UNIVERSITY DEPARTMENTS

ANNA UNIVERSITY, CHENNAI 600 025

REGULATIONS - 2013

M.E. THERMAL ENGINEERING WITH SPECIALISATION IN REFRIGERATION AND AIR CONDITIONING (FULL TIME)

I TO IV SEMESTERS CURRICULUM AND SYLLABUS

SEMESTER I

SL. NO.	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1.	RA8101	Refrigeration Systems Design	3	0	0	3
2.	IC 8151	Advanced Heat Transfer	3	1	0	4
3.	IC 8152	Advanced Thermodynamics	3	1	0	4
4.	MA8155	Advanced Numerical Methods	3	1	0	4
5.		Elective I	3	0	0	3
6.		Elective II	3	0	0	3
PRACTICAL						
7	RA8111	Refrigeration and Air conditioning lab	0	0	3	2
		TOTAL	**18**	**3**	**3**	**23**

SEMESTER II

SL. NO.	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1	RA8201	Air Conditioning Systems Design	3	0	0	3
2	RA8202	Computer Simulation of Refrigeration and Air Conditioning Systems	3	0	0	3
3	RA8203	Design of Condensers Evaporators and Cooling Towers	3	0	0	3
4	IC8251	Instrumentation for Thermal Systems	3	0	0	3
5		Elective III	3	0	0	3
6		Elective IV	3	0	0	3
PRACTICAL						
7	RA8211	Seminar	0	0	2	1
8	RA8212	Simulation Laboratory	0	0	3	2
		TOTAL	**18**	**0**	**5**	**21**

SEMESTER III

SL. NO.	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1		Elective V	3	0	0	3
2		Elective VI	3	0	0	3
3		Elective VII	3	0	0	3
PRACTICAL						
4	RA8311	Project Work Phase I	0	0	12	6
		TOTAL	**9**	**0**	**12**	**15**

SEMESTER IV

SL. NO.	COURSE CODE	COURSE TITLE	L	T	P	C
PRACTICAL						
1	RA8411	Project Work Phase II	0	0	24	12
		TOTAL	**0**	**0**	**24**	**12**

TOTAL NUMBER OF CREDITS TO BE EARNED FOR AWARD OF THE DEGREE = 71

ELECTIVES FOR M.E. REFRIGERATION AND AIRCONDITIONING

SL. NO.	COURSE CODE	COURSE TITLE	L	T	P	C
1.	RA8001	Air Handling Systems Design	3	0	0	3
2.	RA8002	Behavioural Science and Engineering Management	3	0	0	3
3.	RA8003	Building Architecture and HVAC Systems	3	0	0	3
4.	RA8004	Cryogenic Engineering	3	0	0	3
5.	RA8005	Design of Clean Rooms and Containment Areas	3	0	0	3
6.	RA8006	Design of Thermal Systems	3	0	0	3
7.	RA8007	Energy Conservation in HVACR Systems	3	0	0	3
8.	RA8008	Erection and Maintenance of Refrigeration and Air-conditioning Equipments	3	0	0	3
9.	RA8009	Fans, Blowers and Compressor in Air Conditioning Systems	3	0	0	3
10.	RA8010	Food Processing Preservation and Transport	3	0	0	3
11.	RA8011	Indoor Air Quality Control	3	0	0	3
12.	RA8012	Industrial Refrigeration Systems	3	0	0	3
13.	RA8013	Materials for Low Temperature Applications	3	0	0	3
14.	RA8014	Mini Project	3	0	0	3
15.	RA8015	Quantitative and Qualitative Research Methodologies	3	0	0	3
16.	RA8016	Refrigeration Machinery and Components	3	0	0	3
17.	RA8017	Sorption Heating and Cooling Systems	3	0	0	3
18.	EY8074	Energy Efficient Building Design	3	0	0	3
19.	EY8075	Energy Forecasting, Modeling and Project Management	3	0	0	3
20.	RA8071	Computational Fluid Dynamics	3	0	0	3

Attested

DIRECTOR
Centre For Academic Courses
Anna University, Chennai-600 025.

RA8101 **REFRIGERATION SYSTEMS DESIGN** **L T P C**
3 0 0 3

AIM

- To teach the students about Refrigeration System Design concepts

OBJECTIVES

- Teaching cycle analysis pertaining to Refrigeration systems.
- Teaching performance of system components and their balancing in cycles.
- Teaching the significance of Refrigerants and their impact on the environment

UNIT I REFRIGERATION CYCLES – ANALYSIS 12

Development of Vapor Compression Refrigeration Cycle from Reverse Carnot Cycle- conditions for high COP-deviations from ideal vapor compression cycle, Multipressure System, Cascade Systems-Analysis. Vapor Absorption Systems-Aqua Ammonia & Li-Br Systems, Steam Jet Refrigeration Thermo Electric Refrigeration, Air Refrigeration cycles, Heat pumps.

UNIT II MAIN SYSTEM COMPONENTS 9

Compressor- Types, performance, Characteristics, Types of Evaporators & Condensers and their functional aspects, Expansion Devices and their Behavior with fluctuating load, cycling controls

UNIT III REFRIGERANTS 6

Classification of Refrigerants, Refrigerant properties, Oil Compatibility, Environmental Impact-Montreal / Kyoto protocols-Eco Friendly Refrigerants, alternatives to HCFCS, Secondary Refrigerants

UNIT IV SYSTEM BALANCING 9

Estimation of Cooling Load, System Equilibrium and Cycling Controls.

UNIT V ELECTRICAL DRIVES & CONTROLS 9

Electric circuits in Refrigerators and Air conditioners, Types of Motors, Starters, Relays, Thermostats, Pressure controls and other controls.

TOTAL :45 PERIODS

OUTCOME

- On successful completion of this course the student will be able to conceptually design a Refrigeration system for the given application.

REFERENCES

1. Dossat R.J., Principles of refrigeration, John Wiley , S.I. Version (2001).
2. Stoecker W.F., Refrigeration and Air conditioning , McGraw-Hill Book Company , 1989.
3. Jordan and Priester, Refrigeration and Air conditioning 1985.
4. Langley, Billy C., ‘Solid state electronic controls for HVACR’ pentice-Hall 1986.
5. Air conditioning and Refrigeration, Rex Milter, Mark R.Miller, McGraw Hill 2006

IC8151 **ADVANCED HEAT TRANSFER** **L T P C**
3 1 0 4

AIM

- The course is intended to build up necessary fundamentals for the understanding of the physical behavior of conduction and convection.

OBJECTIVES

- To develop the ability to use the heat transfer concepts for various applications like finned systems, turbulence flows, high speed flows.
- To analyse the thermal analysis and sizing of heat exchangers and to learn the heat transfer coefficient for compact heat exchanges.
- To achieve an understanding of the basic concepts of phase change processes and mass transfer.

UNIT I CONDUCTION AND RADIATION HEAT TRANSFER 10

One dimensional energy equations and boundary condition - three-dimensional heat conduction equations - extended surface heat transfer - conduction with moving boundaries - radiation in gases and vapour Gas radiation and radiation heat transfer in enclosures containing absorbing and emitting media – interaction of radiation with conduction and convection.

UNIT II TURBULENT FORCED CONVECTIVE HEAT TRANSFER 10

Momentum and energy equations - turbulent boundary layer heat transfer - mixing length concept - turbulence model – k Є model - analogy between heat and momentum transfer – Reynolds, Colburn, Prandtl turbulent flow in a tube - high speed flows.

UNIT III PHASE CHANGE HEAT TRANSFER AND HEAT EXCHANGER 8

Condensation with shears edge on bank of tubes - boiling – pool and flow boiling - heat exchanger -Є – NTU approach and design procedure - compact heat exchangers.

UNIT IV NUMERICAL METHODS IN HEAT TRANSFER 9

Finite difference formulation of steady and transient heat conduction problems – discretization schemes – explicit - Crank Nicolson and fully implicit schemes - control volume formulation -steady one-dimensional convection and diffusion problems - calculation of the flow field – SIMPLER Algorithm.

UNIT V MASS TRANSFER AND ENGINE HEAT TRANSFER CORRELATION 8

Mass transfer - vaporization of droplets - combined heat and mass transfers - heat transfer correlations in various applications like I.C. engines - compressors and turbines.

TOTAL (L – 45 + T – 15): 60 PERIODS

OUTCOME

On successful completion of this course the student will be able to apply the law of thermodynamics to engines.

REFERENCES

1. Yunus A.Cengal, Heat and Mass Transfer – A practical Approach, 3rd edition, Tata McGraw - Hill, 2007.
2. Holman.J.P, Heat Transfer, Tata Mc Graw Hill, 2002.
3. Ozisik. M.N., Heat Transfer – A Basic Approach, McGraw-Hill Co., 1985
4. Incropera F.P. and DeWitt. D.P., Fundamentals of Heat & Mass Transfer, John Wiley & Sons, 2002.
5. Nag.P.K, Heat Transfer, Tata McGraw-Hill, 2002
6. Ghoshdastidar. P.S., Heat Transfer, Oxford University Press, 2004
7. Yadav, R., Heat and Mass Transfer, Central Publishing House, 1995.

IC8152 ADVANCED THERMODYNAMICS L T P C
3 1 0 4

AIM

- To enrich the knowledge of students in thermodynamics

OBJECTIVES

- To achieve an understanding of basic principle and scope of thermodynamics.
- To predict the availability and irreversibility associated with the thermodynamic processes.
- To analyse the properties of ideal and real gas mixtures and to understand the basic concepts of fuel and combustions

UNIT I THERMODYNAMIC PROPERTY RELATIONS 9

Thermodynamic Potentials, Maxwell relations, Generalised relations for changes in Entropy, Internal Energy and Enthalpy, Generalised Relations for C_p and C_v, Clausius Clayperon Equation, Joule-Thomson Coefficient, Bridgeman Tables for Thermodynamic Relations.

