ANNA UNIVERSITY, CHENNAI

UNIVERSITY DEPARTMENTS

REGULATIONS - 2019

CHOICE BASED CREDIT SYSTEM

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

THE VISION OF THE DEPARTMENT OF MECHANICAL ENGINEERING

We, at the Department of Mechanical Engineering, Anna University shall strive hard to impart knowledge and state-of-the-art training to our students and expose them to broad areas of Mechanical Engineering, namely Design, Manufacturing, Energy, Thermal Sciences and currently related interdisciplinary areas, so that they can later practice their profession at home or abroad keeping in mind the needs and concern of the society they represent, safeguarding values, ethics and be instrumental in bringing about an overall technological development.

THE MISSION OF THE DEPARTMENT OF MECHANICAL ENGINEERING

1. To deliver knowledge in Mechanical Engineering and Materials Science and Engineering with high educational standards so that the outgoing students are employable and globally competitive.
2. To produce graduate and post graduate engineers with core competency as well as relevant software skills and social responsibility.
3. To be dynamic in imparting knowledge to students depending upon the changing national and International needs

PROGRESS THROUGH KNOWLEDGE

Attested

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

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs) :

I. To motivate students to excel in research and to practice the technologies in the field of Thermal Engineering with Specialization in Refrigeration and Air-conditioning.
II. To provide students with a solid understanding of Thermal Engineering fundamentals and applications required to solve real life problems.
III. To train students with scientific and Engineering knowledge so as to comprehend, analyze, and design products and systems pertaining to Refrigeration and Air conditioning.
IV. To inculcate an attitude to face challenging Thermal problems with confidence through multidisciplinary team approach.
V. To provide students with an academic environment of professional excellence and leadership through interaction with practicing engineers and lifelong learning.

PROGRAMME OUTCOMES (POs):

On successful completion of the programme,

PO#	Attribute	Program Outcome
1	Engineering Knowledge	Demonstrate knowledge of Numerical methods in solving complex thermal problems in general and Refrigeration and Air conditioning problems in particular
2	Problem analysis	Able to identify, define and solve Thermal Engineering problems
3	Design / Development of solutions	Potential to design and conduct experiments, analyze and interpret data
4	Investigation of complex problems	Demonstrate an ability to design systems, components or process as per needs and specifications
5	Modern tool usage	Demonstrate skills to use modern engineering tools, software and equipment to analyze problems
6	The Engineer and Society	Broad perspective of the Thermal behavior of commercial and Industrial Refrigeration and Air conditioning systems
7	Environment and sustainability	Possess a sound understanding in the R & AC system issued with respect to Environment and sustainability
8	Ethics	Demonstrate a sincere attitude towards professional and ethical responsibilities.
9	Individual and team work	Able to works as team member and lead in different role in Refrigeration and Airconditioning industries
10	Communication	Understand published literature and technically communicate
11	Project Management and finance	Implement cost effective and improved sustainbale solution
12	Life-long learning	Continue professional development and learning as a life long activity

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PROGRAM SPECIFIC OUTCOMES (PSOs)

By the completion of Thermal Engineering with Specilization in Refrigeration and Air Conditioning course, the student will have the following Program Specific outcomes

PSO1: Should be able to clearly understand the concepts and applications in the field of thermal engineering in general and refrigeration and air conditioning in particular.

PSO2: Should be able to relate the learning from the courses related to HVAC&R Systems, Energy Management, Building EAQ to arrive at solutions to real world problems

PSO3: Should have the capability to comprehend the technological advancements in the usage of modern design tools to analyze and design subsystems/processes of HVAC&R systems for a variety of applications.

4. PEO/PO Mapping

PEO	PROGRAMME OUTCOMES											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
I	√	√	√	√	√	√	√	√	√	√	√	√
II			√	√			√			√	√	
III				√	√	√			√			
IV					√		√		√		√	√
V				√						√	√	√

PROGRESS THROUGH KNOWLEDGE

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Mapping of Course Outcome and Programme Outcome

		Course Name	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
YEAR 1	SEMESTER 1	Advanced Heat Transfer	✓	✓		✓								
		Advanced Thermodynamics	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Refrigeration systems	✓	✓					✓					✓
		Design of Turbo machines for Refrigeration and Air Conditioning systems												
		Research Methodology and IPR							✓	✓			✓	✓
		Program Elective I												
		Audit Course I				✓		✓	✓	✓			✓	
		Applied Thermal Engineering Laboratory	✓	✓	✓	✓	✓				✓			✓
		Refrigeration Laboratory	✓	✓	✓	✓	✓	✓			✓			✓
	SEMESTER 2	Air-conditioning Systems	✓	✓	✓									✓
		Design of Heat Exchangers for Refrigeration and Air Conditioning Systems	✓	✓	✓	✓	✓							
		Instrumentation for Thermal Systems												
		Program Elective II												
		Program Elective III												
		Audit Course II				✓		✓	✓		✓		✓	✓
		Air-conditioning Laboratory	✓	✓	✓	✓	✓	✓			✓			✓
		Thermal Analysis and Simulation Laboratory	✓	✓	✓	✓	✓				✓			
		Mini Project with Seminar		✓		✓	✓	✓		✓			✓	✓
YEAR 2	SEMEST	Program Elective IV												
		Program Elective V												
		Open Elective								✓			✓	
		Dissertation I	✓		✓			✓		✓			✓	✓
	SE	Dissertation II	✓		✓			✓		✓			✓	✓

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CHOICE BASED CREDIT SYSTEM
M.E THERMAL ENGINEERING (WITH SPECIALISATION IN REFRIGERATION AND AIR-CONDITIONING) (FULL -TIME)

SEMESTER I

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	IC5151	Advanced Heat Transfer	FC	4	0	0	4	4
2.	IC5152	Advanced Thermodynamics	FC	4	0	0	4	4
3.	RA5101	Refrigeration Systems	PCC	3	0	0	3	3
4.	RA5102	Design of Turbo machines for Refrigeration and Air Conditioning systems	PCC	3	0	0	3	3
5.	RM5151	Research Methodology and IPR	RMC	2	0	0	2	2
6.		Program Elective I	PEC	3	0	0	3	3
7.		Audit Course I*	AC	2	0	0	2	0
PRACTICAL								
8.	RA5161	Applied Thermal Engineering Laboratory	EEC	0	0	4	4	2
9.	RA5111	Refrigeration Laboratory	EEC	0	0	4	2	2
			TOTAL	**21**	**0**	**8**	**27**	**23**

* Audit Course is optional.

SEMESTER II

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	RA5201	Air-conditioning systems	PCC	3	0	0	3	3
2.	RA5202	Design of Heat Exchangers for Refrigeration and Air Conditioning Systems	PCC	4	0	0	4	4
3.	IC5252	Instrumentation for Thermal Systems	PCC	3	0	0	3	3
4.		Program Elective II	PEC	3	0	0	3	3
5.		Program Elective III	PEC	3	0	0	3	3
6.		Audit Course – II*	AC	2	0	0	2	0
PRACTICALS								
7.	RA5211	Air-conditioning Laboratory	PCC	0	0	4	4	2
8.	RA5212	Thermal Analysis and Simulation Laboratory	PCC	0	0	4	4	2
9.	RA5213	Mini Project with Seminar	EEC	0	0	4	4	2
			TOTAL	**18**	**0**	**12**	**30**	**22**

* Audit Course is optional.

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SEMESTER III

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.		Program Elective IV	PEC	3	0	0	3	3
2.		Program Elective V	PEC	3	0	0	3	3
3.		Open Elective	OEC	3	0	0	3	3
PRACTICAL								
4.	RA5311	Dissertation I	EEC	0	0	12	12	6
			TOTAL	**9**	**0**	**12**	**21**	**15**

SEMESTER IV

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
PRACTICAL								
1.	RA5411	Dissertation II	EEC	0	0	24	24	12
			TOTAL	**0**	**0**	**24**	**12**	**12**

TOTAL NO. OF CREDITS = 72

PROGRESS THROUGH KNOWLEDGE

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FOUNDATION COURSES (FC)

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	IC5151	Advanced Heat Transfer	FC	4	0	0	4	4
2.	IC5152	Advanced Thermodynamics	FC	4	0	0	4	4

PROGRAM CORE COURSES (PCC)

SL. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	RA5101	Refrigeration Systems	PCC	3	0	0	3	3
2.	RA5102	Design of Turbo machines for Refrigeration and Air Conditioning systems	PCC	3	0	0	3	3
3.	RA5201	Air-conditioning systems	PCC	3	0	0	3	3
4.	RA5202	Design of Heat Exchangers for Refrigeration and Air Conditioning Systems	PCC	4	0	0	4	4
5.	IC5252	Instrumentation for Thermal Systems	PCC	3	0	0	3	3
6.	RA5211	Air-conditioning Laboratory	PCC	0	0	4	4	2
7.	RA5212	Thermal Analysis and Simulation Laboratory	PCC	0	0	4	4	2

PROGRAM ELECTIVE COURSES

SEMESTER I, ELECTIVE I

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	RA5001	Industrial Refrigeration Systems	PEC	3	0	0	3	3
2.	RA5002	Building Architecture and HVAC Systems	PEC	3	0	0	3	3
3.	RA5003	Cryogenic Engineering	PEC	3	0	0	3	3

SEMESTER II, ELECTIVE II

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	EY5076	Environmental Engineering and Pollution Control	PEC	3	0	0	3	3
2.	RA5004	Refrigeration Machinery and Components	PEC	3	0	0	3	3
3.	EY5081	Solar Energy Technologies	PEC	3	0	0	3	3
4.	EY5075	Energy Forecasting, Modeling and Project Management	PEC	3	0	0	3	3

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SEMESTER II, ELECTIVE III

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	IC5251	Computational Fluid Dynamics	PEC	3	0	0	3	3
2.	EY5074	Energy Efficient Buildings Design	PEC	3	0	0	3	3
3.	EY5071	Advanced Energy Storage Technologies	PEC	3	0	0	3	3

SEMESTER III, ELECTIVE IV

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	RA5005	Design and Optimization of Thermal Energy Systems	PEC	3	0	0	3	3
2.	RA5006	Indoor Air Quality Control	PEC	3	0	0	3	3
3.	RA5007	Sorption Heating and Cooling Systems	PEC	3	0	0	3	3
4.	RA5008	Air Handling Systems and Design	PEC	3	0	0	3	3

SEMESTER III, ELECTIVE V

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	RA5009	Commissioning of HVAC and Refrigeration Systems	PEC	3	0	0	3	3
2.	RA5010	Food Processing, Preservation and Transportation	PEC	3	0	0	3	3
3.	RA5011	Design of Clean Rooms and Containment Areas	PEC	3	0	0	3	3
4.	RA5071	Solar Refrigeration and Air Conditioning	PEC	3	0	0	3	3

RESEARCH METHODOLOGY AND IPR COURSES (RMC)

SL. NO.	COURSE CODE	COURSE TITLE	PERIODS PER WEEK			CREDITS	SEMESTER
			L	T	P		
1	RM5151	Research Methodology and IPR	2	0	0	2	1

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OPEN ELECTIVE COURSES [OEC]

(Out of 6 Courses one Course must be selected)

SL. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
1.	OE5091	Business Data Analytics	OEC	3	0	0	3	3
2.	OE5092	Industrial Safety	OEC	3	0	0	3	3
3.	OE5093	Operations Research	OEC	3	0	0	3	3
4.	OE5094	Cost Management of Engineering Projects	OEC	3	0	0	3	3
5.	OE5095	Composite Materials	OEC	3	0	0	3	3
6.	OE5096	Waste to Energy	OEC	3	0	0	3	3

AUDIT COURSES (AC)

Registration for any of these courses is optional to students

SL. NO.	COURSE CODE	COURSE TITLE	PERIODS PER WEEK			CREDITS
			L	T	P	
1.	AX5091	English for Research Paper Writing	2	0	0	0
2.	AX5092	Disaster Management	2	0	0	0
3.	AX5093	Sanskrit for Technical Knowledge	2	0	0	0
4.	AX5094	Value Education	2	0	0	0
5.	AX5095	Constitution of India	2	0	0	0
6.	AX5096	Pedagogy Studies	2	0	0	0
7.	AX5097	Stress Management by Yoga	2	0	0	0
8.	AX5098	Personality Development Through Life Enlightenment Skills	2	0	0	0
9.	AX5099	Unnat Bharat Abhiyan	2	0	0	0

EMPLOYABILITY ENHANCEMENT COURSES (EEC)

Sl. No	Course Code	Course Title	Periods per week			Credits	Semester
			Lecture	Tutorial	Practical		
1.	RA5161	Applied Thermal Engineering Laboratory	0	0	4	2	1
2.	RA5111	Refrigeration Laboratory	0	0	4	2	1
3.	RA5213	Mini Project with Seminar	0	0	4	2	2
4.	RA5311	Dissertation I	0	0	12	6	3
5.	RA5411	Dissertation II	0	0	24	12	4

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IC5151	ADVANCED HEAT TRANSFER	L	T	P	C
		4	0	0	4

COURSE OBJECTIVES:

1. To impart knowledge on conduction heat transfer associated with Radiation.
2. To impart knowledge on the turbulent forced convective heat transfer.
3. To impart knowledge on the significance of Phase Change Heat Transfer and Mass Transfer.
4. To teach the heat exchanger design aspects including compact heat exchangers.
5. To impart knowledge on Mass transfer as an engineering phenomenon.

UNIT – I CONDUCTION AND RADIATION HEAT TRANSFER 12

One dimensional energy equations and boundary condition - three-dimensional heat conduction equations - extended surface heat transfer - 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 12

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 12

Condensation with shears edge on bank of tubes - boiling – pool and flow boiling - heat Transfer Enhancement Techniques.

UNIT – IV HEAT EXCHANGERS 12

Heat Exchanger – Є- NTU approach and design procedure – compact heat exchangers – Plate heat exchangers – Heat pipes – Mini and Micro Channel heat exchangers, Heat transfer correlations for specific cases.

UNIT – V MASS TRANSFER 12

Mass transfer - vaporization of droplets - combined heat and mass transfers applications – Cooling Towers, Evaporative condensers, solar pond, Cooling and dehumidification systems.

TOTAL: 60 PERIODS

COURSE OUTCOMES:

Upon completion of this course, the students will be able to:

1. Analyse problems on heat transfer associated with conduction and convection and radiation through vapors and gases**.**
2. Analyse problems on turbulent heat transfer and also solve high speed flow problems.
3. Analyse problems on phase change heat transfer.
4. Estimate the performance of compact heat exchangers and also understand the use of correlations to predict heat transfer from specific devices
5. Understand and analyse the mass transfer associated with heat transfer in engineering systems

REFERENCES:

1. Amir Faghri, Yuwen Zhang and John R. Howell, Advanced Heat and Mass Transfer, Global Digital Press, 2010
2. Ghoshdastidar. P.S., Heat Transfer, Oxford University Press, 2004
3. Holman.J.P, Heat Transfer, Tata McGraw Hill, 2002.
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. Ozisik. M.N., Heat Transfer – A Basic Approach, McGraw-Hill Co., 1985
7. Yadav, R., Heat and Mass Transfer, Central Publishing House, 1995.
8. YunusA.Cengal, Heat and Mass Transfer – A practical Approach, 3rd edition, Tata McGraw - Hill, 2007.

