UNIVERSITY OF MADRAS

DEPARTMENT OF NUCLEAR PHYSICS

M. Phil. Physics (2021-22)

Course Code	Course title	Core/ Elective	Credits			
			L	T	P	C
First Semester						
PHY C101	Research Methodology	C	4	1	0	5
PHY C102	Advanced Topics in Physics	C	4	1	0	5
PHY E101	Characterisation of Materials	E	4	1	0	5
PHY E102	Application of Thermal Analysis Techniques	E	4	1	0	5
PHY E104	Reactor Physics	E	4	1	0	5
Second Semester						
PHY C103	Dissertation and Viva-Voce	C	-	-	-	21

List of Courses:

Semester	Course Code	Title of the Course (M.Phil)	Core/Elective/ Soft Skill	Credits
I	**PHY C101**	**Research Methodology**	**CORE**	**4**

Course Outcomes	At the end of the course, students should be able to 1. To emphasize and impart scientific research methods systematically 2. Enhance communication and writing skills in an explicit manner 3. Identifying the key concepts and developing reports to approach his or her research problems 4. To develop thematic concepts with a logical approach to solving research problems 5. Imparting the importance of journals and methods to collect them in an appropriate manner 6. Understanding the essence of scientific tools and research software for literature surveys, and data analysis. To teach and impart the essence of data presentation scientifically. 7. To assess the knowledge of recent topics in physics via lectures
Course I	**CORE**
Title of the Course:	**Research Methodology**
Credits:	4
Pre-requisites, if any:	M.Sc Physics, basic knowledge on some important topics on condensed matter physics, solid state physics, lasers, materials science
Course Objectives	1) Introduces students to understand the research arena, its methods, its types and various methodologies for designing problems 2) Provide students with the skill to develop concepts, descriptive writing, and enable them to elucidate the research process and emphasise the importance of literature survey and review 3) Impart analytical skills in data presentation and analysis by mathematical modelling 4) Highlight the importance of academic data base, Research Guides, hand books, libraries and relevant software to search and maintain records. Learning research/reference article management software for typo formatting. Plagiarism software to assess the writing skill and improve its efficacy. 5) Lectures in physics communicate and evaluate the recent topics of the research domain

Units	
I	**Research Methodology of Science:** Areas of Science, Philosophy of science, Characteristics of Research, Types of research, Research process; Methodology: Topic selection, Hypothesis, Designing experiments, Analysis, Results, Models; Critical thinking and Science: Strategies and common fallacies.
II	**Research Design, Qualitative and Quantitative Research:** Concept types and uses, Descriptive Research Designs – concept, types and uses. Experimental Design: Concept of Independent & Dependent variables, Qualitative research – Quantitative research – Concept of measurement, causality, generalization, and replication. Merging the two approaches, literature survey and reviews
III	**Data Reduction and Error Analysis:** The presentation of physical quantities with their inaccuracies, significant figures, Errors: classification and propagation, Probability distributions, Processing of experimental data, Graphical handling of data with errors, Fitting functions to data.
IV	**Use of tools / techniques for Research:** Encyclopedias, Research Guides, Handbook etc., Academic Databases for Computer Science Discipline, methods to search required information effectively, Reference Management Software like Zotero/Mendeley, Software for paper formatting like LaTeX/MS Office, Software for detection of Plagiarism.
V	**Lecture on a topic of recent interest in Physics**
Reading List (Print and Online)	1. Introduction to Research Methodology - B.L. Garg, R. Karadia, RBSA Publishers, U.K., 2002. 2. Research Methodology - S.C. Sinha and A. K. Dhiman, Ess Ess Publications, New Delhi, 2002, 2 volumes. 3. Research Methodology: Methods and Techniques, C. R. Kothari, New Age International Publishes, New Delhi, 2nd Ed., 2004. 4. A Students Guide to Data and Error Analysis, Hernan J C Berendsen, Cambridge, 2011. 5. Introduction To Error Analysis: The Study of Uncertainties in Physical Measurements J.R. Taylor, University Science Books, 2nd Ed., 1997. 6. Data reduction and error analysis for the physical sciences, P Bevington, McGraw-Hill Science, 3rd Ed, 2002.
Recommended Texts	1. The Scientific Endeavor -Methodology and Perspectives of Sciences- Jeffrey A.Lee, Pearson India, 2010.

