Department of Physics

M.Sc. Physics
Curriculum and Syllabus

(Applicable to the students admitted from AY: 2023 onwards)

School of Engineering and Sciences
SRM University *AP*, Andhra Pradesh

Department Vision

To create a vibrant centre of academic excellence and interdisciplinary research, aimed at inspiring the next generation of physicists to serve society through interactive learning, fundamental research, industry partnerships, and academic collaborations.

Department Mission

1. Deliver a curriculum that provides a modern understanding of laws and extensive exposure to teaching and research laboratories, fulfilling industry needs.
2. Create a research and innovation hub equipped with world class facilities to make a lasting impact towards fundamental discoveries and translational research.
3. Cultivate an atmosphere to identify and address problems aligned with national and societal needs.

Program Educational Objectives (PEO)

1. Equip graduates with advanced knowledge and expertise in their chosen specialization to conduct cutting-edge research and drive innovation in academic and industry sectors.
2. Empower graduates to effectively communicate their scientific knowledge and findings and collaborate effectively in multidisciplinary teams to address societal challenges.
3. Instill ethical responsibility and lifelong learning in graduates, preparing them to adapt to scientific advancements and contribute positively to society through science advocacy and public engagement.

Mission of the Department to Program Educational Objectives (PEO) Mapping

	PEO 1	PEO 2	PEO 3
Mission Statement 1	3	1	2
Mission Statement 2	3	2	2
Mission Statement 3	2	2	3

Program Specific Outcomes (PSO)

1. Demonstrate a deep understanding of theoretical principles of core and specialization topics of physics and apply mathematical and computational methods to solve complex physical problems.
2. Equip graduates with skills to design, conduct, analyze, and interpret complex experiments in their specialization using modern laboratory equipment and numerical/computational tools.
3. Engage students in interdisciplinary research projects and encourage them to pursue entrepreneurial ventures that integrate physics knowledge with other scientific and engineering disciplines to address complex real-world challenges.

Mapping Program Educational Objectives (PEO) to Program Learning Outcomes (PLO)

Program Learning Outcomes (PLO)															
	POs												PSOs		
PEOs	Scientific and Disciplinary Knowledge	Analytical Reasoning and Problem Solving	Critical and Reflective Thinking	Scientific Reasoning and Design Thinking	Research Related Skills	Modern Tools and ICT Usage	Environment and Sustainability	Moral, Multicultural and Ethical Awareness	Individual and Teamwork Skills	Communication Skills	Leadership Readiness Skills	Self-Directed and Lifelong Learning	PSO 1	PSO 2	PSO 3
PEO 1	3	3	1	1	1	3	2	1	1	1	3	1	3	2	3
PEO 2	1	2	1	1	2	3	3	3	3	3	2	1	2	2	3
PEO 3	1	2	1	1	2	3	3	3	3	3	2	1	2	2	3

Category Wise Credit Distribution			
Course Sub-Category	**Sub-Category Credits**	**Category Credits**	**Learning hours**
Ability Enhancement Courses (AEC)		3	90
University AEC	0		
School AEC	3		
Value Added Courses (VAC)		3	90
University VAC	0		
School VAC	3		
Skill Enhancement Courses (SEC)		6	180
School SEC	0		
Department SEC	6		
SEC Elective	0		
Foundation / Interdisciplinary courses (FIC)		9	270
School FIC	9		
Department FIC	0		
Core + Core Elective including Specialization (CC)		43	1290
Core	28		
Core Elective (Inc Specialization)	15		
Minor (MC) + Open Elective (OE)	0	0	0
Research / Design / Internship/ Project (RDIP)		19	570
Internship / Design Project / Startup / NGO	5		
Internship / Research / Thesis	14		
Total		**83**	**2490**

Semester wise Course Credit Distribution Under Various Categories						
Category	**Semester**					
	I	**II**	**III**	**IV**	**Total**	**%**
Ability Enhancement Courses - AEC	2	0	1	0	3	**4**
Value Added Courses - VAC	0	3	0	0	3	**4**
Skill Enhancement Courses - SEC	3	3	0	0	6	**8**
Foundation / Interdisciplinary Courses - FIC	3	3	3	0	9	**11**
CC / SE / CE / TE / DE / HSS	16	14	13	0	43	**54**
Minor / Open Elective - OE	0	0	0	0	0	**0**
(Research/ Design/ Industrial Practice/Project/Thesis/Internship) -RDIP	0	0	5	14	19	**20**
Grand Total	**24**	**23**	**22**	**14**	**83**	**100**

Note: L-T/D-P/Pr and the class allocation is as follows.

a) Learning Hours : 30 learning hours are equal to 1 credit.

b) Lecture/Tutorial : 15 contact hours (60 minutes each) per semester are equal to 1 credit.

c) Discussion : 30 contact hours (60 minutes each) per semester are equal to 1 credit.

d) Practical : 30 contact hours (60 minutes each) per semester are equal to 1 credit.

e) Project : 30 project hours (60 minutes each) per semester are equal to 1 credit.

SEMESTER - I								
S. No	**Category**	**Sub-Category**	**Course Code**	**Course Title**	**L**	**T/D**	**P/Pr**	**C**
1	AEC	U AEC	AEC 501	Effective Communication for Impactful Interviews	2	0	0	2
2	VAC	S VAC	VAC 501	Community Engagement and Social Responsibility	0	0	1	1*
3	SEC	D SEC	SEC 501	Introduction to R and Python	1	1	1	3
4	FIC	S FIC	FIC 501	Data Science for Beginners	3	0	0	3
5	Core	CC	PHY 501	Mathematical Methods	2	2	0	4
6	Core	CC	PHY 502	Classical Mechanics	2	2	0	4
7	Core	CC	PHY 503	Quantum Mechanics	2	1	1	4
8	Core	CC	PHY 504	Electromagnetic Theory	2	1	1	4
				Semester Total	**14**	**7**	**4**	**22**

SEMESTER - II								
S. No	**Category**	**Sub-Category**	**Course Code**	**Course Title**	**L**	**T/D**	**P/Pr**	**C**
1	VAC	S VAC	VAC 502	Community Engagement and Social Responsibility	0	0	1	1
2	VAC	S VAC	VAC 503	Entrepreneurial Mindset	2	0	0	2
3	SEC	D SEC	SEC 105	Research Design and Methods	3	0	0	3
4	FIC	S FIC	FIC 108	Design Thinking	3	0	0	3
5	Core	CC	PHY 505	Statistical Mechanics	2	2	0	4
6	Core	CC	PHY 506	Condensed Matter Physics	2	0	2	4
7	Elective	DE		Department Elective -I	3	0	0	3
8	Elective	DE		Department Elective -II	3	0	0	3
				Semester Total	**18**	**2**	**3**	**23**

SEMESTER - III

S. No	Category	Sub-Category	Course Code	Course Title	L	T/D	P/Pr	C
1	AEC	S AEC	AEC 503	Research Seminar	0	0	1	1
2	FIC	S FIC	FIC 124	Psychology for Everyday Living	3	0	0	3
3	Core	CC	PHY 507	Electronics	2	0	2	4
4	Elective	CE		Core Elective	3	0	0	3
5	Elective	CE		Core Elective	3	0	0	3
6	Elective	CE		Core Elective	3	0	0	3
7	RDIP	RDIP	PHY 508	Project - I	0	0	3	3
8	RDIP	RDIP	PHY 510	Summer Internship	0	0	2	2
				Semester Total	**14**	**0**	**8**	**22**

SEMESTER - IV

S. No	Category	Sub-Category	Course Code	Course Title	L	T/D	P/Pr	C
1	RDIP	RDIP	PHY 509	Thesis Project	0	0	14	14
				Semester Total	**0**	**0**	**14**	**14**

Department Electives

S. No	Category	Sub-Category	Course Code	Course Title	L	T/D	P/Pr	C
1	Elective	CE	PHY 550	Numerical Methods in Physics	2	1	0	3
2	Elective	CE	PHY 551	Atomic and Molecular Physics	2	1	0	3
3	Elective	CE	PHY 552	Nuclear and Particle Physics	2	1	0	3

Specialization: Condensed Matter (Research Track)

S. No	Category	Sub-Category	Course Code	Course Title	L	T/D	P/Pr	C
1	Elective	CE/SE	PHY 553	Condensed Matter Physics - II	2	1	0	3
2	Elective	CE/SE	PHY 554	Spintronics & Nano-magnetism – MEMS & NEMS	2	0	1	3
3	Elective	CE/SE	PHY 555	Soft Matter Physics	2	1	0	3

Specialization: Astrophysics and Cosmology (Research Track)

S. No	Category	Sub-Category	Course Code	Course Title	L	T/D	P/Pr	C
1	Elective	CE/SE	PHY 556	Introduction to Astrophysics	2	1	0	3
2	Elective	CE/SE	PHY 557	General Relativity and Cosmology	2	1	0	3
3	Elective	CE/SE	PHY 558	Standard Model of Particle Physics	2	1	0	3
4	Elective	CE/SE	PHY 571	Quantum Field Theory	2	1	0	3

Specialization: Quantum Technologies (Research Track)

S. No	Category	Sub-Category	Course Code	Course Title	L	T/D	P/Pr	C
1	Elective	CE/SE	PHY 559	Quantum Optics	2	1	0	3
2	Elective	CE/SE	PHY 560	Advanced Quantum Mechanics	2	1	0	3
3	Elective	CE/SE	PHY 561	Quantum Information and Computation	2	1	0	3

Core Electives

S. No	Category	Sub-Category	Course Code	Course Title	L	T/D	P/Pr	C
1	Elective	CE/SE	PHY 562	Artificial Intelligence in Complex Systems.	2	1	0	3
2	Elective	CE/SE	PHY 563	Data Science and Statistics	2	1	0	3
3	Elective	CE/SE	PHY 564	Risk and Resource Management	2	1	0	3
4	Elective	CE/SE	PHY 565	Solid State Battery Technologies	2	0	1	3
5	Elective	CE/SE	PHY 566	Li-ion and beyond Li-ion Batteries	2	0	1	3
6	Elective	CE/SE	PHY 567	Optoelectronic Devices	2	0	1	3
7	Elective	CE/SE	PHY 568	Semiconductor Device Physics	2	0	1	3
8	Elective	CE/SE	PHY 569	Fundamentals, Technology and Applications	2	0	1	3
9	Elective	CE/SE	PHY 570	Lithography and Additive Manufacturing	2	0	1	3

Effective Communication for Impactful Interviews

Course Code	AEC 501	**Course Category**	AEC		L	T	P	C
					2	0	0	2
Pre-Requisite Course(s)		**Co-Requisite Course(s)**		**Progressive Course(s)**				
Course Offering Department	Literature and Language	**Professional / Licensing Standards**						

Course Objectives / Course Learning Rationales (CLRs)

1. This course equips the learners for successful job hunting by fostering a comprehensive understanding and application of the KASB Model in professional communication, enhancing verbal communication skills to excel in interviews, mastering non-verbal communication for a positive first impression, and guiding them in customizing application materials to stand out from the crowd.

Course Outcomes / Course Learning Outcomes (CLOs)

	At the end of the course the learner will be able to	**Bloom's Level**	**Expected Proficiency Percentage**	**Expected Attainment Percentage**
Outcome 1	Identify key components of verbal and non-verbal communication and their significance in the interview process.	1	50%	50%
Outcome 2	Develop the skill to articulate thoughts clearly and concisely, using effective interview responses.	2	65%	60%
Outcome 3	Exhibit proficiency in the art of storytelling as a communication tool in interviews.	2	65%	60%
Outcome 4	Create personalized and tailored resumes, cover letters, and SOPs to align with specific job or educational opportunities.	3	70%	60%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	**Program Learning Outcomes (PLO)**														
	Scientific and Disciplinary Knowledge	**Analytical Reasoning and Problem Solving**	**Critical and Reflective Thinking**	**Scientific Reasoning and Design Thinking**	**Research Related Skills**	**Modern Tools and ICT Usage**	**Environment and Sustainability**	**Moral, Multicultural and Ethical Awareness**	**Individual and Teamwork Skills**	**Communication Skills**	**Leadership Readiness Skills**	**Self-Directed and Life Long Learning**	**PSO 1**	**PSO 2**	**PSO 3**
Outcome 1	2	1	1	1	3	1		3	2	3	2	3			
Outcome 2	2	3	3	1	3	1		3	2	3	3	3			
Outcome 3	2	1	3	2	3	2		3	2	3	3	3			
Outcome 4	2	3	3	2	3	3		3	2	3	3	3			
Average	**2**	**2**	**2.5**	**1.5**	**3**	**1.75**		**3**	**2**	**3**	**2.75**	**3**			

Course Unitization Plan

Unit No.	Unit Name	Required Contact Hours	CLOs Addressed	References Used
Unit 1	**Introduction: An Overview**	**9**		
	Types of interview	2	1	4
	Communication as a strategy	3	1	4,5
	The KASB Model	4	1	4
Unit 2	**Articulation Skills**	**8**		
	The 3 Vs of Communication	2	1	1,4
	Tone, Pitch and Modulation	4	2	4,5
	Practice session	4	2	
Unit 3	**Story Telling**	**6**		
	The Importance of story telling	2	3	6
	Creating stories around' Tell Me About Yourself'	2	3	6,7
	Group Discussion	2	3	8
Unit 4	**Written Strategy**	**10**		
	Resume	4	4	2,4
	Cover Letter	4	4	2,4
	SOP	2	4	2,4
Unit 5	Mock Interview Sessions	**12**		
			1,2,3.4	
	Total Hours	**45**		

Learning Assessment

Bloom's Level of Cognitive Task		Continuous Learning Assessments (60%)				Interview Handling Process (40%)
		CLA-1 15%	Mid-1	CLA-2 15%	CLA-3 15%	
Level 1	Remember	100%		30%	50%	20%
	Understand					
Level 2	Apply			70%	50%	50%
	Analyse					
Level 3	Evaluate					30%
	Create					
Total		**100%**	**100%**	**100%**	**100%**	**100%**

Recommended Resources

1. Cialdini, R. B. (2021). Influence: The psychology of persuasion (Revised edition). Harper Perennial Modern Classics.
2. Dipboye, R. L., & Cole, C. H. (2019). Secrets of a hiring manager: How to land any job and win over any boss. HarperBusiness.
3. LaFare, M. (2013). Veritas: A game of lies. Penguin Books.
4. Mock, P., & Turner, L. (2019). The interview for dummies (6th edition). John Wiley & Sons.
5. Stone, D. D., Patton, B., & Heen, S. (2000). Difficult conversations: How to discuss what matters most (2nd edition). Viking.
6. Dolan, G. (2019). Storytelling for job interviews: How to use stories, nail an interview and land your dream job. BookBaby.
7. Pink, S. (2014). To sell is human: The science of persuasion. Penguin Books.
8. Lewis, V. J. (2018). Group discussion: A practical guide (7th edition). Kogan Page

Other Resources

Introduction to R and Python

					L	T	P	C
Course Code	SEC 501	**Course Category**	SEC		1	1	1	3
Pre-Requisite Course(s)		**Co-Requisite Course(s)**		**Progressive Course(s)**				
Course Offering Department	Mathematics	**Professional / Licensing Standards**						

Course Objectives / Course Learning Rationales (CLRs)

1. In Python, identify and describe essential elements such as syntax, keywords, variables, indentation, data types, lists, tuples, sets, dictionaries, operators, control statements, and loops.
2. Understand the significance of built-in functions, user input-output, matrix computations, linear equations, and graphing curves and surfaces using Matplotlib and file handling in Python.
3. Implement R programming fundamentals, including objects, vectors, matrices, arrays, data manipulation techniques (sub setting, filtering, merging), and data frames, and create visualisations using ggplot2 in R.
4. Synthesise knowledge from Python and R to perform comprehensive data analysis and create reports that include descriptive statistics, linear regression, hypothesis testing, and time series forecasting.

Course Outcomes / Course Learning Outcomes (CLOs)

	At the end of the course the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	Demonstrate an understanding of Python programming fundamentals, including syntax, keywords, variables, data types, lists, tuples, sets, dictionaries, operators, and control statements.	2	80	70
Outcome 2	Grasp core programming concepts by comprehending the role of built-in functions, user input-output, file handling and graphing curves and surfaces using Matplotlib in Python.	3	75	70
Outcome 3	Apply programming skills in R by effectively using objects, vectors, matrices, arrays, and data frames, and will demonstrate the practical application of data manipulation techniques, including sub-setting, filtering, and merging, and create visualizations using ggplot2 in R.	4	75	70
Outcome 4	Integrate Python and R knowledge to perform sophisticated data analysis that incorporates descriptive statistics, linear regression, hypothesis testing, and time series forecasting, showcasing a synthesis of programming skills across both languages.	5	75	70
Outcome 5	Demonstrate an understanding of Python programming fundamentals, including syntax, keywords, variables, data types, lists, tuples, sets, dictionaries, operators, and control statements.	2	80	70

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	Program Learning Outcomes (PLO)														
	Scientific and Disciplinary Knowledge	Analytical Reasoning and Problem Solving	Critical and Reflective Thinking	Scientific Reasoning and Design Thinking	Research Related Skills	Modern Tools and ICT Usage	Environment and Sustainability	Moral, Multicultural and Ethical Awareness	Individual and Teamwork Skills	Communication Skills	Leadership Readiness Skills	Self-Directed and Life Long Learning	PSO 1	PSO 2	PSO 3
Outcome 1	3	3	3	3					1			2	3	1	2
Outcome 2	3	3	3	2	1				2			2	3	2	2
Outcome 3	3	3	3	3	1				2			2	3	2	2
Outcome 4	3	3	3	3	3				3			2	3	2	2
Outcome 5	3	2	3	3	3				2			3	2	2	2
Average	**3**	**3**	**3**	**3**	**2**				**2**			**2**	**3**	**2**	**2**

Course Unitization Plan Theory

Unit No.	Unit Name	Required Contact Hours	CLOs Addressed	References Used
Unit 1		**6**		
	Introduction to data and its different types of scales.	3	1,2	1
	Summarising data, different types of descriptive statistics	3	1,2	1
Unit 2		**9**		
	Introduction to Vectors, matrices	3	2,3	1
	Recursive functions, Matrix computations and linear equations	3	2,3	1
	Solving system of Linear Equations. Consistency, transpose, determinants, inverses, trace,	3	2,3	1
Unit 3		**15**		
	Basic principles of probability, Random variables.	2	3,4	2
	The Binomial, Normal and other popular distributions.	2	3,4	2
	Inference for one or two samples means using the t-distribution, statistical power for comparing two groups	2	3,4	2
	Introduction to Correlation Analysis, Correlation coefficient for Categorical and Continuous data.	2	4	2
	Introduction to the logistics regression.	4	4	2
Total Contact Hours		**30**		

Course Unitization Plan Lab

Unit No.	Unit Name	Required Contact Hours	CLOs Addressed	References Used
1	Write a program to demonstrate the use of Python syntax, keywords, and variables.	2	1	1
2	Create a program that uses indentation and comments to improve code readability.	2	1	1
3	Implement a program that showcases different data types in Python (int, float, string, Boolean).	2	1	1
4	Write a program that manipulates lists (e.g., sorting, appending, slicing).	2	1	1
5	Create a program that demonstrates using tuples and sets in Python.	2	2	1
6	Implement a dictionary to store and retrieve information.		2	1
7	Write a program that uses different operators in Python (+, -, *, /, //, %, **).	2	2	1
8	Create a program that includes control statements (if-else, nested if-else, switch-case) and loops (for, while).	2	2	1
9	Write a program to create and manipulate objects in R.	2	3	2
10	Implement a program that demonstrates using vectors and matrices in R.	2	3	2
11	Create a program that works with arrays and lists in R.	2	3	2
12	Write a program to handle missing data in a data frame.	2	3	2
13	Implement a program that reads and writes data to CSV or text files.	2	4	2
14	Create a program that performs data manipulation tasks (subsetting, filtering, merging) on a data frame.	2	4	2
15	Write a program that uses ggplot2 to create a plot in R.	2	3,4	2
Total Contact Hours		**30**		

Learning Assessment

Bloom's Level of Cognitive Task		Continuous Learning Assessments (60%)								End Semester Exam (40%)	
		CLA-1 20%		Mid-1 20%		CLA-2 10%		CLA-3 10%			
		Th	Pr	Th	Pr	Th	Pr	Th	Pr	Th	Pr
Level 1	Remember / Understand	70%	80%	40%	40%	60%	30%	50%		40%	30%
Level 2	Apply / Analyse	30%	20%	40%	40%	40%	40%	50%		50%	50%
Level 3	Evaluate / Create			20%	20%		30%			10%	20%
Total		**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**		**100%**	**100%**

Recommended Resources

1. Guido van Rossum and the Python development team Python Tutorial Release 3.7.0.
2. W. N. Venables, D. M. Smith and the R Core Team, An Introduction to R
3. R in Action, Robert L. Kabacoff, Second Edition, Paperback, Dreamtech Press
4. A Beginner's Guide to R, Alain F. Zuur, Elena N. Ieno, Erik H. W. G. Meesters, Springer New York.
5. The Absolute Beginner's Guide to Python Programming, A Step-by-Step Guide with Examples and Lab Exercises, Kevin Wilson, Apress Berkeley, CA
6. Python Programming Fundamentals, Kent D. Lee, Springer London

Other Resources

Data Science for the Beginners

Course Code	FIC 501	**Course Category**	FIC		**L**	**T**	**P**	**C**
					3	0	0	3
Pre-Requisite Course(s)		**Co-Requisite Course(s)**		**Progressive Course(s)**				
Course Offering Department	Mathematics	**Professional / Licensing Standards**						

Course Objectives / Course Learning Rationales (CLRs)

1. After completing this course, students will fully grasp different data types and representations. Also, they have a basic understanding of descriptive statistics for the given datasets.
2. Students will understand linear algebra concepts well, enabling them to manipulate vectors and matrices and solve linear systems efficiently.
3. Upon completing the course, students will be proficient in applying probability principles and conducting statistical inference, including point estimation, confidence intervals, and hypothesis testing for various scenarios.
4. Equip the Students with the knowledge and skills necessary to apply regression techniques for modelling numerical outcomes and logistic regression for classification tasks, both for numerical and categorical data.

Course Outcomes / Course Learning Outcomes (CLOs)

	At the end of the course the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	Explain the different types of data and graphical representation of data.	2	70%	65%
Outcome 2	Compute descriptive statistics for any given dataset, such as different measures of central tendency and variation in the data.	3	70%	65%
Outcome 3	Interpret different definitions of probability and the different types of random variables. Illustrate the application of the central limit theorem. Draw inferences about the population parameters.	4	70%	65%
Outcome 4	Describe regression analysis using the concept of matrices and the solution of the system of equations.	5	70%	65%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	Program Learning Outcomes (PLO)													
	Scientific and Disciplinary Knowledge	Analytical Reasoning and Problem Solving	Critical and Reflective Thinking	Scientific Reasoning and Design Thinking	Research Related Skills	Modern Tools and ICT Usage	Environment and Sustainability	Moral, Multicultural and Ethical Awareness	Individual and Teamwork Skills	Communication Skills	Leadership Readiness Skills	Self-Directed and Life Long Learning	PSO 1	PSO 2	PSO 3
Outcome 1	2	3	2	2	1	2									
Outcome 2	1	2	2	2	1	-									
Outcome 3	2	2	1	1	1	-									
Outcome 4	2	2	2	1	2	3									
Average	**2**	**2**	**2**	**1**	**1**	**2**									

Course Unitization Plan

Session	Description of Topic	Required Contact hours	CLOs Addressed	Reference Used
	Unit-I: Data Representations	**9**		
1.	Introduction to data, data structures	1	1	1,3
2.	Variables and Basic data collection techniques	1	1	1,3
3.	Summarising data, Descriptive Statistics	2	1,2	1,3
4.	Graphics, Histograms, and Popular database software.	2	1,2	1,3
5.	A glimpse inside the mind of a data scientist	1	1	1,3
6.	Discussion and Tutorial-I	2	1	1,3
	Unit-II: Basics of Linear Algebra	**10**		
7.	Introduction to Vectors, matrices and linear systems,	1	4	1,2
8.	Solving system of Linear Equations. Consistency, transpose, determinants, inverses, trace,	1	4	2
9.	Vector space, subspaces,	1	4	2
10.	Independence of vectors, basis and dimension, dot product, inner product, Eigenvalues and Eigenvectors.	2	4	1,2
11.	Dot product, inner product and its application	2	4	2
12.	Eigenvalues and Eigenvectors.	1	4	2
13.	Discussion on Practical applications of vector spaces and Matrices.	2	2,4	1,2,4
	Unit-III: Probability Distributions and Inferential Statistics	**12**		
14.	Basic principles of probability, Different approaches for defining the probability.	1	3	1,3
15.	Random variables, Types of random Variables and their distribution.	1	3	1,3
16.	The Binomial, Normal and other popular distributions.	1	3	1,3
17.	Foundations for Statistical inference, Point and Interval Estimates.	1	3	1,3
18.	Discussion and Tutorial	1		1,3
19.	General ideas for statistical inference in estimating the population proportion, Central Limit theorem and its application.	2	3	1,3
20.	Inference for proportions and tables using the normal and chi-square distributions.	1	3	1,3
21.	Inference for categorical data,	1	3	1,3
22.	Inference for one or two samples means using the t-distribution, statistical power for comparing two groups	2	3	1,3
23.	Tutorial-III	1	3	1,3,4
	Unit-IV: Regression and Classification	**14**		
24.	Introduction to Correlation Analysis, Correlation coefficient for Categorical and Continuous data.	2	4	
25.	Introduction to linear regression, Scatter Plot.	1	4	1,4
26.	Regression for a numerical outcome with one predictor Variable,	2	4	1,4
27.	Brief Discussion about Model Adequacy, accuracy, and validation.	2	4	1,3,4
28.	Regression for numerical and categorical data using many Predictors,	1	4	1,4
29.	Logistic regression for classification,	2	4	1,4
30.	Tutorial and Doubt Clearing Session	1	4	1,4
31.	Practical applications of Regression and Classification in prediction and forecasting	2	4	1,4
32.	Tutorial-II	1	4	1,4
Total Contact Hours		**45**		

Learning Assessment

Bloom's Level of Cognitive Task		Continuous Learning Assessments (50%)								End Semester Exam (50%)	
		CLA-1 (10%)		Mid-term (20%)		CLA-2 (10%)		CLA-3 (10%)			
		Th	Prac	Th	Prac	Th	Prac	Th	Prac	Th	Prac
Level 1	Remember	30%		25%		30%		20%		20%	
	Understand	30%		25%		30%		20%		30%	
Level 2	Apply	20%		25%		20%		30%		25%	
	Analyse	20%		25%		20%		30%		25%	
Level 3	Evaluate										
	Create										
Total		**100%**		**100%**		**100%**		**100%**		**100%**	

Recommended Resources

1. Openintro Statistics (4th edition), Diez David M Christopher D Barr and Çetinkaya, 2019.
2. Linear Algebra and its Applications, Gilbert Strang, Publisher Cengage India Private Limited, 2005.
3. First Course in Probability (11th Edition), Sheldon Ross, Academic Press, 2014.
4. An Introduction to Statistical Learning, with Applications in R, by James, Witten, Hastie and Tibshirani, Springer, 2013

Other Resources

Mathematical Methods in Physics

						L	T	P	C
Course Code	PHY 501	**Course Category**	CC			2	2	0	4
Pre-Requisite Course(s)		**Co-Requisite Course(s)**		**Progressive Course(s)**					
Course Offering Department	Physics	**Professional / Licensing Standards**							

Course Objectives / Course Learning Rationales (CLRs)

1. To understand fundamental concepts of vectors with practical applications.
2. To understand fundamental concepts of complex numbers to solve real problems.
3. To understand fundamental concepts of group theory with practical applications.
4. To understand the concepts of differential equations and various integral transforms.
5. To understand the probability concept with practical applications.