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PO & PSO Mapping:

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9	0.6		0.3									0.9	0.6	0.3
2	0.9	0.6		0.3									0.9	0.6	0.3
3	0.9	0.6		0.3									0.9	0.6	0.3
4	0.9	0.6		0.3									0.9	0.6	0.3
5	0.9	0.6		0.3									0.9	0.6	0.3

IC5152 ADVANCED THERMODYNAMICS L T P C
4 0 0 4

OBJECTIVES:

- To demonstrate the use of correlations for the important properties.
- To achieve an understanding of real gas equations and multi component systems.
- To predict the availability and irreversibility associated with the thermodynamic processes and Chemical availability of reactive systems.
- To introduce phase equilibrium concept for pure substance and mixtures.
- To apply the first and second law of thermodynamics to reactive systems.

UNIT I THERMODYNAMIC PROPERTY RELATIONS 12

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 Thermodyanmic Relations.

UNIT II REAL GAS BEHAVIOUR AND MULTI-COMPONENT SYSTEMS 12

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.

UNIT III CHEMICAL AVAILABILITY 12

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 of closed system and control volume, Environmental state, Fuel Chemical availability, Evaluation of Availability of Hydrocarbon fuels.

UNIT IV PHASE EQUILIBRIUM OF MIXTURES 12

Phase equilibrium – Two phase system – Multiphase systems, Gibbs phase rule. Simplified criteria for phase equilibrium – General criteria of any solution, Ideal solution and Raoult's law, Vapour as Ideal gas mixture, Pressure and Temperature diagrams. Completely miscible mixtures – Liquid-vapour mixtures.

UNIT V THERMO CHEMISTRY 12

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 constant evaluation K_P and K_f, Equilibrium composition evaluation of ideal gas and real gas mixtures

OUTCOME

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

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REFERENCES:

1. Kenneth Wark., J.R, Advanced Thermodynamics for Engineers, McGraw-Hill Inc., 1995.
2. K.Annamalai, I.K.Puri, M.A.Jog, Advanced Thermodynamics Engineering, Second Edition, CRC Press, 2011.
3. Advanced Thermodynamics, S.S. Thipse, Narosa Publishing Home Pvt. Ltd., 2013
4. Yunus A. Cengel and Michael A. Boles, Thermodynamics, McGraw-Hill Inc., 2006.
5. B.P. Pundir, I.C. engine combustion and emissions. Bejan, A., Advanced Engineering Thermodynamics, John Wiley and Sons, 1988.
6. Holman,J.P., Thermodynamics, Fourth Edition, McGraw-Hill Inc., 1988.

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9	0.6		0.3									0.9	0.6	0.3
2	0.9	0.6		0.3									0.9	0.6	0.3
3	0.9	0.6		0.3									0.9	0.6	0.3
4	0.9	0.6		0.3									0.9	0.6	0.3
5	0.9	0.6		0.3									0.9	0.6	0.3

RA5101 REFRIGERATION SYSTEMS

L	T	P	C
3	0	0	3

COURSE OBJECTIVES:

1. To impart knowledge on the analysis of various Refrigeration cycles.
2. To impart knowledge about various Refrigerants and their energy efficiency as well as environmental impact.
3. To impart knowledge on the performance parameters of the different components of the refrigeration system.
4. To teach the heat load estimation procedures and balancing aspects of Refrigeration systems.
5. To teach the student about Not-in-kind Refrigeration technologies and some fundamental Electrical aspects of Refrigeration System drives / controls.

UNIT – I FUNDAMENTALS AND REFRIGERANTS 9

Carnot Cycle for Refrigeration, Heat Pumps – Ideal vapour cycle – Refrigerant Classification, Refrigerant designation, Refrigerant oil relationship – Environmental Impact – Montreal / Kyoto protocols – Kigali Amendment – Eco friendly Refrigerants for different refrigeration sectors

UNIT – II REFRIGERATION CYCLE ANALYSIS 9

Solar Ideal VCR cycle – Practical VCR cycle – Sub cooling, super heating, LSHX, Comparison with Carnot Refrigeration Cycle. Factors influencing performance, Multi pressure Cycle, Cascade Cycle.

UNIT – III COMPONENTS 9

Classification and performance aspects of Compressor, Condenser, Expansion devices, Evaporator

UNIT – IV LOAD ESTIMATION AND BALANCING 9

Estimation of Cooling Load, Cold Storages, Cool Storages, System Balancing – Graphical Analysis, Capacity modulation and Cycling Controls

UNIT – V NOT IN KIND SYSTEMS AND ELECTRIC DRIVES / CONTROLS 9

Vapour Absorption systems, Steam jet Refrigeration, Thermo Electric Refrigeration, Vortex Tube Refrigeration, Magnetic Refrigeration. Types of Electric drives, Starting Relays, Overload projecting Relays, Electric Circuits for domestic and commercial appliances.

TOTAL: 45 PERIODS

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COURSE OUTCOMES:

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

1. Analyse the different refrigeration cycle with practical consideration.
2. Understand the functional aspects of different types of refrigeration system components.
3. Make informed decision on the choice of refrigerants for different applications.
4. Estimate the cooling load for different applications and also do system balancing analysis.
5. Understand the different Not-in-kind Refrigeration Technologies and also the electric drives / controls in some refrigeration systems.

REFERENCES:

1. Arora, C.P., Refrigeration and Air conditioning, McGraw Hill, 3rd Ed., 2010.
2. Dossat R.J., Principles of refrigeration, John Wiley, S.I. Version, 2001.
3. Ibrahim Dincer, Refrigeration Systems and Applications, John Wiley & Sons, 2017.
4. Jordan and Priester, Refrigeration and Air conditioning 1985.
5. Langley, Billy C., 'Solid state electronic controls for HVACR' Prentice-Hall 1986.
6. Stoecker W.F., Refrigeration and Air conditioning, McGraw-Hill Book Company, 1989.
7. Rex Milter, Mark R.Miller., Air conditioning and Refrigeration, McGraw Hill, 2006.

PO & PSO Mapping:

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9	0.6					0.9					0.3	0.6	0.3	0.3
2	0.9	0.6										0.3	0.6	0.3	0.3
3	0.9	0.6										0.3	0.6	0.3	0.3
4	0.9	0.6										0.3	0.6	0.3	0.3
5	0.9	0.6					0.6					0.3	0.6	0.3	0.3

RA5102 DESIGN OF TURBO MACHINES FOR REFRIGERATION AND AIR CONDITIONING SYSTEMS

L	T	P	C
3	0	0	3

COURSE OBJECTIVES:

1. Understand the Energy Transfer process in Turbo machines.
2. To impart the knowledge on fundamentals of Centrifugal Blowers.
3. To learn about different types of axial fans.
4. To understand the working and performance of different compressors.
5. To understand the working and performance of different compressors.

UNIT – I INTRODUCTION **9**

Basics of isentropic flow – static and stagnation properties – diffuser and nozzle configurations – area ratio – mass flow rate – critical properties. Energy transfer between fluid and rotor velocity triangles for a generalized turbo machines – velocity diagrams. Euler's equation for turbo machines and its different forms. Degree of reaction in turbo-machines – various efficiencies – isentropic, mechanical, thermal, overall and polytropic.

UNIT – II CENTRIFUGAL BLOWERS **9**

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.

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UNIT – III AXIAL FLOW FANS 9

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 9

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 9

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

TOTAL: 45 PERIODS

COURSE OUTCOMES:

Upon completion of this course, the students will be able to:

1. Analyze the fundamentals of Turbo machinery and solve the problems on Energy Transfer.
2. Design the Centrifugal Blowers and Fans for various applications.
3. Design and analyze the performance of axial fans.
4. Analyze the performance of different compressors.
5. Design the compressors for the given applications.

REFERENCES:

1. Austin H. Church, Centrifugal pumps and blowers, John Wiley and Sons, 1980.
2. Dixon, Fluid Mechanics, Thermodynamics of turbo machinery Pergamon Press, 1984.
3. Fans & Ventilation A practical guide (Bill) cory WTW, Elsvier, 2005.
4. Jay Matley., Fluid Movers: Pumps, Compressors, Fans and Blowers, McGraw-Hill Publications, 1990..
5. Royce N. Brown, Compressors: Selection and Sizing, Elsevier, 2005.
6. Tony Giampaolo, Compressor Hand Book Principles and Practice, The Fairmont Press, 2010.
7. Yahya S. M., Turbines compressors and fans(4th Edition), Tata McGraw-Hill, 2010.

PO & PSO Mapping:

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9	0.6	0.6	0.3									0.3		0.3
2	0.9	0.6		0.6										0.3	
3	0.9	0.6	0.6	0.6	0.3									0.3	
4	0.9	0.6	0.6	0.6	0.3										0.6
5	0.9	0.6	0.6	0.6	0.3								0.9	0.6	0.6

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RM5151 **RESEARCH METHODOLOGY AND IPR** **L T P C**
2 0 0 2

COURSE OBJECTIVES:

To impart knowledge and skills required for research and IPR:

- Problem formulation, analysis and solutions.
- Technical paper writing / presentation without violating professional ethics
- Patent drafting and filing patents.

UNIT I RESEARCH PROBLEM FORMULATION 6

Meaning of research problem- Sources of research problem, criteria characteristics of a good research problem, errors in selecting a research problem, scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, necessary instrumentations

UNIT II LITERATURE REVIEW 6

Effective literature studies approaches, analysis, plagiarism, and research ethics.

UNIT III TECHNICAL WRITING /PRESENTATION 6

Effective technical writing, how to write report, paper, developing a research proposal, format of research proposal, a presentation and assessment by a review committee.

UNIT IV INTRODUCTION TO INTELLECTUAL PROPERTY RIGHTS (IPR) 6

Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

UNIT V INTELLECTUAL PROPERTY RIGHTS (IPR) 6

Patent Rights: Scope of Patent Rights. Licensing and transfer of technology.Patent information and databases.Geographical Indications. New Developments in IPR: Administration of Patent System, IPR of Biological Systems, Computer Software etc.
Traditional knowledge Case Studies, IPR and IITs.

TOTAL: 30 PERIODS

COURCE OUTCOMES:

1. Ability to formulate research problem
2. Ability to carry out research analysis
3. Ability to follow research ethics
4. Ability to understand that today's world is controlled by Computer, Information Technology, but tomorrow world will be ruled by ideas, concept, and creativity
5. Ability to understand about IPR and filing patents in R & D.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓										
CO2	✓											
CO3	✓							✓				
CO4	✓				✓							
CO5	✓					✓						✓

REFERENCES:

1. Asimov, "Introduction to Design", Prentice Hall, 1962.
2. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd ,2007.
3. Mayall, "Industrial Design", McGraw Hill, 1992.
4. Niebel, "Product Design", McGraw Hill, 1974.
5. Ranjit Kumar, 2nd Edition, "Research Methodology: A Step by Step Guide for beginners" 2010

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RA5161 APPLIED THERMAL ENGINEERING LABORATORY

L	T	P	C
0	0	4	2

OBJECTIVES

1. To educate the students on the realities of thermal engineering.
2. To educate the students about calibration and its essentiality in thermal systems.

LIST OF EXPERIMENTS

1. Experimental Studies on Thermal Boundary Layer for different geometries.
2. Calibration of Temperature Transducers (Thermocouple, RTD & Thermistors).
3. Calibration of Pressure Transducers.
4. Experimental Analysis of Organic Rankine Cycle.
5. Fluid and Thermal Transfer Properties of Liquid Fuels / Heat Transfer Fluids.
6. Experimental Studies on Pool Boiling of Water using Flow Visualization Technique.
7. Flow Characteristic occurrence between Bodies in Wind Tunnel.
8. Experimental Studies on Fluidization of Solid Fuels.
9. Studies on Absorption Refrigeration System.
10. Experimental Studies on Drying of Agro Products.
11. Determining the Actual p-v Diagram of an IC Engine.

TOTAL: 60 PERIODS

COURSE OUTCOMES:

Upon completion of this course, the students will be able to:

1. Plot the error curve and correction curve for different measuring instruments.
2. Analyze the critical/influential properties of thermal systems.

PO & PSO Mapping:

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9	0.9	0.6	0.6	0.6	-	-	-	0.6	-	-	0.6	0.9	0.6	-
2	0.9	0.9	0.6	0.6	0.6	-	-	-	0.6	-	-	0.6	0.9	0.6	-

RA5111 REFRIGERATION LABORATORY

L	T	P	C
0	0	4	2

COURSE OBJECTIVES:

1. To educate the students on different components and refrigerants used in refrigeration systems.
2. To educate the students on special refrigeration systems.

LIST OF EXPERIMENTS

1. Studies on various components of Refrigeration and Air conditioning systems and tools
2. Performance studies on vapour compression refrigeration system with air / water cooled condensers
3. Performance studies on heat pump for different indoor and outdoor conditions
4. Performance study on Pumpless absorption cooler
5. Performance Study on Deep freezers
6. Studies on Heat Exchangers and their performance
7. Studies on Thermoelectric refrigeration systems
8. Performance studies on cascade refrigeration systems
9. Studies on vortex refrigeration systems

Attested

TOTAL: 60 PERIODS

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COURSE OUTCOMES:

Upon completion of this course, the students will be able to:

1. Analyze the thermal performance of refrigeration system.
2. Learn and understand the advancements in the field of refrigeration.

PO & PSO Mapping:

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9	0.6	0.3	0.3	0.6	0.3			0.6			0.3	0.3		0.6
2	0.9	0.9	0.6	0.6	0.6	0.6							0.3	0.6	0.9

RA5201 AIR-CONDITIONING SYSTEMS

L	T	P	C
3	0	0	3

COURSE OBJECTIVES:

1. To teach the psychrometric concepts underlying Air conditioning processes.
2. To impart knowledge on heat load estimation procedures for different applications.
3. To teach the different types of Air conditioning systems.
4. To impart knowledge on various subsystems used for Air Distribution and its design.
5. To teach the components in a MAC system and also the control units for temperature, humidity and Air flow.

UNIT – I PSYCHROMETRICS OF AIR CONDITIONING PROCESSES 9

Properties of Moist Air, Psychrometric Chart and processes - Air Washer - Summer and winter Air conditioning processes – Psychrometric Analysis, Evaporative Cooling.

UNIT – II AIR CONDITIONING LOAD ESTIMATION 10

Sources of heat load – Influence of Geographic location, orientation, Building envelopes – Procedures for estimating heat loads for Summer and Winter Air conditioning – Different Applications.

UNIT – III AIR CONDITIONING SYSTEMS 8

Packaged Air conditioning systems, Centralized Air conditioning systems, VAV systems, Under floor distribution systems, Radiant cooling systems, Hydronic systems, Air handling systems.

UNIT – IV AIR DISTRIBUTION 10

Flow through Ducts, Static and Dynamic Losses, Diffusers, Duct Design – Equal Friction Method and Static Regain Method, Duct Balancing. Selection of Fans, Operational Characteristics - Fan Coil units.

UNIT – V MAC SYSTEMS AND CONTROLS 8

Automotive A/c System layout, Components and Safety devices – Start - Stop systems, Refrigerants and oils, Influence of Suction line heat exchangers, Control of temperature, humidity and air flow, MAC for Electric Vehicles.

TOTAL: 45 PERIODS

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COURSE OUTCOMES:

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

1. Analyse psychrometrically the Air conditioning processes.
2. Estimate the heat load for summer and winter Air conditioning applications.
3. Understand and appreciate the utility of different Air conditioning systems for different applications.
4. Design a fan-duct system for Air conditioning application.
5. Understand and appreciate the individual components of an automobile Air conditioning system.