	2. How to write and Publish: Robert A Day and Barbara Gastel, Cambridge, 2006. 3. The Craft of Scientific Writing: Michael Alley, Springer,1996. 4. LaTeX A Document Preparation System 2nd ed, Lamport, AW,1994. 5. http://www.gnuplot.org
Method of Evaluation:	1. Sessional Test I: 20% (Descriptive Essay, Problems, Assignment, Seminar, Presentation) 2. Sessional Test II : 20% (Descriptive Essay, Problems, Assignment, Seminar, Presentation) 3. End Semester Examination : 60% (Descriptive type questions and Problems)

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Mapping of Course outcomes (CO) with Programme Outcomes (PO):

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO 10**
	Impart Concept	**Acquire Knowledge**	**Understand**	**Enhance**	**Problem solving Skills**	**Create & Analytical skill**	**Experimental Skill**	**Research skill**	**Apply knowledge**	**Achieve**
CO 1	S	S	S	S	L	S	L	S	S	S
CO 2	S	S	S	S	L	M	S	S	S	S
CO 3	S	S	S	M	S	S	S	S	S	S
CO	S	S	L	L	L	S	L	S	S	L

4										
CO 5	S	S	S	S	L	S	L	S	S	S

S-Strong M-Medium L-Low

	Description	**Knowledge Level**
CO1	**What** is a Science and research methodology, **Understand** different research methods in constructing research problems? **Developing** critical thinking and logics to approach the identified research problems.	K1, K2, K3
CO2	**Develop** concept and **enabling** descriptive writing methods to emphasise the research articles. **Distinguish** the need for Scientific literature and review. **Understand** the components of measurement, causality, generalization, and Replication its essentiality in research.	K2, K4, K6
CO3	**Explicate and extend** the importance of errors, accurate figures and data represent in research. **Develop** mathematical models and simulation to extract the numerical values and represent them in thematic way.	K3,K4,K6
CO4	**Explore** the scientific resources like Encyclopaedias, Research Guides, Handbook etc., Academic via computer data base for **developin**g a concrete research background. **Employing** article/ reference management software's towards documentation and typo setting formats for relevant journals. **Imparts** the plagiarism importance.	K2,K3,K4,K5 & K6
CO5	Lectures in physics **bring** communication **skills** and **evaluate** knowledge depth on the recent topics of the research domain.	K5 & K6

K1 - Recall; **K2** - Understand; **K3** - Apply; **K4** - Analyze; **K5** - Evaluate; **K6** - Create

List of Courses:

Semester	Course Code	Title of the Course (M.Phil)	Core/Elective/ Soft Skill	Credits
I	**PHY C102**	**Advanced Topics in Physics**	**CORE**	**4**

Course Outcomes	At the end of the course, students should be able to 1. Understand the theory of lasers and nonlinear optics and applications 2. Enhance knowledge on various concepts on condensed matter physics with a focus on magnetic and electrical properties 3. Understand the theory of Plasmons, polaritons and polarons 4. Gain knowledge on ion implantation for materials science research 5. Develop skills to deliver seminar on the advanced topics on condensed matter physics, lasers and ion implantation.
Course I	**CORE**
Title of the Course:	**Advanced Topics in Physics**
Credits:	4
Pre-requisites, if any:	M.Sc Physics, basic knowledge on some important topics on condensed matter physics, solid state physics, lasers, materials science
Course Objectives	1. To understand the theory of laser physics with a focus on solid state lasers, semiconductor lasers, nonlinear optics and applications. 2. To describe the theory of magnetism and superconductivity and apply the skills for research and development 3. To gain knowledge on plasmons, polaritons, polarons, exciton physics 4. To understand the principle and theory of ion implantation and apply the knowledge for materials science research 5. To apply the knowledge on condensed matter physics, lasers and ion beam implantation for the applied materials and device research.
Units	
I	**Laser and Nonlinear Optics** Basic principle and properties of lasers, Einstein Coefficient, Gain Coefficient, Threshold Condition, Guassian beam optics, Q-switching, mode locking, Principle and working of solid state lasers, gas Lasers,

