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(Institution of Eminence Deemed to be University)

Manipal Centre for Natural Sciences

Centre of Excellence

Revised Regulations for the Integrated MSc-PhD Programme and Outcome-Based Education (OBE) Framework for Physics Discipline

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NATURE AND EXTENT OF THE PROGRAMME

Manipal Centre for Natural Sciences (MCNS) is the first dedicated "all-research" Centre to be established within the 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 Programme is enhanced by integrating it with active research. Efforts are made towards producing 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 and 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 a research-integrated learning experience.

The Integrated MSc-PhD programme is open for students with bachelor's degrees, highly meritorious and motivated towards fundamental research in the frontier areas of Natural Sciences. A student in this programme would complete the courses mandatory for a PhD, along with the courses essential for an MSc., during the first two semesters and acquire ample research experience by working on a research project during the 3rd and the 4th semesters. On successful completion of four semesters, the student can opt to exit with an MSc by Research in *discipline* or can opt to continue for a PhD. *"discipline"* stands for the appropriate subject discipline in Natural Sciences pursued by the student under this programme. The Integrated MSc-PhD programme in the Physics discipline is being offered from the Academic Year 2021-22 onwards. PhD level work begins in the 5th semester. Such a student would be more equipped than a regular MSc student while beginning to do PhD level work.

1. Objective

To identify talented and dedicated bachelor's degree holders with a keen sense of scientific enquiry and motivate them to pursue high-priority research in frontier areas of Natural Sciences.

2. Eligibility for Admission:

The Integrated MSc-PhD programme accepts students who have completed B.Sc./ B.E./ B. Tech degree with an excellent academic record, and who are strongly motivated to pursue a career in research.

3. Number of Students

The number of students to be admitted to this Integrated MSc-PhD programme per discipline per academic year is presently limited to a maximum of 20.

4. Selection

Candidates are invited to apply in response to advertisements issued by MAHE. The applicants are required to take the written test and/or interview.

5. Financial Support:

A maximum of six Dr. TMA Pai PhD fellowships per discipline would be made available for students proceeding to the 5th semester and beyond under this Integrated MSc-PhD programme. Such students will receive financial support from the Manipal Academy of Higher Education for three years, starting from the 5th semester of the programme.

6. Course Fees

The course fee for the first four semesters will be the same as for the Master's by Research programme.

The fees applicable to a student proceeding to the 5th semester and beyond under this programme would be similar to that for a regular PhD student of MAHE.

Financial support may become admissible, as mentioned in item 5 above.

PROGRAMME REGULATIONS - Integrated MSc-PhD Programme

1. The Integrated MSc-PhD Programme and its Structure

1.1 The programme is structured for those talented bachelor's degree holders from the Science or Engineering stream who are determined to do a PhD in the frontier areas of Natural Sciences. The graduates enrolled on this programme will be equipped with master's level skills in the first two years and will be registered for the PhD work in the third year. The programme includes essential academic curricula, but its structure emphasises a research orientation. The students need to show exceptional aptitude and progress to continue in the programme.

1.2 The Integrated MSc-PhD, in principle, is a single programme, apparently including two parts, viz., the MSc part and the PhD part.

1.3 The minimum total duration of the programme is five years.

1.4 The MSc part is covered in the first two years through 4 semesters. The first two semesters are devoted to teaching the essential subjects at the master's level and the specific courses that are mandatory for the PhD. The 3rd and the 4th semesters are combinedly earmarked for research project work at the master's level.

1.5 The programme provides for an 'Exit Option' after the MSc part is completed.

1.6 The PhD part: This part follows the procedures and regulations of the regular full-time PhD programme in MAHE, except for the need for the mandatory courses, which are covered in the MSc Part as per 1.4 above.

1.7 The medium of instruction is English.

2. The semesters

2.1 There are two semesters per academic year during the MSc part.

2.2 The academic programme includes sessions for lectures, tutorials, lab work, seminars, fieldwork, revisions, and quizzes.

2.3 The 3rd and the 4th semesters are together earmarked for the MSc level research, per 1.4 above. A student chooses a consenting MCNS faculty as a guide and selects a topic for a research project with the guide's advice. A senior post-doctoral fellow (PDF) in MCNS can also be chosen as the project mentor, subject to special approval of the competent authority, who will assign a regular faculty member as a nominal guide.

2.4 The PhD part (starting from the 3rd year) shall be applicable as per MAHE regulations for a regular full-time PhD programme.

3. Distribution of credits

3.1 The MSc part (2 years/ 4 semesters)

The total minimum credits for the MSc Part, which has four semesters, is 80, as per MAHE guidelines.

3.2 The MSc part 1st year: 2 semesters

3.2.1 Each semester includes contact sessions for lectures, tutorials, lab work, fieldwork, revisions, seminars, and quizzes. The credit distribution with minimum hours requirement per credit is given below:

- Lectures (L): 1 hour/week = 1 credit
- Tutorials (T): 1 hour/week = 1 credit
- Practical (P): 2 hours/week = 1 credit
- Seminar (S): 1 hour/week = 1 credit

3.2.2 Credits in a semester are distributed as follows:

- Maximum Credit for a Theory course: 4
- Practical course: 3
- Seminar: 1

3.2.3 The aggregate credits for the 1st year are, as follows:

- Theory, practical, and seminar per semester: 20
- Theory, practical, and seminar for the two semesters: 40

3.3 The MSc part 2nd year: 3rd and 4th Semesters

3.3.1 Both semesters combined are reserved for a Research Project. It includes theoretical and practical studies, both requiring intense interaction with the mentor and other advisors. It may include, in certain cases, attending specialized online/offline courses. The practical work may include lab work, fieldwork, on campus or out of campus.

3.4 The PhD part

3.4.1 The courses worth 12 credits, which are mandatory for regular PhD students, viz. for those registered after an MSc course done under a different scheme, are not included in this part since these courses have been covered in the MSc part. Except for this, the PhD part of the Integrated MSc-PhD programme is identical to the regular PhD programme of MAHE.

3.4.2 The mandatory course on 'Research and Publication Ethics' will have to be taken in the 5th semester.

4. Attendance

4.1 To appear for the End-Semester (Term-End) examination, a minimum of 75% attendance is required in every course in each semester. A maximum allowed leave of 25% includes medical leave as well.

5. Examination

5.1 The MSc Part 1st year (semesters 1&2)

5.1.1 There are two forms of assessment, viz., (1) Internal Assessment Component (IAC) and (2) End Semester Examination (ESE). IAC includes sessional examinations like mid-semester examination, quizzes etc., and short classroom tests, called viva-voce, assignments, seminars, or any other component as applicable. The weightage of IAC and ESE is given in the table below.

	IAC Weightage (%)	ESE Weightage (%)
Theory	50	50
Practical	100	0
Seminar	100	0
Project	0	100

5.1.2 ESE will be conducted by the university as per the rules and regulations of MAHE.

5.1.3 The final evaluation for each course shall be done based on the IAC and the ESE component, using appropriate weightages (as indicated in clause 5.1) given for respective courses.

5.1.4 A minimum of 40% marks per subject is required in ESE and in aggregate to pass each course.

5.1.5 If a student is eligible but fails to appear in any subject in the ESE with a valid reason, such as a serious medical emergency, upon approval of HOI, will be awarded and I grade (incomplete) for that subject in the grade sheet.

5.1.6 Any student with an F or I grade in any subject can opt for taking a supplementary examination (in that subject), which will be conducted in about three weeks after the result declaration. A maximum C grade will be awarded to those who appeared for the supplementary exam with an F grade. A student with an I grade will be allowed to retain whatever grades he/she obtained in the supplementary exam.

5.1.7 In case a student is unable to pass in the first attempt in the supplementary exam in a subject, as in 5.1.5 above, he/she will be permitted to make a second attempt during the next regular ESE in that subject, i.e., typically one year later. No further chance of this kind shall be permitted.

5.2 The Academic Advisory Committee (AAC): An Academic Advisory Committee will be constituted for all the students in each discipline enrolled in the same academic year. The Committee would include a chairperson, the thesis guides of the students and other members as nominated by the chairperson.

5.3 The MSc Part 2nd year (semesters 3&4)

5.3.1 Assessment of performance during the 2nd year

- Level of understanding of the selected research project, execution, presentation, will be assessed periodically throughout the 3rd and the 4th semesters.
- The student will have to present a protocol in the initial phase and interim progress report.
- The project will be evaluated based on the final report and the presentation at the end of the 2nd year by AAC.

5.3.2 A student obtaining an E grade or above in each subject will obtain the degree of "MSc by Research in *discipline*".

5.3.3 Every student should inform in writing to the HOI, whether they wish to proceed to 3rd year for the PhD part of the programme or to exit with the degree of "MSc by Research in *discipline* ".

5.4 Proceeding to do PhD work

5.4.1 Students who have successfully completed all courses with at least a CGPA of 7.5 in the aggregate are eligible to proceed for the PhD part of the Integrated MSc-PhD programme (3rd year onwards).

5.4.2 Based on the performance in the first two years, and the interaction with the respective student, the AAC will recommend proceeding to the PhD part.

5.4.3 A student, who has cleared the MSc part with adequate grades but is not recommended by AAC to proceed to register for PhD, will have to exit the programme with the MSc by Research in *discipline* degree mentioned in section 5.3.2.

5.5 The PhD Part

5.5.1 Individual **Doctoral Advisory Committee (DAC)** will be constituted for each student proceeding to the PhD part, as per the MAHE PhD guidelines.

5.5.2 Regular assessment of the PhD student is done by the DAC.

6. Transcripts and Degree(s)

6.1 Transcripts will be prepared and issued for the courses in the MSc part. Additional transcripts of the PhD Course work will be issued to those students who proceed to the PhD part.

Transcripts will carry the programme title "Integrated MSc-PhD Programme in *discipline*."

In the case of the Physics discipline, the grades for the following courses that must be completed during the MSc part will be transferred to the PhD transcript; therefore, a student who proceeds to the PhD part does not need to take these courses again. See also 3.4.1.

NS PH 5101 Research Methodology
NS PH 5102 Advanced Mathematical Techniques
NS PH 5103 Numerical Techniques & Applications

6.2 Students who complete the first four semesters of the course successfully will be awarded the degree: "MSc by Research in *discipline*".

6.3 Students who successfully complete the Integrated MSc-PhD programme will be awarded a PhD degree (in addition to the MSc by Research degree).

6.4 Students who are declared successful in the first four semesters but not recommended to proceed further in the programme would exit the programme. Such students will be awarded an "MSc by Research in *discipline*" degree.

6.5 Those students who exit the programme after the successful completion of first four semesters shall return the original transcripts, that will be replaced with the transcripts with the programme title "MSc by Research in *discipline*."

7. Grading

7.1 Evaluation and Grading of students shall be based on Grade Point Average (GPA) and Cumulative Grade Point Average (CGPA).

7.2 A relative grading method will be followed as per MAHE rules. A minimum of absolute 40% marks in aggregate is required to pass a course.

7.3 A 10-point grading system (credit value) is used for awarding a letter grade in each course.

Letter Grade	A+	A	B	C	D	E	F/DT/I
Credit Value	10	9	8	7	6	5	0

F – Fail, DT – Detained/Attendance shortage, I – Incomplete

7.4 Calculation of GPA and CGPA will be as per the standard method followed by MAHE.

Manipal Centre for Natural Sciences

Centre of Excellence

Manipal Academy of Higher Education, Manipal - 576104

Outcome-Based Education (OBE) Framework

Integrated MSc – PhD Programme in Physics

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1. PROGRAMME EDUCATION OBJECTIVES (PEO)

The objectives of the Learning Outcome-based Curriculum Framework (LOCF) for the Integrated MSc-PhD program meare as follows.

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

2. 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 life.
4	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; to interpret experimental observations and extract scientific ideas; and to solve issues using established methods of enquiry.
5	Effective communication	Ability to summarise or explain ideas and observations and to effectively communicate the same to peers and others in writing or through oral presentation.
6	Research and creativity	Generate new knowledge through the process of research in natural sciences.
7	Technologically Efficient R&D Professional	Acquire modern technological skills required for an R&D professional. This includes computational skills, experimental and instrumentational skills, effective communicational skills, and ease of using modern technology.
8	Ethical Awareness	Graduates are to be imparted with values of research and academic ethics, the importance of being original thinkers and creators and readiness to give credit and acknowledgement to other researchers.
9	Teamwork	Trained to work in a team in cooperation with the other members of the team as well as with other collaborators.

