PSN COLLEGE OF ENGINEERING AND TECHNOLOGY

(An Autonomous Institution Recognised by AICTE, New Delhi

and Affiliated to Anna University, Chennai)

Accredited with A+ Grade by NAAC. An ISO 9001:2015 Certified Institution

Melathediyoor, Tirunelveli – 627 152

Curriculum approved by Board of Studies for Core and

Interdisciplinary Service Courses offered in I to IV semesters

M.E. - Cryogenic Engineering

Under Regulation 2022

PSN COLLEGE OF ENGINEERING AND TECHNOLOGY

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REGULATIONS – R2022 (Full Time)

M.E. – CRYOGENIC ENGINEERING

INDEX

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REGULATIONS – R2022 (Full Time)
M.E. CRYOGENIC ENGINEERING

1. INSTITUTION VISION & MISSION

Institution Vision	To emerge as a pioneer institute inculcating engineering education skills, research, values and ethics.	
Institution Mission	**IM-1**	To achieve greater heights of excellence in technical knowledge and skill development through innovative teaching and learning practices.
	IM-2	To develop the state of art infrastructure to meet the demands of technological revolution.
	IM-3	To improve and foster research in all dimensions for betterment of society.
	IM-4	To develop individual competencies to enhance employability and entrepreneurship among students.
	IM-5	To instill higher standards of discipline among students, inculcating ethical and moral values for societal harmony and peace.

2. DEPARTMENT VISION & MISSION

Department Vision	To Pre-eminent department to produce quality mechanical engineering graduates to meet national and global needs.	
Department Mission	**DM-1**	To educate students to be creative, inquisitive and innovative to become entrepreneurs.
	DM-2	To instil advanced knowledge with research capabilities for global careers and higher studies.
	DM-3	To inculcate moral and ethical standards in life and career.

3. PROGRAM EDUCATIONAL OBJECTIVES (PEOS):

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)	
Sl. No.	**PEOs**
PEO1	The Graduates of Mechanical Engineering program will excel in technical knowledge, innovation and entrepreneurial skills.
PEO2	The Graduates will be able to design and develop various Mechanical Systems for interdisciplinary and multi-disciplinary applications.
PEO3	The Graduates will exhibit ethical attitude, human values, leadership quality and ability to solve engineering problems to a broader social context.

4. PROGRAM OUTCOMES (POS):

PO's No	KNOWLEDGE	STATEMENTS
1	Engineering Knowledge	Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2	Problem Analysis	Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3	Design / Development of Solutions	Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4	Conduct Investigations of Complex Problems	Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5	Modern Tool usage	Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6	The Engineer and Society	Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7	Environment and Sustainability	Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8	Ethics	Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9	Individual and Team Work	Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10	Communication	Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

11	Project Management and Finance	Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12	Life-long Learning:	Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

5. PROGRAM SPECIFIC OUTCOMES (PSOS):

PROGRAM SPECIFIC OUTCOMES (PSOs)
PSO1: To Prepare Mechanical Engineering Graduates with an outstanding knowledge of industrial automation for a successful career **PSO2**: To develop an ability to accept global challenges and apply engineering knowledge for solving various problem in the area of mechanical engineering using computer aided engineering

PSN COLLEGE OF ENGINEERING AND TECHNOLOGY
(Autonomous)

CURRICULUM – R 2022

M.E. – CRYOGENIC ENGINEERING

SEMESTER I

SL. NO.	COURSE CODE	COURSE NAME	CLASSIFICATION		L	T	P	C
1	CS624001	Applied Mathematics	IC	Theory	3	1	0	4
2	CY622001	Cryogenic Engineering & Applications	PC	Theory	3	0	0	3
3	CY622002	Advanced Heat and Mass Transfer	PC	Theory	3	0	0	3
4	CY622003	Advanced Refrigeration and Air Conditioning Systems	PC	Theory	3	0	0	3
5		Programme Elective I	PE	Theory	3	0	0	3
6	CY622004	Research Methodology & IPR	IC	Theory	3	0	0	3
7	CY622501	Technical Seminar-I	EEC	Practical	2	0	0	1.0
8	CY622101	Term Paper on Topics of Relevance to Cryogenic Engineering	PC	Practical	0	0	4	2
9		English for Manuscript Writing	IM	Institute Mandatory	2	0	0	0
				TOTAL	22	1	4	**22**

SEMESTER II

SL. NO	COURSE CODE	COURSE TITLE	CLASSIFICATION		L	T	P	C
THEORY								
1	CY622005	Advanced Cryogenic Systems	PC	Theory	3	0	0	3
2	CY622006	Advanced Design of Cryogenic Equipment And Accessories	PC	Theory	3	0	0	3
3	CY622007	Advanced Fluid Mechanics	PC	Theory	3	0	0	3
4	CY622008	Cryogenic Plants and Equipments	PC	Theory	3	0	0	3
5		Programme Elective -II	PE	Theory	3	0	0	3
6		Programme Elective -III	PE	Theory	3	0	0	3
7	CY622502	Technical Seminar-II	EEC	Theory	2	0	0	2
8	CY622102	Advanced Cryogenic Engineering Laboratory	PC	Theory	0	0	4	2
9		Literature reading skills	IM	Practical	2	0	0	0
				TOTAL	22	0	4	22

SEMESTER III

SL. NO	COURSE CODE	COURSE TITLE	CLASSIFICATION		L	T	P	C
THEORY								
1		Programme Elective-IV	PE	Theory	3	0	0	3
2		Programme Elective-V	PE	Theory	3	0	0	3
3		Institute Elective	IE	Theory	3	0	0	3
4	CY622301	Project Phase - I	EEC	Theory	0	0	8	8

TOTAL	9	0	8	17

SEMESTER IV

SL. NO	COURSE CODE	COURSE TITLE	CLASSIFICATION		L	T	P	C
THEORY								
1	CY622302	Project Phase - II	EEC	Theory	0	0	12	12
				TOTAL	0	0	12	**12**

PROGRAMME ELECTIVE - I							
Sl.No	**Course code**	**Course Name**	**Classification**	**L**	**T**	**P**	**C**
1	CY622201	Engineering Materials for Low Temperature Applications	PE	3	0	0	3
2	CY622202	Productivity Management and Re-engineering	PE	3	0	0	3
3	CY622203	Cryophysics	PE	3	0	0	3
4	CY622204	Systems and Simulation	PE	3	0	0	3

PROGRAMME ELECTIVE - II							
Sl.No	**Course code**	**Course Name**	**Classification**	**L**	**T**	**P**	**C**
1	CY622205	Materials Structure and Properties	PE	3	0	0	3
2	CY622206	Advanced Vacuum Techniques	PE	3	0	0	3
3	CY622207	Computer Aided Design Of Cryogenic Process	PE	3	0	0	3
4	CY622208	Cryogenic Heat Exchangers	PE	3	0	0	3

PROGRAMME ELECTIVE - III							
Sl.No	**Course code**	**Course Name**	**Classification**	**L**	**T**	**P**	**C**
1	CY622209	Advanced Cryo Coolers	PE	3	0	0	3
2	CY622210	Engineering Materials	PE	3	0	0	3
3	CY622211	Super Conductivity and Low Temperature Physics	PE	3	0	0	3

4	CY622212	Material Characterization Techniques	PE	3	0	0	3
5	CY622213	Advanced computational Fluid Dynamics	PE	3	0	0	3

PROGRAMME ELECTIVE - IV							
Sl.No	**Course code**	**Course Name**	**Classification**	**L**	**T**	**P**	**C**
1	CY622214	Low Temperature Measurement& Instrumentation	PE	3	0	0	3
2	CY622215	Cryo fuel Systems	PE	3	0	0	3
3	CY622216	Radiant Heating And Cooling Systems	PE	3	0	0	3
4	CY622217	Advanced Thermodynamics	PE	3	0	0	3
5	CY6222218	Food Processing, Preservation and Transport	PE	3	0	0	3

PROGRAMME ELECTIVE - V							
Sl.No	**Course code**	**Course Name**	**Classification**	**L**	**T**	**P**	**C**
1	CY622219	Industrial Refrigeration Systems	PE	3	0	0	3
2	CY622220	Computer Simulation of Refrigeration & Air-conditioning Systems	PE	3	0	0	3
3	CY622221	Advanced Cryogenics & Applied Superconductivity	PE	3	0	0	3
4	CY622222	Design of Condensers, Evaporators & Cooling Towers	PE	3	0	0	3
5	CY622223	Advanced Cryogenic Rocket Propulsion	PE	3	0	0	3

INSTITUTE ELECTIVES - PG							
Sl.No	**Course code**	**Course Name**	**Classification**	**L**	**T**	**P**	**C**
1	CY622901	Fundamentals of Cryogenic Engineering & Applications	IC	3	0	0	3

Chairman
Board of Studies
Mechanical Engineering
PSNCET (Autonomous)

PSN COLLEGE OF ENGINEERING AND TECHNOLOGY

(Autonomous)

CURRICULUM – R 2022

M.E. – CRYOGENIC ENGINEERING

SUMMARY SHEET

SEMESTER	I	II	III	IV	V	VI	VII	VII	TOTAL
CREDITS	22	22	17	12					**74**

Chairman
Board of Studies
Mechanical Engineering
PSNCET (Autonomous)

Course Code	FUNDAMENTALS OF CRYOGENIC ENGINEERING & APPLICATIONS	L	T	P	C
CY622901		3	0	0	3
Course Category: ***Professional Core***	**Course Type:** ***Theory***				

Course Objective(s):

To enhance the basic knowledge in the field of cryogenics and to provide a vast exposure to cryogenic engineering.