REFERENCES:

1. Arora C.P., Refrigeration and Air Conditioning, Tata McGraw Hill Pub. Company, 2010.
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. Billy C. Langley., Fundamentals of Air Conditioning Systems, The Fairmont Press, Inc., 2000.
5. Carrier Air Conditioning Co., Handbook of Air Conditioning Systems design, McGraw Hill, 1985.
6. Jones, Air Conditioning Engineering, Edward Amold pub. 2001.
7. Langley, Billy C. Refrigeration and Air Conditioning Ed. 3, Engie wood Cliffs (N.J) Prentice Hall 1986.

PO & PSO Mapping:

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9	0.6	0.6									0.6	0.3	0.6	0.3
2	0.9	0.6	0.6									0.6	0.3	0.6	0.3
3	0.9	0.6										0.6	0.3	0.6	0.3
4	0.9	0.6										0.6	0.3	0.6	0.3
5	0.9	0.6										0.6	0.3	0.6	0.3

RA5202 DESIGN OF HEAT EXCHANGERS FOR REFRIGERATION AND AIR CONDITIONING SYSTEMS

L	T	P	C
4	0	0	4

COURSE OBJECTIVES:

1. To impart knowledge on fundamentals and various types of heat exchangers.
2. To provide thermal design aspects of heat exchangers.
3. To teach the students to have a broad understanding on design aspects of condensers.
4. To make the students to understand the thermal design of evaporators.
5. To impart the knowledge on cooling towers and its performance assessments.

UNIT – I BASIC CONCEPTS IN HEAT EXCHANGERS 12

Classification and types of heat exchangers, Temperature distribution and its implications, LMTD, Effectiveness, Flow Distribution and Stress Analysis – Thermal and hydraulic aspects - pressure drop, Friction factor and heat transfer. Effect of Turbulence, Channel divergence. Thermal Stress in tubes, Types of failures. Estimation of heat transfer coefficient, Fouling factor.

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UNIT – II DESIGN ASPECTS 12

Design procedures for double pipe heat exchangers without and with fins, Shell and Tube heat exchangers - Kern Method – Bell Delware method - The stream analysis method. Air - Cooled heat exchangers - Air side pressure and heat transfer coefficient, Design guidelines, Fan and Motor sizing.

UNIT – III CONDENSERS 12

Different types of condensers, Condensation on tubes and finned tubes, Selection of condensers. Design procedure for Air - Cooled, Water - Cooled shell and tube, Plate, Micro channel, Evaporative and Direct contact condensers. Wilson Plots.

UNIT – IV EVAPORATORS 12

Types of evaporators, Feeding of evaporators, General design consideration of evaporators, Design of Water cooling, Air cooling, Plate type and Micro channel evaporators. Standards for evaporators, Composite materials and its application in heat exchangers.

UNIT – V COOLING TOWERS 12

Types and performance evaluation, Efficient system operation, Flow control strategies, Natural Draft towers, Mechanical Draft Towers - Forced and Induced draft towers, Packings, Spray design, Selection of Pumps, Fans, Testing and Maintenance, Assessment of cooling towers and Energy saving opportunities.

TOTAL: 60 PERIODS

COURSE OUTCOMES:

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

1. Understand the fundamentals, types, constructional features and use of different correlations to predict the thermo – hydraulic parameters of the heat exchangers
2. Design the tubular and shell and tube heat exchangers for a given heat duty.
3. Analyse the problems on condensation and design the condensers.
4. Understand the real time applications of the evaporators along with optimal design strategies.
5. Design and analyse the cooling towers for various applications.

REFERENCES:

1. Cooling Towers: Principles and Practice, Hill G. B., Pring E. J., Peter D. Osborn, Butterworth-Heinemann 2013
2. Kays W. M., London A. L., Compact Heat Exchangers, Krieger Publishing Company, 1998.
3. Kern K.H., Process heat transfer, McGraw-Hill, 2002.
4. Manfred Nitsche and Raji Olayiwola Gbadamosi, Heat Exchanger Design Guide: A Practical Guide for Planning, Selecting and Designing of Shell and Tube Exchangers.
5. Robert W. Serth, Thomas Lestina, Process Heat Transfer: Principles and Applications, Elsevier Ltd 2014.
6. Sadik Kakaç, Hongtan Liu, Anchasa Pramuanjaroenkij, Heat Exchangers: Selection, Rating, and Thermal Design, CRC Press, 2012.
7. TEMA Hand book, Tubular Exchanger Manufacturer Association, New York, 2004.

PO & PSO Mapping:

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9	0.6	0.6	0.6	0.3								0.3	0.6	
2	0.9	0.9	0.9	0.6									0.3	0.6	0.9
3	0.9	0.6	0.6	0.6	0.3								0.3		0.9
4	0.9	0.6	0.6	0.6	0.3								0.3		0.9
5	0.9	0.6	0.6	0.6	0.3								0.3		0.9

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IC5252	INSTRUMENTATION FOR THERMAL SYSTEMS	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES :

1. To expose students to basic characteristics of measurement parameters
2. To enable the students use appropriate measurement system for various applications
3. To enable the students to measure thermo physical properties of solids and fuels
4. To elaborate the students on the need, types of control systems and components of a control system
5. To design a suitable control system for various thermal systems

UNIT I MEASUREMENT CHARACTERISTICS 9

Introduction to measurements, Errors in measurements, Statistical analysis of data, Regression analysis, correlation, estimation of uncertainty and presentation of data, design of experiments – Experimental design factors and protocols

UNIT II MEASUREMENTS IN THERMAL SYSTEMS 9

Basic Electrical measurements, Transducers and its types, Signal conditioning and processing - Measurement of temperature, pressure, velocity, flow – basic and advanced techniques, and radiation properties of surfaces

UNIT III MEASUREMENT OF FUEL PROPERTIES AND POLLUTANTS 9

Thermo / Physical / Chemical and transport properties of solids, liquids and gaseous fuels, Analysers – Flame Ionisation Detector, Non-Dispersive Infrared Analyser, Chemiluminescent detector, Smoke meters, and Gas chromatography

UNIT IV CONTROL SYSTEMS, COMPONENTS AND CONTROLLERS 9

Introduction, Open and closed loop control systems, Transfer function. Types of feedback and feedback control system characteristics – Control system parameters – DC and AC servomotors, servo amplifier, potentiometer, synchro transmitters, synchro receivers, synchro control transformer, stepper motors - Continuous, Discontinuous and Composite control modes – Analog and Digital controllers

UNIT V DESIGN OF MEASUREMENT AND CONTROL SYSTEMS 9

Data logging and acquisition - Sensors for error reduction, elements of computer interfacing, Timers, and Counters, Designing of measurement and control systems for specific applications - Fault finding – Computer based controls

TOTAL:45 PERIODS

COURSE OUTCOMES :

The students will be able to

1. Understand the fundamental concepts of measurement parameters
2. Select the suitable type of sensor for a measuring a fundamental parameter
3. Use appropriate devices to measure different properties of solids and fuels
4. Distinguish between measurement and control systems, and use appropriate control system for an application
5. Construct a complete control system for a thermal application

REFERENCES:

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

Interested
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Hill, New Delhi, Second Edition 2003
6) Norman A. Anderson, Instrumentation for Process Measurement and Control, Third Edition, CRC Press,1997
7) Venkatesan S.P, Mechanical Measurements, Ane Publications, Second edition, 2015.

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9	-	-	-	-	-	0.6	-	-	-	-	0.3	0.9	0.6	0.3
2	0.9	0.6	0.6	0.6	0.3	0.3	0.6	-	-	-	0.6	0.6	0.6	0.9	-
3	0.3	0.3	0.3	0.3	0.6	-	-	0.3	0.6	-	0.9	-	-	-	0.9
4	0.3	0.3	-	0.3	0.3	-	-	0.3	0.3	-	0.9	0.6	-	0.6	-
5	0.3	-	-	-	-	0.6	0.9	0.3	-	-	0.6	0.3	0.9	-	-

RA5211 AIR-CONDITIONING LABORATORY

L	T	P	C
0	0	4	2

COURSE OBJECTIVES:

The students will be able to

1. To teach the students on different components in HVAC systems.
2. To teach the students about Indoor Air Quality.

LIST OF EXPERIMENTS

1. Performance study on Air conditioning system performance evaluation of boiler adopting direct and indirect method
2. Performance studies on cooling towers
3. Computation of pump & pumping system characteristics (pump curve, system curve and BEP)
4. Analysis on Blowers/fans characteristic curves
5. Analysis on pipe and valve characteristics
6. Studies on Air Distribution Systems
7. Hybrid Evaporative Cooler - Performance
8. Environment air quality measurement and analysis.
9. Building Energy Studies – Field visit

TOTAL: 60 PERIODS

COURSE OUTCOMES:

Upon completion of this course, the students will be able to:

1. Analyze the performance of HVAC systems for any applications.
2. Analyze the energy consumption and air quality of a conditioned space.

PO & PSO Mapping:

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9	0.6	0.3	0.3	0.6	0.3			0.6			0.6	0.3	0.3	0.6
2	0.9	0.6	0.3	0.3	0.3	0.6			0.6			0.6	0.6	0.3	0.6

Attested

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RA5212 **THERMAL ANALYSIS AND SIMULATION LABORATORY**

L	T	P	C
0	0	4	2

COURSE OBJECTIVES:

1. To teach the features of simulation in thermal systems.
2. To teach the simulation of piping systems.

LIST OF EXPERIMENTS

1. Heat exchanger Simulation
2. Simulation of various refrigeration cycles
3. Simulation of air conditioning processes
4. Simulation of Lumped heat transfer analysis
5. Radiation heat transfer analysis – Emissivity
6. Simulation of Critical radius of insulation
7. Building Energy Simulation - HVAC aspects
8. Combined Heat transfer analysis using EES – for various applications
9. Simulation of piping systems

TOTAL: 60 PERIODS

COURSE OUTCOMES:

Upon completion of this course, the students will be able to:

1. Simulate and analyze the various parameters in any thermal system.
2. Predict the energy consumption in any

PO & PSO Mapping:

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.6	0.9	0.6	0.6	0.9				0.3				0.6		0.9
2	0.6	0.6	0.9	0.6	0.6				0.3					0.6	0.9

RA5213 **MINI PROJECT WITH SEMINAR**

L	T	P	C
0	0	4	2

OUTCOME

On successful completion of this course, the student will be able to present his thoughts and organize the material for presentation for a particular application / process / systems.

TOTAL = 60 PERIODS

RA5311 **DISSERTATION I**

L	T	P	C
0	0	12	6

OUTCOME

The students' would apply the knowledge gained from theoretical and practical courses in solving problems, so as to give confidence to the students to be creative, well planned, organized, coordinated in their project work phase – II.

Evaluation

Project work evaluation is based on Regulations of Credit system University Departments - Post graduate programmes of Anna University

Attested

TOTAL = 90 PERIODS

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RA5411 **DISSERTATION II** **L T P C**
0 0 24 12

OUTCOME
The students' would apply the knowledge gained from theoretical and practical courses in solving problems, so as to give confidence to the students to be creative, well planned, organized, coordinated project outcome of the aimed work.

EVALUATION
Project work evaluation is based on Regulations of Credit system University Departments - Post graduate programmes of Anna University

Total = 180 Periods

RA5001 **INDUSTRIAL REFRIGERATION SYSTEMS** **L T P C**
3 0 0 3

COURSE OBJECTIVES:
1. To differentiate industrial refrigeration system from conventional system.
2. To study various refrigerant compressors used in industries.
3. To give an overview of refrigerant condenser, evaporator used in industries.
4. To understand the importance of vessel in industrial refrigeration.
5. To educate various aspects of energy conservation techniques.

UNIT – I INTRODUCTION **9**
Introduction to industrial refrigeration-difference from conventional system -industrial and comfort air conditioning - Different applications.

UNIT – II COMPRESSORS **9**
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 **9**
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 **9**
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

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COURSE OUTCOMES:

Upon completion of this course, the students will be able to:

1. Illustrate the fundamentals of industrial refrigeration system.
2. Discuss the working principle and capacity control of refrigerant compressors.
3. Discuss the theory and concepts of condensers and evaporators used in refrigeration industry.
4. Explain the types and importance of vessel in industrial refrigeration.
5. Examine the energy conservation aspects in industrial refrigeration systems.

REFERENCES:

1. ASHRAE Hand Book: Fundamentals, 2017
2. ASHRAE Hand Book: Refrigeration, 2018
3. ASHRAE Hand Book: HVAC Systems and Equipment, 2016.
4. Refrigeration commissioning guide for commercial and industrial systems, 2013
5. Wilbert F.Stoecker, Industrial Refrigeration Hand Book, McGraw-Hill, 1998

PO & PSO Mapping:

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.3												0.6	0.3	0.3
2		0.2													
3		0.6													
4	0.4														
5							0.3								

RA5002 BUILDING ARCHITECTURE AND HVAC SYSTEMS

L	T	P	C
3	0	0	3

COURSE OBJECTIVES:

1. To teach the climate and the factors that affects the comfort conditions.
2. To teach various types of building materials employed in the buildings
3. To teach the IAQ parameters and their influence on human comfort
4. To teach various HVAC systems
5. To teach ECBC for the buildings

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.

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UNIT – V HVAC SYSTEMS **9**

HVAC systems, components, Building Automation and Energy Management–Passive and Active Systems, Solar heating, ECBC concept on buildings

TOTAL: 45 PERIODS

COURSE OUTCOMES:

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

1. Appreciate the influence of climate and weather in building architecture.
2. Estimate the requirement of building materials and heat flow through building envelop.
3. Understand the factors that affect the IAQ in buildings and the method to reduce its effects on human health.
4. Carryout the building design based upon different climate conditions.
5. Analyze the various HVAC system components for various applications in the building requirements.

REFERENCES:

1. ASHRAE Hand Book–HVAC Systems & Equipment 2011, HVAC Applications 2012, ASHRAEInc. Atlanta.
2. Davis A. J. and Schubert P. P., Alternative Natural Energy Sources in Building Design , IIEdition, Van Nostrand Reinhold Co, New York, 1981.
3. Konya, A., Design Primer for Hot climates, Architectural Press, London, 1980.
4. Givoni B., Man, Climate & Architecture, Barking Esser Applied Science, 1982.
5. Manfred Hegger, Matthias Fuchs, Thomas Stark and Martin Zeumer., Energy Manual: Sustainable Architecture, Walter de Gruyter, 2012.
6. National Building Code of India, 2015, Bureau of Indian Standards.

PO & PSO Mapping:

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.3					0.6					0.3			0.6	
2		0.3			0.6		0.9						0.3	0.6	0.3
3			0.3							0.3			0.3	0.6	
4				0.3			0.6		0.3					0.6	0.3
5		0.3										0.9		0.9	

RA5003 CRYOGENIC ENGINEERING **L T P C**

3 0 0 3

COURSE OBJECTIVES:

1. To learn the material properties at cryogenic temperatures.
2. To give an overview of different cryogenic liquefaction cycles.
3. To explain the separation of cryogenic liquids in rectification column.
4. To learn the working principle of cryogenic refrigerator.
5. To educate the cryogenic handling techniques.

UNIT – I INTRODUCTION **9**

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 **9**

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.

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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 9

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 9

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

COURSE OUTCOMES:

Upon completion of this course, the students will be able to:

1. Recall the material properties at cryogenic temperature.
2. Estimate the performance of liquefaction cycle.
3. Analyze the cryogenic separation rectification column.
4. Discuss the working principle of cryogenic refrigerator.
5. Discuss the types of vaccum pumps and various instruments used in handling of crygens.

