment
18-455-0306	Computational Fluid Dynamics

SYLLABUS FOR
M.Tech DEGREE PROGRAMME IN INDUSTRIAL SAFETY
(Specialisation: HSE Management)

SEMESTER I

18-455-0101: STATISTICAL AND COMPUTATIONAL METHODS

Course Outcomes:

On completion of this course the student will be able to:

1. *Apply basic statistical inference techniques, including confidence intervals, hypothesis testing and analysis of variance, to engineering problems.*
2. *Employ appropriate regression models to determine statistical relationships.*
3. *Develop the skill in basic understanding on fuzzy and neural network*
4. *Develop and implement a basic trainable neural network (or) a fuzzy logic system.*

Module I

Statistical hypothesis: Testing statistical hypothesis – Hypothesis and test procedures – Tests concerning hypothesis about means and categorical population – Testing the form of distribution. Analysis of Variance – Terminology and Concepts – Single factor ANOVA – Interpreting ANOVA results – Randomized block experiments.

Module II

Experimental Design: Terminology and Concepts – Two factor designs – Multi factor designs – 2 k designs – Fractional factorial designs. Inferential methods in Regression and Correlation - Regression Models involving a single independent variable – Inferences about the slope coefficient β – Inferences based on estimated regression lines – Multiple regression models – Inferences in multiple regressions.

Module III

Fuzzy Logic: Basic concepts of fuzzy set theory – operations of fuzzy sets – properties of fuzzy sets – Crisp relations – Fuzzy relational equations – operations on fuzzy relations – fuzzy systems – propositional logic – Inference – Predicate Logic – Inference in predicate logic – fuzzy logic principles – fuzzy quantifiers – fuzzy inference – fuzzy rule based systems – fuzzification and defuzzification – types.

Module IV

Neural Networks : Fundamentals of neural networks – model of an artificial neuron – neural network architectures – Learning methods – Taxonomy of Neural network architectures – Standard back propagation algorithms – selection of various parameters – variations. Applications of back propagation algorithms.

References:

1. Montgomery, D. C., Design and Analysis of Experiments.7th Edition, Wiley, New York, 2009.
2. Daniel, C., Applications of Statistics to Industrial Experimentation, Wiley, New York, 1976.

3. Rajasekaran. S. Vijayalakshmi Pai. G.A. Neural Networks, Fuzzy Logic and Genetic Algorithms: Synthesis and Applications, Prentice Hall of India Private Limited, 2003.
4. Timothy J.Ross, Fuzzy logic with Engineering Applications, McGraw Hill, 1995.
5. Zurada J.M. Introduction to Artificial Neural Systems, Jaico Publishing House, 1994.

18-455-0102: ENVIRONMENTAL ENGINEERING AND MANAGEMENT

Course Outcomes:

On completion of this course the student will be able to:

1. *Understand the type and nature of air pollutants, the behavior of plumes and relevant meteorological determinants influencing the dispersion of air pollutants.*
2. *Suggest suitable air pollution prevention and control equipments and techniques for various gaseous and particulate pollutants*
3. *Recognise the common physical, chemical and biological unit operations encountered in treatment processes;*
4. *Formulate a preliminary design of a water and/or wastewater treatment plant.*
5. *Identify key sources, typical quantities generated, composition, and properties of solid and hazardous wastes*
6. *Identify waste disposal or transformation techniques for solid and hazardous wastes*
7. *Perform the screening and scoping of an EIA, based on existing requirements, evaluate the imapcts and draw meaningful conclusions from the results of the EIA*

Module I

Type and nature of air pollutants. Meteorological aspects of air pollutant dispersion – Temperature lapse rates and stability, wind velocity and turbulence, plume behaviour, dispersion of air pollutants, solutions to the atmospheric dispersion equation, The Gaussian plume model.

Air pollution control methods and equipment – Control methods, source correction methods, cleaning of gaseous effluents, particulate emission control – working principle and design of gravitational settling chambers, cyclone separators, fabric filters, electrostatic precipitators, wet scrubbers - selection of a particulate collector, control of gaseous emissions, absorption by liquids, adsorption by solids, combustion, biological methods. Indoor air pollution. Noise sources and control.

Module II

Water quality models for dissolved oxygen – Organic self purification-quantitative definition- reoxygenation-oxygen balance and stream dissolved oxygen profile-oxygen sag curve-Streeter Phelp's equation-Critical deficit-problems.

Pollutants in water and wastewater – characteristics,. Principles of Screening, Mixing, Equalization, Sedimentation, Filtration. Principles of Chemical treatment – Coagulation flocculation. Design of sedimentation and filtration systems for water and waste water treatment.

Objectives of biological treatment – significance – aerobic and anaerobic treatment kinetics of biological growth.

Aerobic treatment systems – Activated Sludge process and variations, Sequencing Batch reactors, Membrane Biological Reactors-Trickling Filters-Bio Tower-RBC-Moving Bed Reactors-fluidized bed reactors, aerated lagoons, waste stabilization ponds. Design of activated Sludge process, trickling filter and biotower.

Design and operation of biological nitrification – de-nitrification system; luxurious phosphorus uptake.

Anaerobic treatment: process microbiology and biochemistry; Attached and suspended growth systems, Design of units – Up flow filters, UASB, Fluidized beds.

Module III

Sources & types of solid wastes, Sampling & characterization, Composition of MSW, Collection of solid wastes, Types of solid wastes collection systems, Analysis of collection systems, Alternative Techniques for collection systems, Collection & Transfer of solid wastes, Unit operations used in separating and processing material recovery facility, Sanitary landfill- planning, Site selection, Design and operation, Aerobic landfill stabilization, Biological oxidation, Composting, Vermicomposting, Pyrolysis, Incineration & Energy Recovery. Definition & identification of Hazardous Wastes, Sources & Characteristics of hazardous wastes, Hazardous waste regulations & legislations, Minimization of Hazardous wastes, Handling & storage of Hazardous wastes, Hazardous Waste Treatment technologies, Physical, chemical & thermal methods of stabilization, Solidification, Chemical Fixation & encapsulation, Incineration of Hazardous waste landfills, Reclamation of Hazardous waste landfill sites.

Module IV

Components of EIA and Methods– screening – setting – analysis – prediction of impacts – mitigation.Matrices – Networks – Checklists. Importance assessment techniques – cost benefit analysis – analysis of alternatives – methods for Prediction and assessment of impacts – air – water – soil – noise – biological – cultural – social – economic environments. Environmental Management Plan - preparation, implementation and review.

Cleaner Production Project Development and Implementation: Overview of CP Assessment Steps and Skills, Preparing for the Site visit, Information Gathering, and Process Flow Diagram, Material Balance, CP Option Generation – Technical and Environmental Feasibility analysis – Economic valuation of alternatives - Total Cost Analysis – CP Financing.

Life Cycle Assessment and Environmental Management Systems: Elements of LCA – Life Cycle Costing – Eco Labelling – International Environmental Standards – ISO 14001 – Environmental audit, Green building & Green energy concepts and management

Industrial Ecology: Introduction to IE and its Relation to the concept of Sustainability - Biological and Industrial Ecosystems - Industrial Symbiosis - Anthropogenic Resource Cycles in Space and Time - Energy in Industrial Ecology - Water in Industrial Ecology - Consumption and the Rebound Effect.

References:

1. Arcadio P. Sincero and Gregoria A. Sincero. Environmental Engineering – A Design Approach. Prentice-Hall of India, New Delhi, 1999.
2. R.J. Heinsohn, and R.L. Kabel. Sources and Control of Air Pollution. Prentice Hall, NJ, 1999.
3. Metcalf & Eddy, Inc. Wastewater Engineering: Treatment and Reuse. Fourth Edition. Tata McGraw-Hill Education Pvt. Ltd., New Delhi, 2003
4. George Tchobanoglous, Hilary Theisen, and Samuel Vigil. Integrated Solid Waste Management: Engineering Principles and Management Issues. McGraw Hill Education (India) Pvt. Ltd., New Delhi, 2014.
5. Larry W Canter. Environmental Impact Assessment. Second Edition, McGraw-Hill, Boston, 1996.

18-455-0109: HSE LABORATORY

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

1. *Evaluate the ambient air quality and the quality of stack emissions*
2. *Estimate the important characteristics of waste water generated in industries*
3. *Measure heat stress and evaluate it.*
4. *Measure the quality of air, noise level and illumination level in the work environment*

List of experiments:

1. Determination of total suspended particulate matter and reparable particulate matter in ambient air.
2. Estimation of sulphurdioxide, carbon monoxide and nitrogen oxides in ambient air. Study of important waste water characteristics
3. Determination of BOD and COD of wastewater samples
4. Development of complete treatment schemes for industrial waste water (organic and inorganic)
5. Determination of noise levels at selected sites
6. Measurement of illumination level in work environment
7. Monitoring of work environment using personal sampler
8. Thermal stress analysis
9. Determination of pollutants from chimney sources
10. Study of occupational diseases with photographic models.

