Program

Integrated MSc Mathematics-Physics Curriculum and Syllabi

(effective 2016 admissions onwards)

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Program and Program Specific Outcomes

Program Outcomes

PO1. **Scientific Knowledge and Pursuit:** Gain and apply knowledge of basic scientific and mathematical fundamentals, to develop deeper understanding of the Nature and apply it to develop new theories and models.

PO2. **Theoretical Methods & Problem Analysis:** Develop analytical skills to analyze complex phenomena using first principles enabling one to identify underlying structure.

PO3. **Experimental Skills andDevelopment of solutions:** Use of research-based knowledge and research methods including design of physical/computational experiments, Design of solutions for complex chemistry/physics/ mathematics problems and evolve procedures appropriate to a given problem.

PO4. **Computational, Numerical and Data Analysis:** Numerical analysis and simulation modeling and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5. **Modern Analytical Tool Usage:** Select, and apply appropriate techniques, resources, and modern analytical tools.

PO6. **Scientific Communication:**Communicate orally and in writing on complex scientific activities with peers, educators, science community, and with society at large, such as being able to comprehend and write effective scientific articles, make effective presentations, and give and receive clear instructions.

PO7. **Individual and team work:** Think critically and work independently, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO8. **Project management and finance:** Demonstrate knowledge and understanding of the scientific and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments

PO9. **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of scientific practice.

PO10. **The scientist and society:** Apply reasoning through the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional scientific practice.

PO11. **Environment and sustainability:** Understand the impact of scientific processes in societal and environmental contexts, and demonstrate the knowledge, and need for sustainable development.

PO12. **Life-long learning:** Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of scientific and technological changes for up-to-date research and teaching methods.

Program Specific Outcomes

PSO1. Students will demonstrate proficiency in mathematics and the mathematical concepts needed for a proper understanding of physics.

PSO2. Students will demonstrate knowledge of classical mechanics, electromagnetism, quantum mechanics, and thermal and statistical physics, and be able to apply this knowledge to analyze a variety of physical phenomena and related subjects like solid state, atomic & molecular, nuclear physics and other selected applied fields, including electronics.

PSO3. Students will show that they have learned laboratory skills, enabling them to take measurements in a physics laboratory and analyze the measurements to draw valid conclusions. In addition, students will demonstrate skills in solving problems numerically using computer programming, plotting tools, and related software.

PSO4. Students will be capable of oral and written scientific communication and will demonstrate that they can think critically and work independently as well as in a team and play beneficial role in the society as a person of science combined with value-based education, both in professional and personal lives.

Program Educational Objectives

To produce graduates in Mathematics/Physics, who, immediately after graduation or within five years of it will benefit from our program with the following program educational objectives:

1. To provide sufficient understanding of the fundamentals of mathematics and physics, with experimental and computational techniques, and lay a foundation for higher education in mathematics/physics and other related interdisciplinary fields, and lifelong learning.

2. To facilitate progressive careers in teaching, academia, research organizations and related industry.

3. To equip our students with sufficient communication and interpersonal, and teamwork skills to enable them to fulfil professional responsibilities, retaining scientific fervour in day-to-day affairs.

4. To expose them to value-based education with live-in-labs which will enable them to become ethical and responsible towards themselves, co-workers, the society and the Nation.

General Information

Code Numbering

Each course is assigned an 8-character Code number. The first two digits indicate the year of curriculum revision. The next three letters indicate the Department offering the course. The last three digits are unique to the course – the first digit indicates the level of the course (100, 200, 300, 400 etc.); the second digit indicates the type of the course, viz. 0, 1 and 2 indicate the core courses; 3,4,5,6 and 7 indicate the Elective courses; 8 indicates the Lab. or practical-based courses and 9 indicates Projects**.**

ABBREVIATIONS USED IN THE CURRICULUM

Cat-   Category
Cr -   Credits
ES -   Exam Slot
L   -   Lecture
P   -   Practical
T   -   Tutorial

DISCIPLINES

AVP   -   Amrita Values Programmes
BUS   -   Business Management
CHY   -   Chemistry
CMJ   -   Communication and Journalism
COM   -   Commerce
CSA   -   Computer Science and Applications
CSN   -   Computer Systems and Network
CUL   -   Cultural Education
ECO   -   Economics
ELL   -   English Language and Literature
ENG   -   English
ENV   -   Environmental Sciences
FNA   -   Fine Arts
HIN   -   Hindi
KAN   -   Kannada
LAW   -   Law
MAL   -   Malayalam
MAT   -   Mathematics
MCJ   -   Mass Communication and Journalism
OEL   -   Open Elective
PHY   -   Physics
SAN   -   Sanskrit
SSK   -   Soft Skills
SWK   -   Social Work
TAM   -   Tamil