	semiconductors lasers, Theory of Nonlinear optics - Second Harmonic Generation (SHG), Phase matching, Pockels effect, Kerr effect, Laser applications in materials processing, optical fibre communication, and biophotonics.
II	**Energetic Ion beams in Materials Science** Ion solid interaction, Low and high energy ion beams, Electronic and nuclear energy loss, radiation damage and structural change, Range and projected range, Monte carlo simulation of radiation damage process, SRIM, TRIM model, Thermal spike model. Basic idea of low and high energy accelerators, Different applications of ion beams in materials science, Ion implantation and ion irradiation.
III	**Magnetic Properties of Materials** Basics of Magnetism: Definition and Units – Experimental methods – Diamagnetism and paramagnetism – Antiferromagnetism – Ferromagnetisms – Ferromagnetism – Magnetization and the magnetic moment – Magnetic hysteresis loop – magnetic ordering and the Curie temperature – Different types of magnetic anisotropy – Magnetostriction and the effects of stress – Nanomagnetic materials thermal stability – size effect of fine particles and thin films – Domains and domain wlls – soft magnetic and hard magnetic materials
IV	**Electrical Properties of Materials** Classification of solids – Expressions of DC electrical conductivity in materials – Influence of temperature, frequency and magnetic field on conductivity – Classical Hall Effect – Quantum Hall Effect – Superconducvity – AC and DC Josephson Effects – SQUIDS - Superionic conductors – Ferroelectric and Piezoelectric materials.
V	**Plasmons, Polaritons and Polarons** Dielectric function of the electron gas – Definition of the dielectric, Plasma optics, Dispersion relation for electromagnetic wave – Transverse optical modes in a transparency of metals in the ultraviolet – longitudinal plasma oscillations Plasmons – electrostatic screening – screened Coulomb potential – Mott metal -insulator transition – screening and phonons in metals Polaritons – LST relation; Electron-electron interaction – Fermi liquid –

	Electron-electron collisions – Electron phonon interaction; Polarons **Optical Processes and Excitons:** Optical reflectance – Kramers – Kronig relations – conductivity of collision less electron gas – electronic interband transitions Excitons – Frenkel excitons – Alkali halides – Molecular crystals – Weakly bound (MottWanner) excitons – Exciton condensation into electron-hole drops (EHD)
Reading List (Print and Online)	This course requires text books, reference books, research papers: **Laser and Nonlinear Optics** 1. Photonics and Lasers: An Introduction, Richard S. Quimby (John Wiley & Sons, Inc). 2. Lasers: Theory and Applications. Thyagarajan and A.K. Ghatak, (Springer Publications) 3. Optical Fiber Communications Principles and Practice, John M.Senior (Prentice Hall) **Condensed Matter Physics** 4. Introduction to Solid state physics, C. Kittel, John – Wiley 5. Solid State Physics, A.J. Dekker, Macmillan India Ltd. 6. Solid State Physics, S.O.Pillai, New Age International Pvt. Ltd. **Ion Implantation** 7. Ion Implantation and Beam Processing, J.S. Williams and J.M. Poate, Academic Press, 1984 8. Optical Effects of Ion Implantation, P. D. Townsend, P. J. Chandler, L. Zhang, Cambridge University Press, 1994
Recommended Texts	**Laser and Nonlinear Optics** 1. Photonics and Lasers: An Introduction, Richard S. Quimby (John Wiley & Sons, Inc). 2. Solid-State Laser Engineering, W.Koechner, (Springer) 3. Laser Material Processing: W.M.Steen, (Springer Verlag). 4. Biophotonics Concepts to Applications: Keiser, Gerd, (Springer) **Condensed Matter Physics** 5. Condensed Matter in a Nutshell, Gerald D. Mahan, Princeton University Press. 6. Introductory Solid State Physics, H.P. Myers, Taylor and Francis. 7. Dielectric Phenomena in Solids, Kwan Chi Kao, Elsevier Academic Press, 2004. **Materials Science and Engineering** 8. Essentials of Materials Science and Engineering, Donald R.