Course Outcomes / Course Learning Outcomes (CLOs)

	At the end of the course the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	Summarize the use of mathematical concepts and methods (i.e., Vectors, Complex variables, Differential equations, statistics & probability theory etc.) in Physics related problems.	2	70%	65%
Outcome 2	Employ vectors, matrix algebra and complex variable methods to study physical systems	3	70%	65%
Outcome 3	Demonstrate the symmetry transformations, group representations, and apply those for physical systems	3	70%	65%
Outcome 4	Solve problems related to simple physical systems using integral transforms and differential equations	3	70%	65%
Outcome 5	Examine the role of the concept of probability in statistical problems	4	70%	65%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	Program Learning Outcomes (PLO)													
	Scientific and Disciplinary Knowledge	Analytical Reasoning and Problem Solving	Critical and Reflective Thinking	Scientific Reasoning and Design Thinking	Research Related Skills	Modern Tools and ICT Usage	Environment and Sustainability	Moral, Multicultural and Ethical Awareness	Individual and Teamwork Skills	Communication Skills	Leadership Readiness Skills	Self-Directed and Life Long Learning	PSO 1	PSO 2	PSO 3
Outcome 1	3	3	3	3					1			2	3	1	2
Outcome 2	3	3	3	2	1				2			2	3	2	2
Outcome 3	3	3	3	3	1				2			2	3	2	2
Outcome 4	3	3	3	3	3			1	3	2		2	3	2	2
Outcome 5	3	2	3	3	3			1	2	2		2	2	2	2
Average	**3**	**2.8**	**3**	**3**	**2**			**1**	**2**	**2**		**2**	**2.8**	**1.8**	**2**

Course Unitization Plan

Unit No.	Unit Name	Req-uired Contact Hours	CLOs Addressed	References
Unit No. 1	**Vector Space and Matrices**	**12**		
	Definition of vector space, Dirac notation, basis vectors	1	1, 2	3,4
	Discussion-I: Dimensionality, inner product, linear independence	1	1, 2	3,4
	Discussion-II: Orthonormality and completeness	1	1, 2	3,4
	Gram-Schmidt orthonormalization	1	1, 2	3,4
	Discussion-III: Matrix algebra, similarity transformation	1	1, 2	3,4
	Functions of matrices; Cayley-Hamilton theorem	1	1, 2	3,4
	Discussion-IV: Eigen vectors computation	1	1, 2	3,4
	Discussion-V: Orthogonal, Hermitian and Unitary matrices	1	1, 2	3,4,5
	Orthonormality of eigen vectors	1	1, 2	3,4,5
	Diagonalisation	1	1, 2	3,4
	Elementary ideas of tensors	1	1, 2	3,4
	Discussion-VI: Covariant and contravariant tensors	1	1, 2	3,4
Unit No. 2	**Complex variables**	**12**		
	Recapitulations: Complex numbers, Schwarz inequality	1	1, 2	1, 2,3
	Discussion-I: Single and multi-valued functions of complex variables	1	1, 2	1, 2,3
	Discussion-II: Limit and continuity	1	1, 2	1,2,3
	Differentiation – Cauchy-Riemann equations	1	1, 2	1, 2,3
	Discussion-III: Analytic and harmonic functions	1	1, 2	1, 2,3
	Complex integrals	1	1, 2	1, 2,3
	Discussion-IV: Cauchy's theorem	1	1, 2	1,2,3
	Taylor and Laurent expansions	1	1, 2	1, 2,3
	Discussion-V: Classification of singularities	1	1, 2	1,2,3
	Discussion-VI: Branch point, branch cut	1	1, 2	1,2,3
	Residue theorem	1	1, 2	1,2,3
	Applications of residue theorem in evaluating real integrals	1	1, 2	1, 2,3
Unit No. 3	**Group theory**	**12**		
	Definitions, multiplication table	1	1, 3	1, 2
	Rearrangement theorem	1	1, 3	1, 2
	Discussion-I: Isomorphism, homomorphism	1	1, 3	1,2
	Applications to point symmetry groups	1	1, 3	1, 2
	Discussion-II: Faithful and unfaithful representations	1	1, 3	1, 2
	Discussion-III: Reducible and irreducible representations	1	1, 3	1,2
	Tutorial - I	1	1, 3	1, 2
	Lie groups	1	1, 3	1, 2
	Lie algebra	1	1, 3	1, 2
	Examples with SU(2) and O(3)	1	1, 3	1,2
	Tutorial II	1	1, 3	1,2
	Tutorial III	1	1, 3	1,2
Unit No. 4	**Differential equations**	**12**		
	Discussion-I: Singular points: regular and irregular	1	1, 4	2,3
	Frobenius method, Fuch's theorem	1	1, 4	2,3
	Discussion-II: Linear independence of solutions - Wronskian	1	1, 4	2,3
	Discussion-III: Sturm-Liouville theory	1	1, 4	2,3
	Inhomogeneous equations – Green's function	1	1, 4	2,3
	Applications of Green's functions	1	1, 4	2,3
	Special functions: Bessel, Legendre	1	1, 4	2,3
	Special functions: Hermite, Laguerre	1	1, 4	2,3
	Discussion-IV: Spherical harmonics	1	1, 4	2,3
	Discussion-V: Fourier and inverse Fourier transforms	1	1, 4	2,3
	Discussion-VI: Laplace and inverse Laplace transforms	1	1, 4	2,3

	Use of integral transforms in solving differential equations	1	1, 4	2,3
Unit No. 5	**Probability theory**	**12**		
	Probability and Random variables	1	1, 5	3
	Probability distributions and densities	1	1, 5	3
	Discussion-I: Discrete and continuous probability distributions	1	1, 5	3
	Tutorial-I: Problems on probability distributions	1	1, 5	3
	Discussion-II: Moments and generating functions	1	1, 5	3
	Tutorial-II: Problems on moments and generating functions	1	1, 5	3
	Conditional probability, Bayes' theorem	1	1, 5	3
	Joint distributions, covariance, correlations	1	1, 5	3
	Discussion-III: Central limit theorem	1	1, 5	3
	Applications of central limit theorem	1	1, 5	3
	Elements of extreme value statistics; Weibull, Gumbel and Frechet distributions	1	1, 5	3
	Tutorial-III: Applications of extreme value statistics	1	1, 5	3
Total Contact Hours		**60**		

Learning Assessment

Bloom's Level of Cognitive Task		**Continuous Learning Assessments (50 %)**								**End Semester Exam (50 %)**	
		CLA-1 (15 %)		**CLA-2 (15 %)**		**CLA-3 (__%)**		**Mid Term (20 %)**			
		Th	**Prac**	**Th**	**Prac**	**Th**	**Prac**	**Th**	**Prac**	**Th**	**Prac**
Level 1	Remember / Understand	40%		40%				40%		30%	
Level 2	Apply / Analyse	60%		60%				60%		70%	
Level 3	Evaluate / Create										
Total		**100%**		**100%**				**100%**		**100%**	

Recommended Resources

1. .Arefken, G. B., Weber, H. J., & Harris, F. E. (2012). Mathematical methods for physicists, 7th ed. Amsterdam:Elsevier.
2. 2. Riley, K. F., & Hobson, M. P. (2011). Essential mathematical methods for the physical sciences, 1st ed. Cambridge: Cambridge University Press
3. 3. Boas, M. L. (2006). Mathematical methods in the physical sciences, 3rd ed. Wiley: Wiley Publication.
4. 4. Spiegel, M. R. (2009). Vector analysis, 2nd ed. McGraw Hill Education.

Other Resources

1. YouTube. (2024). Mathematical methods for physics. Retrieved from https://www.youtube.com/playlist?list=PL_LAJKOptm3ZWZHVNr8FmMzsWgb989ltu

Classical Mechanics

Course Code	PHY 502	**Course Category**	CC	**L**	**T**	**P**	**C**
				2	2	0	4
Pre-Requisite Course(s)		**Co-Requisite Course(s)**		**Progressive Course(s)**			
Course Offering Department	Physics	**Professional / Licensing Standards**					

Course Objectives / Course Learning Rationales (CLRs)

1. Review Newtonian mechanics, and learn variational principle and its application
2. To learn Lagrangian mechanics and its advantage over Newtonian mechanics for solving motion under constrained using generalized coordinates
3. To learn Hamiltonian mechanics and its advantage over Lagrangian formalism
4. To understand Poisson brackets, and canonical transformations
5. To describe and solve central force problem and weakly coupled small oscillations
6. To understand different dynamical behaviour in the presence of nonlinearity

Course Outcomes / Course Learning Outcomes (CLOs)

	At the end of the course the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	Review basic concepts of Newtonian, Lagrangian, Hamiltonian and Relativistic mechanics	2	70%	65%
Outcome 2	Solve complex problems involving kinematics & dynamics of single particle & system of particles	3	70%	65%
Outcome 3	Examine the role of variational principle and canonical transformation in Lagrange's and Hamilton's equation (respectively)	3	70%	65%
Outcome 4	Interpret the effect of nonlinearity on dynamical systems	4	70%	65%
Outcome 5	Investigate the role of special theory of relativity in kinematics and electrodynamics.	4	70%	65%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	Program Learning Outcomes (PLO)														
	Scientific and Disciplinary Knowledge	Analytical Reasoning and Problem Solving	Critical and Reflective Thinking	Scientific Reasoning and Design Thinking	Research Related Skills	Modern Tools and ICT Usage	Environment and Sustainability	Moral, Multicultural and Ethical Awareness	Individual and Teamwork Skills	Communication Skills	Leadership Readiness Skills	Self-Directed and Life Long Learning	PSO 1	PSO 2	PSO 3
Outcome 1	3	2	2	2	2				3			2	3	1	2
Outcome 2	3	3	3	3	2				2			3	3	1	2
Outcome 3	3	3	3	3	3				3			3	3	2	2
Outcome 4	3	3	3	3	3			1	3	2		3	3	2	2
Outcome 5	3	3	3	3	3			1	3	2		3	3	2	2
Average	3	2.8	2.8	2.8	2.6			1	2.8	2		2.8	3	1.6	2

Course Unitization Plan

Unit No.	Unit Name	Required Contact Hours	CLOs Addressed	References
Unit No. 1	**Newtonian Mechanics**	**12**		1,2
	Motion, Frame of reference, Newton's Law	1	1	1,2
	Mechanics of a single particle	1	1, 2	1,2
	Mechanics of a system of particles	1	1, 2	1,2
	Tutorial: Central force, Kepler's Law	1	1, 2	1,2
	Conservative and nonconservative forces, Potential energy, Work energy theorem	1	1, 2	1,2
	Rotational motion, Angular momentum, Torque	1	1, 2	1,2
	Discussion: Velocity dependent potentials and dissipations	1	1, 2	1,2
	Rigid body dynamics	1	1, 2	1,2
	Discussion: Moment of Inertia	1	1, 2	1,2
	Tutorial: Oscillations of single degrees of freedom	1	1	1,2
	Tutorial: Laboratory frame and Centre of mass frame	1	1	1,2
	Discussion: Two body Collisions	1	1, 2	1,2
Unit No. 2	**Variational Principle and Lagrange's Equation**	**12**		
	Constraints and generalized coordinates	1	1, 2, 3	1,2
	D'Alembert's principle and Lagrange's equation	1	1, 2, 3	1,2
	Cyclic coordinates, generalized momentum	1	1, 2, 3	1,2
	Discussion: Noether's theorem	1	1, 3	1,2
	Hamilton's principle	1	1, 3	1,2
	Calculus of variations	1	1, 3	1,2
	Tutorial: Examples on Variational principle	1	1, 3	1,2
	Lagrange's equation of motion from variational principle	1	1, 3	1,2
	Tutorial: Problems on Lagrange's equation	1	1, 2, 3	1,2
	Tutorial: Problems on Lagrange's equation	1	1, 2, 3	1,2
	Discussion: Lagrange's equation for LC circuit	1	1, 3	1,2
	Discussion: Lagrange's equation for non-conservative forces	1	1, 2, 3	1,2
Unit No. 3	**Hamiltonian Mechanics and Canonical Transformation**	**12**		
	Legendre transformations	1	1, 3	1,2,3,6
	Hamilton's equations of motion	1	1, 3	1,2,6
	Discussion: Symmetry and conservation principle	1	1, 3	1,2,3
	Canonical transformations	1	1, 3	1,2,3
	Generating functions	1	1, 3	1,2
	Poisson brackets	1	1, 3	1,2
	Liouville's theorem	1	1, 3	1,2
	Tutorial: Examples of Canonical transformations	1	1, 3	1,2
	Tutorial: Examples of Canonical transformations	1	1, 3	1,2
	Tutorial: Infinitesimal canonical transformations	1	1, 3	1,2
	Discussion: Hamilton Jacobi equation	1	1, 3	1,2
	Discussion: Angular momentum Poisson bracket relations	1	1, 3	1,2
Unit No. 4	**Small oscillations and Non-linear dynamics**	**12**		
	Small oscillations and single oscillator	1	1, 3	1,2
	Linearly coupled oscillators	1	1, 3	1,2
	Normal modes	1	1, 3	1,2
	Tutorial: coupled pendulum	1	1, 3	1,2
	Tutorial: coupled mass-spring system	1	1, 3	1,2
	Discussion: Discrete to continuous - wave on a string	1	1, 3	1,2
	Dynamics in presence of nonlinearity	1	4	1,4
	Stable/unstable nodes, limit cycle, bifurcation	1	4	1,4
	Tutorial: Examples of table/unstable nodes, limit cycle, bifurcation	1	4	1,4

	Discussion: Nonlinear conservative and nonconservative systems	1	4	1,4
	Logistic map and chaos	1	4	1,4
	Discussion: Lyapunov exponent	1	4	1,4
Unit No. 5	**Relativistic Mechanics**	**12**		
	Michelson Morley experiment, Galilean transformations	1	1	5
	Discussion: Postulates of Special Theory of Relativity, Lorentz transformations	1	1	5
	Tutorial: Length contraction and Time dilation	1	1, 5	5
	Four vectors: Velocity and Momentum	1	1, 5	5
	Mass-Energy relationship, Rest mass and Relativistic mass	1	1, 5	5
	Discussion: Time-like and Space-like intervals	1	1, 5	5
	Tensors, Raising/lowering of indices, Symmetric and antisymmetric tensors	1	1, 5	5
	Stress-Energy tensor in EM theory	1	1, 5	5
	For dimensional form of Maxwell's equations	1	1, 5	5
	Tutorial: Lagrangian formulation of Electrodynamics	1	1, 5	5
	Tutorial: Motion of a particle in an EM field	1	1, 5	5
	Discussion: Geometry of Space-time	1	1, 5	5
Total contact hours		**60**		

Learning Assessment

Bloom's Level of Cognitive Task		**Continuous Learning Assessments (50 %)**								**End Semester Exam (50 %)**	
		CLA-1 (15 %)		**CLA-2 (15 %)**		**CLA-3(__%)**		**Mid Term(20 %)**			
		Th	**Prac**	**Th**	**Prac**	**Th**	**Prac**	**Th**	**Prac**	**Th**	**Prac**
Level 1	Remember Understand	40%		40%				40%		30%	
Level 2	Apply Analyse	60%		60%				60%		70%	
Level 3	Evaluate Create										
Total		**100%**		**100%**				**100%**		**100%**	

Recommended Resources

1. Goldstein, H., Poole, C. P., & Safko, J. (2001). Classical mechanics, 3rd ed. Pearson.
2. Taylor, J. R. (2005). Classical mechanics, 1st ed. University Science Books.
3. Percival, I., & Richards, D. (1982). Introduction to dynamics, 1st ed. Cambridge University Press.
4. Strogatz, S. H. (2018). Nonlinear dynamics and chaos, 2nd ed. CRC Press.
5. Resnick, R. (1968). Introduction to special relativity, 1st ed. Wiley

Other Resources

1. YouTube. (2011). Classical mechanics. Retrieved from https://www.youtube.com/playlist?list=PL47F408D36D4CF129

Quantum Mechanics

						L	T	P	C
Course Code	PHY 503	**Course Category**	Core			2	1	1	4
Pre-Requisite Course(s)	BSc level QM Courses	**Co-Requisite Course(s)**	PHY 501, PHY 502	**Progressive Course(s)**					
Course Offering Department	Physics	**Professional / Licensing Standards**							

Course Objectives / Course Learning Rationales (CLRs)

1. To understand the concept of "quantum mechanics" and the difference from classical mechanics.
2. To understand the quantum states and quantum momentum
3. To implement the concept of approximation to solve the real-world problem in an easy way.
4. Application of the Schrodinger equation to understand the scattering of quantum particles. Dirac's theory to understand the deeper concept of Quantum particle states.

Course Outcomes / Course Learning Outcomes (CLOs)

	At the end of the course the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	Explain foundational concepts of quantum mechanics such as linear algebra, Schrodinger equation solutions in non-relativistic and relativistic cases	2	70%	65%
Outcome 2	Illustrate quantum mechanical framework orbital angular momenta and spin angular momenta	3	70%	65%
Outcome 3	Analyse exact and approximate solutions of the Schrodinger equation with different potentials to find allowed energy levels	4	70%	65%
Outcome 4	Relate relativistic formulation of quantum mechanics to particle-hole theory	4	70%	65%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	Program Learning Outcomes (PLO)													
	Scientific and Disciplinary Knowledge	Analytical Reasoning and Problem Solving	Critical and Reflective Thinking	Scientific Reasoning and Design Thinking	Research Related Skills	Modern Tools and ICT Usage	Environment and Sustainability	Moral, Multicultural and Ethical Awareness	Individual and Teamwork Skills	Communication Skills	Leadership Readiness Skills	Self-Directed and Life Long Learning	PSO 1	PSO 2	PSO 3
Outcome 1	3	3	3	3	2				3			2	3	1	2
Outcome 2	3	3	3	3	2				2			3	3	2	2
Outcome 3	3	3	3	3	2			1	3	2		3	3	2	2
Outcome 4	3	3	3	3	3			1	3	2		3	3	2	2
Average	**3**	**3**	**3**	**3**	**2.25**			**1**	**2.75**	**2**		**2.75**	**3**	**1.75**	**2**

Course Unitization Plan

Unit No.	Syllabus Topics	Required Contact Hours	CLOs Addressed	References Used
Unit No. 1	**Origin of Quantum Mechanics**	**9**		
	Linear Vector Space	1	1	1, 2
	Hilbert Space, Energy Eigenfunctions and Eigenvalues coordinate precession	1	1	1, 2
	Schrödinger's time-dependent and time-independent wave equations	1	1,3	1, 2
	Scattering states and Bound States	1	1, 3	1, 2
	Reflection and transmission of particles	1	1	1, 2
	Finite, infinite wells and delta function and harmonic oscillator potential	1	1,3	1, 2
	Tutorial Class (Eigen value equation)	1	1,3	1, 2
	Tutorial Class (Potential Steps)	1	1,3	1, 2
	Tutorial Class (Potential Steps and SHO)	1	1,3	1, 2
Unit No. 2	**Angular Momentum and Variational Principle**	**9**		
	Orbital Angular Momentum; Commutation Relations involving: L^2, Lx, Ly, Lz	1	1, 2	1, 2
	Eigenvalues and Eigenfunctions of L^2	1	2	1, 2
	Generalized angular momentum, J – commutation relations between J^2 and components of J. J+ and J- -	1	1	1, 2
	Eigenvalues of J^2 and Jz. Matrix representation for J^2 and Jz	1	2	1, 2
	Spin angular momentum-Pauli spin matrices and their properties; Addition of angular momenta, Clebsch-Gordon coefficients	1	1, 2	1, 2
	Recursion relations-C-G coefficients for J1 = ½, J2 = ½, and J1 = ½, J2 =1, as examples	1	1, 2	1, 2
	Principle of Variational method	1	1	1, 2
	Tutorial class (Angular Momentum)	1	1, 2	1, 2
	Problem-practice class (Addition of angular momenta)	1	1	1, 2
Unit No. 3	**Perturbation Theory**	**9**		
	Time Independent Perturbation Theory: Approximation Methods.	1	1,3	1, 2
	Non-degenerate case, First and second Order Case	1	3	1, 2,6
	Examples of harmonic and an-harmonic Oscillators	1	3	1, 2,6
	Degenerate case- Stark effect for H-atom for n=2 level.	1	3	1, 2
	WKB approximation method; Alpha decay	1	1,3	1, 2
	Time development of the state, variation of constants (coefficients). Transition probability- Selection rules for transition.	1	3	1, 2
	Constant perturbation	1	3	1, 2
	Transition probability to closely spaced leaves- Fermi's golden rule.	1	3	1, 2
	Problem Practice Class (Perturbation Theory)	1	1,3	1, 2
Unit No. 4	**Scattering**	**9**		
	Kinematics of Scattering Process; differential and total cross-section	1	3	3,4
	Asymptotic form of scattering wave function	1	1,3	3,4

	Scattering amplitude by Green's method	1	3	3,4
	Born approximation method	1	1,3	3,4
	Screened Coulomb potential and square well potential as examples; Partial wave analysis and phase shift	1	3	3,4
	Relationship between phase shift and Potential;	1	3	3,4
	Scattering by Hard sphere	1	1,3	3,4
	Tutorial (Green's Method)	1	3	3,4
	Problem Practice Class (Scattering)	1	3	3,4
Unit No. 5	**Free particle Dirac equation**	**9**		
	Discrepancies faced by Schrödinger equations	1	1,4	3,4
	Klein-Gordon equation, and its drawbacks	1	1,4	3,4
	Dirac's equation for a free particle; Dirac matrices	1	1,4	3,4
	Covariant form of Dirac equation; Probability and current densities	1	1,4	3,4
	Free particle solutions of Dirac equation	1	1,4	3,4
	Non-conservation of Orbital Angular momentum and idea of spin	1	4	3,4
	Interpretation of negative energy and hole theory	1	4	3,4
	Tutorial class (Klein-Gordon equation)	1	4	3,4
	Problem-practice class (Dirac matrices)	1	4	3,4
	Total contact hours	**45**		

<u>Course Unitization Plan: Laboratory</u>

Serial No.	Experiment Name	Required Contact Hours	CLOs Addressed	References Used
1	Millikan's oil drop Experiment to find electron charge	6	1	1,2
2	Determination of Planck constant using CS Photocell	6	1	1,2
3	Observation of Balmer Series of H, He & Ne discharge tubes	3	2	1,2
4	Estimation of Rydberg constant using Balmer Series spectra of Hydrogen gas	3	2	1,3
5	Frank-Hertz Experiment	6	3	1,2
6	Computation lab on Quantum Mechanical Problems	6	4	2,3
	Total contact hours (Experiments +Demo + Extra class)	**30 Hours**		

Learning Assessment

Bloom's Level of Cognitive Task		Continuous Learning Assessments (50 %)								End Semester Exam (50 %)	
		CLA-1 (15 %)		CLA-2 (15 %)		CLA-3 (__%)		Mid Term (20 %)			
		Th	Prac	Th	Prac	Th	Prac	Th	Prac	Th	Prac
Level 1	Remember	40%		40%				40%		30%	
	Understand										
Level 2	Apply	60%		60%				60%		70%	
	Analyse										
Level 3	Evaluate										
	Create										
Total		100%		100%				100%		100%	

Recommended Resources

1. Griffiths, D. J. (2004). Introduction to quantum mechanics, 2nd ed. Pearson.
2. Aruldhas, G. (2013). Quantum mechanics, 2nd ed. New DelhiQuantum Mechanics by L.I. Schiff
3. Schiff, L. I. (1968). Quantum mechanics. 3rd ed. New York, NY: McGraw-Hill.
4. Sakurai, J. J. (1994). Modern quantum mechanics. Upper Saddle River, NJ: Pearson.
5. Ghatak, A., & Lokanathan, S. (1981). Quantum mechanics: Theory and applications. 2nd ed. Delhi: Macmillan.