Course Schedule

Semesters 1 – 6

Course Code	SEMESTER 1 Course Title	L T P	Cr	ES	Course Code	SEMESTER 2 Course Title	L T P	Cr	ES
15ENG101	Communicative English	2 0 2	3		15ENG121	Professional Communication	1 0 2	2	
	Language Paper I	1 0 2	2			Language Paper II	1 0 2	2	
15CHY102	Chemistry I	3 0 0	3		15CHY112	Chemistry II	3 0 0	3	
16CSA107	Introduction to Programming in C	3 0 0	3		16CSA118	Advanced Programming in C	3 0 2	4	
16MAT107	Calculus	3 1 0	4		16MAT118	Vector Calculus	3 1 0	4	
15PHY103	Mechanics	3 1 0	4		15PHY113	Electricity and Magnetism	3 1 0	4	
16CSA192	Introduction to Programming Lab. I	0 0 2	1		15ENV300	Environmental Science and Sustainability	3 0 0	3	
15CHY182	Chemistry Lab.	0 0 2	1		15PHY184	Physics Lab. I	0 0 3	1	
15CUL101	Cultural Education I	2 0 0	2		15CUL111	Cultural Education II	2 0 0	2	
	TOTAL		23			TOTAL		25	
	SEMESTER 3					SEMESTER 4			
15MAT222	Differential Equations	3 1 0	4		15MAT224	Probability and Statistics	3 1 0	4	
16MAT229	Introduction to Linear Algebra	3 1 0	4		16MAT238	Introduction to Modern Algebra	3 1 0	4	
16PHY200	History and Philosophy of Science	2 0 0	2		15MAT201	Discrete Mathematics	3 1 0	4	
16PHY204	Heat and Thermodynamics	3 1 0	4		16PHY215	Oscillations, Waves and Optics	3 1 0	4	
15PHY203	Basic Electronics	2 1 0	3		15PHY312	Intermediate Mechanics	3 1 0	4	
15PHY186	Physics Lab. II	0 0 2	1		16PHY286	Physics Lab. III	0 0 2	1	
16PHY282	Basic Electronics Lab.	0 0 2	1			Open Elective A*	3 0 0	3	
15SSK201	Life Skills I	1 0 2	2		15SSK211	Life Skills II	1 0 2	2	
15AVP201	Amrita Value Programme I		1		15AVP211	Amrita Value Programme II		1	
	TOTAL		22			TOTAL		27	
	SEMESTER 5					SEMESTER 6			
15MAT234	Numerical Methods	3 1 0	4		16MAT327	Introduction to Complex Analysis	3 1 0	4	
16MAT326	Introduction to Real Analysis	3 1 0	4		15MAT328	Introduction to Number Theory	3 1 0	4	
16PHY305	Intermediate Electrodynamics	3 1 0	4		16PHY315	Atomic, Molecular and Nuclear Physics	3 1 0	4	
16PHY306	Relativity and Modern Physics	3 1 0	4		16PHY316	Solid State Physics and Devices	3 1 0	4	
16BUS306	Fundamentals of Management	2 0 0	2			Elective A	3 0 0	3	
16MAT380	MATLAB	0 0 2	1		16MAT391	Mathematics Seminar	0 0 2	1	
16PHY391	Physics Seminar	0 0 2	1					20	
16MPJ390	Live in Lab.@ / Open Elective B*	3 0 0	3		16MPJ399	Project (for Exit-option students)		6	
15SSK301	Life Skills III	1 0 2	2			Total – for Exit-option students		26	
	Total		25						
Total 142 credits (For exit option students 148 credits)								

UG Electives (both Mathematics and Physics)

	ELECTIVE A (any ONE)								
15MAT337	Linear and Nonlinear Optimizations	3 0 0	3		15PHY331	Astronomy	3 0 0	3	
15MAT338	Special Functions	3 0 0	3		16PHY341	Introduction to Nonlinear Dynamics	3 0 0	3	
15MAT339	Testing of Hypothesis and Analysis of Variances	3 0 0	3		16PHY342	Mathematical Aspects of Mechanics	3 0 0	3	
15MAT340	Integral Transforms and Fourier Series	3 0 0	3		16PHY343	Physics of Semiconductor	3 0 0	3	
15MAT341	Introduction to Operations Research	3 0 0	3		16PHY344	Lasers and its Applications	3 0 0	3	
					15PHY535	Earth's Atmosphere	3 0 0	3	
					15PHY536	Earth's Structure and Evolution	3 0 0	3	