Course Outcomes: (COs)

At the end of the course, the student will be able to

CO 1	Ability to understand the fundamentals of cryogenic engineering.
CO 2	Ability to gain knowledge in various measurement systems.
CO 3	Ability to understand the importance of cryogenic insulations
CO 4	Ability to gain Knowledge in hazard waste management and superconductive devices.
CO 5	Ability to obtain ideas in the various applications of cryogenic systems.

UNIT I INTRODUCTION **9**

Insight on Cryogenics, Properties of Cryogenic fluids, Material properties at Cryogenic Temperatures. Applications of Cryogenics in Space Programs, Superconductivity, Cryo Metallurgy, Medical applications.

UNIT II LIQUEFACTION CYCLES **9**

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

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, opacities powder insulation, multi layer insulation, comparison of performance of various insulations.

UNIT IV HAZARD WASTE MANAGEMENT **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 environmental safety department. Powder insulation by boil off calorimeter method.

UNIT V SALIENT APPLICATIONS OF CRYOGENIC SYSTEMS **9**

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

TEXT BOOKS:

1. Cryogenic Systems (Monographs on Cryogenics, No 3) by Randall F. Barron, McGraw-Hill 1985.
2. Applications of Cryogenic technology Robert W. Vance ,Volume II Tinnon-brown Inc,1970.
3. Cryogenic fundamentals- Haselden, Academic press New York,1972.

REFERENCES:

1. Advance cryogenic – C.A.Bailey, Plenum press 1971.
2. Cryogenic engineering - Russell B.Scott Met Chemical Research 1988.
3. Cryogenic Engineering & Gas Applications , - Dr. P.K.Bose Everest Publishing House 2005.

WEB REFERENCES:

1. https://www.youtube.com/watch?v=4gGMBNEzeuc
2. https://www.youtube.com/watch?v=f42L-HEWg0Q

CO PO MAPPING:

COs	**POs**											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	-	-	-	-	-	-	-	-	-	-	2
CO2	3	2	2	-	-	-	-	-	-	-	-	2
CO3	3	-	-	-	-	-	-	-	-	-	-	2
CO4	3	-	-	-	-	-	3	-	-	-	-	2
CO5	3	-	-	-	-	-	3	-	-	-	-	2

Course Code	ADVANCED HEAT AND MASS TRANSFER	L	T	P	C
CY622002		3	0	0	3
Course Category: *Professional Core*	**Course Type:** *Theory*				

Course Objective(s):

To provide adequate knowledge in heat and mass transfer and also various methods are to be studied.

Course Outcomes: (COs)

At the end of the course, the student will be able to

CO 1	Ability to gain knowledge in conduction and radiation.
CO 2	Ability to obtain knowledge in heat transfer systems.
CO 3	Ability to understand the heat exchanger and its design
CO 4	Ability to understand the mass transfer and modes.
CO 5	Ability to obtain ideas in the various applications of cryogenic systems.

UNIT I CONDUCTION AND RADIATION HEAT TRANSFER 9

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

UNIT II TURBULENT FORCED CONVECTIVE HEAT TRANSFER 9

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

UNIT III TWO PHASE FLOW & HEAT TRANSFER 9

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 9

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 **9**

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

TEXT BOOKS:

1. J.P. Holman, ―Heat Transfer‖, McGraw Hill Book Co. 9th edition, 2008.
2. Younus.A.Cenjel ―Heat and mass transfer – A Practical approach‖ Mc Graw Hill Book Co. 2004.
3. L S Tong and Y S Tang. Boiling Heat Transfer and Two-Phase Flow. Taylor and Francis, 1997.

REFERENCES:

1. Roshenow, W. Hartnell, J. Ganic, ―Hand Book of Heat Transfer‖, Vol. 1 & 2, Mcgraw Hill, 2005.
2. Incropera & Hewitt, ―Fundamentals of Heat & Mass Transfer‖, John Willey, 2005.
3. Collier, J.B. and Thome, J.R., Convective boiling and condensation, Oxford Science Publications, 1994.

WEB REFERENCES:

1. https://www.youtube.com/watch?v=qa-PQOjS3zA
2. https://www.youtube.com/watch?v=QcTr0-QrSMY

CO PO MAPPING:

COs	POs											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	2	-	-	-	-	-	-	-	2
CO2	3	3	2	2	-	-	-	-	-	-	-	2
CO3	3	3	2	2	-	-	-	-	-	-	-	2
CO4	3	3	2	2	-	-	-	-	-	-	-	2
CO5	3	3	2	2	-	-	-	-	-	-	-	2

Course Code	ADVANCED REFRIGERATION AND AIR CONDITIONING SYSTEMS	L	T	P	C
CY622003		3	0	0	3
Course Category: ***Professional Core***	**Course Type:** ***Theory***				

Course Objective(s):

To obtain knowledge in the refrigeration systems and to gain ideas in the process of various refrigeration concepts .

Course Outcomes: (COs)

At the end of the course, the student will be able to

CO 1	Ability to obtain knowledge in refrigeration systems.
CO 2	Ability to obtain ideas in refeigerants and its properties.
CO 3	Understanding of absorption refrigeration systems.
CO 4	Knowledge in aircycle refrigeration systems.
CO 5	Knowledge in heat pumps and performances.

UNIT IINTRODUCTION **9**

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 IIREFRIGERANTS **9**

Applications, Unit of refrigeration – Ideal cycles - Classification of Refrigerants, Refrigerant properties, Oil Compatibility, Environmental Impact-Montreal / Kyoto protocols-Eco Friendly Refrigerants, alternatives to HCFCS, Secondary Refrigerants.

UNIT III REFRIGERATION CYCLES – ANALYSIS **9**

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

UNIT IV AIR CYCLE REFRIGERATION **9**

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. Thermoelectric refrigeration: Thermo-electric effects, analysis of thermo electric cooling, COP, FOM, thermoelectric, materials.

UNIT V HEAT PUMPS **9**

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.

TEXT BOOK:

1. Refrigeration and air conditioning, C. P. Arora Tata Mcgraw - Hill Education Third edition 2008.
2. Ashrae hand book, refrigeration Amer society of heating Har/ Cdr Edition 2010.
3. Refrigeration and air conditioning, W F stocker and J W Jones Mc Graw Hill publishing company , Second edition 2013.

REFERENCES:

1. Mechanical refrigeration, sparks and dilio
2. Industrial refrigeration handbook ,stoecker,1998M.E. I(MECHANICAL)
3. Advances in Air Conditioning and Refrigeration: Select Proceedings of RAAR 2019. (2020). Germany: Springer Singapore.

WEB RESOURCES:

1. https://www.youtube.com/watch?v=nlsNmhiID74
2. https://www.youtube.com/watch?v=QZp7LzYEMCs

CO PO MAPPING:

COs	POs											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	-	-									2
CO2	3	2	2	2								2
CO3	3	2	2	2								2
CO4	3	2	2	2								2

CO5	3	-	-									2

Course Code	RESEARCH METHODOLOGY & IPR	L	T	P	C
CY622004		3	0	0	3
Course Category: *Institutional Core*	**Course Type:** *Theory*				

Course Objective(s):

- To give an overview of the research methodology and explain the technique of defining a research
- Problem To explain the functions of the literature review in research.
- To explain carrying out a literature search, its review, developing theoretical and conceptual frameworks and writing a review.
- To explain various research designs and their characteristics.
- To explain the details of sampling designs, measurement and scaling techniques and also different methods of data collections.
- To explain several parametric tests of hypotheses and Chi-square test.
- To explain the art of interpretation and the art of writing research reports.
- To explain various forms of the intellectual property, its relevance and business impact in the changing global business environment.

To discuss leading International Instruments concerning Intellectual Property Rights.

Course Outcomes: (COs)

At the end of the course, the student will be able to

CO 1	Ability to understand the concepts of research methodology.
CO 2	Knowledge in understanding of literature.
CO 3	Knowledge in understanding of Sample Surveys, Measurement and Scaling.
CO 4	Ability to understand the Testing of Hypotheses, Chi-Square Test.
CO 5	Knowledge in Intellectual Property.

UNIT I RESEARCH METHODOLOGY **9**

Introduction, Meaning of Research, Objectives of Research, Types of Research, Research Approaches, Significance of Research, Research Methods versus Methodology, Research and

Scientific Method, Research Process, Criteria of Good Research, Problems Encountered by Researchers in India. Research Problem, Selecting the Problem, Necessity of Defining the Problem, Technique Involved in Defining a Problem, An Illustration.

UNIT II REVIEWING THE LITERATURE & RESEARCH DESIGN 9

Place of the literature review in research, Bringing clarity and focus to research problem, Improving research methodology, Broadening knowledge base in research area, Enabling contextual findings, Review of the literature, searching the existing literature, reviewing the selected literature, Developing a theoretical framework, Developing a conceptual framework, Writing about the literature reviewed. Meaning of Research Design, Need for Research Design, Features of a Good Design, Important Concepts Relating to Research Design, Different Research Designs, Basic Principles of Experimental Designs, Important Experimental Designs.