UNIT II REAL GAS BEHAVIOUR AND MULTI-COMPONENT SYSTEMS 9

Equations of State (mention three equations), Fugacity, Compressibility, Principle of Corresponding States, Use of generalised charts for enthalpy and entropy departure, fugacity coefficient, Lee-Kesler generalised three parameter tables. Fundamental property relations for systems of variable composition, partial molar properties, Real gas mixtures, Ideal solution of real gases and liquids, Equilibrium in multi-phase systems, Gibbs phase rule for non-reactive components

UNIT III CHEMICAL AVAILABILITY 9

Introduction, Reversible work, Availability, Irreversibility and Second-Law Efficiency for a closed System and Steady-State Control Volume. Availability Analysis of Simple Cycles. Chemical availability, Environmental state, Air-conditioning processes. Fuel Chemical availability, availability analysis of chemical processes – steam power plant, combustion and heat transfer losses, preheated inlet air, problems.

UNIT IV FUEL – AIR CYCLES AND THEIR ANALYSIS 9

Ideal gas laws and properties of Mixtures, Combustion Stoichiometry, Application of First Law of Thermodynamics – Heat of Reaction – Enthalpy of Formation – Adiabatic flame temperature. Second law of Thermodynamics applied to combustion – entropy, maximum work and efficiency

UNIT V THERMO CHEMISTRY 9

Ideal gas laws and properties of Mixtures, Combustion Stoichiometry, Application of First Law of Thermodynamics – Heat of Reaction – Enthalpy of Formation – Adiabatic flame temperature. Second law of Thermodynamics applied to combustion – entropy, maximum work and efficiency Chemical equilibrium: - Equilibrium combustion products. Dynamic properties of working fluids: - Unburned mixture – Low temperature combustion products – High temperature combustion products, problems.

TOTAL (L – 45 + T – 15): 60 PERIODS

OUTCOME

- On successful completion of this course the student will be able to apply the law of thermodynamics to thermal systems.

REFERENCES

1. Kenneth Wark., J. R, Advanced Thermodynamics For Engineers, McGraw-Hill Inc., 1995.
2. Yunus A. Cengel and Michael A . Boles, Thermodynamics, McGraw-Hill Inc., 2006.
3. B.P. Pundir, I.C. engine combustion and emissions.
4. Bejan, A., Advanced Engineering Thermodynamics, John Wiley and Sons, 1988.
5. Holman,J.P., Thermodynamics, Fourth Edition, McGraw-Hill Inc., 1988.
6. Smith, J.M. and Van Ness., H.C., Introduction to Chemical Engineering Thermodynamics, Fourth Edition, McGraw-Hill Inc., 1987.

7. Sonntag, R.E., and Van Wylen, G, Introduction to Thermodynamics, Classical and Statistical, Third Edition, John Wiley and Sons, 1991.
8. Sears, F.W. and Salinger G.I., Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Third Edition, Narosa Publishing House, New Delhi, 1993.
9. DeHotf, R.T., Thermodynamics in Materials Science, McGraw-Hill Inc., 1993.
10. Rao, Y.V.C., Postulational and Statistical Thermodynamics, Allied Publisher Limited, New Delhi, 1994.

MA8155 ADVANCED NUMERICAL METHODS **L T P C**
3 1 0 4

AIM

OBJECTIVES

- To impart knowledge on numerical methods that will come in handy to solve numerically the problems that arise in engineering and technology. This will also serve as a precursor for future research.

UNIT I ALGEBRAIC EQUATIONS (9+3)

Systems of linear equations: Gauss Elimination method, pivoting techniques, Thomas algorithm for tridiagonal system – Jacobi, Gauss Seidel, SOR iteration methods - Systems of nonlinear equations: Fixed point iterations, Newton Method, Eigenvalue problems: power method, inverse power method, Faddeev – Leverrier Method.

UNIT II ORDINARY DIFFERENTIAL EQUATIONS (9+3)

Runge Kutta Methods for system of IVPs, numerical stability, Adams-Bashforth multistep method, solution of stiff ODEs, shooting method, BVP: Finite difference method, orthogonal collocation method, orthogonal collocation with finite element method, Galerkin finite element method.

UNIT III FINITE DIFFERENCE METHOD FOR TIME DEPENDENT PARTIAL DIFFERENTIAL EQUATION (9+3)

Parabolic equations: explicit and implicit finite difference methods, weighted average approximation - Dirichlet and Neumann conditions – Two dimensional parabolic equations – ADI method; First order hyperbolic equations – method of characteristics, different explicit and implicit methods; numerical stability analysis, method of lines – Wave equation: Explicit scheme- Stability of above schemes.

UNIT IV FINITE DIFFERENCE METHODS FOR ELLIPTIC EQUATIONS (9+3)

Laplace and Poisson’s equations in a rectangular region: Five point finite difference schemes, Leibmann’s iterative methods, Dirichlet and Neumann conditions – Laplace equation in polar coordinates: finite difference schemes – approximation of derivatives near a curved boundary while using a square mesh.

UNIT V FINITE ELEMENT METHOD (9+3)

Partial differential equations – Finite element method - orthogonal collocation method, orthogonal collocation with finite element method, Galerkin finite element method.

TOTAL (L – 45 + T – 15): 60 PERIODS

OUTCOME

- It helps the students to get familiarized with the numerical methods which are necessary to solve numerically the problems that arise in engineering.

REFERENCES

1. Saumyen Guha and Rajesh Srivastava, “Numerical methods for Engineering and Science”, Oxford Higher Education, New Delhi, 2010.
2. Gupta S.K., “Numerical Methods for Engineers”, New Age Publishers, 1995
3. Burden, R.L., and Faires, J.D., “Numerical Analysis – Theory and Applications”, Cengage Learning, India Edition, New Delhi, 2009.
4. Jain M. K., Iyengar S. R., Kanchi M. B., Jain , “Computational Methods for Partial Differential Equations”, New Age Publishers,1993.
5. Morton K.W. and Mayers D.F., “Numerical solution of partial differential equations”, Cambridge University press, Cambridge, 2002.

RA8111	REFRIGERATION AND AIR CONDITIONING LAB	L	T	P	C
		0	0	3	2

AIM:

- To impart knowledge on the practical aspects of refrigeration and air conditioning systems.

OBJECTIVES

- To understand the behaviour of system at different operating conditions
- To understand the influence of individual components on the Overall performance of the system.
- To understand the usage of different refrigeration tools.

LIST OF EXPERIMENTS

1. Study of Refrigeration and Air conditioning system components.
2. Study and use of Refrigeration and Air conditioning components and tools.
3. Performance study in a Refrigerator with calorimeter.
4. Performance study in a heat pump for different indoor and outdoor conditions
5. Performance study in a deep freezer for different coil temperature
6. Performance study in a transparent VCR system for different coil temperature
7. Performance comparison of a window Air conditioner with air-cooled and water-cooled condenser.
8. Performance study on Automobile Air conditioner.
9. Performance study of finned tube evaporator.
10. Performance study in a walk-in cooler
11. Heat transfer and flow characteristics of secondary refrigerant in a tubular heat exchange
12. Performance study in a water cooler for various load conditions.

LABORATORY EQUIPMENT REQUIREMENTS:

1. Cut section model of various Refrigeration and Air conditioning system components.
2. Refrigeration and Air conditioning tools.
3. Refrigerator with calorimeter Heat pump setup
4. Deep freezer setup.
5. Cooling tower experimental setup
6. Window air conditioner with air-cooled and water-cooled condenser.
7. Automobile Air conditioner test rig
8. Walk-in cooler
9. Refrigerator with different capillary length
10. water cooler experimental setup

11. Finned tube evaporator
12. Tubular heat exchanger with necessary instrumentation
13. Charging unit

OUTCOME

- On successful completion of this course, the student will be able to understand the basic analysis of any refrigeration system and design the heat exchanger for a particular application.

TOTAL :45 PERIODS

RA8201 AIRCONDITIONING SYSTEMS DESIGN

L	T	P	C
3	0	0	3

AIM

- To impart knowledge on working principles and design aspects of Air conditioning systems.

OBJECTIVES

- To learn the psychometric concepts underlying Air conditioning process.
- To learn the design features of specific Air conditioning system.
- To learn the load estimation principles in Air conditioning system.
- To learn about the critical auxiliary systems such as air distribution circuits, water distribution circuits etc.

UNIT I TYPES OF AIR CONDITIONING SYSTEMS AND PSYCHROMETRICS 12

Moist Air properties, use of Psychrometric Chart, Various Psychrometric processes, Air Washer, Adiabatic Saturation. Summer and winter Air conditioning, Types of air conditioning systems.

UNIT II LOAD ESTIMATION 9

Solar Radiation-Heat Gain through Glasses, Heat Transfer through Walls and Roofs-Total Cooling Load Estimation.

UNIT III AIR DISTRIBUTION 9

Flow through Ducts , Static & Dynamic Losses , Diffusers , Duct Design–Equal Friction Method , Duct Balancing , Fans & Duct System Characteristics , Fan Arrangement Variable Air Volume systems , Air Handling Units and Fan Coil units.

UNIT IV AIR CONDITIONING CONTROL 9

Controls of Temperature, Humidity and Air flow.