	LANGUAGES								
15HIN101	Hindi I	1 0 2	2		15HIN111	Hindi II	1 0 2	2	
15KAN101	Kannada I	1 0 2	2		15KAN111	Kannada II	1 0 2	2	
15MAL101	Malayalam I	1 0 2	2		15MAL111	Malayalam II	1 0 2	2	
15SAN101	Sanskrit I	1 0 2	2		15SAN111	Sanskrit II	1 0 2	2	
15TAM101	Tamil I	1 0 2	2		15TAM111	Tamil II	1 0 2	2	

@Project – 6 to 12 credits depending on the course.
* **Two Open Elective** courses are to be taken by each student, one each at the **4th and the 5th** semesters, from the list of Open electives offered by the School.
@ Students undertaking and registering for a Live-in-Lab project, can be exempted from registering for an Open Elective course in the fifth semester.

Semesters 7 – 10 Course Schedule (Physics Stream)

Curriculum for the Integrated M.Sc (PM) (Physics Stream) Semesters 7-10									
SEMESTER 7					**SEMESTER 8**				
15PHY501	Classical Mechanics	3 1 0	4		15PHY511	Quantum Mechanics ll	3 1 0	4	
15PHY503	Mathematical Physics I	3 1 0	4		15PHY512	Mathematical Physics II	3 1 0	4	
15PHY504	Quantum Mechanics I	3 1 0	4		15PHY513	Statistical Mechanics	3 1 0	4	
15PHY506	Computational Physics	3 1 0	4		15PHY514	Advanced Electrodynamics	3 1 0	4	
15PHY547	Optics	3 1 0	4		15PHY515	Experimental Techniques	3 1 0	4	
15PHY582	Simulation Lab.	0 0 3	1		15PHY585	Physics Lab. B	0 0 3	1	
15PHY581	Physics Lab. A	0 0 3	1		15PHY591	Seminar A	-	1	
	Total		**22**			**Total**		**22**	
SEMESTER 9					**SEMESTER 10**				
15PHY604	Advanced Electronics	3 1 0	4		15PHY696	Project	-	10	
15PHY603	Nuclear and Particle Physics	3 1 0	4						
15PHY602	Condensed Matter Physics	3 1 0	4						
	ELECTIVE 1	3 0 0	3						
	ELECTIVE 2	3 0 0	3						
15PHY682	Advanced Electronics Lab.	0 0 6	2						
15PHY691	Seminar B	-	1						
	TOTAL		**21**			**TOTAL**		**10**	
Total credits: 75									
Total credits for the 5-yr programme with Physics stream = 217									

Physics PG Electives

Integrated M.Sc (PM) (Physics Stream) - PHYSICS ELECTIVES 1 and 2 (anyTwo)									
15PHY531	Antennas and Wave Propagation	3 0 0	3		15PHY550	Applied Quantum Mechanics and Material Modelling	3 0 0	3	
15PHY533	Biophotonics	3 0 0	3		15PHY551	Epistemological Foundations of Quantum Mechanics	3 0 0	3	
15PHY534	Biophysics	3 0 0	3		15PHY552	Introduction to Fourier Optics	3 0 0	3	
15PHY537	Fibreoptic Sensors and Applications	3 0 0	3		15PHY553	Introduction to Nanophysics and Applications	3 0 0	3	
15PHY538	Fibreoptics and Technology	3 0 0	3		15PHY554	Optoelectronics	3 0 0	3	
15PHY539	Nanophotonics	3 0 0	3		15PHY555	Physics of the Atmosphere	3 0 0	4	
15PHY541	Nuclear Physics	3 0 0	3		15PHY556	Python for Scientific Computing	3 0 0	4	
15PHY543	Physics of Cold Atoms and Ions	3 0 0	3		15PHY557	Astrophysics and Cosmology	3 0 0	3	
15PHY544	Quantum Electrodynamics	3 0 0	3		15PHY558	Nonlinear Dynamics and Chaos	3 0 0	3	
15PHY545	Quantum Optics	3 0 0	4		15PHY559	Physics of Optoelectronic Devices	3 0 0	3	
15PHY546	Thin Film Technology	3 0 0	3						
15PHY548	Fundamentals of Plasma Physics	3 0 0	3						
15PHY549	Space Physics								

Semesters 7 – 10 Course Schedule (Math Stream)