18-455-0110: SEMINAR I

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

1. ***Communicate with group of people on different topics***
2. ***Prepare a seminar report that includes consolidated information on a topic***

The students will work for three hours per week guided by a group of staff members. They will be asked to give a presentation on any topic of their choice related to Industrial Safety (HSE Management) and to engage in discussion with the audience. A brief report of their presentation also should be submitted. Similarly, the students will have to present a seminar of about 20 minutes and they will have to defend their presentation. Evaluation will be based on the technical presentation and the report and also on the interaction shown during the seminar.

18 -455- 0111: RESEARCH METHODOLOGY AND IPR

Course Outcomes:

On completion of this course the student will be able to:

1. *Demonstrate knowledge of research processes (reading, evaluating, and developing)*
2. *Perform literature reviews using print and online databases*
3. *Summarize and discuss important issues and trends within the actual research area.*
4. *Write a scientific article within a limited topic but with a quality such that the article could be accepted for presentation in a conference or workshop*
5. *Create a scientifically sound and reasonable and well documented plan for a Masters thesis project of excellent quality.*
6. *Understand the basics of the four primary forms of intellectual property rights.*
7. *Compare and contrast the different forms of intellectual property protection in terms of their key differences and similarities.*

Module I

Meaning of research problem, Sources of research problem, Criteria and Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem.

Approaches to investigation of solutions for research problem - data collection, analysis, interpretation. Necessary instrumentation.

Module II

Effective literature review approaches, Plagiarism, Research ethics.

Effective technical writing. How to write a good report and a paper?

Developing a Research Proposal, Format of research proposal, Presentation and assessment by a review committee.

Module III

Nature of Intellectual Property: Patents, Industrial Designs, Trademark and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development.

International Scenario: International cooperation on Intellectual Property. Procedure for grant of patents, Patenting under Patent Cooperation Treaty (PCT).

Module IV

Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indication of goods,.

New Developments in IPR: Administration of Patent System. IPR of Biological Systems, Computer Software etc. Traditional knowledge: Indigenous, medicinal and bioprospecting knowledge, Need for protection. Case Studies.

References:

1. Stuart Melville and Wayne Goddard, Research methodology: An introduction for Science & Engineering students, Juta & Co Ltd, 1996.
2. Ranjit Kumar, Research Methodology: A Step by Step Guide for beginners, 2nd Edition, Pearson, 2005.
3. Gopalakrishnan N S, and Agitha T G, Principles of Intellectual Property, 2nd Edition, Eastern Book Company, 2015.
4. Bansal K and Bansal P, Fundamentals of Intellectual Property for Engineers, BS Publications, 2013.
5. Deborah E. Bouchoux, Intellectual Property: The Law of Trademarks, Copyrights, Patents, and Trade Secrets, 4th Edition, Cengage Learning, 2012.
6. Markel, Mike, Technical Communication. 11th Edition, Mac Millan, 2015.

SEMESTER II

18-455-0201: HAZARD ANALYSIS AND RISK ASSESSMENT

Course Outcomes:
On completion of this course the student will be to:
1. Understand Risk Assessment and Hazard Analysis techniques and apply them to System Safety Engineering.
2. Identify and assess the risk and hazards of a process and operation and determine the underlying causes of the hazards.
3. Design a safe process, to determine how safe a process or operation is, and to ensure that a system is safe for all people, environment and equipment
4. Have technical and practical knowledge to develop controls, and methods to either eliminate the hazards or mitigate their consequences.
5. Perform LOPA studies in process units and storage facilities
6. Apply fuzzy logic in risk assessment tools to improve their effectiveness.

Module I
Hazard and risk, Hazard identification and quantifications:- Preliminary hazard analysis ,Dow index, Mond's index, HAZOP, Failure mode and effect analysis – FMEA - FMECA – Fault tree analysis- Event tree analysis- case studies Cause - consequence analysis, Modelling of fire, explosion and toxic gas dispersion, Case studies, Detailed analysis and application of these models – Safe distances between plant items. Software applications.

Module II
Bow tie analysis**,** Risk estimation, Presentation and perception; Individual risk, societal risk, risk estimation, risk representations, Risk targets, tolerability and acceptability, risk perception, risk reduction methods. Software applications in risk analysis such as Aloha, Phast. Case studies – industries and industrial areas.

Module III
Layer of protection analysis (LOPA), Use of LOPA in the process life cycle, How LOPA works, How to implement LOPA, Limitations of LOPA, Benefits of LOPA, Estimation of consequence and severity for LOPA analysis, Developing scenario for LOPA, Initiating event and their frequency, IPL and its characteristics, Risk decision using LOPA.

Module IV
Dynamic Risk analysis, Domino effect analysis, Evaluation of the Characteristics of Vapor Cloud Explosions, Flash Fires, and BLEVEs., Risk Matrix and its importance in risk analysis, Inherently safer design, Site security of process plants. Introduction to fuzzy sets and fuzzy logic. Application of fuzzy logic in Safety.

References :
(1) Sam Mannan, Lees' Loss Prevention in Process Industries: Hazard Identification, Assessment and Control (3 Volumes), 4th Edition, Butterworth-Heinemann, 2012.
(2) Ian T. Cameron and Reghu. Raman, Process Systems Risk Management, Volume 6 (Process Systems Engineering*)* Elsevier Academic press, 2005.

(3) Layer of Protection Analysis : Simplified process risk assessment. CCPS/AIChE, New York, 2001.
(4) Guidelines for Evaluating the Characteristics of Vapor Cloud Explosions, Flash Fires, and BLEVEs. CCPS/AIChE, 1994
(5) Guidelines for Chemical Process Quantitative Risk Analysis. 2nd Edition, CCPS/AIChE, New York 2000.
(6) Guideline for Hazard evaluation Procedures. 2nd edition, CCPS/AIChE, New York,1992.

18-455-0202: OCCUPATIONAL HEALTH AND HYGIENE

Course Outcomes:
On completion of this course the student will be able to:
1. Describe the nature of the health effects associated with exposure to industrial agents;
2. Analyse and apply industrial hygiene strategies with respect to chemical, biological, and physical hazards.
3. Identify industrial hygiene standards, testing systems, and monitoring techniques. Recognize, assess, and control chemical, biological, and physical hazards.
4. Apply the laws and legal threshold limit values around hazardous exposure.
5. Perform a workplace exposure assessment.
6. Apply basic knowledge of physical ergonomics such as physical load, anthropometry, biological variation and biomechanics

Module I
Concept and spectrum of health- functional units and activities of occupational health services-occupational and work related diseases- levels of prevention of diseases- Notifiable occupational diseases- their effects and prevention. Industrial toxicology. Local and systemic effects. Chronic and acute effects. Chemical hazards: dusts, fumes, gases etc. Recognition of chemical hazards – Sampling and analysis for air contaminants. Methods of Controlling the Work Environment- Prevention and mitigation of accidental chemical releases, General methods for the control of airborne hazards, Dilution ventilation, Local exhaust ventilation, Testing, monitoring, and troubleshooting of existing ventilation systems, Personal protective clothing, Respiratory protection.

Module II
TLV for air contaminants, TLVs of mixture of gases. Hazards of VOC's and control measures. Biological indicators of chemical dosage. Types of biological monitoring, Biochemical problems associated with biological monitoring. Biological TLV. Body defense Mechanism to toxicant exposure: Membrane defenses to absorption and distribution: factors influencing membrane transfer: skin, Lung, Gastrointestinal tract. Membrane barriers to distribution in the body. Non membrane defenses to absorption and distribution: Protein Binding as a barrier to toxicant Distribution. Excretory defense mechanisms. Biochemical defenses.

Module III
Physical Hazards: Noise and vibration – types – surveying procedure – permissible levels – health effects – control measures. Thermal stress – parameters – measurement – indices – heat disorders – control measures . Effects of radiation and control measures . Radiation hazards; different types of radiation hazards, its source, and its control measures. Lighting and illumination – measurement – artificial lighting – quality and quantity of illumination – biological effects.

Module IV

Physiology of respiration, cardiac cycle, muscle contraction, nerve conduction system, etc. Assessment of Workload based on Human Physiological reactions. Permissible limits of load for manual lifting and carrying. Criteria for fixation limits.

Working posture: Its effect on cardio-vascular and musculo-skeletal system and implications on health. Nutrition and its importance in manual work. Nutritional requirements of diet. Aerobic work capacity (physical work capacity), methods of its determination (use of bicycle, ergometer, treadmill, step-stool ergometer). Factors affecting aerobic capacity and work performance.

Introduction to Ergonomics, Definition, Aims and Scope, Man-machine (Job), Environment System, Constituents of Ergonomics, Application of Ergonomics in industry for Safety, Health and Environment. Ergonomics of Automation / Assembly, Visual Fatigue, Ergonomics of Rehabilitation while assigning alternate jobs. Anthrapometry and fundamentals of bio-mechanics. Anthropometric measurements and their usefulness in industry. Ergonomic Design of Work Station: Concept of workstation and its design. Improving safety and productivity through work station design.