3. 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) predicting the probable outcomes of the study.
4.	Publishing skills	Demonstrate skills in publishing the results of the study in quality journals

4. PROGRAMME OUTCOMES

After successful completion of the MSc part of the PhD. Programme in Physics, the Students will be able to:

PO No	**Attribute**	**Competency**
PO1	Domain Knowledge	Acquire essential knowledge of scientific fundamentals and apply it to solve problems in Physics.
PO2	Problem analysis:	Identify, formulate, and analyse scientific problems using principles of Physics.
PO3	Design/development of solutions	Design theoretical models/experiments and apply professional skills in modelling, statistical data analysis and laboratory experiments to address fundamental problems in Physics.
PO4	Conduct investigations of complex problems:	Conduct scientific investigations, provide valid reasoning, and draw conclusions following appropriate research methodology.
PO5	Modern tool usage:	Apply appropriate techniques, resources, and modern tools, with an understanding of their merits & limitations, in research investigations.
PO6	Science and society	Understand the importance of science in societal contexts and take responsibility for propagating and disseminating scientific information to society.
PO7	Ethics:	Commit to the professional ethics and norms of scientific practices.
PO8	Individual and teamwork:	Function effectively as an individual and as a member of a team.
PO9	Communication:	Communicate effectively, orally and in writing or through presentations on scientific matters, in a scientific or a social gathering, and give & receive instructions clearly.
PO10	Life-long learning:	Engage in independent and lifelong learning to be up to date with respect to scientific developments.

5. COURSE STRUCTURE

Table 6.1: Semester I

Subject Code	Subject title	L	T	P	C	Internal Max Marks	External Max Marks	Total Max Marks
NS PH 5101	Research Methodology	3	1	0	**4**	50	50	100
NS PH 5102	Advanced Mathematical Techniques	3	1	0	**4**	50	50	100
NS PH 5103	Numerical Techniques & Applications	3	1	0	**4**	50	50	100
NS PH 5104	Quantum Mechanics & Applications	3	1	0	**4**	50	50	100
NS PH 5130	Lab I	0	0	9	**3**	100	-	100
NS PH 5131	Seminar /Colloquium		1		**1**	100	-	100
	Total				**20**			

Table 6.2: Semester II

Subject Code	Subject title	L	T	P	C	Internal Max Marks	External Max Marks	Total Max Marks
NS PH 5201	Modern Physics I	3	1	0	**4**	50	50	100
NS PH 5202	Modern Physics II	3	1	0	**4**	50	50	100
*	Elective I * Options are given in Table 6.3	3	1	0	**4**	50	50	100
*	Elective II * Options are given in Table 6.3	3	1	0	**4**	50	50	100
NS PH 5230	Lab II	0	0	9	**3**	100	-	100
NS PH 5231	Seminar/Colloquium		1		**1**	100	-	100
	Total				**20**			

Table 6.3

#	Subject Code	Elective Course Name	Credits
1	NS PH 5203	Introduction to Astrophysics	4
2	NS PH 5206	Introduction to Quantum Field Theory	4
3	NS PH 5207	Nuclear and Particle Physics	4
4	NS PH 5210	Radiative Processes in Astrophysics	4

Table 6.4: Semester III & IV

Subject Code	Subject title	C	Internal Max Marks	External Max Marks	Total Max Marks
NS PH 6001	Research Project	40	60	40	100
	Total	40			

* **Electives:** In 2nd Semester, the students will have to choose any of the two courses as electives (Elective 1 and Elective 2) from the options given below.

6. COURSE OUTCOME DETAILS

Name of the Institution / Department: Manipal Centre for Natural Sciences

Name of the Programme:	Integrated MSc-PhD in Physics
Course Title:	Research Methodology
Course Code: NS PH 5101	**Course Instructor:**
Academic Year:	**Semester:** I
No of Credits: 4	**Prerequisites:** B.Sc./B. Tech
Synopsis:	This regular four-credit course aims to equip students with the research methodology essential for pursuing quality research. It intends to acquaint the students with identifying a research problem, carrying out quantitative analysis, and verifying and testing scientific hypotheses.
Course Outcomes (COs):	On successful completion of this course, students will be able to
CO 1:	Understand the crux of a given research problem in physical sciences and demonstrate the ability to choose methods suitable to solve it (C2), with due respect to professional Ethics.
CO 2:	Explain the basics of descriptive statistics, error analysis, and rules of probability (C2) and apply them to problems in physics (C3)
CO 3:	Explain the Gaussian, Poisson, and Binomial distribution functions, and apply them to characterize given data sets (C2, C3)
CO 4:	Apply and Analyse hypothesis testing to a given data set (C3, C4) to assess the validity of a theoretical model (C5) and estimate corresponding model parameters (C5)
CO 5:	Develop a report using LaTeX on a scientific research topic (C3)

Mapping of COs to POs

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10
CO 1	X						X		X	X
CO 2	X	X							X	X
CO 3	X	X			X				X	X
CO 4	X	X	X	X	X					X
CO 5	X				X		X		X	X

Course content and outcomes:

Content	Competencies	No of Hours
Unit 1: Introduction to Research Methodology and Scientific writing		
Introduction to scientific methods: Roles of experiments and theory in research, Deduction versus Induction, Reductionism and Wholism: example of the synthesis of protein and ant heap Occam's razor, Simplicity in Science, Types of research,	• Illustrate Deduction versus Induction, and reductionism and wholism (C2) • Explain Occam's razor and its importance (C2) • Explain research method versus research methodology, thought	12

Method versus methodology in research, The thought experiment (Gedanken experiment), and Ethics of research. LaTeX, Shell Programming; Overview of Operating Systems; Linux as the preferred environment: Introduction to Octave and python. Review of Literature: Need, purpose and relevance for Reviewing Literature - What to Review and for What Purpose - Literature Search - Procedure - Sources of Literature, Differentiate between a good and a bad research publication, Selection of a problem for research Communication: Written vs oral communication, Precis writing, Abstract writing. Scientific writing: report and research paper: structure, the flow of writing, Citation. Home assignment: Report writing using Latex on a research topic	experiment (C2) • Select appropriate literature for review and differentiate between a good and a bad research paper (C3) • Explain the structure of scientific report writing (C2) • Develop a report using latex on a scientific research topic (C3)	
Unit 2: Descriptive Statistics		
Introduction to statistics, Sampling of data. Descriptive statistics: (A) Organizing data Variables and data; Grouping data; Graphs and charts: Histograms, Dot-plots, Pie Charts and bar Graphs; Distribution shapes: Symmetry and skewness; Misleading graphs (B) Descriptive Measures, Measures of centre: mean, median and mode of a dataset; the sample mean; Measures of variation: The sample standard deviation; the five-number summary (Min, Max, first, second, and third quartile): boxplots; Descriptive measures of populations: use of samples	• Explain different kinds of statistics (C2) • Explain symmetry and skewness of a distribution (C2) • Define mean, median and mode of a dataset (C1) • Illustrate five-number summary of a data set (C2) • Solve for mean, median, mode, and the five-point summary of a dataset (C3) • Solve for the sample variance of a discrete random sample (C3)	6

Unit 3: Applications of Quantum Mechanics		
(A) Introduction to probability: Basics; Rules of probability; Contingency Tables, Joint and Marginal Probabilities; Conditional probability; Bayer's rule; The Multiplication Rule; The Counting Rules: Permutation, Combination. (B) Discrete random variables: Random variables and probability distributions; The mean and variance of a discrete random variable; The Binomial Distributions: Mean and Standard Deviation of a Binomial Random variable; The Poisson distribution: Mean and Standard deviation of a Poisson random variable; The Gaussian Distribution: Basics; Area under the standard normal curve; Mean Standard deviation and z-score; (C) The Sampling distribution of the sample mean. Sampling error; Mean and standard deviation of the sample mean.	• Explain rules of probability and Bayer's rule and apply them to problems in physics (C2, C3) • Explain mean and standard deviation of a discrete random sample (C2) • Explain the Gaussian, Poisson, and Binomial distributions, and apply them to characterize given data sets (C2, C3) • Explain sampling distribution of the sample mean (C2) • Solve for sample mean and error in sample mean for a normally distributed variable (C3)	12
Unit 4: Inferential Statistics		
(A) Confidence intervals of one population mean. Estimating a population mean; Confidence interval of one population mean with known standard deviation; Margin of error; Confidence interval of one population mean with unknown standard deviation; (B) Hypothesis test of one population mean: Basics; Hypothesis test for one population mean with known sigma; Type I and type II errors; Alpha and P-values;	• Explain confidence interval and hypothesis testing (C2) • Illustrate type I and type II errors (C2) • Apply and analyse hypothesis testing in simple problems (C3, C4) and assess acceptance/ rejection of a model (C5) • Explain Chi-square distribution and quantitative fitting (C2) • Solve for confidence intervals for a population mean (C3) • Apply the Chi-square test to a given data set (C3) to Assess the validity	10

(C) The sample distribution of the difference between two sample means for independent samples (D) Error analysis accuracy and precision, systematic and random errors, error propagation (E) Chi-Square test: Basics; Chi-square test of a distribution; distribution, Introduction to curve fitting, goodness of fit.	of a theoretical model (C5) and estimate various parameters of a model (C5)	
Unit 5: Regression, Correlation and ANOVA		
(A) Regression and Correlation analysis: Linear equations with one independent variable; The regression equation; The coefficient of determination; Linear correlation; Inferential methods in regression and Correlation (B) Interpolation, Extrapolation, Analysis of variance	• Explain regression equation and coefficient of determination (C2) • Explain linear correlation coefficient (C2) • Explain analysis of variance (C2) • Illustrate interpolation and extrapolation of a data set (C2) • Examine and compare different models for a given data set (C4, C5)	8

Learning strategies, contact hours and student learning time		
Learning strategy	Contact hours	Student learning time (Hrs)
Lecture	36	108
Seminar		
Small Group Discussion (SGD)		
Self-directed learning (SDL)		
Problem Based Learning (PBL)	12	52
Case Based Learning (CBL)		
Clinic		
Practical		
Revision	6	12
Assessment	6	2
TOTAL	**60**	**174**
Assessment Methods:		
Formative:	**Summative:**	

Class tests			Sessional examinations (Mid Semester Examination, Quiz1, Quiz2)		
Assignments/presentations			End semester examination		
Group discussions					
Mapping of assessment with Cos					
Nature of assessment	CO 1	CO 2	CO 3	CO 4	CO 5
Quiz 1	X	X			
Mid Semester Examination	X	X	X		
Quiz 2			X		X
End Semester Examination	X	X	X	X	X
Formative Assessments	X	X	X	X	X

Feedback Process	• Mid-Semester Feedback • End-Semester Feedback
Reference Material	1. "Introductory Statistics", Neil A. Weiss, Pearson Education 2. "Data Reduction and Error Analysis for the Physical Sciences", P.R. Bevington and R. K. Robinson 3. "THE SCIENTIST'S GUIDE TO WRITING" Stephen B. Heard, Princeton University Press. 4. "The Art of Being a Scientist: A Guide for Graduate Students and their Mentors", Roel Snieder and Ken Larner 5. "Research Methodology Methods and Techniques", C.R. Kothari, Gaurav Garg 6. "How to write a first-class paper", Nature, 2018, 555, 129 7. "What is Occam's Razor?" (https://math.ucr.edu/home/baez/physics/General/occam.html) 8. "Simplicity", Stanford Encyclopedia of Philosophy (https://plato.stanford.edu/entries/simplicity/)

Name of the Institution / Department: Manipal Centre for Natural Sciences

Name of the Programme:	Integrated MSc-PhD in Physics
Course Title:	Advanced Mathematical Techniques
Course Code: NS PH 5102	**Course Instructor:**
Academic Year:	**Semester:** I
No of Credits: 4	**Prerequisites:** B.Sc./B. Tech
Synopsis:	This course aims to make students master the knowledge and the skills in Mathematical Techniques that are frequently required in research in Physics.

Course Outcomes (COs):	On successful completion of this course, students will be able to
CO 1:	Explain Mathematical Techniques in Vector Analysis (C2) and apply them to solve problems in Physics (C3).
CO 2:	Explain Mathematical Techniques in Fourier Analysis (C2) and apply them to solve problems in Physics (C3).
CO 3:	Explain Mathematical Techniques in Differential Equations (C2) and apply them to solve problems in Physics (C3).
CO 4:	Explain Mathematical Techniques in Complex Analysis (C2) and apply them to solve problems in Physics (C3).
CO 5:	Explain Mathematical Techniques in Rotation Group (C2) and apply them to solve problems in Physics (C3).
CO 6:	Choose appropriate Mathematical Techniques to solve problems in Physics (C5).