Other Resources

1. 6. Barton Zwiebach. (2019). MIT 8.06 Quantum Physics III. Retrieved from
2. https://www.youtube.com/playlist?list=PLUl4u3cNGP60Zcz8LnCDFI8RPqRhJbb4L

Course Designers

Electromagnetic Theory

Course Code	PHY 504	Course Category	CC		L	T	P	C
					2	1	1	4
Pre-Requisite Course(s)	BSC level Electrodynamics Courses	**Co-Requisite Course(s)**	PHY 501 PHY 502	**Progressive Course(s)**				
Course Offering Department	Physics	**Professional / Licensing Standards**						

Course Objectives / Course Learning Rationales (CLRs)

1. To review concepts in Electrostatics and Magnetostatics.
2. To study Maxwell's Equation & electromagnetic wave theory.
3. To understand the propagation of electromagnetic waves.
4. To learn the fundamentals of radiation due to electric and magnetic dipole.
5. To explore the basics of Relativistic Electrodynamics.

Course Outcomes / Course Learning Outcomes (CLOs)

	At the end of the course the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	Review basic concepts of vector, tensor and electrostatics.	2	70%	65%
Outcome 2	Solve complex problems and conduct experiments related to magnetism and magnetostatics.	3	70%	65%
Outcome 3	Discuss Maxwell Equation and propagation of electromagnetic waves.	2	70%	65%
Outcome 4	Investigate radiation process in EM Theory	4	70%	65%
Outcome 5	Examine the role of special theory of relativity in electrodynamics.	4	70%	65%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	Program Learning Outcomes (PLO)														
	Scientific and Disciplinary Knowledge	Analytical Reasoning and Problem Solving	Critical and Reflective Thinking	Scientific Reasoning and Design Thinking	Research Related Skills	Modern Tools and ICT Usage	Environment and Sustainability	Moral, Multicultural and Ethical Awareness	Individual and Teamwork Skills	Communication Skills	Leadership Readiness Skills	Self-Directed and Life Long Learning	PSO 1	PSO 2	PSO 3
Outcome 1	3	3	2	2	2				1			2	3	1	1
Outcome 2	3	3	2	2	2	3		1	2			3	3	2	2
Outcome 3	3	3	3	3	2	3		1	2	2		3	3	2	2
Outcome 4	3	3	3	3	3				2	2		3	3	2	2
Outcome 5	3	3	3	3	3			1	2	2		3	3	2	2
Average	**3**	**3**	**2.6**	**2.6**	**2.4**	**3**		**1**	**1.8**	**2**		**2.8**	**3**	**1.8**	**1.8**

Course Unitization Plan

Unit No.	Syllabus Topics	Required Contact Hours	CLOs Addressed	References Used
Unit No. 1	**Review of Electrostatics & Magnetostatics**	**9**		
	Review of Vector & tensor	1	1	1, 2,4
	Electro-static scalar potential and Laplace equation	1	1	1, 2,4
	Electric Fields in Matter: Polarization	1	1	1, 2,4
	The electric displacement and Linear dielectrics	1	1	1, 2,4
	Review of Biot Savart Law and Ampere's Law	1	2	1, 2,4
	Magnetic Vector Potential and Magnetostatic Boundary Conditions	1	2	1, 2
	Tutorials I – III: Problems on Electrostatics and Magnetostatics	3	1, 2	1, 2
Unit No. 2	**Maxwell's Equation**	**9**		
	Maxwell's Equation in Free Space and Matter	1	3	1,2
	Gauge Transformations - transformation – Coulomb and Lorentz Gauge.	1	3	1,2
	Tutorial – I: Generalized solutions of scalar and vector potential	1	1, 2, 3	1,2
	Continuous distribution and retarded potentials: Jefimenko's equations	1	1, 2, 3	1,2
	Electromagnetic energy and momentum,	1	1, 2, 3	1,2
	Conservation of momentum in electrodynamics	1	1, 2, 3	1,2
	Poynting's theorem & related problems and applications	1	2, 3	1,2
	Maxwell Stress Tensor	1	2, 3	1,2
	Tutorial – III: Problems on electromagnetic linear and angular momentum	1	2, 3	1,2
Unit No. 3	**Electromagnetic Wave Propagation**	**9**		
	Tutorial – I: Brief review on transverse sinusoidal waves	1	3	1,2
	EM Wave Equation from Maxwell's Equation, Propagation in free space, EM Spectra and Visible Range	1	2, 3	
	Energy Transfer during EM Wave propagation – Pyonting's Vector	1	3	1,2
	Tutorial – II: Review on types of mediums for EM Wave propagation	1	2, 3	1,2
	EM Wave propagation through linear dielectric and conductor – skin depth.	1	2, 3	1,2
	Reflection and transmission at Normal incidence	1	3	1,2
	Polarization of EM Wave	1	3	1,2
	Applications of EM Wave – Fibre Optics, Telecommunication, Radar, and Microwave	1	3	1,2
	Tutorial – III: Problems on EM Wave propagation in medium	1	2, 3	1,2
Unit No. 4	**Radiation**	**9**		
	What is radiation - Electric & Magnetic dipole radiation	1	1, 2, 4	1,2

	Radiation from an arbitrary source	1	4	1,2
	Tutorial – I: Problems on dipole radiation	1	1, 2, 4	1,2
	Radiation by moving charges: Lienard-Wiechert Potentials	1	4	1,2
	Fields of a Moving Point Charge	1	1, 4	1,2
	Power Radiated by accelerated Point Charge	1	4	1,2
	Tutorial – II: Problems on LW Potentials	1	1, 2, 4	1,2,3
	Radiation Reaction & Mechanism Responsible for the Radiation Reaction	1	1, 4	1,2,3
	Tutorial – III: Problems on Radiation Reaction	1	4	1,2
Unit No. 5	**Electrodynamics and Relativity**	**9**		
	Review of Special theory of relativity	1	5	1,2
	Lorentz Transformation & Relativistic Mechanics	1	5	1,2
	Tutorial – I: Problems on relativistic kinematics and dynamics	1	5	
	Relativistic Energy and Momentum	1	5	1,2,3
	Magnetism as a Relativistic Phenomenon	1	2, 5	1,2,3
	Tutorial – II: Transformations of electromagnetic fields under Lorentz transformations and related Problems.	1	2, 3, 5	
	Electromagnetic Field Tensor & Electrodynamics in Tensor Notation	1	2, 3, 5	1,2,3
	Relativistic Potentials	1	2, 3, 5	1,2,3
	Tutorial – III: Problems on relativistic electrodynamics	1	2, 5	1,2,3
	Total contact hours	**45**		

<u>Course Unitization Plan: Laboratory</u>

Serial No.	Experiment Name	Required Contact Hours	CLOs Addressed	References Used
1	Helmholtz coil Experiment	4	2	1, 2
2	BH curve with deep lite	2	2	1, 2
3	To determine susceptibility of paramagnetic sample by using Quinck's tube method.	4	2	1, 2
4	Fiber optics experiments	4	3	1, 2
5	Verification of Malus Law using diffraction	4	3	1, 2
6	Ultrasonic Diffraction to find sound velocity	4	3	1, 2
7	Interference and diffraction using He-Ne laser	4	3	1, 2
8	Michelson interferometer Experiment	4	3	1, 2
	Total contact hours (Experiments +Demo + Extra class)	**30 Hours**		

Learning Assessment

Bloom's Level of Cognitive Task		Continuous Learning Assessments (50 %)								End Semester Exam (50 %)	
		CLA-1 (15 %)		CLA-2 (15 %)		CLA-3 (__%)		Mid Term (20 %)			
		Th	Prac	Th	Prac	Th	Prac	Th	Prac	Th	Prac
Level 1	Remember	40%		40%				40%		30%	
	Understand										
Level 2	Apply	60%		60%				60%		70%	
	Analyse										
Level 3	Evaluate										
	Create										
Total		100%		100%				100%		100%	

Recommended Resources

1. 1. Griffiths, D. J. (2015). Introduction to electrodynamics, 4th ed. Upper Saddle River, NJ: Pearson.
2. 2. Jackson, J. D. (2007). Classical electrodynamics, 3rd ed. Wiley.
3. 3. Purcell, E. M. (2017). Electricity and magnetism (in SI units): Berkeley physics course - Vol. 2. 2nd ed. McGraw-Hill Education.

Other Resources

1. YouTube. (2018). Advanced Electromagnetism. Retrieved from https://www.youtube.com/playlist?list=PLp0hSY2uBeP-S-fTaklDhGOOg4wpKYc6K

COMMUNITY SERVICE AND SOCIAL RESPONSIBILITY

<table>
<tr><td rowspan="2">Course Code</td><td rowspan="2">VAC 502</td><td rowspan="2">Course Category</td><td rowspan="2" colspan="3">VAC</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td>0</td><td>0</td><td>2</td><td>2</td></tr>
<tr><td>Pre-Requisite Course(s)</td><td></td><td>Co-Requisite Course(s)</td><td></td><td>Progressive Course(s)</td><td colspan="5"></td></tr>
<tr><td>Course Offering Department</td><td>CEL</td><td>Professional / Licensing Standards</td><td colspan="7"></td></tr>
</table>

Course Objectives / Course Learning Rationales (CLRs)

1. Encourage initiatives that address local needs, foster self-sufficiency, and promote environmental sustainability within the community.
2. Equip participants with a deeper understanding of social issues and a sense of responsibility towards marginalized communities.
3. Inspire active participation in community service programs and foster a culture of giving back among individuals and organizations.
4. Develop and implement programs that contribute to skill development, economic empowerment, and equal opportunities for underprivileged sections of society.

Course Outcomes / Course Learning Outcomes (CLOs)

	At the end of the course the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	Develop effective strategies for identifying and addressing community needs.	3	80%	80%
Outcome 2	Demonstrate empathy and cultural sensitivity when engaging with diverse community groups.	4	80%	75%
Outcome 3	Implement sustainable solutions and evaluate their impact on social well-being.	5	90%	85%
Outcome 4	Collaborate effectively within teams to design and lead community service projects.	6	90%	80%

Learning Assessment

<table>
<tr><td colspan="2" rowspan="2">Bloom's Level of Cognitive Task</td><td colspan="4">Continuous Learning Assessments 50%</td><td rowspan="2">End Semester Exam 50%</td></tr>
<tr><td>CLA-1 20%</td><td>Mid-1 20%</td><td>CLA-2 20%</td><td>CLA-3 20%</td></tr>
<tr><td rowspan="2">Level 1</td><td>Remember</td><td rowspan="2">10%</td><td rowspan="2">10%</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2">20%</td></tr>
<tr><td>Understand</td></tr>
<tr><td rowspan="2">Level 2</td><td>Apply</td><td rowspan="2"></td><td rowspan="2">10%</td><td rowspan="2">10%</td><td rowspan="2"></td><td rowspan="2">20%</td></tr>
<tr><td>Analyse</td></tr>
<tr><td rowspan="2">Level 3</td><td>Evaluate</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2">10%</td><td rowspan="2">10%</td></tr>
<tr><td>Create</td></tr>
<tr><td colspan="2">Total</td><td>10%</td><td>20%</td><td>10%</td><td>10%</td><td>50%</td></tr>
</table>

Entrepreneurial Mindset

Course Code	VAC 503	**Course Category**	VAC		**L**	**T**	**P**	**C**
					2	0	0	2
Pre-Requisite Course(s)		**Co-Requisite Course(s)**		**Progressive Course(s)**				
Course Offering Department	Management	**Professional / Licensing Standards**						

Course Objectives / Course Learning Rationales (CLRs)

1. To develop the Entrepreneurial Mindset of Students.
2. To provide tools and techniques for navigating the uncertain path of entrepreneurship

Course Outcomes / Course Learning Outcomes (CLOs)

	At the end of the course the learner will be able to	**Bloom's Level**	**Expected Proficiency Percentage**	**Expected Attainment Percentage**
Outcome 1	Explain the key entrepreneurship and innovation concepts	1	80%	80%
Outcome 2	Explain concepts of Startup Funding and Pitching	1	80%	80%
Outcome 3	Identify Entrepreneurial Opportunity and ideate solutions	2	80%	70%
Outcome 4	Articulate innovative business plans with sound entrepreneurial concepts.	3	70%	70%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	**Program Learning Outcomes (PLO)**														
	Scientific and Disciplinary Knowledge	**Analytical Reasoning and Problem Solving**	**Critical and Reflective Thinking**	**Scientific Reasoning and Design Thinking**	**Research Related Skills**	**Modern Tools and ICT Usage**	**Environment and Sustainability**	**Moral, Multicultural and Ethical Awareness**	**Individual and Teamwork Skills**	**Communication Skills**	**Leadership Readiness Skills**	**Self-Directed and Life Long Learning**	**PSO 1**	**PSO 2**	**PSO 3**
Outcome 1			2				1								
Outcome 2			2						3		3				
Outcome 3		3	3		2				3	2	3	3			
Outcome 4		3	3		2				3		3	3			
Average		**1.5**	**2.5**		**1**		**0.25**		**2.25**	**0.5**	**2.25**	**1.5**			

Course Unitization Plan

Unit No.	Unit Name	Required Contact Hours	CLOs Addressed	References Used
UNIT-1	**Introduction to Entrepreneurship**	2		
	What and Why of Entrepreneurship		1	1,2
	Need of Entrepreneurship		1	1,2
	Entrepreneurship at SRM-AP		1	1,2
UNIT-2	**Entrepreneurial Orientation**	4		
	Characteristics of successful entrepreneurs		1,2	1,2
	Mindset shifts: from an employee to an entrepreneur		1,2	1,2
	Overcoming challenges and dealing with failures		1,2	1,2
UNIT-3	**Entrepreneurial Skills**	4		
	Skillsets of an Entrepreneur		1,2	1,2
	Design Thinking, Growth Mindset		1,2	1,2
	Design Thinking		1,2	1,2
UNIT-4	**Entrepreneurial Opportunity & Ideation**	2		
	Difference between idea and opportunity		1,2	1,2
	Opportunities in Vibrant Indian Entrepreneurial Ecosystem		1,2	1,2
	Opportunity Recognition (Sources of Opportunity)		1,2	1,2
	Idea Generation		1,2	1,2
UNIT-5	**Business Model Canvas**	2		
	Why BMC		3	1,2
	Value Proposition		3	1,2
	Customer Discovery		3	1,2
	Customer Relationship		3	1,2
	Channels		3	1,2
	Key Partners		3	1,2
	Key Activities		3	1,2
	Key Resources		3	1,2
	Revenue Structure		3	1,2
	Cost Structure		3	1,2
UNIT-6	**Startup Financing & Pitching**	2		
	Stages of Fundraising		4	1,2
	Mode of Investment		4	1,2
	Startup Valuation		4	1,2
	From Pitch to Hitch (Pitch Deck)		4	1,2
UNIT-7	**Growth Mindset and Sales Ability**	2		
	Importance of Sales skill for Entrepreneur		3	1,2
	Sales Techniques		3	1,2
	Developing Growth Mindset		3	1,2
UNIT-8	**Developing the Business Plan**	12	3,4	1,2
	Total Hours	30		

Learning Assessment

Bloom's Level of Cognitive Task		Continuous Learning Assessments (100%)			End Semester Exam (40%)
		CLA-1 (10%)	**CLA-2 (20%)**	**CLA-3 (30%)**	
Level 1	Remember		20%	20%	100%
	Understand				
Level 2	Apply	100%	80%	80%	
	Analyse				
Level 3	Evaluate				
	Create				
Total		**100%**	**100%**	**100%**	**100%**

Recommended Resources

1. Bruce R. Barringer, R. Duane Ireland. Entrepreneurship Successfully Launching New Ventures, Pearson; 2020
2. Robert D. Hasrich, Dean A. Shepherd, Michael P. Peters, Entrepreneurship, McGraw Hill, 2021

Other Resources

1. Best business courses online (n.d.). Coursera. https://www.coursera.org/browse/business/entrepreneurship

Research Design and Methods

Course Code	SEC 105	**Course Category**	SEC		**L**	**T**	**P**	**C**
					3	0	0	3
Pre-Requisite Course(s)		**Co-Requisite Course(s)**		**Progressive Course(s)**				
Course Offering Department	Chemistry	**Professional / Licensing Standards**						

Course Objectives / Course Learning Rationales (CLRs)

1. To understand and apply various research designs and methodologies.
2. Equip students with the practical skills necessary to conduct research independently.
3. Foster an understanding of ethical considerations in research.

Course Outcomes / Course Learning Outcomes (CLOs)

	At the end of the course the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	Students will be able to identify a research problem	2	85%	80%
Outcome 2	Students will develop the ability to critically evaluate and compare different research designs and methodologies.	3	80%	75%
Outcome 3	Students will demonstrate an understanding of ethical considerations in research.	5	80%	75%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	Program Learning Outcomes (PLO)														
	Scientific and Disciplinary Knowledge	Analytical Reasoning and Problem Solving	Critical and Reflective Thinking	Scientific Reasoning and Design Thinking	Research Related Skills	Modern Tools and ICT Usage	Environment and Sustainability	Moral, Multicultural and Ethical Awareness	Individual and Teamwork Skills	Communication Skills	Leadership Readiness Skills	Self-Directed and Life Long Learning	PSO 1	PSO 2	PSO 3
Outcome 1	3	2	3	2	3		3	2	3	3	3		2	1	3
Outcome 2	2	1	2	2	1		2	2	1	2	3		3	2	2
Outcome 3	3	3	3	3	2		2	1	2	2	1		1	3	1
Average	3	2	3	2	2		2	2	2	2	2		2	2	2

Course Unitization Plan

Unit No.	Unit Name	Required Contact Hours	CLOs Addressed	References Used
Unit 1	**Introduction to Research Design and Methods**	**10**	**1**	**1,2**
	Overview of research: Definition, significance, purpose, and types.	4		
	Types of Research: Basic and applied research.	4		
	Google scholar, ResearchGate, Citations, h-index, i10 index Bibliography, Reference manager	2		
Unit 2	**Formulating Research Questions and Hypotheses**	**10**	**2**	**1,3**
	Developing clear and focused research questions	2		
	Literature survey, various sources of research information	2		
	Methodology of research	2		
	Importance of research design	2		
	Steps in conducting research	2		
Unit 3	**Introduction to scientific ethics**	**10**	3	**1,2,3**
	Key ethical principles: Honesty, integrity, transparency.	4		
	The role of ethics in experimental design	2		
	Ethical considerations in data collection and analysis.	2		
	Human and animal research ethics.	2		
Unit 4	**Report your findings**	**10**	3	**1,2,3**
	Writing reports, Structuring reports	2		
	Writing journal articles,	3		
	Writing research proposals	3		
	Producing oral presentations	2		
Total Contact Hours		**45**		

Learning Assessment

Bloom's Level of Cognitive Task		Continuous Learning Assessments (50%)				End Semester Exam (50%)
		CLA-1 (10%)	**Mid-1 (15%)**	**CLA-2 (15%)**	**CLA-3 (10%)**	
Level 1	Remember Understand	40%	60%	40%	60%	30%
Level 2	Apply Analyse	60%	40%	60%	40%	70%
Level 3	Evaluate Create					
Total		**100%**	**100%**	**100%**	**100%**	**100%**

Recommended Resources

1. Bordens K.S. and Abbott, B.b.: Research Design and Methods, McGraw Hill, 2008.
2. John W. Creswell and J. David Creswell Research Design: Qualitative, Quantitative, and Mixed Methods Approaches" SAGE Publications, 2017
3. Wayne C. Booth, Gregory G. Colomb, Joseph M. Williams, Joseph Bizup and William T. FitzGerald, The Craft of Research, Fourth Edition, University of Chicago Press, 2016

Other Resources

SRM University *AP*, Andhra Pradesh
Neerukonda, Mangalagiri Mandal,
Guntur District, Mangalagiri, Andhra Pradesh – 522240.

Design Thinking

Course Code	FIC 108	**Course Category**	FIC		**L**	**T**	**P**	**C**
					3	0	0	3
Pre-Requisite Course(s)		**Co-Requisite Course(s)**		**Progressive Course(s)**				
Course Offering Department	Management	**Professional / Licensing Standards**						

Course Objectives / Course Learning Rationales (CLRs)

1. Familiarize with the principles of Design Thinking
2. Learn to apply the principles of Design Thinking
3. Apply Design Thinking to solve problems.

Course Outcomes / Course Learning Outcomes (CLOs)

	At the end of the course the learner will be able to	**Bloom's Level**	**Expected Proficiency Percentage**	**Expected Attainment Percentage**
Outcome 1	Importance of Design Thinking	1	75%	90%
Outcome 2	Grasp the Concepts and process of Design Thinking	3	75%	90%
Outcome 3	Learn the process of Design Thinking	2	85%	90%
Outcome 4	Solve a problem using Design Thinking Principles	3	75%	65%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	**Program Learning Outcomes (PLO)**														
	Scientific and Disciplinary Knowledge	**Analytical Reasoning and Problem Solving**	**Critical and Reflective Thinking**	**Scientific Reasoning and Design Thinking**	**Research Related Skills**	**Modern Tools and ICT Usage**	**Environment and Sustainability**	**Moral, Multicultural and Ethical Awareness**	**Individual and Teamwork Skills**	**Communication Skills**	**Leadership Readiness Skills**	**Self-Directed and Life Long Learning**	**PSO 1**	**PSO 2**	**PSO 3**
Outcome 1	3					-	-	-	-	-	-	-	3	3	3
Outcome 2	3					-	-	-	-	-	-	1	3	1	3
Outcome 3	3					-	-	-	3	-	-	2	3	2	3
Outcome 4	3	3	3	3		-	-	-	3	3	3	3	3	3	3
Average	**3**	**3**	**3**	**3**		**-**	**-**	**-**	**3**	**3**	**3**	**2**	3	2	3

Course Unitization Plan

Unit No.	Unit Name	Required Contact Hours	CLOs Addressed	References Used
Unit 1	An Introduction to the innovation Process	15		1,2
	Understanding of Design Thinking & its Importance, Pillars of Design Thinking		2	1,2
Unit 2	Process – Understanding the Stages of Design Thinking	15	2	1,2
Unit 3	Identifying Opportunity Areas: Problem Framing & Definition	10	2	1,2,3
Unit 4	Idea Generation and Concept Development	10	2	1,2,3
Unit 5	Implementation and Managing Innovation	10	4	1,2,3

Learning Assessment

Bloom's Level of Cognitive Task		Continuous Learning Assessments (50%)			End Semester Exam (50%)	
		CLA-1 20%	**CLA-2 15%**	**CLA-3 15%**		
Level 1	Remember	60%	60%	40%	30%	
	Understand					
Level 2	Apply	40%	40%	60%	40%	30%
	Analyse					
Level 3	Evaluate					
	Create					
Total		**100%**	**100%**	**100%**	**70%**	**30%**

Recommended Resources

1. Design Thinking – Techniques and Approaches, N. Siva Prasad
2. Design Thinking, Nigel Cross , BERG Publishing
3. Design Thinking- Integrating Innovation, Customer Experience and Brand Value, Thomas Lockwood , De-sign Management Institute, 2009

Other Resources

1. HBS – Online – Design Thinking & Innovation – course material
2. Case studies

Statistical Mechanics

Course Code	PHY 505	Course Category	CC		L	T	P	C
					2	2	0	4
Pre-Requisite Course(s)		**Co-Requisite Course(s)**		**Progressive Course(s)**				
Course Offering Department	Physics	**Professional / Licensing Standards**						

Course Objectives / Course Learning Rationales (CLRs)

1. To review basics of probabilities and thermodynamics
2. Understand origin of thermodynamics from equilibrium statistical mechanics.
3. Learn formulation of classical and quantum equilibrium statistical mechanics
4. Calculate statistical behavior for some systems with noninteracting particles
5. Understanding phase transition

Course Outcomes / Course Learning Outcomes (CLOs)

	At the end of the course the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	Understand probability theory, ensemble approaches and thermodynamic laws	2	70%	65%
Outcome 2	Apply partition functions to interpret different classical and quantum properties of thermodynamic systems	3	70%	65%
Outcome 3	Examine the role of statistical mechanics in thermodynamic laws	4	70%	65%
Outcome 4	Asses the roles of interaction in emergent properties of many particle systems	5	70%	65%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	Program Learning Outcomes (PLO)														
	Scientific and Disciplinary Knowledge	Analytical Reasoning and Problem Solving	Critical and Reflective Thinking	Scientific Reasoning and Design Thinking	Research Related Skills	Modern Tools and ICT Usage	Environment and Sustainability	Moral, Multicultural and Ethical Awareness	Individual and Teamwork Skills	Communication Skills	Leadership Readiness Skills	Self-Directed and Life Long Learning	PSO 1	PSO 2	PSO 3
Outcome 1	3	3	3	3	2				3			2	3	1	2
Outcome 2	3	3	3	3	2				2			3	3	2	2
Outcome 3	3	3	3	3	3			1	3	2		3	3	2	2
Outcome 4	3	3	3	3	3			1	3	2		3	3	2	2
Average	**3**	**3**	**3**	**3**	**2.5**			**1**	**2.75**	**2**		**2.75**	**3**	**1.75**	**2**

