AFFILIATED INSTITUTIONS

ANNA UNIVERSITY, CHENNAI

REGULATIONS - 2009

M.E. CRYOGENIC ENGINEERING

II TO IV SEMESTERS (FULL TIME) CURRICULUM AND SYLLABUS

SEMESTER II

S.NO	SUB CODE	TITLE	L	T	P	C
1	CY9321	Cryogenic Systems	3	1	0	4
2	CY9322	Cryogenic Plants And Equipments	3	0	0	3
3	CY9323	Advanced Air Conditioning	3	1	0	4
4	CY9324	Computational Fluid Dynamics	3	0	0	3
5	CY9325	Cryogenic Applications	3	0	0	3
6	E2	Elective II	3	0	0	3
PRACTICALS						
7	CY9327	Cryogenic Systems Laboratory	0	0	3	2
		TOTAL CREDITS	18	2	3	22

SEMESTER III

S.NO	SUB CODE	TITLE	L	T	P	C
1	E3	Elective III	3	0	0	3
2	E4	Elective IV	3	0	0	3
3	E5	Elective V	3	0	0	3
PRACTICALS						
4	CY9334	Project Work (Phase I)	0	0	12	6
		TOTAL CREDITS	9	0	12	15

SEMESTER IV

S.NO	SUB CODE	TITLE	L	T	P	C
1	CY9341	Project Work (Phase II)	0	0	24	12
		TOTAL CREDITS	0	0	24	12

LIST OF ELECTIVES

1	CY9001	Cryogenic Heat Exchangers	3	0	0	3
2	CY9002	Materials For Low Temperature Applications	3	0	0	3
3	CY9003	Advanced Fluid Mechanics	3	0	0	3
4	CY9004	Super Conductivity & Low Temperature Physics	3	0	0	3
5	CY9005	Advanced Cryo Coolers	3	0	0	3
6	CY9006	Productivity Management And Re-Engineering	3	0	0	3
7	CY9007	Industrial Refrigeration Systems	3	0	0	3
8	CY9008	Gas Turbines And Jet Propulsion	3	0	0	3
9	CY9009	Cryo Physics	3	0	0	3
10	CY9010	Radiant Heating And Cooling Systems	3	0	0	3
11	CY9011	Low Temperature Measurement & Instrumentation	3	0	0	3
12	CY9012	Advanced Cryogenics & Applied Super Conductivity	3	0	0	3
13	CY9013	Systems And Simulation	3	0	0	3
14	CY9014	Cryofuel Systems	3	0	0	3
15	CY9015	Computer Aided Design Of Cryogenic Process	3	0	0	3
16	CY9016	Cryogenic Rocket Propulsion	3	0	0	3

CY9321 CRYOGENIC SYSTEMS L T P C
3 1 0 4

UNIT I CRYOGENIC REFRIGERATION SYSTEM: 9

Ideal isothermal and reversible isobaric source refrigeration cycles, Joule Thomson system, cascade or pre-cooled joule–Thomson refrigeration systems, expansion engine and cold gas refrigeration systems, Philips refrigerators, Importance of regenerator effectiveness for the Philips refrigerators, Gifford single volume refrigerator, Gifford double volume refrigerators analysis, COP, FOM ,regenerators ,pulse tube refrigerators , various types of pulse tube refrigerator

UNIT II REFRIGERATORS USING SOLIDS AS WORKING MEDIA: 9

Magnetic cooling, magnetic refrigeration systems, thermal; valves, nuclear demagnetization

UNIT III GAS LIQUEFACTION SYSTEMS: 9

Introduction, thermodynamically ideal systems ,joule Thomson effect, liquefaction systems such as Lnde Hampton ,precooled Linde Hampson ,linde dual pressure ,cascade, Claude ,Kapitza ,Heyland systems using
expanders, comparison of liquefaction systems .liquefaction systems for neon ,hydrogen & helium

UNIT IV ADSORBENTS: **9**

various adsorbents, salient features – properties, determination of mass of absorbents for the adsorption of gases

UNIT V ADSORPTION PROCESSES 9

Physical principles of adsorption , BET equation for single and multiple layer , Use of sorption process in cryogenics static and dynamic arrangement for the sorption processes , Adsorption columns , PSA and VSA adsorption systems, isotherms, reactivisation

L +T = 45 +15 : TOTAL: 60 PERIODS

REFERENCES:

1. Cryogenic Systems, **Barron, McGraw Hill Book Co**.
2. Theory and design of cryogenic systems : **A.Arkherov**
3. Cryogenic process engineering **Timmerchand & Flynn**
4. **"**Theory and design of cryogenic systems", **Mikulin,** MIR Publication, 2002

CY9322 CRYOGENIC PLANTS AND EQUIPMENTS L T P C
3 0 0 3

UNIT I GAS SEPARATION AND GAS PURIFICATION SYSTEM : 9

Thermodynamically Ideal separation system, general characteristics of mixtures , temperature composition diagram for cryogenic gas mixtures , fugacity , enthalpy composition diagrams, Simple condensation and evaporation, principles of rectification, theoretical plate calculations for columns, Mecabe – Thiele method for theoretical plate calculation , types of rectification columns

UNIT II AIR SEPARATION AND PURIFICATION SYSTEMS: 9

Linde single column, double column, Linde-Frank1 and Heylandt systems, argon, xenon and krypton. 'L' Air liquede systems fir hydrogen, hydrogen – deuterium in separation systems, helium separation system, separation of helium isotopes , purification of helium.

UNIT III

Modern air liquefaction , liquid nitrogen and oxygen plants**. 9**

UNIT IV 9

Dewars, classification of Dewars, static and chassis mounted cryogenic liquid storage and transport tanks LNG storage tanks, construction Liquid and vapour shielded vessels, cryogenic liquid transfer pumps, liquid transfer lines their design, vacuum insulated line joints, and cryogenic valves liquid transfer systems.