	Askeland, Pradeep P. Fulay, (Cengage Learning) 9. Science of Engineering Materials, C.M. Srivastava and C. Srinivasan, New Age International (P) Ltd., 1994. **Ion Implantation** 10. Ion Implantation and Synthesis of Materials, Michael Nastasi, James W. Mayer, Springer Publications., 2006. 11. Ion Implantation: Basics to Device Fabrication, Emanuele Rimini, Springer publications, 1995 12. Ion Implantation in Semiconductors , Susumu Namba, Springer Publications, 1975.
Method of Evaluation:	1. Sessional Test I: 20% (Descriptive Essay, Problems, Assignment, Seminar, Presentation) 2. Sessional Test II : 20% (Descriptive Essay, Problems, Assignment, Seminar, Presentation) 3. End Semester Examination : 60% (Descriptive type questions and Problems)

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Mapping of Course outcomes (CO) with Programme Outcomes (PO):

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO 10**
	Impart Concept	**Acquire Knowledge**	**Understand**	**Enhance**	**Problem solving Skills**	**Create & Analytical skill**	**Experimental Skill**	**Research skill**	**Apply knowledge**	**Achieve**
CO 1	S	S	S	S	S	S	L	S	S	S
CO 2	S	S	S	M	M	S	M	M	S	S
CO 3	S	S	S	M	S	M	L	S	M	S
CO 4	S	S	S	M	S	M	M	S	S	S
CO 5	S	S	S	M	L	M	L	S	S	S

S-Strong M-Medium L-Low

	Description	Knowledge Level
CO1	Understand the theory of lasers and nonlinear optics and applications	K1, K2
CO2	Enhance knowledge on various concepts on condensed matter physics with a focus on magnetic and electrical properties	K2,K4 & K5
CO3	Understand the theory of Plasmons, polaritons and polarons	K1, K2 & K3
CO4	Gain knowledge on ion implantation for materials science research	K2, K3, K4 & K5
CO5	Develop skills to deliver seminar on the advanced topics on condensed matter physics, lasers and ion implantation.	K2, K3, K4,K5 & K6

K1 - Recall; **K2** - Understand; **K3** - Apply; **K4** - Analyze; **K5** - Evaluate; **K6** - Create

List of Courses:

Semester	Course Code	Title of the Course (M.Phil)	Core/Elective/ Soft Skill	Credits
I	**PHY E101**	**Characterisation of Materials**	**Elective**	**4**

