ANNA UNIVERSITY, CHENNAI

AFFILIATED INSTITUTIONS

M.E. CRYOGENIC ENGINEERING

REGULATIONS - 2009

CURRICULUM I SEMESTER (FULL TIME)

SEMESTER I

S.NO	SUB CODE	TITLE	L	T	P	C
1	MA9332	Applied Mathematics for Thermal Engineers	3	1	0	4
2	CY9311	Elements Of Cryogenic Engineering	3	0	0	3
3	CY9312	Advanced Heat & Mass Transfer	3	1	0	4
4	CY9313	Vaccum Engineering	3	0	0	3
5	CY9314	Advanced Refrigeration	3	1	0	4
6		Elective - I	3	0	0	3
LABORATORY						
7	CY9316	Cryogenic Engineering Laboratory	0	0	3	2
		TOTAL	**18**	**3**	**3**	**23**

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

MA9332 APPLIED MATHEMATICS FOR THERMAL ENGINEERS L T P C
3 1 0 4

UNIT I APPLICATIONS OF FOURIER TRANSFORM 9

Fourier Transform methods – one-dimensional heat conduction problems in infinite and semi-infinite rod – Laplace Equation – Poisson Equation.

UNIT II CALCULUS OF VARIATIONS 9

Concept of variation and its properties – Euler's equation – Functionals dependant on first and higher order derivatives – Functionals dependant on functions of several independent variables – Variational problems with moving boundaries – Direct methods – Ritz and Kantorovich methods.

UNIT III CONFORMAL MAPPING AND APPLICATIONS 9

The Schwarz- Christoffel transformation – Transformation of boundaries in parametric form – Physical applications:Fluid flow and heat flow problems.

UNIT IV FINITE DIFFERENCE METHODS FOR PARABOLIC EQUATIONS 9

One dimensional parabolic equation – Explicit and Crank-Nicolson Schemes – Thomas Algorithm – Weighted average approximation – Dirichlet and Neumann conditions – Two dimensional parabolic equations – ADI method.

UNIT V FINITE DIFFERENCE METHODS FOR ELLIPTIC EQUATIONS 9

Solutions of Laplace and Poisson equations in a rectangular region – Finite difference in polar coordinates – Formulae for derivatives near a curved boundary while using a square mesh.

L +T: 45+15 = 60 PERIODS

REFERENCE BOOKS:

1. Mitchell A.R. and Griffith D.F., The Finite difference method in partial differential equations, John Wiley and sons, New York (1980).
2. Sankara Rao, K., Introduction to Partial Differential Equations, Prentice Hall of India Pvt. Ltd., New Delhi (1997).
3. Gupta, A.S., Calculus of Variations with Applications, Prentice Hall of India Pvt. Ltd., New Delhi (1997).
4. Spiegel, M.R., Theory and Problems of Complex Variables and its Application (Schaum's Outline Series), McGraw Hill Book Co., Singapore (1981). Andrews, L.C. and Shivamoggi, B.K., Integral Transforms for Engineers, Prentice Hall of India Pvt. Ltd., New Delhi (2003).
5. Elsgolts, L., Differential Equations and the Calculus of Variations, MIR Publishers, Moscow (1973).
6. Mathews, J.H. and Howell, R.W., Complex Analysis for Mathematics and Engineering, Narosa Publishing House, New Delhi (1997).
7. Morton, K.W. and Mayers, D.F. Numerical solution of partial differential equations, Cambridge University press, Cambridge (2002).
8. Jain, M. K., Iyengar, S. R. K. and Jain, R. K. " Computational Methods for Partial Differential Equations", New Age International (P) Ltd., 2003.

CY9311 ELEMENTS OF CRYOGENIC ENGINEERING L T P C
3 0 0 3

UNIT I INTRODUCTION 9

Meaning & definition of cryogenics, Importance of cryogenics studies, 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 CRYOGENIC MEASUREMENT SYSTEMS 9

Temperature measurements, pressure measurements, flow measurements, liquid level measurements, fluid quality measurements.

UNIT III IMPORTANCE OF CRYOGENIC INSULATIONS 9

Various factors for selection of insulations, 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 SALIENT APPLICATIONS OF CRYOGENIC SYSTEMS 9

Super conductive devices such as bearings, motors, cryotrons, magnets, space technology, space simulation chamber, cryogenics in biology and medicine, food preservation and industrial applications, nuclear propulsions ,chemical propulsions.