UNIT V 9

Design of cryostat. Various types of cryostats, construction, their salient features.Fabrications and jointing techniques, flanged and bolted joints , joining of dissimilar metals , welding of stainless steel and alloy steels

TOTAL: 45 PERIODS

REFERENCES:

1. Cryogenic Systems, **Barron, McGraw Hill Book Co**.

2. Theory and design of cryogenic systems : **A.Arkherov**

3. Cryogenic process engineering **Timmerchand & Flynn**

CY9323 ADVANCED AIR CONDITIONING L T P C
3 1 0 4

UNIT I PSYCHOMETRIC CHARTS : 9

ASHRE and CARRIER charts ,their differences ,application of corrections of different charts Applied psychrometry : Combinations of different processes and their representation on psychrometric charts, psychrometric calculations for cooling and dehumidification .High latent heat load ,dehumidified air quantities based on total and effective room loads ,GSHF and ESHF ,effect of fan and duct heat gain or dehumidified air quantity ,effective surface temperature ,effect of bypass factor on on GSHF ,analysis for using all outside air ,psychrometric of partial load control. Cooling tower: Different types ,construction working performance ,testing different types of desert coolers ,testing of desert coolers as per BIS,Air washer, different types, construction performance

UNIT II HEAT GAIN CALCULATIONS : **9**

choices of supply conditions . Solar heat gain: Terminology calculation different solar angles ,relation between different angles ,calculation of the intensity of direct ,diffused and ground radiation , solar air temperature ,empirical methods to evaluate heat transfer through walls, and roofs, TETD and its determination by calculation and tables ,Heat gain through glass ,Solar heat gain factor, use of equations and tables ,shading of glass ,solar chart and its use .shading of glass ,solar chart and its use, shading devices and its selection ,load due to other sources, stack effect ,different methods of calculating cooling load as per ASHRE-some brief idea(other than TETD methods)

UNIT III DUCT DESIGN 9

Types of ducts ,duct construction ,factors affecting duct construction ,friction charts and other correction factors ,losses ,design velocity and its selection ,duct heat gain or loss ,duct insulation ,duct layouts, duct sizing methods ,equal friction static regains and T-method design simple idea .Noise and their isolation ,duct materials and their accessories. Air Distribution: Terminology ,outlet performance ,types of outlets ,location of outlets ,factors affecting grill performance ,selection of outlets using monographs ,tables and line charts ,room air diffusions, performance index (ADPI)and its use in outlet selection ,use of different equations.

UNIT IV AIR CONDITIONING SYSTEMS 9

Factors affecting the selection of the systems ,classification ,systems ,design procedure ,system features ,psychrometric analysis ,controls of all air ,air water ,all water ,DX ,VAV and dual duct systems basic idea of cold air distributions systems and dessicant cooling systems. Thermal effects :-Human thermo regulation, different equations governing thermal exchanges ,factors affecting comforts, environmental indices, AQ and its importance –Human comfort and health.

UNIT V AIR CONDITIONING CONTROLS 9

Characteristics of HVAC noise ,Acoustical rating systems and criteria ,RC ,NC, and NR criteria for noise rating ,noise control methods for VAV units ,cooling towers ,air devices roof top units ,chillers ,pumps ,AHU rooms, compressors. Air handling systems : Fans ,types ,construction performance characteristics ,fan laws ,testing as per BS ,IS and AMCA standards, fan selection with the help of tables charts and curves, fan drive arrangements and discharge from fans,duct design fan selection etc.

L +T = 45 +15 TOTAL : 60 PERIODS

REFERENCES:

1. Air Conditioning Engineering -By Jones 5th 2001
2. Thermal Environmental Engineering, Threlkeld
3. Hand book of air conditioning systems design :carrier corporation 1965
4. Air conditioning principles and systems –pita
5. HVAC testing adjusting and balancing manual :Gladstone 3 rd 1997

Ashrae Data Book, (1) Fundamentals (2001) (2) application (1999)
(3)System and equipments (2000)

6. Hand book of air conditioning and refrigeration : wang 2 (1993
7. Air conditioning application and design by jones 2nd1997
8. Air conditioning system design manual : lorach1993
9. Fan handbook :bleier 1998

CY9324 COMPUTATIONAL FLUID DYNAMICS L T P C

3 0 0 3

UNIT I INTRODUCTION & BASIC CONCEPTS: 9

Introduction of CFD, Types of fluids and basic equations of flow, Conservation of mass, Newton's Second law of Motion, Governing equations of fluid flow, Navier-Stokes equations, Boundary layer equations, Expanded form of N-S equations, Conservation of energy principle, Special form of N-S equations, Classification of second order partial differential equations, Initial and boundary conditions, Governing equations in generalized coordinates. Review of essentials of fluid dynamics.

UNIT II DIFFERENTIAL EQUATIONS & DISCRETIZATION: 9

Elementary Finite Difference Equations, Basic aspects of Finite Difference Equations, Errors and Stability Analysis, Discretization , Application to heat conduction and convection, Problems on 1-D and 2-D steady state and unsteady state conduction, Problem on Advection phenomenon, Incorporation of Advection scheme.

UNIT III INTRODUCTION TO FINITE ELEMENT PHILOSOPHY: 9

Basics of finite element method, stiffness matrix, isoperimetric elements, formulation of finite elements for flow & hear transfer problems.

UNIT IV INTRODUCTION TO FINITE VOLUME PHILOSOPHY: 9

Integral approach, discretization & higher order schemes, Application to Complex Geometry.

UNIT V INTRODUCTION TO SOLUTIONS OF VISCOUS 9

incompressible flows using MAC and simple algorithm. Solutions of viscous incompressible flows by stream function, vorticity formulation. Two dimensional incompressible viscous flow, estimation of discretization error, applications to curvilinear geometries, derivation of surface pressure & drag.