UNIT V HVAC SYSTEM IN AUTOMOBILES 6

Automotive System layout and Components- Commonly used Refrigerants- Safety devices – Climate control – Fuel efficiency aspects

TOTAL :45 PERIODS

OUTCOME

On successful completion of this course the student will be able to understand conceptually the design of a HVAC system.

REFERENCES

1. Arora C.P. , Refrigeration and Air Conditioning , Tata McGraw Hill Pub. Company , New Delhi - 2000.

2. ALI VEDAVARZ, SUNIL KUMAR, Mohammed Iqbal, Hussain Handbook of Heating , Ventilation and Air conditioning for Design Implementation ,Industrial press Inc,2007.
3. ASHRAE , Fundamentals and equipment , 4 volumes-ASHRAE Inc. 2005
4. Jones , Air Conditioning Engineering , Edward Amold pub. 2001.
5. Carrier Air Conditioning Co., Handbook of Air Conditioning Systems design , McGraw Hill , 1985.
6. Langley , Billy C. Refrigeration and Air Conditioning Ed. 3 , Engie wood Cliffs (N.J) Prentice Hall 1986.

RA8202 COMPUTER SIMULATION OF REFRIGERATION AND AIR-CONDITIONING SYSTEMS **L T P C 3 0 0 3**

AIM

- To provide a clear understanding of mathematical modeling and to illustrate the student with various optimization techniques.

OBJECTIVES

- To introduce the concept of mathematical model for simulation of R & AC system.
- To expose the students to various optimization techniques

UNIT I BASIC CONCEPTS **8**

Introduction to thermodynamic cycles, Process in Refrigeration and Air conditioning systems, Exergy concept, Computer application , and Simulation methodology.

UNIT II MATHEMATICAL MODELLING FOR SIMULATION **7**

Mathematical models , Workable and Optimal system Principles , Types , Curve fitting and Regression Analysis , Newton-Raphson method , Mathematical modeling of Refrigeration and Air Conditioning components

UNIT III OPTIMIZATION TECHNIQUES **10**

Information flow diagram, Optimization techniques-Lagrange method , Search method, Dynamic programming, Geometric programming method , Linear programming method , Case studies.

UNIT IV SIMULATION OF REFRIGERATION SYSTEMS **8**

Simulation of compressor, Condenser, Evaporator, and Expansion devices, simulation of refrigeration piping and control systems

UNIT V SIMULATION OF AIR CONDITIONING SYSTEMS **12**

Computerized cooling load calculations, Packages, Simulation of psychometric processes, and Simulation of air flow in ducts, EER assessment, Simulation of air diffusion in space.

TOTAL : 45 PERIODS

OUTCOME

- On successful completion of this course the students can understand the basics of product design, simulation methods and gaining knowledge in complete simulation of HVAC and R systems.

REFERENCES

1. Stoecker, W.F., Design of Thermal Systems, 3rd Edition, McGraw-Hill Book Company , New York, 1989.
2. Yogesh Jaluria., Design and Optimization of Thermal systems , McGraw-Hill Book Company , New York , 1998
3. Kapur J.N., Mathematical Modelling , Wiley Eastern Limited , New Delhi , 1989
4. Stoecker,W.F., Refrigeration and air conditioning , McGraw Hill Pub. Company, 1989.

5. Anand A. Samuel , Computer Simulation of R&AC Systems- Web course hand book Anna University , 2000.
6. Dossat, R. J., Principles of refrigeration, John Wiley, 2001.
   Lanqley, Billy C., Refrigeration and Air-conditioning Edn.3, Engle Wood Chiffs (NJ), Prentice Hall, 1986.
7. Lanqley, Billy C., Refrigeration and Air-conditioning Edn.3, Engle Wood Chiffs (NJ), Prentice Hall, 1986.

RA8203 DESIGN OF CONDENSERS, EVAPORATORS AND COOLING TOWERS **L T P C**
3 0 0 3

AIM

- To equip the students in designing of condensers, evaporators and cooling Towers

OBJECTIVES

- To provide design procedures in designing of different types of condensers.
- To provide design procedures in designing of different types of evaporators.
- To provide design procedures in designing of different types cooling towers

UNIT I INTRODUCTION 5

Principles of heat transfer, Types of heat exchangers, Standard Representation, Parts description, TEMA Classifications.

UNIT II CONDENSERS 10

Estimation of heat transfer coefficient, Fouling factor, Friction factor. Design procedures, Wilson plots, designing different types of condensers, BIS Standards

UNIT III EVAPORATORS 10

Different types of evaporators, Design procedure, Selection procedure, Thermal Stress calculations, matching of components, Design of evaporative condensers

UNIT IV COOLING TOWERS 10

Types of Cooling towers, Analytical and graphical design procedures, Tower Characteristics Parametric analysis, Packaging, Flow control strategies and energy saving opportunities, Assessment of cooling towers.

UNIT V COMPACT AND PLATE HEAT EXCHANGER 10

Types – Merits and Demerits – Design of compact heat exchangers, plate heat exchangers, Mixing of plates, performance influencing parameters, limitations.

TOTAL: 45 PERIODS

OUTCOME

- On successful completion of this course, the student will be able to design different types of condensers, evaporators and cooling towers for HVAC applications.

REFERENCES

1. Arthur, P. Frass, Heat Exchanger Design, John Wiley and Sons, 1988.
2. Kern K.H., Process heat transfer, McGraw-Hill, 2002.
3. Sarit Kumar Das, Process Heat Transfer, Narosa Publishing House, 2009.
4. Lieke Wang, Bengt Sundén, Raj M.. Manglik., Plate Heat Exchangers: Design, Applications and Performance, WIT Press, 2007.
5. TEMA Hand book, Tubular Exchanger Manufacturer Association, New York, 2004.

IC8251 INSTRUMENTATION FOR THERMAL SYSTEMS

L	T	P	C
3	0	0	3

AIM

- To enhance the knowledge of the students about various measuring instruments, importance of error and uncertainty analysis, and advanced measurement

OBJECTIVES

- To understand the working of measuring instruments and errors associated with them
- To carry out error analysis and uncertainty of measurements
- To measure pressure and heat release from an IC engine, understand use of flow visualisation techniques

UNIT I MEASUREMENT CHARACTERISTICS 9

Instruments - Classification and Characteristics – Static and dynamic, Systematic and random errors, Statistical analysis, Uncertainity, Experimental planning and selection of measuring instruments.

UNIT II MEASUREMENT OF PHYSICAL QUANTITIES 12

Measurement of Temperature- Thermistor, Resistance Temperature Detector, Thermocouples, Pressure – Manometer, Bourdon gauge, Diaphragm gauge, electrical methods, In cylinder pressure transducer, Flow – Venturimeter, Rotameter, Ultrasonic flow meter, Vortex flow meter, Thermal mass flow meter, Turbine flow meter.

UNIT III ADVANCED MEASUREMENTS 9

Interferometer, Laser Doppler Anemometer, Hot wire Anemometer, Particle Image Velocimetry. Gas Analysers – Flame Ionisation Detector, Non-Dispersive Infrared Analyser, Chemiluminescent detector, Smoke meters, and Gas chromatography.

UNIT IV CONTROL SYSTEMS 10

Open & closed loop control systems, Response, Transfer function, Types of feedback, feedback Control system characteristics, Control system parameters, Servo motors, Stepper motors, Servo Amplifiers, Continuous control modes.

UNIT V DATA ACQUISITION SYSTEM 5

Data logging and acquisition - Sensors for error reduction, elements of computer interfacing, Timers and Counters, Analog to Digital & Digital to Analog conversion.

TOTAL: 45 PERIODS

OUTCOME

On successful completion of this course the student will be able to plan their experiments and understand the suitability, accuracy and uncertainty associated with the instrument used for measuring thermal system parameters.

REFERENCES

1. Holman, J.P., Experimental methods for Engineers, Tata McGraw-Hill, 7th Ed.2001.
2. Barney G.C, Intelligent Instrumentation, Second Edition, Prentice Hall of India, 1988.
3. Bolton.W, Industrial Control & Instrumentation, Universities Press, Second Edition, 2001.
4. Doblin E.O, Measurement System Application and Design, Second Edition, McGraw Hill, 1978.
5. Nakra, B.C., Choudhry K.K., Instrumentation, Measurements and Analysis Tata McGraw Hill, New Delhi, 2nd Edition 2003.
6. Morris.A.S, Principles of Measurements and Instrumentation, Prentice Hall of India, 1998.

RA8212 SIMULATION LABORATORY L T P C
0 0 3 2

AIM

- To analyze the heat transfer problems in the field of refrigeration and air conditioning using MAT LAB, CFD software

OBJECTIVES

- To builds a solid foundation in the MATLAB, CFD software
- To encourage a "hand's – on" approach to solving heat transfer problems

FOCUS: USE OF STANDARD APPLICATION SOFTWARE FOR SOLVING HEAT TRANSFER PROBLEMS

1. Heat exchanger analysis – NTU method
2. Heat exchanger analysis – LMTD method
3. Convection heat transfer analysis – Velocity boundary layer
4. Convection heat transfer analysis – Internal flow
5. Radiation heat transfer analysis – Emissivity
6. Critical radius of insulation
7. Lumped heat transfer analysis
8. Conduction heat transfer analysis
9. Condensation heat transfer analysis

DYNAMIC LINKING OF MAT LAB AND REF PROP SOFTWARE
SIMPLE CFD PROBLEMS FOR PRACTICE

SIMULATION LAB – REQUIREMENT:

1. Software - Modeling software like ProE, Gambit, Ansys etc Analysis software like ANSYS, Fluent, CFX, etc ,Equation solving software like Matlab, Engg. equation soler

NOTE

1. Every students in a batch must be provided with a terminal
2. Hardware are compatible with the requirement of the above software.