UNIT III DESIGN OF SAMPLE SURVEYS, MEASUREMENT AND SCALING 9

Design of Sampling: Introduction, Sample Design, Sampling and Non-sampling Errors, Sample Survey versus Census Survey, Types of Sampling Designs. Qualitative and Quantitative Data, Classifications of Measurement Scales, Goodness of Measurement Scales, Sources of Error in Measurement, Techniques of Developing Measurement Tools, Scaling, Scale Classification Bases, Scaling Technics, Multidimensional Scaling, Deciding the Scale. Data Collection: Introduction, Experimental and Surveys, Collection of Primary Data, Collection of Secondary Data, Selection of Appropriate Method for Data Collection, Case Study Method.

UNIT IV TESTING OF HYPOTHESES, CHI-SQUARE TEST 9

Testing of Hypotheses: Hypothesis, Basic Concepts Concerning Testing of Hypotheses, Testing of Hypothesis, Test Statistics and Critical Region, Critical Value and Decision Rule, Procedure for Hypothesis Testing, Hypothesis Testing for Mean, Proportion, Variance, for Difference of Two Mean, for Difference of Two Proportions, for Difference of Two Variances, P-Value approach, Power of Test, Limitations of the Tests of Hypothesis. Test of Difference of more than Two Proportions, Test of Independence of Attributes, Test of Goodness of Fit, Cautions in Using Chi Square Tests.

UNIT V INTERPRETATION AND REPORT WRITING & INTELLECTUAL PROPERTY 9

Interpretation and Report Writing: Meaning of Interpretation, Technique of Interpretation, Precaution in Interpretation, Significance of Report Writing, Different Steps in Writing Report, Layout of the Research Report, Types of Reports, Oral Presentation, Mechanics of Writing a Research Report, Precautions for Writing Research Reports. Nature of Intellectual Property: Patents, Designs, Trade Mark and Copyright. Process of Patenting and Development: technological research, innovation, patenting & development. Procedure for grants of patents, Patenting under PCT.Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications. New Developments in IPR: Administration of Patent System.

TEXT BOOK:

1. Kothari, C. R. (2004). Research Methodology: Methods and Techniques. India: New Age International (P) Limited.
2. Kumar, R. (2014). Research Methodology: A Step-by-Step Guide for Beginners. United Kingdom: SAGE Publications.

REFERENCES:

1. Trochim, W. M. K. (2005). Research Methods: The Concise Knowledge Base. United Kingdom: Atomic Dog Pub.
2. Fink, A. (2010). Conducting Research Literature Reviews: From the Internet to Paper. India: SAGE Publications.
3. Deb, D., Dey, R., Balas, V. E. (2018). Engineering Research Methodology: A Practical Insight for Researchers. Germany: Springer Nature Singapore.

WEB RESOURCES:

1. https://www.youtube.com/watch?v=E2gGF1rburw&t=1s
2. https://youtu.be/dKrBVUXlRR4

CO PO MAPPING:

COs	POs											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	-				2	2			2	3

CO2	3	2	-				2	2			2	3
CO3	3	-	-				2	2			2	3
CO4	3	-	-				2	2			2	3
CO5	3	-	-				2	2			2	3

Course Code	TERM PAPER ON TOPICS OF RELEVANCE TO	L	T	P	C
CY622101	CRYOGENIC ENGINEERING	0	0	4	2
Course Category: ***Professional Core***		**Course Type:** ***Theory***			

Course Objective(s):

To enhance and obtain knowledge in the fundamentals of cryogenic engineering concepts and to develop strong skills in cryogenics.

Course Outcomes: (COs)

At the end of the course, the student will be able to

CO 1	Gain a knowledge in the cryogenic propulsion.
CO 2	Gain a knowledge in the material processing
CO 3	Ability to understand the latest developments in cryogenics
CO 4	Ability to understand properties of materials in low temperature
CO 5	Gain a knowledge in the various cryogenic applications in marine.

Some Topics are suggested below:

1. Cryogenics in propulsion.
2. Cryogenics in material processing.
3. Latest developments in production of Liquid Helium and liquid Nitrogen.
4. Effect of low temperature on engineering properties of materials (any one material for exhaustive study).
5. Cryogenic in Marine Engineering

Total -60 periods

CO PO MAPPING:

COs	**POs**											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3								2			

CO2	3								2			
CO3	3								2			2
CO4	3								2			
CO5	3								2			

NOTE:

1. Students can identify topics with the above and also of their own with the approval of course coordinator.
2. Students should submit a report at the end of the semester.
3. The report should be minimum of 20 pages and also 20 lines per page.

Course Code	ENGLISH FOR MANUSCRIPT WRITING	L	T	P	C
		2	0	0	0
Course Category: *Institute Mandatory*		Course Type: *Theory*			

Course Objective(s):

To enhance knowledge and implement ideas to write manuscript in English for publishing journals.

Course Outcomes: (COs)

At the end of the course, the student will be able to

CO 1	Understand the manuscript writing in English
CO 2	Gain knowledge in sentence making & use of words.
CO 3	Gain knowledge about plagiarism.
CO 4	Understand the importance of proofreading of manuscript.
CO 5	Apply the knowledge in literature citation.

Some Topics are suggested below:

1. Why Publish in English?
2. General Considerations in Preparing the Manuscript
3. Sentence and Paragraph Structure
4. Use of Words
5. Special Properties of Manuscript Parts
6. Plagiarism
7. Proofreading the Manuscript
8. Literature Cited

WEB RESOURSE:

1. https://www.researchgate.net/publication/301786286_Writing_Scientific_Journal_Manuscripts_in_English
2. https://www.letpub.com/author_education_manuscript_creation_for_english_language_journals_part_1

CO PO MAPPING:

COs	**POs**											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	-				2	2			2	3
CO2	3	2	-				2	2			2	3
CO3	3	-	-				2	2			2	3
CO4	3	-	-				2	2			2	3
CO5	3	-	-				2	2			2	3

Course Code	ADVANCED CRYOGENIC SYSTEMS	L	T	P	C
CY622005		3	0	0	3
Course Category: *Professional Core*	Course Type: *Theory*				

Course Objective(s):

To enhance knowledge and implement ideas in the cryogenic system and to gather knowledge in various adsorbents process.

Course Outcomes: (COs)

At the end of the course, the student will be able to

CO 1	Ability to understand the cryogenic refrigeration system.
CO 2	Understanding of refrigerators.
CO 3	Ability to gain knowledge in gas liquefaction systems.
CO 4	Understanding of various adsorbents and features
CO 5	Knowledge in process of adsorption.

UNIT ICRYOGENIC 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 -Gifford single and double volume refrigerators analysis, COP, FO, regenerators, pulse tube refrigerators-types.

UNIT IIREFRIGERATORS USING SOLIDS AS WORKING MEDIA 9

Magnetic cooling-magnetic refrigeration systems-thermal, valves-nuclear demagnetization Methods –Types -Applications.

UNIT III GAS LIQUEFACTION SYSTEMS 9

Introduction, Basics of refrigeration, Comparative study, symbols, Methods of Production, Refrigerator & Liquefier, Joule Thompson Expansion, Joule-Thompson Effect, liquefaction systems such as Linde Hampson ,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 AND HANDLING OF CRYOGENS **9**

Physical principles of adsorption, BET equation for single and multiple layer, Use of adsorption process in cryogenics static and dynamic arrangement for the sorption processes, Adsorption columns , PSA and VSA adsorption systems, isotherms, reactivisation. Cryogenic Dewar, Cryogenic Transfer Lines. Insulations used in Cryogenic Systems, Instrumentation to measure Flow, Level and Temperature.

TEXT BOOK:

1. Cryogenic Systems, Randall.F.Barron, Oxford University Press second edition ,1989 (UNIT I,II,III).
2. Cryogenic process engineering Timmerchand & Flynn Springer First edition ,2013 (UNIT IV,V)

REFERENCES:

1. “Theory and design of cryogenic systems‖, Mikulin, MIR Publication, Second edition , 2002.
2. Fundamentals of Cryogenic engineering Mamata Mukhopadhyay second edition PHI learning ,2010
3. Dinçer, I. (2017). Refrigeration Systems and Applications. Germany: Wiley.

WEB RESOURCES:

1. https://www.youtube.com/watch?v=UOi9JXlicXA
2. https://www.youtube.com/watch?v=PsXOrNumAUE

CO PO MAPPING:

COs	POs											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	2	2								2
CO2	3	-	-									2
CO3	3	2	2	2								2
CO4	3	-	-									2
CO5	3	-	-									2

Course Code	ADVANCED DESIGN OF CRYOGENIC EQUIPMENT AND ACCESSORIES	L	T	P	C
CY622006		3	0	0	3
Course Category: *Professional Core*	Course Type: *Theory*				

Course Objective(s):

To enhance knowledge in the field of gases & air separation and to get ideas in the designing of cryogenic equipments.

Course Outcomes: (COs)

At the end of the course, the student will be able to

CO 1	Understanding of gas and air purification systems.
CO 2	Ability to obtain knowledge in gas and air separation systems.
CO 3	Understanding of cryogenic liquefaction process.
CO 4	Designing of cryogenic equipments.
CO 5	Designing and understanding of cryostat and its types.

UNIT I GAS SEPARATION AND GAS PURIFICATION SYSTEM 9

Introduction, gas separation, Ideal separation system, Parametric study, thermal equilibrium, thermostatic properties, temperature composition diagram, Dalton's law+Raoult's law, Gibbs's Dalton's law, G-D's law+Raoult's law, Distribution coefficient, Enthalpy composition diagram, gas separation, Real Rectification Column, Theoretical plate calculation, Mccabe-Thiele method.