TOTAL; 45 PERIODS

REFERENCES:

1. Anderson D.A., Tannehil j.c.Pletcher R.H." Computational fluid mechanics & heat transfer" Hemisphere publishing corporation,. Newyork, U.S.A2004.
2. Anker S.V., "Numerical heat transfer & flow" Hemisphere corporation,2001
3. H.K.verstag & W.Malalsekra," An introduction to computational fluid dynamics" Longman-2000
4. Carnahan B, "Applied numerical method" John Wiley & Sons-2001.
5. Patankar, " Numerical heat transfer & Fluid Flow", Mc.GrawHill.,2002
6. Murlidhar K., Sunderrajan T., "Computational Fluid Mechanics and Heat Transfer", Narosa Publishing House.
7. Date A. W., "Introduction to Computational Fluid Dynamics", Cambrige Uni. Press, 2005.
8. Ferziger J. H., Peric M., "Computational Methods for Fluid Dynamics", Springer, 2002.

CY9325 CRYOGENIC APPLICATIONS L T P C
3 0 0 3

UNIT I CRYOGENIC PROPERTIES OF MATERIALS: 9

thermal properties, electrical properties, superconductivity, super fluidity. Space applications: Missile launching, propellant pressurizing systems, vehicle cooling, cryopropollents, space simulators

UNIT II BIOLOGICAL APPLICATIONS: 9

semen preservation, blood preservation, bone morrow preservation, tissue and micro organism preservation, 4. Medical Application: cryosurgery, skin disease treatment

UNIT III ELECTRONIC APPLICATIONS: **9**

MASER, LASER, infrared detectors, photomultipliers. Superconductive devices: Superconducting bearings, magnets, motors gyroscope and switches, cryotrons, MRI.

UNIT IV NUCLEAR APPLICATIONS: **9**

bubble chambers, radioactive waste disposal. Metal fabrication applications: cold stretching, cryoforming, metal stress reliving, annealing. Food handling applications: food freezing, food shipment and handling.

UNIT V LOW TEMPERATURE PRESERVATION OF TISSUES: **9**

harvesting of tissues, processing of tissues, preservation and storage of tissue, deep freezing, freeze drying. Agriculture applications: fisheries, animal science. Genetic applications, embryo freezing. Miscellaneous applications

TOTAL : 45 PERIODS

REFERENCES:

1. Cryogenics research and applications – Marshall Sittig & Stephen Kidd
2. Advances in Cryogenics – Proceedings of International Conference on Cryogenics, Calcutta, December 6-10, 1988.
3. Cryogenic Engineering & Gas Applications – By Dr. P.K.Bose.
4. Cryogenic technology and Applications – By A. R. Jha.

CY9327 CRYOGENIC SYSTEMS LABORATORY **L T P C**
0 0 3 2

Experiments on cryogen production machines and associated equipment and instrumentation, closed cycle refrigeration

TOTAL :45 PERIODS

CY9001 CRYOGENIC HEAT EXCHANGERS **L T P C**
3 0 0 3

UNIT I ADVANCED HEAT TRANSFER: **9**

steady state conduction with two and three dimension with heat generation, solution of problem by numerical, finite difference and graphical methods, matrix, finite element methods, transient heat conduction and solution by analytical correlation for convective heat transfer for natural and forced convection, transition flow, flow outside of duets, boiling heat transfer coefficients .pressure drop in two phase flow, frost formulation ,condensation ,heat transfer coefficient during condensation.

UNIT II **9**

Shell & tube type heat exchangers-design, Fin effectiveness, surface effectiveness and overall coefficients of heat transfer. Overall pressure drop, effectiveness- NTU approach solution by equations and graphical methods,. Effect of heat-exchanger effect of various specific on exchanger performance.

UNIT III

Design of regenerative type heat exchanger for single and multi stage, Philips, Gifford single volume, double volume, Vuilleumier, magnetic cry refrigerators. Design of heat exchangers for liquefaction systems, single tube, and double tube Linde heat exchangers three channel heat exchangers, multiple tube type, Giaque Hampton and Collins type heat exchangers.

UNIT IV **9**

Finned tube and plate type heat exchangers, different configuration heat transfer coefficients and friction coefficient for various configurations. Single tube Linde exchanger, double tube type, three channel heat exchanger. Linde multiple tube type, Giauque Hampson, Collin's,

UNIT V **9**

Plate fin heat exchanger, different fin configuration, heat transfer coefficients, and friction factors for various configurations. Testing of heat exchangers as per standards.

TOTAL : 45 PERIODS

REFERENCES:

1. Saunders, E.A.D., "Heat exchange – selection design and construction", Longmann Scientific and Technical, N.Y.2001.
2. Kays, V.A and London,A.L., "Compact Heat Exchangers", McGraw Hill, 2002
3. Holger Martin , "Heat Exchanger" Hemisphere Publ.Corp., Washington,2001
4. Kuppan,T., "Heat Exchangert Design Handbook", Macel Dekker, Inc., N.Y.,2000
5. Seikan Ishigai, "Steam Power Engineering, Thermal and Hydraulic Design Principles", Cambridge Univ. Press,2001

CY9002 MATERIALS FOR LOW TEMPERATURE APPLICATIONS **L T P C**
3 0 0 3

AIM: To impart knowledge on material characterization at low temperature and selection for low temperature applications.

OBJECTIVE:

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

UNIT I MATERIAL BEHAVIOR 10

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

UNIT II MATERIALS SELECTION 10

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

UNIT III NON METALLIC MATERIALS 7

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

UNIT IV TESTING METHODS AND TECHNIQUES 10

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

UNIT V MODERN METALLIC MATERIALS 8

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

TOTAL: 45 PERIODS

TEXT BOOKS:

1. Wigley D.A., "Mechanical Properties of Materials at Low Temperatures", Plenum Press, New York, 1972.

REFERENCES:

1. Richard P. Reed, Alan F. Clark, Materials at low Temperature, ASME International, Dec 1983.
2. Thomas H.Courtney , "Mechanical Behavior of Materials", (2nd Edition), McGraw-Hill , 2004.

CY9003 ADVANCED FLUID MECHANICS L T P C
3 0 0 3

AIM:

To introduce the advanced concepts of fluid mechanics and aerodynamics with the emphasis on practical applications.

OBJECTIVES:

- To understand the laws of fluid flow for ideal and viscous fluids.
- To represent the real solid shapes by suitable flow patterns and to analyze the same for aerodynamics performances.
- To understand the changes in properties in compressible flow and shock expansion.