Mapping of COs to POs

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10
CO 1	X	X							X	X
CO 2	X	X							X	X
CO 3	X	X							X	X
CO 4	X	X							X	X
CO 5	X	X							X	X
CO 6	X	X	X	X	X					X

Course content and outcomes:

Content	Competencies	No of Hours
Unit 1: Linear Spaces and Vector Analysis		
Linear Spaces, Matrices, Eigenvalue Problems, Cartesian Coordinates, Vectors, Gradient, Divergence, Curl, Gauss Theorem, Stokes Theorem, Curvilinear Coordinates, Differential Operators and Integrations in Curvilinear Coordinates.	• Explain (C2) and apply (C3) Mathematical Techniques in Linear Space and Vector Analysis, such as eigenvalue problems, differential operators and integration theorems, and curvilinear coordinates. • Choose appropriate Mathematical Techniques to solve problems in Physics (C5) (after completing all the units).	12
Unit 2: Fourier Analysis		

Fourier Series, Fourier Transform, Convolution	• Explain (C2) and apply (C3) Mathematical Techniques in Fourier Analysis. • Choose appropriate Mathematical Techniques to solve problems in Physics (C5) (after completing all the units).	8
Unit 3: Differential Equations and Special Functions		
Ordinary Differential Equations (ODEs), Second-Order Homogeneous- and Inhomogeneous- equations, Wronskian, General Solutions, Delta Functions, Green's Functions, Legendre-, Hermite- and Laguerre- Differential Equations and the Associated Polynomials, Generating Functions, Probability Distributions that frequently appear in Statistical Data Analysis (binomial, Poisson, Gauss normal).	• Explain and apply Mathematical Techniques in Differential Equations, such as solving second-order ordinary differential equations by various methods such as series expansion (C2, C3). • Explain representative special functions (C2) and apply them in solving differential equations (C3). • Explain probability distributions that frequently appear in Statistical Data Analysis (C2) • Choose appropriate Mathematical Techniques to solve problems in Physics (C5) (after completing all the units).	12
Unit 4: Complex Analysis		
Complex Variables and Functions, Cauchy-Riemann Conditions, Cauchy's Integration Theorem, Laurent Expansion, Singularities, Residues, Applications for Evaluating Definite Integrals and Series Sums.	• Explain (C2) and apply (C3) Mathematical Techniques in Complex Analysis, such as Cauchy's integration theorem and applications for evaluating definite integrals (C2, C3). • Choose appropriate Mathematical Techniques to solve problems in Physics (C5) (after completing all the units).	8
Unit 5: Rotation and Elements of Group Theory		
Introduction to Group Theory, Representations of Group, Symmetries in Physics, Rotation of Axes, Angular Momentum, Addition of Angular Momenta, Spherical Harmonics, Addition Theorem, Multipole Expansion.	• Explain and apply Mathematical Techniques in Rotation Group and Group Theory, such as the Addition of Angular Momenta (C2, C3). • Choose appropriate Mathematical Techniques to solve problems in	8

	Physics (C5) (after completing all the units).	

Learning strategies, contact hours and student learning time		
Learning strategy	Contact hours	Student learning time (Hrs)
Lecture	36	108
Seminar		
Small Group Discussion (SGD)		
Self-directed learning (SDL)		
Problem Based Learning (PBL)	12	42
Case Based Learning (CBL)		
Clinic		
Practical		
Revision	6	12
Assessment	6	-
TOTAL	60	162

Assessment Methods:	
Formative:	**Summative:**
Class tests	Sessional examinations (Mid Semester Examination, Quiz1, Quiz2)
Assignments/presentations	End semester examination
Group discussions	

Mapping of assessment with Cos						
Nature of assessment	CO 1	CO 2	CO 3	CO 4	CO 5	CO 6
Quiz 1	X					
Mid Semester Examination	X	X	X			
Quiz 2		X	X	X		
End Semester Examination	X	X	X	X	X	X
Formative Assessments	X	X	X	X	X	X

Feedback Process	• Mid-Semester Feedback • End-Semester Feedback
Reference Material	1. Arfken, Weber and Harris, "Mathematical Methods for Physicists," 7th Edition, Elsevier. 2. Boas M L, "Mathematical Methods for Physical Sciences," 3rd Ed., Wiley. 3. Dennery P, Krzywicki A, "Mathematics for Physicists," Dover Publication. 4. Kreyszig E, "Advanced Engineering Mathematics," 10th Ed., Wiley. 5. Potter M C, Goldberg J L, "Mathematical Methods," 2nd Ed. PHI Learning. 6. Riley K F, Hobson M P, Bence S J, "Mathematical Methods for Physics and Engineering," 3rd Ed, Cambridge Univ. Press.

	7. Ghatak A K, Goyal I C, Chua S J, “Mathematical Physics,” Trinity Press. 8. Spiegel M R, Lipschutz S, Spellman D, “Vector Analysis,” 2nd Ed, McGraw Hill. 9. Spiegel M R, “Fourier Analysis,” McGraw Hill. 10. Spiegel M R, Lipschutz S, Schiller J J, Spellman D, “Complex Variables,” 2nd Ed, McGraw Hill. 11. Davis H F, Snider A D, “Introduction to Vector Analysis,” 7th Ed. Brown Co. 12. Bracewell R N, “The Fourier Transform and Its Applications,” 3rd Ed. McGraw Hill. 13. Brigham E O, “The First Fourier Transform and Its Applications,” Prentice Hall. 14. James J F, “A Student’s Guide to Fourier Transforms,” 3rd Ed. Cambridge Univ. Press. 15. Brown J W, Churchill R V, “Complex Variables and Applications,” 9th Ed. McGraw Hill. 16. Lang S, “Complex Analysis,” 4th Ed. Springer. 17. Farlow S J, “Partial Differential Equations for Scientists and Engineers,” Dover Publications. 18. Snider A D, “Partial Differential Equations,” Dover Publications. 19. Bell W W, “Special Functions,” Dover Publications. 20. Lebedev N N, “Special Functions & Their Applications,” Dover Publications. 21. Greiner W, Muller B, “Quantum Mechanics: Symmetries,” Springer. 22. Zee A, “Group Theory in a Nutshell for Physicists,” Princeton Univ. Press.

Name of the Institution / Department: Manipal Centre for Natural Sciences

Name of the Programme:	Integrated MSc-PhD in Physics
Course Title:	Numerical Techniques & Applications
Course Code: NS PH 5103	**Course Instructor:**
Academic Year:	**Semester:** I
No of Credits: 4	**Prerequisites:** B.Sc./B. Tech
Synopsis:	The course will cover the fundamental numerical techniques frequently required in research in physical sciences and other related branches.
Course Outcomes (COs):	On successful completion of this course, students will be able to:
CO 1:	Explain Numerical Techniques used in research in Physical Sciences and related fields (C2)
CO 2:	Utilise different plotting and approximation (fitting, interpolation) algorithms and programs to plot and fit data & models (C3)
CO 3:	Choose appropriate Numerical Techniques to analyse and solve problems in Physical Sciences (C5, C4, C3)
CO 4:	Design algorithms by choosing appropriate numerical techniques and develop programs in any one of the high-level programming languages (C6, C3)

Mapping of COs to POs

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10
CO 1	X	X				X			X	X
CO 2	X	X			X	X				X
CO 3	X	X	X		X	X				X
CO 4	X	X	X		X	X				X

Course content and outcomes:

Content	Competencies	No of Hours
Unit 1: Introduction to Errors in Numerical Computations		
Analytical vs Numerical Methods, Contents of the Course, Errors in Numerical Computations, Binary Machine Numbers, Roundoff Errors, Absolute Errors and Relative Errors, Truncation Errors, Algorithms and Convergence, Rate of Convergence, and Stability.	• Explain (C2) the difference between analytical Vs numerical methods, the errors, convergence and stability. • Apply (C3) the knowledge of Errors while solving Physical Problems. • Choose (C5) the right algorithms for solving problems using the knowledge of convergence and stability	8
Unit 2: Linear Spaces and Matrices		
Homogenous equation and non-homogenous equations, Sparse matrix, Minors, Cofactors of a matrix,	• Explain (C2) the numerical methods used to solve linear equations and matrices.	8

Determinant, Inverse of a matrix by Cramer's rule, Gauss-Jordan augmentation method, Solution of linear equations, Diagonalization of a Matrix, Eigenvalues and Eigenvectors, Gram-Schmidt orthogonalization of vectors.	• Solve linear equations and matrix operations using numerical methods(C3) • Compare different algorithms and choose the right algorithms after analysing the physical problems. (C3, C4, C5) • Design & Develop Programs, compile and run in any one of the programming languages (C6)	
Unit 3: Roots of an Equation		
Non-linear equations in one variable, Fixed point method, Bisection method, Newton-Raphson method, Secant method, Steepest decant method, Regula-Falsi method	• Explain (C2) the numerical methods used to find the solution (roots) to non-linear equation equations. • Compare different algorithms and choose the right algorithms after analysing the physical problems. (C3, C4, C5) • Design & Develop Programs, compile and run in any one of the programming languages (C6)	8
Unit 4: Numerical Differentiation & Approximation		
Analytical differentiation Vs Numerical differentiation, Forward difference formula, Backward difference formula, Three-point formulas, five-point formula Richardson's extrapolation, Polynomial interpolation, cubic spline interpolation, least square fitting, chi-square fitting, Levenberg-Marquardt Algorithm (LMA).	• Explain (C2) the numerical methods in differentiation, interpolation, and curve fitting. • Experiment with data sets and try different types of interpolations and curve fitting. (C3) • Compare different algorithms and choose the right algorithms after analysing the physical problems. (C3, C4, C5) • Design & Develop Programs, compile and run in any one of the programming languages (C6)	8
Unit 5: Numerical Integration		

Newton-Cotes methods: Rectangle rule, midpoint rule, Trapezoidal rule, Simpson's rule etc., order of error, Romberg integration, Adaptive quadrature method, Gauss quadrature method, Monte-Carlo quadrature.	• Explain (C2) the numerical methods used to solve Integrals. • Solve Integrals using numerical methods (C3) • Compare different algorithms and choose the right algorithms after analysing the physical problems. (C3, C4, C5) • Design & Develop Programs, compile and run in any one of the programming languages (C6)	8
Unit 6: Solutions of ordinary differential equations (ODE)		
Euler's method, Higher order Taylor's method, Runge-Kutta methods, Multi-step methods, Boundary value problems, Eigen value problems.	• Explain (C2) the numerical methods used to solve ordinary differential equations. • Solve examples of Ordinary Differential Equations using numerical methods (C3) • Compare different algorithms and choose the right algorithms after analysing the physical problems. (C3, C4, C5) • Design & Develop Programs, compile and run in any one of the programming languages (C6)	8

Learning strategies, contact hours and student learning time		
Learning strategy	Contact hours	Student learning time (Hrs)
Lecture	36	108
Seminar		
Small Group Discussion (SGD)		
Self-directed learning (SDL)		
Problem Based Learning (PBL)	12	42
Case Based Learning (CBL)		
Clinic		
Practical		
Revision	6	12
Assessment	6	-
TOTAL	60	162
Assessment Methods:		

Formative:	**Summative:**
Class tests	Sessional examinations (Mid Semester Examination, Quiz1, Quiz2)
Assignments/presentations	End semester examination
Group discussions	

Mapping of assessment with Cos				
Nature of assessment	CO 1	CO 2	CO 3	CO 4
Quiz 1			X	X
Mid Semester Examination	X	X		
Quiz 2			X	X
End Semester Examination	X	X	X	X
Formative Assessments	X	X	X	X

Feedback Process	• Mid-Semester Feedback • End-Semester Feedback
Reference Material	1. Richard L. Burden & J. Douglas Faires, "Numerical Analysis" Cengage Learning India Pvt. Ltd. 2. Alex Gezerlis, "Numerical Methods in Physics with Python", Cambridge University Press 3. Steven C. Chapra & Raymond P. Canale, "Numerical Methods for Engineers", Mc Graw Hill Education. 4. V. Rajaraman, "Computer Oriented Numerical Methods", PHI Publications

Name of the Institution / Department: Manipal Centre for Natural Sciences

Name of the Programme:	Integrated MSc-PhD in Physics
Course Title:	Quantum Mechanics & Applications
Course Code: NS PH 5104	**Course Instructor:**
Academic Year:	**Semester:** I
No of Credits: 4	**Prerequisites:** B.Sc./B. Tech
Synopsis:	This course aims to make students master the knowledge and the skills in the following areas of Physics: Concepts of Quantum Physics, Hilbert space and observables, Applications of Schrodinger wave equation and Approximate methods in Quantum Mechanics.
Course Outcomes (COs):	On successful completion of this course, students will be able to
CO 1:	Explain the concept of wave-particle duality and the Heisenberg Uncertainty principle. (C2)
CO 2:	Explain Hilbert space, Matrix formulation of QM and Fourier transformation. (C2)
CO 3:	Apply Schrodinger's wave equation to the systems having central potential such as Harmonic oscillator, Coulomb potential etc.(C3)
CO 4:	Solve the realistic problems using approximate methods such as perturbation theory, WKB approximation etc. (C3)

Mapping of COs to POs

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10
CO 1	X								X	X
CO 2	X								X	X
CO 3	X	X		X						X
CO 4	X	X		X						X

Course content and outcomes:

Content	Competencies	No of Hours
Unit 1: Introduction to Quantum Mechanics		
Wave–Particle Duality, De Broglie Hypothesis, Wave Packets, Phase and Group Velocity, Heisenberg's Uncertainty Principle, Schrodinger Wave Equation.	• Explain the concept of wave-particle duality, the Heisenberg Uncertainty principle, and the Schrodinger Wave Equation (C2).	6
Unit 2: Hilbert space and Observables		
General Formalism: Basic Axioms; Hilbert Space, Linear Vector Spaces and Operators, Observables, Fourier Transforms, Momentum Representation, Minimum Uncertainty Wave Packet, Unitary Transformation, Eigenvalue Problem, and Representations.	• Explain the concepts of Hilbert Space and inner product vector Spaces (C2). • Explain the operators and observables formalism of quantum mechanics, Matrix representation (C2).	8
Unit 3: Applications of Quantum Mechanics		