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 GAS LIQUEFACTION AND REFRIGERATION SYSTEMS 9

Introduction, Basics of refrigeration, Refrigerator & Liquefier, Joule Thompson expansion, Joule Thompson effect, Real gas, Real gas equation, Isenthalpic line, Ideal gas law, Gas liquefaction systems, Ideal work requirement. Ideal thermodynamic cycle, Gas liquefaction parameters, Gas liquefaction fundamentals, Liquid EU, compressed gas, Liquid yield.

UNIT IV CRYOGENIC EQUIPMENTS **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 CRYOSTAT **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.

TEXT BOOK:

1. Fundamentals of Cryogenic engineering Mamata Mukhopadhyay second edition PHI learning ,2010.(UNIT I,II,III)
2. Cryogenic Laboratory Equipment (International Cryogenic s monograph series) A.J.Croft Springer First Edition 1970.(UNIT IV)
3. "Theory and design of cryogenic systems‖, Mikulin, MIR Publication, Second edition , 2002.(UNIT V)

REFERENCES:

1. Cryogenic process engineering Timmerchand & Flynn Springer First edition ,2013.

WEB RESOURCES:

1. https://www.youtube.com/watch?v=UOi9JXlicXA
2. https://www.youtube.com/watch?v=PsXOrNumAUE&t=4s

CO PO MAPPING:

COs	POs											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2-	-									2
CO2	3	2	-									2
CO3	3	2	-									2
CO4	3	-	-									2
CO5	3	-	-									2

Course Code	ADVANCED FLUID MECHANICS	L	T	P	C
CY622007		3	0	0	3
Course Category: *Professional Core*	Course Type: *Theory*				

Course Objective(s):

- To enhance ideas in the basic equations of fluid flow.
- To obtain knowledge in the potential flow and viscous flow theory
- To obtain knowledge in the boundary layer concepts.
- To enhance the ideas in compressible fluid flows

Course Outcomes: (COs)

At the end of the course, the student will be able to

CO 1	Ability to understand the concepts of basic fluid flow.
CO 2	Knowledge in understanding of potential flow theory.
CO 3	Knowledge in understanding of viscous flow theory.
CO 4	Ability to understand the boundary layer concept.
CO 5	Knowledge in compressible fluid flows.

UNIT I BASIC CONCEPTS AND FLUID PROPERTIES 9

Definition of fluids, continuum concept, indicial notation, tensors, Cauchy stress tensor, fluid statics, fluid properties, importance of studying viscous flows, examples of fluid flow problems. Eulerian and Lagrangian description, strain-rate, vorticity, circulation, streamlines, streaklines and pathlines, streamfunction, Derivation of continuity equation, Navier--Stokes (N--S) equation and energy equations; Stokes hypothesis, special cases, conservative and non-conservative forms, boundary conditions, cylindrical coordinates, vorticity equation, control volume formulation, integral and differential approaches in fluid dynamics, laminar and turbulent flow

UNIT II POTENTIAL FLOW THEORY 9

Rotational and irrotational flows - circulation – vorticity - stream and potential functions for standard flows and combined flows – representation of solid bodies by flow patterns. 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 air foil 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.

TEXT BOOK:

1. Streeter, V.L., Wylie, E.B., and Bedford, K.W., Fluid Mechanics, WCB McGrawHill, Boston, 1998. (UNIT I, II)
2. Munson, B.R., Young, D.F. and Okiisi, T.H., Fundamentals of Fluid Mechanics, John Wiley and Sons Inc., NewYork, 1990
3. Houghten, E.L. and Carruthers, N.B., Aerodynamics for Engineering Students, Arnold Publishers, 1993.(UNIT IV,V)

REFERENCES:

1. Kumar, K.L., Engineering Fluid Mechanics, Eurasia Publishing House, New Delhi, 2002.
2. Anderson, J.D., Fundamentals of Aerodynamics, McGraw Hill, Boston, 2001.
3. Graebel, W. P. (2007). Advanced Fluid Mechanics. Netherlands: Elsevier Science.

WEB RESOURCES:

1. https://youtu.be/PVonbnDtZ4w
2. https://youtu.be/DKDx4g4APa0

CO PO MAPPING:

COs	**POs**											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	2	2								2
CO2	3	2	2	2								2
CO3	3	2	2	2								2
CO4	3	2	2	2								2
CO5	3	2	2	2								2

Course Code	CRYOGENIC PLANTS AND EQUIPMENTS	L	T	P	C
CY622008		3	0	0	3
Course Category: *Professional Core*		Course Type: *Theory*			

Course Objective(s):

- To enhance ideas in the cryogenic plants and equipments.

Course Outcomes: (COs)

At the end of the course, the student will be able to

CO 1	Ability to understand the concepts of gas separation and gas purification.
CO 2	Knowledge in understanding of air separation and air purification.
CO 3	Knowledge in understanding of modern air liquefaction .
CO 4	Ability to understand the storage system.
CO 5	Knowledge in fabrication and joining.

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 9

Modern air liquefaction , liquid nitrogen and oxygen plants.

UNIT IV STORAGE **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 CRYOSTAT **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.

TEXT BOOK:

1. Cryogenic Systems, Barron, McGraw Hill Book Co.
2. Cryogenic Processes and Equipment, 1989: The Seventh Intersociety Cryogenics Symposium, Presented at the Twelfth Annual Energy-Sources Technology Conference and Exhibition, Houston, Texas, January 22-25, 1989. (1988). United States: American Society of Mechanical Engineers, United Engineering Center.

REFERENCES:

1. Theory and design of cryogenic systems : A.Arkherov
2. Cryogenic process engineering Timmerchand & Flynn.
3. Jha, A. (2011). Cryogenic Technology and Applications. Netherlands: Elsevier Science.

WEB RESOURCES:

1. https://www.youtube.com/watch?v=PXtSZi9HO0w
2. https://www.youtube.com/watch?v=e3BYTtlp4AM

CO PO MAPPING:

COs	POs											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	-									2
CO2	3	2	-									2

CO3	3	-	-									2
CO4	3	-	-									2
CO5	3	-	-									2

Course Code	ADVANCED CRYOGENIC ENGINEERING	L	T	P	C
CY622102	LABORATORY	0	0	4	2
Course Category: *Professional Core*	Course Type: *Practical*				

Course Objective(s):

To enhance knowledge in the various measurement techniques by performing practical experiments in the laboratory at cryogenic temperatures.

Course Outcomes: (COs)

At the end of the course, the student will be able to

CO 1	At the end the students shall have an exposure to experimented the different measurementTechniques at cryogenic low temperatures

LIST OF EXPERIMENTS

1. Calibration of a cryogenic temperature measuring device
2. Temperature measurements in cryogen and also in low temperature set up.
3. Strain measurements in cryo-treated plate and also inside Dewar.
4. Electrical conductivity of titanium alloy and Getwick niobium wires.
5. Demonstration of diamagnetic nature of YBCO superconductor pellets.
6. Measurement of lowest temperature achieved and COP of a refrigerator.
7. Demonstration of strength and hardness improvement in cryo-treatment.
8. Measurement of electrical conductivity of cryogenically treated copper.

TOTAL:60 PERIODS

Course Code	LITERATURE READING SKILLS	L	T	P	C
		3	0	0	3
Course Category: *Institute Mandatory*	Course Type: *Theory*				

Course Objective(s):

To enhance knowledge in the literature reading skills to analyse the various journals and papers.

Course Outcomes: (COs)

At the end of the course, the student will be able to

CO 1	Gain a knowledge in decode the concepts in the journals
CO 2	Understand the vocabulary and deliver with fluency.
CO 3	Gain a knowledge in sentence making and cohesion.
CO 4	Understand the background knowledge.
CO 5	Apply the knowledge to make the work with ease and working attention.

LIST OF EXERCISES:

1. Decoding.
2. Fluency.
3. Vocabulary.
4. Sentence construction and cohesion.
5. Reasoning and background knowledge.
6. Working memory and attention.

WEB RESOURSE:

1. https://www.understood.org/en/articles/6-essential-skills-needed-for-reading-comprehension
2. https://www.jmu.edu/valleyscholars/files/studyreadingskills.pdf

Programme Elective -I

Course Code	ENGINEERING MATERIALS FOR LOW TEMPERATURE APPLICATIONS	L	T	P	C
CY622201		3	0	0	3
Course Category: *Professional Elective*	Course Type: *Theory*				

Course Objective(s):

To enhance ideas in the various materials and testing process for low temperature applications.

Course Outcomes: (COs)

At the end of the course, the student will be able to

CO 1	Ability to understand the behaviour of materials.
CO 2	Understanding of material selection.
CO 3	Understanding of non- metallic materials
CO 4	Ability to gain a knowledge in testing methods and techniques of the materials
CO 5	Ability to gain a knowledge in modern metallic materials.