References:

1. Lewis J. Cralley & Lester V. Cralley, Patty's Industrial Hygiene and Toxicology, Volume III, Second edition, John Wiley & Sons, New York, 1985.
2. Barbara A. Plog and Patricia J. Quinlan, Fundamentals of Industrial Hygiene by, 6th Edition, National Safety Council, USA, 2012.
3. D.H. Anna (Editor). The Occupational Environment - Its Evaluation, Control, and Management.. AIHA, Fairfax, Virginia, 2011.
4. Bridger, RS: Introduction to Ergonomics, 2nd Edition, Taylor &Francis, 2003.
5. Gayle Woodside & Dianna Kocurek, Environmental, Safety and Health Engineering, John Wiley & Sons, New York, 1997.
6. ILO, Encyclopedia of Occupational Health and Safety, Vol.I and II, International Labour Office.

18-455-0209: FIRE ENGINEERING LABORATORY

Course Outcomes:

On completion of this course the student will be able to

1. Demonstrate the understanding of refilling of portable extinguishers

2. Demonstrate the understanding firefighting using portable extinguishers

3. Decide the acceptability of portable extinguishers

4. Understand the influence of fire on building materials (Concrete and masonry units)

List of experiments

1. Refilling of water, DCP, and foam type portable extinguisher.
2. Fire Fighting with CO_2, water, DCP, and foam type portable extinguisher
3. Performance study of portable extinguishers
4. Tests on DCP and foam as per relevant Indian standard specifications
5. Study on the effect of temperature on Concrete and Masonry unit.
6. Fire simulation using FDS software
7. Fire modeling using ALOHA

18-455-0210: SEMINAR II

Course Outcomes:

On successful completion of this course, the student will be able to:

1. Communicate with group of people on different topics

2. Prepare a seminar report that includes consolidated information on a topic related to the proposed dissertation project.

The students will work for three hours per week guided by a group of staff members. They will be asked to give a presentation on a topic related to the proposed dissertation project of the student and to engage in discussion with the audience. A brief report of their presentation also should be submitted. Similarly, the students will have to present a seminar of about 20 minutes and they will have to defend their presentation. Evaluation will be based on the technical presentation and the report and also on the interaction shown during the seminar.

18-455-0211: INTERNSHIP

Course Outcomes*:*
On completion of this course the student will be able to:
1. Work safely in industrial environment.
2. Work with various interest groups, disciplines, professionals, managers, technicians etc.
3. Polish the engineering skills by applying the knowledge in day-to-day operation, troubleshooting and minor-modifications.
4. Building relations with University and Industry that will help mutual cooperation over long-term.

Every Student should undergo summer training (summer internship programme) in a petroleum oil & gas producing industry/ chemical industry/engineering industry/ construction site for 2 weeks and submit a report on the status of HSE management in the respective units.

18-455-0307: DISSERTATION - PHASE I

Course Outcomes:
On completion of this course the student will be able to:
1. Identify the problem based on literature survey
2. Formulate the problem
3. Identify the methods or techniques required for the solution
4. Develop the solution methodology

The student individually works on a specific topic approved by a faculty member who is familiar in this area of interest. The student can select any topic which is relevant to his/her specialization of the programme. The topic may be experimental or analytical or case studies. At the end of the semester, a detailed report on the work done should be submitted which contains clear definition of the identified problem, detailed literature review related to the area of work and methodology for carrying out the work.

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18-455-0401: DISSERTATION - PHASE II

Course Outcomes:
On completion of this course the student will be able to:
1. Implement the methods/techniques identified in dissertation phase-I
2. Analyze and interpret the results obtained
3. Compare the results obtained with literature.
4. Demonstrate the original contribution to knowledge

The student should continue the phase I work on the selected topic as per the formulated methodology. At the end of the semester, after completing the work to the satisfaction of the supervisor and review committee, a detailed report should be prepared and submitted to the head of the department. The students will be evaluated based on the report and the viva-voce examination by a panel of examiners.

ELECTIVES

18-455-0103: INDUSTRIAL SAFETY MANAGEMENT – CONCEPTS AND PRACTICES

Course Outcomes:

On successful completion of this course the student will be able to:

1. Appreciate the theoretical concepts and practices of industrial safety

2. Evaluate the state of safety based on various indices

3. Analyse the causes of accidents and prepare reports

4. Apply basic principles of management to safety

5. Develop and design the basic outlines of a safety programme

Module I

Concept of safety – Goals of safety engineering – History of safety movement – Theories and principles of accident causation – Roles of Stake holders in safety: management, supervisors, workmen, trade unions, government, voluntary organizations etc. – Workers' participation in safety management – Engineering, education and enforcement (3 E's) of safety.

Module II

Indices of safety performance – Definitions: Accident, Injury, Unsafe acts, Unsafe conditions, Dangerous occurrence, Reportable accidents – Classification of injuries – Accident reporting and investigation – Personal Protective Equipments – Work permit – Plant safety inspection – Safety audit – Job safety analysis – First aid: principles, aims and objectives – Product safety – Cost analysis – Human factors in safety management – Behaviour-based safety.

Module III

Health and safety management: Safety organization – Organisational management – Employee awareness Organisational management – Safety in System life cycle – Developing a system safety programme – Closed-loop process – Benchmarking – HSE policy – Risk management: techniques, strategies and programmes.

Module IV

Disaster management: importance – types of disasters – On-site and off-site emergency plans – mock drills – Oil-spill contingency plan– Cases of important industrial disasters – Natural disasters: predictions, rescue, relief and rehabilitation – Legal provisions.

References:

1. Nicholas J. Bahr. System Safety Engineering And Risk Assessment – A Practical Approach: Taylor & Francis, 1997.
2. Mc Cornick and Sanders. Human Factors in Engineering and Design, McGraw Hill, New York, 1993.
3. Jeremy Stanks. The Manager's Guide to Health & Safety at Work, 8th Edition, Kogan Page Ltd., UK, 2006.
4. ILO, Geneva (1988). Major Hazard Control – a Practical Manual.

5. UNEP, Paris (1998). APELL – A Process for responding to technological accidents - A Handbook. Industry & Environment Office, UNEP.
6. National Safety Council, USA (2009). Accident Prevention Manual for Business and Industry, Vol. I (13th ed)

18-455-0104: RELIABILITY ENGINEERING

Course Outcomes:

On completion of this course the student will be able to:

1. Understand the concepts of reliability, availability and maintainability

2. Develop hazard-rate models to know the behaviour of components

3. Build system reliability models for different configurations

4. Assess reliability of components and systems using field and test data

5. Implement strategies for improving reliability of repairable and non-repairable systems

Module I

Reliability: Definition; Probability Concept; Addition of Probabilities; Complimentary Events; Kolmogorov Axioms.

Failure Data Analysis: Introduction, Mean Failure Rate, Mean Time to Failure (MTTF), Mean Time between Failures (MTBF), Graphical Plots, MTTF in terms of Failure Density, MTTF in Integral Form.

Module II

Hazard Models: Introduction, Constant Hazard; Linearly Increasing Hazard, The Weibull Model, Density Function and Distribution Function, Reliability Analysis, Important Distributions and their Choice, Standard Deviation and Variance.

Conditional Probability: Introduction, Multiplication Rule, Independent Events, Vernn Diagram, Hazard Rate as conditional probability, Bayes Theorem.

Module III

System Reliability: Series. Parallel and Mixed Configurations, Complex Systems, Logic Diagrams, Markov Models.

Reliability Improvement & Repairable Systems: Redundancy, Element, Unit and standby Redundancy, Optimization; Reliability – cost trade- off, Introduction to Repairable Systems, Instantaneous Repair Rate, MTTR, Reliability and Availability Functions, Important Applications.

Module IV

Fault-Tree Analysis and Other Techniques: Fault-tree Construction, Calculation of Reliability, Tie- set and Minimal Tie-set.

Maintainability and Availability: Introduction, Maintenance Planning, Reliability and Maintainability trade – off.

References :

1. L.S. Srinath, Reliability Engineering, Affiliated East-West Press, New Delhi, 2005.
2. Charles Ebling, An Introduction to Reliability and Maintainability Engineering, Tata McGraw Hill, New Delhi, 2000.
3. Singiresu S.Rao, Reliability Engineering, Pearson Education India, New Delhi, 2016
4. K.C. Kapur and L.R. Lamberson, Reliability in Engineering Design, Wiley India,New Delhi, 2009
5. Roger D. Leitch, Reliability Analysis for Engineers – An Introduction, Oxford University Press, 1995

18-455-0105: INDUSTRIAL NOISE AND VIBRATION CONTROL

Course Outcomes:

On completion of this course the student will be able to

1. Conceptualize noise and vibration and its propagation in environments

2. Demonstrate competency in solving vibration problems.

3. Describe noise problems conceptually and translate into theory

4. Design noise-control measures to solve basic noise problems

5. Demonstrate the understanding to measure vibrations, vibration characteristics and understand various methods for vibration control for real life problem.

Module I

Fundamentals of vibrations: Simple harmonic motion, combination of two simple harmonic motions, beats, Fourier analysis. Single degree of freedom system: Free un-damped vibrations: Equivalent systems linear and torsional, natural frequency estimation, energy methods. Damped vibrations - Damping models, structural, coulomb, and viscous dampings, critically, under and over-damped system, logarithmic decrement. Forced vibrations - Harmonic excitation, support motion, vibration isolation, critical speeds of shafts in bending.