SEMESTER 7					SEMESTER 8				
15MAT501	Advanced Algebra	4 0 0	4		15MAT503	Topology	4 0 0	4	
15MAT502	Advanced Real Analysis	4 0 0	4		15MAT512	Functional Analysis	4 0 0	4	
15MAT511	Advanced Complex Analysis	4 0 0	4		15MAT513	Graph Theory	4 0 0	4	
15MAT504	Ordinary Differential Equations	4 0 0	4		15MAT514	Partial Differential Equations	4 0 0	4	
	Elective I	3 0 0	3			Elective II	3 0 0	3	
	TOTAL		**19**			**TOTAL**		**19**	
SEMESTER 9					SEMESTER 10				
15MAT601	Advanced Topology	4 0 0	4			Elective IV	3 0 0	3	
15MAT605	Differential Geometry	4 0 0	4			Elective V	3 0 0	3	
15MAT603	Measure and Integration	4 0 0	4		15MAT696	Dissertation		10	
15MAT604	Operator Theory	4 0 0	4						
	Elective III	3 0 0	3						
	TOTAL		**19**			**TOTAL**		**16**	

										Total credits		73	
		Total credits for the 5-yr programme with Mathematics stream = 215											
		Mathematics PG ELECTIVES I, II, III, IV and V (any five - minimum three from a single Stream)											
		Algebra Stream					**Analysis Stream**						
	15MAT631	Algebraic Geometry	3 0 0	3		15MAT641	Fixed Point Theory	3 0 0	3				
	15MAT632	Algebraic Topology	3 0 0	3		15MAT642	Fractals	3 0 0	3				
	15MAT633	Coding Theory	3 0 0	3		15MAT643	Harmonic Analysis	3 0 0	3				
	15MAT634	Commutative Algebra	3 0 0	3		15MAT644	Nonlinear Partial Differential Equations	3 0 0	3				
	15MAT635	Lie Algebra	3 0 0	3		15MAT645	Wavelet Analysis	3 0 0	3				
	15MAT636	Theory of Manifolds	3 0 0	3									
		Statistics Stream					**Fluid Mechanics Stream**						
	15MAT651	Queuing Theory and Inventory Control Theory	3 0 0	3		15MAT661	Advance Boundary Layer Theory	3 0 0	3				
	15MAT652	Random Process	3 0 0	3		15MAT662	Computational Fluid Dynamics	3 0 0	3				
	15MAT653	Statistical Pattern Classifications	3 0 0	3		15MAT663	Finite Element Methods	3 0 0	3				
	15MAT654	Statistical Quality Control and Six Sigma Quality Analysis	3 0 0	3		15MAT664	Magneto-Hydro Dynamics	3 0 0	3				
	15MAT655	Theory of Sampling and Design of Experiments	3 0 0	3		15MAT665	Mathematical Foundations of Incompressible Fluid Flow	3 0 0	3				
	15MAT656	Time Series Analysis	3 0 0	3									
		Computer Stream											
	15MAT671	Advanced Data Structures and Algorithms	3 0 0	3									
	15MAT672	Advanced Graph Theory	3 0 0	3									
	15MAT673	Computer Aided Design of VLSI Circuits	3 0 0	3									
	15MAT674	Cryptography	3 0 0	3									
	15MAT675	Fuzzy Sets and its Applications	3 0 0	3									
	15MAT676	Introduction to Soft Computing	3 0 0	3									
	15MAT677	Object-Oriented Programming and Python	3 0 0	3									

Open Electives (UG)

OPEN ELECTIVES (3 0 0 3)			
Code	**Title**	**Code**	**Title**
15OEL231	Advertising	15OEL255	Introduction to Translation
15OEL232	Basic Statistics	15OEL256	Linguistic Abilities
15OEL233	Citizen Journalism	15OEL257	Literary Criticism and Theory
15OEL234	Creative Writing for Beginners	15OEL258	Macro Economics
15OEL235	Desktop Support and Services	15OEL259	Managing Failure
15OEL236	Development Journalism	15OEL260	Media Management
15OEL 237	Digital Photography	15OEL261	Micro Economics
15OEL238	Emotional Intelligence	15OEL262	Micro Finance, Small Group Management and Cooperatives
15OEL239	Essence of Spiritual Literature	15OEL263	Negotiation and Counselling
15OEL240	Film Theory	15OEL264	New Literature
15OEL241	Fundamentals of Network Administration	15OEL265	Non- Profit Organization
15OEL242	Gender Studies	15OEL266	Personal Effectiveness
15OEL243	Glimpses of Indian Economy and Polity	15OEL267	Perspectives in Astrophysics and Cosmology
15OEL244	Graphics and Web- designing Tools	15OEL268	Principles of Marketing
15OEL245	Green Marketing	15OEL269	Principles of Public Relations
15OEL246	Healthcare and Technology	15OEL270	Science, Society and Culture
15OEL247	History of English Literature	15OEL271	Statistical Analysis
15OEL248	Indian Writing in English	15OEL272	Teamwork and Collaboration
15OEL249	Industrial Relations and Labour Welfare	15OEL273	The Message of Bhagwad Gita
15OEL250	Introduction to Ancient Indian Yogic and Vedic Wisdom	15OEL274	Understanding Travel and Tourism
15OEL251	Introduction to Computer Hardware	15OEL275	Videography
15OEL252	Introduction to Event Management	15OEL276	Vistas of English Literature
15OEL253	Introduction to Media	15OEL277	Web- Designing Techniques
15OEL254	Introduction to Right to Information Act		