OUTCOME:

On successful completion of this course, the student can solve and analyse the practical refrigeration and air condition problems using MATLAB & CFD software

TOTAL: 45 PERIODS

RA8001 AIR HANDLING SYSTEMS DESIGN L T P C
3 0 0 3

AIM

- To impart knowledge on various AHU unit, design procedure, energy saving methods and the International standard for maintaining thermal comfort and IAQ.

OBJECTIVES

- To provide knowledge on various system configuration available of HVAC system.
- To understand the various steps involved in the design process.
- To learn to use standard practice and standard data.

UNIT I BASIS CONCEPTS 10

Psychrometric, Classifications of Air-Handling Units, Main components, Selection of Air-Handling units, economizer cycle, single zone system, multi zone system-Design Consideration, duct design-static Regain-equal friction-T method.

UNIT II CONSTANT AND VARIABLE VOLUME SYSTEMS 9

Terminals reheat system, Double-Duct systems, Sub zone heating, Draw-through cooling, Triple-Duct system, Fan Coil Unit, Induction system. Various System Configurations -Hydronic heat pump, Heat recovery and Economizer, Indirect evaporative cooling, Energy conservation and system retrofit.

UNIT III AIR SYSTEM: COMPONENTS 9

Fan-types, Construction, Arrangement, and Selection, Coil Characteristics and Accessories, Condensate control and Freeze-up protection

UNIT IV VENTILATION FOR CONTROL OF WORK ENVIRONMENT 10

Ventilation, Measurements control and exhaust, Air cleaning devices, Rating and Assessments, Test method for air filters, and replacement-Air system, evaluation and control of the thermal Environment, Indoor Air Quality and Outside Air Requirements

UNIT V AIR CONTROLS 7

Demand control ventilations, Thermostats, Damper and damper motor, Automatic Valves, Direct digital control, Application of fuzzy logic & neural network-Demand control ventilation.

TOTAL: 45 PERIODS

OUTCOME

- On successful completion of this course the student can demonstrates confidence, willingness to make, and implement decisions when investigating and designing HVAC systems.

REFERENCES

1. Ysen - Yao Sun, Air handling system design, McGraw–Hill, Inc., NY – 1994
2. William A. Burges, Michael j. Ellen Becker, Robert D. Treitman, Ventilation for control of the work environment, A Wiley - Interscience Publication NY - 1989.
3. John I. Levenhagen, Donald H. Spethmann, HVAC controls and systems, McGraw - Hill international Edition. NY - 1992. Allan T. Kirkpatrick & James S. Elleson, cold air distribution system design guide, ASHEAC - 1996 USA.
4. Shan K.Wang, Handbook of Air-conditioning and Refrigeration, McGraw -Hill, 2001.
5. SMACNA, HVAC System Duct Design, SMACNA Virginia - 1990.

RA8002 BEHAVIOURAL SCIENCE AND ENGINEERING MANAGEMENT

L	T	P	C
3	0	0	3

AIM

- To equip the students with managements skills and impact knowledge on total quality management

OBJECTIVES

- To improve the interactive behaviors among students.
- To make the students understand the need for total quality management in engineering industries.
- To train the students in project report preparation and in economic analysis.

UNIT I ORGANISATION BEHAVIORS 5

Principles-Framework-Personality-Understanding self and others-Learning methods-Development of Personality-Case study.

UNIT II GROUP DYNAMICS 10

Types-Attributes-Interactive behaviors-Transactional analysis-Johari Window-Stress management-Team building-Creative problem solving-Motivation-Maslows Theory-Managing People-Case study.

UNIT III CHANGE MANAGEMENT 5

Change Management Principles-Transition Model-Resistance to change-Conflict Management-Case study.

UNIT IV TOTAL QUALITY MANAGEMENT 20

Quality Management-Demings Philosophy-TQM Models-Customer Focus-Systems approach-ISO 9000 series certification-Benchmarking-Quality culture-Quality circles- PDCA cycle-Management Tools-Case study.

UNIT V PROJECT MANAGEMENT 5

Principles planning, Scheduling-Project Report Preparation-Economic Analysis-Case study.

TOTAL: 45 PERIODS

OUTCOME

- On successful completion of this course the student will be able to understand and apply principles of management in any engineering organization.

REFERENCES

1. Fred luthans , Organisational Behaviour , McGraw-Hill , Inc., USA , 2002
2. Joel E. Ross, Total Quality Management, Kogan Page Ltd, USA, 1999
3. Max Hand & Brain Plowman, Quality Management, Butterworth Heinemann Ltd, UK , 1992.
4. Rao, K.S. Organisational Behaviour , Tata McGraw-Hill , New Delhi , 1997.
5. James L. Lamprecht, ISO 9000, ASQC Quality Press, USA, 1993.

RA8003 BUILDING ARCHITECTURE AND HVAC SYSTEMS L T P C
3 0 0 3

AIM

- To expose the student to the different types of power generation techniques, electrical power transmission systems, characteristic and utilization of electrical drives

OBJECTIVES

- To impart knowledge on Conventional Power Plants (Steam, Hydro, Nuclear and Gas Turbine plants) and Renewable Energy Power generation.
- To understand the Economics of Power generation and Utilization of Electrical Energy for Various applications

UNIT I CLIMATE AND ARCHITECTURE 9

Factors that determine climate , climatic variations–Natural and Manmade systems , Climate and Vernacular Architecture , Natural Cooling , Effects of Geographical Location.

UNIT II WEATHER AND COMFORT 9

Climate and its components , Characteristics of human metabolic activities with changing climate, The sensation of heat and comfort zone , Design of solar shading devices and Mechanical ventilation systems.

UNIT III BUILDING MATERIALS–THERMAL STUDIES 9

Building Aesthetics and Thermal Infiltration, Periodic heat flow through building elements for weather conditions all round the air, tropical conditions

UNIT IV ENVIRONMENT INFLUENCE ON IAQ AIR QUALITY CONTROL 9

IAQ concepts, Air movement and Orientation of buildings, Landscaping in the tropics, Design consideration in different climate conditions, Tropical sky scrapers, Effects of greenery –Natural ventilation.

UNIT V INTELLIGENT BUILDINGS AND HVAC SYSTEMS 9

Energy Resources and Conservation related to Building Environment, Building Automation and Energy Management–Passive and Active Systems, Solar heating, ECBC concept

TOTAL: 45 PERIODS

OUTCOME

- On successful completion of this course the student will be able to understand and appreciate the incorporation of building architectural aspects in the design procedures for HVAC systems.

REFERENCES:

1. Konya, A., Design Primer for Hot climates, Architectural Press, London, 1980.
2. Davis A. J. and Schubert P. P., Alternative Natural Energy Sources in Building Design , II Edition , Van Nostrand Reinhold Co , New York , 1981.
3. ASHRAE Hand Book–HVAC Systems & Equipment 2008, HVAC Applications 2007, ASHRAE Inc. Atlanta
4. National Building Code of India , 2005 , Bureau of Indian Standards
5. Givoni B., Man, Climate & Architecture, Barking Esser Applied Science, 1982.

RA8004 CRYOGENIC ENGINEERING L T P C
3 0 0 3

AIM

- To review the overall cryogenics fundamentals along with an introduction of low temperature applications and also it will familiarize students with various insulation instruments used cryogenic systems and as well as low temperature refrigeration systems

OBJECTIVES

- To builds a solid foundation in the fundamentals of cryogenics
- To encourage a “hand’s – on” approach to solving cryogenic problems
- To provide update cryogenic information

UNIT I INTRODUCTION 8

Insight on Cryogenics, Properties of Cryogenic fluids, Material properties at Cryogenic Temperatures. Applications of Cryogenics- Mechanical, Space, Medicine, Gas industry, High energy physics, Superconductivity.

UNIT II LIQUEFACTION CYCLES 10

Carnot Liquefaction Cycle, F.O.M. and Yield of Liquefaction Cycles. Inversion Curve- Joule Thomson Effect. Linde Hampson Cycle, Precooled Linde Hampson Cycle, Claude Cycle Dual Pressure Cycle, Ortho-Para hydrogen conversion, Critical Components in Liquefaction Systems.

UNIT III SEPARATION OF CRYOGENIC GASES 9

Binary Mixtures, T-C and H-C Diagrams , Principle of Rectification, Rectification Column Analysis-McCabe Thiele Method , Adsorption Systems for purification.

UNIT IV CRYOGENIC REFRIGERATORS 8

Joule-Thomson (J.T.) Cryocoolers, Stirling Cycle Refrigerators, Gifford-McMahon (G.M.) Cryocoolers, Pulse Tube Refrigerators Regenerators used in Cryogenic Refrigerators, Magnetic Refrigerators

UNIT V HANDLING OF CRYOGENS 10

Cryogenic Dewar Design, Cryogenic Transfer Lines. Insulations in Cryogenic Systems, Operating principle of different Types of Vacuum Pumps, Instruments to measure Flow, Level and Temperature operating principles

TOTAL: 45 PERIODS

OUTCOME

- On successful completion of this course students can understand fundamentals of cryogenic cycles, cryogenic refrigerator, separation storage and transportation of cryogenic liquids.