UNIT V HAZARDS 9

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. powder insulation by boil off calorimeter method.

TOTAL: 45 PERIODS

REFERENCE BOOKS:

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
6. Cryogenic Engineering & Gas Applications – By Dr. P.K.Bose.

CY9312 ADVANCED HEAT & MASS TRANSFER L T P C
3 1 0 4

UNIT I CONDUCTION 12

Factors affecting thermal conductivity of solids, liquids & gases. General three dimensional heat conduction equation in Cartesian, cylindrical & spherical coordinates. Initial condition and various boundary conditions. Heat sources systems, Critical thickness of insulation. Different types of fins & their analysis. Two dimensional steady state conduction. Transient heat conduction.

UNIT II CONVECTIO 12

Free & forced convection, Similarity & simulation of convection heat transfer, Boundary layer theory, Turbulent flow heat transfer. Analogy between momentum & heat transfer. Heat transfer with liquid metals. Recent developments in the theory of turbulent heat transfer. Natural convection under different situations. Empirical relations in convection heat transfer.

UNIT III TWO PHASE FLOW & HEAT TRANSFER 12

Boiling- Introduction to boiling heat transfer, regimes of boiling heat transfer, pool boiling, flow boiling. Condensation- Heat transfer in condensation, Drop wise & film wise condensation. Empirical equations. Laws of thermal radiation. Shape factors. Radiation heat transfer between black, diffuse & gray surface.

UNIT IV DESIGN OF HEAT EXCHANGER 12

LMTD Methods, importance of fouling factor, Overall heat transfer co-efficient, NTU-effectiveness method, Analysis of compact heat exchanger—plate-fin heat exchangers, regenerative type heat exchanger. Optimization & simulation of heat exchangers. 6. Basic aspects of heat transfer in porous media.

UNIT V MASS TRANSFER 12

Modes of mass transfer, comparison between heat & mass transfer, Frick's law of diffusion, general mass diffusion equation, diffusion through stagnant gas, convective mass transfer, dimensionless parameters & dimensional analysis of convective mass transfer, Evaporation of water in air.

TOTAL = 45L + 15 :60 PERIODS

REFERENCE BOOKS:

1. 1. J.P. Holman, "Heat Transfer", McGraw Hill Book Co. 9th edition, 2008.
2. Roshenow, W. Hartnell, J. Ganic, "Hand Book of Heat Transfer", Vol. 1 & 2, Mcgraw Hill, 2005.
3. Incropera & Hewitt, "Fundanentals of Heat & Mass Transfer", John Willey, 2005.
4. Engineering heat & mass transfer by **Mahesh M. Rathore**.
5. S.P.Sukhatme "Heat Transfer " University Press
6. Eckert and Drake. Heat and Mass transfer. McGraw Hill
7. Collier, J.B. and Thome, J.R., Convective boiling and condensation, Oxford Science Publications, 1994.
8. L S Tong and Y S Tang. Boiling Heat Transfer and Two-Phase Flow. Taylor and Francis, 1997.
9. P.B Whalley. Boiling, Condensation and Gas-Liquid Flow. Oxford University Press, 1987.
10. Louis C Burmeister, Convective Heat Transfer, John Wiley and Sons, 1993.
11 Adrian Bejan, Convective Heat Transfer, John Wiley and Sons, 1995.

CY9313 VACCUM ENGINEERING L T P C
3 0 0 3

UNIT I EQUATION OF STATE 9

For ideal gases ,real gases ,velocity and speed of gas molecules ,the mean free path ,volume occupied by gas molecules.

UNIT II BASIC THEORY OF PUMPING 9

Basic definitions, resistance and conductance of arbitrary vacuum pipe work, fundamental equation of vacuum technique, regions of gas flow in pipes, calculation of pump down time. Interaction of gases with solid-taking up and evolution of gases by solids, adsorption and desorption of gases.

UNIT III PRODUCTION OF VACUUM 9

classification of vacuum pump-Calculation, operating limits of vacuum pump, their ranges, Types of vacuum pumps-oil sealed rotary, roots blower, ejector ,diffusion, turbo molecular ,sorption, getter pumps ,cold cathode &cryogenic pumps principles ,construction ,operation of pump and their salient features.