Dimensional Potential Problems: Particle in a Box, Potential Well, Potential Barrier and Tunnelling, Linear Harmonic Oscillator. Polynomial and Algebraic Solutions, Energy Spectrum – Wave-functions, Creation and Annihilation Operators Three Dimensions: H – Atom, Angular Momentum – Spherical Harmonics, Spin and Addition of Angular Momenta, Energy Spectrum and Wave Functions, Calculation of Simple Observables.	• Apply Schrodinger's equation and Quantum principles to solve a few potentials such as Harmonic oscillator, 3D potentials, Coulomb potential etc. (C3) • Explain symmetries in the potentials (C2) and apply the angular momentum algebra of real physical systems (C3).	16
Unit 4: Approximate methods and applications		
Many Body Systems: Approximate Methods: Time Independent Perturbation Theory, Zeeman and Stark Effects, Time-Dependent Perturbation Theory, Absorption and Emission of Radiation, Einstein Coefficients, WKB Approximation, Variational Methods, Mean Field Concept – Applications.	• Apply approximation methods for Energy eigenvalues application to complex systems for which it is difficult to solve Schrodinger's equation (C3). • Apply these methods to atomic spectra in atomic physics. (C3)	18

Learning strategies, contact hours and student learning time		
Learning strategy	Contact hours	Student learning time (Hrs)
Lecture	36	108
Seminar		
Small Group Discussion (SGD)		
Self-directed learning (SDL)		
Problem Based Learning (PBL)	12	42
Case Based Learning (CBL)		
Clinic		
Practical		
Revision	6	12
Assessment	6	-
TOTAL	**60**	**162**

Assessment Methods:	
Formative:	**Summative:**
Class tests	Sessional examinations (Mid Semester Examination, Quiz1, Quiz2)
Assignments/presentations	End semester examination
Group discussions	
Mapping of assessment with Cos	

Nature of assessment	CO 1	CO 2	CO 3	CO 4
Quiz 1	X	X		
Mid Semester Examination	X	X		
Quiz 2		X	X	
End Semester Examination	X	X	X	X
Formative Assessments	X	X	X	X

Feedback Process	• Mid-Semester Feedback • End-Semester Feedback
Reference Material	1. Quantum Mechanics by L I Schiff 2. Quantum Mechanics I, II by Claude Cohen-Tannoudji, Bernard Diu 3. Principles of Quantum Mechanics by R Shankar 4. The Principles of Quantum Mechanics, P A M Dirac 5. Lectures on Quantum Mechanics, A Das 6. Modern Quantum Mechanics, J J Sakurai

Name of the Institution / Department: Manipal Centre for Natural Sciences

Name of the Programme:	Integrated MSc-PhD in Physics
Course Title:	Lab I
Course Code: NS PH 5130	**Course Instructor:**
Academic Year:	**Semester:** I
No of Credits: 4	**Prerequisites:** B.Sc./B. Tech
Synopsis:	This module will provide information on Data and error analysis in problem-solving Stochastic numerical (Monte-Carlo) techniques in problem-solving. Optics experiments

Course Outcomes (COs):	On successful completion of this course, students will be able to
CO 1:	Build computer programs to solve problems in Physics (C3, C3)
CO 2:	Utilize Monte-Carlo and statistical techniques to determine physical parameters (C3, C5)
CO 3:	Explain basic principles of Optics like interference, diffraction, dispersion, polarization etc. (C3)
CO 4:	Interpret Fraunhofer's pattern to explain the physical situation causing this pattern and the theory. (C3, C5)

Mapping of COs to POs

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10
CO 1	X	X			X	X	X			X
CO 2	X	X	X	X	X	X				X
CO 3	X	X			X	X	X	X	X	X
CO 4	X	X	X	X	X	X	X	X	X	X

Course content and outcomes:

Content	Competencies	No of Hours
Unit 1: Computational Data Analysis		
At least five experiments from the list below 1. Introduction to Monte Carlo techniques and generate pseudo-random number 2. Apply the Monte-Carlo technique to estimate the value of π 3. Apply the Monte Carlo technique for the propagation of even error and compare it with the analytical value 4. Apply the Monte Carlo technique for the propagation of uneven error	• Build computer programs to solve problems in Physics (C3, C3) • Utilize Monte-Carlo techniques to determine the cumulative error due to propagation from errors in the variables (C3, C5) • Determine model parameters by fitting data points using various statistical techniques (C5)	45

5. Estimate model parameters by fitting data points with chi-squares using the Levenberg-Marquardt algorithm 6. Estimate model parameters by fitting data points with Likelihood analysis 7. Estimate model parameters by fitting data points with the Bayesian approach.		
Unit 2: Optics		
At least three experiments from the list below: 1. Determination of the slit width from Fraunhofer diffraction of a single slit. Compare the observed intensity pattern with the theoretical distribution. 2. Study of the intensity distribution of Fraunhofer diffraction from a double slit. 3. Study of the diffraction pattern and dispersion due to different gratings. 4. Study of polarisation of light and determining the degree of polarisation. 5. Demonstration of grazing incidence and the principle of X-ray imaging with a segment of the gold-plated conical mirror.	• Explain basic principles of optics, like diffraction, interference, dispersion, polarisation, grazing incidence etc. (C3) • Experiment with the optical setup in the laboratory. (C3) • Interpret the results and compare them with the theoretical predictions (C5)	27

Learning strategies, contact hours and student learning time		
Learning strategy	Contact hours	Student learning time (Hrs)
Lecture		
Seminar		
Small Group Discussion (SGD)		
Self-directed learning (SDL)		
Problem Based Learning (PBL)		
Case Based Learning (CBL)		
Clinic		
Practical	72	144

Revision	9	18
Assessment	4	
TOTAL	**85**	**162**

Assessment Methods:

Formative:	**Summative:**
Group Discussion	Lab Work & Record Evaluation
	Mid Semester Examination
	End Semester Examination

Mapping of assessment with COs

Nature of assessment	CO 1	CO 2	CO 3	CO 4
Lab Work & Record Evaluation	X	X	X	X
Mid Semester Examination				
End Semester Examination	X	X	X	X
Formative Assessments	X	X	X	X

Feedback Process	• Mid-Semester Feedback • End-Semester Feedback
Reference Material	1. Press et al. Numerical Recipes 2. Rajaraman, Computer Programming in Fortran 90 3. Joakim Sundnes, Introduction to Scientific Computing in Python 4. Jenkins F, White H E, Fundamental of optics 5. Ghatak, optics.

Name of the Institution / Department: Manipal Centre for Natural Sciences

Name of the Programme:				Integrated MSc-PhD in Physics						
Course Title:				Seminar/Colloquium						
Course Code: NS PH 5131				**Course Instructor:**						
Academic Year:				**Semester:** I						
No of Credits: 1				**Prerequisites:** B.Sc./B. Tech						
Synopsis:	This course aims to make students get acquainted with a wide range of topics in physics, deepen subject knowledge through group discussions and enhance their presentation skills.									
Course Outcomes (COs):			On successful completion of this course, students will be able to							
CO 1:			Plan a presentation on topics of physics (C3)							
CO 2:			Demonstrate the ability to communicate given topics in physics effectively. (C2)							
Mapping of COs to POs										
COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10
CO 1	X								X	X
CO 2	X								X	X

Course content and outcomes:

Content	Competencies	No of Hours
Unit 1:		
Fundamentals of Physics and Mathematics, Study of the important findings/discoveries in Physics, Learn how to prepare a scientific presentation, Presentation with clarity	• Plan a presentation on topics of physics (C3) • Demonstrate the ability to communicate given topics in physics effectively. (C2)	

Learning strategies, contact hours and student learning time

Learning strategy	Contact hours	Student learning time (Hrs)
Lecture		
Seminar	15	45
Small Group Discussion (SGD)		
Self-directed learning (SDL)		
Problem Based Learning (PBL)		
Case Based Learning (CBL)		

Clinic		
Practical		
Revision		
Assessment		
TOTAL	**15**	**45**

Assessment Methods:	
Formative:	**Summative:**
Presentation	
Group Discussion	

Mapping of assessment with Cos		
Nature of assessment	CO 1	CO 2
Presentation	X	X
Group Discussion	X	X

Feedback Process	• Mid-Semester Feedback • End-Semester Feedback
Reference Material	

Name of the Institution / Department: Manipal Centre for Natural Sciences

Name of the Programme:	Integrated MSc-PhD in Physics
Course Title:	Modern Physics I
Course Code: NS PH 5201	**Course Instructor:**
Academic Year:	**Semester:** II
No of Credits: 4	**Prerequisites:** B.Sc./B. Tech
Synopsis:	This course aims to make students master the knowledge and skills in the following areas of Physics: Classical Mechanics, Special Relativity, Nuclear Physics, Particle Physics and Statistical Mechanics.
Course Outcomes (COs):	On successful completion of this course, students will be able to
CO 1:	Solve appropriate physical problems using the Lagrangian and Hamiltonian formulations of classical mechanics (C3).
CO 2:	Explain the principles of special relativity (C2) and apply them to relativistic systems to explain the outcomes of various experiments (C3).
CO 3:	Explain the basic nuclear properties, decay processes and working principles of nuclear particle detectors (C2).
CO 4:	Explain the quark model and conservation laws of particle physics (C2).
CO 5:	Explain the principles of statistical mechanics and their representative applications (C2).
CO 6:	Apply the principles of statistical mechanics to solve problems in physical systems that consist of a large number of constituent elements (C3).

Mapping of COs to POs

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10
CO 1	X	X								X
CO 2	X	X							X	X
CO 3	X								X	X
CO 4	X								X	X
CO 5	X								X	X
CO 6	X	X								X

Course content and outcomes:

Content	Competencies	No of Hours
Unit 1: Classical Mechanics		
Generalized coordinates, Constraints, D'Alembert's principle, Lagrangian and Hamiltonian formalism, Calculus of variations, Principle of least action, Noether theorem and	• Explain the basic principles of classical mechanics (C2). • Find the Lagrangian and Hamiltonian of a physical system (C1).	8

conservation laws, Canonical transformations, Poisson brackets	• Apply the various principles to physical systems (C3) and explain how it works (C2).	
Unit 2: Special Relativity		
Principle of relativity, Michelson–Morley experiment, Simultaneity, Lorentz transformation, Velocity addition, Aberration and Doppler Effect of relativity, Mass-energy equivalence, Light cone, Minkowski spacetime, Four vectors	• Explain the basic principles of special relativity (C2). • Explain the difference between relativistic and non-relativistic systems (C2). • Apply basic principles to relativistic systems (C3), and explain results obtained from high-energy and electromagnetic experiments (C2). • Explain the inseparability of space-time and its importance (C2).	8
Unit 3: Nuclear and Particle Physics		
Review of Bulk Properties of Nuclei; Mass, Binding Energy, Stability, Size, Density Distribution. Nuclear Interaction; Deuteron Problem, Nuclear Shell Model, Nuclear Excitations and Decays (α, β, and γ). Quark Model, Leptons, Gauge Bosons, Symmetries, Conservation Laws, Gas Filled and Solid-State Detectors.	• Explain the basic properties of a nucleus (C2) and find the spin-parity of a nucleus using the shell model (C1). • Explain the nuclear decay processes and the nature of EM transitions (C2). • Explain the Quark model and conservation laws of particle physics. (C2). • Explain the working of the gas-filled and the solid-state detectors (C2).	16
Unit 4: Statistical Mechanics		
Relation Between Thermodynamics and Statistical Mechanics, Kinetic Theory of Gases, Mean Free Path, Ensemble: Micro Canonical, Canonical, Grand Canonical, Maxwell-Boltzmann Distribution, Bose-Einstein and Fermi-Dirac Statistics, Applications (Ideal Bose & Fermi Gas, Black Body Radiation, etc.)	• Explain the principles of statistical mechanics and their relation to thermodynamics (C2). • Explain Ensembles (Micro Canonical, Canonical, Grand Canonical) (C2). • Explain different statistics (Classical, Bose-Einstein, Fermi-Dirac) and their consequences in many body systems (C2). • Explain representative applications of the principles of statistical mechanics (Ideal Bose & Fermi Gas, Black Body Radiation, etc.) (C2).	16

	• Apply the principles of statistical mechanics to physical systems that consist of a large number of constituent elements (C3).	

