MANIPAL
ACADEMY of HIGHER EDUCATION
(Institution of Eminence Deemed to be University)

Manipal Centre for Natural Sciences

Outcome Based Education (OBE) Framework

Part A: Program summary and outcomes.

PhD Program in PHYSICS

MANIPAL ACADEMY of HIGHER EDUCATION
(Institution of Eminence Deemed to be University)

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1. NATURE AND EXTENT OF THE PROGRAM

Manipal Centre for Natural Sciences (MCNS) is the first dedicated "all-research" Centre to be established within Manipal Academy of Higher Education (MAHE). MCNS nurtures fundamental research in all branches of the Natural Sciences and it is a 'Centre of Excellence' under the MAHE. The quality of the Academic Program is enhanced by integrating it with active research. Efforts are made towards the production of quality scientific research in all branches of Natural Sciences. MCNS is striving to establish a technology-enabled learning environment. The Academic and Research Ecosystem in the Centre is enhanced through the free flow of ideas and information as well as through the interaction with eminent scientists from other reputed national and international institutions. MCNS attempts to enhance the quality of Interdisciplinary Research through collaborations. MCNS promotes a culture of the research-integrated learning experience

The objective of the PhD program in Physics is to nurture cutting edge research in the field of fundamental subjects of Physics. Students with a PG degree in Physics can join the PhD program.

The following are necessary for successful completion of the PhD degree. However, the courses mentioned below are program and student centric, and are independent of other regular academic courses offered in MCNS.

(i) Three mandatory courses as per MAHE guidelines and at least one elective course specific to the chosen topic of research to be studied. These courses are necessary for every student registering for PhD in Physics, in MCNS, and shall be offered during the initial stages of the research work.
(ii) Research work and publications as per MAHE rules for PhD.
(iii) Student's progress monitored, guided, and assessed by a specific Doctoral Assessment Committee (DAC).
(iv) Award of the degree further depends on the standard of the thesis as assessed by the examiners, as per the standard university procedures.

2. PROGRAM EDUCATION OBJECTIVES (PEO)

The overall objectives of the Learning Outcome-based Curriculum Framework (LOCF) for the PhD program are as follows.

PEO No	**Education Objective** After the successful completion of the programme,
PEO 1	the students would have acquired essential knowledge in the basic concepts, and professional skills to address fundamental problems in Physics.
PEO 2	the students would be able to model phenomena in Physics theoretically with expertise, and do critical scientific analysis of the model with needed mathematical skills.
PEO 3	the students would be able to plan and conduct experiments in modern laboratories with state-of-the-art experimental facilities.
PEO 4	the students would be able to quantitatively analyse experimental data with state-of-the-art computational tools and statistical techniques.
PEO 5	the students would be able to practice the profession with a highly professional and ethical attitude, strong communication skills, and effective professional skills to work in a team with a multidisciplinary/international environment.
PEO 6	the students would be able to participate in a lifelong learning process for a highly productive career, and also to relate the concepts learnt towards serving the needs of the society.

3. GRADUATE ATTRIBUTES:

S No.	Attribute	Description
1	Disciplinary Knowledge	Knowledge in fundamental Physics, both theoretical modelling and experimental/ observational methods to verify the models.
2	Understanding different subsets of Physics	Basic post graduate level knowledge in core branches of Physics, Mathematics and Computational physics. Advanced level knowledge in chosen electives in the area of research.
3	Lifelong and autonomous learner	Qualities to become an autonomous learner throughout the life.
3	Measurable Skills in R&D – Analytical and Problem solving	Skill set required for any R&D professional, ability to collect, analyse and evaluate information and ideas, to solve problems by thinking clearly, critically and creatively, interpret experimental observations and extract scientific ideas, and to solve issues using established methods of enquiry.
4	Effective and Influencing communication	Ability to summarise or explain the ideas and observations, and to effectively communicate the same to peers and others in writing, or through oral presentation.
5	Leadership readiness/ Qualities	Confidence and qualities to take up challenges of solving a problem readily, as a leader, and to show directions to the others.
6	Research and creativity	Generate new knowledge through the process of research in natural sciences.
7	Technologically Efficient R&D Professional	Acquire all modern technological skills required for an R&D professional. This includes, computational skills, experimental and instrumentational skills, and effective communicational skills, and ease of using modern technology.
8	Ethical Awareness	Graduate to be imparted with values of research and academic ethics, importance of being original thinker and creator and readiness to give credits and acknowledgment to other researchers.
10	Team Work, Cooperation and Leadership	Trained to work in a team in cooperation with the other members of the team as well as along with other collaborators, and to gain skills to lead the team.