Course Outcomes	At the end of the course, students should be able to 1. Impart the design and develop of the X-Ray, Mossbauer spectroscopy, Positron annihilation, Impedance spectroscopy, and Thermal analysis techniques and study the materials properties. 2. Understand and analyze the various types of materials character 3. Analysis and confirm the Structure, defects, dielectric properties and due to thermal, materials behaves related information. 4. Equip the student with the skill to operate the equipments and understand the subjects. 5. Create an idea to study the characterization analysis.
Course I	**Elective**
Title of the Course:	Characterisation of Materials
Credits:	4
Pre-requisites, if any:	Students should know the basic concepts in Characterisation analysis Technique.
Course Objectives	1. To acquire the fundamental knowledge of Various Characterization Techniques, and its applications 2. To introduce the basic theory of Characterisation techniques and study the material properties 3. To inculcate the basic configurations of materials changes due to Materials unique properties 4. To emphasis the role of X-Ray, Mossbauer, Positron annihilations, Impedance spectroscopy, and Thermal To create idea to implement to the materials and study the materials properties and its applications
Units	
I	**Positron Annihilation and its Lifetime Technique :**Block diagram detail in the Positron Lifetime Technique and discuss - positron interacting with matter - nature of S- and W- parameters extracted from Doppler broadening spectrum- Applications of Positron annihilation.
II	**X-Ray Powder Diffraction:** Geometry of crystals – Diffraction – Experimental powder crystallography- Analytical Techniques and

	Applications – Crystal Structures from powder data.
III	**Mössbauer spectroscopy** : Theory of Mössbauer effect - Recoilless emission and absorption, Mössbauer Spectrometer - Isomer shift- Quadrupole Splitting, Nuclear Zeeman Interaction - Chemical shift - Applications of Mossbauer effect – Analysis of Mossbauer Spectra.
IV	**Thermal Analysis techniques:** Basic principle of TMA - Specifications of TMA - TMA (model TMS-2) and its working principles - various types of sample probes and Temperature Calibrations - Applications of TMA to nanomaterials (Inorganic, Metals and alloys and polymeric materials) and in some factors affecting the TMA results.
V	**Impedance spectroscopy:** Basic Definition – Dielectrics – Types of polarization – Basic impedance spectroscopy Experiments – Respnce to a small signal stimulus in the frequency domain- general AC circuit theory – impedance related functions – Applications – Advantages – Limitations. Elementary analysis of IS: physical models for equivalent circuit elements – single RC circuit – Analysis – Analysis of sigle impedance Arcs – constant phase elements (CPE)-simple combination.
Reading List (Print and Online)	1. B. D. Cullity, Elements of X-ray Diffraction, 2nd Edition, Addison Wesley publishing Co., Londdon, 1978. 2. Leonid V. Azaroff and Martin J. Buerger, The Powder Method in X-ray crystallography, McGraw-Hill Book Co., New York. 3. Stout, G. H. and L. H. Jensen (1989), X-Ray Structure Determination, 2nd ed., John Wily & Sons, New York. 4. N. N. Greenwood and T. C.Gibb, Mossbauer spectroscopy, Chapman and Hall, London (1971). 5. G. K. Wertheim, Mossbauer effect; Principles and Applications, Academic Press, New York (1964). 6. R. L. Mossbauer and M. J. Clauser, Hyperfine, Interactions, Eds. A. J. Freeman and R. B. Frankel, Academic Press Inc, New York (1967) p.498.
Recommended Texts	1. C.N. Banwell, Fundamentals of Molecular Spectroscopy, Mc Graw Hill, New York, 1981. 2. G. Aruldhas, Molecular Structure and Spectroscopy, Prentice Hall, New Delhi, 2006. 3. E.L. Charsley, S.B. Warrington, Thermal Analysis: Techniques and Applications, Royal Society of Chemistry, Cambridge : 1992. 4. Evgenij Barsoukov, Dr. J. Ross Macdonald, Impedance Spectroscopy: Theory, Experiment, and Applications, 2nd edn., 2005 John Wiley & Sons, Inc.
Method of Evaluation:	1. Sessional Test I: 20% (Descriptive Essay, Problems, Assignment, Seminar, Presentation) 2. Sessional Test II : 20%

	(Descriptive Essay, Problems, Assignment, Seminar, Presentation) 3. End Semester Examination : 60% (Descriptive type questions and Problems)

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Mapping of Course outcomes (CO) with Programme Outcomes (PO):