REFERENCES:

1. Klaus D. Timmerhaus and Thomas M. Flynn, Cryogenic Process Engineering, Plenum Press NewYork, 1989.
2. Mukhopadhay Mamata, Fundamentals of cryogenic engineering, PHI learning, 2010.
3. Pipkov, "Fundamentals of Vacuum Engineering", Meer Publication.
4. Randall F. Barron, "Cryogenics Systems", Second Edition Oxford University Press New York, Clarendon Press, Oxford, 1985.
5. Thomas Flynn, Cryogenic Engineering, Revised and Expanded, CRC Press, 2004.

PO & PSO Mapping:

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.3												0.3	0.3	0.3
2	0.3														
3			0.6												
4		0.3													
5						0.6									

EY5076 ENVIRONMENTAL ENGINEERING AND POLLUTION CONTROL

L	T	P	C
3	0	0	3

OBJECTIVES:

1. To impart knowledge on the atmosphere and its present condition and, global warming.
2. To detail on the sources of water pollution and possible solutions for mitigating their degradation.
3. To detail on the sources of air pollution and possible solutions for mitigating their degradation.
4. To detail on the sources of solid waste and possible ways to dispose them safely.
5. To impart knowledge on hazardous waste management.

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UNIT – I INTRODUCTION **9**

Man & Environment – Types of Pollution – Global Environmental issues – Environmental Impact Assessment – Global Warming Issues – CO_2 Mitigation – Basic definition of Pollution Indicators – Noise Pollution

UNIT – II WATER POLLUTION **9**

Pollutants in Water & Wastewater – Physical and Chemical Treatment Methods – (An Overview) Neutralization – Aeration –Colour / Odour Removal - Sludge dewatering – Biological Treatment including Aerobic & Anaerobic Treatment

UNIT – III AIR POLLUTION **9**

Sources – Ambient Air Quality Standards – Emission Limits – Equipment for Ambient Air & Stack Monitoring – Principles of operation of Particulate Control Equipments -ESPs, Bag Filters, Cyclone Separators– Vehicular Pollution and its Control – BS standards

UNIT – IV SOLID WASTE MANAGEMENT **9**

Types & Sources – Types– Waste Generation – Composition – Physical, Chemical and Biological Properties – Transformation Technologies for Waste Treatment – Landfill Management – Layout, Closure & Post Closure Operation – Reclamation Leachate Generation – e Waste Disposal

UNIT – V HAZARDOUS WASTE MANAGEMENT **9**

Sources – Classification – Characterization of waste - health effects - Incineration– Radioactive Waste from nuclear power plants and disposal options - RDF- Mass Firing – Material Recycling

TOTAL: 45 PERIODS

OUTCOMES:

Upon completion of this course, the students will be able to:

1. Types and effects of each type of pollution on man – earth will be made known.
2. Technical aspects of Global Warming will make them understand the impact they have on climate
3. Technologies that are available for reduction of pollutants dumped into the atmosphere
4. Cursory / superficial formation - the students – had in Hazardous waste, waste disposal hitherto will be deep & sensible enough after studying this subject
5. Comprehend the different techniques available for safe disposal of hazardous waste

REFERENCES:

1. Peavy, H.S. and D.R. Rowe, G.Tchobanoglous: Environmental Engineering - McGraw-Hill Book Company, NewYork, 1985.
2. Ludwig, H. W.Evans: Manual of Environmental Technology in Developing Countries, International Book Company, Absecon Highlands, N.J, 1991.
3. Arcadio P Sincero and G. A. Sincero, Environmental Engineering – A Design Approach, Prentice Hall of India Pvt Ltd, New Delhi, 2002.
4. G. Masters: Introduction to Environmental Engineering and Science, Prentice Hall of India Pvt Ltd, New Delhi, 2003.
5. Richard J. Watts, Hazardous Wastes - Sources,Pathways, Receptors John Wiley and Sons, New York,1997

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.6	0.3	0.3	0.3	0.3	0.3	0.3						0.3		
2	0.6	0.3	0.3	0.3	0.3		0.3						0.3		0.3
3	0.9	0.3	0.6	0.3	0.3		0.6						0.3	0.9	0.3
4	0.6	0.3	0.3	0.3	0.3		0.6						0.3	0.3	0.3
5	0.3	0.3	0.6	0.6	0.9										0.9

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RA5004 REFRIGERATION MACHINERY AND COMPONENTS

L	T	P	C
3	0	0	3

COURSE OBJECTIVES:

1. To teach how refrigeration components and systems perform their tasks
2. To teach to identify and explain various system accessories and controls in refrigeration systems
3. To teach to know about various appliances use these machinery and components
4. To teach hydronic systems applicable to building HVAC systems
5. To teach various types of control systems in the HVAC systems

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

Special components for refrigeration / air Conditioning in Automobiles, Railway Wagons, Marine Vessels, Aircraft and Other Commercial Applications.

UNIT – V SYSTEM ACCESSORIES AND CONTROLS 9

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

TOTAL: 45 PERIODS

COURSE OUTCOMES:

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

1. Understand working of the refrigeration compressors and control systems.
2. Identify the various components of refrigerant compressors and its functionality.
3. Analysis the hydronic need of the refrigeration systems.
4. Estimate the special components requirements for the various applications of the refrigeration systems.
5. Understand the systems with the accessories and controls.

REFERENCES:

1. Althose, A.D. &Turnquist, C.H. “Modern Refrigeration and Airconditioning” Good Heart-Wilcox Co.Inc., 1985.
2. Cooper &Williams, B. “Commercial, Industrial, Institutional Refrigeration, Design, Installation and Trouble Shooting” Eagle Wood Cliffs (NT) Prentice Hall, 1989.
3. Dosset, R.J. “Principles of Refrigeration”, John Wiley & Sons, 2001.
4. Hains, J.B, “Automatic Control of Heating &Airconditioning” McGraw Hill, 1981.
5. Mouafak A. Zaher, Refrigeration and Air Conditioning Fundamentals, Components, Application and Services, Create Space Independent Publishing Platform, 2013.
6. Recent release of BIS Code for relevant testing practice. ASHRAE Hand book (Fundamentals & Equipments), 2005.

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PO & PSO Mapping:

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.3		0.3				0.6							0.3	
2				0.6		0.6				0.9			0.6		0.9
3		0.3			0.6			0.9				0.3			
4									0.3				0.6		0.9
5	0.3			0.3										0.3	

EY5081 SOLAR ENERGY TECHNOLOGIES L T P C

3 0 0 3

COURSE OBJECTIVES:

1. To learn and study the solar radiation and various solar collectors
2. To study the various solar thermal energy technologies and their applications
3. To learn about various solar PV cell materials and conversion techniques
4. To learn various Solar SPV systems designs and their applications
5. To know about various solar passive building techniques for cooling and heating applications

UNIT – I SOLAR RADIATION AND COLLECTORS 9

Solar angles – Sun path diagrams – Radiation - extraterrestrial characteristics - measurement and estimation on horizontal and tilted surfaces - flat plate collector thermal analysis - testing methods- evacuated tubular collectors - concentrator collectors – classification - design and performance parameters - tracking systems - compound parabolic concentrators - parabolic trough concentrators - concentrators with point focus - Heliostats – performance of the collectors.

UNIT – II SOLAR THERMAL TECHNOLOGIES 9

Principle of working, types, design and operation of - Solar heating and cooling systems - Thermal Energy storage systems – Solar Desalination – Solar cooker : domestic, community – Solar pond – Solar drying-solar chimney-solar thermal electricity conversion.

UNIT – III SOLAR PV FUNDAMENTALS 9

Semiconductor – properties - energy levels - basic equations of semiconductor devices physics. Solar cells - p-n junction: homo and hetro junctions - metal-semiconductor interface - dark and illumination characteristics - figure of merits of solar cell - efficiency limits - variation of efficiency with band-gap and temperature - efficiency measurements - high efficiency cells – Solar thermo-photovoltaics.

UNIT – IV SPV SYSTEM DESIGN AND APPLICATIONS 9

Solar cell array system analysis and performance prediction- Shadow analysis: reliability - solar cell array design concepts - PV system design - design process and optimization - detailed array design - storage autonomy - voltage regulation - maximum tracking - centralized and decentralized SPV systems - standalone - hybrid and grid connected system - System installation - operation and maintenances - field experience - PV market analysis and economics of SPV systems.

UNIT – V SOLAR PASSIVE ARCHITECTURE 9

Thermal comfort - bioclimatic classification – passive heating concepts: direct heat gain - indirect heat gain - isolated gain and sunspaces - passive cooling concepts: evaporative cooling - Radiative cooling- application of wind, water and earth for cooling; shading - paints and cavity walls for cooling – roof radiation traps - earth air-tunnel – energy efficient landscape design - thermal comfort.

TOTAL: 45 PERIODS

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COURSE OUTCOMES:

Upon completion of this course, the students will be able to:

1. Learn and study the solar radiation and various solar collectors
2. Know the various solar thermal energy technologies and their applications
3. Aware about various solar PV cell materials and conversion techniques
4. Learn various Solar SPV systems designs and their applications
5. Know about various solar passive building techniques for cooling and heating applications

REFERENCES:

1. Chetan Singh Solanki, Solar Photovoltatics – Fundamentals, Technologies and Applications, PHI Learning Private limited, 2011
2. John A. Duffie, William A. Beckman, Solar Engineering of Thermal Processes, John Wiley & Sons, 2013
3. Lovegrove K., Stein W., Concentrating Solar Power Technology, Woodhead Publishing Series in Energy, Elsevier, 1st Edition, 2012
4. Solar Energy International, Photovoltaic – Design and Installation Manual, New Society Publishers, 2006
5. Sukhatme S P, Nayak J K, Solar Energy – Principle of Thermal Storage and collection, Tata McGraw Hill, 2008

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9	0.6	0.3		0.3		0.9	0.6				0.9	0.6	0.3	
2	0.9	0.6	0.6		0.6	0.3	0.9	0.6				0.9			0.6
3	0.9	0.6	0.3		0.6		0.9	0.6				0.9		0.3	-
4	0.9	0.9	0.6			0.6	0.9	0.6				0.9	0.3	-	0.6
5	0.6	0.3	0.9		0.6	0.6	0.9	0.9				0.9	0.3	0.3	0.6

EY5075 ENERGY FORECASTING, MODELING AND PROJECT MANAGEMENT

L	T	P	C
3	0	0	3

OBJECTIVES:

1. To understand about National energy scenario.
2. To predict the energy demand using various forecasting models.
3. To develop an optimization model for the effective utilisation of energy sources.
4. To know the procedure to the write the project proposal.
5. To know the energy policies in the country.

UNIT – I ENERGY SCENARIO **9**

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 **9**

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 **9**

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.

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UNIT – IV PROJECT MANAGEMENT **9**

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 **9**

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)-Costing.

TOTAL: 45 PERIODS

OUTCOMES:

Upon completion of this course, the students will be able to:

1. Have knowledge in the National energy scenario.
2. Do Energy prediction using various forecasting techniques.
3. Develop optimization model for energy planning.
4. Capable of writing project proposals.
5. Understand the National and state energy policies.

REFERENCES:

1. Armstrong J.Scott (ed.), Principles of forecasting: a hand book for researchers and practitioners, Norwell, Massachusetts: Kluwer Academic Publishers.2001.
2. DhandapaniAlagiri, Energy Security in India Current Scenario, The ICFAI University Press, 2006.
3. Fred Luthans, Brett C. Luthan, Kyle W. Luthans, Organisational Behaviour: An Evidence-Based Approach, Information Age Publishing; 13 edition, 2015
4. Spyros G. Makridakis, Steven C. Wheelwright, Rob J. Hyndman, Forecasting: Methods and Applications, 4th Edition, ISBN: 978-0-471-53233-0,2003
5. Yang X.S., Introduction to mathematical optimization: From linear programming to Metaheuristics, Cambridge, Int. Science Publishing, 2008.

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.3	0.3	0.6	0.3	0.3	0.3	0.9	0.3	0.3	0.6	0.3	0.9	0.9	0.6	0.3
2	0.9	0.6	0.9	0.9	0.9	0.6	0.6				0.3	0.6	0.9	0.6	0.6
3	0.6	0.9	0.9	0.9	0.9			0.6			0.3	0.3	0.6	0.6	0.9
4	0.6	0.3	0.3	0.6		0.6		0.6	0.6	0.9	0.9	0.6	0.6	0.9	0.6
5	0.3	0.3				0.6	0.9	0.6	0.6	0.9	0.9	0.6	0.6	0.9	0.3

IC5251 COMPUTATIONAL FLUID DYNAMICS **L T P C**
3 0 0 3

COURSE OBJECTIVES:

- This course aims to introduce numerical modeling and its role in the field of heat, fluid flow and combustion 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.
- To develop finite volume discretised forms of the governing equations for diffusion processes.
- To develop finite volume discretised forms of the convection-diffusion processes.
- To develop pressure based algorithms for flow processes.
- To introduce various turbulence models, Large Eddy Simulation and Direct Numerical Simulation.

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UNIT – I GOVERNING DIFFERENTIAL EQUATIONS AND DISCRETISATION TECHNIQUES 8

Basics of Heat Transfer, Fluid flow – Mathematical description of fluid flow and heat transfer – Conservation of mass, momentum, energy and chemical species - Classification of partial differential equations – Initial and Boundary Conditions – Discretisation techniques using finite difference methods – Taylor's Series - Uniform and non-uniform Grids, Numerical Errors, Grid Independence Test.

UNIT – II DIFFUSION PROCESSES : FINITE VOLUME METHOD 10

Steady one-dimensional diffusion, Two and three dimensional steady state diffusion problems, Discretisation of unsteady diffusion problems – Explicit, Implicit and Crank-Nicholson's schemes, Stability of schemes.

UNIT – III CONVECTION-DIFFUSION PROCESSES : FINITE VOLUME METHOD 9

One dimensional convection – diffusion problem, Central difference scheme, upwind scheme – Hybrid and power law discretization techniques – QUICK scheme.

UNIT – IV FLOW PROCESSES : FINITE VOLUME METHOD 8

Discretisation of incompressible flow equations – Pressure based algorithms, SIMPLE, SIMPLER & PISO algorithms.

UNIT – V TURBULENCE MODELS 10

Turbulence – RANS equation - Algebraic Models, One equation model, Two equation models – k – □ & standard k – ϵ model, Low Reynold number models of k- ϵ, Large Eddy Simulation (LES), Direct Numerical Simulation (DNS) - Introduction. Solving simple cases using standard CFD codes.

TOTAL:45 PERIODS

OUTCOMES:

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

- Analyse the governing equations and boundary conditions.
- Analyse various discretization techniques for both steady and unsteady diffusion problems.
- Analyse the various convection-diffusion problems by Finite-Volume method.
- Analyse the flow processes by using different pressure bound algorithms.
- Select and use the different turbulence models according to the type of flows.

REFERENCES:

1. Versteeg and Malalasekera, N, "An Introduction to computational Fluid Dynamics The Finite Volume Method," Pearson Education, Ltd., Second Edition, 2014.
2. Ghoshdastidar, P.S., "Computer Simulation of Flow and Heat Transfer", Tata McGraw-Hill Publishing Company Limited, New Delhi, 1998.
3. Muralidhar, K., and Sundararajan, T., "Computational Fluid Flow and Heat Transfer", Narosa Publishing House, New Delhi, 2003.
4. Subas and V.Patankar "Numerical heat transfer fluid flow", Hemisphere Publishing Corporation,1980.
5. Jiyuan Tu, Guan Heng Yeoh, Chaogun Liu, "Computational Fluid Dynamics A Practical Approach" Butterworth – Heinemann An Imprint of Elsevier, Madison, U.S.A., 2008
6. John D. Anderson. JR. "Computational Fluid Dynamics The Basics with Applications" McGraw-Hill International Editions, 1995.