4. QUALIFICATIONS DESCRIPTORS

1.	Research skills	Demonstrate (i) a systematic, extensive and coherent knowledge and understanding of (a) the chosen topic of study in the field of Physics, including a critical understanding of the established theories, principles and concepts, (b) the advanced and emerging issues in and related to the chosen field, and of (c) the links to related disciplinary areas/subjects of study, that could benefit from or contribute to the chosen study. (ii) ability to (a) state the problem on hand, (b) describe its importance, methodology of solutions, and utility of the study, and (c) assess the resource requirement. (iii) skills of analyses using Mathematical, numerical, computational, and graphical tools (iv) professional communication skills to present the topic in perspective, using conventional as well as advanced techniques of communication.
2.	Learning skills	Demonstrate eagerness to achieve specific as well as comprehensive knowledge, through the study of professional literature, and through interactions with scholars in the field.
3.	Probing skills	Demonstrate skills in (a) performing experiments if needed, (b) interpreting observations to derive fundamental notions, (c) theoretical modelling and verification, and (d) in predicting the probable outcomes of the study.
4.	Publishing skills	Demonstrate skills to publish the results of the study in high quality journals

5. PROGRAM OUTCOMES:

After successful completion of the PhD Program in Physics, the Students will be able to:

PO No	Attribute	Competency
PO 1	Domain knowledge	apply the professional knowledge to analyse and solve fundamental problems in Physics.
PO 2	Problem analysis	Attempt to analyse contemporary problems in Physics.
PO 3	Design/develop solutions	design innovative theoretical models/experiments and apply professional skills in theoretical modelling and analysis, statistical data analysis and experiments to address fundamental problems in Physics.
PO 4	Conduct investigations of complex problems	divide a complex problem into a set of simpler problems so that the original problem can be solved at the end of solving all the simpler problems.
PO 5	Modern tool usage	undertake research on fundamental problems in physics with state-of-the-art experimental/computational facilities and up-to-date theoretical techniques.
PO 6	Business and society	relate the concepts learnt in Natural Sciences towards serving the needs of society.
PO 7	Environment and sustainability	relate the concepts learnt in Natural Sciences towards serving the needs of sustainability of essential resources.
PO 8	Ethics	undertake the profession with a highly professional and ethical attitude.
PO 9	Individual / Team work	work independently and in a team with a multidisciplinary/ international environment.
PO 10	Communication	communicate with national and international leading experts with strong communication skills and deep knowledge on the chosen discipline.
PO 11	Project management and finance	convince funding agencies, as a leader investigator, to obtain adequate finance for the research projects, and execute the project using adequate human and material resources. Interphase with administration in managing funds.
PO 12	Life-long learning	participate in a life-long learning process for a highly productive professional career.

6. PROGRAM SPECIFIC OUTCOMES:

After the successful completion of the PhD Program in Physics, the students will be able to:

PSO 1	identify the most important problems in Physics that can be addressed at current time, and make workable plans to address the problems.
PSO 2	conduct highly original research on fundamental problems in Physics.
PSO 3	lead a research team in the fields of Physics with strong leadership and communication skills.

The following are necessary for successful completion of the degree:

(i) Three mandatory courses as per MAHE guidelines and at least one elective course specific to the chosen topic of research to be studied. These courses are necessary for every student registering for PhD in Physics, in MCNS, and shall be offered during the initial stages of the research work.

(ii) Research work and publications as per MAHE rules for PhD.

7. COURSE STRUCTURE [for partial fulfilment of PhD Degree (As in 2021)]

Subject Code	Subject Title (Mandatory)	L	T	P	C	Subject Code	Subject Title (Electives)	L	T	P	C
NS PH 5101	Research Methodology	3	1	0	4	NS PH 5202/ NS PH 5203/ NS PH 5204	Elective I: Introduction to Astrophysics / Special Topics in Experimental Nuclear Physics I: Neutron Physics / Elements of Reactor Physics	3	1	0	4
NS PH 5102	Mathematical Techniques / Quantitative Analysis	3	1	0	4	NS PH 5210/ NS PH 5211	Elective II: Radiative Processes in Astrophysics / Advanced Reactor Physics	3	1	0	4
NS PH 5103	Numerical Techniques & Applications	3	1	0	4						
	Total				12		Total				8

- The syllabi for the above courses are given in the Annexure 1.
- The courses are necessary for every PhD student, and are independent of other regular academic programs in MCNS.

8. ANNEXURE – 1: COURSE SYLLABI.

A. Compulsory Coursework: (after registration)

1) Research Methodology: (4 Credits)

Précis, Composition and the Art of Writing a Scientific Paper

- Tools of the Trade: LaTeX, Shell Programming; Overview of Operating Systems; Linux and Unix as the Preferred Environment

Data Collection, Statistical Analysis: Probability Theories, Gaussian, Poisson and Binomial Distributions, Standard Deviation and Means, Chi-Squares Fitting, Coefficient of Variations, Interpolation, Extrapolation, Covariance, Correlation and Regression Analysis, Plotting of Graphs.