Course Unitization Plan

Unit No.	Syllabus Topics	Required Contact Hours	CLOs Addressed	References Used
Unit No. 1	**Probability theory**	12		
	Random variables and general definitions	1	1	3,5
	Some important probability distributions	1	1	3,5
	Multivariate random variables	1	1	3,5
	Discussion-I: Conditional and joint probability distribution	1	1	3,5
	Tutorial-I: Expectation and variance	1	1	3,5
	Random walk	1	1	3,5
	Tutorial-II: Random walk	1	1	3,5
	Sum of random numbers	1	1	3,5
	Discussion -II: Central limit theorem	1	1	3,5
	Tutorial-III: Law of large numbers and thermodynamic limit	1	1,3	3,5
	Information, Entropy and Estimation	1	1,3	5
	Tutorial – III : Information, Entropy and Estimation	1	1,3	5
Unit No. 2	**Classical statistics - I**			
	Review of laws of thermodynamics	1	1	1,3
	Tutorial I: Problems of laws of thermodynamics	1	1	1,3
	Liouville's Theorem and its consequences	1	1	1,3
	Concept of ensembles	1	1	1,3
	Microcanonical ensemble	1	1	1,3
	Tutorial II: Problems on microcanonical ensemble	1	1,2	1,3
	Statistical basis of thermodynamics	1	1,3	1,3
	Canonical ensemble	1	1,2	1,3
	Fluctuations of energy	1	2,3	1,2,3
	Thermodynamic laws from statistical ensembles	1	2,3	1,2,3
	Tutorial III: Problems on ensembles	1	2,3	1,2,3
	Review problems	1	2,3	1,2,3
Unit No. 3	**Classical statistics - II**	**12**		
	Equipartition theorem	1	2	1,2,3
	Tutorial -I: Two state systems	1	2	1,2,3
	Discussion -I: Magnetic systems	1	2	1,2,3
	Tutorial -II: Magnetic systems	1	2	1,2,3
	Discussion -II: System of harmonic oscillators	1	2	1,2,3

	Grand canonical ensemble	1	1,2	1,2,3
	Density fluctuation in grand canonical ensemble	1	1,3	1,2,3
	Equivalence of canonical and grand canonical ensemble	1	1	1,2,3
	Tutorial III: Problems on grand canonical ensemble	1	3	1,2,3
	Discussion III	1	3	1,2,3
	Ideal gas	1	1	1,2,3
	Mixing entropy and Gibb's paradox	1	1	1,2,3
Unit No. 4	**Quantum statistics**	**12**		
	Failure of classical statistical mechanics	1	1	1,2,3
	Specific heat at low temperature	1	1	1,2,3
	Tutorial -I: Black body radiation	1	1	1,2,3
	Quantum mechanical microstates and macrostates	1	2	1,2,3
	Discussion I: Density matrix	1	2	1,2,3
	Canonical and grand canonical formalism	1	1,2	1,2,3
	Ideal Fermi gas	1	2	1,2,3
	Discussion -II: Ideal Fermi gas	1	2	1,2,3
	Tutorial -II: Ideal Fermi gas	1	2	1,2,3
	Ideal Bose gas	1	2	1,2,3
	Discussion -III: Ideal Bose gas	1	2	1,2,3
	Tutorial – III: Ideal Bose Gas	1	2	1,2,3
Unit No. 5	**Statistical mechanics of interacting systems**	**12**		
	Problem of condensation	1	1,4	2,3
	Discussion-I: condensation van der Walls gas	1	4	2,3
	Tutorial-I: Phase transition in van der Walls gas	1	4	1,2,3
	Magnetic systems	1	4	1,2,3
	Tutorial -II: qualitative discussions on lower and upper critical dimensions	1	4	1,2,3
	mean field theory	1	1,4	2,4
	Discussion -II: Applicability of mean field theory	1	4	2,4
	Tutorial -III: Problems on mean field theory	1	1,4	2,4
	Discussion -III: Interacting systems and phase transition	1	4	2,4
	Comparisons between ideal and real gas	1	1,4	2,4
	Review problems	1	4	2,4
	Universality	1	4	2,4
Total contact hours		**60**		

Learning Assessment

Bloom's Level of Cognitive Task		Continuous Learning Assessments (50 %)								End Semester Exam (50 %)	
		CLA-1 (15 %)		CLA-2 (15 %)		CLA-3(__%)		Mid Term (20 %)			
		Th	Prac	Th	Prac	Th	Prac	Th	Prac	Th	Prac
Level 1	Remember	40%		40%				40%		30%	
	Understand										
Level 2	Apply	60%		40%				60%		50%	
	Analyse										
Level 3	Evaluate			20%						20%	
	Create										
Total		**100%**		**100%**				**100%**		**100%**	

Recommended Resources

1. Huang, K. (1987). Statistical mechanics, 2nd ed. New York, NY: Wiley.
2. Pathria, R. K. (1972). Statistical mechanics, 1st ed. Oxford: Pergamon Press.
3. Kardar, M. (2007). Statistical physics of particles, 1st ed. Cambridge: Cambridge University Press.
4. Gardiner, C. W. (2009). Handbook of stochastic methods: For physics, chemistry, and the natural sciences, 4th ed. Springer.

Other Resources

Condensed Matter Physics

						L	T	P	C
Course Code	PHY 506	**Course Category**	CC			2	0	2	4
Pre-Requisite Course(s)	BSC level Condensed Matter Courses	**Co-Requisite Course(s)**	PHY 511	**Progressive Course(s)**					
Course Offering Department	Physics	**Professional / Licensing Standards**							

Course Objectives / Course Learning Rationales (CLRs)

1. Understand the basic concepts of crystal structure and binding, including the different types of lattices, defects, and diffraction methods.
2. Describe the lattice vibrations and thermal properties of solids, including the different types of modes, phonon dispersion relations, and heat capacity.
3. Explain the band theory of solids, including the concepts of Bloch's theorem, density of states, and effective mass.
4. Describe the dielectric and electrical properties of solids, including polarization, dielectric susceptibility, and ferroelectricity. Explain the different types of magnetism in solids, including diamagnetism, paramagnetism, ferromagnetism, and antiferromagnetism.
5. Describe the basic properties of superconductors, including the Meissner effect, London's equations, and the BCS theory.

Course Outcomes / Course Learning Outcomes (CLOs)

	At the end of the course the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	Demonstrate a comprehensive understanding of the fundamental concepts of condensed matter physics, including crystal structure, lattice vibrations, and band theory.	2	70%	65%
Outcome 2	Employ the principles of condensed matter physics to illustrate thermal, electrical, dielectric and magnetic properties of matter.	2	70%	65%
Outcome 3	Interpret different types of magnetism and superconductivity, including their basic properties and underlying mechanisms.	3	70%	65%
Outcome 4	Solve complex problems and conduct experiments related to condensed matter physics	3	70%	65%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	Program Learning Outcomes (PLO)														
	Scientific and Disciplinary Knowledge	Analytical Reasoning and Problem Solving	Critical and Reflective Thinking	Scientific Reasoning and Design Thinking	Research Related Skills	Modern Tools and ICT Usage	Environment and Sustainability	Moral, Multicultural and Ethical Awareness	Individual and Teamwork Skills	Communication Skills	Leadership Readiness Skills	Self-Directed and Lifelong Learning	PSO 1	PSO 2	PSO 3
Outcome 1	3	3	3	3	2				3			2	3	1	2
Outcome 2	3	3	3	3	2				2			3	3	2	2
Outcome 3	3	3	3	3	2	3		2	3	2		3	3	2	2
Outcome 4	3	3	3	3	3	3		2	3	2		3	3	2	2
Average	**3**	**3**	**3**	**3**	**2.25**	**3**		**2**	**2.75**	**2**		**2.75**	**3**	**1.75**	**2**

Course Unitization Plan

Unit No.	Syllabus Topics	Required Contact Hours	CLOs Addressed	References Used
Unit No. 1	**Crystal structure and bindings**	**6**		1,2,3,4
	Fundamental types of lattices-Two-Dimensional lattice types, three-Dimensional lattice types, indexing crystal planes	1	1	1,2,3,4
	Packing density: SC, BCC and FCC, simple crystal structures- NaCl, CsCl, diamond cubic structures and ZnS.	1	1	1,2,3,4
	Defects in Solids (fundamental): basics of point defects, line defects and dislocations.	1	1	1,2,3,4
	Bragg's law, Experimental diffraction methods- Laue method and powder method, Derivation of scattered wave amplitude, Geometrical Structure Factor	1	1, 4	1,2,3
	Reciprocal lattice, Reciprocal lattice to SC lattice, BCC lattice and FCC Lattice, Properties of reciprocal lattice, Brillouin Zone, Neutron diffraction, Electron diffraction	1	1, 4	1,2,3
	Types of crystal binding, London theory of van der Waals forces, ionic bonding, and Madelung constant.	1	1, 4	1,2,3
Unit No. 2	**Lattice vibrations and Thermal Properties**	**6**		
	Elastic waves in one dimensional array of identical atoms, Vibrational modes of a diatomic linear lattice and dispersion relations	1	1, 4	1,2,3,5
	Acoustic and optical modes, Infrared absorption in ionic crystals, Phonons, and verification of dispersion relation in crystal lattices	1	1, 4	1,2,3,5
	Lattice heat capacity- Einstein and Vibrational modes of continuous medium-Debye theory.	1	1, 2, 4	1,2,3,5
	Origin of thermal expansion and Gruneisen relation.	1	1, 2, 4	1,2,3,5
	Measurement of phonon frequencies and inelastic scattering	1	1, 2, 4	1,2,3,5
	Impurity scattering and phonon scattering; Normal and Umklapp processes, Mobility of charge carriers and Seebeck coefficient.	1	1, 2, 4	1,2,3,5
Unit No. 3	**Band Theory of solids**	**6**		
	Electronic states in solids, Sommerfeld model, thermodynamic properties due to free electrons	1	1, 2	1,2,3,5
	Band structures: basic concepts, Bloch's theorem, density of states, nearly free electron approach and pseudopotentials	1	1, 2	1,2,3,5
	tight-binding and linear combination of atomic orbital method, Modern band structure methods.	1	1, 2, 4	1,2,3,5
	Motion of electrons in solids: semiclassical model, band velocity, effective mass, concept of electrons and holes	1	1, 2, 4	1,2,3,5
	Distinction between metal, semiconductor and insulator, Intrinsic and extrinsic semiconductors (P-type and N-type)	1	1, 2, 4	1,2,3,5
	Hall effect, Fermi surface, De-Haas-Van Alphen effect, Anomalous skin effect and cyclotron resonance	1	1, 2, 4	1,2,3,5

Unit No. 4	**Dielectric and electrical properties**	**6**		
	Polarization, Local electric field at an atom	1	1, 2	1,2,3,5
	Depolarization field, Dielectric susceptibility and polarizability	1	1,2	1,2,3,5
	Dielectric constant, Clausius-Mosotti equation	1	1, 2, 4	1,2,3,5
	Crystal symmetry and macroscopic physical properties	1	1,2	1,2,3,5
	Concepts of pyroelectricity, ferroelectricity	1	1,2	1,2,3,5
	Electrical conductivity, and piezoelectricity.	1	1,2	1,2,3,5
Unit No. 5	**Magnetism and Superconductivity**	**6**		
	Diamagnetism, paramagnetism of insulators and metals	1	1, 2, 3	1,2,3,5
	Ferromagnetism, Curie-Weiss law, introduction to other types of magnetic order	1	1, 2, 3, 4	1,2,3,5
	Superconductors, Phenomenology, review of basic properties	1	1, 2, 3	1,2,3,5
	Thermodynamics of superconductors	1	1, 2, 3	1,2,3,5
	London's equation and Meissner effect, Type-I and Type-II superconductors	1	1, 2, 3, 4	1,2,3,5
	Elementary discussion of the BCS theory, High TC superconductors	1	1, 2, 3, 4	1,2,3,5
Total contact hours		**30**		

Course Unitization Plan: Laboratory

Serial No.	Experiment Name	Required Contact Hours	CLOs Addressed	References Used
1	To measure the resistivity of a material using two probe method.	4	2, 4	1,6
2	Experiments using Four Probe Set up: (a) Study the variation of resistivity of a semiconductor with temperature and hence to determine the Band Gap (b) To study conductivity of thin film by four probe method.	8	2, 4	1,6
3	Thin film deposition using Thermal evaporator / sputtering	8	4	1,6
4	To analyse X-ray diffraction pattern of a given material to determine the crystal structure and estimate the particle using the Debye-Scherrer method.	8	1, 4	1,6
5	Measurement of dielectric constant: To measure dielectric constant of a ferroelectric material as a function of temperature and to observe ferroelectric to paraelectric transition.	8	2, 4	1,6
6	Determination of hall co-efficient in semiconductor samples by using Van der Pauw Set-Up.	8	2, 4	1,6
7	To determine the Curie temperature of phase transition for ferroelectric materials	8	2, 4	1,6
8	To study V-I characteristics of given semiconductor sample, p-n junction and LED	8	1, 2, 4	1,6
	Total contact hours (Experiments +Demo + Extra class)	**60**		

Learning Assessment

Bloom's Level of Cognitive Task		Continuous Learning Assessments (50 %)								End Semester Exam (50 %)	
		CLA-1 (15 %)		CLA-2 (15 %)		CLA-3 (__%)		Mid Term(20 %)			
		Th	Prac	Th	Prac	Th	Prac	Th	Prac	Th	Prac
Level 1	Remember Understand	40%		40%				40%		30%	
Level 2	Apply Analyse	60%		60%				60%		70%	
Level 3	Evaluate Create										
Total		100%		100%				100%		100%	

Recommended Resources

1. Kittel, C. (2004). Introduction to solid state physics, 8th ed. John Wiley & Sons.
2. Omar, M. A. (2015). Elementary solid-state physics, revised ed. Boston, MA: Pearson.
3. Ashcroft, N. W., & Mermin, N. D. (1976). Solid state physics, 1st ed. New York, NY: Holt, Rinehart, and Winston..
4. Dekker, A. J. (2000). Solid state physics. 1st ed. McGraw-Hill.
5. Pillai, S. O. (2014). Solid state physics, 6th ed. New Delhi: New Age International Publishers.
6. Schroder, D. K. (2006). Semiconductor material and device characterization, 3rd ed. Wiley.

Other Resources

Psychology for Everyday Living

				L	T	P	C
Course Code	FIC 124	**Course Category**	FIC	3	0	0	3
Pre-Requisite Course(s)		**Co-Requisite Course(s)**		**Progressive Course(s)**			
Course Offering Department	Psychology	**Professional / Licensing Standards**					

Course Objectives / Course Learning Rationales (CLRs)

1. To understand the fundamental psychological processes in everyday living.
2. To apply knowledge of psychology in improving self and others.
3. To apply knowledge of psychology in enhancing quality of life.

Course Outcomes / Course Learning Outcomes (CLOs)

	At the end of the course the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	Explain fundamental psychological processes in everyday living	2	80%	70%
Outcome 2	Describe important theories in psychology in the areas of sensation, perception, personality and learning	2	75%	70%
Outcome 3	Illustrate personal, professional and social applications of psychology	4	75%	60%
Outcome 4	Interpret results from certain personality tests	5	70%	60%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	Program Learning Outcomes (PLO)														
	Scientific and Disciplinary Knowledge	Analytical Reasoning and Problem Solving	Critical and Reflective Thinking	Scientific Reasoning and Design Thinking	Research Related Skills	Modern Tools and ICT Usage	Environment and Sustainability	Moral, Multicultural and Ethical Awareness	Individual and Teamwork Skills	Communication Skills	Leadership Readiness Skills	Self-Directed and Life Long Learning	PSO 1	PSO 2	PSO 3
Outcome 1	2							1				1			
Outcome 2	1			1					2	1					
Outcome 3	1	1	1				1	1	2	2		2			
Outcome 4	2		2		1			2	1	1		1			
Average	2	1	2	1	1		1	1	2	1		1			

Course Unitization Plan

Unit No.	Syllabus Topics	Required Contact Hours	CLOs Addressed	References
Unit No. 1	**Myths and Misconceptions in Psychology**	**12**	1	1
	Definition, nature and goals of psychology	4		
	Common myths and misconceptions about psychology	4		
	Schools of psychology; Basic and applied areas of psychology	4		
Unit No. 2	**The Role of Perception and Attitude towards Understanding the World**	**12**	2, 3	2
	Perception: Understanding perception, Gestalt laws of organization, common illusions	3		
	Perceptual constancy - depth perception, size perception, perception of movement	3		
	Attitude formation	3		
	Attitude change	3		
Unit No. 3	**Intelligence and Learning**	**12**	2, 3	2
	Definitions and nature of intelligence	3		
	Emotional and social intelligence; Measuring IQ, EQ and SQ	3		
	Fundamentals of learning and its applications	3		
	Memory techniques	3		
Unit No. 4	**Understanding the Self**	**12**	2, 4	1
	Definition; Approaches to personality – trait and type	4		
	Psychoanalytical and humanistic theory, Tests of personality – MBTI and NEO-PI	4		
	Identity; Self-concept, self-esteem and self-efficacy	4		
Unit No. 5	**Stress, Coping and Quality of Life**	**12**	2, 3	1
	Nature, sources of stress and its reactions	3		
	Factors influencing stress	3		
	Coping with and managing stress - cognitive and behavioural techniques	3		
	Improving quality of life	3		

Learning Assessment

Bloom's Level of Cognitive Task		Continuous Learning Assessments (50%)				End Semester Exam (50%)
		CLA-1 (15%)	Mid-1 (15%)	CLA-2 (10%)	CLA-3 (10%)	
		Th	Th	Th	Th	Th
Level 1	Remember Understand	50%	60%	60%	30%	50%
Level 2	Apply Analyse	50%	40%	40%	70%	50%
Level 3	Evaluate Create					
Total		**100%**	**100%**	**100%**	**100%**	**100%**

Recommended Resources

1. Baron, R. A. (2001). Psychology. New Delhi: Pearson Education India.
2. Nolen-Hoeksema, S., Fredrickson, B.L. & Loftus, G.R. (2014). Atkinson & Hilgard's Introduction to Psychology. 16th Ed. United Kingdom: Cengage Learning.

Other Resources

1. Morgan, C. T., King, R. A., & Schopler, J. (2004). Introduction to Psychology. New Delhi: Tata McGraw Hill.

SRM University *AP*, Andhra Pradesh

Neerukonda, Mangalagiri Mandal,
Guntur District, Mangalagiri, Andhra Pradesh – 522240.

Electronics

Course Code	PHY 507	**Course Category**	CC		**L**	**T**	**P**	**C**
					2	0	2	4
Pre-Requisite Course(s)	BSC level Electronics Courses	**Co-Requisite Course(s)**		**Progressive Course(s)**				
Course Offering Department	Physics	**Professional / Licensing Standards**						

Course Objectives / Course Learning Rationales (CLRs)

1. To understand operation of semiconductor devices and their DC analysis and AC models.
2. To apply concepts for the design of Regulators and Amplifiers
3. To analyse logic processes and implement logical operations using combinational logic circuits.
4. To understand characteristics of memory and their classification.

Course Outcomes / Course Learning Outcomes (CLOs)

	At the end of the course the learner will be able to	**Bloom's Level**	**Expected Proficiency Percentage**	**Expected Attainment Percentage**
Outcome 1	Relate fundamentals of semiconductor physics with electronic circuit design and performance	2	70%	65%
Outcome 2	Interpret electrical characteristics of dc circuits like Field Effect Transistor (FETs) and relate them with ac models of semiconductor devices.	2	70%	65%
Outcome 3	Demonstrate basic operation and crucial applications of different analog electronic circuits.	3	70%	65%
Outcome 4	Investigate frequency responses of analog filter, power regulator and amplifier circuits.	3	70%	65%
Outcome 5	Inspect circuit design and performance of sequential and combinational logic circuits.	4	70%	65%
Outcome 6	Differentiate basic operation, fabrication and applications of digital memory devices.	4	70%	65%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	**Program Learning Outcomes (PLO)**														
	Scientific and Disciplinary Knowledge	**Analytical Reasoning and Problem Solving**	**Critical and Reflective Thinking**	**Scientific Reasoning and Design Thinking**	**Research Related Skills**	**Modern Tools and ICT Usage**	**Environment and Sustainability**	**Moral, Multicultural and Ethical Awareness**	**Individual and Teamwork Skills**	**Communication Skills**	**Leadership Readiness Skills**	**Self-Directed and Life Long Learning**	**PSO 1**	**PSO 2**	**PSO 3**
Outcome 1	3	3	3	3	2	1			3			2	3	1	2
Outcome 2	3	3	3	3	2	2			2			2	3	2	2
Outcome 3	3	3	3	3	2	2			3			2	3	2	2
Outcome 4	3	3	3	3	3	1		2	3	2		3	3	2	2
Outcome 5	3	3	3	3	3	3		2	3	2		3	3	2	2
Outcome 6	3	3	3	3	3	3		2	3	2		3	3	2	2
Average	**3**	**3**	**3**	**3**	**2.5**	**2**		**2**	**2.8**	**2**		**2.5**	**3**	**1.8**	**2**

Course Unitization Plan

Unit No.	Syllabus Topics	Required Contact Hours	CLOs Addressed	References Used
Unit No. 1	**Semiconductor Fundamentals**	**6**		1, 2
	Metal–Semiconductor Junctions: Schottky Barriers, Rectifying Contacts, Ohmic Contacts.	1	1	1, 2
	Field Effect Transistor Operation – (FET) The Load Line, amplification and switching	1	1, 2	1, 2
	Metal–Semiconductor FET, Basic Operation and Fabrication	1	1, 2	1, 2
	The Ideal MOS Capacitor, MOS capacitance–voltage Analysis	1	1, 2	1, 2
	Current–voltage characteristics of MOS Gate Oxides	1	1, 2	1, 2
	MOS Field-effect Transistor - Output characteristics, Transfer characteristics	1	1, 2	1, 2
Unit No. 2	**Analog Electronics**	**6**		
	General Feedback structure, Negative and Positive feedback, Feedback amplifier types, Stability problem, Frequency compensation.	1	1	1, 2, 3,9
	Basic principles of sinusoidal oscillators, Op-amp RC oscillator	1	3	1, 2, 3,9
	Wein Bridge oscillator, MOSFET Crystal oscillators	1	2,3	1, 2, 3
	Bistable multivibrators, 555 timer IC and applications	1	3	1, 2, 3
	Rectifies and Active filters	1	2,3	1, 2, 3
	Power supplies: ripple removal and regulation	1	1, 2	1, 2, 3
Unit No. 3	**Combinational Circuit Design**	**6**		
	Binary Number system and logic gates	1	3	4, 5
	De Morgan’s theorem, SOP, POS, PI and EPI, Karnaugh maps (up to 4 variable) codes	1	3	4, 5
	Half Adder & Full Adder	1		4, 5
	Binary Parallel Adder, Carry look ahead adder, BCD Adder,	1	1, 2, 3, 4	4, 5
	Encoder, Priority Encoder, Decoder	1	1, 2, 3, 4	4, 5
	Multiplexer, Demultiplexer, Magnitude Comparator	1	3, 4	4, 5
Unit No. 4	**Synchronous Sequential Circuits**	**6**		
	Latches, Flip flops – SR, JK, T, D	1	3, 4	4, 5
	Master/Slave FF, operation, and excitation tables, Triggering of FF, Analysis and design of clocked synchronous sequential circuits	1	3, 4	4, 5
	Design – Moore/Mealy models, State minimization, State assignment	1	2, 4	4, 5
	Circuit implementation – Design of Counters, Ripple Counters, Ring Counters, Johnson Counters	1	4	4, 5
	Shift Registers, Universal Shift Register	1	4	4, 5

	Asynchronous sequential circuits, brief introduction, operation of asynchronous up/down counter	1	4	4, 5
Unit No. 5	**Memory Devices**	**6**		
	Introduction to Digital Integrated Circuits, Diode- logic (DL) Diode-transistor logic (DTL), Resistor transistor logic (RTL), Transistor-transistor logic (TTL)	1	5, 6	4, 5,10
	Emitter-coupled logic (ECL)	1	5, 6	4, 5,10
	Classification of memories – ROM, PROM, EPROM – EEPROM – EAPROM	1	5, 6	4, 5
	Programmable Logic Devices, PLA and PAL	1	5, 6	4, 5
	Field Programmable Gate Arrays (FPGA)	1	5, 6	4, 5
	Implementation of combinational logic circuits using ROM, PLA, PAL	1	5, 6	4, 5
Total contact hours		**30**		

Course Unitization Plan: Laboratory

Serial No.	Experiment Name	Required Contact Hours	CLOs Addressed	References Used
1	OPAMP as comparator and Schmitt Trigger	4	3	1, 2, 3
2	Differentiator, Integrator and filter circuits with IC741	4	2, 3	1, 2, 3
3	Phase shift oscillator using IC741	4	3	1, 2, 3
4	Design and study of full adder and subtractor circuits	4	3	1, 2, 3
5	Design and study of flip flops circuits (RS, D, JK, T)	4	5, 6	4, 5
6	Design and study of various counter circuits (up, down, ring, mod-n)	8	5, 6	4, 5
7	Design and study of multivibrator circuits using IC555	8	5, 6	4, 5,6,7,8
8	Simple Calculator using 6 digit seven segment display and Hex Keyboard interface to 8051	8	5, 6	4, 5
9	Alphanumeric LCD panel and Hex keypad input interface to 8051	8	5, 6	4, 5
10	External ADC and Temperature control interface to 8051	8	5, 6	4, 5
	Total contact hours (Experiments +Demo + Extra class)	**60**		

Learning Assessment

Bloom's Level of Cognitive Task		Continuous Learning Assessments (50 %)								End Semester Exam (50 %)	
		CLA-1 (15 %)		CLA-2 (15 %)		CLA-3 (__%)		Mid Term(20 %)			
		Th	Prac	Th	Prac	Th	Prac	Th	Prac	Th	Prac
Level 1	Remember	40%		40%				40%		30%	
	Understand										
Level 2	Apply	60%		60%				60%		70%	
	Analyse										
Level 3	Evaluate										
	Create										
Total		**100%**		**100%**				**100%**		**100%**	