Module II

Two degree of freedom system: Free vibrations of spring coupled system, general solution, torsional vibrations, two degree of freedom mass coupled system, bending vibrations in two degree of freedom system, forced vibrations of an undamped two degree of freedom system, dynamic vibration absorber, forced damped vibrations

Module III

Multi-degree of freedom system:Free un-damped analysis.Numerical methods: Dunkerley's, Rayleigh, Holzer methods. Experimental methods in vibration analysis: Vibration measurement devices and analysers, balancing of rigid rotors.

Module IV

Analysis and measurement of sound: One dimensional waves in a gas, sound perception and the decibel scale, the ear, combining sound levels in decibels, octave bands, loudness, weightings, directionality of acoustic sources and receivers, directivity index.

Noise control: Noise criteria, sound absorption and insulation, noise barriers, acoustic enclosures, silencers.

References:

1. Rao S S. Mechanical Vibrations, Fifth Edition, Pearson Education Inc. NJ, 2011.
2. Munjal M L, Noise and Vibration Control (IISc Lecture Notes Series), World Scientific Publishing Company, 2013.
3. Weaver W jr, Timoshenko S P, and Young D H. Vibration Problems in Engineering, 5th Edition, John Wiley & Sons Inc, 1992.
4. Lewis H. Bell, Douglas H. Bell. Industrial Noise Control: Fundamentals and Applications. 2nd edition. Marcel Dekker Inc, 1994.

18-455-0106: CORROSION AND SURFACE ENGINEERING

Course Outcomes:
On completion of this course the student will be able to
1. Identify the factors that influence the metallic corrosion.
2. Carry out standard corrosion test and interpret the test data.
3. Relate the principles of electrochemistry to various forms of corrosion and breakdown of passivation.
4. Select proper corrosion resistant materials for application environment.

Module I
Introduction to tribology, surface degradation, wear and corrosion, types of wear, adhesive, abrasive, oxidative, corrosive, erosive and fretting wear, roles of friction and lubrication-, expressions for corrosion rate. emf and galvanic series – merits and demerits -Pourbaix diagram for iron, magnesium and aluminium. Forms of corrosion – Uniform, pitting, intergranular, stress corrosion. corrosion fatigue. dezincification. erosion corrosion, crevice corrosion – Cause and remedial measures – Pilling Bedworth ratio – High temperature oxidation-Hydrogen embrittlement – Remedial Measures.

Module II
Kinetics of corrosion: Exchange current density, polarization – concentration, activation and resistance, Tafel equation; passivity, electrochemical behaviour of active/passive metals, Flade potential, theories of passivity, Effect of oxidising agents

Module III
Corrosion of industrial components: Corrosion in fossil fuel power plants, Automotive industry, Chemical processing industries, corrosion in petroleum production operations and refining, Corrosion of pipelines.- wear of industrial components.
Purpose of corrosion testing – Classification – Susceptibility tests for intergranular corrosion- Stress corrosion test. Salt spray test humidity and porosity tests, accelerated weathering tests. ASTM standards.

Module IV
Protection methods: Organic, Inorganic and Metallic coatings, electro and Electroless plating and Anodising – Cathodic protection, corrosion inhibitors – principles and practice – inhibitors for acidic neutral and other media. Special surfacing processes – CVD and PVD processes, sputter coating. Laser and ion implantation, Arc spray, plasma spray, Flame spray, HVOF.

References:

1. Fontana and Greene. Corrosion Engineering. McGraw Hill Book Co. New York. 1986.
2. Kenneth G Budinski. Surface Engineering for Wear Resistance. Prentice Hall Inc. Engelwood Cliff., New Jersey. 1988
3. Denny A. Jones, Principles and Prevention of Corrosion, 2nd Edition, Prentice Hall of India, 1996.
4. Uhlig. H.H. “Corrosion and Corrosion Control”. John Wiley & Sons. New York. USA. 1985.

18-455-0107: REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM

Course Outcomes:

On completion of this course the student will be able to:

1. Demonstrate the knowledge of the principles of remote Sensing and GIS.

2. Analyse RS and GIS data and interpret the data for modelling applications.

3. Demonstrate an understanding of the basic elements of image interpretation

4. Perform modelling in GIS for practical applications

Module 1

EMR and its interaction with atmosphere and earth material: Definition of remote sensing and its components – Electromagnetic spectrum – wavelength regions important to remote sensing – Wave theory, Particle theory, Stefan-Boltzman and Wein's Displacement Law – Atmospheric scattering, absorption – Atmospheric windows – spectral signature concepts – typical spectral reflective characteristics of water, vegetation and soil.

Module 2

Platforms and sensors: Types of platforms – orbit types, Sun-synchronous and Geosynchronous – Passive and Active sensors – resolution concept – Pay load description of important Earth Resources and Meteorological satellites – Airborne and spaceborne TIR and microwave sensors.

Module 3

Image interpretation and analysis: Types of Data Products – types of image interpretation – basic elements of image interpretation – visual interpretation keys – Digital Image Processing – Pre processing – image enhancement techniques – multispectral image classification – Supervised and unsupervised.

Module 4

Geographic information system: Introduction – Maps – Definitions – Map projections – types of map projections – map analysis – GIS definition – basic components of GIS – standard GIS softwares – Data type – Spatial and nonspatial (attribute) data – measurement scales – Data Base Management Systems (DBMS).

Data entry, storage and analysis: Data models – vector and raster data – data compression – data input by digitization and scanning – attribute data analysis – integrated data analysis – Modeling in GIS Highway alignment studies – Land Information System.

References:

1. Lillesand,T.M., Kiefer, R.W. and J.W.Chipman. "Remote Sensing and Image Interpretation" 5th Edition. John Willey and Sons Asia Pvt. Ltd., New Delhi, 2004.
2. Anji Reddy, M. "Textbook of Remote Sensing and Geographical Information System" 2nd edition. BS Publications, Hyderabad, 2001.
3. Lo. C.P.and A.K.W.Yeung, "Concepts and Techniques of Geographic Information Systems",Prentice Hall of India Pvt. Ltd., New Delhi, 2002
4. Peter A.Burrough, Rachael A. McDonnell, " Principles of GIS", Oxford University Press, 2000

18-455-0108: FOOD SAFETY AND SANITATION

Course Outcomes:
On completion of this course the student will be able to:
1. Identify food safety hazards and their control
2.Identify and prevent potential sources of food contamination
3.Apply a range of food quality systems
4.Prepare a food safety plan

Module I
Sanitation and the Food Industry: The food industry - What is sanitation? - Why sanitation- Sanitation laws and regulations and guidelines- Establishment of sanitary practices.
The Relationship of Biosecurity to Sanitation: Potential risks of food borne bioterrorism - Bioterrorism protection measures -The role of pest management in biosecurity.
The Relationship of Microorganisms to Sanitation: How microorganisms relate to food sanitation- What causes microorganisms to grow? - Effects of microorganisms on spoilage - Effects of microorganisms on food borne illness - Food borne illnesses - Microbial destruction - Microbial growth control - Microbial load determination- Diagnostic tests.
The Relationship of Allergens to Sanitation: What are allergens? - Allergen control.

Module II
Food Contamination Sources: Transfer of contamination - Contamination of foods - Other contamination sources - Protection against contamination.
Personal Hygiene and Sanitary Food Handling: Personal hygiene - Sanitary food handling.
The Role of HACCP in Sanitation: What is HACCP? - HACCP development - Interface with GMPs and SSOPs - HACCP principles - Organization, implementation, and maintenance.
Quality Assurance for Sanitation: The role of total quality management - Quality assurance for effective sanitation - Organization for quality assurance - Establishment of a quality assurance program.

Module III
Cleaning Compounds: Soil characteristics - Effects of surface characteristics on soil deposition - Soil attachment characteristics - Cleaning compound characteristics - Classification of cleaning compounds - Cleaning auxiliaries - Scouring compounds - Cleaning compound selection - Handling and storage precautions.
Sanitizers: Sanitizing methods. Sanitation equipment – Sanitation costs – Equipment selection – Cleaning equipment – Sanitizing equipment – Lubrication equipment.

Module IV
Waste Product Handling: Strategy for waste disposal – Planning the survey – Solid waste disposal – Liquid waste disposal.
Pest control: Insect infestation – Cockroaches – Insect destruction – Rodents – Birds – Use of pesticides – Integrated pest management.

Sanitary design and construction for Food Processing: Site selection – Site preparation – Building construction considerations – Processing and design considerations – Pest control design – Construction materials.
Principles of meat and poultry plant sanitation, seafood plant sanitation, fruit and vegetable processing plant sanitation. Sanitary procedures for food preparation, Contaminant reduction, Food service sanitation requirements.
Enforcement of food safety – Indian scenario.

References:

1. Norman G. Marriot, Robert G. Gravani. Principles of Food Sanitation, Fifth Edition. Springer Science, 2006.
2. Paul L. Knechtges. Food Safety Theory and Practice. Jones & Bartlett Learning, USA. 2012.
3. Biosafety: Principles and Practices, 4th Edition from the American Society of Microbiology Press, 2006.
4. Thomas J. Montville and Karl R. Matthews. Food Microbiology, An Introduction. 3rd Edition**.** ASM Press**,** 2008
5. Inteaz Alli. Food Quality Assurance, Principles and Practices. CRC Press, 2004.