UNIT I MATERIAL BEHAVIOUR 9

Deformation process in pure, impure metals and alloys–effect of low temperature transformation-Stress and strain relations-Elements of elasticity and plasticity-Plastic deformation -Fracture and Fracture Mechanics-Fatigue- Low temperature deformation and creep- Deformation of noncrystalline materials- Deformation of composite materials

UNIT II MATERIALS SELECTION 9

Classification of engineering materials – selection of materials for engineering purposes – selection of materials and shape –classification metal and alloys, polymers, ceramics and glasses, composites, natural materials, smart materials - physical, metrical properties of metals

UNIT III NON-METALLIC MATERIALS 9

Polymeric materials for Cryogenic Application, Ceramics and Glasses, Cryogenic properties of composites, Polymeric materials–Formation of polymer structure– Production techniques of fibres, foams, 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 9

Basic types of Cryostats 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 9

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

TEXT BOOK:

1. Wigley D.A., ―Mechanical Properties of Materials at Low Temperatures‖, Plenum Press, NewYork, 1972
2. Thomas H. Courtney, ―Mechanical Behaviour of Materials‖, (2nd Edition), McGraw-Hill 2004.

REFERENCES:

1. Richard P. Reed, Alan F. Clark, Materials at low Temperature, ASME International, 1983.
2. S.W. Van Sciver, Helium Cryogenics, International Cryogenics Monograph Series, DOI 10.1007/978-1-4419-9979-5_2, # Springer Science+Business Media, LLC 2012
3. Zainul Huda, Mechanical Behavior of Materials, Springer Cham publications,2021

WEB RESOURSE:

1. https://www.youtube.com/watch?v=JQG2m9jSkws
2. https://www.youtube.com/watch?v=2Lf7dABEzfg

CO PO MAPPING:

COs	POs											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	2									2
CO2	3	2	2									2
CO3	3	2	2									2
CO4	3	3	3									3
CO5	3	2	2									2

Course Code	PRODUCTIVITY MANAGEMENT AND RE-ENGINEERING	L	T	P	C
CY622202		3	0	0	3
Course Category: *Professional Elective*	Course Type: *Theory*				

Course Objective(s):

To develop ideas and sharing of information in productivity management and also gaining of knowledge in reengineering concepts.

Course Outcomes: (COs)

At the end of the course, the student will be able to

CO 1	To obtain ideas in productivity engineering
CO 2	Understanding of various system approach to productivity measurement
CO 3	Understanding of organizational transformation
CO 4	Knowledge in re-engineering process models
CO 5	Knowledge in implementation of reengineering tools.

UNIT I PRODUCTIVITY **9**

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

UNIT II - PRODUCTIVITY MEASUREMENT AND EVALUATION **9**

Productivity measurement in International, National and Industrial level – Total Productivity Model -Productivity measurement in Manufacturing and Service sectors – Performance

Objective Productivity (POP) model – Need for Productivity Evaluation – Evaluation Methodology.

UNIT III PRODUCTIVITY PLANNING AND IMPLEMENTATION 9

Need for Productivity Planning – Short term and long-term productivity planning – Productivity improvement approaches, Principles – Productivity Improvement techniques – Technology based, Material based, Employee based, Product based techniques – Managerial aspects of Productivity Implementation schedule, Productivity audit and control**.**

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.

TEXTBOOKS:

1. Sumanth, D.J., ‗Productivity Engineering and Management ‘, TMH, New Delhi, 1990.

2. Edosomwan, J.A., ―Organisational Transformation and Process Re-engineering‖, LibraryCataloging in Pub. Data, 1996.

REFERENCE BOOKS:

1. Rastogi, P.N., ―Re-engineering and Re-inventing the Enterprise‖, Wheeler Pub. New Delhi 1995.

2. Premvrat, Sardana, G.D. and Sahay, B.S, ―Productivity Management – A Systems Approach‖, Narosa Publishing House. New Delhi, 1998.

3. Johnson Aimie Edosomwan, Integrating Productivity and Quality Management, Marcel Dekker Inc,2018.

WEB RESOURSES:

1. https://www.youtube.com/watch?v=VDY04ORqGpQ
2. https://www.youtube.com/watch?v=PMmTEaptm38

CO PO MAPPING:

COs	POs											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12

CO1	3	3	2									2
CO2	3	3	2									2
CO3	3	3										2
CO4	3	3										2
CO5	3	3	2									3

Course Code	CRYOPHYSICS	L	T	P	C
CY622203		3	0	0	3
Course Category: *Professional Elective*	Course Type: *Theory*				

Course Objective(s):

To enhance knowledge in the cryophysics and to gain ideas in the measurement systems and various applications for low temperatures.

Course Outcomes: (COs)

At the end of the course, the student will be able to

CO 1	Ability to obtain knowledge in quantum mechanics.
CO 2	Ability to obtain ideas in refrigerants and its properties.
CO 3	Understanding of absorption refrigeration systems.
CO 4	Knowledge in air-cycle refrigeration systems.
CO 5	Knowledge in heat pumps and performances.

UNIT I - INTRODUCTION **9**

Introduction to quantum mechanics, the electronic structure of atoms, Molecular orbits and Covalent bonds, Molecular interaction, Stereochemistry and Chirality, Thermodynamics-Entropy, Enthalpy, Free energy of a system, Chemical Potential, Oxidation-Reduction Potential, Radioactivity-rate of radioactivity decay and application of radio isotopes.

UNIT II MEASUREMENT SYSTEMS FOR LOW TEMPERATURES **9**

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

UNIT III - CHROMATOGRAPHY **9**

Separation techniques-Chromatography-Column Chromatography, Thinlayer Chromatography, Paper Chromatography, Adsorption Chromatography, partition Chromatography, Gas Liquid Chromatography, Ion-exchange Chromatography, Molecular Exclusion Chromatography, Affinity Chromatography

UNIT IV APPLICATIONS OF CRYOGENIC SYSTEMS **9**

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 **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.

TEXT BOOK:

1. Randall F. Barron Cryogenic Systems Oxford University Press USA, 1985.
2. Cryogenic fundamentals- Haselden, Academic press New York, 1972

REFERENCES:

1. Advanced cryogenics. International cryogenics monograph series. Editor, Colin Alfred Bailey. Publisher, Plenum Press, 1971
2. Cryogenic technology – Robert W. Vance, Volume II Tinnon-brown Inc,1970
3. Advance cryogenic – C.A.Bailey, Plenum press 1971
4. Cryogenic engineering - Russell B.Scott Met Chemical Research 1988

WEB RESOURSE:

1. https://www.youtube.com/watch?v=gaBXQW9rCDA
2. https://www.youtube.com/watch?v=FOjEH4VoTxE

CO PO MAPPING:

COs	**POs**											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	2								2
CO2	3	2										2

CO3	3	2										2
CO4	3	2										2
CO5	3	2	2	2		2	2					2

Course Code	SYSTEMS AND SIMULATION	L	T	P	C
CY622204		3	0	0	3
Course Category: *Professional Elective*	Course Type: *Theory*				

Course Objective(s):

To enhance the knowledge in systems and simulation concepts and to obtain ideas in the designing of simulation language and various experiments.

Course Outcomes: (COs)

At the end of the course, the student will be able to

CO 1	Understanding of fundamentals in systems and simulation
CO 2	Knowledge in probability and statistical methods.
CO 3	Designing of simulation experiments.
CO 4	Knowledge in simulation language
CO 5	Understanding of case studies for simulation models.

UNIT I INTRODUCTION TO SYSTEMS AND SIMULATION 9

History of simulation – Concept – Types of simulation – System: system components – simulation as a decision-making tool – Advantages and limitations of simulation – Applications – Monte Carlo simulation-Simulators.

UNIT II RANDOM NUMBER 9

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 9

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 organizations.

UNIT IV SIMULATION LANGUAGE 9

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 QUEUING POLICIES, ALGORITHMS AND CASE STUDIES 9

Introduction to basic Single – pass heuristics, meta-heuristics and applications – Application of Genetic algorithms and Ant colony-based algorithms in Discrete event simulation models with simple examples. Development of simulation models using the simulation language studies for systems for systems like, queuing systems, production systems, inventory systems, maintenance and replacement systems, investment analysis and network. Manual simulation problems.

TEXT BOOKS:

1. Jerry Banks And John S.Carson," Discrete event system simulation ", Prentice Hall, Edition four 2009.

2. R.E.Shannon," Systems simulation, the art and science ", Prentice Hall, sixth edition 2008.

REFERENCE BOOKS:

1. Joe H. Mize and J. Grady Cox," Essentials of Simulation ", Prentice Hall Inc.1968.

2. Jeffrey L. Whitten, Lonnie D.Bentley and Victor M.Barice, ―System Analysis and Design Methods ", Galgotia Publications Pvt Ltd., 1991

3. Thomas J. Schriber, ―Simulation Using Gps ", John Wiley, 1974.

WEB RESOURSE:

1. https://www.youtube.com/watch?v=zmbS_TmNDP4&list=PLSGws_74K01-4rcWuB5BEATHSsOrBd1ye
2. https://www.youtube.com/watch?v=P_tbPDQ9RAM

CO PO MAPPING:

COs	POs											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	1		2					2
CO2	3	2	2									2
CO3	3	3	3	2	3		3				3	3
CO4	3	3	3	3	3		2				3	3

CO5	3	3	3	3	3		2				3	3

Programme Elective -II

Course Code	MATERIALS STRUCTURE AND PROPERTIES	L	T	P	C
CY622205		3	0	0	3
Course Category: *Professional Elective*	Course Type: *Theory*				

Course Objective(s):

- To make a student to get expertise on the structure of different kind of materials
- To make them to learn different properties of materials like thermal, mechanical, electrical, magnetic and optical etc.

Course Outcomes: (COs)

At the end of the course, the student will be able to

CO 1	Understanding the various classification of materials.
CO 2	Ability to obtain knowledge in heat and thermodynamic systems.
CO 3	Understanding various dynamic and mechanical properties of a material.
CO 4	To gain a knowledge on the thermal properties and material.
CO 5	To gain a knowledge on the magnetic properties and material.