REFERENCES:

1. Randall F. Barron, Cryogenic Systems, McGraw-Hill, 1985.
2. Scott R.B., Cryogenic Engineering, Van Nostrand and Co., 1988.
3. Klaus D. Timmerhaus and Thomas M. Flynn, Cryogenic Process Engineering, Plenum Press New York, 1989.
4. Herald Weinstock , Cryogenic Technology , 1969.
5. Robert W. Vance, Cryogenic Technology, Johnwiley & Sons, Inc., New York, London, 1969.
6. Mukhopadhay Mamata, Fundamentals of cryogenic engineering, PHI learning, 2010.

RA8005 DESIGN OF CLEAN ROOMS AND CONTAINMENT AREAS

L	T	P	C
3	0	0	3

AIM:

- The student has to acquire a basic knowledge of, and skills in, the design maintenance of clean rooms and containment areas**.**

OBJECTIVES:

- To have knowledge of different classes of clean room standard for various application.
- Appreciation of quality concerns in designing clean rooms.
- To provide sufficient knowledge on cot and energy efficiency.

UNIT I INTRODUCTION 9

The History of Clean rooms , Containment of Contamination , Supply of Liquid and Gases to Cleanrooms , International Standards for the Design of Cleanrooms , cleanroom Classes-Present Engineering Classes , New ISO Classification Standard , Biocontamination and Pharmaceutical Classes , Containment Classes , Other Standards for the Cleanroom , Abbreviations/ Source Code

UNIT II CLEANROOM DESIGN 12

Microelectronics Industry-Manufacturing Semiconductor Circuits , Design Guidelines , Design Features–Air flow pattern , air quantity , Pharmaceutical Industry-Types of Pharmaceutical Processes , Facility Design , Environmental Cleanliness , Commissioning and Performance Qualification , Medical Device Industry , Biotechnology Industry

UNIT III HIGH EFFICIENCY AIR FILTRATION 7

Construction of High Efficiency Filters-HEPA Filters , ULPA Filters , Particle Removal Mechanisms , High Efficiency Filter Testing of High Efficiency Filters , Filter Housings for High Efficiency Filters , In-service Tests for High Efficiency Filters , Filter Standards

UNIT IV CONSTRUCTIONAL FEATURES 10

General Considerations, Performance Criteria of Construction Materials and Surfaces, Specific Components, Materials and Features of Construction, Assembly, Materials for Services Pipework-Metallic Pipeline Materials, Polymeric Pipeline Materials

UNIT V COST AND ENERGY EFFICIENCY 7

Air Flow Rate Optimum for Cost, Optimization of Energy Consumption in Cleanroom Systems, Cost Indications

TOTAL: 45 PERIODS

TEXT BOOKS:

1. Whyte W., Cleanroom Design , Second Edition , John Wiley & Sons , 1999
2. Bengt Ljungqvist and Berit Reinmuller CLEAN ROOM DESIGN: Minimizing Contamination Through Proper Design , CRC; 1 edition , 1996

REFERENCES:

1. Whyte W., Cleanroom Technology: Fundamentals of Design, Testing and Operation, Wiley, 2001.
2. David M. Carlberg , Cleanroom Microbiology for the Non-Microbiologist, Second Edition, CRC; 2 edition, 2004.

RA8006 DESIGN OF THERMAL SYSTEMS

L	T	P	C
3	0	0	3

AIM

- To provide review and use knowledge from thermodynamics, heat transfer and fluid mechanics, modeling and stimulation techniques for thermal system component analysis and their synthesis in integral engineering systems and processes

OBJECTIVES

- To learn basic principles underlying piping, pumping, heat exchangers; modeling and optimization in design of thermal systems.
- To develop representational modes of real processes and systems.
- To optimization concerning design of thermal systems.

UNIT I DESIGN CONCEPTS 9

Design Principles, Workable Systems, Optimal Systems, Matching of System Components, Economic Analysis, Depreciation, Gradient Present Worth factor

UNIT II MATHEMATICAL MODELLING 9

Equation Fitting, Nomography, Empirical Equation, Regression Analysis, Different Modes of Mathematical Models, Selection, Computer Programmes for Models.

UNIT III MODELLING THERMAL EQUIPMENT 10

Modeling Heat Exchangers, Evaporators, Condensers, Absorption and Rectification Columns, Compressors, Pumps, Simulation Studies, Information Flow Diagram, Solution Procedures

UNIT IV OPTIMIZATION 12

Objective Function Formulation, Constraint Equations, Mathematical Formulation, Calculus Method, Dynamic Programming, Search Methods, ANN and Genetic Algorithm.

UNIT V DYNAMIC BEHAVIOUR 5

Steady state Simulation, Laplace Transformation, Feedback Control Loops, Stability Analysis, Non-Linearities

TOTAL: 45 PERIODS

OUTCOME

- On successful Completion of this course the student will be understand modeling and optimization of Thermal systems.

REFERENCES:

1. Stoecker W. F., Design of Thermal Systems, McGraw Hill Edition, 1989.
2. .Bejan A., George Tsatsaronis , Michael J. Moran , Thermal Design and Optimization , Wiley , 1996.
3. Kapur J. N., Mathematical Modelling , Wiley Eastern Ltd , New York , 1989.
4. Yogesh Jaluria , Design and Optimization of Thermal Systems , CRC Press , 2007.
5. Rao S. S., Engineering Optimization Theory and Practice, New Age Publishers, 2000.

RA8007 ENERGY CONSERVATION IN HVACR SYSTEMS L T P C
3 0 0 3

AIM

- To provide the concept on general principles or energy conservation using first and second law analysis of HVAC systems and to establish energy and environmental emission reductions.

OBJECTIVES

- To learn energy audit and management practices on HVAC systems.
- Learn to analysis heat conversion systems for HVAC applications
- To update new system/ equipments for the utilization of both thermal and electrical energy optimally.

UNIT I FIRST AND SECOND LAW ANALYSIS 8

Thermodynamics of Energy conservation-Second law -Exergy-Irreversibility and efficiency - Analysis of Refrigeration and Air conditioning cycles, Heat pumps.

UNIT II ENERGY CONSERVATION TECHNIQUES 8

Principle of Energy audit, Identifying avenues for Energy conservation, Conservation through periodic maintenance of HVAC systems, Predictive and Preventive maintenance, Thermal insulation.

UNIT III REFRIGERATION AND AIR CONDITIONING EQUIPMENTS 10

Energy conservation in Air Handling units-Fans, Air conditioning apparatus-Unitary equipments, Refrigeration Equipments-Reciprocating Refrigeration Machine, Centrifugal Refrigeration Machine, Absorption Refrigeration Machine, Heat Rejection Equipments, and Energy Efficient motors.

UNIT IV HEATING AND VENTILATING SYSTEMS 10

Energy conservation feasibility analysis-conventional ventilating systems, constant volume induction system, Multizone unit system, Variable volume induction system, constant temperature system. Heat Pipe Applications in Air conditioning systems.

UNIT V HEAT CONVERSION SYSTEMS 9

Theory of Heat transformers-Heat Pumps, Two temperature level, Three Temperature level-Vapour compression, Heat pump.

TOTAL: 45 PERIODS

OUTCOME

- On successful completion of this course the student can create and evaluates the building environments, demonstrating consideration of sustainability, safety and functional issues in terms of Energy.

REFERENCES

1. George Alefeld and Reinhard Radermacher , Heat conversion systems , CRC press , 1994
2. Carrier Air conditioning Co., Hand Book of Air conditioning System Design , McGraw-Hill , 1985.
3. Plant Engineers and Manager's Guide to Energy Conservation, Fair Mount Press, 2008.
4. ASHRAE Hand Book–Equipment, 2005
5. Energy conservation in Heating, Cooling and Ventilating Building, Proceeding Hemisphere Publishing Corporation, 1988.
6. Edward Hartmann, Maintenance Management, Productivity and Quality Publishing Pvt. Ltd. Madras, 1995.

RA8008	ERECTION AND MAINTENANCE OF REFRIGERATION AND AIR-CONDITIONING EQUIPMENTS	L T P C
		3 0 0 3

AIM

- To impact knowledge on energy prediction for the future and to develop skills on the development of optimization model to meet the future energy demand

OBJECTIVES

- To develop forecasting models and optimization models for energy planning.
- To equip the students in writing project proposals and making project cost estimation.
- To evaluate the limit cost of energy for various renewable energy systems

UNIT I ENERGY SCENARIO 10

Role of energy in economic development and social transformation: Energy & GDP,GNP and its dynamics - Energy Sources and Overall Energy demand and Availability - Energy Consumption in various sectors and its changing pattern - Status of Nuclear and Renewable Energy: Present Status and future promise

UNIT II FORECASTING MODEL 10

Forecasting Techniques - Regression Analysis - Double Moving Average - Double Experimental Smoothing - Triple Exponential Smoothing – ARIMA model - Validation techniques – Qualitative forecasting – Delphi technique - Concept of Neural Net Works.

UNIT III OPTIMIZATION MODEL 10

Principles of Optimization - Formulation of Objective Function - Constraints - Multi Objective Optimization – Mathematical Optimization Software – Development of Energy Optimization Model - Development of Scenarios – Sensitivity Analysis - Concept of Fuzzy Logic.