UNIT I BASIC EQUATIONS OF FLOW 6

Three dimensional continuity equation - differential and integral forms – equations of motion momentum and energy and their engineering applications.

UNIT II POTENTIAL FLOW THEORY 12

Rotational and irrorational flows - circulation – vorticity - stream and potential functions for standard flows and combined flows – representation of solid bodies by flow patters.Pressure distribution over stationery and rotating cylinders in a uniform flow - magnus effect - Kutta – Zhukovsky theorem.Complex potential functions.Conformal transformation to analyze the flow over flat plate, cylinder, oval body and airfoils.Thin airfoil theory – generalized airfoil theory for cambered and flapped airfoils.

UNIT III VISCOUS FLOW THEORY 9

Laminar and turbulent Flow - laminar flow between parallel plates - Poiseuille's equation for flow through circular pipes.Turbulent flow - Darcy Weisbach equation for flow through circular pipe - friction factor - smooth and rough Pipes - Moody diagram – losses during flow through pipes. Pipes in series and parallel – transmission of power through pipes.

UNIT IV BOUNDARY LAYER CONCEPT 9

Boundary Layer - displacement and momentum thickness - laminar and turbulent boundary layers in flat plates - velocity distribution in turbulent flows in smooth and rough boundaries - laminar sub layer.

UNIT V COMPRESSIBLE FLUID FLOW 9

One dimensional compressible fluid flow – flow through variable area passage – nozzles and diffusers – fundamentals of supersonics – normal and oblique shock waves and calculation of flow and fluid properties over solid bodies (like flat plate, wedge, diamond) using gas tables

TOTAL: 45 PERIODS

TEXT BOOKS:

1.Houghten, E.L. and Carruthers, N.B., Aerodynamics for Engineering Students, Arnold Publishers, 1993.

2. Anderson, J.D., Fundamentals of Aerodynamics, McGraw Hill, Boston, 2001.

REFERENCES:

1 .Streeter, V.L., Wylie, E.B., and Bedford, K.W., Fluid Mechanics, WCB McGraw Hill, Boston, 1998.

2. Munson, B.R., Young, D.F. and Okiisi, T.H., Fundamentals of Fluid Mechanics, John Wiley and Sons Inc., NewYork, 1990

3. Kumar, K.L., Engineering Fluid Mechanics, Eurasia Publishing House, New Delhi, 2002

4. Bansal, R.K., Fluid Mechanics, Saurabh and Co., New Delhi, 1985.

CY9004 SUPER CONDUCTIVITY & LOW TEMPERATURE PHYSICS L T P C

3 0 0 3

UNIT I **9**

Properties Of Cryo Liquids, Liquid Air, Liquid Nitrogen, Liquid Oxygen, Liquid Hydrogen, Liquid Helium, General Properties, Phase Diagrams, Thermodynamic Properties

UNIT II SUPER FLUID 4HE – HELIUM II : **9**

Experimental Observations, Two – Fluid Model, Bose – Einstein Condensation, Macroscopic Quantum State, Excitation Spectrum of Helium Ii, Critical Phenomena Near The Lambda Point

UNIT III NORMAL FLUID 3HE : **9**

Ideal Fermi Gas –Comparison With 3He, The Landau Fermi Liquid Theory, Zero Sound

UNIT IV **9**

Super Fluid 3He -- Phase Diagrams , Specific Heat, Superfluidity, Nuclear Magnetic Resonance , Relevance Of Two Fluid Model, Quantum States Of Pairs Of Coupled Quasiparticles, Order Parameter Orientation – Textures, Leggett Equations Transverse Resonance, Longitudinal Resonance, Superflow, Macroscopic Quantum Interference – Josephson Effect, Normal Fluid Density – Quasiparticle Scattering , Collective Excitations, Sound Propagation

UNIT V MIXTURES OF 3HE & 4HE: **9**

Specific Heat, Phase Diagram And Solubility, Normal Fluid Component, Sound Propagation, Transport Properties, Search For a Superfluid Phase Of 3He In Mixtures.

TOTAL : 45 PERIODS

REFERENCES:

1. Low Temperature Superconductivity & Superconductivity By Christian Enss & Siegfried Hunklinger

2. Matter & Methods At Low Temperature By F.Pobell.
Experimental low temperature physics by Anthony Kent

CY9005 ADVANCED CRYO COOLERS L T P C
3 0 0 3

UNIT I CRYOCOOLERS: 9

Classification of cryocoolers, Working of cryocoolers, Selection of cryocooler and comparison of different types of cryocoolers, Ideal working Cycles, Important parameters –mass, volume, vibration, acoustic noise, electromagnetic interface, operating life, Technical parameters - cooling effect, compressor power requirement, cooling water requirement, service requirement of compressor ,Vibration control, Steady flow and oscillating flow cryocoolers, Different types of at exchangers, Applications of cryocoolers –military, environmental , commercial, medical, transportation, energy, police and security.

UNIT II GIFFORD MCMAHON CRYOCOOLER: 9

Advantages and disadvantages of G-M cryocooler, Design of two stage G-M cryocooler , Efficiency of pressure oscillators, 4K operation, improved valve timing, Application of GM Cooler, Monolithic regenerator technology for low temperature cryocoolers, Progress of multilayered regenerators.

UNIT III STIRLING CRYOCOOLER: 9

Ideal Stirling cycle, Concept of practical Stirling cycle, First order analysis Stirling cycle, Second order analysis, Third order analysis , Loss analysis, Comparison of Stirling and Carnot cycle, Design and optimization of Stirling Cryocoolers, Performance and reliability improvement of low cost Stirling cooler, Development of long life stirling cooler, Analysis of Stirling Cycle, Multi stage Cryocooler, hybrid cooler , Long life tactical and commercial Stirling cooler, Miniature stirling cryocooler, Linear compressor design.