Evaluation Scheme and Grading System

R.14   AssessmentProcedure

R.14.1   The academic performance of each student in each course will be assessed on the basis of Internal Assessment (including Continuous Assessment) and an end-semesterexamination.

Normally, the teachers offering the course will evaluate theperformance of the students at regular intervals and in the end- semester examination.

Intheorycourses(thataretaught primarilyinthelecturemode),the weight for the Internal Assessment and End-semester examination willbe50:50.TheInternalassessmentintheorycoursesshallconsist ofatleasttwoperiodicaltests,weeklyquizzes,assignments,tutorials, viva-voce etc. The weight for these components, for theory-based coursesshallbe20marksfortheContinuousassessment,comprising ofQuizzes,assignments,tutorials,viva-voce,etc.and15markseach for both the PeriodicalTests.

Attheendofthesemester,therewillbeanend-semesterexamination of three hours duration, with a weight of 50 marks, in each lecture- basedcourse.

R.14.2   In the case of laboratory courses and practical, the relative weight forInternalassessmentandEnd-semesterexaminationwillbe80:20. TheweightforthecomponentsofInternalassessmentwillbedecided by the course committee/class committee at the beginning of the course.

Evaluation pattern for course having both Theory and Lab. components:
Courseshavingonly onehourperweekforlecture/tutorial,betreated as a Lab. course, for evaluation purposes; and evaluation pattern willbe80marksforcontinuousassessmentoflab.workand20marks for end-semester lab.examination.

Courses having two hours per week for theory and/or tutorials, be given a weight of 60 marks and 40 marks for the Theory and Lab. components, respectively; The Lab. component evaluation will be based on continuous evaluation, without any end-semester practical evaluation.10markswillbeforcontinuousassessmentofthetheory portion,10marksforeach ofthetwoperiodicaltests,30marksforthe theory end-semester examination and 40 marks for continuous assessment of lab.work and courses having three hours per week for theory and/or tutorials, be given a weight of 70 marks and 30 marks for the Theory and Lab. components, respectively; The Lab. component evaluation will be based on continuous evaluation, without any end-semester practical evaluation.15markswillbeforcontinuousassessmentofthetheory portion,10marksforeach ofthetwoperiodicaltests,35marksforthe theory end-semester examination and 30 marks for continuous assessment of lab.work.

R.14.3   It is mandatory that the students shall appear for the end-semester examinations in all theory and practical courses, for completion of therequirementsofthecourse.Thosewhodonotappearintheend-semesterexaminationswillbeawarded'F'grade,subjecttomeeting the attendancerequirement.

Attheendofasemester,examinationsshallbeheldforallthesubjects that were taught during that semester and those subjects of the previous semesters for which the students, shall apply for supplementary examination, with a prescribedfee

R.14.4   PROJECTWORK:Thecontinuousassessmentofprojectworkwill becarriedoutasdecidedbythecoursecommittee.Atthecompletion of the project work, the student will submit a bound volume of the project report in the prescribed format. The project work will be evaluated by a team of duly appointedexaminers.

The final evaluation will be based on the content of the report, presentationbystudentandaviva-voceexaminationontheproject. Therewillbe40%weightforcontinuousassessmentandtheremaining 60% for finalevaluation.

Iftheprojectworkisnotsatisfactoryhe/shewillbeaskedtocontinue the project work and appear for assessmentlater.

R.15   PUBLICATION/INTERNSHIP

R.15.1   All students, if they are to be considered for award of Degree at the time of graduation, are required to have published ONE paper in Scopus-indexedJournal/Conference.

R.15.2   Additional5-10markswillbeawardedforeachPublication,subject toamaximumofONEpaperpersemester.

The additional marks shall be awarded in the semester in which the paper is published or accepted for publication, if applied for, within 10 days of the publication of results of the concerned semester. The additionalmarkscanbeawardedtoanycourse(s)wherethestudent has to improve his/hergrade.

R.15.3   All publications shall be in Scopus-indexed Journals/Conferences and shall be as per the guidelines prescribed by theUniversity.