UNIT IV PROJECT MANAGEMENT 10

Project Preparation – Feasibility Study – Detailed Project Report - Project Appraisal – Social-cost benefit Analysis - Project Cost Estimation – Project Risk Analysis - Project Financing – Financial Evaluation

UNIT V ENERGY POLICY 5

National & State Level Energy Issues - National & State Energy Policy - Energy Security - National solar mission - state solar energy policy - Framework of Central Electricity Authority (CEA), Central & States Electricity Regulatory Commissions (CERC & ERCs)

TOTAL : 45 PERIODS

OUTCOMES

- Knowledge in Energy prediction using various forecasting techniques
- Ability to develop optimization model for energy planning
- Understanding of National and state energy policies

REFERENCES

1. S. Makridakis, Forecasting Methods and applications. Wiley 1983
2. Yang X.S. Introduction to mathematical optimization: From linear programming to Metaheuristics, Cambridge, Int. Science Publishing, 2008
3. Austin H. Church, centrifugal pumps and blowers, John Wiley and sons, 1980.
4. Fred Luthans, Organisational Behaviour, McGraw Hill, Inc, USA, 1992.
5. Armstrong, J.Scott (ed.) Principles of forecasting: a hand book for researchers and practitioners, Norwell, Masschusetts:Kluwer Academic Publishers.2001
6. Dhandapani Alagiri, Energy Security in India Current Scenario, The ICFAI University Press,2006
7. Sukhvinder Kaur Multani, Energy Security in Asia Current Scenario, The ICFAI University Press, 2008

RA8009 FANS, BLOWERS AND COMPRESSORS IN AIR CONDITIONING SYSTEMS

L T P C
3 0 0 3

AIM

- To enable the students to know the basic principles of fluids dynamic and thermodynamic to various kinds of turbo machinery and the impact of these machine field of refrigeration and air-conditioning systems

OBJECTIVES

- To understand the basic characteristics and special features of fans, blowers and compressors
- To have basic skills to analyze fans, blowers and compressors
- To acquire a limited design experience of fans and blowers

UNIT I PRINCIPLES OF TURBO MACHINERY 10

Introduction to turbo machines-Transfer of energy to fluids-Performance characteristics-fan laws-Dimensionless parameters-Specific speed-selection of centrifugal, axial, mixed flow, Axial flow machines

UNIT II CENTRIFUGAL BLOWERS 10

Centrifugal Blowers: Theoretical characteristic curves , Eulers characteristics and Eulers velocity triangles , losses and hydraulic efficiency , flow through impeller casing inlet nozzle volute , diffusers , leakage disc friction mechanical losses multivane impellers of impulse type , cross flow fans.

UNIT III AXIAL FLOW FANS 10

Axial flow fans: Rotor design airfoil theory, vortex theory, cascade effects, degree of reaction, blade twist stage design, surge and stall, stator and casing, mixed flow impellers.

UNIT IV COMPRESSORS 8

Reciprocating compressors, Constructional details – open, hermetic and semi sealed, effect of cylinder cooling, heating and friction, Dynamic compressor, centrifugal compressor, velocity triangles, performance characteristics, part load operation, Capacity control.

UNIT V DESIGN AND APPLICATIONS 7

Special design and applications of compressors for air conditioning plants, Multi stage refrigeration.

TOTAL : 45 PERIODS

OUTCOME

- On successful completion of this course, the students will be able to design the fans and blowers for HVAC application.

REFERENCES

1. Austin H. Church, Centrifugal pumps and blowers, John Wiley and Sons, 1980.
2. Royce N. Brown, Compressors: Selection And Sizing,Elsevier, 2005.
3. Dixon, Fluid Mechanics, Thermodynamics of turbomachinery Pergamon Press, 1984.
4. Tony Giampaolo,Compressor Hand Book Principles and Practice, The Fairmont Press, 2010.
5. S. M. Yahya, Turbines compressors and fans(4th Edition), Tata McGraw-Hill, 2010

RA8010	**FOOD PROCESSING, PRESERVATION AND TRANSPORT**	**L T P C** **3 0 0 3**

AIM

- To review the overall food processing and preservation methods along with refrigerated transportation. It will familiarize students with design of cold storage, freezing and thawing time calculation.

OBJECTIVES

- To builds a solid foundation in the fundamentals of food processing and preservation techniques
- To study the thermodynamic properties of food materials

UNIT I MICROBIOLOGY OF FOOD PRODUCTS 9

Microbiology of food products, Mechanism of food spoilage, critical microbial growth requirements, Design for control of micro organisms, Regulations and Standards.

UNIT II PROCESSING & PRESERVATION 12

Thermodynamic Properties , Water Content , Initial Freezing Temperature , Ice Fraction, Transpiration of Fresh Fruits and Vegetables , Food Processing Techniques for Dairy Products, Poultry , Meat , Fruits and Vegetables

UNIT III FREEZING & DRYING 12

Precooling, Freeze Drying Principles, Cold Storage and Freezers , Freezing Drying limitations, Irradiation Techniques , Cryo Freezing , Energy Conservation in Food industry , Numerical and Analytical Methods in Estimating Freezing , Thawing Times.

UNIT IV COLD STORAGE DESIGN & INSTRUMENTATION 7

Initial Building Consideration , Building Design , Specialized Storage Facility , Construction Methods , Refrigeration Systems , Insulation Techniques , Control and Instrumentation , Fire Protection , Inspection and Maintenance

UNIT V TRANSPORT **5**

Refrigerated Transportation refrigerated Containers and Trucks, Design Features, Piping and Role of Cryogenics in Freezing and Transport.

TOTAL: 45 PERIODS

OUTCOME

- Students can understand various food processing techniques, analysis of thermodynamic properties of food and cold storage design.

REFERENCES

1. Peter Fellows, Food Processing Technology: Principles and Practice, Wood Head,2000.
2. Romeo T. Toledo, Fundamentals of Food Process Engineering, Springer III Edition, 2007.
3. Frazier W.C., Westhoff D.C., Food Microbiology, 4th Ed., McGraw-Hill, New York 1988.
4. Michael .J. Waites, Neil L. Morgan, John S. Rockey, Gary Higton, Industrial Microbiology, Wiley BlackWell, 2001.
5. S. Yanniotis, B. Sunden, Heat Transfer in Food Processing, Recent Developments and Applications, WIT Press, Southampton, 2007
6. C. V. J. Dellino, Cold and Chilled Storage Technology, Springer II Edition, 1997
7. Andrew D. Althouse, Carl H. Turnquist, Alfred F. Bracciano, Modern Refrigeration and Air Conditioning, Goodheart-Wilcox, 18th Edition, 2003.
8. Sivasankar. B, Food processing and preservation, PHI learning, 2005.

RA8011 INDOOR AIR QUALITY CONTROL **L T P C**
3 0 0 3

AIM

- To ensure that the student have a sound understanding of the fundamentals concepts of indoor air quality control and to asset their ability to identify and react to IAQ problems.

OBJECTIVE

- To insist importance of maintaining indoor air quality.
- To gain knowledge on maintaining IAQ.
- To learn the use various international standard on IAQ.
- To have knowledge on threshold limit of various indoor air pollutants.

UNIT I AIR QUALITY **8**

Air Pollution–Indoor, Outdoor; statistics in India-Contaminants-sources-effects of air quality on health and productivity-IAQ-ASHRAE standards.

UNIT II INDOOR AIR QUALITY & SICK BUILDING SYNDROME **10**

Effect of temperature , Velocity , Pressure , Humidity on IAQ-Noise-Source-damping methods-Air distribution-diffuser design-location-air charge calculations-age of air-SBS- psycho social effects-Parameters causing SBS-Bio contaminants-diagonising Building problems-NIOSH standards.

UNIT III AIR FILTRATION **7**

Principles of air filtration-impingement filters, HEPA & ULPA filters, Electronic air cleaners, filters-Filter Standards-filter efficiency-filter testing methods-NAFA certification.

UNIT IV DESIGN OF CLEANROOMS **12**

History of clean rooms-classification-clean room standards-different contaminants-ISO classification-interiors-Recommended practices-Design of clean rooms for Hospitals, Pharmaceutical, micro electronic, Bio technology food industries and manufacture industries-International standards.

Attested

UNIT V IAQ MEASUREMENTS & CONTROL 8

Contaminants measurement-sampling sampling methods-Quality assurance-calibration-data interpretation-instruments-specifications-source control–prevention-Dilution Ventilation- demand control volume method.

TOTAL: 45 PERIODS

TEXT BOOKS:

1. Whyte W. Clean Room Design II Edition, John Wiley & Sons (NY)–1999.

REFERENCES:

1. American Institutes of Architects (AIA) , Guidelines for Design & Construction of Hospital & Health care facilities , AIA, Washington–2001.
2. Thad Godish , Sick Buildings , Lecois Publishers , Ann Arbor , 1994.
3. National Air Filtration Association, NAFA guide to Air Filtration-III edition-NAFA Washington DC-2001.
4. ASHRAE Hand Book, HVAC Systems and Equipment, I-P Edition 1996.

RA8012 INDUSTRIAL REFRIGERATION SYSTEMS

L	T	P	C
3	0	0	3

AIM

- To impart knowledge on Industrial Refrigeration System components and special energy conservation measures in them.

OBJECTIVES

- To understand the key issues in Industrial Refrigeration systems.
- To understand the operational features of compressors in large systems.
- To understand the operational features of Evaporators & Condensers in Industrial Refrigeration System.
- To understand the energy conservation aspects of Industrial Refrigeration System

UNIT I INTRODUCTION 6

Introduction to industrial refrigeration-difference from conventional system -industrial and comfort air-conditioning-Different applications

UNIT II COMPRESSORS 10

Reciprocating and screw compressor: effect of evaporating temperature and condensing temperature on volumetric efficiency refrigerating effect and COP. Variable speed drive of screw compressor, variable volume ratio, oil injection and separation-oil cooling methods- capacity regulation-Economizers-side port options.