UNIT IV PULSE TUBE CRYOCOOLERS: 9

Advantages and disadvantages of pulse tube cryocooler, History of pulse tube Cryocooler, Comparison of stirling and orifice pulse tube cryocoolers, Double inlet pulse tube refrigerator, Geometry of pulse tube –U-tube, co-axial, in-line, Two stage pulse tube refrigerator design , Thermoacoustically driven pulse tube refrigerator, Different methods of analysis, Phasor analysis , Oscillating flow behavior of PTR, Valve timing effect on performance of 4K pulse tube cryocooler. Design of Dual use PTR, Low vibration flexure bearing compressor, Miniature 50 k to 80 K space application of PTR, Experimental characteristics of PTR, Effect of D.C. flow, Active phase control of stirling type PTR, Expansion efficiency considering shuttle heat transfer, Co-axial PTR for high Tc- SQUID, Characteristics of Double inlet PTR, Experimental study and analysis of components of orifice pulse tube refrigerator. Theoretical model of G-M type pulse tube refrigerator, High frequency pulse tube cryocooler with base temperature below 20 K, Novel regenerator material Er3 Ni Hx-He-H2 mixture, Numerical and experimental study of Rotary valve for pulse tube, . Valve timing effect on cooling performance of pulsetube cryocooler, V-M type PTR, Variable resistance orifice, Effect of valve timing on PTR, Performance of single stage pulse tube, Some of the phase shifting types of two stage G-M type pulse tube refrigerator, Small He3 PTR Multi stage pulse tube cooler 4 K technology - new material

UNIT V SPACE PULSE TUBE CRYOCOOLER DEVELOPMENT : 9

Miniature pulse tube cryocooler for space, High frequency pulse tube cooler, High performance cryocooler compressor, Vibration reduction in balanced linear compressor, G-M type pulse tube cryocooler . Regenerator material analysis and material development Ductile, High heat capacity magnetic regenerator alloy material, Manufacturing considerations of rare earth powder used in cryocooler

TOTAL : 45 PERIODS

REFERENCES:

1. Cryocoolers by G. Walker
2. Cryocoolers Volumes (Proceedings of International Cryocooler conference) Journal 'Cryogenics' published by Elsevier available at www.sciencedirect.com
3. Advances in Cryogenic Engineering. (Proceedings of International Cryogenic Engineering Conference)

CY9006 PRODUCTIVITY MANAGEMENT AND RE-ENGINEERING L T P C
3 0 0 3

UNIT I PRODUCTIVITY 9

Productivity Concepts – Macro and Micro factors of productivity – Dynamics of Productivity - Productivity Cycle Productivity Measurement at International, National and Organisation level - Productivity measurement models

UNIT II SYSTEMS APPROACH TO PRODUCTIVITY MEASUREMENT 9

Conceptual frame work, Management by Objectives (MBO), Performance Objectivated Productivity (POP) – Methodology and application to manufacturing and service sector.

UNIT III ORGANISATIONAL TRANSFORMATION 9

Elements of Organisational Transformation and Reengineering-Principles of organizational transformation and re-engineering, fundamentals of process re-engineering, preparing the workforce for transformation and re-engineering, methodology, guidelines, LMI CIP Model – DSMC Q & PMP model.

UNIT IV RE-ENGINEERING PROCESS IMPROVEMENT MODELS 9

PMI models, PASIM Model, Moen and Nolan Strategy for process improvement, LMICIP Model, NPRDC Model.

UNIT V RE-ENGINEERING TOOLS AND IMPLEMENTATION 9

Analytical and process tools and techniques – Information and Communication Technology – Implementation of Reengineering Projects – Success Factors and common implementation Problem – Cases.

TOTAL : 45 PERIODS

REFERENCES

1. Sumanth, D.J., 'Productivity Engineering and Management', TMH, New Delhi, 1990.
2. Edosomwan, J.A., "Organisational Transformation and Process Re-engineering", Library Cataloging in Pub. Data, 1996.
3. Rastogi, P.N., "Re-engineering and Re-inventing the Enterprise", Wheeler Pub. New Delhi, 1995.
4. Premvrat, Sardana, G.D. and Sahay, B.S., "Productivity Management – A Systems Approach", Narosa Publishing House. New Delhi, 1998.

CY9007 INDUSTRIAL REFRIGERATION SYSTEMS L T P C
3 0 0 3

UNIT I INTRODUCTION 6

Introduction to industrial refrigeration - difference from conventional system - applications - industrial and comfort air - conditioning - conditions for high COP

UNIT II COMPRESSORS 10

Reciprocating and screw compressor: Multistage industrial applications, cylinder arrangement, cooling methods - oil injection and refrigeration injection, capacity regulations - Economizers.

UNIT III EVAPORATORS AND CONDENSERS 12

Types of Evaporators, Liquid circulation: Mechanical pumping and gas pumping - advantage and disadvantage of liquid re-circulation - circulation ratio - top feed and bottom feed refrigerant - Net Positive Suction Head (NPSH) - two pumping vessel system - suction risers – design - piping loses. Different Industrial Condensers arrangement, Evaporators-Types and arrangement, liquid circulation, type of feed, refrigerant piping design , functional aspects. Lubricating oil: types - physical properties, types of circulation and oil separator

UNIT IV VESSELS 8

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

UNIT V ENERGY CONSERVATION 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

REFERENCES:

1. Wilbert F.Stoecker, Industrial Refrigeration Hand Book, McGraw-Hill, 1998.
2. ASHRAE Hand Book: Fundamentals, 1997.
3. ASHRAE Hand Book: Refrigeration, 1998.
4. ASHRAE Hand Book: HVAC Systems and Equipment, 1996.
5. Transport properties of SUVA Refrigerants, Du-Pont Chemicals, 1993.

CY9008 GAS TURBINES AND JET PROPULSION L T P C
3 0 0 3

UNIT I GAS TURBINE CYCLES 10

Gas turbine cycles – Air Standard Analysis, Different configurations – Re-heater, Intercooler, Heat Exchanger; Component behaviour.

UNIT II AXIAL FLOW COMPRESSORS 9

Momentum and energy transfer in rotors - Velocity triangles - Stage performance - Degree of reaction - Three-dimensional analysis - Cascade testing - Compressor characteristic curves – Howell's Correlation - Surging and stalling.