Recommended Resources

1. Streetman, B. G., & Banerjee, S. K. (2015). Solid state electronic devices, 7th ed. Boston, MA: Pearson.
2. Neamen, D. A., & Biswas, D. (2012). Semiconductor physics and devices, 5th ed. McGraw-Hill
3. Boylestad, R. L., & Nashelsky, L. (2015). Electronic devices and circuit theory, 11th ed. Pearson.
4. Leach, D., Malvino, A., & Saha, G. (2010). Digital principles and applications, 7th ed. Tata McGraw-Hill.
5. Lincoln, B. (2014). Digital electronics, 1st ed. Pearson.
6. Lincoln, B. (2014). Digital electronics, 1st ed. Pearson.
7. MIT OpenCourseWare. (2007). Introductory analog electronics laboratory, 6.101. Retrieved from https://ocw.mit.edu/courses/6-101-introductory-analog-electronics-laboratory-spring-2007/pages/study-materials/
8. MIT OpenCourseWare. (2007). Circuits and electronics, 6.002. Retrieved from https://ocw.mit.edu/courses/6-002-circuits-and-electronics-spring-2007/
9. MIT OpenCourseWare. (2003). Analysis and design of digital integrated circuits, 6.374. Retrieved from https://ocw.mit.edu/courses/6-374-analysis-and-design-of-digital-integrated-circuits-fall-2003/
10. Pavan, S. (2020). Analog electronic circuits. NPTEL. Retrieved from https://nptel.ac.in/courses/108/106/108106084/
11. Saha, G. Digital electronic circuits. NPTEL. Retrieved from https://nptel.ac.in/courses/108/106/108106091/

Other Resources

Summer Internship

<table>
<tr><td rowspan="2">Course Code</td><td rowspan="2">PHY 510</td><td rowspan="2">Course Category</td><td rowspan="2" colspan="2">RDIP</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td>0</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td>Pre-Requisite Course(s)</td><td></td><td>Co-Requisite Course(s)</td><td></td><td>Progressive Course(s)</td><td colspan="4"></td></tr>
<tr><td>Course Offering Department</td><td>Physics</td><td>Professional / Licensing Standards</td><td colspan="6"></td></tr>
</table>

Course Objectives / Course Learning Rationales (CLRs)

1. Integrate Academic Knowledge with Practical Applications
2. Build Technical Proficiency in Field-Specific Tools and Techniques
3. Develop Analytical Skills through Systematic Research and Data Interpretation
4. Foster Ethical, Professional, and Safety-Conscious Work Practices
5. Enhance Communication Skills for Effective Scientific Dissemination

Course Outcomes / Course Learning Outcomes (CLOs)

	At the end of the course the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	Apply Theoretical Knowledge to Practical Research or Industrial Challenges	2	70%	80%
Outcome 2	Develop and Demonstrate Technical Skills Relevant to Discipline-Specific Techniques and Tools	2	70%	80%
Outcome 3	Conduct Systematic Research and Analyze Results Critically	3	70%	80%
Outcome 4	Demonstrate Professionalism, Ethics, and Adherence to Safety and Quality Standards	1	70%	80%
Outcome 5	Communicate Scientific Findings Effectively	3	70%	80%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	Program Learning Outcomes (PLO)														
	Scientific and Disciplinary Knowledge	Analytical Reasoning and Problem Solving	Critical and Reflective Thinking	Scientific Reasoning and Design Thinking	Research Related Skills	Modern Tools and ICT Usage	Environment and Sustainability	Moral, Multicultural and Ethical Awareness	Individual and Teamwork Skills	Communication Skills	Leadership Readiness Skills	Self-Directed and Lifelong Learning	PSO 1	PSO 2	PSO 3
Outcome 1	3	3	2	3	2	2	1	1	2	2	1	3	3	3	3
Outcome 2	3	3	2	2	3	3	2	1	2	2	2	3	3	3	3
Outcome 3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	3
Outcome 4	2	1	2	1	2	1	1	3	2	2	1	2	2	2	3
Outcome 5	2	2	2	1	2	2	1	2	3	3	2	3	3	3	3
Average	**2.6**	**2.4**	**2.2**	**2**	**2.4**	**2**	**1.4**	**1.8**	**2.2**	**2.2**	**1.6**	**2.6**	**2.6**	**2.6**	**3**

Course Unitization Plan

Unit No.	Unit Name	CLOs Addressed
Unit 1	**Problem Definition** - Identify and define the research or industrial problem to be addressed. - Review relevant literature or existing solutions. - Formulate a clear and concise problem statement.	1,3
Unit 2	**Methodology and Technical Skill Development** - Learn and practice field-specific tools, software, and techniques. - Outline methods to tackle the defined problem. - Design a step-by-step plan for experimentation or project execution.	2,3
Unit 3	**Data Collection and Analysis** - Conduct experiments or data collection using appropriate techniques. - Use analytical tools to interpret data accurately. - Summarize findings in preliminary results.	3
Unit 4	**Ethics, Quality, and Safety Compliance** - Review and adhere to safety protocols and ethical guidelines. - Follow quality control measures and document compliance. - Reflect on the importance of ethics in research and industry.	4
Unit 5	**Presentation and Reporting** - Prepare a scientific presentation summarizing the project. - Write a report or manuscript detailing methodology, results, and conclusions. - Engage in peer reviews and receive feedback.	5

Learning Assessment

Bloom's Level of Cognitive Task		Continuous Learning Assessments (50%)				End Semester Exam (50%)
		Diary 10%	Mid Sem 20%	Synopsis 10%	Report 10%	
Level 1	Remember Understand	100%	40%	50%	40%	30%
Level 2	Apply Analyse		60%	50%	60%	70%
Level 3	Evaluate Create					
Total		**100%**	**100%**	**100%**	**100%**	**100%**

Recommended Resources

Other Resources

Thesis Project

Course Code	PHY 509	**Course Category**	RDIP		L T P C 0 0 14 14		
Pre-Requisite Course(s)		**Co-Requisite Course(s)**		**Progressive Course(s)**			
Course Offering Department	Physics	**Professional / Licensing Standards**					

Course Objectives / Course Learning Rationales (CLRs)

1. Students will master advanced research techniques, including experimental design, data analysis, and critical literature review, to investigate specific research topics.
2. Through presentations and reports, students will learn to effectively communicate scientific findings, tailoring their message to diverse audiences.

Course Outcomes / Course Learning Outcomes (CLOs)

	At the end of the course the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	Sketch the theme of the research project and demonstrate the advanced methods needed for theoretical modelling/experimental design	3	75%	70%
Outcome 2	Proficiently analyse data, create plots, and draw meaningful conclusions.	4	75%	70%
Outcome 3	Prepare a scientific project report and convey the scientific findings through oral presentations.	5	75%	70%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	Program Learning Outcomes (PLO)													
	Scientific and Disciplinary Knowledge	Analytical Reasoning and Problem Solving	Critical and Reflective Thinking	Scientific Reasoning and Design Thinking	Research Related Skills	Modern Tools and ICT Usage	Environment and Sustainability	Moral, Multicultural and Ethical Awareness	Individual and Teamwork Skills	Communication Skills	Leadership Readiness Skills	Self-Directed and Life Long Learning	PSO 1	PSO 2	PSO 3
Outcome 1	3	3	2	3	2	1	2	3	3	2	2	3	3	2	3
Outcome 2	3	3	3	3	3	1	2	3	3	3	2	3	2	3	3
Outcome 3	3	3	3	3	3	2	2	3	3	3	2	3	2	3	3
Average	**3**	**3**	**2.7**	**3**	**2.7**	**1.3**	**2**	**3**	**3**	**2.7**	**2**	**3**	**2.3**	**2.7**	**3**

Course Unitization Plan

Unit No.	Syllabus Topics	Required Contact hours	CLOs Addressed	References Used
Unit No. 1	Refinement of Idea	40	1	1-6
Unit No. 2	Implement the Mathematical model & optimize the mathematical model for the considered problem	60	2	
Unit No. 3	Conduct the simulation/experimental data analysis and extract the results	200	2	
Unit No. 4	Validate the results obtained with Literature survey	90	2,3	
Unit No. 5	Publish and present results and finding	30	3	
Total Contact Hours		**420 hours**		

Learning Assessment

Bloom's Level of Cognitive Task		Continuous Learning Assessments (50 %)						End Semester Exam (50%)	
		CLA-1		CLA-2		Mid Term		Project	
		(Project Performance)		(Project Performance)		(Presentation)		Presentation + Project	
		(15 %)		(15 %)		(20%)		(50%)	
		Th	Prac	Th	Prac	Th	Prac		Proj
Level 1	Remember Understand								
Level 2	Apply Analyse		80%		70%		70%		60%
Level 3	Evaluate Create		20%		30%		30%		40%
Total			**100%**		**100%**		**100%**	**50%**	**50%**

Recommended Resources

1. As recommended by the Advisor pertaining to the student's research interest.

Other Resources

1. https://arxiv.org/
2. https://www.sciencedirect.com/
3. www.springer.com
4. https://onlinelibrary.wiley.com/
5. https://www.overleaf.com/learn/latex/Tutorials (For Latex)

Numerical Methods in Physics

Course Code	PHY 550	**Course Category**	CE		**L**	**T**	**P**	**C**
					2	1	0	3
Pre-Requisite Course(s)		**Co-Requisite Course(s)**		**Progressive Course(s)**				
Course Offering Department	Physics	**Professional / Licensing Standards**						

Course Objectives / Course Learning Rationales (CLRs)

1. To understand the common numerical algorithms.
2. To apply numerical methods to obtain solutions to physical and mathematical problems.
3. To analyse and evaluate the accuracy of numerical methods.
4. To implement numerical methods in C and Python.

Course Outcomes / Course Learning Outcomes (CLOs)

	At the end of the course the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	Summarize fundamental concepts related to computer algorithm and computer programming	2	70%	65%
Outcome 2	Solve linear, non-linear & differential equations using numerical methods	3	70%	65%
Outcome 3	Demonstrate numerical integration and differentiation	3	70%	65%
Outcome 4	Develop programming & numerical codes for real world physical and mathematical problems	5	70%	65%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	Program Learning Outcomes (PLO)														
	Scientific and Disciplinary Knowledge	Analytical Reasoning and Problem Solving	Critical and Reflective Thinking	Scientific Reasoning and Design Thinking	Research Related Skills	Modern Tools and ICT Usage	Environment and Sustainability	Moral, Multicultural and Ethical Awareness	Individual and Teamwork Skills	Communication Skills	Leadership Readiness Skills	Self-Directed and Life Long Learning	PSO 1	PSO 2	PSO 3
Outcome 1	3	3	3	3	2				3			2	3	1	2
Outcome 2	3	3	3	3	2				2			3	3	2	2
Outcome 3	3	3	3	3	2				3	2		3	3	2	2
Outcome 4	3	3	3	3	3	2		1	3	2		3	3	2	2
Average	**3**	**3**	**3**	**3**	**2.25**	**2**		**1**	**2.75**	**2**		**2.75**	**3**	**1.75**	**2**

Course Unitization Plan

Unit No.	Syllabus Topics	Required Contact Hours	CLOs Addressed	References Used
Unit No. 1	**Introduction to Programming**	**12**		
	Computer Algorithm	1	1	1,2
	Data types	1	1	1,2
	Programming syntax for Input/Output	1	1	1,2
	Variables and Operators	1	1, 4	1,2
	Tutorial-I	1	1, 4	1,2
	Expressions	1	1, 4	1,2
	Control statements	1	1, 4	1,2
	Loops	1	1, 4	1,2
	Tutorial – II	1	1, 4	1,2
	Functions	1	1, 4	1,2
	Arrays, and structures	1	1, 4	1,2
	Tutorial – III	1	1, 4	1,2
Unit No. 2	**Roots of Linear and Nonlinear Equations**	**12**		
	Roots of functions	1	2	1,2
	Linear equations: Gauss method	1	2	1,2
	Linear equations: Gauss-Jordan elimination	1	2	1,2
	Tutorial - I	1	1, 2	1,2
	Linear equations: Gauss-Seidel	1	2	1,2
	Linear equations: LU decomposition	1	2	1,2
	Tutorial – II	1	1, 2	1,2
	Nonlinear Equations of one variable: Bisection Method	1	2	1,2
	Nonlinear Equations of one variable: False position Method	1	2	1,2
	Nonlinear Equations of one variable: Newton Raphson Method	1	2	1,2
	Eigen Value problem	1	2	1,2
	Tutorial – III	1	1, 2	1,2
Unit No. 3	**Numerical Differentiation and Integration**	**13**		
	Numerical differentiation: forward difference formula	1	1, 3	1,2
	Numerical differentiation: backward difference formula	1	1, 3	1,2
	Numerical differentiation: centred difference formula	1	1, 3	1,2
	Tutorial - I	1	1, 3	1,2
	Numerical Integration: Quadrature rule	1	1, 3	1,2
	Numerical Integration: Trapezoidal rule	1	1, 3	1,2
	Tutorial – II	1	1, 3	1,2
	Numerical Integration: Simpson's 1/3 rule	1	1, 3	1,2
	Numerical Integration: Simpson's 3/8 rule	1	1, 3	1,2
	Tutorial – III	1	1, 3	1,2
	Numerical Integration: Gauss's quadrature formula	1	1, 3	1,2
	Numerical Integration: Newton – Cotes formula	1	1, 3	1,2
	Tutorial – IV	1	1, 3	1,2
Unit No. 4	**Differential Equations**	**13**		
	Solutions of ordinary differential equations: initial value problems	1	1, 2	1,2
	Taylor's series method	1	1, 2	1,2
	Tutorial – I	1	1, 2	1,2
	Euler's method	1	1, 2	1,2
	Modified Euler's method	1	1, 2	1,2
	Tutorial – II	1	1, 2	1,2
	Second order Runge-Kutta method	1	1, 2	1,2
	Fourth order Runge-Kutta method	1	1, 2	1,2
	Tutorial – III	1	1, 2	1,2
	Boundary value problems	1	1, 2	1,2
	Finite difference method	1	1, 2	1,2

	Concepts of Monte Carlo method	1	1, 2	1,2
	Tutorial – IV	1	1, 2	1,2
Unit No. 5	**Hands-on Applications**	**10**		
	1D Schrodinger equation –wave function and eigen values	2	1, 2, 3, 4	1,2
	Volume of van der Waals gas and comparison with ideal gas	2	1, 2, 3, 4	1,2
	Monte-Carlo simulations: value of π	2	1, 2, 3, 4	1,2
	Prediction of particle motion under certain conditions	2	1, 2, 3, 4	1,2
	Fall of a body in a viscous medium	2	1, 2, 3, 4	1,2
	Total contact hours	**60**		

Learning Assessment

Bloom's Level of Cognitive Task		**Continuous Learning Assessments (50 %)**								**End Semester Exam (50 %)**	
		CLA-1 (15 %)		**CLA-2 (15 %)**		**CLA-3 (__%)**		**Mid Term (20 %)**			
		Th	**Prac**	**Th**	**Prac**	**Th**	**Prac**	**Th**	**Prac**	**Th**	**Prac**
Level 1	Remember Understand	40%		40%				40%		30%	
Level 2	Apply Analyse	60%		40%				60%		50%	
Level 3	Evaluate Create			20%						20%	
Total		**100%**		**100%**				**100%**		**100 %**	

Recommended Resources

1. Chapra, S. C., & Canale, R. P. (2002). Numerical methods for engineers, 4th ed. New Delhi: Tata McGraw-Hill.
2. Mathews, J. H. (1998). Numerical methods for mathematics, science, and engineering, 2nd ed. New Delhi: Prentice Hall of India.

Other Resources

Atomic and Molecular Physics

Course Code	PHY 551	Course Category	CE		L	T	P	C
					2	1	0	3
Pre-Requisite Course(s)	PHY 213, PHY 302	Co-Requisite Course(s)	PHY 303 PHY 301L	Progressive Course(s)				
Course Offering Department	Physics	Professional / Licensing Standards						

Course Objectives / Course Learning Rationales (CLRs)

1. To understand the quantum mechanical phenomena at the atomic and molecular level.
2. To understand periodic table & origin of Atomic and Molecular Spectra.
3. To understand multi-electron atoms and spin-orbit coupling in multi-electron atoms.
4. To learn spin orbit interactions and Zeeman effect.
5. To gain an insight of molecular spectroscopy.
6. To understand the various spectroscopy techniques, i.e., Raman, Photoelectron and X-Ray Fluorescence spectroscopy.

Course Outcomes / Course Learning Outcomes (CLOs)

	At the end of the course the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	Summarize inter-relation between quantum mechanics and atomic structure.	2	70%	65%
Outcome 2	Interpret periodic table & origin of Atomic and Molecular Spectra.	3	70%	65%
Outcome 3	Illustrate Alkali Metal Spectroscopy using Quantum Mechanical Model	3	70%	65%
Outcome 4	Explain the spin orbit coupling and Zeeman effect	2	70%	65%
Outcome 5	Interpret Molecular Spectroscopy	3	70%	65%
Outcome 6	Differentiate fundamental working principle and applications of the Raman, Photoelectron and X-Ray Fluorescence Spectroscopy	4	70%	65%
Outcome 7	Summarize inter-relation between quantum mechanics and atomic structure.	2	70%	65%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	Program Learning Outcomes (PLO)													
	Scientific and Disciplinary Knowledge	Analytical Reasoning and Problem Solving	Critical and Reflective Thinking	Scientific Reasoning and Design Thinking	Research Related Skills	Modern Tools and ICT Usage	Environment and Sustainability	Moral, Multicultural and Ethical Awareness	Individual and Teamwork Skills	Communication Skills	Leadership Readiness Skills	Self-Directed and Life Long Learning	PSO 1	PSO 2	PSO 3
Outcome 1	3	3	3	3	2				2			2	3	1	2
Outcome 2	3	3	3	2	3				2			3	3	2	1
Outcome 3	3	3	3	3	3				2			2	3	2	2
Outcome 4	3	3	3	3	3				2	2		2	3	2	2
Outcome 5	3	3	3	3	3				2	2		2	3	2	2
Outcome 6	3	3	3	3	3				2	2		2	3	2	2
Outcome 7	3	3	3	3	3				2	2		2	3	2	2
Average	**3**	**3**	**3**	**2.8**	**2.8**				**2**	**2**		**2.1**	**3**	**1.8**	**1.8**

Course Unitization Plan

Unit No.	Syllabus Topics	Required Contact Hours	CLOs Addressed	References Used
Unit No. 1	**Atomic Models**	**9**		
	Quantum Theory and Bohr Atomic Model	1	1	1, 2
	Atomic Spectra of Hydrogen Atom	1	1, 2	1, 2
	Tutorial - I	1	1, 2	1, 2
	Sommerfeld's Atomic Model: Elliptic Orbits	1	1	1, 2
	De-Broglie Hypothesis: Dual Nature	1	1	1, 2
	Tutorial - II	1	1, 2	1, 2
	Schrödinger Wave Equation	1	1	1, 2
	Alkali Metals and Periodic Table	1	3	1, 2
	Tutorial - III	1	1, 2	1, 2
Unit No. 2	**Alkali Metal Spectroscopy**	**9**		
	Quantum Mechanical Model	1	1,2	1, 2
	Penetrating and Non-Penetrating Orbits: Classical	1	1,2	1, 2
	Tutorial - IV	1	1,2	1, 2
	Penetrating and Non-Penetrating Orbits: Quantum	1	1,2	1, 2
	Double Fine Structure	1	1,2	1, 2
	Tutorial - V	1	1,2	1, 2
	Selection and Infinity Rules	1	2	1, 2
	Vector Atomic Model	1	2	1, 2
	Tutorial - VI	1	1,2	1, 2
Unit No. 3	**One and Two Valence Electron Systems**	**9**		
	Zeeman Effect	1	4	1, 2
	Paschen Back Effect	1	2	1, 2
	Tutorial - VII	1	2,4	1, 2
	Stark effect	1	4	1, 2
	Pauli's Principle	1	3	1, 2
	Tutorial - VIII	1	3,4	1, 2
	Spin-orbit coupling: L-S and j-j Coupling	1	3	1, 2
	Multi-Electron Atoms	1	3	1, 2
	Tutorial - IX	1	3	1, 2
Unit No. 4	**Infrared and Microwave Spectroscopy**	**9**		
	Rotational Spectra	1	2, 5	2, 3
	Diatomic and Polyatomic Molecules	1	2, 5	2, 3
	Tutorial - X	1	2, 5	2, 3
	Chemical Analysis by Microwave Spectroscopy	1	2, 5	2, 3
	Diatomic Vibrational Spectra	1	2, 5	2, 3
	Tutorial - XI	1	2, 5	2, 3
	Born-Oppenheimer Approximation	1	5	2, 3
	Analysis by Infrared Techniques	1	2	2, 3
	Tutorial - XII	1	2	2, 3
Unit No. 5	**Raman and Electron Spectroscopy**	**9**		
	Raman Spectra: Rotational	1	2, 6	2, 3, 4,5
	Raman Spectra: Vibrational	1	2, 6	2, 3, 4,5
	Tutorial - XIII	1	2, 6	2, 3,4,5
	Structure Determination	1	2, 6	2, 3,4,5
	Photoelectron Spectroscopy and X-Ray Fluorescence Spectroscopy	1	2, 6	2, 3
	Tutorial - XIV	1	2, 6	2, 3
	Zeeman Effect	1	4, 6	2, 3
	Nuclear Spin	1	1, 6	2, 3
	Tutorial - XV	1	2, 6	2, 3
Total contact hours		**45**		

Learning Assessment

Bloom's Level of Cognitive Task		Continuous Learning Assessments (50 %)								End Semester Exam (50 %)	
		CLA-1 (15 %)		CLA-2 (15 %)		CLA-3 (__%)		Mid Term (20 %)			
		Th	Prac	Th	Prac	Th	Prac	Th	Prac	Th	Prac
Level 1	Remember Understand	40%		40%				40%		30%	
Level 2	Apply Analyse	60%		60%				60%		70%	
Level 3	Evaluate Create										
Total		100%		100%				100%		100%	

Recommended Resources

1. White, H. W. (1934). Introduction to atomic spectra, 1st ed. New York: McGraw-Hill Book Company.
2. Banwell, C. N. (2015). Fundamentals of molecular spectroscopy, 3rd ed. New York: McGraw-Hill Book Company.
3. Sindhu, P. S. (2011). Fundamentals of molecular spectroscopy, 2nd ed. New Delhi: New Age International Publisher.
4. Brooks, R. L. (2013). The fundamentals of atomic and molecular physics, 1st ed. New York: Springer-Verlag.
5. Bransden, B. H., & Joachain, C. J. (2003). Physics of atoms and molecules, 2nd ed. New Delhi: Pearson Education India.

Other Resources

Nuclear and Particle Physics

Course Code	PHY 552	**Course Category**	CE		**L**	**T**	**P**	**C**
					2	1	0	3
Pre-Requisite Course(s)	PHY 403 PHY 404	**Co-Requisite Course(s)**		**Progressive Course(s)**				
Course Offering Department	Physics	**Professional / Licensing Standards**						

Course Objectives / Course Learning Rationales (CLRs)

1. To understand the basic properties of Nucleus and Nuclear Models
2. To discuss Nuclear Radioactivity, it's classifications and applications
3. To introduce Nuclear Reactions, Reactors and Particle Accelerators
4. To review fundamental forces of Nature and discuss the physics of elementary particles

Course Outcomes / Course Learning Outcomes (CLOs)

	At the end of the course the learner will be able to	**Bloom's Level**	**Expected Proficiency Percentage**	**Expected Attainment Percentage**
Outcome 1	Understand nuclear properties, relate to the stability of nucleus, solve scattering problems: Rutherford scattering	2	70%	65%
Outcome 2	Solve n-p scattering, analyze different models of nucleus, categorize different decay processes and evaluate transition probabilities in different decay processes	4	70%	65%
Outcome 3	Interpret different nuclear reactions and contrast working principle of nuclear detectors and particle accelerators.	4	70%	65%
Outcome 4	Evaluate the symmetry and conservation laws in particle physics, categorize elementary particles based on Gell-Mann diagarm and relate to weak interactions.	5	65%	60%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	**Program Learning Outcomes (PLO)**														
	Scientific and Disciplinary Knowledge	**Analytical Reasoning and Problem Solving**	**Critical and Reflective Thinking**	**Scientific Reasoning and Design Thinking**	**Research Related Skills**	**Modern Tools and ICT Usage**	**Environment and Sustainability**	**Moral, Multicultural and Ethical Awareness**	**Individual and Teamwork Skills**	**Communication Skills**	**Leadership Readiness Skills**	**Self-Directed and Life Long Learning**	**PSO 1**	**PSO 2**	**PSO 3**
Outcome 1	3	3	3	1	1	1						2	3	1	1
Outcome 2	3	3	3	2	2	1	1		2			2	3	1	1
Outcome 3	3	3	3	3	3	2	3	1	2			2	3	2	1
Outcome 4	3	3	3	2	3	2	1		2			3	3	2	1
Average	**3**	**3**	**3**	**2**	**2.2**	**1.5**	**1.6**	**1**	**2**			**2.2**	**3**	**1.5**	**1**

Course Unitization Plan

Unit No.	Syllabus Topics	Required Contact Hours	CLOs Addressed	References Used
Unit No. 1	**Nuclear properties**	9		
	Basic properties: Composition, charge, size, density, spin	1	1	1,2
	Rutherford scattering	1	1	1,2
	Mass defect, Binding energy, Stability of nuclei	1	1	1,2
	Angular momentum, Electromagnetic moments	1	1	1,2
	Two-nucleon system	1	1	1,2
	Tutorial – I: Schrodinger equation and its solution for ground state of deuteron	1	1	1,2
	Tutorial – II: Magnetic moments of deuteron	1	1	1,2
	n-p scattering, effective range, and scattering length	1	1,2	1,2
	Tutorial - III: Partial wave analysis and phase shifts	1	1,2	1,2
Unit No. 2	**Nuclear Structure and Radioactive Decays**	9		
	Liquid drop model, Bethe-Weizsacker mass formula	1	1,2	1,2
	Fermi model, Shell Model	1	1,2	1,2
	Tutorial – I: Collective model	1	1,2	1,2
	Alpha decay, Geiger-Nuttall law	1	1,2,3	1, 2
	Gamow's theory of alpha decay	1	1,2,3	1,2
	Beta decay, energy spectra, Fermi Theory, Neutrinos	1	1,2,3	1, 2
	Tutorial – II: Beta transitions, Selection rules, Parity violation	1	1,2,3	1,2
	Gamma rays: Nature of gamma rays, Passage through matter	1	1,2,3	1, 2
	Tutorial – III: Multipole gamma transitions	1	1,2,3	1,2
Unit No. 3	**Nuclear Reactions and Reactors**	9		
	Types of Nuclear reactions, conservation laws	1	2,3	1,2
	Reaction kinematics, Q-value equation	1	2,3	1,2
	Tutorial – I: Exothermic and Endothermic, Threshold energy	1	2,3	1,2
	Nuclear cross-section, reaction yield	1	2,3	1,2
	Nuclear fission, chain reaction and critical mass	1	2,3	1,2
	Nuclear fusion	1	2,3	1,2
	Tutorial – II: Nucleosynthesis	1	2,3	1,2
	Nuclear reactors	1	2,3	1,2
	Tutorial – III: Homogeneous and heterogeneous reactors	1	2,3	1,2
Unit No. 4	**Detectors and Accelerators**	9		
	Gas filled Detectors (G. M. counter)	1	2,3	1,2
	Solid-state detectors (scintillation counter)	1	2,3	1,2
	Tutorial – I: Photo-multiplier tube (PMT)	1	2,3	1,2
	Semi-conductor detector	1	2,3	1,2
	Cherenkov detector	1	2,3	1,2
	Tutorial – II: Fixed target vs collider experiments	1	2,3	1,2
	Particle Accelerators, Cyclotrons	1	2,3	2,3
	Synchrotrons	1	2,3	2,3
	Tutorial – III: LHC and Linear accelerators	1	2,3	2,3
Unit No. 5	**Elementary particle physics**	9		
	Symmetries and conservation laws	1	1,4	3
	Baryon number, Lepton number, Isospin	1	1,4	3
	Hadrons – classification by isospin and hypercharge	1	1,4	3
	Leptons and gauge bosons	1	1,4	3
	Weak Interactions, V-A theory	1	4	3
	EM interactions, gauge invariance	1	4	3
	Tutorial – I: Electroweak theory	1	4	3
	Tutorial – II: Neutrinos, mixing and oscillation	1	4	3
	Tutorial – III: Standard Model Lagrangian (Qualitative)	1	4	3
Total contact hours		**45**		

Learning Assessment

Bloom's Level of Cognitive Task		Continuous Learning Assessments (50 %)								End Semester Exam (50 %)	
		CLA-1 (15 %)		CLA-2 (15 %)		CLA-3 (__%)		Mid Term (20 %)			
		Th	Prac	Th	Prac	Th	Prac	Th	Prac	Th	Prac
Level 1	Remember	30%		20%				40%		30%	
	Understand										
Level 2	Apply	70%		60%				60%		50%	
	Analyse										
Level 3	Evaluate			20%						20%	
	Create										
	Total	**100%**		**100%**				**100%**		**100%**	

Recommended Resources

1. Krane, K. S. (1987). Introductory nuclear physics, Student ed. Hoboken, NJ: Wiley.
2. Perkins, D. H. (2000). Introduction to high energy physics, 4th ed. Cambridge: Cambridge University Press.
3. Thomson, M. (2013). Modern particle physics, 1st ed. Cambridge: Cambridge University Press.