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10
	Impart Concept	Acquire Knowledge	Understand	Enhance	Problem solving Skills	Create & Analytical skill	Experimental Skill	Research skill	Apply knowledge	Achieve
CO 1	S	S	M	S	M	L	M	L	S	S
CO 2	S	M	M	S	S	M	L	M	S	S
CO 3	S	M	L	L	M	M	S	S	S	S
CO 4	S	S	M	S	S	S	M	M	S	S
CO 5	S	M	M	M	L	S	M	L	S	S

S-Strong M-Medium L-Low

	Description	Knowledge Level
CO1	Impart the design and develop of the X-Ray, Mossbauer spectroscopy, Positron annihilation, Impedance spectroscopy, and Thermal analysis techniques and study the materials properties.	K4,K5 & K6
CO2	Understand and analyze the various types of materials character	K1, K2 ,K4 & K5
CO3	Analysis and confirm the Structure, defects, dielectric properties and due to thermal, materials behaves related information.	K4 & K5
CO4	Equip the student with the skill to operate the equipments and understand the subjects.	K1,K2,K3 & K5
CO5	Create an idea to study the characterization analysis.	K6

K1 - Recall; K2 - Understand; K3 - Apply; K4 - Analyze; K5 - Evaluate; K6 – Create

List of Courses:

Semester	Course Code	Title of the Course (M.Phil)	Core/Elective/ Soft Skill	Credits
I	PHY E102	Applications of Thermal Analysis Techniques	Elective	4

Course Outcomes	At the end of the course, students should be able to 1. Impart the design and develop of the Thermal analysis techniques and study the materials characterization. 2. Understand and analyze the various materials due to Temperature. 3. Analysis and confirm the exothermic and endothermic. 4. Equip the student with the skill to operate the equipment and understand the subject. 5. Create an idea to study the thermal analysis.
Course I	**Elective**
Title of the Course:	Application of Thermal Analysis Techniques
Credits:	4
Pre-requisites, if any:	Students should know the basic concepts in Thermal analysis Technique.
Course Objectives	1. To acquire the fundamental knowledge of Thermal analysis and itsapplications 2. To introduce the basic theory of Thermal analysis techniques and study the material properties 3. To inculcate the basic configurations of materials changes due to thermal 4. To emphasis the role of Thermal techniques To create idea to implement to the materials and study materials applications
Units	
I	**Thermogravimetric Analysis (TGA):** Basic definition of Thermal Analysis - basic principle of TGA - Specifications of TGA - Important major working parts (Furnace, Microbalance, weight) of TGA - Calibration (Furnace calibration, Two point calibration - weight calibration) of TGA, - Multirame mode operation of TGA - Applications of TGA to nanomaterials (Inorganic, pharmaceuticals, polymeric materials) and in some factors affecting the TGA results .
II	**Differential Scanning Calorimetry (DSC):** Basic principle of DSC - Specifications of DSC - Various types of DSC (Heat flux, Power compensation, Modulated) and its working principles - Calibration (Base