UNIT I: MATERIAL CLASSIFICATION AND STRUCTURE 9

Engineering materials and their classification: metals/ceramics/composites, Intrinsic and extrinsic, Structure sensitive and Structure insensitive properties. Structure-property-processing co-relationship as a theme of materials science. Bravais lattice and reciprocal lattice concept; Metallic, ionic and covalent solids; Crystal structures of NaCl, CsCl, Diamond cubic, Zinc Blende, Wurtzite, Rutile, Fluorite, Fullerenes, Spinel, Perovskite etc.,

UNIT II: HEAT AND THERMODYNAMICS 9

Phonon heat capacity- Plank distribution- Density of states in one dimension- Density of states in three dimensions- Debye model for density of states- Debey T3 law- Einstein model of the density of states- Thermal expansion- Thermal conductivity- Thermal resistivity of

phone gas- Umklapp process- Imperfections- Thermodynamics for condensed phases- Internal energy - Enthalpy - Entropy- Free energy- Chemical potential- Gibbs phase rule- Unary phase diagram- The Level Rule.

UNIT III: MECHANICS OF MATERIALS 9

Elasticity- Hooke's law- Moduli and Poisson's ratio- ductility- slip incrystalline and polycrystalline materials - Annealing and recrystallization - Strength and Hardness- Thermomechanical effects - Thermo elastic effect- Tensile Test- Modulus and strength determination- Yield stress and proof stress- Toughness and Resilience - Super elasticity and super plasticity- Fracture- Molecular origins of Fracture- Griffith theory- Fatigue-Creep.

UNIT IV: THERMAL PROPERTIES OPTICAL BEHAVIOR 9

Lattice vibrations, vibrations of simple lattice-optical and acoustic phonons, Heat capacity, Thermal expansion, Thermal conductivity thermal stress in materials with example and characteristics in metals and non-metals Interaction of radiation with matter (metals and non-metals), Phosphorescence, luminescence and optical active materials, Structure property relationship in anisotropic media

UNIT V:MAGNETIC AND OPTICAL PROPERTIES OF MATERIALS 9

Magnetic properties - molecular origin of magnetism - Types of magnetism - dia, para, ferro, anti-ferro and ferri magnetism - magnetic domain and hysteresis - soft and hard magnets - Ferrites - Optical properties - reflection, refraction - refractive index - dispersion - absorption and colour - opacity - transparency - translucency - photo conduction – decay process – luminescence flurescence and phosphorescence - photo emission - stimulated emission - laser - three level and four level laser.

TEXT BOOK:

l. M.A.Wahab, Solid State Physics: Structure and Properties of Materials 2nd Edition, Narosa Book Distributors Pvt Ltd (2009) ISBN 8173196034

2. V S R Murthy, A K Jena, K P Gupta, G S Murthy, Structure and Properties ot Engineering Materials, Tata McGraw-Hill (2005) ISBN 0-07-048287-X

3. Brian S Mitchell, An Introduction to Materials Engineering and Science for Chemical and Materials Engineers, Wiley – Interscience (2004) ISBN 0-471-43623-2

REFERENCES:

1. Charles Kittel, Introduction to solid state physics, Wiley 7th edition, 1996.

2. Walter Benenson, John W.Harris, Horst Stocker, Holger Lutz, Handbook of Physics, Fourth edition, springer-Verlag publication (2002), ISBN 0-387-95269-1.
3. K H J Buschow, F R de Boer, Physics of Magnetism and Magnetic Materials, Kluwer Academic Publishers (2004), ISBN 0-306-48408-0.
4. V.Raghavan, Materials Science and Engineering, Prentice Hall,2003.
5. D.R.Tilley and J. Tilley, Super fluidity and superconductivity, 3rd Edition, Hilger, 1990.

WEB RESOURSE:

1. https://www.youtube.com/watch?v=dwm_kegn-Tg&list=PL090DAFDD7A36E27B
2. https://www.youtube.com/watch?v=Yl43KpsNncw

CO PO MAPPING:

COs	**POs**											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2-										2
CO2	3	2	2	2								2
CO3	3	2	2	2								2
CO4	3	2	2	2								2
CO5	3	2	2	2								2

Course Code	ADVANCED VACUUM TECHNIQUES	L	T	P	C
CY622206		3	0	0	3
Course Category: *Professional Elective*	Course Type: *Theory*				

Course Objective(s):

- To enhance knowledge in the basic concept of vacuum techniques and also in the vacuum production.

Course Outcomes: (COs)

At the end of the course, the student will be able to

CO 1	Ability to understand the fundamental pumping concepts.
CO 2	Ability to gain knowledge in the basic pumping theory.
CO 3	Ability to gain knowledge in the vacuum instrumentation and design.
CO 4	Ability to identify and gained ideas in vacuum system components
CO 5	Understanding of various vacuum gauges.

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**

Gas kinetic theory, pressure, conductance, gas flow regimes, vapour pressure, pumping speed, throughput. Gas surface interactions: physisorption, chemi-sorption, condensation. Vacuum Pumps: Mechanical, diffusion, molecular drag, turbo molecular, cryopumps, ion pumps - general working principles, operating regimes.

UNIT III-VACCUM INSTRUMENTATION & DESIGN **9**

Vaccum Instrumentation: Vacuum gauges, gas regulators, flow meters, residual gas analysers, interpretation of data.

Design Concepts: Materials, chambers, components, joins, seals, valves. Overall system design and integration

UNIT IV VACUUM SYSTEM COMPONENTS **9**

Demountable vacuum joints, electrical lead, introduction to vacuum valves, various types, and their election. 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

UNIT V 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.

TEXT BOOK:

1. A Pipko ―Fundamentals of Vacuum Techniques‖ Moscow. MIR Publishers, First edition 1984.
2. Vacuum technology Andrew Gutheries First edition wiley publishers 1965.

REFERENCES:

1. Vacuum technology: A.roth
2. Hand book of high vacuum engineering , Steinherz. Second edition 2011
3. V.V. Rao, T.B. Ghosh, K.L.Chopra,, Vacuum Science and Technology, Allied Publishers Ltd., New Delhi

WEB RESOURSE:

1. https://www.youtube.com/watch?v=Vuqk-Ag7xV4
2. https://www.youtube.com/watch?v=nLohZYiiHuc

CO PO MAPPING:

COs	**POs**											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2										2
CO2	3	2	2	2								2
CO3	3	2	2	2							2	2

CO4	3	2	2	2		2						2
CO5	3	2										2

Course Code	ADVANCED CRYOGENIC ROCKET PROPULSION	L	T	P	C
		3	0	0	3
Course Category: ***Professional Elective***	**Course Type:** ***Theory***				

Course Objective(s):

- To introduce the learner about cryogenic rocket engine technology and to gain knowledge in cryogenic rocket propulsion systems.

Course Outcomes: (COs)

At the end of the course, the student will be able to

CO 1	Able to understand the concepts of rockets propulsion.
CO 2	Knowledge in rocket propellants.
CO 3	Able to understand the concept of fuel feed systems.
CO 4	Able to understand the cryogenic engine and also various design.
CO 5	Able to gain knowledge in the various components of cryoengine system

UNIT I INTRODUCTION **9**

Classification of rockets – chemical, electrical and nuclear; Applications of rockets in launch vehicles, spacecraft, and missiles-Flight performance of rocket vehicles- Trajectories and orbits

UNIT II ROCKET PROPELLANTS **9**

Double- base and composite propellants, grain configurations, erosive burning; Liquid rocket engines, types of propellants; cryogenic and gelled propellants,

UNIT III FUEL FEED SYSTEMS **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 CRYOGENIC ENGINE **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 CRYOENGINE COMPONENTS **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.

TEXT BOOK:

1. Sutton, G.P; Biblarz, O. Rocket Propulsion Elements. New York, Wiley Eighth edition 2010.
2. Huzel, D. K.; Huang, D. H., Design of Liquid Propellant Rockets, NASA second edition 2009

REFERENCES:

1. Larson, W.J., Wertz, J. R. (1992). Space Mission Analysis &Design. Boston: KAP.
2. Wolfgang Kitsche (2010) Operation of a Cryogenic Rocket Engine: An Outline with Down- to-Earth and Up-to-Space Remarks, Springer, USA.
3. G. P. Sutton and O. Biblarz, Rocket Propulsion Elements, Wiley, 2001

WEB RESOUSRE:

1. https://www.youtube.com/watch?v=vQiIt-jX0BM&list=PL99EA5ECCC34949DB
2. https://www.youtube.com/watch?v=nZmvLNhcK_w&list=PLbMVogVj5nJTCNrek8ZsX1-YOe-O5NVI-

CO PO MAPPING:

COs	POs											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2										2
CO2	3	2										2
CO3	3	2				2						2
CO4	3	2	2	2			2	2				2

CO5	3	2										2

Course Code	CRYOGENIC HEAT EXCHANGERS	L	T	P	C
CY622208		3	0	0	3
Course Category: *Professional Elective*	Course Type: *Theory*				

Course Objective(s):

To enhance knowledge in the field of heat exchanger and to gain ideas in the designing of heat exchanger systems.