Condensed Matter Physics - II

Course Code	PHY 553	**Course Category**	CE		L	T	P	C
					2	1	0	3
Pre-Requisite Course(s)	Mathematical methods, Quantum mechanics, Condensed matter physics	**Co-Requisite Course(s)**		**Progressive Course(s)**				
Course Offering Department	Physics	**Professional / Licensing Standards**						

Course Objectives / Course Learning Rationales (CLRs)

1. To Understand free electron gas and electron-electron interactions.
2. To learn about plasma oscillations in free electron gas.
3. To get overview of spin-interactions and magnon.
4. To receive fundamental knowledge of superconductivity and superfluidity.
5. To understand about electron transport in disordered system.

Course Outcomes / Course Learning Outcomes (CLOs)

	At the end of the course the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	Describe free and interacting electron many body systems	2	70%	65%
Outcome 2	Analyze physical phenomena such as plasma oscillation, superconductivity and superfluidity, arising out of interacting electrons	4	70%	65%
Outcome 3	Examine the transport properties and critical behavior seen in imany electron systems	4	70%	65%
Outcome 4	Asses the role of disorder in many particle systems	5	70%	65%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	Program Learning Outcomes (PLO)													
	Scientific and Disciplinary Knowledge	Analytical Reasoning and Problem Solving	Critical and Reflective Thinking	Scientific Reasoning and Design Thinking	Research Related Skills	Modern Tools and ICT Usage	Environment and Sustainability	Moral, Multicultural and Ethical Awareness	Individual and Teamwork Skills	Communication Skills	Leadership Readiness Skills	Self-Directed and Lifelong Learning	PSO 1	PSO 2	PSO 3
Outcome 1	3	3	2	2	2				3			2	3	1	2
Outcome 2	3	3	3	3	3			1	2			3	3	2	2
Outcome 3	3	3	3	3	3			1	3	2		3	3	2	2
Outcome 4	3	3	3	3	3			2	3	2		3	3	2	2
Average	**3**	**3**	**3**	**2.7**	**2.7**			**1.3**	**2.7**	**2**		**2.7**	**3**	**1.7**	**2**

Course Unitization Plan

Unit No.	Syllabus Topics	Required Contact Hours	CLOs Addressed	References Used
Unit No. 1	**UNIT-I- Fundamentals of Hartree-Fock theory**	**9**		
	Hamiltonian of a solid: electronic and ionic part	1	1	3,4
	Adiabatic approximation	1	1	3,4
	Born-Oppenheimer approximation	1	1	3,4
	Hartree-Fock theory: HF equation, Koopman theorem	1	1	3,4
	Many electron Hamiltonian: occupation number representation	1	1,3	3,4
	Tutorial-I: on occupation number representation	1	1,3	3,4
	Free electron gas	1	1,3	3,4
	Tutorial-II: First order perturbation (free electron gas)	1	1	3,4
	Tutorial III: Second order perturbation (free electron gas)	1	1	3,4
Unit No. 2	**UNIT II – Plasma oscillations in free electron gas**	**9**		
	HF approximation for free electron gas	1	1	1, 2,3
	Ground state energy	1	1	1, 2,3
	Single particle energy levels	1	1	1,2,3
	Tutorial I: Problems on HF approximations	1	1	1, 2,3
	Correlation energy: long and short range	1	1	1, 2,3
	Wigner’s formula in high and low density	1	1	1, 2,3
	Cohesive energy in metals	1	1,3	1,2,3
	Tutorial II: Screening and plasmons	1	1,3	1, 2,3
	Tutorial III: Experimental observations of plasmons	1	1,3	1,2,3
Unit No. 3	**UNIT III – Spin-spin interactions: Magnons**	**9**		
	Origin of exchange interactions, Direct exchange, super exchange	1	1	1, 2
	Indirect exchange, itinerant exchange	1	1	1,2
	Spin-waves: ferromagnets & anti-ferromagnets	1	3	1, 2
	Holstein-Primakoff transformation	1	3	1,2
	Spontaneous symmetry breaking with continuous symmetry	1	3	1, 2
	Thermodynamics of magnons	1	3	1, 2
	Tutorial I: Mean-field theory, critical behavior for large S models	1	3	1, 2
	Tutorial- II	1	3	1,2
	Tutorial- III	1	3	1,2
Unit No. 4	**UNIT IV: Superconductivity and superfluidity**	**9**		
	Cooper pairs	1	2	2,3
	BCS theory, Bogoliubov transformation	1	3	2,3
	Ginzburg-Landau theory, London equation	1	3	2,3
	Meissner effect	1	3	2,3
	Type-II superconductors: characteristics length, Josephson effect	1	2,3	2,3
	Tutorial I: High temperature superconductors	1	2,3	2,3
	Superfluid Helium 4: Basic phenomenology	1	2,3	2,3
	Tutorial II: BE condensation, two fluid model	1	3	2,3
	Tutorial- III: Review problems	1	3	2,3
Unit No. 5	**UNIT V: Disordered systems**	**9**		
	Substitutional, positional and topographical disorders	1	4	3
	Short and long range ordering	1	4	3
	Atomic correlation and structural descriptions of glasses and liquids	1	4	3
	Tutorial I: Anderson model, mobility edge	1	4	3
	Tutorial II: Annealed disorder (Fisher renormalization)	1	3,4	3
	Quenched disorder (Harris criterion)	1	3,4	3
	Elementary idea of spin glass: RKKY interactions	1	4	3
	Introductions to Edwards-Anderson model & Sherrington-Kirpatrik model	1	4	3
	Tutorial- III: Review problems	1	4	3
Total contact hours		**45**		

Learning Assessment

Bloom's Level of Cognitive Task		Continuous Learning Assessments (50 %)								End Semester Exam (50 %)	
		CLA-1 (15 %)		CLA-2 (15 %)		CLA-3 (__%)		Mid Term (20 %)			
		Th	Prac	Th	Prac	Th	Prac	Th	Prac	Th	Prac
Level 1	Remember / Understand	40%		40%				40%		30%	
Level 2	Apply / Analyse	60%		40%				60%		50%	
Level 3	Evaluate / Create			20%						20%	
	Total	**100%**		**100%**		**-**	**-**	**100 %**		**100%**	

Recommended Resources

1. Kittel, C. (2005). Introduction to solid state physics, 8th ed. New York: John Wiley & Sons.
2. 2. Ashcroft, N., & Mermin, N. (1976). Solid state physics. Philadelphia: Saunders College Publishing.
3. 3. Raimes, S. (1972). Many electron theory, 1st ed. Amsterdam: North-Holland Publishing Company.
4. 4. Mezard, M., Parisi, G., & Virasoro, M. (1987). Spin glass theory and beyond, 1st ed. Singapore: World Scientific

Other Resources

Spintronics & Nano-magnetism – MEMS & NEMS

						L	T	P	C
Course Code	PHY 554	**Course Category**	CE			2	0	1	3
Pre-Requisite Course(s)	PHY 403, 404 & 502	**Co-Requisite Course(s)**		**Progressive Course(s)**					
Course Offering Department	Physics	**Professional / Licensing Standards**							

Course Objectives / Course Learning Rationales (CLRs)

1. To review concepts in Magnetostatics and bulk magnetism.
2. To study Magnetic materials and magnetic order.
3. To learn the fundamentals of magnetism of various regular shaped nanostructures.
4. To explore the basics of spintronics and magnetic memory.
5. To know the foundation of micro- and nano-fabrication techniques.

Course Outcomes / Course Learning Outcomes (CLOs)

	At the end of the course the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	Review basics of magnetostatics and inter-relation of Magnetisation (M), Magnetic Intensity (H) and magnetic induction (B)	2	70%	65%
Outcome 2	Investigate origin of magnetic order in solids and the role of dimension & size.	3	70%	65%
Outcome 3	Analyze fundamental aspects of spin-electronics and magnetic recording	4	70%	65%
Outcome 4	Categorize MEMS & NEMS designs and inspect them for applications in micro and nano-level sensors and actuators	4	70%	65%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	Program Learning Outcomes (PLO)													
	Scientific and Disciplinary Knowledge	Analytical Reasoning and Problem Solving	Critical and Reflective Thinking	Scientific Reasoning and Design Thinking	Research Related Skills	Modern Tools and ICT Usage	Environment and Sustainability	Moral, Multicultural and Ethical Awareness	Individual and Teamwork Skills	Communication Skills	Leadership Readiness Skills	Self-Directed and Life Long Learning	PSO 1	PSO 2	PSO 3
Outcome 1	3	3	3	3	2				3			2	3	1	2
Outcome 2	3	3	3	3	2				3			3	3	2	2
Outcome 3	3	3	3	3	3	2			3	2		3	3	2	2
Outcome 4	3	3	3	3	3	2			3	2		3	3	2	2
Average	**3**	**3**	**3**	**3**	**2.5**	**2**			**3**	**2**		**2.7**	**3**	**1.7**	**2**

Course Unitization Plan

Unit No.	Syllabus Topics	Required Contact Hours	CLOs Addressed	References Used
Unit No. 1	**Review of Magnetism**	**9**		
	Review of Magnetostatics	1	1	1,2
	Magnetisation (M), Magnetic Intensity (H) and magnetic induction (B) – their mathematical relations	1	1	1,2
	Tutorial I – Problems on Biot savart & Ampere's Law	1	1	
	Magnetism of electrons – Orbital and spin moments	1	1, 2	1,2
	Magnetic field effects	1	1, 2	1,2
	Tutorial II – Problems on Magnetism of electrons in solids	1	1, 2	1,2
	Magnetism of localized electrons on the atom	1	1, 2	1,2
	Origin of Para magnetism	1	1, 2	1,2
	Tutorial III – Problems on paramagnetic materials	1	1, 2	1,2
Unit No. 2	**Magnetic Materials and Magnetic Order**	**9**		
	Magnetic Materials - An Overview	1	1,2	1,2
	Tutorial I – Scientific comparison of material properties of Dia, Para and ferro-magnetic materials.	1	1,2	1,2
	Ferromagnetism and exchange – mean field theory	1	1,2	1,2
	Exchange interactions & Band Magnetism	1	1,2	1,2
	Collective excitations	1	1,2	1,2
	Tutorial II – Problems on ferromagnetism in solids	1	1,2	1,2
	Molecular field theory of anti-ferromagnetism	1	1,2	1,2
	Ferrimagnets & Spin Glasses	1	1,2	1,2
	Tutorial III – Problems and discussions on AFM order	1	1,2	1,2
Unit No. 3	**Magnetism at nanoscale**	**9**		
	Micro-magnetism and Micromagnetic energy	1	1, 2	1,2
	Magnetic domain theory – domain and domain walls	1	1, 2	1,2
	Tutorial I – Problems on Micro-magnetism	1	1, 2	1,2
	Nano-scale magnetism & Characteristic length scales	1	1, 2	1,2
	Magnetism of nanoparticles and quantum dots (0-D)	1	1, 2	1,2
	Magnetism of nanowire and nanotubes (1-D)	1	1, 2	1,2
	Magnetism of thin-film and hetero-structures (2-D)	1	1, 2	1,2
	Tutorial II	1	1, 2	1,2
	Tutorial III	1	1, 2	1,2
Unit No. 4	**Spin electronics and magnetic recording**	**9**		
	Spin polarization and spin-currents	1	3	1, 2
	Spin injection and spin accumulation	1	3	1, 2
	Spin-transfer torque	1	3	1, 2
	Tutorial I – Problems on spin-polarization	1	3	1, 2
	Materials for spin-electronics – sensors & devices	1	2, 3	1, 2
	Magnetic memories – MRAM devices	1	1,2, 3	1, 2
	Tutorial II – Interaction and problem solving	1	1,2,3	1, 2
	Spin transistor	1	3	1, 2
	Tutorial III – Discussion on logic of spin-electronics	1	3	1, 2
Unit No. 5	**Micro and Nanofabrication (NEMS & MEMS)**	**9**		
	Overview of Nano and Microelectromechanical Systems	1	4	3,4,5
	Design of MEMS and NEMS	1	4	3,4,5
	Tutorial I - Materials for MEMS and NEMS: Silicon, silicon compounds, polymers, metals.	1	1, 2, 4	3,4,5
	MEMS Fabrication Technologies – Photolithography	1	4	3,4,5
	MEMS Fabrication Technologies – Micromachining	1	4	
	Tutorial II – NEMS fabrication – Fabrication at low dimension	1	2, 4	3,4,5
	Brief review of MEMS Sensors & Actuators	1	4	3,4,5
	MEMS & Nano-magnetism – Magnetic Transducers	1	1, 2, 4	3,4,5
	Tutorial III	1	1, 4	3,4,5
Total contact hours		**45**		

Learning Assessment

Bloom's Level of Cognitive Task		Continuous Learning Assessments (50 %)								End Semester Exam (50 %)	
		CLA-1 (15 %)		CLA-2 (15 %)		CLA-3 (__%)		Mid Term (20 %)			
		Th	Prac	Th	Prac	Th	Prac	Th	Prac	Th	Prac
Level 1	Remember Understand	40%		40%				40%		30%	
Level 2	Apply Analyse	60%		60%				60%		70%	
Level 3	Evaluate Create										
Total		**100%**		**100%**				**100%**		**100%**	

Recommended Resources

1. Coey, J. M. D. (2009). Magnetism and magnetic materials, 1st ed. Cambridge: Cambridge University Press.
2. Cullity, B. D., & Graham, C. D. (2009). Introduction to magnetic materials, 2nd ed. IEEE Press/Wiley.
3. Lyshevski, S. E. (2002). MEMS and NEMS: Systems, devices, and structures, 1st ed. Boca Raton, FL: CRC Press.
4. Ogale, S. B., Venkatesan, T. V., & Blamire, M. (2018). Functional metal oxides: New science and novel applications, 1st ed. Hoboken, NJ: Wiley.
5. Seshan, K. (2012). Handbook of thin film deposition techniques: Principles, methods, equipment, and applications, 2nd ed. Boca Raton, FL: Taylor & Francis Group.

Other Resources

Soft Matter Physics

Course Code	PHY 555	**Course Category**	CE		**L**	**T**	**P**	**C**
					2	1	0	3
Pre-Requisite Course(s)	Elementary Statistical Physics	**Co-Requisite Course(s)**		**Progressive Course(s)**				
Course Offering Department	Physics	**Professional / Licensing Standards**						

Course Objectives / Course Learning Rationales (CLRs)

1. Introduction to soft matter systems.
2. Soft matter in solutions and its understanding.
3. To study various soft matter systems: colloids, liquid crystals, surfactants.
4. To learn the effect of flow, deformation, and material responses.
5. To develop understanding about various experimental and computational tools and analyse soft matter systems.

Course Outcomes / Course Learning Outcomes (CLOs)

	At the end of the course the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	Describe soft matter and its properties	2	70%	65%
Outcome 2	Develop understanding about soft matter in solutions and different properties	2	70%	65%
Outcome 3	Illustrate colloids, liquid crystals and surfactant and different properties and applications	3	70%	65%
Outcome 4	Compute effect of flow in a soft matter system, its structural changes, response of external flow	4	70%	65%
Outcome 5	Inspect soft matter systems using experimental and computational tools	4	70%	65%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	**Program Learning Outcomes (PLO)**													
	Scientific and Disciplinary Knowledge	**Analytical Reasoning and Problem Solving**	**Critical and Reflective Thinking**	**Scientific Reasoning and Design Thinking**	**Research Related Skills**	**Modern Tools and ICT Usage**	**Environment and Sustainability**	**Moral, Multicultural and Ethical Awareness**	**Individual and Teamwork Skills**	**Communication Skills**	**Leadership Readiness Skills**	**Self-Directed and Life Long Learning**	**PSO 1**	**PSO 2**	**PSO 3**
Outcome 1	3	3	3	3	2				3			2	3	1	2
Outcome 2	3	3	3	3	2				2			3	3	2	2
Outcome 3	3	3	3	3	2				3			3	3	2	2
Outcome 4	3	3	3	3	3				3			3	3	2	2
Outcome 5	3	3	3	3	3				3			3	3	2	2
Average	**3**	**3**	**3**	**3**	**2.4**				**2.8**			**2.8**	**3**	**1.8**	**2**

Course Unitization Plan

Unit No.	Syllabus Topics	Required Contact Hours	CLOs Addressed	References Used
Unit No. 1	**Introduction to Soft Matter**	**9**		
	What is soft matter and why soft matter?	1	1, 5	1,2
	Various examples: Polymers, surfactants, colloids, liquid crystals	1	1, 5	1,2
	Tutorial – I: Characteristic properties of soft matter systems	1	1, 5	1,2
	What is common in soft matter?	1	1, 5	1,2
	Different Interactions: Bonded interaction and non-bonded	1	1, 5	1,2
	Tutorial – II : Fluctuations in the systems, Brownian motion	1	1, 5	1,2
	Random Walk problem	1	1, 5	1,2
	Langevin dynamics & Fluctuation dissipation theorem	1	1, 5	1,2
	Tutorial – III	1	1, 5	1,2
Unit No. 2	**Soft matter solutions**	**9**		
	Basic concepts and thermodynamics of solutions	1	1, 2, 5	1,2
	Mixing free energy, Osmotic pressure, Chemical Potentials	1	1, 2, 5	1,2
	Tutorial I - Relations with miscibility of solute and solvents	1	1, 2, 5	1,2
	Soft matter solutions and its essential characteristics	1	1, 2, 5	1,2
	Phase separation and coexistence of two phases	1	1, 2, 5	1,2
	Lattice model description and effective interaction	1	1, 2, 5	1,2
	Tutorial II -Lattice model of polymer solutions	1	1, 2, 5	1,2
	Structure factor, form factor, effect of correlation	1	1, 2, 5	1,2
	Tutorial III - Multi-component solutions	1	1, 2, 5	1,2
Unit No. 3	**Colloids, Liquid crystals, and surfactants**	**12**		
	Classification, basic concepts of elasticity of polymer	1	1, 3, 5	1,2
	Continuum mechanics for elastic materials	1	1, 3, 5	1,2
	T-I: Freely jointed chain model, end – to end length	1	1, 3, 5	1,2
	Kuhn's theory for rubber elasticity	1	3, 5	1,2
	Surface and surface tensions, examples	1	3, 5	1,2
	T-2: Wetting phenomenon, Liquid droplet on surface	1	1, 3, 5	1,2
	Surfactants & Colloids	1	3, 5	1,2
	Liquid crystals	1	3, 5	1,2
	Tutorial III	1	1, 3, 5	1,2
Unit No. 4	**Flow and Deformation**	**9**		
	Mechanical properties of soft matter	1	1, 4, 5	1,2
	Concepts of viscosity, elasticity, and viscoelasticity	1	1, 4, 5	1,2
	Viscoelasticity of entangled & non-entangled polymers	1	4, 5	1,2
	T-I: Examples studies: Rod-like polymers	1	4, 5	1,2
	Statistical concepts of material response and fluctuations	1	4, 5	1,2
	Liouville equation, time correlation functions	1	4, 5	1,2
	Tutorial II: Equilibrium and non-equilibrium responses	1	4, 5	1,2
	Derivation of Smoluchowskii equation from Langevin equation	1	4, 5	1,2
	Tutorial – III	1	4, 5	1,2,3
Unit No. 5	**Experimental and Computational approach to study soft matter systems**	**9**		
	Various experimental techniques: x-ray, neutron scattering, light scattering to study soft matter	1	1, 5	1,2
	Basic insights gained from experimental approaches	1	1, 5	1,2
	Tutorial I: Computational tools: Monte Carlo, Molecular dynamics	1	1, 5	1,2
	Introduction to Monte Carlo techniques	1	1, 5	1,2,3
	Importance sampling, Metropolis Algorithm	1	1, 5	1,2,3
	Kinetic Monte Carlo approach	1	1, 5	1,2,3
	Introduction to molecular dynamics	1	1, 5	1,2,3
	Tutorial II - Solving problems applying Monte Carlo	1	1, 5	1,2,3
	Tutorial III - Solving problems applying molecular dynamics	1	1, 5	1,2,3
Total contact hours		**45**		

Learning Assessment

Bloom's Level of Cognitive Task		Continuous Learning Assessments (50 %)								End Semester Exam (50 %)	
		CLA-1 (15 %)		CLA-2 (15 %)		CLA-3 (__%)		Mid Term (20 %)			
		Th	Prac	Th	Prac	Th	Prac	Th	Prac	Th	Prac
Level 1	Remember	40%		40%				40%		30%	
	Understand										
Level 2	Apply	60%		60%				60%		70%	
	Analyse										
Level 3	Evaluate										
	Create										
	Total	100%		100%				100%		100%	

Recommended Resources

1. Doi, M. (2013). Soft matter physics, 1st ed. Oxford: Oxford University Press.
2. Brochard-Wyart, F., Nassoy, P., & Puech, P.-H. (2019). Essentials of soft matter science, 1st ed. Boca Raton, FL: CRC Press.
3. Witten, T. A., & Pincus, P. A. (2004). Structured fluids: Polymers, colloids, surfactants, 1st ed. Oxford: Oxford University Press.