UNIT IV VACUUM GAUGES 9

classification –ranges of vacuum gauges, McLeod, mechanical, thermal conductivity gauges, hot cathode and cold cathode ionization gauges, ionization gauges with upper range-principle, construction and salient features. Metered leak measurement.
Leak hunting: Tightness of vacuum system, leak detection methods, halide leak detector, and mass spectrometer leak detector.

UNIT V VACUUM SYSTEM COMPONENTS 9

demountable vacuum joints, electrical lead ,introduction to vacuum valves, various types, their selection. Vacuum materials:-basic requirements, metals & their alloys, non metals, pump fluids. Selection of pumping facilities –determination of intrinsic speed-matching pumps operating in series and in parallel, calculation of fire vacuum cylinders. . Application of vacuum – vacuum systems for space simulation chamber,

TOTAL: 45 PERIODS

REFERENCE BOOKS:

1. Fundamentals Of Vacuum Techniques-A Pipko
2. Vacuum technology: Andrew Gutheries.
3. Vacuum technology :A.roth
4. Hand book of high vacuum engg .:Steinherz.

CY9314 ADVANCED REFRIGERATION L T P C
3 1 0 4

UNIT I 12

Balancing of vapor compression refrigeration system, Dual pressure vapor compression system and its analysis, Compound compression with flash cooler and flash intercooler, multiple expansions, parallel operation, sectionalizing, booster operations, various types of cascade systems analysis

UNIT II **12**

Refrigerants: Ecofriendly refrigerants & their properties, secondary Refrigerants, mixture of refrigerants, azeotropics, salient characteristics of various refrigerants. Synthetic lubricating oil &their properties

UNIT III **12**

Absorption refrigeration: H-x charts of LiBr-H2O and NH3-H2O solutions.,
analysis of vapor absorption refrigeration system on H-X charts, mass concentration &equilibrium charts , heat balance, COP comparison with vapor compression refrigeration systems, two stage vapor absorption refrigeration system ,balancing of vapor absorption refrigeration systems.

UNIT IV **12**

Air cycle refrigeration, Analysis of various cycles and their applications. Calculations of COP Steam jet refrigeration - cycle analysis, analysis on H-O charts performance, control and various applications. Thermo-electric refrigeration: Thermo-electric effects, analysis of thermoelectric cooling, COP, FOM, thermoelectric, materials.

UNIT V **12**

Heat pumps: Sources and sinks, refrigerant circuits, heating and cooling performance of heat pumps. Design of refrigeration systems for industrial &other application for transport refrigeration ,walk in coolers & cold storages for different applications. Preservation & processing of food by use of refrigeration.

TOTAL: 60 PERIODS

REFERENCE BOOKS:

1. Mechanical refrigeration, sparks and dilio
2. Refrigeration and air conditioning, stocker
3. Refrigeration and air conditioning, Jordan and priester
4. Refrigeration and air conditioning, C. P. Arora
5. Ashrae hand book, refrigeration 1998
6. Thermal environmental engineering-threlked 1998
7. Industrial refrigeration handbook ,stoecker,1998M.E. I(MECHANICAL)

CY9316 **CRYOGENIC ENIGEERING LABORATORY** **L T P C**
0 0 3 2

Expriments on Temperature measurement and calibration, physical properties of materials at Cryogenic Temperature, Electrical and Magnetic properties of Superconductors, Vacuum Technology.

ELECTIVES LIST

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

UNIT I

Advanced heat transfer: 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

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

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

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

REFERENCE BOOKS:

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.

REFERENCE BOOKS:

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

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

UNIT IV

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: 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

REFERENCE BOOKS:

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:

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:

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:

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:

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 :

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

Magnetic refrigerator:

Magnetic refrigerator –Its development and its utility in magnetic hydrogen liquefier. Government Cryocooler development program Military space cryogenic cooling requirement, Linear drive Cryocooler for weapon system, Cryocooler reliability

TOTAL: 45 PERIODS

REFERENCE BOOKS:

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 IV 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

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

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

UNIT III

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

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

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.

REFERENCE BOOKS:

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

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

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

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

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

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

REFERENCE BOOKS:

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:

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:

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

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

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

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

REFERENCE BOOKS:

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

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

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

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

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

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.

REFERENCE BOOKS:

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 1 0 4

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

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

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

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

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

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

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

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

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

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

UNIT I

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

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

UNIT III

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

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

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.