Course Outcomes: (COs)

At the end of the course, the student will be able to

CO 1	Ability to obtain ideas in the steady state conduction and pressure drop.
CO 2	Ability to obtain knowledge in the designing of heat exchanger.
CO 3	Knowledge in some special case heat exchanger.
CO 4	Knowledge in heat exchanger configuration.
CO 5	Understanding of testing techniques.

UNIT I INTRODUCTION **9**

Steady state conduction with two and three dimensions with heat generation, solution of problem by numerical- Background, Application, Classification, Common terminologies- Thermal and hydraulic aspects, pressure drop and heat transfer, sizing and rating - F-LMTD and -NTU method

UNIT II DESIGN OF HEAT EXCHANGERS **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 SPECIAL CASE HEAT EXCHANGER **9**

Direct contact heat exchangers, types, application, simple analysis Microscale Heat Exchangers and heat sinks; heat transfer and Fluid flow through narrow conduits, special design considerations- Phase change HEX; phase change heat transfer, introduction to evaporators and condensers.

UNIT IV HEAT EXCHANGER CONFIGURATION **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 TESTING TECHNIQUES **9**

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

TEXT BOOK:

1. Saunders, E.A.D., ‖Heat exchange – selection design and construction‖, Longmann Scientific and Technical, N.Y.2001.
2. Holger Martin , —Heat Exchanger‖ Hemisphere Publ.Corp., Washington,2001

REFERENCES:

1. Kays, V.A and London,A.L., —Compact Heat Exchangers‖, McGraw Hill, 2002
2. Kuppan,T., —Heat Exchanger Design Handbook‖, Macel Dekker, Inc., N.Y.,2000
3. Seikan Ishigai, —Steam Power Engineering, Thermal and Hydraulic Design Principles‖, Cambridge Univ. Press,2001

WEB RESOURSE:

1. **https://archive.nptel.ac.in/content/syllabus_pdf/112105248.pdf**
2. **https://www.youtube.com/watch?v=puWckyT5xxg**
3. **https://www.youtube.com/watch?v=oN92OYyTyeA&list=PLbRMhDVUMngd2xQIxWLv9utozJnGnxfMS**

CO PO MAPPING:

COs	POs											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	2	2								3
CO2	3	2	2	2							2	3
CO3	3	2				2					2	3
CO4	3	2				2					2	3

CO5	3	2	2	2		2					2	3

Programme Elective -III

Course Code	ADVANCED CRYO COOLERS	L	T	P	C
CY622209		3	0	0	3
Course Category: ***Professional Elective***	**Course Type:** ***Theory***				

Course Objective(s):

To enhance the ideas and to gain knowledge in the cryocooler system and also to apply various ideas in the types of cryo coolers in industries

Course Outcomes: (COs)

At the end of the course, the student will be able to

CO 1	Ability to understand the basics of cryocoolers.
CO 2	Knowledgein classifications of cryocoolers.
CO 3	Understandingof G-M &Stirlingcryocooler.
CO 4	Understandingofpulsetubecryocoolers.
CO 5	Knowledgeinthe cryogenic liquefaction system.

UNIT I CRYOCOOLERS **9**

Classification of Cryocoolers, Working - Selection and comparison of different types of cryocoolers, Ideal working Cycles, Important parameters – Technical parameters -cooling effect- compressor power requirement, cooling water requirement, service requirement of compressor- Vibration control, Applications of cryo coolers.

UNIT II COMMON CRYOCOOLER **9**

Types of cryocoolers and application Recuperative type cryocoolers, The principle of operation and analysis of JT, sorption, reverse Brayton cryo coolers. Regenerative cryocoolers, The principle of operation and analysis of Vuilleumier.

UNIT III G-M AND STIRLING CRYOCOOLERS 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 - Ideal Stirling cycle, Concept of practical Stirling cycle, First order analysis Stirling cycle, Second order analysis, Third order analysis -Loss analysis,

UNIT IV PULSE TUBE CRYOCOOLERS 9

History of pulse tube Cryocooler, Double inlet pulse tube refrigerator, Geometry of pulse tube –U-tube, co-axial, in-line, Two stage pulse tube refrigerator design ,Thermo acoustically driven pulse tube refrigerator, Different methods of analysis, Phasor analysis , Oscillating flow behaviour of PTR, Valve timing effect on performance of 4K pulse tube cryocooler. Design of Dual use PTR, Low vibration flexure bearing compressor,

UNIT V CRYOGENIC LIQUEFACTION SYSTEM 9

Basic vapor compression refrigeration, Carnot cycle for liquefaction and problems, effects on liquefaction rate due to compressor characteristics, Precooling in liquefaction systems, Problems, Different liquefaction process.

TEXT BOOKS:

1. Cryocoolers G. Walker – Plenum press New York Third edition 1983.
2. Cryogenics Theory Processes and Applications – Allyson. E.Hayes Nova second edition 2010

REFERENCES:

1. Cryocoolers Volumes (Proceedings of International Cryocooler conference) Journal_Cryogenics ‘published in Elsevier.
2. Cryocoolers, Graham Walker, Springer Science Business Media,LLC,ISBN 978-1-4899-5288-2,New York in 1983
3. Stirling and Pulse-tube Cryo-coolers, ALLEN J ORGAN,ISBN: 9781860584619,Wiley Publisher, 2005.

WEB RESOUSRE:

1. https://www.youtube.com/watch?v=r4wZEnYVf_Y
2. https://www.youtube.com/watch?v=72K9zyrlcas

3. https://www.jlab.org/IR/Cryocooler_Fundamentals_Course_Notes/CEC-RGR_1_200dpi-final.pdf

CO PO MAPPING:

COs	POs											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2				2					2	2
CO2	3	2				2					2	2
CO3	3	2				2					2	2
CO4	3	2				2					2	2
CO5	3	2				2	1				2	2

Course Code	ENGINEERING MATERIALS	L	T	P	C
CY622210		3	0	0	3
Course Category: *Professional Elective*		Course Type: *Theory*			

Course Objective(s):

To enhance ideas in the engineering materials and to gain knowledge in understanding different engineering materials widely used in industrial applications.

Course Outcomes: (COs)

At the end of the course, the student will be able to

CO 1	Ability to gain knowledge in nano structural materials
CO 2	Knowledge in composite materials.
CO 3	Understanding of light weight high strength materials.
CO 4	Understanding of opto electronic materials.
CO 5	Knowledge in technological materials.

UNIT I NANOSTRUCTURAL MATERIALS **9**

Definition of Nano, Scientific revolution- Atomic Structure and atomic size, emergence and challenges of nanoscience and nanotechnology, carbon age-nano form of carbon (CNT to Graphene), influence of nano over micro/macro, large surface to volume ratio, surface effects on the properties, Nanotechnology in agriculture, Nanomedicine, Application of nanotechnology in remediation of pollution

UNIT II COMPOSITE MATERIALS **9**

Geometric and Physical definitions, natural and man-made composites, Aerospace and structural applications, types and classification of composites. Reinforcements: Fibres – Glass, Silica, Kevlar, carbon, boron, silicon carbide, and born carbide fibres. Particulate composites, Polymer composites, Thermoplastics, Thermosets, Metal matrix and ceramic composites.

UNIT III LIGHT WEIGHT HIGH STRENGTH MATERIALS 9

Properties and structure of Titanium - alloying elements- manufacture of titanium wrought products - mechanical properties and microstructure correlation - , and + alloys, aerospace and medical applications - yttrium based iron-chromium aluminum alloy mechanical alloying process of MA 956 alloy - MAODS super alloys - high temperature and medical applications

UNIT IV OPTO ELECTRONIC MATERIALS 9

Injection luminescence and LEDs - LED materials - LED construction - double heterojunction LED and related materials - edge emitter and super luminescent LED materials-liquid crystals properties and structure-liquid crystal displays-comparison between LED and LC display optical amplifier - erbium doped silica fiber.

UNIT V TECHNOLOGICAL MATERIALS 9

Electrets - properties and applications - metallic glasses - properties and applications - SMART materials - piezoelectric, magneto strictive, electro strictive materials - shape memory alloys - rheological fluids - CCD device materials and applications - single crystalline solar cells - amorphous silica solar cells - thin film polycrystalline solar cells - surface acoustic wave and sonar transducer materials and applications.

TEXTBOOKS:

1. George C.Hadjipanayis and Gary A.Prinz (Eds), Science and Technology of Nano structured Magnetic Materials, NATO ASI series, Plenum Press, New York, 1991. (UNIT I, V).

2. S.C.Sharma, Composite Materials, Narosa Publishing House, New Dellhi,2000. (UNIT II).

Charlie Brooks. R, Heat Treatment Structure and properties of non-ferrous, American Society for Metals, U.S.A, 1984. (UNIT III).