18-455-0203: CONSTRUCTION SAFETY AND FIRE ENGINEERING

Course Outcomes:

On completion of this course the student will be able to:

1. Visualize the safety issues at different stages of construction activity.

2. Understand the safety requirements in various construction operations and develop guidelines to ensure safety at construction site.

3. Understand the safety requirements in material handling and equipments and develop guidelines to ensure safety at construction site.

4. Learn and apply the legal provisions with respect to the health and welfare of workers at construction site.

5. Understand the fundamentals of fire initiation, its development, types of flames, product of combustion, and the principles of fire extinguishment

6. Understand the general life safety requirements applicable to all buildings and to plan, design and locate exits in buildings.

7. Understand the behaviour of building materials after exposure to fire and the concept of zone modeling of compartment fire

Module I

Introduction to safety issues in construction industry - Human factors in construction safety management. Framing of contract conditions on safety, and related matters. Ergonomics in construction safety.

Safety in construction operations- excavation, blasting, piling, shoring and underpinning, working in confined space; Safety in demolition of buildings, use of ladders; Safety in erection and using of scaffold

Module II

Safety in transportation, storage and handling of construction materials- Cement, Aggregates, building blocks, Reinforcing steel, glass, door and window frames, paint.

Safety in operation and maintenance of equipments at construction site- vehicles, mobile cranes, tower cranes, lifting gears, hoists & lifts, wire ropes, pulley blocks, mixers, pneumatic and hydraulic tools and heavy equipments.

Contract Labour Act and Central Rules- Registration of Establishments, Licensing of Contractors, Welfare and Health provisions in the Act and the Rules, Penalties, Rules regarding wages.

Building & Other Construction Workers (RE & CS) Act, and Central Rules- Applicability, Administration, Registration, Welfare Board & Welfare Fund, Training of Building workers, General Safety, Health & Welfare provisions, Penalties. Social security of construction workers.

Module III

Introduction to types of ignition, ignition sources, types of combustion, development of fire, classification of fire; Diffusion flames-zones of combustion, characteristics of

diffusion flame; Premixed flames-burning velocity, limits of flammability, explosion and expansion ratios, deflagration and detonation, characteristics of premixed flame;

Product of combustion-flame, heat, smoke, fire gases; Smoke– constituents of smoke, quantity and rate of production of smoke, quality of smoke, smoke density, visibility in smoke, smoke movement in buildings;

Principles of Fire Extinguishments-extinction of premixed flames, diffusion flames and burning metals, fire triangle, fire tetrahedron; Basic concept of fire fighting with water, carbon dioxide, powders and foam.

Module IV

Classification of buildings based on occupancy and type of construction according to fire resistance as per NBC; Fire zone; General fire safety requirements applicable to all individual occupancies. General exit requirements as per NBC; Internal staircases; horizontal exits; fire tower; ramps; fire lifts; external fire escape ladders; Planning of location and calculation of capacity, number and width of exit as per NBC for different occupancy classification.

Development of compartment fire; factors affecting growth phase. Factors affecting behaviour of building materials under fire; properties of building materials under elevated temperatures; Thermal and material data for steel, concrete, masonry, timber and aluminium.

Fire safety modeling- zone modeling of pre-flashover fire; one zone modeling of post-flashover fire.

References:

1. K.N. Vaid, Construction Safety Management, NICMAR, Bombay.
2. Mishra, R.K.,Construction Safety, AITBS Publishers, Delhi
3. V.J. Davies and K. Tomasin, Construction Safety Handbook, 2nd Revised edition, Thomas Telford Ltd.,1996
4. Contract Labour Act and Central Rules
5. Building & Other Construction Workers (RE &CS) Act, and Central Rules.
6. Encyclopedia of Occupational Safety & Health, 4th edition, International Labour Organisation, 1998.
7. Jain V.K. (2010). Fire safety in buildings (2nd edn.). New Age International (P) Ltd., New Delhi.
8. Barendra Mohan Sen (2013). Fire protection and prevention the essential handbook, UBS publishers and Dist., New Delhi.
9. John A. Purkiss (2009). Fire safety engineering design of structures (2nd edn.), Butterworth-Heinemann, Oxford, U.K.
10. Rasbas D, Ramachandran G, Kandola B, Watts J, and Law M, Evaluation of Fire Safety, John Wiley & Sons Ltd. England, 2004
11. National Building Code of India, Part 4, 7 and relevant Indian standard code of practices

18-455-0204: HEALTH, SAFETY AND ENVIRONMENTAL LAWS

Course Outcomes:

On completion of this course the student will be able to:

1. Analyse and interpret the safety and health provisions in HSE laws

2. Calculate applicable compensations towards social security

3. Correlate important provisions with decided cases

4. Prepare checklists for legal compliance

5. Decide the legal consequences of non-compliance

Module I

Factories Act– Definitions, Preliminary, Inspecting staff, Health, Safety, Provisions relating to hazardous processes, Welfare, Working hours of adults, Employment of young persons, Special provisions. **Dock Workers (Safety, Health and Welfare) Act** - Definitions, Powers of inspectors, Power of Govt. to direct inquiry, Obligation of dock workers. Duties of Safety Officers, Reporting of accidents, Emergency Action Plan, Safety Committee.

Module II

Employees' Compensation Act: Definitions, Employer's liability for compensation, Calculation of amount of compensation. **ESI Act and Rules**: Applicability, Definitions and Benefits. **Public Liability Insurance Act and Rules-** Definitions, Calculation of amount of relief, Environmental Relief Fund, Advisory Committee, Powers of District Collector, Extent of Liability, Contribution to Relief Fund.

Module III

Explosives Act: Definitions, Categories of Explosives, General Safety Provisions, Use of Explosives, Grant of license, Notice of Accidents, Inquiry into ordinary and more serious accidents, Extension of definition to other explosive substances. **Explosives Rules**, **SMPV Rules** and **Gas Cylinder Rules** (in brief). **Petroleum Act** with important rules - definitions, safety in the import, transport, storage, license, exemption, notice of accidents.

Module IV

Water Act and **Air Act**: Definitions, powers and functions of Boards, prevention and control of pollution, consent administration. **Environment (Protection) Act and Rules**-Definitions, powers of central government, power of giving directions, authorities. **MSIHC Rules**- Definitions, Duties of authorities, Notification of major accidents, safety Reports, safety audit, on-site & off-site emergency plans, safety information to public. **Food Safety laws**.

Note: Case laws may be referred if necessary, but those are beyond the scope of this course.

References:

1. Factories Act, 1948.
2. Dock Workers (SHW) Act, 1986.
3. Latest bare Acts and concerned Rules on social security.
4. Explosives Act and related Rules.
5. Petroleum Act and Rules.
6. Environmental Acts & relevant Rules as above.
7. Food Safety and Standards Act, 2006

18-455-0205: HAZARD CONTROL IN MANUFACTURING

Course Outcomes:

On completion of this course the student will be able to:

1. Explain the manufacturing processes employed by engineering industries

2. Identify the health hazards associated with manufacturing processes in engineering industries

3. Demonstrate the safe work practices followed in manufacturing industries

4. Decide the strategies for the prevention of health hazards in manufacturing and material handling

5. Assess the safety features of material handling equipment

Module I

Introduction - Classification of Engineering Industry –Manufacturing Processes

Hot Working-Foundry operations-furnace and equipment, health hazard, safe methods of operation. Forging operations, heat radiation, maintenance of machines, shop equipment and hand tools - safe work practice. Operations in hot and cold rolling mills.

Module II

Machinery safeguard-Point-of-Operation, Principle of machine guarding - breakdown of machine guarding - types of guards and devices.

Cold Working-Safety in Power Presses, primary & secondary operations - shearing - bending - rolling – drawing. Metal Cutting- safety in turning, boring, milling, planning and grinding. Maintenance of machine tools - health hazards and prevention.

Module III

Welding and Cutting-Safety Precautions of Gas welding and Arc Welding, Cutting and Finishing. Gas Cylinders and Equipments. Heat Treatment- Furnaces and Salt baths-operations and maintenance -safety in handling and storage of salts- disposal of effluents - health precautions, exposure to hazardous fumes, source of fumes, ventilation and fume protection.

Module IV

Material Handling-Classification-safety consideration- manual and mechanical handling. Handling assessments and techniques- lifting, carrying, pulling, pushing, palletizing and stocking. Material Handling Equipments-operation & maintenance. Maintenance of common elements-wire rope, chains slings, hooks, clamps.

Reference

1. Accident Prevention Manual for Industrial Operations: National Safety Council, Chicago, 1974.
2. Roland P. Blake (Ed), Industrial Safety, Prentice_Hall, 1961.
3. Blunt and Balchin, Health and Safety in Welding and Allied Processes, 5th edition, Woodhead Publishing, 2002.
4. S. Kalpakjian and S.R. Schmid, Manufacturing Engineering and Technology, 4th edn, Pearson Education Asia, 2000.