Other Resources

Introduction to Astrophysics

					L	T	P	C
Course Code	PHY 556	**Course Category**	CE		2	1	0	3
Pre-Requisite Course(s)	PHY203, PHY212, PHY302, PHY313	**Co-Requisite Course(s)**		**Progressive Course(s)**				
Course Offering Department	Physics	**Professional / Licensing Standards**						

Course Objectives / Course Learning Rationales (CLRs)

1. To introduce the basics of Astrophysics such as Astronomical coordinate system, distance and mass measurement techniques, stellar radiation
2. To introduce the stellar structure, stellar spectra.
3. To introduce the theory of the Sun as a star
4. To learn more about the stars such as stellar evolution
5. To introduce the Astronomical instruments and discuss the recent discoveries in Astronomy

Course Outcomes / Course Learning Outcomes (CLOs)

	At the end of the course the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	Calculate the apparent and absolute magnitude of brightness of a star and astronomical distance.	3	70%	65%
Outcome 2	Compute gravitational energy, thermal energy of stars using virial theorem.	3	70%	65%
Outcome 3	Illustrate all the distinctive regions of the Sun as a star	2	70%	65%
Outcome 4	Understand Stellar evolution, White Dwarf and Chandrasekhar limit, Neutron star and Black hole, binary systems and Galaxy	2	70%	65%
Outcome 5	Review astronomical instruments and recent discoveries.	2	65%	65%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	Program Learning Outcomes (PLO)													
	Scientific and Disciplinary Knowledge	Analytical Reasoning and Problem Solving	Critical and Reflective Thinking	Scientific Reasoning and Design Thinking	Research Related Skills	Modern Tools and ICT Usage	Environment and Sustainability	Moral, Multicultural and Ethical Awareness	Individual and Teamwork Skills	Communication Skills	Leadership Readiness Skills	Self-Directed and Life Long Learning	PSO 1	PSO 2	PSO 3
Outcome 1	3	3	3	2	2	2			2	2		2	3	1	1
Outcome 2	3	3	3	2	3	2			2	2		2	3	1	1
Outcome 3	3	3	3	2	3	2			2	2		2	3	2	1
Outcome 4	3	3	3	2	3	2			2	2		2	3	2	1
Outcome 5	3	3	3	3	3	2			2	2		2	3	2	1
Average	**3**	**3**	**3**	**2.2**	**2.8**	**2**			**2**	2		**2**	**3**	**2**	**1**

Course Unitization Plan

Unit No.	Syllabus Topics	Required Contact Hours	CLO's Addressed	References Used
Unit No. 1	**Introduction to Astronomy and Astronomical Scales**	9		
	Motivation & brief history of Astronomy, scales related to Astronomy	1	1	1, 4, 6
	How do we collect the information about the Universe	1	1	1, 4, 6
	Tutorial: Kepler law and Kepler orbit	1	1	1, 4, 6
	The sky and the celestial sphere	1	1	1, 4, 6
	Tutorial: Application of Physics to Astrophysics	1	1	1, 4, 6
	Determination of distance by using parallax technique, Aberration	1	1	1, 4, 6
	Tutorial: Aberration, Doppler effect	1	1	1, 4, 6
	Stellar mass measurement: Visual, eclipsing binaries, Spectroscopic binaries	1	1	2, 4, 5, 6
	Radiation, Luminosity, Radius and temperature of stars	1	1, 2	2, 4, 5, 6
Unit No. 2	**Stellar Structure**	9		
	Tutorial: Blackbody radiation	1	1, 2	2, 4, 5, 6
	Basic equations for stellar structure: Basic equations for stellar structure, Hydrostatic equilibrium in stars	1	1, 2	2, 4, 5, 6
	Virial theorem	1	2	2, 4, 5, 6
	Constructing stellar models, Relation among stellar quantities	1	1, 2	2, 4, 5, 6
	Tutorial: Nuclear energy production: Binding energy per nucleon, Efficiency of fusion	1	2	2, 4, 5, 6
	Important nuclear reactions in stars: pp chain, Neutrino production	1	2	2, 4, 5, 6
	Observed stellar spectra: Main sequence	1	1, 2, 3	2, 4, 5, 6
	Luminosity dependence on mass, Stellar classification based on spectra	1	1, 2, 3	2, 4, 5, 6
	Tutorial: Luminosity, Stellar classification	1	1, 2, 3	2, 4, 5, 6
Unit No. 3	**Stellar Structure & Sun as a star**	**9**		
	Saha ionization, HR diagram	1	2, 3	2, 4, 5, 6
	Tutorial: Saha ionization, HR diagram	1	2, 3	2, 4, 5, 6
	Solar spectrum, Effective Temperature, Solar Luminosity	1	2, 3	5, 6
	Photospheric absorption lines, Kelvin Time Scale	1	2, 3	5, 6
	Tutorial: Nuclear Fusion, Thompson Scattering, Mean free Path	1	2, 3	5,6
	Energy Transport in the Sun, Photon Diffusion inside the Sun	1	2, 3, 4	2, 5, 6
	Photosphere, Chromosphere	1	2, 3, 4	2, 5, 6
	Transition Region, Corona	1	2, 3, 4	2, 5, 6
	Tutorial:	1	2, 3, 4	5, 6

	X – Ray Emission, Magnetic Fields, Sunspots			
Unit No. 4	**Stellar evolution, Galaxy**	9		
	Stellar evolution: Mass loss from stars, Stellar winds	1	3, 4	5, 6
	Tutorial: Supernovae, White Dwarf	1	3, 4	2, 5, 6, 7
	Neutron star, Chandrasekhar limit	1	4	2, 5, 6, 7
	Black hole	1	4	2, 5, 6, 7
	Tutorial: Extra solar planet	1	4	5, 6
	Binary Systems: Classification of Binary Stars	1	1, 4	3, 5, 6
	Basic Structure & properties of different types of Galaxies, Milky Way	1	3, 4	3, 5, 6
	Tutorial: Milky Way cont2 ., Nature of rotation of Milky Way	1	3, 4	3, 5
	Nature of rotation continues (Differential rotation of the Galaxy), Brief idea of Dark Matter	1	3, 4	3, 5
Unit No. 5	**Recent Observations in Astronomy**	**9**		
	Accretion (gas accretion onto black holes or neutron stars.)	1	4, 5	2, 5, 7
	Accretion cont. (Origin of accreted gas, geometry (Bondi/disk))	1	4, 5	2, 5, 7
	Tutorial: Astronomical Instruments: Basic Optical Definitions for Magnification, Light Gathering Power	1	5	4, 5, 7
	Tutorial: Astronomical Instruments cont.: Limiting magnitude, Resolving Power, Diffraction Limit	1	5	4, 5, 7
	Tutorial: Astronomical Instruments cont.: Optical telescopes, Hubble space telescope	1		4, 5, 7
	A brief introduction to the theory of Gravitational waves: An introduction to how LIGO works? Discoveries of 2015 and 2017 GWs signal	1	5	7
	Open questions in Astrophysics	1	4, 5	2, 5, 7
	Why to look beyond the Astrophysical scale - Gateway to Cosmology	1	4, 5	2, 3, 5, 7
	What Cosmology deals with	1	5	2, 3, 5
Total contact hours		**45**		

Learning Assessment

Bloom's Level of Cognitive Task		**Continuous Learning Assessments (50 %)**								**End Semester Exam (50 %)**	
		CLA-1 (15 %)		**CLA-2 (15 %)**		**CLA-3 (__%)**		**Mid Term (20 %)**			
		Th	**Prac**	**Th**	**Prac**	**Th**	**Prac**	**Th**	**Prac**	**Th**	**Prac**
Level 1	Remember Understand	30%	-	30%	-	-	-	40%	-	30%	-
Level 2	Apply Analyse	70%	-	70%	-	-	-	60%	-	70%	-
Level 3	Evaluate Create	-	-	-	-	-	-	-	-	-	-
Total		**100%**		**100%**				**100%**		**100%**	-

Recommended Resources

1. Padmanabhan, T. (2000). Theoretical astrophysics, Vol-1: Astrophysical processes, 1st ed. Cambridge: Cambridge University Press.
2. Padmanabhan, T. (2001). Theoretical astrophysics, Vol-II: Stars and stellar systems, 1st ed. Cambridge: Cambridge University Press.
3. Padmanabhan, T. (2002). Theoretical astrophysics, Vol-III: Galaxies and cosmology, 1st ed. Cambridge: Cambridge University Press.
4. Jain, P. (2010). An introduction to astronomy and astrophysics, 1st ed. Cambridge: Cambridge University Press.
5. Carroll, B. W., & Ostlie, D. A. (2007). An introduction to modern astrophysics, 2nd ed. Pearson Addison Wesley.
6. Choudhuri, A. R. (2007). Astrophysics for physicists, 1st ed. Cambridge: Cambridge University Press.
7. Webpage link for LIGO:
8. https://labcit.ligo.caltech.edu/~rana/docs/LIGO_Science.pdf
9. https://labcit.ligo.caltech.edu/~ajw/gwaves_review.pdf
10. https://indico.cern.ch/event/806259/attachments/1922819/3186014/CERN_Academic_Lecture_1_Jo_van_den_Brand.pdf
11. https://indico.cern.ch/event/806260/attachments/1923785/3186015/CERN_Academic_Lecture_2_Jo_van_den_Brand.pdf
12. https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.116.061102
13. https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.119.161101
14. g) https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.125.101102

Other Resources

General Relativity and Cosmology

Course Code	PHY 557	**Course Category**	CE		**L**	**T**	**P**	**C**
					2	1	0	3
Pre-Requisite Course(s)		**Co-Requisite Course(s)**		**Progressive Course(s)**				
Course Offering Department	Physics	**Professional / Licensing Standards**						

Course Objectives / Course Learning Rationales (CLRs)

1. To introduce the mathematical basis of Einstein's General Relativity (GR) which is defined in the background of curved spacetime
2. To introduce the concept of curvature tensors
3. To construct the Einstein's equation of motion in GR
4. To obtain the solution of the Einstein's equations for different black hole spacetime
5. To introduce the concept of time dependent FLRW metric and its several characteristics:

Course Outcomes / Course Learning Outcomes (CLOs)

	At the end of the course the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	Apply tensor algebra in GR, relate to the concept of curvature tensors, principle of equivalence in SR and GR and derive Einstein's equation	3	70%	65%
Outcome 2	Understand parallel transport and diffeomorphism, solve the vacuum solution of the Einstein's equation	2	70%	65%
Outcome 3	Illustrate Schwarzschild geometry under several coordinate transformations, analyse Reissner-Nordstrom BH solution	4	70%	65%
Outcome 4	Relate to the Kerr BH and FLRW metric in cosmology and illustrate Penrose diagramme	4	65%	60%
Outcome 5	Evaluate perihelion precession, bending of light, gravitational redshift, relate scale factor with the cosmological evolution and interpret inflationary cosmology along with big bang nucleosynthesis	5	65%	60%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	**Program Learning Outcomes (PLO)**														
	Scientific and Disciplinary Knowledge	**Analytical Reasoning and Problem Solving**	**Critical and Reflective Thinking**	**Scientific Reasoning and Design Thinking**	**Research Related Skills**	**Modern Tools and ICT Usage**	**Environment and Sustainability**	**Moral, Multicultural and Ethical Awareness**	**Individual and Teamwork Skills**	**Communication Skills**	**Leadership Readiness Skills**	**Self-Directed and Life Long Learning**	**PSO 1**	**PSO 2**	**PSO 3**
Outcome 1	3	3	3	3	2	1			3			3	3	1	1
Outcome 2	3	3	3	3	2	1			2			3	3	2	1
Outcome 3	3	3	3	3	3	1			3			3	3	2	1
Outcome 4	3	3	3	3	3	1			3			3	3	2	1
Outcome 5	3	3	3	3	3	1			3			3	3	2	1
Average	**3**	**3**	**3**	**3**	**2.2**	**1**			**3**			**3**	**3**	**2.2**	**1**

Course Unitization Plan

Unit No.	Syllabus Topics	Required Contact Hours	CLOs Addressed	References Used
Unit No. 1	**Tensor algebra**	9		
	Motivation: Why we need GR over Newtonian Gravitational Theory?	1	1	1, 3
	Review of Special Relativity (SR) and Lorentz algebra	1	1	1, 2
	Tutorial: Metric algebra	1	1	1, 3
	Diffeomorphism	1	1, 2	1, 3, 4
	Covariant and Contravariant tensors	1	1	1, 3, 4, 5
	Tutorial: Tensor algebra	1	1	1, 3, 4, 5
	Covariant and Contravariant tensors under General Coordinate Transformation (GCT)	1	1	1, 3, 4, 5
	Parallel Transport	1	1, 2	1, 3, 4
	Tutorial: Additional problems on tensor algebra	1	1, 2	1, 3, 4
Unit No. 2	**Curvature tensors & Einstein's equation**	9		
	Affine Connection	1	1, 2	1, 3, 4, 5
	Use of curvature tensors in GR: Riemann curvature tensor	1	1, 2	1, 3, 4, 5
	Tutorial: Properties of Affine Connection	1	1, 2	1, 3, 4, 5
	Properties of Riemann curvature tensor cont.	1	1, 2	1, 3, 4, 5
	Ricci tensor, Ricci scalar	1	1, 2	1, 3, 4, 5
	Tutorial: Christoffel connection, tensor algebra	1	1, 2	1, 3, 4, 5
	Einstein's equation in GR	1	1, 2	1, 3, 4, 5
	Principle of Equivalence in SR and GR	1	1, 2	1, 3, 4, 5
	Tutorial: Curvature tensor	1	1, 2	1, 3, 4, 5
Unit No. 3	Einstein's equation & it's solutions	9		
	Energy momentum tensor	1	2, 3	1, 4, 5
	Spherically symmetric solution of Einstein's equation	1	2, 3	1, 3, 4, 5
	Tutorial: Curvature tensor, Einstein's tensor	1	1, 2, 3	1, 3, 4, 5
	Birkhoff's theorem	1	3	1, 3, 4
	Schwarzschild geometry	1	2, 3	1, 3, 4, 5
	Tutorial: Energy momentum tensor	1	2, 3	1, 4, 5
	Spacetime diagram of Schwarzschild geometry	1	2, 3	1, 3, 4, 5
	Tests of Einstein's equation: Perihelion precession	1	5	1
	Tutorial: Schwarzschild black hole	1	2, 3	1, 3, 4, 5
Unit No. 4	**Black hole solution**	9		
	Bending of light	1	5	1
	Gravitational redshift	1	5	1
	Tutorial: Tests of Einstein's GR	1	5	1
	Reissner-Nordstrom (RN) geometry	1	3, 4	1, 3, 4, 5
	Kerr geometry	1	3, 4	1, 3, 4, 5
	Tutorial: RN and Kerr black hole	1	3, 4	1, 3, 4, 5
	Penrose coordinate	1	3, 4	1, 3, 4, 5
	Penrose diagramme	1	3, 4	1, 3, 4, 5
	Tutorial: RN and Kerr black hole	1	3, 4	1, 3, 4, 5
Unit No. 5	**Introduction to Cosmology**	9		
	Why to learn Cosmology? Cosmological principle	1	4, 5	1, 3
	Friedmann–Lemaître–Robertson–Walker (FLRW) metric	1	4, 5	1, 3
	Tutorial: FLRW metric	1	4, 5	1, 3
	Characteristics of FLRW metric cont.	1	4, 5	1, 3
	Equation of state	1	4, 5	1, 3
	Tutorial: FLRW metric, equation of state	1	4, 5	1, 3
	Hubble constant	1	4, 5	1, 3
	Introduction to Inflationary cosmology	1	4, 5	1, 3
	Tutorial: Inflation	1	4, 5	1, 3
Total contact hours		**45**		

Learning Assessment

Bloom's Level of Cognitive Task		Continuous Learning Assessments (50 %)								End Semester Exam (50 %)	
		CLA-1 (15 %)		CLA-2 (15 %)		CLA-3 (__%)		Mid Term (20 %)			
		Th	Prac	Th	Prac	Th	Prac	Th	Prac	Th	Prac
Level 1	Remember	30%	-	20%	-	-	-	40%		30%	
	Understand										
Level 2	Apply	70%	-	60%	-	-	-	60%		50%	
	Analyse										
Level 3	Evaluate	-	-	20%	-	-	-	-		20%	
	Create										
Total		**100%**	-	**100%**	-	**-**	**-**	**100%**		**100%**	

Recommended Resources

1. Padmanabhan, T. (2010). Gravitation: Foundation and frontiers, 1st ed. Cambridge: Cambridge University Press.
2. Cresser, J. D. (2018). Lecture notes on special relativity, 1st ed. Department of Physics, Macquarie University.
3. Carroll, S. M. (2019). An introduction to general relativity: Spacetime and geometry, 2nd ed. Cambridge: Cambridge University Press.
4. Blau, M. (2009). Lecture notes on general relativity, 1st ed. Albert Einstein Centre for Fundamental Physics, CH-3012 Bern, Switzerland.
5. Townsend, P. K. (2011). Black holes, 1st ed. Lecture notes. DAMTP, University of Cambridge.

Other Resources

Standard Model of Particle Physics

						L	T	P	C
Course Code	PHY 558	**Course Category**	CE			2	1	0	3
Pre-Requisite Course(s)		**Co-Requisite Course(s)**		**Progressive Course(s)**					
Course Offering Department	Physics	**Professional / Licensing Standards**							

Course Objectives / Course Learning Rationales (CLRs)

1. To understand the basic properties of Fundamental Particles and their interactions.
2. To introduce the concepts of Parton and Electroweak unification.
3. To discuss the Lagrangian of the Standard Model of Particle Physics, one of the most successful theories of the sub-atomic world.

Course Outcomes / Course Learning Outcomes (CLOs)

	At the end of the course the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	Understand the principles of relativistic kinematics to compute and interpret scattering cross sections and decay kinematics	2	70%	65%
Outcome 2	Develop a deeper understanding of the concept of particle exchange in mediating fundamental interactions, especially for QED and Electroweak theories	3	70%	65%
Outcome 3	Employ the concept of Partons and unification of fundamental forces to construct the Lagrangian of the Standard Model of Particle Physics	4	60%	55%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	Program Learning Outcomes (PLO)													
	Scientific and Disciplinary Knowledge	Analytical Reasoning and Problem Solving	Critical and Reflective Thinking	Scientific Reasoning and Design Thinking	Research Related Skills	Modern Tools and ICT Usage	Environment and Sustainability	Moral, Multicultural and Ethical Awareness	Individual and Teamwork Skills	Communication Skills	Leadership Readiness Skills	Self-Directed and Life Long Learning	PSO 1	PSO 2	PSO 3
Outcome 1	3	2	2	1	2	1	-	-	1	1	-	2	2	2	-
Outcome 2	3	3	3	2	3	1	-	1	2	2	-	3	3	3	1
Outcome 3	3	3	3	3	3	2	-	2	2	2	1	3	3	3	2
Average	**3**	**2.7**	**2.7**	**2**	**2.7**	**1.3**	**-**	**1.5**	**1.7**	**1.7**	**1**	**2.7**	**2.7**	**2.7**	**1.5**

Course Unitization Plan

Unit No.	Syllabus Topics	Required Contact Hours	CLOs Addressed	References Used
Unit No. 1	**Basics**	9		
	Introduction	1	1	1,3
	Relativistic kinematics: collision and decay kinematics	1	1	2,3,4, 5
	Tutorial – I: Mandelstam variables	1	1	2,3,4, 5
	Reaction thresholds, phase space	1	1	2,3,4, 5
	Fermi's golden Rule	1	1	2,3,4, 5
	Particle decays – Two body decays	1	1	2,3,4, 5
	Tutorial – II: Interaction Cross-section and Centre-of-mass frame	1	1	2,3,4, 5
	Differential cross sections	1	1	2,3,4, 5
	Tutorial – III: Computation of cross sections in laboratory frames	1	1	2,3,4, 5
Unit No. 2	**Interaction by particle exchange**	9		
	Time-ordered perturbation theory	1	1,2	2,3,4
	Feynman diagrams and virtual particles	1	1,2	2,3,4
	Introduction to QED	1	1,2	2,3,4
	Tutorial – I: Feynman rules in QED	1	1,2	2,3,4
	Electron-positron annihilation	1	1,2	2,3,4
	Tutorial – II: Compton Scattering	1	2	2,3,4
	Photons and Polarization vectors	1	2	2,3,4
	Photon Propagator	1	2	2,3,4
	Tutorial – III: Massive Vector Particles	1	2	2,3,4
Unit No. 3	**Deep inelastic scattering and Parton Model**	9		
	Rutherford scattering	1	1,2	1, 2,3,4,5
	e-p inelastic scattering and Form factors	1	1,2	2,3,4,5
	Partons and Parton Model	1	2,3	2,3,4,5
	Bjorken scaling	1	3	2,3,4,5
	Tutorial – I: Parton distribution function	1	3	1, 2,3,4,5
	Gluons, Colour quantum number	1	3	1, 2,3,4,5
	Tutorial – II: Altarelli-Parisi Equation	1	3	1, 2,3,4,5
	Quantum Chromodynamics	1	3	1, 2,3,4,5
	Tutorial – III: Hadon-Hadron collisions	1	2,3	1, 2,3,4,5
Unit No. 4	**Weak interactions and Electroweak unification**	9		
	Weak charge-current interaction, Parity violation	1	3	1, 2,3,4,5
	V-A structure of weak interaction, Muon Decay	1	2,3	1, 2,3,4,5
	Nuclear Beta decay	1	2,3	1, 2,3,4,5
	Neutral Current	1	3	1, 2,3,4,5
	Tutorial – I: Neutrino-electron and Neutrino-quark scattering	1	2,3	2,3,4,5
	Weak mixing angles and CKM matrix	1	2,3	2,3,4
	Tutorial – II: CP violation	1	3	2,3,4
	Weak isospin and Hypercharges	1	2,3	2,3,4
	Tutorial – III: Electroweak unification	1	2,3	2,3,4
Unit No. 5	**Symmetry Breaking and the Standard Model**	9		
	Global and Local gauge invariance	1	3	2,3,4
	Spontaneous symmetry breaking of global symmetry	1	3	2,3,4
	Higgs mechanism	1	3	2,3,4
	Tutorial – I: Spontaneous symmetry breaking of local symmetry	1	3	2,3,4
	Electroweak interaction – revisited	1	2,3	2,3,4
	Masses of the gauge bosons	1	2,3	2,3,4
	Masses of the fermions	1	2,3	2,3,4
	Tutorial – II: SM Lagrangian - I	1	2,3	2,3,4,5
	Tutorial – III: SM Lagrangian - II	1	2,3	2,3,4,5
Total contact hours		**45**		

Learning Assessment

Bloom's Level of Cognitive Task		Continuous Learning Assessments (50 %)								End Semester Exam (50 %)	
		CLA-1 (15 %)		CLA-2 (15 %)		CLA-3 (__%)		Mid Term (20 %)			
		Th	Prac	Th	Prac	Th	Prac	Th	Prac	Th	Prac
Level 1	Remember Understand	40%		40%				40%		30%	
Level 2	Apply Analyse	60%		60%				60%		70%	
Level 3	Evaluate Create										
Total		100%		100%				100%		100%	

Recommended Resources

1. Griffiths, D. (2008). Introduction to elementary particles, 2nd ed. Hoboken, NJ: Wiley Publishing.
2. Halzen, F., & Martin, A. D. (1984). Quarks and leptons, 1st ed. New York: Wiley Publishing.
3. Pal, P. B. (2015). An introductory course on particle physics, 1st ed. Boca Raton, FL: CRC Press.
4. Peskin, M. E., & Schroeder, D. V. (1995). Concepts of elementary particle physics, 1st ed. Oxford: Oxford University Press.
5. Thomson, M. (2013). Modern particle physics, 1st ed. Cambridge: Cambridge University Press.