R.15.4   Students who have undergone Internship at reputed organisations orNational/InternationalInstitutions,withthepriorapprovalofthe concerned Departmental Chairperson and the Head of the School, may be considered for waiver of the requirement of publication, for theawardofDistinction.However,thedecisionoftheDepartmental ChairpersonandtheHeadoftheSchool,inthisregard,shallbefinal.

R.15.5   Co-curricularActivities
The students during their period of study in the University are encouragedtoindulgeinsports,arts,Social/Communityserviceand Seva activities. Bonus marks (1 to 10 marks) shall be awarded for representing AMRITA University in Sports, Cultural and Seva activities.
The procedure for awarding these marks will be published by the Universityfrom time to time.

R.17   Grading

R.17.1   Based on the performance in each course, a student is awarded at theendofthesemester,aletter gradeineachofthecoursesregistered.

Letter grades will be awarded by the Class Committee in its final sitting, without the student representatives.

Letter Grade	Grade Points	Ratings
O	10.0	Outstanding
A+	9.5	Excellent
A	9.0	Very Good
B+	8.0	Good
B	7.0	Above Average
C	6.0	Average
P	5.0	Pass
F	0.0	Fail
FA	0.0	Failed due to insufficient attendance
I	0.0	Incomplete (awarded only for Lab courses/ Project / Seminar)
W		Withheld

R.17.2   FA' grade once awarded stays in the record of the student and is replacedwiththeappropriategradewhenhe/shecompletesthecourse successfully later.

Students who have secured an 'FA' in a course must re-register for thecourseorregisterfor thecourse,ifoffered,underrun-timere-do mode.

R.17.3   A student who has been awarded 'I' Grade in a Lab course, due to reasons of not completing the Lab., shall take up additional Lab. wheneverofferednextandearnapassgrade,whichwillbereflected in the next semester's gradesheet.

The 'I' grade, awarded in a Project/Seminar course, will be subsequently changed into appropriate grade, when the student completes the requirement during the subsequent semester. If he/ shedoesnotcompleteitinthenextsemester,itwillbe converted to 'F'grade.

R.17.4   A student is considered to have successfully completed the course and earned the credit, if he/she scores a letter grade 'P' or better in thatcourse.

R.22   Semester Grade Point Average (SGPA)

On completion of a semester, each student is assigned Semester Grade Point Average (SGPA) which is computed as below for all courses registered by the student during that semester:

$$\text{SGPA} = \frac{\sum C_i \times \text{Gp}_i}{\sum C_i}.$$

where C_i is the credit for ith course in that semester and Gpi is the grade point for that course.

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The summation is over all the courses registered by the student during the semester, including the failed courses. The SGPA is rounded off to two decimals.

R.23   Cumulative Grade Point Average (CGPA)

The overall performance of a student at any stage of the Degree programme is evaluated by the Cumulative Grade Point Average (CGPA) up to that point of time.

$$\text{CGPA} = \frac{\sum C_i \times \text{Gp}_i}{\sum C_i}.$$

where C_i is the credit for ith course in any semester and Gp_i is the grade point for that course.

The summation is over all the courses registered by the student during all the semesters up to that point of time, including the failed courses. The CGPA is also rounded off to two decimals.

R.24   Ranking

The ranking of the students in a batch at any intermediate or final stage is based on CGPA. Only those students who have passed all courses up to that stage in the first attempt are considered for ranking. Students are eligible for final ranking, only if the programme is completed within the normal duration, i.e., within two years from joining the programme.

R.25   Classification of successful candidates:

R.25.1 A student shall be considered to have successfully completed the programme, if he/she has:
   i)   registered and successfully completed all the core courses, electives and projects as mentioned in the curriculum;
   ii)   earned the required minimum number of credits as specified in the curriculum corresponding to the programme, within the stipulated time;
   iii) published a paper at a Scopus-indexed Journal/Conference.

R.25.2 Candidates who have successfully completed the programme, within a period of four semesters from entering the programme, shall be classified as follows:

Candidates securing a CGPA of 8.00 and above   – FIRST CLASS WITH DISTINCTION*

Candidates securing a CGPA between 6.50 and 7.99   – FIRST CLASS

and the same bementioned in the Degree certificate.

(*Subject to satisfying the condition mentioned at R.15.1 and having passed all the courses, in the first attempt, in four semesters, from the date of joining the programme).

If the programme is completed after four semesters of study, the candidates securing even a CGPA of 8.00 and above, shall be classified to have completed the programme, only with FIRST CLASS.