0.3- Low 0.6- Medium 0.9- High

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9						0.6					0.3	0.9	0.6	0.3
2	0.9	0.6	0.6	0.6	0.3	0.3	0.6				0.6	0.6	0.6	0.9	
3	0.3	0.3	0.3	0.3	0.6			0.3	0.6		0.9				0.9
4	0.3	0.3		0.3	0.3			0.3	0.3		0.9	0.6		0.6	
5	0.3					0.6	0.9	0.3			0.6	0.3	0.9		

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EY5074 ENERGY EFFICIENT BUILDINGS DESIGN L T P C
3 0 0 3

OBJECTIVES

1. To learn the green buildings concepts applicable to alternate design
2. To be familiar with basic terminologies related to buildings
3. To learn the building (air) conditioning techniques
4. To know the methods to evaluate the performance of buildings
5. To incorporate Renewable energy systems in buildings

UNIT I INTRODUCTION 9

Climate and Building, Historical perspective, Aspects of green building design – Sustainable Site, Water, Energy, Materials and IAQ, ECBC Standards

UNIT II LANDSCAPE AND BUILDING ENVELOPES 9

Energy efficient Landscape design – Microclimate, Shading, Arbors, Windbreaks, Xeriscaping, Building envelope – Thermal comfort, Psychrometry, Comfort indices, Thermal Properties of Building Materials – Thermal Resistance, Thermal Time Constant (TTC), Diurnal Heat Capacity (DHC), Thermal Lag, Decrement Factor, Effect of Solar Radiation – Sol-air Temperature, Processes of heat exchange of building with environment, Insulation

UNIT III PASSIVE HEATING AND COOLING 9

HVAC introduction, Passive Heating – Solar radiation basics, Sun Path Diagram, Direct Heating, Indirect Heating and Isolated heating, Concept of Daylighting, Passive Cooling – Natural Ventilation (Stack and Wind), Evaporative Cooling and Radiative Cooling.

UNIT IV THERMAL PERFORMANCE OF BUILDINGS 9

Heat transfer due to fenestration/infiltration, Calculation of Overall Thermal Transmittance, Estimation of building loads: Steady state method, network method, numerical method, correlations, Thermal Storage integration in buildings

UNIT V RENEWABLE ENERGY IN BUILDINGS 9

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

TOTAL: 45 PERIODS

OUTCOMES:

Upon completion of this course, the students:

1. Will be familiar with climate responsive building design and basic concepts
2. Will Know the basic terminologies related to buildings
3. Will Know the passive (air) conditioning techniques
4. Will be able to evaluate the performance of buildings
5. Gets acquainted with Renewable energy systems in buildings

REFERENCES:

1. ASHRAE Handbook - 2009 - Fundamentals.
2. Baruch Givoni: Climate considerations in building and Urban Design, John Wiley & Sons, 1998
3. Baruch Givoni: Passive Low Energy Cooling of Buildings by, John Wiley & Sons, 15-Jul-1994
4. JA Duffie and WA Beckman: Solar Engineering of Thermal Processes, Third Edition, John Wiley & Sons, 2006.
5. Jan F. Kreider, Peter S. Curtiss, Ari Rabl, Heating and Cooling of buildings: Design for Efficiency, Revised Second Edition, CRC Press, 28-Dec-2009.

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9	0.9	0.3	0.3	0.6	0.6	0.9	0.3	0.6	0.3			0.9	0.3	
2	0.9	0.9	0.9	0.3	0.3		0.9					0.3	0.3		
3	0.9	0.3	0.9		0.3	0.6	0.9		0.3			0.6	0.6	0.3	
4	0.9	0.9	0.9	0.6	0.6	0.6	0.9				0.6	0.6	0.3	0.3	0.9
5	0.9	0.6	0.9		0.9	0.3	0.9		0.6		0.6	0.6	0.6	0.3	0.9

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EY5071	ADVANCED ENERGY STORAGE TECHNOLOGIES	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES:

1. To understand the various types of energy storage technologies and its applications.
2. To study the various modelling techniques of energy storage systems using TRNSYS.
3. To learn the concepts and types of batteries.
4. To make the students to get understand the concepts of Hydrogen and Biogas storage.
5. To provide the insights on Flywheel and compressed energy storage systems.

UNIT – I INTRODUCTION **9**

Necessity of energy storage – types of energy storage – comparison of energy storage technologies – Applications.

UNIT – II THERMAL STORAGE SYSTEM **9**

Thermal storage – Types – Modelling of thermal storage units – Simple water and rock bed storage system – pressurized water storage system – Modelling of phase change storage system – Simple units, packed bed storage units - Modelling using porous medium approach, Use of TRNSYS.

UNIT – III ELECTRICAL ENERGY STORAGE **9**

Fundamental concept of batteries – measuring of battery performance, charging and discharging of a battery, storage density, energy density, and safety issues. Types of batteries – Lead Acid, Nickel – Cadmium, Zinc Manganese dioxide and modern batteries for example (i) zinc-Air (ii) Nickel Hydride, (iii) Lithium Battery.

UNIT – IV HYDROGEN AND BIOGAS STORAGE **9**

Hydrogen storage options – compressed gas – liquid hydrogen – Metal Hydrides, chemical Storage, Biogas storage - comparisons. Safety and management of hydrogen and Biogas storage - Applications.

UNIT – V ALTERNATE ENERGY STORAGE TECHNOLOGIES **9**

Flywheel, Super capacitors, Principles & Methods – Applications, Compressed air Energy storage, Concept of Hybrid Storage – Applications.

TOTAL: 45 PERIODS

OUTCOMES:

Upon completion of this course, the students will be able to:

1. Identify the energy storage technologies for suitable applications.
2. Analyze the energy storage systems using TRNSYS.
3. Recognize the concepts and types of batteries.
4. Diagnose the principle operations of Hydrogen and Biogas storage.
5. Analyze the concepts of Flywheel and compressed energy storage systems

REFERENCES:

1. Ibrahim Dincer and Mark A. Rosen, Thermal Energy Storage Systems and Applications, John Wiley & Sons 2002.
2. James Larminie and Andrew Dicks, Fuel cell systems Explained, Wiley publications, 2003.
3. Luisa F. Cabeza, Advances in Thermal Energy Storage Systems: Methods and Applications, Elsevier Woodhead Publishing, 2015
4. Robert Huggins, Energy Storage: Fundamentals, Materials and Applications, 2nd edition, Springer, 2015
5. Ru-shiliu, Leizhang, Xueliang sun, Electrochemical technologies for energy storage and conversion, Wiley publications, 2012.

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CO	PO												PSO		
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1	0.9	0.3	0.9	0.3	0.3	0.6	0.9	0.3	0.3	0.3	0.6	0.3	0.9	0.6	0.6
2	0.9	0.3	0.9	0.3	0.3	0.6	0.9	0.3	0.3	0.3	0.6	0.3	0.9	0.6	0.6
3	0.9	0.3	0.9	0.3	0.3	0.6	0.9	0.3	0.3	0.3	0.6	0.3	0.9	0.6	0.6
4	0.9	0.3	0.9	0.3	0.3	0.6	0.9	0.3	0.3	0.3	0.6	0.3	0.9	0.6	0.6
5	0.9	0.3	0.9	0.3	0.3	0.6	0.9	0.3	0.3	0.3	0.6	0.3	0.9	0.6	0.6

RA5005 DESIGN AND OPTIMIZATION OF THERMAL ENERGY SYSTEMS

L	T	P	C
3	0	0	3

COURSE OBJECTIVES:

1. To teach thermal energy system design principles and its model development.
2. To teach modeling technique for thermal systems to arrive at optimal design solution.
3. To teach dynamic behavior of thermal energy systems
4. To teach Heat Exchanger Net work applicable to Industries
5. To teach the trade of between capital and operating cost using pinch point analysis

UNIT – I DESIGN CONCEPTS **9**

Design Principles, Workable Systems, Optimal Systems, Matching of System Components, modelling overview - levels and steps in model development - Examples of models – curve fitting and regression analysis.

UNIT – II MODELLING AND SYSTEMS SIMULATION **9**

Modelling of thermal energy systems – heat exchanger - solar collectors – distillation –rectification-refrigeration systems - information flow diagram - solution of set of nonlinear algebraic equations - successive substitution - Newton Raphson method- examples of thermal systems simulation.

UNIT – III OPTIMISATION **9**

Objectives - constraints, problem formulation - unconstrained problems - necessary and sufficiency conditions. Constrained optimization - Lagrange multipliers, constrained variations, sensitivity analysis - New generation optimization techniques – examples.

UNIT – IV DYNAMIC BEHAVIOUR **9**

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

UNIT – V APPLICATIONS AND CASE STUDIES **9**

Case studies of optimization in thermal systems problems- Dealing with uncertainty- probabilistic techniques – Trade-offs between capital and energy using Pinch analysis.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

Upon completion of this course, the students will be able to:

1. Understand basic design principles of the thermal systems and the type of models suitable for further analysis.
2. Carry out the Simulation and Modelling of typical thermal energy systems.
3. Analysis the effect of constraints on the performance of thermal energy systems.
4. Develop the dynamic analysis of the thermal system with control system feedback arrangement.
5. Design HEN network and perform Energy-Economic Analysis for atypical applications.

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REFERENCES:

1. Arora J.S., Introduction to optimum design- IV Edition, McGraw Hill, 2016.
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. Rao S. S., Engineering Optimization Theory and Practice, New Age Publishers, 2010.
5. Stoecker W. F., Design of Thermal Systems, McGraw Hill Edition, 2011.
6. YogeshJaluria, Design and Optimization of Thermal Systems, CRC Press, 2016.

PO & PSO Mapping:

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9						0.3		0.3				0.3		0.9
2		0.9		0.3	0.6					0.6		0.6		0.6	
3			0.6			0.6							0.9		0.6
4		0.3		0.3		0.3		0.3							
5	0.3				0.3							0.9	0.6		0.3

RA5006 INDOOR AIR QUALITY CONTROL

L	T	P	C
3	0	0	3

COURSE OBJECTIVES:

1. To learn the importance of air quality and standards to be maintained in the rooms
2. To gain knowledge about the air distribution design and IAQ problem diagnosing
3. To know about the principles and varieties of filters and their testing methods
4. To have knowledge on design of clean rooms with international standards for various circumstances
5. To gain knowledge about the measurements and prevention of contaminants

UNIT – I AIR QUALITY **9**

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 **9**

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-diagnosing Building problems-NIOSH standards.

UNIT – III AIR FILTRATION **9**

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 **9**

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

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UNIT – V IAQ MEASUREMENTS & CONTROL 9

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

TOTAL: 45 PERIODS

COURSE OUTCOMES:

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

1. gain knowledge about the IAQ-ASHRAE standards
2. understand the IAQ damping methods and air distribution design and parameters affecting the IAQ
3. gain knowledge about the filter standards and testing methods
4. gain knowledge about the standards in design of clean rooms
5. know the contaminant sampling methods and instruments for IAQ measurements

REFERENCES:

1. American Institutes of Architects (AIA), Guidelines for Design & Construction of Hospital & Health care facilities, AIA, Washington–2001.
2. ASHRAE Hand Book, HVAC Systems and Equipment, Edition, 2012.
3. Hines A.L, Gosh T.K, Loyalka. S.K. and Warder, R.C., Indoor Air Quality & Control, PTR Prentice Hall,1993.
4. National Air Filtration Association, NAFA guide to Air Filtration-III edition-NAFA Washington DC-2001.
5. Thad Godish, Sick Buildings, Lecois Publishers, Ann Arbor, 1994.
6. Whyte W. Clean Room Design II Edition, John Wiley & Sons (NY)–1999.

PO & PSO Mapping:

CO	PO												PSO		
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1	0.9				0.3		0.6						0.6		
2	0.9		0.3		0.6		0.3						0.3		0.9
3	0.9		0.6		0.3								0.6	0.3	
4	0.9	0.6		0.3									0.3		0.6
5	0.9			0.6									0.3	0.6	

PROGRESS THROUGH KNOWLEDGE

RA5007 SORPTION HEATING AND COOLING SYSTEMS

L	T	P	C
3	0	0	3

COURSE OBJECTIVES:

1. To teach fundamentals of sorption cooling systems and analysis and design of LiBr and Ammonia systems.
2. To teach pumpless system and solid sorption systems and their design of components.
3. To teach various applications of sorption systems for heating, cooling and power generation in buildings, industries etc.
4. To teach polygeneration systems
5. To teach the merits of the system for climate change mitigation

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UNIT – I INTRODUCTION **9**

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

UNIT – II LIQUID SORPTION SYSTEMS **9**

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 **9**

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

UNIT – V APPLICATIONS **9**

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

COURSE OUTCOMES:

Upon completion of this course, the students will be able to:

1. Understand the fundamentals of sorption heating and cooling systems and the working fluids requirement and their properties
2. Analyze the energy input requirements for both LiBr and Ammonia systems for various applications
3. Understand the principle of working in respects of pumpless refrigerators and solid sorption heating and cooling systems
4. Estimate the design data of various components used both in liquid and solid sorption heating and cooling systems.
5. Appreciate the use of the systems for various building energy requirements such as heating, cooling and power and its ability for climate change mitigation.

REFERENCES:

1. Alefeld G. and Radermacher R., Heat Conversion Systems, CRC Press, London (1994).
2. ASHRAE Hand Book–HVAC Systems & Equipment 2008, ASHRAE Inc. Atlanta.
3. Herold K. E., Radermacher R. and Klein S. A., Absorption Chillers and Heat Pumps, CRC Press,London (2016).
4. Ibrahim Dincer, Tahir Abdul HussainRatlamwala., Integrated Absorption Refrigeration Systems: Comparative Energy and Exergy Analyses, Springer, 2016.

PO & PSO Mapping:

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2			0.3		0.3				0.3		0.6			0.3	0.6
3		0.6						0.3				0.3			
4				0.3		0.6			0.3				0.9		0.6
5	0.3			0.3						0.3		0.3		0.3	

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RA5008 AIR HANDLING SYSTEMS AND DESIGN

L	T	P	C
3	0	0	3

COURSE OBJECTIVES:

1. To learn about the selection, classification of Air- Handling units and duct design methods
2. To gain knowledge about the constant and variable volume systems in air handling systems.
3. To gain knowledge about the Construction, Arrangement, and Selection of components of air systems.
4. To learn about the ventilation in work environment, the test methods for air filters.
5. To gain knowledge about the digital controlling methods for the ventilation using dampers, thermostats, automatic valves and the application of fuzzy logic & neural network.

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

COURSE OUTCOMES:

Upon completion of this course, the students will be able to:

1. Know the basic terms in psychrometric analysis, briefly about Air-Handling Units and duct design methods.
2. Understand the constant and variable volume systems used in heating and cooling applications
3. Fan Selection and its arrangements in air handling unit systems.
4. Understand the ventilation in work environment, the test methods for air filters and the Indoor air quality and outdoor air requirements.
5. Know about the digital controlling methods for the ventilation using dampers, thermostats, automatic valves and the application of fuzzy logic & neural network.

REFERENCES:

1. Allan T. Kirkpatrick & James S. Elleson, cold air distributionsystem design guide, ASHEAC - 1996 USA.
2. John I. Levenhagen, Donald H. Spethmann, HVAC controls and systems, McGraw – Hill international Edition. NY – 1992.
3. Shan K.Wang, Handbook of Air-conditioning and Refrigeration, McGraw -Hill, 2001.
4. SMACNA, HVAC System Duct Design, SMACNA Virginia - 1990.