Learning strategies, contact hours and student learning time		
Learning strategy	*Contact hours*	*Student learning time (Hrs)*
Lecture	36	108
Seminar		
Small Group Discussion (SGD)		
Self-directed learning (SDL)		
Problem Based Learning (PBL)	12	42
Case Based Learning (CBL)		
Clinic		
Practical		
Revision	6	12
Assessment	6	-
TOTAL	**60**	**162**

Assessment Methods:	
Formative:	**Summative:**
Class tests	Sessional examinations (Mid Semester Examination, Quiz1, Quiz2)
Assignments/presentations	End semester examination
Group discussions	

Mapping of assessment with Cos						
Nature of assessment	CO 1	CO 2	CO 3	CO 4	CO 5	CO 6
Quiz 1	X	X				
Mid Semester Examination	X	X			X	X
Quiz 2			X	X		
End Semester Examination	X	X	X	X	X	X
Formative Assessments	X	X	X	X	X	X

Feedback Process	• Mid-Semester Feedback • End-Semester Feedback
Reference Material	1. Rana N and Joag P, Classical Mechanics, McGraw-Hill 2. Goldstein H, Classical Mechanics, 3rd Ed. Pearson. 3. Landau L D and Lifshitz E M, Mechanics, 3rd Ed. Elsevier 4. Resnick R, Introduction to Special Relativity, Wiley. 5. Cohen B, Concepts of Nuclear Physics, McGraw-Hill. 6. Kaplan I, Nuclear Physics, Narosa. 7. Ghoshal N S, Nuclear Physics, Chand Publishing. 8. Griffiths D, Introduction to Elementary Particles, Wiley

	9. Perkins D H, Introduction to High Energy Physics, Cambridge Univ. Press 4th Ed. 10. Callen H B, Thermodynamics and Introduction to Thermostatistics, 2nd Ed. Wiley. 11. Reif F, Fundamentals of Statistical and Thermal Physics, Sarat Book Distributors. 12. Reif F, Berkeley Physics Course Vol. 5 Statistical Physics, McGraw-Hill. 13. Pathria R K and Baele P T, Statistical Mechanics, 4th Ed. Elsevier. 14. Huang K, Statistical Mechanics, 2nd Ed. Wiley.

Name of the Institution / Department: Manipal Centre for Natural Sciences

Name of the Programme:	Integrated MSc-PhD in Physics
Course Title:	Modern Physics II
Course Code: NS PH 5202	**Course Instructor:**
Academic Year:	**Semester:** II
No of Credits: 4	**Prerequisites:** B.Sc./B. Tech
Synopsis:	This module will provide information on Atomic and molecular spectra give an insight into the interaction of EM radiation with matter which is useful in understanding lasing action. The description of crystal structure and its properties, band theory of solids and concepts of magnetism & superconductivity as well. Different configurations of OPAMPs and their applications, deeper understanding of MUX, DEMUX, registers and counters and the concepts of digital signal processing.
Course Outcomes (COs):	On successful completion of this course, students will be able to
CO 1:	Explain the concepts of atomic spectra and molecular spectra interaction of EM radiation with matter in both classical and QM approach. (C2)
CO 2:	Explain the basic description of crystal and learn how the shape of the crystals determine the different minerals in families (C2)
CO 3:	Explain the band theory of solids and classification of it into three distinct categories(C2)
CO 4:	Explain the important phenomenon of magnetism and superconductivity (C2)
CO 5:	Explain the concept of analogue electronics and digital electronics (C2) and apply them to modern electronic equipment (C3).

Mapping of COs to POs

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10
CO 1	X	X							X	X
CO 2	X	X							X	X
CO 3	X	X							X	X
CO 4	X	X							X	X
CO 5	X	X							X	X

Course content and outcomes:

Content	Competencies	No of Hours
Unit 1: Atomic and Molecular Physics		
Hyperfine structure and isotopic shift, absorption and emission of radiation, the width of spectral lines, Natural, collisional, and Doppler	• Recall the basic concepts of atomic spectra (C1) and applies his/her understanding to label levels based on l,s, and j values, the removal of	18

broadening of spectral lines, LS & JJ couplings. Zeeman, Paschen-Bach & Stark effects. Spontaneous and stimulated emission, population inversion, rate equation, various types of lasers. Electron spin resonance, Nuclear magnetic resonance, Frank-Condon principle, Born-Oppenheimer approximation, Electronic, rotational, vibrational and Raman spectra of diatomic Molecules, selection rules, Fluorescence, and phosphorescence.	degeneracy under external or internal electromagnetic fields (C3). • Explain the emission and absorption of EM radiation, both classical and QM approaches, resonance absorption and applications (C2). • Outline the concept of stimulated emission and how it leads to the development of lasers and conditions for achieving lasing action (C2, C1). • The student develops the concept of Molecular spectra, the Raman effect (C3) and applications (C3).	
Unit 2: Crystallography		
Concept of lattice, Bravais lattices, Reciprocal lattice. X-ray diffraction by a crystal, Overview of the classical theory of specific heat, Einstein and Debye theory of specific heat, Electron motion in a periodic potential,	• After successful completion of this unit, students will be able to recall and summarize the basics of crystal structure (C1, C2); and explain the definitions of the cell, unit cell and lattice parameters, which form the basis of the crystal (C2). • Students will be able to determine (C5) the structure of the crystal using the X-Ray diffraction method (C3). • Students will be able to explain the thermal properties of solids (C1, C2) and the concept of specific heat. They will also be able to explain the Einstein and Debye theory of specific heat (C3).	8
Unit 3: Band theory of Solids		
Bloch theorem, Kronig-Penney model, Band gap, Classification of metal, semiconductor, and insulator; Semiconductors. Hall Effect in metals and semiconductors.	• Students can explain the band theory of solids (C1, C2); what is Bloch theorem and Kronig-Penney Model? And how it forms the basis of the band theory of solids (C2).	7

	• Students will also be explaining the classifications of solids into metal, insulators, and semiconductors (C3). • They can explain and apply the Hall effect in semiconductors and metals (C2, C3).	
Unit 4: Magnetism and Superconductivity		
Diamagnetism, Paramagnetism, Ferromagnetism, Phenomenon of superconductivity, type I and type II superconductors, Elements of BCS theory, applications of superconductors. Superfluidity.	• Students recall and explain the basic concept of magnetism and superconductivity (C1, C2). • They will also be able to l to classify magnetic materials based on their bulk susceptibility (C4). • Students will be able to understand and explain the theory of superconductivity, which is popularly known as a BCS theory (C2). They will be able to explain the Meissner effect and how to classify superconductors based on the effect of an external magnetic field (C1, C4). They can also develop a brief idea of applications of superconductors in various fields (C3).	7
Unit 5: Electronics		
Operational amplifiers and their applications, Multiplexers and Demultiplexers, Counters and Shift registers and their applications, Fourier analysis of discrete-time signals and systems, sampling theorem.	• Students recall the concepts of transistors and biasing of transistors (C1) and explain the working of differential amplifiers (C2) which is the first stage of an OPAMP. Understand and explain the working of inverting and non-inverting operational amplifiers (C2) • Students recall the basics of digital electronics(C1), summarize the working of logic gates and flip-flops (C2), explain the working of Multiplexers and demultiplexers (C2), working of counters and registers (C2) and their applications.	8

	• Explain about sampling theorem, ADC and DAC and apply it in digital signal processing. (C2, C3)	

Learning strategies, contact hours and student learning time		
Learning strategy	Contact hours	Student learning time (Hrs)
Lecture	36	108
Seminar		
Small Group Discussion (SGD)		
Self-directed learning (SDL)		
Problem Based Learning (PBL)	12	42
Case Based Learning (CBL)		
Clinic		
Practical		
Revision	6	12
Assessment	6	-
TOTAL	60	162

Assessment Methods:	
Formative:	**Summative:**
Class tests	Sessional examinations (Mid Semester Examination, Quiz1, Quiz2)
Assignments/presentations	End semester examination
Group discussions	

Mapping of assessment with Cos					
Nature of assessment	CO 1	CO 2	CO 3	CO 4	CO 5
Quiz 1		X			X
Mid Semester Examination		X	X		X
Quiz 2	X			X	
End Semester Examination	X	X	X	X	X
Formative Assessments	X	X	X	X	X

Feedback Process	• Mid-Semester Feedback • End-Semester Feedback
Reference Material	1. Banwell C N and E M McCash, Fundamentals of Molecular Spectroscopy IV Edn. Tata McGraw Hill (1994) 2. H E White: Introduction to Atomic Spectroscopy: McGraw Hill Book Company Inc 3. Thyagarajan K & Ghatak A, “Lasers: Fundamentals and Applications”, Springer US (2011) 4. Dekker A J, Solid State Physics, Macmillan (1971) 5. Kittel C, Introduction to Solid State Physics, Iv Edn, Wiley Eastern (1974) 4. Ashcroft F W & Mermin N D, Solid State Physics, Harcourt (1976)

	5. Millman J & Halkias C, "Integrated Electronics," Tata McGraw Hill Education (2001) 6. Gayakwad R A, "Opamps and Linear Integrated Circuits", Prentice Hall of India Pvt. Ltd (2003). 7. Floyd T L, Digital Fundamentals, Pearson Education Asia (2002). 8. George Kennedy, Bernard Davis, Electronic Communication Systems, Tata McGraw Hill; Fourth Edition.

Name of the Institution / Department: Manipal Centre for Natural Sciences

Name of the Programme:	Integrated MSc-PhD in Physics
Course Title:	Introduction to Astrophysics
Course Code: NS PH 5203	**Course Instructor:**
Academic Year:	**Semester:** II
No of Credits: 4	**Prerequisites:** B.Sc./B. Tech
Synopsis:	The course will provide a broad overview of various branches of modern astrophysics covering stars, our Galaxy, and extragalactic objects. The physical concepts, mathematical derivations, and observational data are combined in a balanced manner to provide a unified treatment.
Course Outcomes (COs):	On successful completion of this course, students will be able to
CO 1:	Explain the astronomical coordinate systems, observational techniques, telescope instrumentation, photometric concepts, magnitudes, distance measurement techniques, and elementary properties of radiation. (C2)
CO 2:	Explain, and apply radiative transfer equations and examine the various astrophysical scenarios such as stellar atmosphere and interior (C2, C3, C4)
CO 3:	Construct and apply basic equations of stellar structure to derive order of magnitude relations amongst stellar quantities. (C3, C3)
CO 4:	Illustrate the evolution and end states of stars. (C2)
CO 5:	Explain our Galaxy, including different phases of the interstellar medium, morphological classification of galaxies, and various classes of active galaxies (C2)
CO 6:	Explain relativistic beaming and non-thermal emission mechanisms and examine astrophysical objects such as AGN jet (C2, C4)
CO 7:	Outline the basic idea of general relativity and apply it to Astrophysics and Cosmology to explain the black hole space-time and the evolution of the Universe. (C2, C3)

Mapping of COs to POs

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10
CO 1	X	X							X	X
CO 2	X	X								X
CO 3	X	X							X	X
CO 4	X	X							X	X
CO 5	X	X							X	X
CO 6	X	X							X	X
CO 7	X	X							X	X

Course content and outcomes:		
Content	Competencies	No of Hours
Unit 1: Astronomical scales, coordinate systems, and cosmic rays		
Mass, length and time scales in astrophysics, A.U., parsec, the emergence of modern astrophysics; Astronomical observations: electromagnetic radiation; lookback time, cosmic rays, Fermi acceleration, earth vs space-based observations, the role of atmospheric transmission; observation techniques and telescopes. Celestial sphere, ecliptic, RA/DEC coordinates, galactic coordinates; Luminosity/flux, magnitude scale, absolute/apparent magnitude; Electromagnetic wavebands, spectroscopy; Third dimension: distance measurement, standard candles; Astronomy in different bands of electromagnetic radiation: optical, radio, X-ray and gamma-ray, distance ladder;	• Explain mass, length, and time scales in astrophysics, A.U., parsec (C2) • Illustrate the emergence of modern astrophysics, sources of astronomical information, including electromagnetic radiations (C2) • Explain the concept of lookback time, Fermi acceleration, details of cosmic ray observed spectra, and the origin of cosmic rays (C2) • Summarize different observational techniques and telescope instrumentations. (C2) • Compare the advantages and disadvantages of earth and space-based observatories: role of atmospheric transmission (C2) • Illustrate the celestial sphere, different astronomical coordinate systems (ecliptic, RA/DEC coordinates, and galactic coordinates), and their importance (C2) • Explain the conversion law between alt-azimuth to RA-DEC coordinates (C2) • Explain different observational techniques, and compare different observing instruments (C2, C4) • Explain apparent and absolute magnitude and the relation between flux and magnitude (C2) • Explain different distance	6

	measurement techniques: parallax, standard candles, cosmological redshift (C2) • Explain the model of Atom, spectroscopy and classify spectral lines. (C2, C4) • Explain the atmospheric seeing (C2)	
Unit 2: Introduction to observational astronomy and elementary properties of radiation		
Radiative flux: macroscopic description of propagation of radiation, flux from an isotropic source; the specific intensity and its moments: specific intensity, net flux, momentum flux, radiative energy density, radiation pressure; Radiative transfer: emission, absorption, radiative transfer equation, optical depth, source function, mean free path, radiation force; Thermal radiation: blackbody radiation, Kirchhoff's law for thermal emission, Planck spectrum, properties of Planck law, characteristics temperatures related to Planck spectrum; The Einstein coefficients: the relation between Einstein coefficients, absorption, and emission coefficient in terms of Einstein coefficients;	• Explain radiative flux, macroscopic description of propagation of radiation, flux from an isotropic source; the specific intensity and its moments: specific intensity, net flux, momentum flux, radiative energy density, radiation pressure (C2) • Explain radiative transfer: emission, absorption, radiative transfer equation, optical depth, source function, mean free path, radiation force (C2) • Apply the radiative transfer equations and examine the various astrophysical scenarios (C3, C4) • Explain thermal radiation: blackbody radiation, Kirchhoff's law for thermal emission, Planck spectrum, properties of Planck law, characteristics temperatures related to Planck spectrum (C2) • Explain the Einstein coefficients: the relation between Einstein coefficients, absorption and emission coefficient in terms of Einstein coefficients (C2)	4
Unit 3: Stellar astrophysics: atmosphere and interior		