- Tools of the Trade: Design and Execute a Hypothetical Research Project and Write the Report,

Techniques for the Critical Analysis of Research Papers.
Special Topics: Literature Survey, Referencing

2) Mathematical Techniques / Quantitative Analysis: (4 Credits)

Introduction, Linear Spaces , Vectors, Gradient, Divergence, Curl, Stokes Theorem, Matrices , Eigenvalue Problem, Coordinate Systems, Rotation of Axes, Angular Momentum, Addition of Angular Momenta, Spherical Harmonics, Addition Theorem, Multipole Expansion, Fourier Transforms, Ordinary Differential Equations, Second Order Homogeneous and Inhomogeneous Equations, Wronskian, General Solutions, Delta Functions, Green`s Functions, Legendre, Hermite, Laguerre and the Associated Polynomials, Their Differential Equations, Generating Functions, Statistical Analysis.
Prerequisite: B. Sc, B. Tech Level University Program

3) Numerical Techniques & Applications: (4 Credits)

Introduction, Matrices, Matrix Diagonalisation, Eigenvalues & Eigenvectors, Numerical Methods, Numerical Differentiation and Integration, Newton – Raphson and Steepest Descent Methods, Range-Kutta Prescription, Statistical Error Analysis, Chi-Squares Fitting Methods, Graphics, Origin & Gnu Graph Plotting Programs; Programming & Languages
Prerequisite: B. Sc, B. Tech Level University Program

B. Elective Courses

1. Introduction to Astrophysics: (4 Credits)

Mass, Length and Time Scales in Astrophysics, Emergence of Modern Astrophysics, Astronomical Observations: Electromagnetic, Look Back Time, Cosmic Rays, Earth vs. Space Based Observations, Role of Atmospheric Transmission; Celestial Sphere, the Ecliptic, RA/DEC Coordinates, Galactic Coordinates; Luminosity/Flux, Magnitude Scale, Absolute/Apparent Magnitude; Electromagnetic Wavebands, Spectroscopy; the Third Dimension: Distance Measurement, A.U., Parsec; Standard Candles, Astronomy in Different Band of Electromagnetic Radiation: Optical, Radio, X-ray and Gamma-Ray, Distance Ladder
Spectral Classification of Stars, Electro-Magnetic Spectrum, Doppler Shift, Planck`s Radiation Formula, Thermal Equilibrium and Boltzmann Factor, Saha-Boltzmann Ionization Equation, Astronomical Scale, Units of Stellar Brightness, Radius of Star, Effective Temperature, Equation of State for Stellar Atmosphere
Sources of Continuous Spectrum, Opacity, Abundance of Elements, Variation of Abundances and Isotope Ratio

Structure Equation, Mode of Energy Transport, Nuclear Reactions, Formation and Evolution of Stars, White Dwarfs, Neutron Stars and Black Holes, Interstellar Matter,
21 cm and Molecular Lines, Galaxies and Quasars
Prerequisite: M Sc/ B Tech / BE Level University Program

2. Radiative Processes in Astrophysics: (4 Credits)

Radiative Transfer
Radiation field
Radiation from moving charges
Special Relativity
Bremsstrahlung
Synchrotron Radiation
Compton and Inverse Compton Scattering
Plasma Effects
Radiative Transition
Molecular Structure
Prerequisite: M Sc/ M Tech level University program

3. Special Topics in Experimental Nuclear Physics I: Neutron Physics: (4 Credits)

Fundamentals of Physics with Neutrons, Accelerators, Reactors; Neutron Transmission Studies, Neutron Spectroscopy.
Lab at MCNS: Measurement of Gamma Spectra from NAA,
NAA analysis – Physics & Techniques
Prerequisite: Nuclear and Particle Physics / Experimental Nuclear Physics Course, Basic Knowledge of Radiation Physics: B Sc/BTech/M Sc/M Tech Level

4. Elements of Reactor Physics: (4 Credits)

Neutron/Gamma interaction cross-sections with nuclei/atoms. Neutron spectrometry. Neutron activation analysis.
Radiation transport equation and its various forms. Neutron diffusion equation, its validity and its solution with and without external sources.
Elements of nuclear reactor theory. Reactor criticality and spatial neutron distribution. Delayed neutrons and time dependent behaviour neutron distribution.
Reactor types, Nuclear reactors and their fuel cycle.
Numerical analysis and approximate solution of diffusion equation. Monte Carlo methods.

5. Advanced Reactor Physics: (4 Credit)

Fundamental requirements of nuclear reactor design. Modeling the reactor core and shields for solving neutron transport equation. Space homogenisation and energy variation problems. Modeling requirements of thermal and fast neutron reactors; criticality, geometries and material buckling.
Methods of approximate solution of neutron transport equation. Weighted residual methods. Spherical harmonic, discrete ordinate and collision probabilities methods.
Actinide burnup equation and evolution of fuel composition with time. Elements of fuel management. Decay heat estimation.
Large size nuclear reactors and eigenvalue separation. Spatial decoupling and spatial control.
Prerequisite: Elements of Reactor Physics course