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5. Walter T. Grondzik., Air-conditioning System Design Manual, Elsevier, 2007.
6. William A. Burges, Michael j. Ellen Becker, Robert D. Treitman, Ventilation for control of the work environment, A Wiley - Interscience Publication NY – 1989.
7. Ysen - Yao Sun, Air handling system design, McGraw–Hill, Inc., NY – 1994

PO & PSO Mapping:

CO	PO												PSO		
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1	0.6	0.3		0.3									0.3		
2	0.9	0.6		0.6									0.3	0.6	
3	0.9			0.3											0.6
4	0.9	0.3		0.6									0.6		
5	0.9	0.3		0.6										0.6	0.9

RA5009 COMMISSIONING OF HVAC AND REFRIGERATION SYSTEMS L T P C
3 0 0 3

COURSE OBJECTIVES:

1. To teach the various HVAC&R system components and their testing.
2. To teach balancing of HVAC&R systems for various applications.
3. To teach commissioning aspects of HVAC&R systems and its protocols
4. To teach testing and balancing of HVAC&R systems applicable to special applications
5. To teach commissioning aspects of HVAC&R systems applicable to special applications

UNIT – I HVAC & R SYSTEM COMPONENTS 9

Fans, pumps, air distribution, water distribution, motors, electrical, fluid flow, refrigeration, and instrument usage and care.

UNIT – II TESTING OF HVAC & R SYSTEMS 9

General and specific testing and its procedures for constant air volume systems, variable air volume systems, return air systems, Cooling towers and performance, fans and fan performance.

UNIT – III BALANCING OF HVAC & R SYSTEMS 9

HVAC systems, centrifugal pumps and pump performance, analog and digital controls and water balancing procedures using flow meters, system components, and temperatures.

UNIT – IV HVAC & R COMMISSIONING 9

HVAC Commissioning Cost / Benefit Analysis, Selection of Commissioning Provider, The HVAC Commissioning Team Comprehensive HVAC Commissioning, Construction HVAC Commissioning HVAC Commissioning in Existing Buildings and Commissioning of Non-HVAC Building Systems.

UNIT – V SPECIAL APPLICATIONS 9

Energy Storage– Combined power and cooling–Solar Cooling–Low grade Heat Utilization–Economics of Sorption Systems–Sorption refrigeration Systems for Climate Change Mitigation TBC of fume hood systems, clean rooms and report writing on testing, balancing and commissioning and documents for clients.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

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

1. Understand the functioning of HVAC&R systems and the components.
2. Carry out testing of systems and the components for its functioning for a particular applications

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3. Do to balancing of air side and water side components of the HVA&R systems
4. Understand the commissioning procedures for HVAC systems in buildings.
5. Analyze testing, balancing and commissioning requirements for special applications in buildings and Industries.

REFERENCES:

1. ACG Commissioning guide line, AABC Group, 2005.
2. ASHRAE Standard 202-2013, Commissioning Process for Buildings and Systems, 2013.
3. John Gladstone, David Bevirt W., Testing, Adjusting, and Balancing Field Manual, The Fairmont Press, Inc., 2000.
4. Samuel C Sugarman, Testing and Balancing of HVAC Air and Water systems, Fifth Edition, Fairmont Press, 2014.

PO & PSO Mapping:

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1		0.3		0.3						0.6			0.3		
2						0.3						0.9		0.6	
3	0.6			0.3				0.3		0.6			0.6		0.9
4			0.6				0.3								
5												0.3		0.3	

RA5010 FOOD PROCESSING PRESERVATION AND TRANSPORTATION

L	T	P	C
3	0	0	3

COURSE OBJECTIVES:

1. To introduce microbiology of food products.
2. To give an overview of thermodynamic properties of food products and different food processing techniques.
3. To explain the freezing and drying principles and estimate freezing time calculation.
4. To give an understanding of the various cold storage design
5. To introduce design features of refrigerated containers transportation

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 9

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 9

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 9

Cold storage of Agricultural products, Initial Building Consideration, Building Design , Specialized Storage Facility , Construction Methods, Refrigeration Systems , Insulation Techniques , Control and Instrumentation , Fire Protection, Inspection and Maintenance.

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UNIT – V TRANSPORTATION **9**

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

TOTAL: 45 PERIODS

COURSE OUTCOMES:

Upon completion of this course, the students will be able to:

1. Explain microbiology of food products.
2. Estimate the thermodynamic properties of food and discuss various food processing techniques.
3. Calculate freezing and thawing time of food products.
4. Design the cold storage for various types food products.
5. Discuss the design feature of different refrigeration transport.

REFERENCES:

1. ASHRAE Handbook - Refrigeration,www.ashrae.org, 2018.
2. Paul Singh R., Dennis R. Heldman., Introduction to Food Engineering, 4th Edition, Academic Press, Elsevier, 2009.
3. Peter Fellows, Food Processing Technology: Principles and Practice, Wood Head, CRC press, 2000.
4. Sivasankar. B, Food processing and preservation, PHI learning, 2005.
5. Yunus A. Cengel, "Heat Transfer A Practical Approach" – Tata McGraw Hill, Vth Edition – 2013. Topic: " Refrigeration and Freezing of Foods".

PO & PSO Mapping:

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.3												0.3	0.3	0.3
2						0.6									
3		0.6													
4			0.6												
5	0.3														

RA5011 DESIGN OF CLEAN ROOMS AND CONTAINMENT AREAS **L T P C**

3 0 0 3

COURSE OBJECTIVES:

1. To teach the concepts of clean rooms its classification and its standards.
2. To teach clean room design and the requirements of the components and filtration.
3. To teach constructional features of clean room
4. To teach high efficiency filtration techniques related to clean rooms
5. To teach estimation of its cost and efficiency of clean rooms for various applications.

UNIT – I INTRODUCTION **9**

The History of Clean rooms, Containment of Contamination, Supply of Liquid and Gases to Clean rooms, International Standards for the Design of Clean rooms, clean room Classes-Present Engineering Classes, New ISO Classification Standard, Bio contamination and Pharmaceutical Classes, Containment Classes, Other Standards for the Clean room, Abbreviations/ Source Code.

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UNIT – II CLEANROOM DESIGN 9

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 9

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 9

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

UNIT – V COST AND ENERGY EFFICIENCY 9

Air Flow Rate Optimum for Cost, Optimization of Energy Consumption in Clean room Systems, Cost Indications.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

Upon completion of this course, the students will be able to:

1. Understand the classification of clean room and the requirements of its standard for particular application.
2. Design the clean room for various process.
3. Estimate the filter selection and its requirements.
4. Anaysis and arrive at the required constructional features of clean room for an application.
5. Arrive the cost and energy efficiency level of required clean room for a given process / application.

REFERENCES:

1. engtLjungqvist and BeritReinmuller CLEAN ROOM DESIGN: Minimizing Contamination Through Proper Design , CRC; 1 edition , 1996.
2. David M. Carlberg , Clean room Microbiology for the Non-Microbiologist, Second Edition, CRC; 2edition, 2004.
3. Michael Kozicki., Cleanrooms: Facilities and Practices, Springer Science & Business Media, 2012.
4. Whyte W., Clean room Design , Second Edition , John Wiley & Sons, 1999.
5. Whyte W., Clean room Technology: Fundamentals of Design, Testing and Operation, Wiley, 2001.

PO & PSO Mapping:

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.6										0.3		0.3	0.6	0.9
2			0.3			0.3			0.9						
3	0.3			0.6			0.3					0.6		0.6	
4					0.3			0.3			0.6	0.6	0.9		
5		0.6													0.3

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RA5071 SOLAR REFRIGERATION AND AIR-CONDITIONING

L	T	P	C
3	0	0	3

COURSE OBJECTIVES:

1. To impart the knowledge on thermodynamic cycles.
2. To provide thermal aspects on solar cooling.
3. To teach the students to have a broad understanding on absorption chillers.
4. To teach the students on modeling of solar refrigeration system.
5. To learn about economics in solar cooling systems.

UNIT – I INTRODUCTION **9**

Carnot cycle – Refrigerator – Heat Pump – Heat Transformer, Refrigerants – Types and historical developments – Environmental impacts - Thermodynamic Processes.

UNIT – II SOLAR COOLING **9**

Types of solar cooling systems – Solar collectors and storage systems for solar refrigeration and air-conditioning – Jet ejector solar cooling systems - Fuel assisted solar cooling systems – Solar thermo acoustic cooling and hybrid air-conditioning - Solar desiccant cooling systems – Advanced solar cooling systems.

UNIT – III ABSORPTION COOLING **9**

Basics of absorption cooling - Principle of absorption cooling - Solar operation of vapour absorption refrigeration cycle - Open cycle absorption / desorption solar cooling alternatives – Lithium Bromide-Water absorption System – Aqua-ammonia absorption system – Intermittent absorption refrigeration System - Refrigerant storage for solar absorption cooling systems.

UNIT – IV COMPONENT DESIGN VAPOUR COMPRESSION REFRIGERATION **9**

Vapour compression refrigeration cycles - Rankine cycle - Sterling cycle based solar cooling systems - Thermal modelling for continuous and intermittent solar refrigeration and air-conditioning systems.

UNIT – V IMPLEMENTATION TECHNIQUES **9**

PV powered refrigerator – Free cooling - Solar thermoelectric refrigeration and air-conditioning – Solar economics of cooling systems - Case studies.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

Upon completion of this course, the students will be able to:

1. Analyze the performance of different refrigeration cycles.
2. Design the different types of solar collectors for a given cooling load.
3. Analyze the performance of absorption chillers.
4. Design the solar powered vapor compression refrigeration system.
5. To analyze the economics of solar based cooling system.

REFERENCES:

1. Alefeld G. and Radermacher R., Heat Conversion Systems, CRC Press, 2004.
2. ASHRAE Hand Book–HVAC Systems & Equipment, ASHRAE Inc. Atlanta, 2008.
3. McVeigh J.C. and Sayigh A.A.M. Solar Air Conditioning and Refrigeration, Pergamon Press,1992.
4. Rakosh Das Begamudre, Energy Conversion Systems, New Age International, 2007.
5. Reinhard Radermacher, S AKelin and K Herold, Absorption chillers and heat pumps, CRC Press, 1996.
6. Tom P. Hough, Solar Energy: New Research, Nova Publishers, 2006.

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PO & PSO Mapping:

CO	PO												PSO		
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	0.9		0.3				0.6						0.6		
2	0.9	0.6				0.3	0.3							0.6	
3	0.9	0.6		0.3		0.3							0.3	0.6	0.9
4	0.9	0.6		0.3									0.6		0.9
5	0.9	0.6	0.6								0.6		0.6	0.6	

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OPEN ELECTIVE COURSES (OEC)

OE5091 BUSINESS DATA ANALYTICS L T P C
3 0 0 3

COURSE OBJECTIVES:

- To understand the basics of business analytics and its life cycle.
- To gain knowledge about fundamental business analytics.
- To learn modeling for uncertainty and statistical inference.
- To understand analytics using Hadoop and Map Reduce frameworks.
- To acquire insight on other analytical frameworks.

UNIT I OVERVIEW OF BUSINESS ANALYTICS 9

Introduction – Drivers for Business Analytics – Applications of Business Analytics: Marketing and Sales, Human Resource, Healthcare, Product Design, Service Design, Customer Service and Support – Skills Required for a Business Analyst – Framework for Business Analytics Life Cycle for Business Analytics Process.

Suggested Activities:

- Case studies on applications involving business analytics.
- Converting real time decision making problems into hypothesis.
- Group discussion on entrepreneurial opportunities in Business Analytics.

Suggested Evaluation Methods:

- Assignment on business scenario and business analytical life cycle process.
- Group presentation on big data applications with societal need.
- Quiz on case studies.

UNIT II ESSENTIALS OF BUSINESS ANALYTICS 9

Descriptive Statistics – Using Data – Types of Data – Data Distribution Metrics: Frequency, Mean, Median, Mode, Range, Variance, Standard Deviation, Percentile, Quartile, z-Score, Covariance, Correlation – Data Visualization: Tables, Charts, Line Charts, Bar and Column Chart, Bubble Chart, Heat Map – Data Dashboards.

Suggested Activities:

- Solve numerical problems on basic statistics.
- Explore chart wizard in MS Excel Case using sample real time data for data visualization.
- Use R tool for data visualization.

Suggested Evaluation Methods:

- Assignment on descriptive analytics using benchmark data.
- Quiz on data visualization for univariate, bivariate data.

UNIT III MODELING UNCERTAINTY AND STATISTICAL INFERENCE 9

Modeling Uncertainty: Events and Probabilities – Conditional Probability – Random Variables – Discrete Probability Distributions – Continuous Probability Distribution – Statistical Inference: Data Sampling – Selecting a Sample – Point Estimation – Sampling Distributions – Interval Estimation – Hypothesis Testing.

Suggested Activities:

- Solving numerical problems in sampling, probability, probability distributions and hypothesis testing.
- Converting real time decision making problems into hypothesis.

Suggested Evaluation Methods:

- Assignments on hypothesis testing.
- Group presentation on real time applications involving data sampling and hypothesis testing.
- Quizzes on topics like sampling and probability.

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UNIT IV ANALYTICS USING HADOOP AND MAPREDUCE FRAMEWORK 9

Introducing Hadoop – RDBMS versus Hadoop – Hadoop Overview – HDFS (Hadoop Distributed File System) – Processing Data with Hadoop – Introduction to MapReduce – Features of MapReduce – Algorithms Using Map-Reduce: Matrix-Vector Multiplication, Relational Algebra Operations, Grouping and Aggregation – Extensions to MapReduce.

Suggested Activities:

- Practical – Install and configure Hadoop.
- Practical – Use web based tools to monitor Hadoop setup.
- Practical – Design and develop MapReduce tasks for word count, searching involving text corpus etc.

Suggested Evaluation Methods:

- Evaluation of the practical implementations.
- Quizzes on topics like HDFS and extensions to MapReduce.

UNIT V OTHER DATA ANALYTICAL FRAMEWORKS 9

Overview of Application development Languages for Hadoop – PigLatin – Hive – Hive Query Language (HQL) – Introduction to Pentaho, JAQL – Introduction to Apache: Sqoop, Drill and Spark, Cloudera Impala – Introduction to NoSQL Databases – Hbase and MongoDB.

Suggested Activities:

- Practical – Installation of NoSQL database like MongoDB.
- Practical – Demonstration on Sharding in MongoDB.
- Practical – Install and run Pig
- Practical – Write PigLatin scripts to sort, group, join, project, and filter data.
- Design and develop algorithms to be executed in MapReduce involving numerical methods for analytics.

Suggested Evaluation Methods:

- Mini Project (Group) – Real time data collection, saving in NoSQL, implement analytical techniques using Map-Reduce Tasks and Result Projection.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

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

- Identify the real world business problems and model with analytical solutions.
- Solve analytical problem with relevant mathematics background knowledge.
- Convert any real world decision making problem to hypothesis and apply suitable statistical testing.
- Write and Demonstrate simple applications involving analytics using Hadoop and MapReduce
- Use open source frameworks for modeling and storing data.
- Apply suitable visualization technique using R for visualizing voluminous data.