Planck's radiation formula, thermal equilibrium and Boltzmann factor, Saha-Boltzmann ionization equation; Astronomical scale, units of stellar brightness, a radius of a star, effective temperature, equation of state for stellar atmosphere, sources of a continuous spectrum, radiative energy transport in stellar interior, opacity, formation of spectral lines; Stellar structure equations, the virial theorem for stars, mode of energy transport;	• Recall of Maxwell-Boltzmann distribution law, Planck's radiation formula (C1) • Explain the Saha-Boltzmann ionization equation, local thermodynamic equilibrium (LTE): validity of LTE inside the star (C2) • Explain the radiation transfer through stellar atmospheres considering plane-parallel atmosphere (C2) • Construct the radiative transfer equations for the stellar atmosphere and derive the deviation from blackbody radiation (C3) • Explain temperature and effective temperature (C2) • Explain Eddington approximation, the specific intensity in terms of angle: limb-darkening (C2) • Explain the formation of a spectral line: simple derivation considering frequency dependence of absorption coefficient and considering LTE (C2) • Explain radiative energy transport in stellar interior and Construct the condition of radiative equilibrium for non-grey atmosphere: Rosseland mean (C2, C3) • Construct the basic equations of stellar structure (C3) • Explain the virial theorem for stars (C2)	10

	• Explain convection inside stars and derive the Schwarzschild stability condition (C2)	
Unit 4: Formation, evolution, and end state of stars		
Spectral classification of stars, some relations amongst stellar quantities like luminosity, mass, radius, temperature, lifetime, HR diagram of nearby stars, main sequence, red giants and white dwarfs, the end of the main sequence, Eddington limit; Stellar evolution, evolution in binary systems, mass loss from stars, Supernovae: Type I, Type II; End states of stellar collapse, degeneracy pressure of a Fermi gas, Chandrasekhar mass limit, white dwarf, The neutron drip and neutron stars, Pulsars; A stellar-mass blackhole, binary X-ray sources: accretion disks;	• Apply basic stellar equations to derive order of magnitude relations amongst stellar quantities like luminosity, mass, radius, temperature, and lifetime (C3). • Explain the HR diagram, main sequence, red giants and white dwarfs, and Eddington limit (C2). • Classify the evolution process of low and high-mass stars (C2). • Explain the importance of nuclear reaction in stellar evolution (C2). • Explain electron degeneracy, solve the condition for degenerate stellar matter in the relativistic and non-relativistic limit, explain the Chandrasekhar limit (C2, C3) • Justify the conditions required to form a white dwarf, Neutron stars and Black hole. (C4) • Explain Stellar evolution, evolution in binary systems, and Mass loss from stars (C2) • Illustrate Type I and Type II supernovae (C2) • Explain neutron drip and neutron stars (C2) • Explain binary blackhole sources and accretion disks (C2)	9

Unit 5: Our Galaxy, Interstellar matter, galaxies, and quasars		
Our Galaxy and interstellar matter: the shape and size of our Galaxy, Kapteyn universe and Shapley's model, interstellar extinction and reddening, Galactic rotation, Oort constants, HI clouds, molecular clouds, HII regions; Normal galaxies: morphological classification, Hubble's tuning fork diagram; Active galaxies: the AGN zoo, superluminal motion in quasars, blackhole as central engine, AGN unification scheme; Emission from AGN jet: relativistic beaming and synchrotron radiation, introduction to inverse Compton emission;	• Explain Kapteyn universe, Shapley's model (C2) • Explain the Galactic rotation curve, different phases of interstellar medium such as molecular clouds HI and HII regions (C2) • Explain the morphological classification of galaxies, Hubble's tuning fork diagram • Explain superluminal motion in quasars, AGN unification scheme (C2) • Explain relativistic beaming (C2) • Explain synchrotron emission and examine the various astrophysical scenarios (C2, C4) • Explain inverse Compton emission (C2)	10
Unit 6: General relativity and cosmology		
Elements of General Relativity: metric, curved space-time, geodesics, Einstein equation. Astrophysical/cosmological applications of General Relativity: Schwarzschild Black Hole solution, Evolution of homogeneous and isotropic Universe, cosmological redshifts.	• Illustrate the basic concepts in general relativity, such as metric, curved space-time, geodesics, and dynamical space-time. (C2) • Outline Schwarzschild Black Hole and gravitational redshifts. (C2) • Outline the evolution of homogeneous and isotropic universes for radiation/matter/vacuum energy-dominated cases. (C2) • Explain cosmological redshifts. (C2)	9

Learning strategies, contact hours and student learning time		
Learning strategy	Contact hours	Student learning time (Hrs)
Lecture	36	108

Seminar		
Small Group Discussion (SGD)		
Self-directed learning (SDL)		
Problem Based Learning (PBL)	12	42
Case Based Learning (CBL)		
Clinic		
Practical		
Revision	6	12
Assessment	6	-
TOTAL	**60**	**162**

Assessment Methods:

Formative:	**Summative:**
Class tests	Sessional examinations (Mid Semester Examination, Quiz1, Quiz2)
Assignments/presentations	End semester examination
Group discussions	

Mapping of assessment with Cos

Nature of assessment	CO 1	CO 2	CO 3	CO 4	CO 5	CO 6
Quiz 1	X	X				
Mid Semester Examination	X	X	X			
Quiz 2			X	X	X	X
End Semester Examination	X	X	X	X	X	X
Formative Assessments	X	X	X	X	X	X

Feedback Process	• Mid-Semester Feedback • End-Semester Feedback
Reference Material	1. Astrophysics for Physicists – A. Rai Choudhuri; Cambridge University Press, South Asian Edition (2010) 2. Astrophysics Processes: the physics of Astronomical Phenomena – Hale Bradt; Cambridge University Press 3. The Physical Universe: An Introduction to Astronomy - Frank H. Shu 4. “Radiative Processes in Astrophysics,” Rybicki & Lightman 5. An Introduction to Active Galactic Nuclei – B.M. Peterson; Cambridge University Press (1997) 6. “Classical Electrodynamics,” Jackson, J.D. 7. “High Energy Astrophysics,” Longair, M.S. 8. “Stellar structure and Evolution,” Rudolf Kippenhahn 9. "An Introduction to Relativity," Narlikar

Name of the Institution / Department: Manipal Centre for Natural Sciences

Name of the Programme:	Integrated MSc-PhD in Physics
Course Title:	Introduction to Quantum Field Theory
Course Code: NS PH 5206	**Course Instructor:**
Academic Year:	**Semester:** II
No of Credits: 4	**Prerequisites:** B.Sc./B. Tech
Synopsis:	This course aims to make students master the knowledge and the skills in the following areas of Physics: Relativistic quantum mechanics, Interacting fields and Feynman diagrams, renormalization, and electroweak interactions.

Course Outcomes (COs):	On successful completion of this course, students will be able to
CO 1:	Explain the relativistic quantum mechanical equations for scalar, fermionic and vector fields. (C2)
CO 2:	Explain Noether's theorem and canonical quantization. (C2)
CO 3:	Describe scattering amplitude and Feynman's diagrams in perturbation theory. (C2)
CO 4:	Apply renormalization and regularization techniques of quantum field theory. (C3)
CO 5:	Describe spontaneous symmetry breaking and the Standard model of electroweak interactions. (C1, C2)

Mapping of COs to POs

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10
CO 1	X								X	X
CO 2	X								X	X
CO 3	X	X							X	X
CO 4	X	X		X						X
CO5	X								X	X

Course content and outcomes:

Content	Competencies	No of Hours
Unit 1: Relativistic dynamics		
Creation and annihilation operators, mathematical structure of special relativity, Natural units, Euler-Lagrange equations and Noether's theorem, Scalar, fermionic and electromagnetic field equations, Quantization of free fields.	• Explain creation and annihilation operators, Euler-Lagrange equations and natural units. (C2) • Explain the Klein-Gordon, Dirac and electromagnetic field equations. (C2)	14

	• Explain Noether's theorem and quantization of free fields. (C2)	
Unit 2: Interacting fields and Feynman Diagrams		
Interaction representation, S-matrix expansion, Evolution operator, Wick's theorem, Yukawa interaction: decay of a scalar, normalized states, and calculation of a matrix element, Feynman rules, Virtual particles.	• Explain the S-matrix expansion and time-ordered product. (C2) • Explain the matrix element of scattering amplitude and corresponding Feynman rules. (C2)	10
Unit 3: Renormalization		
Degree of divergence of a diagram, Ward-Takahashi identity, Regularization of self-energy diagrams, counter terms, observable effects of renormalization.	• Apply regularization and renormalization techniques of quantum field theory. (C3) • Explain the observable effects of renormalization. (C2)	10
Unit 4: Electroweak Interactions		
Local gauge invariance, Classification of symmetries, Symmetry group, Spontaneous breaking of symmetries and Higgs mechanism, Electroweak unification, Glashow-Weinberg-Salam model of electroweak symmetry breaking, Masses of vector bosons.	• Explain local gauge invariance. (C2) • Explain the classification of symmetries and corresponding group structure. (C2) • Explain spontaneous symmetry breaking. (C2) • Describe electroweak unification and the Standard Model of particle physics. (C2)	14

Learning strategies, contact hours and student learning time		
Learning strategy	Contact hours	Student learning time (Hrs)
Lecture	36	108
Seminar		
Small Group Discussion (SGD)		
Self-directed learning (SDL)		
Problem Based Learning (PBL)	12	42

Case Based Learning (CBL)		
Clinic		
Practical		
Revision	6	12
Assessment	6	-
TOTAL	**60**	**162**

Assessment Methods:	
Formative:	**Summative:**
Class tests	Sessional examinations (Mid Semester Examination, Quiz1, Quiz2)
Assignments/presentations	End semester examination
Group Discussions	

Mapping of assessment with Cos

Nature of assessment	CO 1	CO 2	CO 3	CO 4	CO 5
Quiz 1	X	X			
Mid Semester Examination	X	X			
Quiz 2		X	X		
End Semester Examination	X	X	X	X	X
Formative Assessments	X	X	X	X	X

Feedback Process	• Mid-Semester Feedback • End-Semester Feedback
Reference Material	1. A First Book of Quantum Field Theory, Amitabha Lahiri, Palash B. Pal 2. Quantum Field Theory in a Nutshell, A Zee 3. Introduction to Elementary Particles by D Griffiths 4. An Introduction to Quantum Field Theory, Daniel V. Schroeder and Michael Peskin 5. Quarks & Leptons by F. Halzen and A. D. Martin 6. Relativistic Quantum Mechanics, J. D. Bjorken and S. D. Drell

Name of the Institution / Department: Manipal Centre for Natural Sciences

Name of the Programme:	Integrated MSc-PhD in Physics
Course Title:	Nuclear and Particle Physics
Course Code: NS PH 5207	**Course Instructor:**
Academic Year:	**Semester:** II
No of Credits: 4	**Prerequisites:** B.Sc./B. Tech
Synopsis:	This course aims to make students master the knowledge and the skills in the following areas of Physics: Nuclear properties, decays and models, Scattering and Nuclear forces, Radiation Detectors, Nuclear Astrophysics, Quark model of Elementary Particles, Quark Gluon Plasma, Signals and Phenomenology.
Course Outcomes (COs):	On successful completion of this course, students will be able to
CO 1:	Explain the ground state nuclear properties, liquid drop and shell models, nuclear decays and selection rules (C2)
CO 2:	Explain nuclear forces, scattering theory, deuteron problem (C2)
CO 3:	Explain working principles and apply them to radiation detectors (C2, C3)
CO 4:	Explain concepts in nuclear astrophysics, stellar nucleosynthesis, elemental abundances, r-, s-, p- processes, Maxwellian averaged cross- sections and astrophysical S-factor. (C1, C2)
CO 5:	Explain the quark model for baryons and mesons; reactions of hadrons and leptons; quark-gluon plasma state of matter, jet quenching, strangeness production and phenomenological quark-quark potential. (C2)

Mapping of COs to POs

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10
CO 1	X								X	X
CO 2	X								X	X
CO 3	X	X							X	X
CO 4	X	X		X						X
CO5	X								X	X

Course content and outcomes:

Content	Competencies	No of Hours
Unit 1: Nuclear properties, decays and models		
Introduction: Review of general properties of nuclei Nuclear models: liquid drop model, mass parabolas, beta stability line, Shell model, ground state spins, magic numbers. Collective models, collective rotations and vibrations.	• Explain the ground-state nuclear properties, liquid drop and shell models to understand ground-state properties & fusion and fission (C2) • Explain alpha-, beta, gamma – decays and selection rules (C2)	12