18-455-0206: PIPELINE ENGINEERING

Course Outcomes:
On completion of this course the student will be able to:
1. Understand the key steps in a pipeline's lifecycle
2. Identify the various elements and stages involved in the transportation of oil and gas
3. Illustrate the use of international standards and practices in piping design
4. Discuss the various equipment and their operation in pipeline transportation

Module I
Elements of pipeline design: Fluid properties – Environment - Effects of pressure and temperature - Supply / Demand scenario - Route selection - Codes and standards - Environmental and hydrological considerations – Economics - Materials / Construction – Operation - Pipeline protection - Pipeline integrity monitoring. Pipeline route selection, survey and geotechnical guidelines: Introduction - Preliminary route selection - Key factors for route selection - Engineering survey - Legal survey - Construction / As-built survey - Geotechnical design.

Module II
Natural gas transmission: General flow equation – Steady state - Impact of gas molecular weight and compressibility factor on flow capacity - Flow regimes - Widely used steady-state flow equations – Summary of the impact of different gas and pipeline parameters on the gas flow efficiency – Pressure drop calculation for pipeline in series and parallel – Pipeline gas velocity – Erosional velocity – Optimum pressure drop for design purposes – Pipeline packing – Determining gas leakage using pressure drop method – Wall thickness / pipe grade – Temperature profile – Optimization process – Gas transmission solved problems.

Module III
Gas compression and coolers: Types of compressors – Compressor drivers – Compressor station configuration – Thermodynamics of isothermal and adiabatic gas compression – Temperature change in adiabatic gas compression – Thermodynamics of polytropic gas compression – Gas compressors in series – Centrifugal compressor horsepower – Enthalpy / Entropy charts (Mollier diagram) – Centrifugal compressor performance curve – Influence of pipeline resistance on centrifugal compressor performance-Reciprocating compressors.

Module IV
Liquid flow and pumps: Fully developed laminar flow in a pipe – Turbulent flow – Centrifugal pumps – Retrofitting for centrifugal pumps (Radial-flow) – Pump station control – Pump station piping design. Transient flow in liquid and gas pipelines: Purpose of transient analysis – Theoretical fundamentals and transient solution technique – Applications – Computer applications. Pipeline mechanical design: Codes and standards – Location classification – Pipeline design formula – Expansion and flexibility – Joint design for pipes of unequal wall thickness.
Materials selection and quality management: Elements of design – Materials designation standards – Quality management. Pipeline construction: Construction – Commissioning. Pipeline protection, Instrumentation, pigging & Operations.

References:

1. M. Mahitpour, H. Golshan and M.A. Murray. Pipeline Design and Construction: A Practical Approach, , 2nd Edition, ASME Press, 2007.
2. Henry Liu, Pipeline Engineering, Lewis Publishers (CRC Press), 2003.
3. George A. Antaki, Piping and Pipeline Engineering: Design, Construction, Maintenance Integrity and Repair, CRC Press, 2003
4. E. Shashi Menon. Liquid Pipeline Hydraulics, Marcel Dekker Inc., 2004.
5. E. Shashi Menon. Gas Pipeline Hydraulics, Taylor & Francis, 2005.

18-455-0207: DISASTER PREPAREDNESS AND EMERGENCY PLANNING

Course Outcomes

On completion of this course the student will be able to:

1. Effectively define and describe the terminology used within disaster planning and emergency management

2. Comprehend the scope, extent, and complexity of natural and man-made disasters and emergencies

3. Understand the problems associated with government collaboration and assistance to state and local governments and non-governmental organizations

4. Discuss effective means to plan, mitigate, respond, and recover from disasters and emergencies, natural and man-made

5. Articulate the knowledge gained from a review of case studies of significant importance

Module I

Concepts of Hazard, Vulnerability, and Risk. Natural Disasters (earthquake, Cyclone, Floods, Volcanoes), and Man Made Disasters (Armed conflicts and civil strip, Technological disasters, Human Settlement, Slow Disasters (famine, drought, epidemics) and Rapid Onset Disasters(Air Crash, tidal waves, Tsunami). Terrorism. Difference between Accidents and Disasters, Simple and Complex Disasters. Disaster cycle, Phases of disaster. The historical context of emergency management. Chemical, biological, radiological and nuclear disasters – case studies. The disciplines of emergency management. Political, Social, Economic impacts of Disasters, Gender and Social issues during disasters, principles of psychosocial issues and recovery during emergency situations, Equity issues in disasters, Relationship between Disasters and Development and vulnerabilities, different stake holders in Disaster Relief

Mitigation- Mitigation tools – Hazard identification and mapping – Impediments to mitigation.

Module II

Preparedness for emergencies - A Systems Approach - The Preparedness Cycle

Mitigation versus Preparedness. The Emergency Operations Plan, Education and Training Programs, Emergency Management Exercises, Evaluation and Improvement. The Whole Community Concept, the National Preparedness System, Evacuation Planning, Emergency Planning for Access and Functional Needs, Preparedness Equipment.

Early warning Systems Models in disaster preparedness, Components of Disaster Relief-(Water, food, sanitation, shelter, Health and Waste Management), Community based DRR, Structural nonstructural measures in disaster risk reduction, Factors affecting Vulnerabilities, , Mainstreaming disaster risk reduction in development, Undertaking risk and vulnerability assessments, Policies for Disaster Preparedness Programs, Preparedness Planning, Roles and Responsibilities, Public Awareness and Warnings, Conducting a participatory capacity and vulnerability analysis, , Sustainable Management, Survey of Activities Before Disasters Strike, Survey of Activities During Disasters, DRR Master Planning for the Future, Capacity Building, Sphere Standards. Rehabilitation measures and long term reconstruction. Psychosocial care provision during the different phases of disaster.

Module III

Role of communication in emergencies – Audiences/customers – communicating in the context of homeland security - Disaster Communications in a Changing Media World - Building an Effective Disaster Communications Capability in a Changing Media World - Creating Effective Disaster Communications.

Response to emergencies - Local Response - State Response- Volunteer Group Response - Incident Command System – Key response officials – Response resources. Disaster recovery operations - The National Response Framework for Disaster Recovery Operations - Recovery Planning Tools - Long-Term Recovery Planning Community Long-Term Recovery Planning.

Emergency management and the terrorist threat, the future of emergency management.

Module IV

Hazard and Vulnerability Profile of India, Disaster Management: Indian scenario, Disaster Management Act 2005 and Policy guidelines, National Institute of Disaster Management, , National Disaster Response Force (NDRF)National Disaster Management Authority, States Disaster Management Authority, District Disaster Management Authority Cases Studies : Bhopal Gas Disaster, Gujarat Earth Quake, Orissa Super-cyclone, south India Tsunami, Bihar floods, Plague at Surat, Landslide in North East, Heat waves of AP& Orissa, Cold waves in UP. Bengal famine, best practices in disaster management, Local Knowledge Appropriate Technology and local Responses, Indigenous Knowledge, Development projects in India (dams, SEZ) and their impacts, Logistics management in specific emergency situation. Rajiv Gandhi Rehabilitation package, Integrated Coastal Zone Management, National Flood Risk Mitigation Project (NFRMP), Mines Safety in India, Indian Meteorological Department, National Crisis Management Committee, Indian NATIONAL Centre for Oceanic Information System (INCOIS)

References

1. George D. Haddow, Jane A. Bullock, and Damon P. Coppola. Introduction to Emergency Management, 4th ed. Elsevier, 2011.
2. Phillips, Brenda, Neal, David, & Webb, Gary. Introduction to Emergency Management. CRC Press: Boca Raton, FL, 2012.
3. Major Hazard Control – A Practical Manual – ILO, Geneva, 1988.
4. Disaster Management Guidelines. GOI-UNDP Disaster Risk Reduction Programme (2009-2012)
5. Disaster Management: A Disaster Manager's Handbook. Asian Development Bank, Manila.

18-455-0208: ECOLOGICAL ENGINEERING

Course Outcomes:

On successful completion of this course the student will be able to:

1. Understand the concepts of ecological engineering and its role in waste treatment.

2. Implement systems based on ecotechnology for the treatment of waste

3. Understand and appreciate the functions of an ecosystem and nutrient turnover.

4. Apply systems approach to environmental systems

Module I

Ecosystems and ecotechnology: Aim, scope and applications of ecology – Development and evolution of ecosystems – Principles and concepts pertaining to communities in ecosystem – Energy flow and material cycling in ecosystems – productivity in ecosystems.

Module II

Systems approach in ecological engineering: Principles, components and characteristics of systems – Classification of systems – Structural and functional interactions of environmental systems – Environmental systems as energy systems – Mechanisms of steady-state maintenance in open and closed systems – Modelling and ecotechnology – Elements of modeling – Modelling procedure – Classification of ecological models- Applications of models in ecotechnology – Ecological economics.

Module III

Ecological engineering processes: Self-organizing design and processes – Multi seeded microcosms – Interface coupling in ecological systems – Concept of energy – Determination of sustainable loading of ecosystems.