Syllabus and Course Outcomes

CULTURAL EDUCATIION

| 15AVP201 | Amrita Values Programme I | 1 0 0 1 |
| 15AVP211 | Amrita Values Programme II | 1 0 0 1 |

Objectives for 15AVP201
The student will gain understanding of the glory of Indian Itihasa (Epics) in general, wherefrom the student get inspired to follow the lifestyle of inspiring characters depicted in Ramayana.

Course Outcomes: After the completion of the course the student will be able to:

CO1   Appreciate the relevance of Ramayana in modern times.

CO2   Understand the family values and ideal human relationships portrayed in the Ramayana.

CO3   Understand Dharma and its universality, emphasizing its applicability in an individual's life.

CO4   Evaluate one's own personal ethics based on benchmarks from the Ramayana

CO5   Apply the spiritual values from Ramayana in resolving personal and social conflicts.

Objectives for 15AVP211
The student will gain understanding of the glory of Indian Itihasa (Epics) in general, wherefrom the student get inspired to follow the lifestyle of inspiring characters depicted in Mahabharata.

Course Outcomes: The course will aim at:

CO1: Understanding the impact of itihasas on Indian civilization with reference to Mahabharata

CO2: Enabling students to appreciate the relevance of Mahabharata and Bhagavad-Gita in the modern world.

CO3: Understanding the four goals of life (Purusharthas) as presented in the Mahabharata

CO4: Assimilating the positive qualities of the characters depicted in the itihasa.

CO5: Analysis of the critical events and turning points in the Mahabharata with emphasis on the underlying values and principles.

Amrita University's Amrita Values Programme (AVP) is a new initiative to give exposure to students about richness and beauty of Indian way of life. India is a country where history, culture, art, aesthetics, cuisine and nature exhibit more diversity than nearly anywhere else in the world.

Amrita Values Programmes emphasize on making students familiar with the rich tapestry of Indian life, culture, arts, science and heritage which has historically drawn people from all over the world.

Students shall have to register for any two of the following courses, one each in the third and the fourth semesters, which may be offered by the respective school during the concerned semester.

Courses offered under the framework of Amrita Values Programmes I and II

Message from Amma's Life for the Modern World
Amma's messages can be put to action in our life through pragmatism and attuning of our thought process in a positive and creative manner. Every single word Amma speaks and the guidance received in on matters which we consider as trivial are rich in content and touches the very inner being of our personality. Life gets enriched by Amma's guidance and She teaches us the art of exemplary life skills where we become witness to all the happenings around us still keeping the balance of the mind.

Lessons from the Ramayana
Introduction to Ramayana, the first Epic in the world – Influence of Ramayana on Indian values and culture – Storyline of Ramayana – Study of leading characters in Ramayana – Influence of Ramayana outside India – Relevance of Ramayana for modern times.

Lessons from the Mahabharata
Introduction to Mahabharata, the largest Epic in the world – Influence of Mahabharata on Indian values and culture – Storyline of Mahabharata – Study of leading characters in Mahabharata – Kurukshetra War and its significance - Relevance of Mahabharata for modern times.

Lessons from the Upanishads

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Introduction to the Upanishads: Sruti versus Smrti - Overview of the four Vedas and the ten Principal Upanishads - The central problems of the Upanishads – The Upanishads and Indian Culture – Relevance of Upanishads for modern times – A few Upanishad Personalities: Nachiketas, Satyakama Jabala, Aruni, Shvetaketu.

Message of the Bhagavad Gita

Introduction to Bhagavad Gita – Brief storyline of Mahabharata - Context of Kurukshetra War – The anguish of Arjuna – Counsel by Sri. Krishna – Key teachings of the Bhagavad Gita – Karma Yoga, Jnana Yoga and Bhakti Yoga - Theory of Karma and Reincarnation – Concept of Dharma – Concept of Avatar - Relevance of Mahabharata for modern times.

Life and Message of Swami Vivekananda

Brief Sketch of Swami Vivekananda's Life – Meeting with Guru – Disciplining of Narendra - Travel across India - Inspiring Life incidents – Address at the Parliament of Religions – Travel in United States and Europe – Return and reception India – Message from Swamiji's life.

Life and Teachings of Spiritual Masters India

Sri Rama, Sri Krishna, Sri Buddha, Adi Shankaracharya, Sri Ramakrishna Paramahamsa, Swami Vivekananda, Sri Ramana Maharshi, Mata Amritanandamayi Devi.

Insights into Indian Arts and Literature

The aim of this course is to present the rich literature and culture of Ancient India and help students appreciate their deep influence on Indian Life - Vedic culture, primary source of Indian Culture – Brief introduction and appreciation of a few of the art forms of India - Arts, Music, Dance, Theatre.