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1. Vignesh Prajapati, “Big Data Analytics with R and Hadoop”, Packt Publishing, 2013.
2. Umesh R Hodeghatta, Umesha Nayak, “Business Analytics Using R – A Practical Approach”, Apress, 2017.
3. Anand Rajaraman, Jeffrey David Ullman, “Mining of Massive Datasets”, Cambridge University Press, 2012.
4. Jeffrey D. Camm, James J. Cochran, Michael J. Fry, Jeffrey W. Ohlmann, David R. Anderson, “Essentials of Business Analytics”, Cengage Learning, second Edition, 2016.
5. U. Dinesh Kumar, “Business Analytics: The Science of Data-Driven Decision Making”, Wiley, 2017.
6. A. Ohri, “R for Business Analytics”, Springer, 2012
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OE5092 **INDUSTRIAL SAFETY** **L T P C**
3 0 0 3

OBJECTIVES:

- Summarize basics of industrial safety
- Describe fundamentals of maintenance engineering
- Explain wear and corrosion
- Illustrate fault tracing
- Identify preventive and periodic maintenance

UNIT I INTRODUCTION **9**

Accident, causes, types, results and control, mechanical and electrical hazards, types, causes and preventive steps/procedure, describe salient points of factories act 1948 for health and safety, wash rooms, drinking water layouts, light, cleanliness, fire, guarding, pressure vessels, etc, Safety color codes. Fire prevention and firefighting, equipment and methods.

UNIT II FUNDAMENTALS OF MAINTENANCE ENGINEERING **9**

Definition and aim of maintenance engineering, Primary and secondary functions and responsibility of maintenance department, Types of maintenance, Types and applications of tools used for maintenance, Maintenance cost & its relation with replacement economy, Service life of equipment.

UNIT III WEAR AND CORROSION AND THEIR PREVENTION **9**

Wear- types, causes, effects, wear reduction methods, lubricants-types and applications, Lubrication methods, general sketch, working and applications, i. Screw down grease cup, ii. Pressure grease gun, iii. Splash lubrication, iv. Gravity lubrication, v. Wick feed lubrication vi. Side feed lubrication, vii. Ring lubrication, Definition, principle and factors affecting the corrosion. Types of corrosion, corrosion prevention methods.

UNIT IV FAULT TRACING **9**

Fault tracing-concept and importance, decision tree concept, need and applications, sequence of fault finding activities, show as decision tree, draw decision tree for problems in machine tools, hydraulic, pneumatic, automotive, thermal and electrical equipment's like, I. Any one machine tool, ii. Pump iii. Air compressor, iv. Internal combustion engine, v. Boiler, vi. Electrical motors, Types of faults in machine tools and their general causes.

UNIT V PERIODIC AND PREVENTIVE MAINTENANCE **9**

Periodic inspection-concept and need, degreasing, cleaning and repairing schemes, overhauling of mechanical components, overhauling of electrical motor, common troubles and remedies of electric motor, repair complexities and its use, definition, need, steps and advantages of preventive maintenance. Steps/procedure for periodic and preventive maintenance of: I. Machine tools, ii. Pumps, iii. Air compressors, iv. Diesel generating (DG) sets, Program and schedule of preventive maintenance of mechanical and electrical equipment, advantages of preventive maintenance. Repair cycle concept and importance

TOTAL: 45 PERIODS

OUTCOMES:

CO1: Ability to summarize basics of industrial safety
CO2: Ability to describe fundamentals of maintenance engineering
CO3: Ability to explain wear and corrosion
CO4: Ability to illustrate fault tracing
CO5: Ability to identify preventive and periodic maintenance

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓											
CO2	✓											
CO3	✓	✓	✓									
CO4	✓	✓	✓									
CO5	✓	✓	✓									

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REFERENCES:

1. Audels, Pump-hydraulic Compressors, Mcgrew Hill Publication, 1978.
2. Garg H P,Maintenance Engineering, S. Chand and Company,1987.
3. Hans F. Winterkorn ,Foundation Engineering Handbook, Chapman & Hall London,2013.
4. Higgins & Morrow , Maintenance Engineering Handbook, Eighth Edition,2008

OE5093 OPERATIONS RESEARCH LT P C
3 0 0 3

OBJECTIVES:

- Solve linear programming problem and solve using graphical method.
- Solve LPP using simplex method
- Solve transportation , assignment problems
- Solve project management problems
- Solve scheduling problems

UNIT I LINEAR PROGRAMMING 9

Introduction to Operations Research – assumptions of linear programming problems - Formulations of linear programming problem – Graphical method

UNIT II ADVANCES IN LINEAR PROGRAMMING 9

Solutions to LPP using simplex algorithm- Revised simplex method - primal dual relationships – Dual simplex algorithm - Sensitivity analysis

UNIT III NETWORK ANALYSIS – I 9

Transportation problems -Northwest corner rule, least cost method, Voges's approximation method - Assignment problem -Hungarian algorithm

UNIT IV NETWORK ANALYSIS – II 9

Shortest path problem: Dijkstra's algorithms, Floyds algorithm, systematic method -CPM/PERT

UNIT V NETWORK ANALYSIS – III 9

Scheduling and sequencing - single server and multiple server models - deterministic inventory models - Probabilistic inventory control models

TOTAL: 45 PERIODS

OUTCOMES:

CO1: To formulate linear programming problem and solve using graphical method.
CO2: To solve LPP using simplex method
CO3: To formulate and solve transportation, assignment problems
CO4: To solve project management problems
CO5: To solve scheduling problems

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓											
CO2	✓											
CO3	✓	✓	✓									
CO4	✓	✓	✓									
CO5	✓	✓	✓									

REFERENCES:

1. Harvey M Wagner, Principles of Operations Research: Prentice Hall of India 2010
2. Hitler Libermann, Operations Research: McGraw Hill Pub. 2009
3. Pant J C, Introduction to Optimisation: Operations Research, Jain Brothers, Delhi, 2008
4. Pannerselvam, Operations Research: Prentice Hall of India 2010
5. Taha H A, Operations Research, An Introduction, PHI, 2008

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OE5094 COST MANAGEMENT OF ENGINEERING PROJECTS L T P C
3 0 0 3

OBJECTIVES:

- Summarize the costing concepts and their role in decision making
- Infer the project management concepts and their various aspects in selection
- Interpret costing concepts with project execution
- Develop knowledge of costing techniques in service sector and various budgetary control techniques
- Illustrate with quantitative techniques in cost management

UNIT I INTRODUCTION TO COSTING CONCEPTS 9

Objectives of a Costing System; Cost concepts in decision-making; Relevant cost, Differential cost, Incremental cost and Opportunity cost; Creation of a Database for operational control.

UNIT II INTRODUCTION TO PROJECT MANAGEMENT 9

Project: meaning, Different types, why to manage, cost overruns centres, various stages of project execution: conception to commissioning. Project execution as conglomeration of technical and nontechnical activities, Detailed Engineering activities, Pre project execution main clearances and documents, Project team: Role of each member,Importance Project site: Data required with significance, Project contracts.

UNIT III PROJECT EXECUTION AND COSTING CONCEPTS 9

Project execution Project cost control, Bar charts and Network diagram, Project commissioning: mechanical and process, Cost Behavior and Profit Planning Marginal Costing; Distinction between Marginal Costing and Absorption Costing; Break-even Analysis, Cost-Volume-Profit Analysis, Various decision-making problems, Pricing strategies: Pareto Analysis, Target costing, Life Cycle Costing.

UNIT IV COSTING OF SERVICE SECTOR AND BUDGETERY CONTROL 9

Just-in-time approach, Material Requirement Planning, Enterprise Resource Planning, Activity-Based Cost Management, Bench Marking; Balanced Score Card and Value-Chain Analysis, Budgetary Control: Flexible Budgets; Performance budgets; Zero-based budgets.

UNIT V QUANTITATIVE TECHNIQUES FOR COST MANAGEMENT 9

Linear Programming, PERT/CPM, Transportation problems, Assignment problems, Learning Curve Theory.

TOTAL: 45 PERIODS

OUTCOMES

CO1 – Understand the costing concepts and their role in decision making
CO2–Understand the project management concepts and their various aspects in selection
CO3–Interpret costing concepts with project execution
CO4–Gain knowledge of costing techniques in service sector and various budgetary control techniques
CO5 - Become familiar with quantitative techniques in cost management

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓	✓	✓		✓			✓	✓		✓	✓
CO2	✓	✓	✓		✓				✓		✓	✓
CO3	✓	✓	✓		✓	✓					✓	✓
CO4	✓	✓	✓		✓		✓				✓	✓
CO5	✓	✓	✓		✓	✓	✓				✓	✓

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REFERENCES:

1. Ashish K. Bhattacharya, Principles & Practices of Cost Accounting A. H. Wheeler publisher, 1991
2. Charles T. Horngren and George Foster, Advanced Management Accounting, 1988
3. Charles T. Horngren et al Cost Accounting A Managerial Emphasis, Prentice Hall of India, New Delhi, 2011
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5. Vohra N.D., Quantitative Techniques in Management, Tata McGraw Hill Book Co. Ltd, 2007

OE5095 COMPOSITE MATERIALS L T P C
3 0 0 3

OBJECTIVES:

- Summarize the characteristics of composite materials and effect of reinforcement in composite materials.
- Identify the various reinforcements used in composite materials.
- Compare the manufacturing process of metal matrix composites.
- Understand the manufacturing processes of polymer matrix composites.
- Analyze the strength of composite materials.

UNIT I INTRODUCTION 9

Definition – Classification and characteristics of Composite materials - Advantages and application of composites - Functional requirements of reinforcement and matrix - Effect of reinforcement (size, shape, distribution, volume fraction) on overall composite performance.

UNIT II REINFORCEMENTS 9

Preparation-layup, curing, properties and applications of glass fibers, carbon fibers, Kevlar fibers and Boron fibers - Properties and applications of whiskers, particle reinforcements - Mechanical Behavior of composites: Rule of mixtures, Inverse rule of mixtures - Isostrain and Isostress conditions.

UNIT III MANUFACTURING OF METAL MATRIX COMPOSITES 9

Casting – Solid State diffusion technique - Cladding – Hot isostatic pressing - Properties and applications. Manufacturing of Ceramic Matrix Composites: Liquid Metal Infiltration – Liquid phase sintering. Manufacturing of Carbon – Carbon composites: Knitting, Braiding, Weaving - Properties and applications.

UNIT IV MANUFACTURING OF POLYMER MATRIX COMPOSITES 9

Preparation of Moulding compounds and prepregs – hand layup method – Autoclave method – Filament winding method – Compression moulding – Reaction injection moulding - Properties and applications.

UNIT V STRENGTH 9

Laminar Failure Criteria-strength ratio, maximum stress criteria, maximum strain criteria, interacting failure criteria, hygrothermal failure. Laminate first play failure-insight strength; Laminate strength-ply discount truncated maximum strain criterion; strength design using caplet plots; stress concentrations.

TOTAL: 45 PERIODS

OUTCOMES:

- CO1 - Know the characteristics of composite materials and effect of reinforcement in composite materials.
- CO2 – Know the various reinforcements used in composite materials.
- CO3 – Understand the manufacturing processes of metal matrix composites.
- CO4 – Understand the manufacturing processes of polymer matrix composites.
- CO5 – Analyze the strength of composite materials.

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	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1		✓	✓	✓								
CO2		✓	✓	✓	✓						✓	
CO3			✓	✓	✓		✓				✓	
CO4			✓	✓	✓		✓				✓	
CO5				✓	✓		✓					

REFERENCES:

1. Cahn R.W. - Material Science and Technology – Vol 13 – Composites, VCH, West Germany.
2. Callister, W.D Jr., Adapted by Balasubramaniam R, Materials Science and Engineering, An introduction, John Wiley & Sons, NY, Indian edition, 2007.
3. Chawla K.K., Composite Materials, 2013.
4. Lubin.G, Hand Book of Composite Materials, 2013.

OE5096 **WASTE TO ENERGY** **L T P C**
3 0 0 3

OBJECTIVES:

- Interpret the various types of wastes from which energy can be generated
- Develop knowledge on biomass pyrolysis process and its applications
- Develop knowledge on various types of biomass gasifiers and their operations
- Invent knowledge on biomass combustors and its applications on generating energy
- Summarize the principles of bio-energy systems and their features

UNITI INTRODUCTION TO EXTRACTION OF ENERGY FROM WASTE 9

Classification of waste as fuel – Agro based, Forest residue, Industrial waste - MSW – Conversion devices – Incinerators, gasifiers, digestors

UNITII BIOMASS PYROLYSIS 9

Pyrolysis – Types, slow fast – Manufacture of charcoal – Methods - Yields and application – Manufacture of pyrolytic oils and gases, yields and applications.

UNIT III BIOMASS GASIFICATION 9

Gasifiers – Fixed bed system – Downdraft and updraft gasifiers – Fluidized bed gasifiers – Design, construction and operation – Gasifier burner arrangement for thermal heating – Gasifier engine arrangement and electrical power – Equilibrium and kinetic consideration in gasifier operation.

UNIT IV BIOMASS COMBUSTION 9

Biomass stoves – Improved chullahs, types, some exotic designs, Fixed bed combustors, Types, inclined grate combustors, Fluidized bed combustors, Design, construction and operation - Operation of all the above biomass combustors.

UNITV BIO ENERGY 9

Properties of biogas (Calorific value and composition), Biogas plant technology and status - Bio energy system - Design and constructional features - Biomass resources and their classification - Biomass conversion processes - Thermo chemical conversion - Direct combustion - biomass gasification - pyrolysis and liquefaction - biochemical conversion - anaerobic digestion - Types of biogas Plants – Applications - Alcohol production from biomass - Bio diesel production -Urban waste to energy conversion - Biomass energy programme in India.

TOTAL: 45 PERIODS

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OUTCOMES:

CO1 – Understand the various types of wastes from which energy can be generated
CO2 – Gain knowledge on biomass pyrolysis process and its applications
CO3 – Develop knowledge on various types of biomass gasifiers and their operations
CO4 – Gain knowledge on biomass combustors and its applications on generating energy
CO5 – Understand the principles of bio-energy systems and their features

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓		✓									✓
CO2	✓		✓									✓
CO3	✓	✓	✓		✓							✓
CO4	✓	✓	✓		✓		✓					✓
CO5	✓	✓	✓		✓							✓

REFERENCES:

1. Biogas Technology - A Practical Hand Book - Khandelwal, K. C. and Mahdi, S. S., Vol. I & II, Tata McGraw Hill Publishing Co. Ltd., 1983.
2. Biomass Conversion and Technology, C. Y. WereKo-Brobby and E. B. Hagan, John Wiley & Sons, 1996.
3. Food, Feed and Fuel from Biomass, Challal, D. S., IBH Publishing Co. Pvt. Ltd., 1991.
4. Non Conventional Energy, Desai, Ashok V., Wiley Eastern Ltd., 1990.