	calibration - Standard materials calibration in high temperatures and low temperature). Specific heat - Isothermal mode of operation in DSC - Applications of DSC to nanomaterials (Inorganic, Organic, clays, pharmaceuticals, purity of the chemicals and polymeric materials) and in some factors affecting the DSC results.
III	**Differential Thermal Analysis (DTA) :**Basic principle of DTA - Specifications of DTA - Difference between DSC and DTA. working principle of DTA - DTA accessories (Furnace, sample holder, low-level dc amplifier, Differential temperature detector, furnace temperature programmer, recorder control equipment atmosphere). Calibration (Baseline calibration, Standard materials calibration in high temperatures). Applications of DTA to nanomaterials (Inorganic, High Temperature ceramic, High-temperature superconducting materials) and in some factors affecting the DTA results.
IV	**Thermomechnical Analysis (TMA):** Basic principle of TMA - Specifications of TMA - TMA (model TMS-2) and its working principles - various types of sample probes and Temperature Calibrations - Applications of TMA to nanomaterials (Inorganic, Metals and alloys and polymeric materials) and in some factors affecting the TMA results.
V	**Dynamic Mechanical Analyzer (DMA):** working principle of DMA – Specification - important parts and its working function - calibration of this instrumemnt - Application of DMA to nanomaterials (Polymer, Inorganic, ceramic, metals).
Reading List (Print and Online)	1. Höhne, G.W.H., Hemminger, W.F., Flammersheim, H.-J. 2nd rev. a. enlarged ed, Differential Scanning Calorimetry, 2003, XII, 298 p. 130 illus., Springer 2. Kevin P. Menard, Dynamic Mechanical Analysis: A practical Introduction, CRC Press, Taylor's & Francis Group, 2008 3. E.L. Charsley, S.B. Warrington, Thermal Analysis: Techniques and Applications, Royal Society of Chemistry, Cambridge : 1992
Recommended Texts	1. WM. Wendlandt, Thermal Analysis, 3rd edn, Wesley John wiley & sons. 2. Antonin Blazek, Differential Thermal Analysis, 1972, Van Nostrand Reinhold Company Ltd. 3. C. J. Keattch and Dollimore, An Introduction to Thermogravimetry, 2nd edn, HEYDEN & son Ltd, 1975.
Method of Evaluation:	1. Sessional Test I: 20% (Descriptive Essay, Problems, Assignment, Seminar, Presentation) 2. Sessional Test II : 20% (Descriptive Essay, Problems, Assignment, Seminar, Presentation) 3. End Semester Examination : 60% (Descriptive type questions and Problems)

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Mapping of Course outcomes (CO) with Programme Outcomes (PO):

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10
	Impart Concept	Acquire Knowledge	Understand	Enhance	Problem solving Skills	Create & Analytical skill	Experimental Skill	Research skill	Apply knowledge	Achieve
CO 1	S	S	M	S	M	L	M	L	S	S
CO 2	S	M	M	S	S	M	L	M	S	S
CO 3	S	M	L	L	M	M	S	S	S	S
CO 4	S	S	M	S	S	S	M	M	S	S
CO 5	S	M	M	M	L	S	M	L	S	S

S-Strong M-Medium L-Low

	Description	**Knowledge Level**
CO1	Impart the design and develop of the Thermal analysis techniques and study the materials characterization.	K2, K3, K4 & K5
CO2	Understand and analyze the various materials due to Temperature.	K1,K2,K4 & K5
CO3	Analysis and confirm the exothermic and endothermic.	K4 & K5
CO4	Equip the student with the skill to operate the equipment and understand the subject.	K5 & K6
CO5	Create an idea to study the thermal analysis.	K6

K1 - Recall; K2 - Understand; K3 - Apply; K4 - Analyze; K5 - Evaluate; K6 - Create

List of Courses:

Semester	Course Code	Title of the Course (M.Phil)	Core/Elective/ Soft Skill	Credits
I	PHY E104	REACTOR PHYSICS	Elective	4

Course Outcomes	At the end of the course, students should be able to 1. Understand Fundamental Nuclear fission processes & Working 2. Able to handle Nuclear reactor Instrumentations & Knowledge of processes involved. 3. Advanced working knowledge of Nuclear reactors & protocols 4. Analysis of Fission parameters useful for production level. 5. Able to do Basic analysis of safety measures in Nuclear environment.
Course I	**Elective**
Title of the Course:	Reactor Physics
Credits:	4
Pre-requisites, if any:	Advanced level Physics.
Course Objectives	• Advanced level introduction to Nuclear Energy fundamnetals, Fission processes & Nuclear reactions. • Intermediate level Nuclear fission principles, Reactor types, Neutron diffusion processes, Techniques Maintaining fission ratio etc. • Types of Reactors Detailed analysis of reactor processes. • Calculation of reactivity rates useful to control fission processes for practical purposes, Finding optimised reaction rate processes. Introduction to Reactor controls & Safety measure protocols, Analysis of control rod usage
Units	
I	**Nuclear energy** Nuclear mass - Binding energy-Radioactivity - Nuclear reactions - Nuclear fission - Mechanism of fission – Fuels - Products of fission - Energy release from fission - Reactor power - Fuel burn up – Consumption.
II	**Neutron diffusion & moderation** Multiplication factor - **n**eutron balance and conditions for criticality - Conversion and breeding Diffusion of neutrons**:** Flux and current density - Equation of continuity - Fick's law - Diffusion equation - Boundary conditions and solutions - Diffusion length - Reciprocity theorem. Energy loss in elastic collision - moderation of neutrons in Hydrogen - lethargy - Space dependent