Stage velocity triangles - impulse and reaction turbines, losses and co-efficient - blade design principles - three-dimensional analysis - testing and performance characteristics – Compounding methods - blade cooling.

UNIT III CENTRIFUGAL COMPRESSORS AND RADIAL TURBINES 10

Construction and working principle - velocity triangles - backward, forward and radially swept blades - losses and coefficients- performance characteristics. Types of inward flow radial (IFR) turbine – velocity triangles – thermodynamics of the 90^0 IFR turbine – optimum design solution of 90^0 IFR turbines – stage losses –performance characteristics.

UNIT IV THERMODYNAMICS OF AIRCRAFT ENGINES 9

Theory of Aircraft propulsion – Thrust – Various efficiencies – Different propulsion systems – Turboprop – Ram Jet – Turbojet, Turbojet with after burner, Turbo fan and Turbo shaft. Engine – Aircraft matching – Design of inlets and nozzles – Performance characteristics of Ramjet, Turbojet, Scramjet and Turbofan engines.

UNIT V ROCKET PROPULSION 9

Theory of rocket propulsion – Rocket equations – Escape and Orbital velocity – Multi-staging of Rockets – Space missions – Performance characteristics – Losses and efficiencies.

Combustion in solid and liquid propellant rockets – Classification of propellants and Propellant Injection systems – Non-equilibrium expansion and supersonic combustion – Propellant feed systems – Reaction Control Systems – Rocket heat transfer.

TOTAL : 45 PERIODS

TEXT BOOKS:

1. Cohen, H., Rogers, G.E.C., and Saravanamuttoo, H.I.H., Gas Turbine Theory, Longman Group Ltd, 1989.
2. Philip G. Hill and Carl R. Peterson, Mechanics and Thermodynamics of Propulsion, Second Edition, Addition – Wesley Publishing Company, New York, 1992.
3. Zucrow N.J. Principles of Jet Propulsion and Gas Turbines, John Wiley and Sons Inc, New York, 1970.
4. Zucrow N.J. Aircraft and Missile Propulsion, Vol. I and Vol. II, John Wiley and Sons Inc, New York, 1975.

CY9009 **CRYO PHYSICS** **L T P C**

3 0 0 3

UNIT I **9**

Properties of engineering materials at cryogenic temperatures, mechanical properties ,thermal properties, electric & magnetic properties, super conducting materials ,thermo electric materials, composite materials, properties of cryogenic fluids, super fluidity of He 3 &He4.

UNIT II **9**

Measurement systems for low temperatures:-Temperature measurements, pressure measurements, flow measurements, liquid level measurements, fluid quality measurements.

UNIT III **9**

Cryogenic insulation:- various types such as expanded foams, gas filled& fibrous insulation, vacuum insulation, evacuated powder& fibrous insulation ,opacified powder insulation, multi layer insulation, comparison of performance of various insulations .

UNIT IV **9**

Applications of cryogenic systems Super conductive devices such as bearings, motors, cryotrons, magnets, D.C. transformers, tunnel diodes, space technology, space simulation, cryogenics in biology and medicine, food preservation and industrial applications, nuclear propulsions ,chemical propulsions.

UNIT V **9**

Hazards:-Physical hazards, Chemical hazards, Physiological hazards, combustion hazards, oxygen hazards, , accidents in cryogenic plants & prevention. Safety in handling of cryogens, care for storage of gaseous cylinders, familiarization with regulations of department of explosives.

TOTAL : 45 PERIODS

REFERENCS:

1. Cryogenic systems-Baron, McGraw-Hill book
2. Cryogenic fundamentals-Haselden, Academic press New York
3. Cryogenic technology –Vance
4. Advance cryogenic –bailey, plenum press
5. Cryogenic engineering –Scott

CY9010 **RADIANT HEATING & COOLING SYSTEM** **L T P C**

3 0 0 3

UNIT I **INTRODUCTION TO RADIANT SYSTEMS** **9**

Radiant phenomenon, Natural thermal environment, Application of Natural principals. ADVANTAGES OF USING RADIANT SYSTEMS-- Occupant thermal comfort, radiant characteristics and applications, radiant energy and operating cost,

UNIT II THE ENERGY BALANCE 9

Concept of control volume and associated thermodynamic principles, internal energy and enthalpy, conservation of energy equation. Transient conduction in soil and Newton's law of cooling.

UNIT III RADIATION HEAT TRANSFER 9

Wavelengths and electromagnetic spectrum of radiations, absolute temperature scales. Radiative intensity, the basic building block of radiative heat transfer, and its application in the built environment. Planck's law, blackbody radiation, Wien's displacement law, Stefan-Boltzmann equation. emissivity, absorptivity, and transmissivity characteristics building material surfaces in a radiant environment. Thermophysical properties of matter encountered in the built environment. View factor calculations, Radiative resistance network approach, radiant heating systems, spherical harmonics method, Monte Carlo method, and discrete ordinates modeling.

UNIT IV THERMAL COMFORT AND THERMAL COMFORT MODELS 9

Concept of Thermal Comfort, and it looks at the effects of thermal distribution systems. The Rohles-Nevin studies, the Fanger and Gagge models, and improvements to the Fanger and Gagge models. Thermal comfort design methodology, concept of The Mean Radiant Temperature, the performance capabilities of radiant heating and cooling systems in comparison to convection. Concept of The Operative Temperature., thermal comfort, measurement techniques, calculations and procedures for thermal comfort calculations.
RADIANT HEATING SYSTEMS --Electric radiant heating panels, high temperature heaters radiant hydronic heating systems, Radiant Heating and Cooling Hybrid Systems, Convective Systems with Radiant Panels, optimization of system combination. Ventilation with Radiant Heating and Cooling systems.

UNIT V CONTROLS FOR RADIANT HEATING AND COOLING SYSTEMS 9

A loworline voltage thermostat, single low-voltage control, over-temperature limitsensor or temperature control, supportive flow and temperature control sensors and valves that interact in response to the master control. Slave orindependent area controls zone control, outdoor reset control, interiorcontrols, motorized mixing valves, safety controls, downstream flow control, and temperature valves of mechanical and electronic equipments.