REFERENCE BOOKS:

1. Hand Book of Nano phase and Nano structured Materials –Kluwer Academic PressZhong Lin Wang ,2002.

2. John M.Senior, Optical Fiber Communications, Prentice-Hall of India Private Ltd., New Delhi (1998) (UNIT IV)

3. Mechanics of Composite Materials/ R. M. Jones/ McGraw Hill Company, New York, 1975.

WEB RESOURSE:

1. https://www.youtube.com/watch?v=2rxbxNem1iI&list=PLyqSpQzTE6M_ON8uXt-PP8uX6hMWJeYSJ

2. https://www.youtube.com/watch?v=KMcsjCXfLQw&list=PLyAZSyX8Qy5Am_2StOOQ5vCUE3VIcAenE

CO PO MAPPING:

COs	POs											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2				2	2	2			2	3
CO2	3	2				2	2	2			2	3
CO3	3	2				2	2	2			2	3
CO4	3	2				2	2	2			2	3
CO5	3	2				2	2	2			2	3

Course Code	SUPER CONDUCTIVITY AND LOW	L	T	P	C
CY622211	TEMPERATURE PHYSICS	3	0	0	3
Course Category: *Professional Elective*	**Course Type:** *Theory*				

Course Objective(s):

To introduce the learner and to explain about the properties of superconductors and liquid helium

Course Outcomes: (COs)

At the end of the course, the student will be able to

CO 1	Ability to gain knowledge in common cryogenic properties.
CO 2	Ability to gain knowledge in production of low temperature
CO 3	Understanding electrical and magnetic properties of superconducting materials.
CO 4	Understanding of super fluidity.
CO 5	Knowledge in mixtures of Helium III and IV.

UNIT I – PROPERTIES OF COMMON CRYOGENS **9**

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

UNIT II - PRODUCTION OF LOW TEMPERATURE **9**

Introduction - Joule Thomson effect - Regenerative cooling - Vacuum pumps - liquefaction of air - Hydrogen - Helium - Maintenance of low temperature -production of temperature

below 1 K - Adiabatic demagnetization - Evaporative cooling of He-3 - Dilution refrigeration - Laser cooling - nuclear demagnetization.

UNIT III - ELECTRICAL AND MAGNETIC PROPERTIES **9**

Experimental observations - Theories of sommerfield and block - Superconductivity - magnetic properties of superconductors - Thermal properties of superconductors - penetration depth and high frequency resistance - Ferromagnetism - Diamagnetism - paramagnetism - Paramagnetic saturation.

UNIT IV - SUPERFLUIDITY **9**

Super Fluid 3He -- Phase Diagrams, Specific Heat, -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 HELIUM III & HELIUM IV **9**

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

TEXTBOOKS:

1. Low Temperature Superconductivity & Superconductivity By Christian Enss & Siegfried Hunk linger Springer second edition 2010

2.Matter & Methods at Low Temperature by F. Pobell. Experimental low temperature physics by Anthony Kent. Second edition 1993.

REFERENCE BOOKS:

1. Daniel V. Schroeder (2007). An Introduction to Thermal Physics. Addison Wesley Longman.

2. Dieter Vollhart, Peter Wolfe (1990). The Super fluid Phases of Helium 3. Taylor and Francis Kindle second edition 2013.

3. Christian E. and Siegfried H, Low Temperature Physics, Springer, 2005

4. Cornelis Jacobus Gorter, D. F. Brewer, Progress in Low Temperature Physics, Elsevier Ltd, 2011.

WEB RESOURSE:

1. https://www.youtube.com/watch?v=D-9M3GWoBrw
2. https://www.youtube.com/watch?v=GglT1RoBPzg

CO PO MAPPING:

COs	POs											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2										2
CO2	3	2										2
CO3	3	2				2						2
CO4	3	2				2					2	3
CO5	3	2			1						2	3

Course Code	MATERIAL CHARACTERIZATION TECHNIQUES	L	T	P	C
CY622212		3	0	0	3
Course Category: *Professional Elective*	Course Type: *Theory*				

Course Objective(s):

- To obtain the knowledge of characterisation of materials of how they behave in practical applications.
- To obtain the knowledge of properties of materials
- To enhance the ideas in alloys, semiconductors, polymers and ceramic

Course Outcomes: (COs)

At the end of the course, the student will be able to

CO 1	Ability to gain knowledge of characteristisation of materials of how they behave in practical applications.
CO 2	Ability to gain knowledge in microscopic methods
CO 3	Ability to gain knowledge of properties of materials.
CO 4	Understanding diffraction methods and surface analysis.
CO 5	Ability to gain Knowledge in Spectroscopy and its applications.

UNIT I: THERMAL ANALYSIS **9**

Introduction – thermogravimetric analysis (TGA) – instrumentation – determination of weight loss and decomposition of products – differential thermal analysis (DTA) – cooling

curves – differential scanning calorimetry (DSC) – specific heat capacity measurements – determination of thermomechanical parameters.

UNIT II: MICROSCOPIC METHODS 9

Optical microscopy: optical microscopy techniques – Bright field optical microscopy – Dark field optical microscopy – dispersion staining microscopy – phase contrast microscopy – differential interreference contrast microscopy – fluorescence microscopy- confocal microscopy – scanning probe microscopy- (STM,AFM)- scanning new field optical microscopy- digital holographic microscopy – oil immersion objectives- quantitative metallography – image analyser.

UNIT III: ELECTRON MICROSCOPY AND OPTICAL CHARACTERISATION 9

Interaction of electrons with solids, scanning electron microscopy Transmission electron microscopy and specimen preparation techniques, Scanning transmission electron microscopy, Energy dispersive spectroscopy, Wavelength dispersive spectroscopy. light – matter interaction – instrumentation – electroluminescence – instrumentation- application.

UNIT IV: DIFFRACTION METHODS AND SURFACE ANALYSIS 9

Diffraction Methods: Fundamental crystallography, Generation and detection of X-rays, Diffraction of X-rays, X-ray diffraction techniques, Electron diffraction. **Surface Analysis:** Atomic force microscopy, scanning tunnelling microscopy, X-ray photoelectron spectroscopy

UNIT V: SPECTROCOPY 9

Principles and instrumentation for UV-Vis-IR, FTIR spectroscopy, Raman spectroscopy, Esr NMR, NQR,XPS,AES and SIMS- proton induced X-ray Emission spectroscopy (PIXE) – Rutherford Back Scattering (RBS) analysis- application.

TEXTBOOKS:

1. Belk, J.A; Electron microscopy and microanalysis of crystalline materials, Applied science Publishers, London, 1979, (MODULE II, III)
2. Lawrence E.Murr, Electron and Ion microscopy and Microanalysis principles and Application, Marcel Dekker Inc., New York, 1991 (MODULE I, IV V)

REFERENCE BOOKS:

1. Stardling R.A; Klipstain, P.C; Growth and Characterization of semiconductors, Adam Hilger, Bristol, 1990.
2. D.Kealey & P.J.Haines, Analytical Chemistry, Viva Books Private Limited, New Delhi 2002

3. Li, Lin, Ashok Kumar Materials Characterization Techniques Sam Zhang; CRC Press, (2008).

WEB RESOURCE:

1. https://www.youtube.com/watch?v=FkPeSMHCoX0&list=PLU_BQrxXuAddD_aEk270mcD9XvFTHb8Pc

2. https://www.youtube.com/watch?v=ifZpBN1KABI&list=PLbMVogVj5nJTHuWr9HO1Uns1g8IBeyFFa

CO PO MAPPING:

COs	**POs**											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2				2	2				2	2
CO2	3	2				2						2
CO3	3	2					2				2	3
CO4	3	2				2	2					3
CO5	3	-				2	2					2

Course Code	ADVANCED COMPUTATIONAL FLUID DYNAMICS	L	T	P	C
CY622213		3	0	0	3
Course Category: *Professional Elective*	Course Type: *Theory*				

Course Objective(s):

- To gain knowledge in the basic concepts and differential equations and discretization.
- To obtain knowledge in the finite element and finite volume philosophy.
- To obtain ideas in the viscous solution in the computational fluid dynamics

Course Outcomes: (COs)

At the end of the course, the student will be able to

CO 1	Ability to understand the fundamental concepts in fluids and fluid flow.
CO 2	Knowledge in differential equations and discretization
CO 3	Ability to gain knowledge finite element philosophy.
CO 4	Understand the CFDHT methodologies
CO 5	Ideas in viscous solution.

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 STEADY / UNSTEADY EQUATIONS & DISCRETIZATION 9

Solution of 1-D/2-D steady/unsteady: Diffusion problems, Convection problems, Convection-diffusion problems, source term linearization. Explicit and Implicit Approach: Explicit and implicit formulation of unsteady problems

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 CFDHT 9

Methodology of CFDHT: Discrete representation of flow and heat transfer domain: Grid generation, Governing equations and boundary conditions based on FVM/FDM

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.

TEXTBOOKS:

1. Anderson D.A., Tannehill J.C. Pletcher R.H.‖ Computational fluid mechanics & heat transfer‖Taylor & Francis Third Edition 2011.(UNIT I,II,III)
2. H.K.Verstag & W.Malalsekra,‖ An introduction to computational fluid dynamics‖ Pearson Publishers second edition 2007. (UNIT IV, V)

REFERENCE BOOKS:

1. Murlidhar K., Sunderrajan T., ―Computational Fluid Mechanics and Heat Transfer‖, Narosa Publishing House.
2. Dale A. W., ―Introduction to Computational Fluid Dynamics‖, Cambrige University Press, second edition 2005
3. P.S. Ghoshdastidar, Computational Fluid Dynamics and Heat Transfer, Cengage Learning

WEB RESOURCE:

1. https://www.youtube.com/watch?v=kwqoyuZTglQ&list=PL8EAF844326CBB2E3
2. https://www.youtube.com/watch?v=aShONtHloUk&list=PLbRMhDVUMngcFmWiK1YBhAbsYo8mYvPKJ

CO PO MAPPING:

COs	POs											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	2	2		2	2				2	3
CO2	3	2	2	2		2	2					2
CO3	3	2	2			2	2				2	3
CO4	3	2	2	2	2		2				3	3
CO5	3	2	2	2	2		2				2	3