	slowing down - Fermi's age theory -Moderation with absorption. Fermi theory of Bare thermal reactor**:** Criticality of an infinite reactor - One region finite thermal reactor - Critical equation - Optimum reactor shape.
III	**Nuclear Reactors**– Classification of reactors- Heterogeneous reactor, Breeder reactor, Heavy water-cooled reactor, CANDU type reactor, Swimming pool reactor, Gas cooled reactors. Spent fuel - light water reactor, light water reactor MOX, fast reactor MOX
IV	**Reactor kinetics** Infinite reactor with and without delayed neutrons - Stable period - Prompt jump - Prompt criticality - Negative reactivity - Changes in reactivity - Temperature coefficient - Burn up and conversion
V	**Control and shielding** Reactor control: Road worth - One control rod - modified one group, two group theory - ring of rods. Radiation shielding: Reactor safeguards - Reactor properties over life - core life estimation.
Reading List (Print and Online)	1. John.R Lamarsh, Introduction to Nuclear Reactor Theory, Addison Wesley Publishing 2. Company 2nd printing (1992) 3. Paul .F. Zweifel, Reactor Physics, Mc Graw Hill Book Company (1973) India.
Recommended Texts	Richard Stepheson, Introduction to nuclear Engineering ,Mc Graw Hill Book Company (1974) New York. 2. Suresh Gard, Feroz Ahmed and L.S Kothari ,Physics of Nuclear Reactors , Tata McGraw Hill Pub.Co.Ltd, London. 3. Samuel Glasstone and Edmund , Nuclear reactor theory, *Hill*, 1998.
Method of Evaluation:	1. Sessional Test I: 20% (Descriptive Essay, Problems, Assignment, Seminar, Presentation) 2. Sessional Test II : 20% (Descriptive Essay, Problems, Assignment, Seminar, Presentation) 3. End Semester Examination : 60% (Descriptive type questions and Problems)

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Mapping of Course outcomes (CO) with Programme Outcomes (PO):

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO 10**
	Impart Concept	**Acquire Knowledge**	**Understand**	**Enhance**	**Problem solving Skills**	**Create & Analytical skill**	**Experimental Skill**	**Research skill**	**Apply knowledge**	**Achieve**
CO 1	S	S	S	M	S	L	L	S	S	S

CO 2	S	S	M	S	M	S	M	S	L	S
CO 3	S	S	S	S	S	M	L	S	S	M
CO 4	S	M	S	S	M	S	M	L	S	S
CO 5	S	S	S	S	S	M	S	S	S	S

S-Strong M-Medium L-Low

	Description	**Knowledge Level**
CO1	Understand Fundamental Nuclear fission processes & Working	K2, K3 & K4
CO2	Able to handle Nuclear reactor Instrumentations & Knowledge of processes involved.	K4 & K5
CO3	Advanced working knowledge of Nuclear reactors & protocols	K1, K2, K3 & K5
CO4	Analysis of Fission parameters useful for production level.	K4 & K5
CO5	Able to do Basic analysis of safety measures in Nuclear environment.	K5 & K6

K1 - Recall; **K2** - Understand; **K3** - Apply; **K4** - Analyze; **K5** - Evaluate; **K6** - Create