UNIT III EVAPORATORS AND CONDENSERS 12

Types of Evaporators, Liquid circulation: Mechanical pumping and gas pumping- advantage and disadvantage of liquid re-circulation-circulation ratio, top feed and bottom feed refrigerant, Net Positive Suction Head (NPSH), two pumping vessel system, suction risers, design-piping loses. Different Industrial Condensers functional aspects. Lubricating oil: types-physical property terms-solubility – viscosity - contaminants and its effect - discharge line oil separator-oil removal from high and low side for ammonia and halocarbon refrigerants

UNIT IV VESSELS 8

Vessels in industrial refrigeration: High pressure receiver-flash tank-liquid and vapour separator-separation enhancers-low pressure receivers-surge drum-surge line accumulator- thermosyphon receiver-oil pots.

UNIT V ENERGY CONSERVATION ASPECTS **9**

Energy conservation and design considerations - source of losses - energy efficient components - heat reclaim - thermal storage: ice builder and ice harvester. Insulation: critical thickness - insulation cost and energy cost - vapour barriers - construction methods of refrigerated spaces.

TOTAL : 45 PERIODS

OUTCOME

- Student can understand the compressor, condensor, evaporator and vessels used in R&AC Industry and its energy conservation techniques.

REFERENCES

1. Wilbert F.Stoecker, Industrial Refrigeration Hand Book, McGraw-Hill, 1998
2. ASHRAE Hand Book: Fundamentals, 2005.
3. ASHRAE Hand Book: Refrigeration, 2006.
4. ASHRAE Hand Book: HVAC Systems and Equipment, 2008.
5. Transport properties of SUVA Refrigerants, Du-Pont Chemicals, 2007

RA8013 MATERIALS FOR LOW TEMPERATURE APPLICATIONS **L T P C**
3 0 0 3

AIM

- To impart knowledge on material characterization at low temperature and selection for low temperature applications

OBJECTIVES

- To understand the behavioral changes in materials at low temperature.
- To understand the selection of material for low temperature applications.
- To understand the testing methods for low temperature behavior of materials.

UNIT I MATERIAL BEHAVIOR **10**

Deformation process in pure , impure metals and alloys–effect of low temperature transformation , plastic deformation at constant stress-creep , Role of dislocations , Tensile , Shear strength of perfect and real crystals , Strengthening mechanisms , Work hardening , strain and strain rate on plastic behavior–super plasticity Ductile and Brittle Failure , Crack Propagation-Fracture , Toughness–fracture toughness , Griffith's theory , stress intensity factor and fracture toughness Toughening mechanisms–Ductile , brittle transition in steel

UNIT II MATERIALS SELECTION **10**

Compatibility with liquid oxygen and other process fluids-external environment, Toughness-pressure vessel codes, Motivation for selection-cost basis and service requirements–Selection for surface durability, corrosion and wear resistance– Relationship between materials selection and processing–Case studies in materials selection.

UNIT III NON METALLIC MATERIALS **7**

Polymeric materials for Cryogenic Application , Ceramics and Glasses , Cryogenic properties of Composites , Polymeric materials–Formation of polymer structure– Production techniques of fibres , foams , adhesives and coatings–Structure , properties and applications of engineering polymers–Advanced structural ceramics , WC , TiC , TaC , Al2O3 , Sic , Si3N4 , CBN and diamond–properties , processing and applications.

UNIT IV TESTING METHODS AND TECHNIQUES 10

Basic types of Cryostat and cooling system , Modification , Variations , and special purpose attachments–multiple specimen testing , compression testing , Flexural , torsional , fatigue and impact testing , Extensometry-Resistive strain gauges , Displacement Transducers , Capacitance gauges.

UNIT V MODERN METALLIC MATERIALS 8

Dual phase steels , micro alloyed , High strength low alloy (HSLA) steel , Transformation induced plasticity (TRIP) steel , Maraging steel-intermettallics , Ni and Ti aluminides–smart materials , shape memory alloys–Metallic glass–Quasi crystal and nano crystalline materials.

TOTAL : 45 PERIODS

OUTCOME

- Students will be able to understands the material behavior, selection and testing techniques at low temperature.

REFERENCES

1. Wigley D.A., "Mechanical Properties of Materials at Low Temperatures", Plenum Press, New York, 1972.
2. Richard P. Reed, Alan F. Clark, Materials at low Temperature, ASME International, Dec 1983.
3. Thomas H.Courtney , "Mechanical Behavior of Materials", (2nd Edition), McGraw-Hill , 2004.

RA8015	QUANTITATIVE AND QUALITATIVE RESEARCH METHODOLOGIES	L T P C
		3 0 0 3

AIM

- To educate quantitative and qualitative research methodologies to the students.

OBJECTIVE

- To train the students in conducting patent survey and literature review.
- To prepare the students to adopt standard tools and computer packages in their research.
- To guide the students in writing of syrupsis, tnesis and case studies.

UNIT I RESEARCH METHODOLOGY 8

Types of research-Literature survey-Patent survey-literature review reporting-ethics and interventions of research-planning for research-research tools-seven management tools- graphical representations-Codes-Standards.

UNIT II QUANTITATIVE METHODS 10

Descriptions-statistics-distribution-sampling-hypothesistesting–regression-ANOVA-reliability-validity - uncertainty-sensitivity analysis-use of SPSS.

UNIT III QUALITATIVE METHODS 10

Historical analogy-market research-survey-analysis-DELPHI methodology-determination of index-life cycle analysis-modeling and simulation.

UNIT IV MEASUREMENTS IN RESEARCH 12

Need for measurement-types of measuring instruments-configurations and functional descriptions of instruments–performance–characteristics-static and dynamic characteristics- manipulation, transmission and recording of data-data acquisition and processing systems- Computer aided experimentation.

UNIT V RESEARCH REPORT PREPARATION 5

Principles of Written communication-content preparation-synopsis writing-result analysis- discussion section-case studies.

TOTAL: 45 PERIODS

TEXT BOOKS

1. Robert B. Burns, Introduction to Research methods, SAGE Publications London, 2000
2. Herman J. Ader, Gidon J. mellenbergh , Research Methodology , SAGE Publications London , 1999

REFERENCES

1. Jeremy Miles& Mark Sherlin , Applying Regression and Correlation , A Guide for students and researchers SAGE Publications London , 2001
2. Ernest O. Doebelin, Measurement Systems-Application and Design IV Edition McGraw-Hill International Edition NY-1990.

RA8016 REFRIGERATION MACHINERY AND COMPONENTS L T P C
3 0 0 3

AIM

- This course is designed to understand each component and controls in a refrigeration and air conditioning system, application in various fields engineering and appliance testing using BIS standards.

OBJECTIVES

- To master how refrigeration components and systems perform their tasks
- To identify and explain various system accessories and controls in refrigeration systems
- To know BIS standard for appliance testing practice

UNIT I REFRIGERANT COMPRESSORS 9

Hermetic compressors - Reciprocating, Rotary, Scroll Compressors, Open type compressors - Reciprocating, Centrifugal, Screw Compressors. Semi hermetic compressors - Construction, working and Energy Efficiency aspects. Applications of each type.

UNIT II REFRIGERATION SYSTEM COMPONENTS 9

Evaporators and condensers-Different types, capacity control, circuitry, Oil return, Oil separators-Different types Refrigerant driers strainers, Receivers, Accumulators, Low pressure receivers, Air Washers, Spray ponds..

UNIT III HYDRONIC SYSTEMS 9

Water piping in Chilled Water Systems, Multiple Fan Coil Units, Condensers - Multiple Condensers and Cooling Towers. System components – Expansion tank, Balancing valves, Pumping systems, Pump selection, Freeze prevention

UNIT IV APPLIANCES & ACCESSORIES 9

Air Conditioning in Automobiles, Railway Wagons, Marine Vessels, Aircraft and Other Commercial Applications.

UNIT V SYSTEM ACCESSORIES AND CONTROLS 8

Refrigerant Pumps, Cooling Tower fans, Compressor Motor protection devices, Oil equalising in multiple evaporators. Different Defrosting and capacity control methods and their implications.

TOTAL: 45 PERIODS

OUTCOME

- On successful completion of this course, the students will be able to understand working of the refrigeration components and systems with the accessories and controls.

REFERENCES

1. Cooper &Williams, B. "Commercial, Industrial, Institutional Refrigeration, Design, Installation and Trouble Shooting" Eagle Wood Cliffs (NT) Prentice Hall, 1989.
2. Dosset, R.J. "Principles of Refrigeration", John Wiley & Sons, 2001
3. Hains, J.B, "Automatic Control of Heating & Airconditioning" Mc Graw Hill, 1981.
4. Althose, A.D. & Turnquist, C.H. "Modern Refrigeration and Airconditioning" Good Heart-Wilcox Co. Inc., 1985.
5. Recent release of BIS Code for relevant testing practice. ASHRAE Hand book (Fundamentals & Equipments), 2005.

RA8017	SORPTION HEATING AND COOLING SYSTEMS	L T P C
		3 0 0 3

AIM

- To understand the types, working of steam generator and their major components, along with design principles and calculations

OBJECTIVES

- To educate the students on the types of boilers with their constructional and functional significance.
- To understand the working and design of fuel preparation units and boilers.
- To introduce the concept of boiler design, emission aspects

UNIT I INTRODUCTION 9

Carnot cycle–Refrigerator–Heat Pump–Heat Transformer,Working Fluids, Properties–Thermodynamic Processes with Mixtures

UNIT II LIQUID SORPTION SYSTEMS 12

Water–LiBr Systems; Single Effect, Double Effect Systems, Types–Analysis of Advanced Cycles for Refrigeration Systems–Heat Pumps and Heat Transformers. Ammonia–Water Systems–Single Effect–GAX Systems.