Module IV

Ecotechnology for waste treatment: Ecological engineering and ecotechnology – Classification of ecotechnology – Principles of ecological engineering. Ecosanitation- Principles and operation of soil infiltration systems – Wetlands and ponds – source separation systems – Aquacultural systems – Agro ecosystems – Detritus based treatment for solid wastes – Applications of ecological engineering for marine systems.

References:

1. Jorgensen, S.E. Ecological Engineering: Principles and Practice. CRC Press, 2003

2. Mitsch, W.J. Ecological Engineering and Ecosystem Restoration, Wiley 2nd Ed., 2003

3. White I.D., Mottershed, D.N. and Harisson, S.J. Environmental systems – An Introductory text, Chapman Hall, London, 1994

4. Mitsch, J.W. and Jorgensen, S.E. Ecological Engineering – An Introduction to Ecotechnology, John Wiley & Sons, New York, 1989.

5. Alan Sitkin. Principles of Ecology and Management, Good Fellow Publishers, 2011

18-455-0301: FLUID POWER SAFETY

Course Outcomes:

On completion of this course the student will be able to:

1.Understand operation of fluid power devices and symbols used in fluid power circuits and select actuators and control components for given applications

2. Know basic elements used in building Hydraulic circuits, their operational and safety features and uses

3. Draw and analyse Hydraulic circuits to perform desired functions

4. Analyse troubleshooting and maintenance of fluid power systems

5. Understand principle of operation of pneumatic control circuits and select actuators and control components for given applications

6. Follow the safety precautions required in the testing and operation of hydraulic and pneumatic systems.

Module I

Introduction to Hydraulics- Pascal's Law- Conservation of energy- Pressure, Work and Power-Principles of Power Hydraulics, Pressure and Flow Measurements- Bernoulli's Principle- Hydraulic symbols- Advantages. Hydraulic fluids, Properties Pipings and Seals- Reservoirs. Actuartors-Cylinders, Rams, Hydraulic Motors. Pumps- Gear, Vane and Piston types- Fixed and variable flow. Testing of Actuators & Pumps- Safety Precautions.

Module II

Directional Control- Check valve, Pilot – operated, Two- way and Four -way valves- Rotary valves. Pressure Control – Relief valves- Different functions. Volume control- Methods and Types. Testing of Control Valves and Safety precautions.

Module III

Pneumatic Systems: Introduction: Production of compressed air, Air Receives, Accumulators, Dry and oil free compressed air.

Pneumatic control: Components, Types of Cylinders, Control Valves- Direction, Pressure and Flow, Air Motors and Pneumatic Symbols.

Maintenance & Safety: Compressors & Accessories.

Module IV

Accessories- Accumulators, Pressure Switches. Fluid Power Systems, Simple circuits- Hydraulic, Pneumatic, Hydropneumatic and Electrohydraulic. System Maintenance and Safety.

References:

1. J.Pippenger & T. Hicks, Industrial Hydraulics, McGraw Hill, 1979.
2. Majumdar.S. R, Pneumatic Systems – Principles & Maintenance, Tata McGraw Hill, 2007.
3. Ernst W, Oil Hydraulics and its Industrial Applications, 2nd edition, McGraw Hill, 1960.
4. Jagadish Lal, Hydraulic Machines (including Fluidics), Metropolitan Book Co Ltd., New Delhi, 2003
5. Anthony Esposito, Fluid Power - with Applications, Pearson, 2011.
6. Andrew Parr, Hydraulics & Pneumatics, Elsevier, 2011.

18-455-0302: HUMAN FACTORS ENGINEERING

Course Outcomes:
On completion of this course the student will be able to:
1. Demonstrate an understanding of the fundamental concepts of ergonomics and human factors principles and theory.
2. Explain measurement techniques related to anthropometric and muscular characteristics of human body and human mind, human mental and physical works, workload and stresses
3. Apply ergonomic principles in the workplace or other environment.
4. Attain a grasp of the fundamental principles of experimental design, collection of data related to human factors, and their analysis and interpretation (laboratory experiments); and
5. Work in a team and communicate effectively through written reports and presentations.

Module I
Foundational Ergonomics: Introduction & background, Ergonomics defined, Ergonomics & safety, Ergonomics domains, Classification of ergonomics problems and History of the field and objectives.
Senses of the Human Body: Introduction and background, Sensory Functions: vision, visual fatigue, Audition, How do we hear?
Environmental Factors in Ergonomics: Visual factors light levels, illumination, noise levels, measuring noise levels. Thermal conditions: temperature & humidity, controlling the thermal conditions. Vibration and the Human Body

Module II
Engineering Anthropometry and Workspace Design (Body Size): Introduction, human variability, statistical analysis, anthropometric data, structural and functional data, use anthropometric data in design, general principles for workspace design.
Workplace Design: Sizing the workplace to fit the body, standing/sitting, manipulation, reaching & grasping, handling loads,. General Principles of Workplace and Design, Work place evaluation tools- Rapid Upper Limb Assessment Tool.
Controls & Displays: Controls, Guidelines for Control Layout and Design, Types of Controls, Displays, Types of Displays, Guidance on Color Coding in Displays.
Biomechanics of Work: The musculoskeletal system, Bones and connective tissues, muscles, biomechanical model, single-segment planner static model, NIOSH lifting guide.

Module III
Heavy Work and Evaluating Physical Workloads and Lifting: Energy consumption during heavy work, energy efficiency of heavy work, effects of heavy work and heat, evaluation of physical workload, VO2max. Manual material handling & lifting: material handling, classification of manual material handling (task characteristics, material characteristics, work practice characteristics & worker characteristics), general ergonomics roles for lifting of loads. Fatigue: muscular fatigue, mental fatigue

and shift work related fatigue, general fatigue and measuring fatigue. Light and Moderate Work

Workload and Stress: What is stress?, Stressor causes stress, Stress causes emotions, Stress at work & leisure, Eliminating stressors at work, Effect of stress, Measurement of stress, Mental workload, Physical Workload, Monotony & Boredom and Borg's Scales. Mental Workload Measurement: Measures of Primary and Secondary Task Performance, Physiological Measures, Psychophysical Assessment.

Module IV

Muscular Work & Nervous Control of Movements: Introduction and background, Muscular Work: Muscular Contractile System, Mechanism of Contraction (Sliding Filament Model), Method to Stimulate and Control the Mechanism of Contraction, Energy That Drives Contraction, Innervations of the Muscular System: Efferent Nerves, Sensory Nerves. Reflexes, Energy Transformation Process for Muscle Activity, Types of Muscular Work, Muscular Fatigue, Types of Muscle Contractions.

Information Ergonomics: Introduction and background, Information Processing: Perception, Attention: Sustain attention, selective attention, focused attention, divided attention. Stimuli responses and reaction time.

References:

1. Bush, P. M. Ergonomics Foundational Principles, Applications, and Technologies. Taylor and Francis (CRC Press), US, 2012.
2. Kromer, K.H. (2008).Fitting the human: Introduction to Ergonomics. 6 th ed. Taylor and Francis (CRC Press), US, 2008.
3. Wickens, K.H., Yili Liu, J. D. and Becker, S. E. An Introduction to Human Factors Engineering. 2 nd ed. Pearson Educational, Inc, US, 2004.

18-455-0303: HSE MANAGEMENT IN HYDROCARBON INDUSTRY

Course Outcomes:

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

1. Explain various Acts related to Safety, Health and Environment in petroleum industry.

2. Demonstrate the knowledge of various drilling fluids handling and safe disposal such toxic products.

3. Gain knowledge of disaster management to fight any crisis.

4. Identify mitigation measures for occupational health hazards in hydrocarbon industry.

5. Demonstrate the understanding of the safety precautions adopted in the design, installation, and operation of natural gas pipelines

Module I

Introduction to environmental control in the petroleum industry: Overview of environmental issues- A new attitude.

Drilling and production operations: Drilling- Production- Air emissions.

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Module II

The impact of drilling and production operations: Measuring toxicity- Hydrocarbons- Salt Heavy metals- Production chemicals- Drilling fluids- Produced water- Nuclear radiation- Air pollution- Acoustic impacts- Effects of offshore platforms- Risk assessment.

Environmental transport of petroleum wastes: Surface paths- Subsurface paths- Atmospheric paths, planning for environmental protection.

Waste treatment methods: Treatment of water- Treatment of solids- Treatment of air Emissions-Waste water disposal: surface disposal.

Well blowout fires and their control- Firefighting equipment, Suppression of hydrocarbons fires

Module III

Oil mines regulations: Introduction- Returns, Notices and plans- Inspector, management and duties- Drilling and workover- Production- Transport by pipelines- Protection against gases and fires- Machinery, plants and equipment- General safety provisions- Miscellaneous-Remediation of contaminated sites- Site assessment- Remediation process.

Module IV

Toxicity, physiological, asphyxiation, respiratory, skin effect of petroleum hydrocarbons and their mixture- Sour gases with their threshold limits- Guidelines for occupational health monitoring in oil and gas industry. Corrosion in petroleum industry- Additives during acidizing, sand control and fracturing.

HSE issues in the storage of liquefied natural gas. Transportation of petroleum products and natural gas by pipelines – safety precautions in the design, installation and operation.