PROGRESS THROUGH KNOWLEDGE

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AUDIT COURSES (AC)

AX5091 ENGLISH FOR RESEARCH PAPER WRITING L T P C
2 0 0 0

OBJECTIVES

- Teach how to improve writing skills and level of readability
- Tell about what to write in each section
- Summarize the skills needed when writing a Title
- Infer the skills needed when writing the Conclusion
- Ensure the quality of paper at very first-time submission

UNIT I INTRODUCTION TO RESEARCH PAPER WRITING 6

Planning and Preparation, Word Order, Breaking up long sentences, Structuring Paragraphs and Sentences, Being Concise and Removing Redundancy, Avoiding Ambiguity and Vagueness

UNIT II PRESENTATION SKILLS 6

Clarifying Who Did What, Highlighting Your Findings, Hedging and Criticizing, Paraphrasing and Plagiarism, Sections of a Paper, Abstracts, Introduction

UNIT III TITLE WRITING SKILLS 6

Key skills are needed when writing a Title, key skills are needed when writing an Abstract, key skills are needed when writing an Introduction, skills needed when writing a Review of the Literature, Methods, Results, Discussion, Conclusions, The Final Check

UNIT IV RESULT WRITING SKILLS 6

Skills are needed when writing the Methods, skills needed when writing the Results, skills are needed when writing the Discussion, skills are needed when writing the Conclusions

UNIT V VERIFICATION SKILLS 6

Useful phrases, checking Plagiarism, how to ensure paper is as good as it could possibly be the first- time submission

TOTAL: 30 PERIODS

OUTCOMES

CO1 –Understand that how to improve your writing skills and level of readability
CO2 – Learn about what to write in each section
CO3 – Understand the skills needed when writing a Title
CO4 – Understand the skills needed when writing the Conclusion
CO5 – Ensure the good quality of paper at very first-time submission

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1										✓		✓
CO2										✓		✓
CO3										✓		✓
CO4										✓		✓
CO5										✓		✓

REFERENCES

1. Adrian Wallwork , English for Writing Research Papers, Springer New York Dordrecht Heidelberg London, 2011
2. Day R How to Write and Publish a Scientific Paper, Cambridge University Press 2006
3. Goldbort R Writing for Science, Yale University Press (available on Google Books) 2006
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AX5092 **DISASTER MANAGEMENT** **L T P C**
2 0 0 0

OBJECTIVES

- Summarize basics of disaster
- Explain a critical understanding of key concepts in disaster risk reduction and humanitarian response.
- Illustrate disaster risk reduction and humanitarian response policy and practice from multiple perspectives.
- Describe an understanding of standards of humanitarian response and practical relevance in specific types of disasters and conflict situations.
- Develop the strengths and weaknesses of disaster management approaches

UNIT I INTRODUCTION **6**

Disaster: Definition, Factors and Significance; Difference between Hazard And Disaster; Natural and Manmade Disasters: Difference, Nature, Types and Magnitude.

UNIT II REPERCUSSIONS OF DISASTERS AND HAZARDS **6**

Economic Damage, Loss of Human and Animal Life, Destruction Of Ecosystem. Natural Disasters: Earthquakes, Volcanisms, Cyclones, Tsunamis, Floods, Droughts And Famines, Landslides And Avalanches, Man-made disaster: Nuclear Reactor Meltdown, Industrial Accidents, Oil Slicks And Spills, Outbreaks Of Disease And Epidemics, War And Conflicts.

UNIT III DISASTER PRONE AREAS IN INDIA **6**

Study of Seismic Zones; Areas Prone To Floods and Droughts, Landslides And Avalanches; Areas Prone To Cyclonic and Coastal Hazards with Special Reference To Tsunami; Post-Disaster Diseases and Epidemics

UNIT IV DISASTER PREPAREDNESS AND MANAGEMENT **6**

Preparedness: Monitoring Of Phenomena Triggering a Disaster or Hazard; Evaluation of Risk: Application of Remote Sensing, Data from Meteorological And Other Agencies, Media Reports: Governmental and Community Preparedness.

UNIT V RISK ASSESSMENT **6**

Disaster Risk: Concept and Elements, Disaster Risk Reduction, Global and National Disaster Risk Situation. Techniques of Risk Assessment, Global Co-Operation in Risk Assessment and Warning, People's Participation in Risk Assessment. Strategies for Survival

TOTAL : 30 PERIODS

OUTCOMES

CO1: Ability to summarize basics of disaster
CO2: Ability to explain a critical understanding of key concepts in disaster risk reduction and humanitarian response.
CO3: Ability to illustrate disaster risk reduction and humanitarian response policy and practice from multiple perspectives.
CO4: Ability to describe an understanding of standards of humanitarian response and practical relevance in specific types of disasters and conflict situations.
CO5: Ability to develop the strengths and weaknesses of disaster management approaches

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	✓											
CO2	✓											
CO3	✓	✓	✓									
CO4	✓	✓	✓									
CO5	✓	✓	✓									

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AX5093 SANSKRIT FOR TECHNICAL KNOWLEDGE L T P C
2 0 0 0

OBJECTIVES

- Illustrate the basic sanskrit language.
- Recognize sanskrit, the scientific language in the world.
- Appraise learning of sanskrit to improve brain functioning.
- Relate sanskrit to develop the logic in mathematics, science & other subjects enhancing the memory power.
- Extract huge knowledge from ancient literature.

UNIT I ALPHABETS **6**

Alphabets in Sanskrit

UNIT II TENSES AND SENTENCES **6**

Past/Present/Future Tense - Simple Sentences

UNIT III ORDER AND ROOTS **6**

Order - Introduction of roots

UNIT IV SANSKRIT LITERATURE **6**

Technical information about Sanskrit Literature

UNIT V TECHNICAL CONCEPTS OF ENGINEERING **6**

Technical concepts of Engineering-Electrical, Mechanical, Architecture, Mathematics

TOTAL: 30 PERIODS

OUTCOMES

- CO1 - Understanding basic Sanskrit language.
- CO2 - Write sentences.
- CO3 - Know the order and roots of Sanskrit.
- CO4 - Know about technical information about Sanskrit literature.
- CO5 - Understand the technical concepts of Engineering.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1										✓		✓
CO2										✓		✓
CO3												✓
CO4												✓
CO5												✓

REFERENCES

1. "Abhyaspustakam" – Dr. Vishwas, Samskrita-Bharti Publication, New Delhi
2. "Teach Yourself Sanskrit" Prathama Deeksha-Vempati Kutumbshastri, Rashtriya Sanskrit Sansthanam, New Delhi Publication
3. "India's Glorious Scientific Tradition" Suresh Soni, Ocean books (P) Ltd., New Delhi, 2017.

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AX5094 **VALUE EDUCATION** **L T P C**
2 0 0 0

OBJECTIVES

Students will be able to

- Understand value of education and self-development
- Imbibe good values in students
- Let the should know about the importance of character

UNIT I

Values and self-development–Social values and individual attitudes. Work ethics, Indian vision of humanism. Moral and non-moral valuation. Standards and principles. Value judgements

UNIT II

Importance of cultivation of values. Sense of duty. Devotion, Self-reliance. Confidence, Concentration. Truthfulness, Cleanliness. Honesty, Humanity. Power of faith, National Unity. Patriotism. Love for nature, Discipline

UNIT III

Personality and Behavior Development-Soul and Scientific attitude. Positive Thinking. Integrity and discipline. Punctuality, Love and Kindness. Avoid fault Thinking. Free from anger, Dignity of labour.

Universal brother hood and religious tolerance. True friendship. Happiness Vs suffering, love for truth. Aware of self-destructive habits. Association and Cooperation. Doing best for saving nature

UNIT IV

Character and Competence–Holy books vs Blind faith. Self-management and Good health. Science of reincarnation. Equality, Nonviolence, Humility, Role of Women. All religions and same message. Mind your Mind, Self-control. Honesty, Studying effectively.

TOTAL: 30 PERIODS

OUTCOMES

Students will be able to

- Knowledge of self-development.
- Learn the importance of Human values.
- Developing the overall personality.

SUGGESTED READING

1. Chakroborty, S.K."Values and Ethics for organizations Theory and practice", Oxford University Press, New Delhi

PROGRESS THROUGH KNOWLEDGE

AX5095 **CONSTITUTION OF INDIA** **L T P C**
2 0 0 0

OBJECTIVES

Students will be able to:

- Understand the premises informing the twin themes of liberty and freedom from a civil rights perspective.
- To address the growth of Indian opinion regarding modern Indian intellectuals' constitutional
- Role and entitlement to civil and economic rights as well as the emergence nation hood in the early years of Indian nationalism.
- To address the role of socialism in India after the commencement of the Bolshevik Revolutionin1917and its impact on the initial drafting of the Indian Constitution.

UNIT I HISTORY OF MAKING OF THE INDIAN CONSTITUTION:

History, Drafting Committee, (Composition & Working)

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UNIT II PHILOSOPHY OF THE INDIAN CONSTITUTION:
Preamble, Salient Features

UNIT III CONTOURS OF CONSTITUTIONAL RIGHTS AND DUTIES:
Fundamental Rights, Right to Equality, Right to Freedom, Right against Exploitation, Right to Freedom of Religion, Cultural and Educational Rights, Right to Constitutional Remedies, Directive Principles of State Policy, Fundamental Duties.

UNIT IV ORGANS OF GOVERNANCE:
Parliament, Composition, Qualifications and Disqualifications, Powers and Functions, Executive, President, Governor, Council of Ministers, Judiciary, Appointment and Transfer of Judges, Qualifications, Powers and Functions.

UNIT V LOCAL ADMINISTRATION:
District's Administration head: Role and Importance, Municipalities: Introduction, Mayor and role of Elected Representative, CEO, Municipal Corporation. Pachayati raj: Introduction, PRI: Zila Pachayat. Elected officials and their roles, CEO Zila Pachayat: Position and role. Block level: Organizational Hierarchy(Different departments), Village level:Role of Elected and Appointed officials, Importance of grass root democracy.

UNIT VI ELECTION COMMISSION:
Election Commission: Role and Functioning. Chief Election Commissioner and Election Commissioners - Institute and Bodies for the welfare of SC/ST/OBC and women.

TOTAL: 30 PERIODS

OUTCOMES
Students will be able to:
- Discuss the growth of the demand for civil rights in India for the bulk of Indians before the arrival of Gandhi in Indian politics.
- Discuss the intellectual origins of the framework of argument that informed the conceptualization
- of social reforms leading to revolution in India.
- Discuss the circumstances surrounding the foundation of the Congress Socialist Party[CSP] under the leadership of Jawaharlal Nehru and the eventual failure of the proposal of direct elections through adult suffrage in the Indian Constitution.
- Discuss the passage of the Hindu Code Bill of 1956.

SUGGESTED READING

1. The Constitution of India,1950(Bare Act),Government Publication.
2. Dr.S.N.Busi, Dr.B. R.Ambedkar framing of Indian Constitution,1st Edition, 2015.
3. M.P. Jain, Indian Constitution Law, 7th Edn., Lexis Nexis,2014.
4. D.D. Basu, Introduction to the Constitution of India, Lexis Nexis, 2015.

AX5096 PEDAGOGY STUDIES L T P C
2 0 0 0

OBJECTIVES
Students will be able to:
- Review existing evidence on there view topic to inform programme design and policy
- Making under taken by the DfID, other agencies and researchers.
- Identify critical evidence gaps to guide the development.

UNIT I INTRODUCTION AND METHODOLOGY:
Aims and rationale, Policy background, Conceptual framework and terminology - Theories of learning, Curriculum, Teacher education - Conceptual framework, Research questions - Overview of methodology and Searching.

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UNIT II THEMATIC OVERVIEW

Pedagogical practices are being used by teachers in formal and informal classrooms in developing countries - Curriculum, Teacher education.

UNIT III EVIDENCE ON THE EFFECTIVENESS OF PEDAGOGICAL PRACTICES

Methodology for the in depth stage: quality assessment of included studies - How can teacher education (curriculum and practicum) and the school curriculum and guidance materials best support effective pedagogy? - Theory of change - Strength and nature of the body of evidence for effective pedagogical practices - Pedagogic theory and pedagogical approaches - Teachers' attitudes and beliefs and Pedagogic strategies.

UNIT IV PROFESSIONAL DEVELOPMENT

Professional development: alignment with classroom practices and follow up support - Peer support - Support from the head teacher and the community - Curriculum and assessment - Barriers to learning: limited resources and large class sizes

UNIT V RESEARCH GAPS AND FUTURE DIRECTIONS

Research design – Contexts – Pedagogy - Teacher education - Curriculum and assessment - Dissemination and research impact.

TOTAL: 30 PERIODS

OUTCOMES

Students will be able to understand:

- What pedagogical practices are being used by teachers informal and informal classrooms in developing countries?
- What is the evidence on the effectiveness of these pedagogical practices, in what conditions, and with what population of learners?
- How can teacher education (curriculum and practicum) and the school curriculum and guidance materials best support effective pedagogy?

SUGGESTED READING

1. Ackers J, HardmanF (2001) Classroom interaction in Kenyan primary schools, Compare, 31(2): 245-261.
2. Agrawal M (2004)Curricular reform in schools: The importance of evaluation, Journal of Curriculum Studies, 36(3):361-379.
3. Akyeampong K (2003) Teacher training in Ghana-does it count? Multi-site teacher education research project (MUSTER) country report 1.London:DFID.
4. Akyeampong K, Lussier K, Pryor J, Westbrook J (2013) Improving teaching and learning of basic maths and reading in Africa: Does teacher preparation count? International Journal Educational Development, 33(3): 272–282.
5. Alexander RJ(2001) Culture and pedagogy: International comparisons in primary education. Oxford and Boston: Blackwell.
6. Chavan M(2003) Read India: Amass scale, rapid, 'learning to read' campaign.
7. www.pratham.org/images/resource%20working%20paper%202.pdf

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AX5097 **STRESS MANAGEMENT BY YOGA** **L T P C**
2 0 0 0

OBJECTIVES

- To achieve overall health of body and mind
- To overcome stress

UNIT I

Definitions of Eight parts of yoga.(Ashtanga)

UNIT II

Yam and Niyam - Do`s and Don't's in life - i) Ahinsa, satya, astheya, bramhacharya and aparigraha, ii) Ahinsa, satya, astheya, bramhacharya and aparigraha.

UNIT III

Asan and Pranayam - Various yog poses and their benefits for mind & body - Regularization of breathing techniques and its effects-Types of pranayam

TOTAL: 30 PERIODS

OUTCOMES

Students will be able to:

- Develop healthy mind in a healthy body thus improving social health also
- Improve efficiency

SUGGESTED READING

1. 'Yogic Asanas for Group Tarining-Part-I":Janardan Swami Yoga bhyasi Mandal, Nagpur
2. "Rajayoga or conquering the Internal Nature" by Swami Vivekananda, Advaita Ashrama (Publication Department), Kolkata

AX5098 **PERSONALITY DEVELOPMENT THROUGH LIFE ENLIGHTENMENT SKILLS** **L T P C**
2 0 0 0

OBJECTIVES

- To learn to achieve the highest goal happily
- To become a person with stable mind, pleasing personality and determination
- To awaken wisdom in students

UNIT I

Neetisatakam-holistic development of personality - Verses- 19,20,21,22 (wisdom) - Verses- 29, 31, 32 (pride & heroism) – Verses- 26,28,63,65 (virtue) - Verses- 52, 53, 59 (dont's) - Verses- 71,73,75,78 (do's)

UNIT II

Approach to day to day work and duties - Shrimad Bhagwad Geeta: Chapter 2-Verses 41, 47,48 - Chapter 3-Verses 13, 21, 27, 35 Chapter 6-Verses 5,13,17,23, 35 - Chapter 18-Verses 45, 46, 48.

UNIT III

Statements of basic knowledge - Shrimad Bhagwad Geeta: Chapter2-Verses 56, 62, 68 Chapter 12 -Verses 13, 14, 15, 16,17, 18 - Personality of role model - shrimad bhagwad geeta - Chapter2-Verses 17, Chapter 3-Verses 36,37,42 - Chapter 4-Verses 18, 38,39 Chapter18 – Verses 37,38,63

TOTAL: 30 PERIODS

OUTCOMES

Students will be able to

- Study of Shrimad-Bhagwad-Geeta will help the student in developing his personality and achieve the highest goal in life
- The person who has studied Geeta will lead the nation and mankind to peace and prosperity
- Study of Neet is hatakam will help in developing versatile personality of students.

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SUGGESTED READING

1. Gopinath, Rashtriya Sanskrit Sansthanam P, Bhartrihari's Three Satakam, Niti-sringar-vairagya, New Delhi,2010
2. Swami Swarupananda , Srimad Bhagavad Gita, Advaita Ashram, Publication Department, Kolkata, 2016.

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