Compound nucleus formation and decay, fission and fusion. Nuclear Decays: Alpha decay: Gamow theory and branching ratios. Beta decay: Energetics, angular momentum and parity selection rules, Fermi theory. Fermi and Gamow - Teller transitions, Kurie plot and mass of a neutrino. Gamma decay: energetics, angular momentum and parity selection rules.		
Unit 2: Nuclear forces:		
Nuclear potential from the study of Deuteron bound states, nuclear scattering processes, neutron-proton and proton-proton scattering at low energies and the general nature of nuclear force, range and strength of potentials.	• Explain nuclear potentials using deuteron-bound states. (C2) • Apply scattering theory to estimate the nature of nuclear forces, range and strength of potentials. (C2)	6
Unit 3: Radiation Detectors:		
Interaction of radiation with matter, detection of nuclear radiations, gas-filled ionization chambers, semiconductor detectors, and scintillation detectors.	• Explain the interaction of radiation, neutrons and charged particles with matter. (C2 • Apply to understand ionisation, semi-conductor, and scintillation detectors (C3)	6
Unit 4: Nuclear Astrophysics		
Introduction: Aspects of Nuclear Physics and Astrophysics, Nuclear reactions: energetics, conservation laws, classification of nuclear reactions. Thermonuclear Reactions: Cross-sections and reaction rates, Particle-induced reactions, Photon-induced Reactions, Abundance Evolution, Reaction Rate at Elevated Temperatures, Nuclear Energy Generations,	• Explain concepts of nucleosynthesis, elemental abundances, and basic nuclear reactions with gamma, neutrons, protons and alpha (C2) • Explain astrophysical S-factor, Maxwellian averaged cross-sections.	12

Nonresonant and Resonant Thermonuclear Reaction rates. Nuclear Burning Stages and Processes: Hydrostatic Hydrogen & Helium Burning, Explosive Burning in Core-collapse Supernovae, Nucleosynthesis Beyond the Iron Peak, s-process, r-process, p-process, Big Bang Nucleosynthesis	• Explain hydrogen and helium burning in stars and supernovae. Synthesis of light elements. • Explain r-, s-, p- processes, synthesis of heavier elements, (C2)	
Unit 5: Quark Model and Particle Phenomenology		
Elementary particles and interactions: leptons, quarks and gauge bosons. Quark model: meson and baryon octets and decuplet. Gell-Mann Okubo mass formula, baryon isospin and baryon magnetic moments in the quark model. Phase Transition: Hadron to the quark phase transition, quark-gluon plasma (QGP) formation, signals of QGP phase, jet quenching, strangeness production, dynamical quark-quark potentials and phenomenology.	• Explain elementary particles, basic interactions, quark model of hadrons, their properties & reactions (C2) • Explain quark (q) to hadron (h) phase transition and QGP formation, signals of QGP phase, jet quenching, strangeness production, and dynamical q-q potentials for phenomenology. (C2)	12

Learning strategies, contact hours and student learning time

Learning strategy	Contact hours	Student learning time (Hrs)
Lecture	36	108
Seminar		
Small Group Discussion (SGD)		
Self-directed learning (SDL)		
Problem Based Learning (PBL)	12	42
Case Based Learning (CBL)		
Clinic		
Practical		
Revision	6	12

Assessment	6	-
TOTAL	**60**	**162**

Assessment Methods:	
Formative:	**Summative:**
Class tests	Sessional examinations (Mid Semester Examination, Quiz1, Quiz2)
Assignments/presentations	End semester examination
Group Discussions	

Mapping of assessment with Cos

Nature of assessment	CO 1	CO 2	CO 3	CO 4	CO 5
Quiz 1	X	X			
Mid Semester Examination	X	X			
Quiz 2			X	X	X
End Semester Examination	X	X	X	X	X
Formative Assessments	X	X	X	X	X

Feedback Process	• Mid-Semester Feedback • End-Semester Feedback
Reference Material	1. Concepts in Nuclear Physics by S. M. Wong 2. Introductory Nuclear Physics by Y. R. Waghmare 3. Concepts in Nuclear Physics by B. L. Cohen 4. Nuclear Physics by I. Kaplan 5. Nuclear Physics by S. N. Ghoshal 6. Introductory Nuclear Physics by Kenneth S. Krane 7. Nuclear Physics of Stars by Christian Iliadis 8. Essentials of Nucleosynthesis and Theoretical Nuclear Astrophysics by Thomas Rauscher 9. Astrophysics for Physicists by Arnab Rai Choudhury 10. Introduction to Elementary Particles by D. Griffiths 11. Introduction to High Energy Physics by D. H. Perkins

Name of the Institution / Department: Manipal Centre for Natural Sciences

Name of the Programme:	Integrated MSc-PhD in Physics
Course Title:	Radiative Processes in Astrophysics
Course Code: NS PH 5210	**Course Instructor:**
Academic Year:	**Semester:** II
No of Credits: 4	**Prerequisites:** B.Sc./B. Tech
Synopsis:	The course will exhaustively cover the fundamentals of numerous radiative processes, where and how they occur in astrophysics, their detection through atomic, molecular spectra and continuum emission, measurements, and their interpretation.
Course Outcomes (COs):	On successful completion of this course, students will be able to
CO 1:	Explain Radiative Transfer and apply the knowledge to the study of the stellar atmosphere (C2, C3)
CO 2:	Demonstrate the basic theories of radiation field and radiation from moving charges (C2)
CO 3:	Explain and analyze the synchrotron emission from the particles with different energy distributions (C2, C4)
CO 4:	(a) Explain and analyze the Bremsstrahlung emission from non-relativistic and relativistic charged particles (C2, C4) (b) Interpret the atomic and molecular spectra (C2)
CO 5:	Explain and analyze Compton emission from the particles with different energy distributions (C2, C4)
CO 6:	Examine the radiations from various astrophysical sources, and formulate the associated emission mechanisms (C4, C6)

Mapping of COs to POs

COs	PO 1	PO 2	PO3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10
CO 1	X	X		X					X	X
CO 2	X	X							X	X
CO 3	X	X		X					X	X
CO 4	X	X		X					X	X
CO 5	X	X		X					X	X
CO 6	X	X		X					X	X

Course content and outcomes:

Content	Competencies	No of Hours
Unit 1: Elementary properties of radiation		
Radiative flux: macroscopic description of propagation of radiation, Flux from an isotropic source; Specific intensity and its moments, Net flux, Momentum flux, Radiative energy density,	• Explain Radiative flux: macroscopic description of the propagation of radiation, Flux from an isotropic source; The specific intensity and its moments: Specific	8

Radiation pressure; Radiative transfer: Emission, Absorption, Radiative transfer equation, Optical depth and source function, Mean free path, Radiation force; Thermal radiation**:** Blackbody radiation, Kirchhoff's law for thermal emission, Planck spectrum, Properties of Planck law, Characteristic temperatures related to Planck spectrum; The Einstein coefficients: Relation between Einstein coefficients, Absorption and Emission coefficient in terms of Einstein coefficients; Scattering effects: Random Walks, Radiative diffusion: Radiative energy transport in a stellar interior, Rosseland approximation, Radiative transfer through the stellar atmosphere, Eddington approximation	intensity, Net flux, Momentum flux, Radiative energy density, Radiation pressure (C2) • Explain Radiative transfer: Emission, Absorption, Radiative transfer equation, Optical depth and source function, Mean free path, Radiation force (C2) • Interpret Thermal radiation: Blackbody radiation, Kirchhoff's law for thermal emission, Planck spectrum, Properties of Planck law, Characteristic temperatures related to Planck spectrum (C2) • Outline the Einstein coefficients: Relation between Einstein coefficients, Absorption and Emission coefficient in terms of Einstein coefficients (C2) • Explain Scattering effects: Random Walks, Radiative diffusion: Radiative energy transport in a stellar interior, Rosseland approximation, Eddington approximation • Apply Radiative transfer to the study of the stellar atmosphere (C3)	
Unit 2: Radiation field and radiation from moving charges		
Radiation field: Review of Maxwell's equations; Plane electromagnetic waves; Radiation spectrum; Polarization and Stokes parameters: Monochromatic waves, Quasi-monochromatic waves; Electromagnetic potentials	• Recall and summarize Maxwell's equations; Plane electromagnetic waves (C1, C2). • Explain Radiation spectrum; Polarization, and Stokes parameters: Monochromatic waves, Quasi-monochromatic waves;	7

Radiation from moving charges: Retarded potentials of single moving charges: The Lienard-Weichart potentials; The velocity and radiation fields; Radiation from the non-relativistic system of particles: Larmor's Formula, The dipole approximation, General multipole expansion; Thompson scattering.	Electromagnetic potentials (C2) • Explain retarded potentials of single moving charges: The Lienard-Weichart potentials; The velocity and radiation fields (C2) • Explain radiation from a non-relativistic system of particles: Larmor's Formula, the dipole approximation, and General multipole expansion; Explain Thompson scattering (C2)	
Unit 3: Relativistic electrodynamics		
Review of Lorentz transformations; Four vectors; Relativistic Doppler effect; Covariance of electromagnetic phenomena, A physical understanding of field transformation. Emission from relativistic particles: Angular distribution of emitted and received power; Invariant phase volume and specific intensity	• Recall and summarize the Lorentz transformations; Four vectors (C1, C2) • Explain the relativistic Doppler effect; Explain the covariance of electromagnetic phenomena. Illustrate the physical understanding of field transformation (C2) • Explain emission from relativistic particles: Angular distribution of emitted and received power; Invariant phase volume and specific intensity (C2)	6
Unit 4: Synchrotron Radiation		
The total emitted power by a relativistic charged particle; Spectrum of Synchrotron radiation: A qualitative approach; Spectral index for power law electron distribution; Spectrum and polarization of Synchrotron radiation; Distinction between received and emitted power; Synchrotron self-absorption, Various astrophysical scenario: Pulsars, astrophysical jets, radio	• Explain the total emitted power; Spectrum of Synchrotron radiation: (a qualitative approach) (C2) • Explain and analyse spectral index for power law electron distribution, spectrum and polarization of Synchrotron radiation (C2, C4) • Illustrate the distinction between received and emitted power (C2)	8

galaxies, Cluster emission.	• Explain synchrotron self-absorption (C2) • Examine various astrophysical scenarios: Pulsars, astrophysical jets, radio galaxies, Cluster emission (C4)	
Unit 5: Bremsstrahlung Radiation and Plasma Effect		
Bremsstrahlung: Emission from single-speed electrons; Thermal Bremsstrahlung emission; Thermal Bremsstrahlung absorption; Relativistic Bremsstrahlung, Various astrophysical scenario: X-ray binaries. Plasma Effects: Plasma frequency, Group and phase velocity and index of refraction; Faraday rotation; Plasma effects in high energy emission processes: Cherenkov radiation, Razin effects	• Explain emission from single-speed electrons; Explain thermal Bremsstrahlung emission and thermal Bremsstrahlung absorption (C2) • Explain relativistic Bremsstrahlung (C2) • Examine various astrophysical scenarios: X-ray binaries (C4) • Explain plasma frequency, Group and phase velocity and index of refraction; Faraday rotation (C2) • Explain plasma effects in high energy emission processes: Cherenkov radiation, Razin effects (C2)	7
Unit 6: Compton and inverse Compton scattering		

Cross section and energy transfer for the fundamental process: Scattering from electron at rest, Scattering from electrons in motion; Inverse Compton power for single scattering; Inverse Compton spectra for single scattering; Inverse Compton spectra and power for repeated scatterings by relativistic electrons of small optical depth, Various astrophysical scenario.	• Explain cross section and energy transfer for the fundamental process: Scattering from electrons at rest, Scattering from electrons in motion (C2) • Explain inverse Compton power for single scattering and inverse Compton spectra for single scattering (C2) • Explain and analyze inverse Compton spectrum and power for repeated scatterings by relativistic electrons of small optical depth (C2, C4)	6
Unit 7: Atomic and Molecular Spectra		
Plasma effects in high energy emission processes: Cherenkov radiation, Razin effects, Zeeman effect; Hyperfine structure; Thermal equilibrium: Boltzmann population of levels, Saha equation.	• Explain the Zeeman effect; Hyperfine structure; Thermal equilibrium: Boltzmann population of levels, Saha equation (C2) • Explain the Semi-classical theory of radiative transitions; Line broadening mechanisms: Doppler broadening, Natural broadening, collisional broadening, combined Doppler and Lorentz profiles (C2) • Explain the Born-Oppenheimer approximation; Pure rotational spectra; Rotational-vibrational spectra; Electronic-rotational-vibrational spectra (C2) • Explain the various line emissions from astrophysical sources (C2)	6

Learning strategies, contact hours and student learning time		
Learning strategy	Contact hours	Student learning time

		(Hrs)
Lecture	36	108
Seminar		
Small Group Discussion (SGD)		
Self-directed learning (SDL)		
Problem Based Learning (PBL)	12	42
Case Based Learning (CBL)		
Clinic		
Practical		
Revision	6	12
Assessment	6	
TOTAL	**60**	**162**