Other Resources

1. Review of Particle Physics: https://iopscience.iop.org/article/10.1088/1674-1137/40/10/100001
2. MIT Course: https://ocw.mit.edu/courses/8-811-particle-physics-ii-fall-2005/pages/lecture-notes/
3. Lecture Notes by David Tong: https://www.damtp.cam.ac.uk/user/tong/pp/pp.pdf

Quantum Field Theory

Course Code	PHY 571	**Course Category**	CE		**L**	**T**	**P**	**C**
					2	1	0	3
Pre-Requisite Course(s)		**Co-Requisite Course(s)**		**Progressive Course(s)**				
Course Offering Department	Physics	**Professional / Licensing Standards**						

Course Objectives / Course Learning Rationales (CLRs)

1. To review concepts of different symmetry principles in physics
2. To study the classical field theory
3. To learn method of quantization of fields in terms of creation and annihilation operators
4. To study S-matrix formalism and to obtain Feynman rules
5. To evaluate scattering and decay rates

Course Outcomes / Course Learning Outcomes (CLOs)

	At the end of the course the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	Understand the concept of fields, use Lorentz and Poincare transformation and relate to the classical theory of fields	2	70%	65%
Outcome 2	Derive Euler Lagrange equation of motion and relate to the concept of the quantization of fields	3	70%	65%
Outcome 3	Connect to scalar, fermion and vector fields quantisation and apply to real-world systems	4	70%	65%
Outcome 4	Illustrate the concept of Feynman diagrams, and use it to different processes in order to evaluate cross-sections and decay widths	5	65%	60%
Outcome 5	Solve and discuss advanced problems involving different interactions amongst fields of different spins	4	65%	60%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	Program Learning Outcomes (PLO)													
	Scientific and Disciplinary Knowledge	Analytical Reasoning and Problem Solving	Critical and Reflective Thinking	Scientific Reasoning and Design Thinking	Research Related Skills	Modern Tools and ICT Usage	Environment and Sustainability	Moral, Multicultural and Ethical Awareness	Individual and Teamwork Skills	Communication Skills	Leadership Readiness Skills	Self-Directed and Life Long Learning	PSO 1	PSO 2	PSO 3
Outcome 1	3	3	3	2	2	2			3	2		2	3	1	1
Outcome 2	3	3	3	2	2	2			3	2		3	3	2	1
Outcome 3	3	3	3	2	2	2			3	2		3	3	2	1
Outcome 4	3	3	3	2	3	2			3	2		3	3	2	1
Outcome 5	3	3	3	2	3	2			3	2		3	3	2	1
Average	**3**	**3**	**3**	**2**	**2.4**	**2**			**3**	**2**		**3**	**3**	**2**	**1**

Course Unitization Plan

Unit No.	Syllabus Topics	Required Contact Hours	CLOs Addressed	References Used
Unit No. 1	Concept of fields, Relativistic quantum mechanics	1	1	4, 5, 6 A, B
	Lorentz and Poincare transformation	1	1	1, 6
	Tutorial I: Lorentz and Poincare transformations	1	1	1, 6
	Review of Special Relativity	1	1	1
	Lagrangian and Hamiltonian in classical field theory	1	1, 2	A
	Tutorial II: Problems related to Lagrangian formalism in classical mechanics	1	1, 2	1
	Lagrangian and Hamiltonian density in field theory, Action in field theory, energy momentum tensor	1	1, 2	4, 6, A
	Principle of least action and derivation of the Euler-Lagrange equation	1	2	4, 5, 6, A, B
	Tutorial III: Problem solving on classical field theory	1	2	4, A
Unit No. 2	Discrete and continuous symmetries, Noether's Theorem	1	2	4, 5, 6, A,
	Lie Groups and Lie algebra	1	2	6
	Tutorial I: Problem solving on symmetries, group properties	1	2	6
	Hamiltonian formalism, conjugate momentum	1	2, 3	4, A
	Derivation of the Klein Gordon equation, Canonical quantisation: concept	1	2, 3	4, A, B
	Tutorial II: problems on Hamiltonian formalism and conjugate momenta	1	2, 3	4, 5, 6, A, B
	Canonical quantisation: creation and annihilation operators, commutation relations in field theory	1	2, 3	4, A
	Free scalar field theory: concept of the vacuum, normal ordering	1	2, 3	4, A
	Tutorial III: correlation functions, operators	1	2, 3	4, A
Unit No. 3	Multiparticle states, bosonic states, Fock space, and relativistic normalisation	1	2, 3	4, 6, A
	Complex scalar fields	1	2, 3	4, 5, 6, A
	Tutorial I: Causality analysis based on spacelike, timelike and lightlike intervals	1	2, 3	4, 5, A
	Propagators, concept of time ordering	1	2, 3	4, 5, 6, A, B
	Wick's theorem	1	2, 3	4, 6, A

	Tutorial II: Recovering quantum mechanics	1	2, 3	A
	Interacting picture, Dyson series, Feynman graphs	1	2, 3, 4	4, 6, A, B
	The Yukawa Potential, ϕ^4 theory	1	2, 3, 4	4, 5, 6, A, B
	Tutorial III: Feynman diagrams for different processes	1	2, 3, 4	4, 5, 6, A, B
Unit No. 4	Dirac equation and its solutions, concept of gamma matrices	1	3, 4	4, 5, 6, A, B
	Helicity and chirality	1	3, 4	4, 6, A
	Tutorial I: Gamma matrix algebra	1	3, 4	4, 6, A
	Representation of spinors	1	3, 4	4, 6, A
	Dirac field quantisation, Feynman propagator, Yukawa theory	1	3, 4	4, 6, A
	Tutorial II: Feynman rules for fermions	1	3, 4	4, 6, A
	Derivation of Maxwell's equation, representation in covariant form	1	3, 4	4, 6, A, B
	Introduction to Quantum Electrodynamics (QED) (concept of gauge choice)	1	3, 4	4, 6, A, B
	Tutorial III: Maxwell's equation, Feynman rules for spin 1 fields	1	3, 4	4, 6, A
Unit No. 5	Review of partial wave theory in quantum mechanics	1	4, 5	2, 3
	Kinematics in scattering and decay	1	4, 5	2, 3
	What we measure: S-matrix, optical theorem and cross section (Mandelstam variables)	1	4, 5	4, 6, B
	Tutorial I: Examples in ϕ^4 theory	1	4, 5	4, 6, A
	Fermi Golden Rule	1	4, 5	2, 4, 6, A
	Tutorial II: Problems of decay processes	1	4, 5	2, 3, 4, 6
	Examples of physical processes: electron scattering	1	4, 5	4, 6, A
	Concept of renormalisation (qualitative)	1	4, 5	4, 5, 6
	Tutorial III: Compton scattering	1	4, 5	4, 5, 6

Learning Assessment

Bloom's Level of Cognitive Task		Continuous Learning Assessments (50 %)								End Semester Exam (50 %)	
		CLA-1 (15 %)		CLA-2 (15 %)		CLA-3 (__%)		Mid Term (20 %)			
		Th	Pr.	Th	Pr.	Th	Pr.	Th	Pr.	Th	Pr.
Level 1	Remember	30%		20%				50%		30%	
	Understand										
Level 2	Apply	70%		60%				40%		50%	
	Analyse										
Level 3	Evaluate			20%				10%		20%	
	Create										
Total		**100%**		**100%**				**100%**		**100%**	

Recommended Resources

1. "Classical Mechanics", Herbert Goldstein, Pearson Education.
2. "Modern Quantum Mechanics", J. J. Sakurai, Addision-Wesley Publishing Company
3. "Principles of Quantum Mechanics", R. Shankar, Plenum Press, New York and London
4. "An Introduction to Quantum Field Theory" by M E. Peskin, D V. Schroeder, The Advanced Book Programme, Perseus Books
5. "A Modern Introduction to Quantum Field Theory", Michele Maggiore, Oxford University Press
6. "Quantum Field Theory and the Standard Model", Matthew D. Schwartz, Cambridge University Press

Other Resources

1. http://www.damtp.cam.ac.uk/user/tong/qft.html ("Quantum Field Theory", lectures by David Tong, Part-III, University of Cambridge)
2. https://www.youtube.com/playlist?list=PL1iySp9JVsLltlFByt1e5Aq5uF1tV5_hB (Video lecture by Ashok Sen on QFT-I)

Quantum Optics

Course Code	PHY 559	Course Category	CE		L	T	P	C
					2	1	0	3
Pre-Requisite Course(s)	BSC level Quantum Mechanics and Introduction to Optics courses	**Co-Requisite Course(s)**		**Progressive Course(s)**				
Course Offering Department	Physics	**Professional / Licensing Standards**						

Course Objectives / Course Learning Rationales (CLRs)

1. To provide a modern understanding for the quantum nature of light.
2. To learn the interaction of atoms with light – classical, semi-classical and quantum pictures.
3. To learn the quantum statistical properties of both classical and quantum light.
4. To explore the various techniques for generating and detecting the quantum sources of light.
5. To explore the applications or protocols implemented using quantum sources of light.

Course Outcomes / Course Learning Outcomes (CLOs)

	At the end of the course the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	Describe light and its quantum nature	2	70%	65%
Outcome 2	Review and apply the fundamental concepts for understanding the field quantization and its interaction with atoms	3	70%	65%
Outcome 3	Investigate the classical and quantum states using the coherence properties	4	65%	60%
Outcome 4	Interpret experimental understanding of quantum nature of light	3	60%	55%
Outcome 5	Verify the quantum nature of light using optical cryptography and communication.	5	60%	55%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	Program Learning Outcomes (PLO)													
	Scientific and Disciplinary Knowledge	Analytical Reasoning and Problem Solving	Critical and Reflective Thinking	Scientific Reasoning and Design Thinking	Research Related Skills	Modern Tools and ICT Usage	Environment and Sustainability	Moral, Multicultural and Ethical Awareness	Individual and Teamwork Skills	Communication Skills	Leadership Readiness Skills	Self-Directed and Life Long Learning	PSO 1	PSO 2	PSO 3
Outcome 1	3	3	3	3	2			2	3	3	2	2	3		3
Outcome 2	3	3	3	3	2			3	2	3	2	3	3		2
Outcome 3	3	3	3	3	2			2	3	2	2	3	3		3
Outcome 4	3	3	3	3	3			2	3	2	1	3	3		2
Outcome 5	3	3	3	3	3			2	3	2	1	3	3		3
Average	**3**	**3**	**3**	**3**	**2.4**			**2.2**	**2.8**	**2.4**	**1.6**	**2.8**	**3**		**2.6**

Course Unitization Plan

Unit No.	Syllabus Topics	Required Contact Hours	CLOs Addressed	References Used
Unit No. 1	**Quantization of the Field**	**9**		
	Introduction and Quantization of Single Mode Field	1	1,2	1,3
	Quantum Fluctuation and Thermal Fields	1	1,2	1,3
	Tutorial I: Quantization	1	1,2	1,3
	Vacuum Fluctuations and Zero Point Energy	1	1,2	1,3
	Quantum Phase	1	1,2	1,3,4
	Tutorial II: Quantum Phase	1	1,2	1,3,4
	Quantum States – Coherent States and their Properties	1	1,2	1,3,4
	Density Operators	1	1,2	1,3,4
	Tutorial III: Density Operators	1	1,2	1,3
Unit No. 2	**Radiation by Atoms**	**9**		
	Atom Field Interaction – Classical	1	1,2	1,3
	Interaction of Atom with Quantized Field	1	1,2	1,3
	Tutorial IV: Quantum field theory	1	1,2	1,3
	The Rabi Model	1	1,2	1,3
	Jaynes Cummings Model	1	1,2	1,3
	Tutorial V: Spectroscopic models	1	1,2	1,3
	The Dressed States	1	1,2	1,3
	Schmidt Decomposition	1	1,2	1,3
	Tutorial VI: Schmidt Decomposition	1	1,2	1,3
Unit No. 3	**Quantum Coherence**	**9**		
	Classical Coherence – Temporal and Spatial	1	3	1,3
	Quantum Coherence Functions and Quantum Picture for Young's Interference	1	3	1,3
	Tutorial VII: Coherence	1	3	1,3
	Higher Order Coherence Functions		3	1,3
	Photon Statistics – Coherent and Thermal Fields	1	3	2
	Tutorial VIII: Photon Statistics	1	3	2
	Photon Statistics – Quantum Fields	1	3	2
	Experimental Measurement of Photon Statistics	1	3	2
	Tutorial IX: Experimental techniques	1	3	1,2,3
Unit No. 4	**Quantum Mechanical Validation**	**9**		
	Photon Sources – SPDC	1	4,5	2,3
	HOM Interferometer and Quantum Eraser	1	4,5	2,3
	Tutorial X: Entangled sources	1	4,5	2,3
	Verification of Bells Theorem and Franson's Experiment	1	4,5	2,3
	Entanglement with Scalar and Vector Fields	1	4,5	2,3
	Tutorial XI: Bells theorem	1	4,5	2,3
	Interaction of Rydberg Atom with Cavity Field	1	4,5	2,3
	Schrodinger Cat States	1	4,5	2,3
	Tutorial XII: Cat states	1	4,5	1,2,3
Unit No. 5	**Quantum Protocols**	**9**		
	Quantum Teleportation	1	4,5	2,3
	Quantum Cryptography – BB84 Protocol	1	4,5	2,3
	Tutorial XIII: Information security	1	4,5	2,3
	Quantum Random Number Generator	1	4,5	2,3
	Metrology with Quantum Optical Sources	1	4,5	2,3
	Tutorial XIV: Random number	1	4,5	2,3
	Quantum Radar and Communication	1	4,5	2,3
	Higher Dimensional Entangled States	1	4,5	2,3
	Tutorial XV: Higher Dimensional Entangled States	1	4,5	1,2,3
Total contact hours		**45**		

Learning Assessment

Bloom's Level of Cognitive Task		Continuous Learning Assessments (50 %)								End Semester Exam (50 %)	
		CLA-1 (15 %)		CLA-2 (15 %)		CLA-3 (__%)		Mid Term (20 %)			
		Th	Prac	Th	Prac	Th	Prac	Th	Prac	Th	Prac
Level 1	Remember Understand	40%		40%				40%		30%	
Level 2	Apply Analyse	60%		40%				60%		50%	
Level 3	Evaluate Create			20%						20%	
Total		**100%**		**100%**				**100%**		**100%**	

Recommended Resources

1. Gerry, C. C., & Knight, P. L. (2005). Introductory quantum optics, 1st ed. Cambridge: Cambridge University Press.
2. Fox, M. (2006). Quantum optics, 1st ed. Oxford: Oxford University Press.
3. Mandel, L., & Wolf, E. (2013). Optical coherence and quantum optics, 1st ed. Cambridge: Cambridge University Press.
4. Sakurai, J. J. (1967). Advanced quantum mechanics, 1st ed. New Delhi: Pearson Education India.

Other Resources

SRM University *AP*, Andhra Pradesh
Neerukonda, Mangalagiri Mandal,
Guntur District, Mangalagiri, Andhra Pradesh – 522240.

Advanced Quantum Mechanics

Course Code	PHY 560	**Course Category**	CE		**L**	**T**	**P**	**C**
					2	1	0	3
Pre-Requisite Course(s)	BSC level Introduction to Quantum Mechanics	**Co-Requisite Course(s)**		**Progressive Course(s)**				
Course Offering Department	Physics	**Professional / Licensing Standards**						

<u>Course Objectives / Course Learning Rationales (CLRs)</u>

1. To provide a modern understanding for the quantum nature of light.
2. To learn the interaction of atoms with light – classical, semi-classical and quantum pictures.
3. To learn the quantum statistical properties of both classical and quantum light.
4. To explore the various techniques for generating and detecting the quantum sources of light.
5. To explore the applications or protocols implemented using quantum sources of light

<u>Course Outcomes / Course Learning Outcomes (CLOs)</u>

	At the end of the course the learner will be able to	**Bloom's Level**	**Expected Proficiency Percentage**	**Expected Attainment Percentage**
Outcome 1	Describe light and its quantum nature	2	70%	65%
Outcome 2	Review fundamental concepts of field quantization and its interaction with atoms	2	70%	65%
Outcome 3	Interpret classical and quantum states using the coherence properties	3	70%	65%
Outcome 4	Interpret experimental understanding of quantum nature of light	4	70%	65%
Outcome 5	Illustrate quantum nature of light in cryptography and communication.	4	70%	65%

<u>Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)</u>

CLOs	**Program Learning Outcomes (PLO)**														
	Scientific and Disciplinary Knowledge	**Analytical Reasoning and Problem Solving**	**Critical and Reflective Thinking**	**Scientific Reasoning and Design Thinking**	**Research Related Skills**	**Modern Tools and ICT Usage**	**Environment and Sustainability**	**Moral, Multicultural and Ethical Awareness**	**Individual and Teamwork Skills**	**Communication Skills**	**Leadership Readiness Skills**	**Self-Directed and Life Long Learning**	**PSO 1**	**PSO 2**	**PSO 3**
Outcome 1	3	3	3	3	2				3			2	3	1	2
Outcome 2	3	3	3	3	2				2			3	3	2	2
Outcome 3	3	3	3	3	2				3			3	3	2	2
Outcome 4	3	3	3	3	3				3			3	3	2	2
Outcome 5	3	3	3	3	3				3			3	3	2	2
Average	**3**	**3**	**3**	**3**	**2.4**				**2.8**			**2.8**	**3**	**1.8**	**2**

Course Unitization Plan

Unit No.	Syllabus Topics	Required Contact Hours	CLOs Addressed	References Used
Unit No. 1	**Axiomatic quantum mechanics**	**9**		
	Postulates (state, evolution, measurement, compositeness)	1	1,5	1,2
	Features of quantum mechanics: Entaglement (Bell states),	1	1,5	1,2
	no-cloning theorem	1	1,5	1,2,3
	teleportation	1	1,5	
	EPR paradox	1	1,5	1,2
	Bell inequality	1	1,5	1,2
	Quantum circuits: reversibility, controlled gates,	1	1,5	1,2
	Quantum circuits: Hadamard gate, oracle	1	1,5	
	Tutorial: Review problems	1	1,5	1,2
Unit No. 2	**Many-body systems-I**	**9**		
	First and second quantization	1	2,5	1,2
	Tutorial I: First and second quantization	1	2,5	1,2
	Tutorial II: First and second quantization	1	2,5	1,2
	Hartree-Fock-, self-consistent-field	1	2,5	1,2
	Problems on Hartree-Fock-, self-consistent-field	1	2,5	1,2
	coupled-cluster methods	1	2,5	1,2
	Classical coupled-cluster emulation of a closed-shell nucleus	1	2,5	1,2
	Example on O16	1	2,5	1,2
	Review problems	1	2,5	
Unit No. 3	**Many Boday Systems- II**	**9**		
	First and second quantised encoding methods: basis-set and real-space	1	2,5	1,2,3
	First and second quantised encoding methods: Jordan-Wigner	1	2,5	1,2,3
	Bravyi-Kitaev	1	2,5	1,2,3
	Quantum phase estimation		2,5	1,2,3
	Problems on Quantum phase estimation	1	2,5	1,2,3
	Tutorial-I	1	2,5	1,2
	Tutorial-II	1	2,5	1,2
	Tutorial-III	1	2,5	1,2
	Variational algorithms	1	2,5	1,2
Unit No. 4	**Error corrections and cryptography**	**9**		
	Quantum decoherence	1	3,5	1,2,3
	Density matrix	1	3,5	1,2,3
	Problems on density matrix	1	3,5	1,2,3
	Quantum cryptography Introduction	1	3,5	1,2,3
	Key distributions	1	3,5	1,2,3
	Di Vincenzo criterion	1	3,5	1,2,3
	Tutorial- I	1	3,5	1,2,3
	Tutorial-II	1	3,5	1,2,3
	Tutorial-III	1	3,5	1,2,3
Unit No. 5	**Quantum communication devices**	**9**		
	Ion traps	1	4,5	1,2
	Qubit operations	1	4,5	1,2
	Quantum circuits	1	4,5	1,2
	Qualitative discussions on cavity QED	1	4,5	1,2
	Tutorial on qubit operation	1	4,5	1,2,3
	Tutorial on quantum circuits	1	4,5	1,2,3
	Review problem-I	1	4,5	1,2,3
	Review problem-II	1	4,5	1,2
	Overview and challenges	1	4,5	

Learning Assessment

Bloom's Level of Cognitive Task		Continuous Learning Assessments (50 %)								End Semester Exam (50 %)	
		CLA-1 (15 %)		CLA-2 (15 %)		CLA-3 (__%)		Mid Term (20 %)			
		Th	Prac	Th	Prac	Th	Prac	Th	Prac	Th	Prac
Level 1	Remember Understand	40%		40%				40%		30%	
Level 2	Apply Analyse	60%		60%				60%		70%	
Level 3	Evaluate Create										
Total		**100%**		**100%**				**100%**		**100%**	

Recommended Resources

1. Nielsen, M. A., & Chuang, I. L. (2000). Quantum computation and quantum information, 1st ed. Cambridge: Cambridge University Press.
2. McArdle, S., Endo, S., Aspuru-Guzik, A., Benjamin, S. C., & Yuan, X. (2020). Quantum computational chemistry. Rev. Mod. Phys., 92(1), 015003. Retrieved from https://doi.org/10.1103/RevModPhys.92.015003
3. Schirmer, J. (2007). Many-body methods for atoms, molecules, and clusters, Lecture Notes in Chemistry 94. Berlin: Springer.

Other Resources

SRM University *AP*, Andhra Pradesh

Neerukonda, Mangalagiri Mandal,
Guntur District, Mangalagiri, Andhra Pradesh – 522240.

Quantum Information and Computation

Course Code	PHY 561	**Course Category**	CE		L	T	P	C
					2	1	0	3
Pre-Requisite Course(s)	PHY 213, PHY 316	**Co-Requisite Course(s)**		**Progressive Course(s)**				
Course Offering Department	Physics	**Professional / Licensing Standards**						

Course Objectives / Course Learning Rationales (CLRs)

1. To understand the advanced applications of quantum mechanics.
2. To understand the mathematical foundation of quantum bits and various quantum gates.
3. To understand various quantum algorithms and their potential applications.
4. To understand the quantum Fourier transform and quantum key distribution.
5. To experience the working of IBM quantum computer and its uses.

Course Outcomes / Course Learning Outcomes (CLOs)

	At the end of the course the learner will be able to	Bloom's Level	Expected Proficiency Percentage	Expected Attainment Percentage
Outcome 1	Explaining the qubits, quantum phenomena's such as quantum entanglement and quantum teleportation	2	70%	65%
Outcome 2	Employ the quantum gates and quantum circuits to qubit systems	3	70%	65%
Outcome 3	Illustrate the physical systems for quantum computer using entangles photons	4	70%	65%
Outcome 4	Interpret quantum algorithms, concept of quantum key distribution, and quantum protocols	4	70%	65%
Outcome 5	Use IBM quantum computer to perform the quantum computation	3	70%	65%

Course Articulation Matrix (CLO) to Program Learning Outcomes (PLO)

CLOs	**Program Learning Outcomes (PLO)**														
	Scientific and Disciplinary Knowledge	**Analytical Reasoning and Problem Solving**	**Critical and Reflective Thinking**	**Scientific Reasoning and Design Thinking**	**Research Related Skills**	**Modern Tools and ICT Usage**	**Environment and Sustainability**	**Moral, Multicultural and Ethical Awareness**	**Individual and Teamwork Skills**	**Communication Skills**	**Leadership Readiness Skills**	**Self-Directed and Life Long Learning**	**PSO 1**	**PSO 2**	**PSO 3**
Outcome 1	3	3	3	3	2				2			2	3	1	2
Outcome 2	3	3	3	2	3				2			3	3	2	1
Outcome 3	3	3	3	3	3				2			2	3	2	2
Outcome 4	3	3	3	3	3				2			2	3	2	2
Outcome 5	3	3	3	3	3				2			2	3	2	2
Average	**3**	**3**	**3**	**3**	**3**				**2**			**2**	**3**	**2**	**2**

Course Unitization Plan

Unit No.	Syllabus Topics	Required Contact Hours	CLOs Addressed	References Used
Unit No. 1	**Elementary units for quantum computation**	**9**	**1**	
	Pre-requisite ideas of quantum mechanics for quantum computation	1	1	1, 2, 3
	Single qubit and its representation in matrix and Bloch sphere	1	1	1, 2, 3
	Multiple qubits (two qubits, three qubits)	1	1	1, 2, 3
	Measurement in quantum computation	1	1	1, 2, 3
	Concept of quantum entanglement	1	1	1, 2, 3
	Quantification of entanglement and its applications	1	1	1, 2, 3
	Quantum teleportation	1	1	1, 2, 3
	Quantum dense coding (superdense coding)	1	1	1, 2, 3
	Tutorial/ Doubt clearing	1		1, 2, 3
Unit No. 2	**Quantum Gates**	**9**	**2**	
	Pauli Gates and Phase gates	1	2	1, 2, 3
	Controlled phase-shift gates and Hadamard gate	1	2	1, 2, 3
	CNOT gate	1	2	1, 2, 3
	Swap gate	1	2	1, 2, 3
	Toffoli gate	1	2	1, 2, 3
	Fredkin gate (controlled Swap gate)	1	2	1, 2, 3
	Combination of Gates	1	2	1, 2, 3
	Quantum circuit	1	2	1, 2, 3
	Tutorial/ Doubt clearing	1	2	1, 2, 3
Unit No. 3	**Physical realization of quantum bits and quantum gates**	**9**	**3**	
	Various physical systems for quantum computation	1	3	1, 2, 3
	Harmonic oscillator and connection with photons (field quantization)	1	3	1, 2, 3
	Photonic qubits and corresponding gates	1	3	1, 2, 3
	Entangled state generation using photons	1	3	1, 2, 3
	Quantum computation using photons	1	3	1, 2, 3
	Realization of optical CNOT gates	1	3	1, 2, 3
	Realization of quantum phase gate	1	3	1, 2, 3
	Demonstration of optical Fredkin gate	1	3	1, 2, 3
	Tutorial/ Doubt clearing	1	3	1, 2, 3
Unit No. 4	**Quantum Algorithm, Key Distribution**	**9**	**4**	
	Quantum Fourier Transformation (QFT)	1	4	1, 2, 3
	QFT for phase estimation	1	4	1, 2, 3
	Deutsch algorithm	1	4	1, 2, 3
	Deutsch-Josza algorithm	1	4	1, 2, 3
	Shor's Algorithm	1	4	1, 2, 3
	Introduction to Quantum key distribution	1	4	1, 2, 3
	BB84 protocol	1	4	1, 2, 3
	BB92 protocol	1	4	1, 2, 3
	Tutorial/ Doubt clearing	1	4	1, 2, 3
Unit No. 5	**Quantum computation in IBM quantum computer**	**9**	**5**	
	Introduction to the cloud-based IBM quantum computer	1	5	1, 2, 4
	Demonstration quantum computation on IBM quantum computer	1	5	1, 2, 4
	Single-qubit gates in IBM	1	5	1, 2, 4
	Two-qubit gates in IBM	1	5	1, 2, 4
	Realization of various 2 qubit gates using fundamental single and two-qubit gates	1	5	1, 2, 4
	Realization of various 3 qubit gates using fundamental single and two-qubit gates	1	5	1, 2, 4
	Experiencing IBM Kit by students – quantum gates	1	5	1, 2, 4
	Experiencing IBM Kit by students – quantum algorithms	1	5	1, 2, 4
	Tutorial/ Doubt clearing	1	5	1, 2, 4
Total contact hours		**45**		

Learning Assessment

<table>
<tr><th colspan="2" rowspan="3">Bloom's Level of Cognitive Task</th><th colspan="8">Continuous Learning Assessments (50 %)</th><th colspan="2" rowspan="2">End Semester Exam (50 %)</th></tr>
<tr><th colspan="2">CLA-1 (15 %)</th><th colspan="2">CLA-2 (15 %)</th><th colspan="2">CLA-3 (__%)</th><th colspan="2">Mid Term (20 %)</th></tr>
<tr><th>Th</th><th>Prac</th><th>Th</th><th>Prac</th><th>Th</th><th>Prac</th><th>Th</th><th>Prac</th><th>Th</th><th>Prac</th></tr>
<tr><td rowspan="2">Level 1</td><td>Remember</td><td rowspan="2">40%</td><td rowspan="2"></td><td rowspan="2">40%</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2">40%</td><td rowspan="2"></td><td rowspan="2">30%</td><td rowspan="2"></td></tr>
<tr><td>Understand</td></tr>
<tr><td rowspan="2">Level 2</td><td>Apply</td><td rowspan="2">60%</td><td rowspan="2"></td><td rowspan="2">60%</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2">60%</td><td rowspan="2"></td><td rowspan="2">70%</td><td rowspan="2"></td></tr>
<tr><td>Analyse</td></tr>
<tr><td rowspan="2">Level 3</td><td>Evaluate</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>Create</td></tr>
<tr><td colspan="2">Total</td><td>100%</td><td></td><td>100%</td><td></td><td></td><td></td><td>100%</td><td></td><td>100%</td><td></td></tr>
</table>

Recommended Resources

1. Nielsen, M. A., & Chuang, I. L. (2000). Quantum computation and quantum information, 1st ed. Cambridge: Cambridge University Press.
2. Kaye, P., Laflamme, R., & Mosca, M. (2007). An introduction to quantum computing, 1st ed. Oxford: Oxford University Press.
3. Pathak, A. (2013). Elements of quantum computation and communication, 1st ed. Boca Raton, FL: Taylor and Francis Group.
4. IBM QISKIT: https://quantum.ibm.com/composer

Other Resources