TOTAL : 45 PERIODS

REFERENCES:

1. Radiant Heating and Cooling by Richard D. Watson and Kirby S.Chapman.
2. Radiant floor heating by R. Dodge Woodson
3. Radiant Heating and cooling manual by John Siegenthaler and Lawrence Drake.
4. Heating and Cooling of Buildings: Design for Efficiency by Kreider J. F., Rabl A. and Curtiss Peter

CY9011 LOW TEMPERATURE MEASUREMENT & INSTRUMETATION L T P C

3 0 0 3

UNIT I MEASURING ENVIRONMENT 9

Significance of measurement & Instrumentation, Measuring systems--Transducers & Its Environment, The Nature of Measurement, Functional Stages of Measuring Systems **,**Measuring problems, the instrumentation problems, Static & dynamic Characteristic of Instruments.

TRANSDUCERS: Physical laws, Static characteristics ---Linear Characteristics, Common Non Linearity & Its Effect, Linearization, Transducer types & modelling, Calibration, Errors in measurement, Selection of alternative test methods.

UNIT II SENSORS 9

Electric Sensing devices, Magnetic sensors, Pressure sensors, Piezo- resistive sensors, Strain sensors, Temperature sensors, Fibre optics sensors, Ultra violet detectors, Chemical sensors.

LEVEL & VOLUME MEASUREMENT: Practice of level measurement, Calibration of level measuring Instruments, Methods of providing full range level measurement, Methods providing short range detection.

UNIT III DENSITY MEASUREMENT 9

Measurement of density using weight, Measurement of density using buoyancy ,Measurement of density using hydrostatic head, Measurement of density using radiation.

FLOW MEASUREMENT: Laminar flow and Turbulent flow, “Direct” flow measurement – Weighing ad volumetric Methods, Positive Displacement Methods, flow visualization, “carrier” systems “Indirect” flow measurement--square root law flow meters, Orifice and venture flow meters, Characteristics of Square root law flow meters, Pitot static tubes, Variable Area flow meters, Drag Force flow meters, Turbine flow meters, ultrasonic flow meter, Electromagnetic flow meter, Impeller flow meter, Thermal mass flow meter

UNIT IV PRESSURE & SOUND MEASUREMENT 9

Pressure measurement, Vacuum measurement, Ultrasound measurement.

THERMOMETRY FOR LOW TEMPERATURE : Gas thermometers, Vapor pressure thermometers, resistance thermometers, Thermocouples, 3He Melting Curve Thermometers, Noise thermometers, Superconducting Fixed point Thermometers, Nuclear Orientation thermometers, Mossbauer – Effect thermometers, Coulomb Blockade Thermometers, Osmotic pressure Thermometers, Infrared thermometers, Fibre – Optic Thermometers, Secondary thermometers.

UNIT V NOISE & DISTORTION 9

Electric Noise Measurement, Electric Distortion Measurement, Intermodulation measurement, Measurement of frequency, phase noise, and amplitude Noise**.**

NON DESTRUCTIVE TESTING : Introduction, Visual examination, surface inspection methods, ultrasonics, Radiography,Underwater non-destructive testing, Developments, Certification of personnel

TOTAL : 45 PERIODS

REFERENCES:

1. Measurement and Instrumentation in Engineering by FRANCIS S. TSE
2. Survey of instrumentation and Measurement by Stephen A. Dyer
3. The measurement, Instrumentation, and Sensors, Handbook by John G. Webster
4. Low temperature physics & superconductivity by Christian Enss & Siegfried Hunklinger

CY9012 ADVANCED CRYOGENICS & APPLIED SUPER CONDUCTIVITY L T P C
3 0 0 3

UNIT I HISTORY OF SUPERCONDUCTIVITY 9

Discovery and early history-Meisserner effect and search for understanding the phenomenon, growth and development in the new era.

UNIT II UNDERSTANDING THE PHENOMENA OF SUPERCONDUCTIVITY 9

Zero electrical resistance, The superconductor as a thermodynamic phase, perfect diamagnetism, super currents, and penetration depth. Magnetic Phase diagram-Critical field and critical temperature. Intermediate state, Gibbs free energy, Type II superconductivity. Thermodynamic and optical properties (the energy gap). Flux Quantization; Magnetic flux through hollow cylinder and ring. Josephson effect and tunnelling, superconductivity and super fluidity

UNIT III SUPERCONDUCTING MATERIALS 9

Materials superconducting at LHe temperature, Structures of the material and composition, High Tc cuparates, composition, structures, properties, and general features of various types of cuparates. Electron super conductors, Oxyhalides, oxycarbonates, ladder cuprates, copper free oxide superconductors, boro carbides, super conducting fullerides and related materials Preparation of cuparates materials, making of films of superconductor by electron-beam evaporation, High pressure oxygen sputtering system, lesser ablation method.

UNIT IV STRANGE CUPRATES 9

The first Cuprate family,La2-xMxCuo4, Insular Material-Elecrical restivity of insular material, Graphical presentation(in Plane) of metallic properties, resistivity, The hall effect, single particle spectrum, Fermi surface, magnetic excitations lower energy scale, the superconducting state, basic electronic model for cuprates, future scope of cuprates.

UNIT V THEORIES OF SUPERCONDUCTIVITY 9

London Equation, London hypothesis, penetration depth and Meissner effect, rigidity of wave function and flux quantization. Landau theory, order parameter idea, free energy function for superconductor, superconducting phase transition, Coherence length, meissner effect and zero electrical resistance, flux quantization, Type II superconducting, Josephson effect, The BCS theory.

APPLICATION OF SUPERCONDUCTIVITY

1) MAGNETS:

High-field magnet application, Nuclear magnetic resonance(NMR),medical diagnostics and spectroscopy, Ore refining (magnetic separators),Magnetic levitation, Magnetic shielding, Large physics machines.