UNIT III PUMPLESS AND SOLID SORPTION SYSTEM 9

Diffusion Absorption Systems–Bubble Pump Systems–Solid Sorption Systems– Working Fluids–Single and Multi effect Systems–Metal Hydride Heating and Cooling Systems–Applications and Issues.

UNIT IV COMPONENT DESIGN 8

Design of Generator–Absorber–Condenser–Evaporator–Solution Heat Exchanger– Reactors–Rectifiers–Overall System Balance.

UNIT V APPLICATIONS 7

Energy Storage– Combined power and cooling–Solar Cooling–Low grade Heat Utilization–Economics of Sorption Systems–Sorption refrigeration Systems for Climate Change Mitigation.

TOTAL: 45 PERIODS

OUTCOME

- On successful completion of this course the student will be able to analyse Sorption Systems for its energy efficiency and cooling capacity.

REFERENCES

1. Herold K. E., Radermacher R. and Klein S. A., Absorption Chillers and Heat Pumps CRC Press ,London (1996).
2. Alefeld G. and Radermacher R. , Heat Conversion Systems , CRC Press , London (1994).
3. ASHRAE Hand Book–HVAC Systems & Equipment 2008 , ASHRAE Inc. Atlanta

EY8074	ENERGY EFFICIENT BUILDING DESIGN	L T P C
		3 0 0 3

AIM

- This course provides the concept of introducing energy efficient practices in building design and construction

OBJECTIVES

- To learn the green buildings concepts applicable to modern buildings
- Acquaint students with the principle theories materials, construction techniques and to create energy efficient buildings

UNIT I INTRODUCTION 9

Conventional versus Energy Efficient buildings – Historical perspective - Water – Energy – IAQ requirement analysis – Future building design aspects – Criticality of resources and needs of modern living

UNIT II LANDSCAPE AND BUILDING ENVELOPES 9

Energy efficient Landscape design - Micro-climates – various methods – Shading, water bodies- Building envelope: Building materials, Envelope heat loss and heat gain and its evaluation, paints, Insulation, Design methods and tools.

UNIT III HEATING, VENTILATION AND AIR-CONDITIONING 9

Natural Ventilation, Passive cooling and heating - Application of wind, water and earth for cooling, evaporative cooling, radiant cooling – Hybrid Methods – Energy Conservation measures, Thermal Storage.

UNIT IV ENERGY EFFICIENCY IN ELECTRICAL SYSTEM 9

Introduction of electrical power supply system – Demand side Management – Conservation measures in building : Lighting, DG sets, Energy efficient motors - Electronic devices: Power consumption pattern, saving methods

UNIT V RENEWABLE SOURCES INTEGRATION 9

Introduction of renewable sources in buildings, Solar water heating, small wind turbines, stand alone PV systems, Hybrid system – Economics.

TOTAL : 45 PERIODS

OUTCOME

Student will be able to do

(a) The energy audit in any type for buildings and suggest the conservation measures.
(b) Provide the renewable energy systems for the buildings

REFERENCES

1. Krieder, J and Rabi, A., Heating and Cooling of buildings : Design for Efficiency, McGraw Hill, 1994.
2. Ursala Eicker, "Solar Technologies for buildings", Wiley publications, 2003.
3. Guide book for National Certification Examination for Energy Managers and Energy Auditors (Could be downloaded from www.energymanagertraining.com)

EY8075	**ENERGY FORECASTING, MODELING AND PROJECT MANAGEMENT**	**L T P C** **3 0 0 3**

AIM

- To impact knowledge on energy prediction for the future and to develop skills on the development of optimization model to meet the future energy demand

OBJECTIVES

- To develop forecasting models and optimization models for energy planning.
- To equip the students in writing project proposals and making project cost estimation.
- To evaluate the limit cost of energy for various renewable energy systems

UNIT I ENERGY SCENARIO 10

Role of energy in economic development and social transformation: Energy & GDP,GNP and its dynamics - Energy Sources and Overall Energy demand and Availability - Energy Consumption in various sectors and its changing pattern - Status of Nuclear and Renewable Energy: Present Status and future promise

UNIT II FORECASTING MODEL 10

Forecasting Techniques - Regression Analysis - Double Moving Average - Double Experimental Smoothing - Triple Exponential Smoothing – ARIMA model - Validation techniques – Qualitative forecasting – Delphi technique - Concept of Neural Net Works

UNIT III OPTIMIZATION MODEL 10

Principles of Optimization - Formulation of Objective Function - Constraints - Multi Objective Optimization – Mathematical Optimization Software – Development of Energy Optimization Model - Development of Scenarios – Sensitivity Analysis - Concept of Fuzzy Logic.

UNIT IV PROJECT MANAGEMENT 10

Project Preparation – Feasibility Study – Detailed Project Report - Project Appraisal – Social-cost benefit Analysis - Project Cost Estimation – Project Risk Analysis - Project Financing – Financial Evaluation

UNIT V ENERGY POLICY 5

National & State Level Energy Issues - National & State Energy Policy - Energy Security - National solar mission - state solar energy policy - Framework of Central Electricity Authority (CEA), Central & States Electricity Regulatory Commissions (CERC & ERCs)

TOTAL: 45 PERIODS

OUTCOME

- Knowledge in Energy prediction using various forecasting techniques
- Ability to develop optimization model for energy planning
- Understanding of National and state energy policies

REFERENCES
1. S. Makridakis, Forecasting Methods and applications. Wiley 1983
2. Yang X.S. Introduction to mathematical optimization: From linear programming to Metaheuristics, Cambridge, Int. Science Publishing, 2008
3. Austin H. Church, centrifugal pumps and blowers, John Wiley and sons, 1980.
4. Fred Luthans, Organisational Behaviour, McGraw Hill, Inc, USA, 1992.
5. Armstrong, J.Scott (ed.) Principles of forecasting: a hand book for researchers and practitioners, Norwell, Masschusetts:Kluwer Academic Publishers.2001
6. Dhandapani Alagiri, Energy Security in India Current Scenario, The ICFAI University Press,2006
7. Sukhvinder Kaur Multani, Energy Security in Asia Current Scenario, The ICFAI University Press, 2008

RA8071 COMPUTATIONAL FLUID DYNAMICS **L T P C**
3 0 0 3

AIM
- This course aims to introduce numerical modeling and its role in the field of heat and fluid flow; it will enable the students to understand the various discretisation methods and solving methodologies and to create confidence to solve complex problems in the field of heat transfer and fluid dynamics

OBJECTIVES
- To develop finite difference and finite volume discretized forms of the CFD equations.
- To formulate explicit & implicit algorithms for solving the Euler Equations & Navier Strokes Equations.

UNIT I GOVERNING DIFFERENTIAL EQUATIONS AND FINITE DIFFERENCE METHOD 10
Classification, Initial and Boundary conditions – Initial and Boundary Value problems – Finite difference method, Central, Forward, Backward difference, Uniform and non-uniform Grids, Numerical Errors, Grid Independence Test.

UNIT II CONDUCTION HEAT TRANSFER BY FINITE DIFFERENCE METHOD AND FINITE VOLUME METHOD 10
Steady one-dimensional conduction, Two and three dimensional steady state problems, Transient one-dimensional problem, Two-dimensional Transient Problems.

UNIT III CONVECTION HEAT TRANSFER BY FINITE DIFFERENCE METHODAND FINITE VOLUME METHOD 10
Steady One-Dimensional and Two-Dimensional Convection – diffusion, Unsteady one-dimensional convection – diffusion, Unsteady two-dimensional convection – Diffusion.

UNIT IV INCOMPRESSIBLE FLUID FLOW BY FINITE DIFFERENCE METHOD AND FINITE VOLUME METHOD 10
Governing Equations, Stream Function – Vorticity method, Determination of pressure for viscous flow, SIMPLE, Computation of Boundary layer flow - Finite difference approach.

UNIT V FINITE ELEMENT METHOD AND TURBULENCE MODELS 5
Introduction to finite element method – solution of steady heat conduction by FEM. Algebraic Models – One equation model, k – ε models - Standard and High and Low Reynolds number models, Prediction of fluid flow and heat transfer using standard codes – Prediction of flow in a sudden pipe contraction and pipe.

TOTAL: 45 PERIODS

OUTCOME

- On successful completion of this course the student will be able to apply concept of CFD to analyse flow in thermal systems.

REFERENCES:

1. Muralidhar, K., and Sundararajan, T., "Computational Fluid Flow and Heat Transfer", Narosa Publishing House, New Delhi, 2003.
2. Ghoshdasdidar, P.S., "Computer Simulation of flow and heat transfer" Tata McGraw-Hill Publishing Company Ltd., 1998.
3. Subas, V.Patankar "Numerical heat transfer fluid flow", Hemisphere Publishing Corporation, 1980.
4. Versteeg and Malalasekera, N, "An Introduction to computational Fluid Dynamics The Finite volume Method," Pearson Education, Ltd., 2007.
5. Taylor, C and Hughes, J.B. "Finite Element Programming of the Navier-Stokes Equation", Pineridge Press Limited, U.K., 1981.
6. Anderson, D.A., Tannehill, J.I., and Pletcher, R.H., "Computational fluid Mechanics and Heat Transfer " Hemisphere Publishing Corporation, New York, USA, 2012.
7. Fletcher, C.A.J. "Computational Techniques for fluid Dynamics 2" Specific Techniques for Different Flow Categories, Springer – Verlag, 1988.
8. Bose, T.K., "Numerical Fluid Dynamics" Narosa Publishing House, 1997.