Assessment Methods:	
Formative:	**Summative:**
Class tests	Sessional examinations (Mid Semester Examination, Quiz1, Quiz2)
Assignments/presentations	End semester examination
Group discussions	

Mapping of assessment with Cos

Nature of assessment	CO 1	CO 2	CO 3	CO 4	CO 5	CO 6
Quiz 1	X	X				
Mid Semester Examination	X	X	X			
Quiz 2			X		X	
End Semester Examination	X	X	X	X	X	X
Formative Assessments	X	X	X	X	X	X

Feedback Process	• Mid-Semester Feedback • End-Semester Feedback
Reference Material	1. "Radiative Processes in Astrophysics", Rybicki & Lightman 2. "Astrophysics for Physicist", A. Raychaudhuri 3. "Classical Electrodynamics", Jackson, J.D. 4. "High Energy Astrophysics", Longair, M.S. 5. Blumenthal, G.R., & Gould, R.J., 1970, Rev. Mod. Phys., 42, 237 6. Finke, J.D., Dermer, C.D., & Boettcher, M., 2008, ApJ, 686, 18

Name of the Institution / Department: Manipal Centre for Natural Sciences

Name of the Programme:	Integrated MSc-PhD in Physics
Course Title:	Lab II
Course Code: NS PH 5230	**Course Instructor:**
Academic Year:	**Semester:** II
No of Credits: 3	**Prerequisites:** B.Sc. / B. Tech
Synopsis:	This course will provide exposure to 1) data analysis to infer physical processes at work in various astrophysical scenarios utilising multiwavelength data from space and ground-based observatories, 2) experiments using radiation sources, detectors and their characteristics such as resolution, efficiency, detection etc., and 3) hands-on experience with basic experimental techniques related to Electronics. They will be able to learn the experiments using different ICs.
Course Outcomes (COs):	On successful completion of this course, students will be able to
CO 1:	Outline the ground-based and space-based astronomical observatories, both present and upcoming, which are required for research in Astrophysics (C2).
CO 2:	Analyze data obtained from various astronomical observatories and evaluate the physical processes at work in different astrophysical scenarios (C4, C5)
CO 3:	Summarize radiation sources and detectors and assess the calibrations, resolution and efficiency determination of radiation detectors (C2, C5).
CO 4:	Construct and analyze electronic circuits using active & passive components, Analog ICs such as Integrators, Differentiator, Amplifiers, Filters etc. (C3, C4)

Mapping of COs to POs

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10
CO 1		X		X	X					X
CO 2	X		X				X			X
CO 3		X	X		X		X			X
CO 4	X	X	X				X			X

Course content and outcomes:

Content	Competencies	No of Hours
Unit 1: Astrophysical Data Analysis		
Introduction: Various observational techniques; present and past astronomical observatories across the electromagnetic wavelength Optical Band: Introduction to the software - Image Reduction and Analysis Facility	• Outline the ground-based and space-based astronomical observatories, both present and upcoming, which are required for research in Astrophysics. (C2)	27

(IRAF). Data reduction of the observations taken from ground-based optical telescopes using IRAF. Aperture and PSF photometric measurements from optical data (imaging) using IRAF. X-Ray band: Introduction to X-ray Spectral fitting package X-Spec. Spectral model fitting of data from astronomical sources to evaluate the underlying physical processes. Cosmic Microwave Background (CMB) Radiation: Introduction to cosmic linear anisotropy solving system CLASS, comparison of simulated CMB spectra with different matter contents of the universe with the CMB data.	• Analyze optical data obtained from the optical observatory (ies) using software packages like IRAF, and evaluate the physical processes at work in different astrophysical scenarios (C4, C5) • Analyze data obtained from X-ray observatory (ies) using software packages like X-Spec, and evaluate the physical processes at work in different astrophysical scenarios (C4, C5) • The experiment simulated the evolution of the universe with different matter contents with the code CLASS. (C3) • Analyze data obtained from CMB observations with the simulated CMB spectra with chi-square analysis. (C4) • Interpret the effect of different matter contents of the universe on CMB. (C5)	
Unit 2: Nuclear Physics Experiments		
At least two experiments from the below set of nuclear experiments on: 1. Inverse Square law of radiation and Gamma Ray Attenuation using GM tube. 2. Determination of efficiency of GM tube with a Radioactive source. 3. Calibration of Sodium Iodide detector to find the energy of Unknown radioactive source. 4. Determination of resolution of Sodium iodide detector. 5. Determination of efficiency of Sodium Iodide detector.	• Experiment with radiation sources and detectors. Determine detector characteristics such as calibration curve, resolution and efficiency (C3, C5)	18
Unit 3: AC characteristics and applications of OPAMP		
OPAMP- Differentiator and Integrator Circuit, Square/Triangular Wave Generator and Active filter circuits	• Construct and analyze the differentiator, Integrator Circuit, Square/Triangular	27

	Wave Generator and Active filter circuits (C2, C3, C4)	

Learning strategies, contact hours and student learning time

Learning strategy	Contact hours	Student learning time (Hrs)
Lecture		
Seminar		
Small Group Discussion (SGD)		
Self-directed learning (SDL)		
Problem Based Learning (PBL)		
Case Based Learning (CBL)		
Clinic		
Practical	72	144
Revision	9	18
Assessment	4	
TOTAL	**85**	**162**

Assessment Methods:

Formative:	**Summative:**
Group Discussion	Lab Work & Record Evaluation
	Mid Semester Examination
	End semester examination

Mapping of assessment with Cos

Nature of assessment	CO 1	CO 2	CO 3	CO 4
Lab Work & Record Evaluation	X	X	X	X
Mid Semester Examination		X	X	X
End Semester Examination	X	X	X	X
Formative Assessments	X	X	X	X

Feedback Process

- Mid-Semester Feedback
- End-Semester Feedback

Reference Material

1. Glenn F. Knoll, Radiation Detection and Measurement, Wiley
2. William R Leo, Techniques for Nuclear and Particle Physics Experiments: A How-to Approach, Springer
3. Ramakant A. Gayakwad, Op-Amps and Linear Integrated Circuits
4. Edmund C. Sutton, Observational Astronomy – Techniques and Instrumentation, Cambridge University Press
5. E. Roy & D. Clarke, Astronomy – principles and practice, Institute of Physics Publishing
6. Hale Bradt, Astronomy Methods – A physical approach to Astronomical Observations, Cambridge University Press

	7. Steve B. Howell, Handbook of CCD Astronomy, Cambridge University Press 8. Jeannette Barnes, A Beginner's Guide to Using IRAF (https://iraf-community.github.io/doc/beguide.pdf) 9. Peter Stetson, DAOPHOT – stellar photometry package (http://www.star.bris.ac.uk/~mbt/daophot/) 10. Keith Arnaud et al., An X-Ray Spectral Fitting Package (https://heasarc.gsfc.nasa.gov/xanadu/xspec/XspecManual.pdf) 11. S. Dodelson, "Modern Cosmology," Elsevier 12. CLASS: Cosmic Linear Anisotropy Solving System 13. (https://github.com/lesgourg/class_public) 14. J. Lesgourgues, The Cosmic Linear Anisotropy Solving System (CLASS) I: Overview, arXiv:1104.2932 15. Planck CMB data 16. (https://pla.esac.esa.int/) 17. N. Aghanim et al. [Planck Collaboration] Planck 2018 results. I. Overview and the cosmological legacy of Planck, Astron. Astrophys. 641 (2020), A1; N. Aghanim et al. [Planck Collaboration], Planck 2018 results. VI. Cosmological parameters," Astron. Astrophys. 641 (2020), A6 [erratum: Astron. Astrophys. 652 (2021), C4 18. Press et al., Numerical Recipes, Cambridge University Press (Chapters 14, 15) 19. (http://numerical.recipes/)

Name of the Institution / Department: Manipal Centre for Natural Sciences

Name of the Programme:	Integrated MSc-PhD in Physics
Course Title:	Seminar/ Colloquium
Course Code: NS PH 5231	**Course Instructor:**
Academic Year:	**Semester:** II
No of Credits: 1	**Prerequisites:** B.Sc/B. Tech
Synopsis:	This course aims to make students get acquainted with a wide range of topics in physics, deepen subject knowledge through group discussions and enhance their presentation skills.
Course Outcomes (COs):	On successful completion of this course, students will be able to
CO 1:	Plan a presentation on topics of physics (C3)
CO 2:	Demonstrate the ability to communicate given topics in physics effectively. (C2)

Mapping of COs to POs

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 8	PO 9	PO 10	PO 12
CO 1	X								X	X
CO 2	X								X	X

Course content and outcomes:

Content	Competencies	No of Hours
Unit 1:		
Fundamentals of Physics and Mathematics, Study of the important findings/discoveries in Physics, Learn how to prepare a scientific presentation, Presentation with clarity	• Plan a presentation on topics of physics (C3) • Demonstrate the ability to communicate given topics in physics effectively. (C2)	

Learning strategies, contact hours and student learning time

Learning strategy	Contact hours	Student learning time (Hrs)
Lecture		
Seminar	15	45
Small Group Discussion (SGD)		
Self-directed learning (SDL)		
Problem Based Learning (PBL)		
Case Based Learning (CBL)		
Clinic		
Practical		
Revision		
Assessment		
TOTAL	**15**	**45**

Assessment Methods:

Formative:	**Summative:**
Presentation	
Group Discussion	

Mapping of assessment with Cos		
Nature of assessment	CO 1	CO 2
Presentation	X	X
Group Discussion	X	X

Feedback Process	• Mid-Semester Feedback • End-Semester Feedback
Reference Material	

Name of the Institution / Department: Manipal Centre for Natural Sciences

Name of the Programme:	Integrated MSc-PhD in Physics
Course Title:	Research Project
Course Code: NS PH 6001	**Course Instructor:**
Academic Year:	**Semester:** III & IV
No of Credits: 40	**Prerequisites:** B.Sc./B. Tech
Synopsis:	This course aims to make students master the skills required for carrying out research: literature review, investigating a research problem, applying appropriate research methodology, communicating research findings, and following ethical scientific practices.
Course Outcomes (COs):	On successful completion of this course, students will be able to
CO 1:	Survey and critically assess existing literature on the topic of research. (C4, C5)
CO 2:	Formulate and examine a scientific research problem as an individual and as part of a group (C6, C4)
CO 3:	Apply appropriate physical models and computational/analytical techniques for achieving the desired research goals. (C3)
CO 4:	Evaluate and analyze the obtained results in the context of existing research literature. (C4, C5)
CO 5:	Compile a clear and coherent technical report on the research work carried out. (C6)
CO 6:	Outline, discuss and defend the research findings on national and international platforms. (C2, C6, C5)
CO 7:	Value ethical scientific practices and understand the consequences of using unacceptable practices like data fabrication, plagiarism etc. (C5, C2)

Mapping of COs to POs

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10
CO 1	X	X								X
CO 2	X	X						X		X
CO 3			X	X	X					X
CO 4				X						X
CO5						X			X	X
CO6						X			X	X
CO7							X			X

Course content and outcomes:

Content	Competencies	No of Hours
Project:		
Introduction to scientific methods: Roles of experiments and theory in research; ethical scientific practices and the consequences of using	• Value ethical scientific practices and understand the consequences of using unacceptable practices like data fabrication, plagiarism etc. (C5, C2).	1300

unacceptable practices like data fabrication, plagiarism Importance of Literature Review, Thorough literature review in the relevant field under the guidance of the guide. Scientific motivation, objectives of a research proposal Methodology: its importance and how to develop Learning various necessary skill sets (theory/observation/experiments) and other necessary scientific software, Carry out relevant theoretical/observational/experimental studies and interpret the findings Writing a scientific report and a draft manuscript, Preparation of an oral presentation on the overall findings	• Survey and critically assess existing literature on the topic of research. (C4, C5) • Examine a research problem in the field of interest (C4) • Identify the shortcomings/ gaps of present findings (C3) • Apply appropriate physical models and computational/analytical techniques for achieving the desired research goals. (C3) • Evaluate and analyze the obtained results in the context of existing research literature. (C4, C5) • Compile a clear and coherent technical report on the research work carried out. (C6) • Outline, discuss and defend the research findings at national/international platforms. (C2, C6, C5)	

Learning strategies, contact hours and student learning time		
Learning strategy	Contact hours	Student learning time (Hrs)
Research Project	1300	2000
Seminar		
Small Group Discussion (SGD)		
Self-directed learning (SDL)		
Problem Based Learning (PBL)		
Case Based Learning (CBL)		
Clinic		
Practical		
Revision		
Assessment		
TOTAL	**1300**	**2000**

Assessment Methods:	
	Summative:
Seminar Presentation	
Project Report	
Draft Manuscript	

Mapping of assessment with Cos

Nature of assessment	CO 1	CO2	CO3	CO4	CO5	CO6	CO7
Seminar Presentation	X	X	X	X	X	X	X
Project Report	X	X	X	X	X	X	X
Draft Manuscript	X	X	X	X	X	X	X
Feedback Process	Mid-Semester Feedback						
Reference Material							