2) ENERGY-RELATED:

Production by magnetic fusion and magneto-hydrodynamics, energy storage, Electrical power transmission.

3) TRANSPORTATION:

High-speed trains, Ship-drive systems.

4) ELECTRONICS AND SMALL DEVICES:

SQUIDS, Josephson devices, Bolometer, Electromagnetic shielding

5) COMPUTERS AND INFORMATION PROCESSING:

Semiconductor-superconductor hybrids, Active superconducting elements, Voltage standard, Optoelectronics, Matched filters.

TOTAL: 45 PERIODS

REFERENCES:

1. D. Schoneberg, Superconductivity, Cambridge University Press, 1954.
2. F.London, Superfluids, Vol.1,Wiley, New York, 1954
3. M.Tinkham, Introduction to superconductivity, McGraw-Hill, New York, 1975.
4. HTSCs for 21st century Technology, Applied superconductivity,5,1-204(1997)
5. P.W. Anderson, The Theory of superconductivity in High-Tc Cuprates, Princeton University Press,1997

CY9013 SYSTEMS AND SIMULATION L T P C
3 0 0 3

UNIT I INTRODUCTION TO SYSTEMS AND SIMULATION 9

Basic concepts of systems, General systems, Elements of systems, theory, concept of simulation-Simulation as a decision making tool-types of simulation-System modelling and types of modelling-desk and bench mark simulation.

UNIT II RANDOM NUMBER 8

Probability and statistical concepts of simulation-Pseudo random numbers-Methods of generating random variables-Discrete and continuous distributions-Testing of random numbers-Sampling-simple random and simulated.

UNIT III DESIGN OF SIMULATION EXPERIMENTS 8

Problem formulation-Data collection and reduction time flow mechanism-Key variables-Logic flowchart starting condition-Run size-Experimental design consideration-Output analysis and interpretation, validation-Application of simulation in Industries, Engineering and scientific organisations.

UNIT IV SIMULATION LANGUAGE 10

Use of digital computer in simulated sampling -Comparison and selection of simulated languages-Analysis-Study of any simulation language-Modification of simulation models using simulation language.

UNIT V CASE STUDIES 10

Development of simulation models using the simulation language studied for systems like: Queuing systems- Production Systems-Inventory systems-Maintenance and replacement systems-Investment analysis and network.

TOTAL : 45 PERIODS

REFERENCES:

1. JERRY BANKS and JOHN S.CARSON," Discrete event system simulation ", Prentice Hall, 1984.
2. R.E.SHANNON," Systems simulation, the art and science ", Prentice Hall, 1975.
3. JOE H. MIZE AND J. GRADY COX," Essentials of simulation ", Prentice Hall Inc.1968.
4. JEFFREY L. WHITTEN, LONNIE D.BENTLEY AND VICTOR M.BARICE, “System analysis and design methods ", Galgotia Publications Pvt Ltd., 1991
5. THOMAS J. SCHRIBER, “Simulation using GPSS ", John Wiley, 1974.

CY9014 CRYOFUEL SYSTEMS L T P C
3 0 0 3

UNIT I 9

Properties of hydrocarbon Mixtures – equations of state, The Law of Corresponding States, transport properties. Liquefied Petroleum Gas – properties, Production and storage.

UNIT II 9

Natural Gas-composition, source and pretreatment. Liquefaction of natural gas –simple cascade, mixed refrigerant and turbine expansion cycles, Ocean transport of LNG membrance and self –supporting tanks.

UNIT III 9

Storage of LNG. Application of NG and LNG and safety aspects.

UNIT IV 9

Hydrogen –properties, production and pretreatment – Liquefaction of hydrogen –Linde, Claude and helium –hydrogen condensing cycle, Ortho-pare conversion.

UNIT V **9**

Storage and handling of liquefied hydrogen –application of hydrogen, and its safety.

TOTAL: 45 PERIODS

CY9015 COMPUTER AIDED DESIGN OF CRYOGENIC PROCESS PLANTS L T P C
3 0 0 3

UNIT I **9**

Introduction to computer aided design; simulation, design and optimization. Sequential modular simultaneous solution method. Simulation of thermal systems.

UNIT II **9**

Thermodynamics and transport properties of Cryogenic fluids, equators of state, vapour – liquid equilibrium. MIPROPS, DDMIX AND ALLPROPS physical properties programs

UNIT III **9**

Cryogenic process plants, development of mass, momentum and energy balance equations.

UNIT IV **9**

Introduction to general and special purpose plant simulators. Simulation of liquefiers and refrigeration based on Linde, Claude and mixed refrigerant cycle using available process simulators.

UNIT V **9**

Computer aided design of heat exchangers, expansion turbines and distillation columns.

TOTAL : 45 PERIODS

CY9016 CRYOGENIC ROCKET PROPULSION L T P C
3 0 0 3

UNIT I **9**

Chemical rocket propulsion, Definitions and fundamentals; thrust, total impulse, mixture ratio, bulk density, characteristics velocity, thrust to weight ratio, exhaust velocity, mass ratio, multistaging.

UNIT II **9**

Types of chemical propellants; solid, liquid, hybrid, physical properties of common earth storable propellants, semi- cryo and cryogenic propellants.

UNIT III **9**

Pressure fed system – sources of pressurizing gas, pump fed systems – engine operating cycles, pumps and turbines –general configuration, fluid circuits of vibration of cryogenic engines and semi –cryogenic engines.

UNIT IV **9**

Design of regenerative cooled combustion chamber, film cooling, dump cooling transpiration cooling and radiation cooling. Design of expansion nozzle – characteristics, design of injector hydraulic characteristics; Engine thrust and mixture ratio control, igniters, Propellant tanks.

UNIT V **9**

Valves: Shut off value, flow control valves, check valve, isolation valve, relief valves, common materials used in cryogenic propulsion; problems in storage and handling of cryogenic propellants: safety aspects, Thermal protection systems for stage tanks, Thermal stratification-desertification, Geysering effect – geysering elimination, Zero “g” problems- restart mechanism.

TOTAL: 45 PERIODS