References:

1. John C. Reis. Environmental Control in Petroleum Engineering, Gulf Publishing Company, 1996.
2. Application of HAZOP and What if Reviews to the Petroleum, Petrochemical and Chemical Process Industries, Dennis P. Nolan, Noyes Publications, 1994.
3. Oil Industry Safety Directorate (OISD) Guidelines, Ministry of Petroleum & Natural Gas, Government of India and Oil Mines Regulations-1984, Directorate General of Mines Safety, Ministry of Labor and Employment, Government of India.
4. Guidelines for Fire Protection in Chemical, Petrochemical and Hydrocarbon Processing Facilities, Centre for Chemical Process Safety, American Institute of Chemical Engineers, 2003.
5. Guideline for Process Safety Fundamentals in General Plant Operations, Centre for Chemical Process Safety, AIChE, 1995.

18-455-0304: FIRE MODELLING

Course Outcomes:
On completion of this course the student will be able to
1. Explain the fluid flow and heat transfer characteristics of two-zone models
2. Describe various flow features in terms of appropriate fluid mechanical principles and force balances.
3. Apply modern CFD software tools to build flow geometries, generate an adequate mesh for an accurate solution, select appropriate solvers to obtain a flow solution, and visualize the resulting flow field
4. Apply CFD software tools for fire modelling

Module I
Purpose of fire modeling, Fire development, Description of fire models. Network models - Description of network models. Description of multizone indoor air quality and ventilation analysis computer program (CONTAM). Two-zone models - A two-zone model for a single compartment, Multi-room two-zone model Fluid flow and heat transfer in two zone models, Plume Entrainment Vent Flows, Mechanical Ventilation, Species Concentration, Heat Release Rate, Combustion Chemistry, Heat Transfer.

Module II
The CFAST model - Model description. CFD models - Derivation of equations Mass Momentum Energy Species. Discretization methods- Nature of numerical methods, Discretization methods, Control volume formulation example. Heat conduction - Basic equations, Grid spacing, Boundary conditions, Solution of linear algebraic equations, Discretization equation, Explicit implicit schemes, Two and three dimensions, Solution of equations

Module III
Convection and diffusion - Steady one-dimensional convection and diffusion, Upwind and other schemes, two and three dimensions. Flow field - Continuity equation, Pressure and velocity corrections, Simple algorithm.

Module IV
Fire modelling using CFD models - Combustion Pyrolysis model, thermally thick, thin and liquid fuels, Sprinklers, Fire suppression by water, Heat release rate (mixture fraction, finite-rate reaction). The fire dynamics simulator - Description of FDS, FDS demo.

References:

1. Suhas V. Patankar. Numerical Heat Transfer and Fluid Flow, CRC Press, 2017.
2. Bjon Karlsson and James G. Quintiere. Enclosure Fire Dynamics, CRC Press, 1999.

18-455-0305: ENVIRONMENTAL IMPACT ASSESSMENT

Course outcomes:
On completion of this course the student will be able to:
1. Perform an environmental impact assessment.
2. Articulate an awareness of the professional standards, including ethical issues, involved in assessing environmental impacts.
3. Demonstrate comprehension of the concept of alternative courses of action that should be included in an environmental impact assessment, and the reason that alternatives are included.
4. Define the legal requirements that affect the scope of an environmental impact assessment.
5. Explain the important role of stakeholders and the value of working with them.
6. *Analyse the basic types of impacts and potentially impacted resources that must be considered.*

Module I
Historical development of Environmental Impact Assessment (EIA). EIA in Project Cycle. Legal and Regulatory aspects in India. – Types and limitations of EIA –.EIA process- screening –scoping - setting – analysis – mitigation. Cross sectoral issues and terms of reference in EIA –Public Participation in EIA-EIA Consultant Accreditation.

Module II
Impact identification and prediction: Matrices – Networks – Checklists –Cost benefit analysis – Analysis of alternatives – Software packages for EIA – Expert systems in EIA. Prediction tools for EIA – Mathematical modeling for impact prediction – Assessment of impacts – air – water – soil – noise – biological — Cumulative Impact Assessment.

Module III
Social impact assessment and EIA documentation: Social impact assessment - Relationship between social impacts and change in community and institutional arrangements. Individual and family level impacts. Communities in transition Documentation of EIA findings – planning – organization of information and visual display materials. Preparation of EIS.

Module IV
EIA Report preparation. Environmental Management Plan - preparation, implementation and review – Mitigation and Rehabilitation Plans – Policy and guidelines for planning and monitoring programmes – Post project audit – Ethical and Quality aspects of Environmental Impact Assessment- Case Studies

References:
1. Canter, L.W., Environmental Impact Assessment, McGraw Hill, New York. 1996
2. Lawrence, D.P., Environmental Impact Assessment – Practical solutions to recurrent problems, Wiley-Interscience, New Jersey. 2003
3. World Bank –Source book on EIA
4. Marriot, Betty, Environmental Impact Assessment: a Practical Guide, McGraw Hill, 1997.

18-455-0306: COMPUTATATIONAL FLUID DYNAMICS

Course Outcomes:

On completion of this course the student will be able to:

1. Develop mathematical models for flow phenomena.

2. Analyse mathematical and computational methods for fluid flow and heat transfer simulations.

3. Solve computational problems related to fluid flows and heat transfer.

4. Evaluate the grid sensitivity and analyze the accuracy of a numerical solution.

5. Evaluate flow parameters in internal and external flows.

6. Develop flow simulation code for fluid flow and heat transfer problems

Module I

Introduction: History and Philosophy of computational fluid dynamics, CFD as a design and research tool, Applications of CFD in engineering, Programming fundamentals, MATLAB programming, Numerical Methods Governing Equations of Fluid Dynamics: Models of the flow, The substantial derivative, Physical meaning of the divergence of velocity, The continuity equation, The momentum equation, The energy equation, Navier-Stokes equations for viscous flow, Euler equations for inviscid flow, Physical boundary conditions, Forms of the governing equations suited for CFD, Conservation form of the equations, shock fitting and shock capturing, Time marching and space marching.

Module II

Mathematical Behavior of Partial Differential Equations: Classification of quasi-linear partial differential equations, Methods of determining the classification, General behavior of Hyperbolic, Parabolic and Elliptic equations. Basic Aspects of Discretization: Introduction to finite differences, Finite difference equations using Taylor series expansion and polynomials, Explicit and implicit approaches, Uniform and unequally spaced grid points.

Grids With Appropriate Transformation: General transformation of the equations, Metrics and Jacobians, The transformed governing equations of the CFD, Boundary fitted coordinate systems, Algebraic and elliptic grid generation techniques, Adaptive grids.

Parabolic Partial Differential Equations: Finite difference formulations, Explicit methods – FTCS, Richardson and DuFort-Frankel methods, Implicit methods – Laasonen, Crank-Nicolson and Beta formulation methods, Approximate factorization, Fractional step methods, Consistency analysis, Linearization.

Module III

Stability Analysis: Discrete Perturbation Stability analysis, von Neumann Stability analysis, Error analysis, Modified equations, Artificial dissipation and dispersion. Elliptic Equations: Finite difference formulation, solution algorithms: Jacobi-iteration method, Gauss-Siedel iteration method, point- and line-successive over-relaxation methods, alternative direction implicit methods.

Hyperbolic Equations: Explicit and implicit finite difference formulations, splitting methods, multistep methods, applications to linear and nonlinear problems, linear damping, flux corrected transport, monotone and total variation diminishing schemes, tvd formulations, entropy condition, first-order and second-order tvd schemes. Scalar Representation of Navier-Stokes Equations: Equations of fluid motion, numerical

algorithms: ftcs explicit, ftbcs explicit, Dufort-Frankel explicit, Maccormack explicit and implicit, btcs and btbcs implicit algorithms, applications.

Module IV

Grid Generation: Algebraic Grid Generation, Elliptic Grid Generation, Hyperbolic Grid Generation, Parabolic Grid Generation Finite Volume Method For Unstructured Grids: Advantages, Cell Centered and Nodal point Approaches, Solution of Generic Equation with tetra hedral Elements, 2-D Heat conduction with Triangular Elements Numerical Solution of Quasi One Dimensionl Nozzle Flow: Subsonic-Supersonic isentropic flow, Governing equations for Quasi 1-D flow, Non-dimensionalizing the equations, MacCormack technique of discretization, Stability condition, Boundary conditions, Solution for shock flows.

References:

1. Anderson, J.D.(Jr), Computational Fluid Dynamics, McGraw-Hill Book Company, 1995.
2. Versteeg H K, and Malalasekera W. An Introduction to Computational Fluid Dynamics: The Finite Volume Method. Longman Scientific & Technical Publishers, 2007.
3. Hoffman, K.A., and Chiang, S.T., Computational Fluid Dynamics, Vol. I, II and III, Engineering Education System, Kansas, USA, 2000.
4. Chung, T.J., Computational Fluid Dynamics, Cambridge University Press, 2003.
5. Anderson, D.A., Tannehill, J.C., and Pletcher, R.H., Computational Fluid Mechanics and Heat Transfer, McGraw Hill Book Company, 2002.