Yoga and Meditation

The objective of the course is to provide practical training in YOGA ASANAS with a sound theoretical base and theory classes on selected verses of Patanjali's Yoga Sutra and Ashtanga Yoga. The coverage also includes the effect of yoga on integrated personality development.

Kerala Mural Art and Painting

Mural painting is an offshoot of the devotional tradition of Kerala. A mural is any piece of artwork painted or applied directly on a wall, ceiling or other large permanent surface. In the contemporary scenario Mural painting is not restricted to the permanent structures and are being done even on canvas. Kerala mural paintings are the frescos depicting mythology and legends, which are drawn on the walls of temples and churches in South India, principally in Kerala. Ancient temples, churches and places in Kerala, South India, display an abounding tradition of mural paintings mostly dating back between the 9th to 12th centuries when this form of art enjoyed Royal patronage. Learning Mural painting through the theory and practice workshop is the objective of this course.

Course on Organic Farming and Sustainability

Organic farming is emerging as an important segment of human sustainability and healthy life. Haritamritam' is an attempt to empower the youth with basic skills in tradition of organic farming and to revive the culture of growing vegetables that one consumes, without using chemicals and pesticides. Growth of Agriculture through such positive initiatives will go a long way in nation development. In Amma's words "it is a big step in restoring the lost harmony of nature".

Benefits of Indian Medicinal Systems

Indian medicinal systems are one of the most ancient in the world. Even today society continues to derive enormous benefits from the wealth of knowledge in Ayurveda of which is recognised as a viable and sustainable medicinal tradition. This course will expose students to the fundamental principles and philosophy of Ayurveda and other Indian medicinal traditions.

Traditional Fine Arts of India

India is home to one of the most diverse Art forms world over. The underlying philosophy of Indian life is "Unity in Diversity" and it has led to the most diverse expressions of culture in India. Most art forms of India are an expression of devotion by the devotee towards the Lord and its influence in Indian life is very pervasive. This course will introduce students to the deeper philosophical basis of Indian Art forms and attempt to provide a practical demonstration of the continuing relevance of the Art.

Science of Worship in India

Indian mode of worship is unique among the world civilisations. Nowhere in the world has the philosophical idea of reverence and worshipfulness for everything in this universe found universal acceptance as it in India. Indian religious life even today is a practical demonstration of the potential for realisation of this profound truth. To see the all-pervading consciousness in everything, including animate and inanimate, and constituting society to realise this truth can be seen as the epitome of civilizational excellence. This course will discuss the principles and rationale behind different modes of worship prevalent in India.

Temple Mural Arts in Kerala

The traditional percussion ensembles in the Temples of Kerala have enthralled millions over the years. The splendour of our temples makes art enthusiast spellbound, warmth and grandeur of colour combination sumptuousness of the outline, crowding of space by divine or heroic figures often with in vigorous movement are the characteristics of murals.

The mural painting specially area visual counterpart of myth, legend, gods, dirties, and demons of the theatrical world, Identical myths are popular the birth of Rama, the story of Bhīma and Hanuman, Shiva, as Kirata, and the Jealousy of Uma and ganga the mural painting in Kerala appear to be closely related to, and influenced by this theatrical activity the art historians on temple planes, wood carving and painting the architectural plane of the Kerala temples are built largely on the pan-Indians almost universal model of the Vasthupurusha.

Organic Farming in Practice

Organic agriculture is the   application of a set of cultural, biological, and mechanical practices that support the cycling of farm resources, promote ecological balance, and conserve biodiversity. These include maintaining and enhancing soil and water quality; conserving wetlands, woodlands, and wildlife; and avoiding use of synthetic fertilizers, sewage sludge, irradiation, and genetic engineering. This factsheet provides an overview of some common farming practices that ensure organic integrity and operation sustainability.

Ayurveda for Lifestyle Modification:

Ayurveda aims to integrate and balance the body, mind, and spirit which will ultimately leads to human happiness and health. Ayurveda offers methods for finding out early stages of diseases that are still undetectable by modern medical investigation. Ayurveda understands that health is a reflection of when a person is living in harmony with nature and disease arises when a person is out of harmony with the cycles of nature. All things in the universe (both living and non-living) are joined together in Ayurveda. This leaflet endow with some practical knowledge to rediscover our pre- industrial herbal heritage.

Life Style and Therapy using Yoga

Yoga therapy is the adaptation of yogic principles, methods, and techniques to specific human ailments. In its ideal application, Yoga therapy is preventive in nature, as is Yoga itself, but it is also restorative in many instances, palliative in others, and curative in many others. The therapeutic effect comes to force when we practice daily and the body starts removing toxins and the rest is done by nature.

Insights into Indian Classical Music

The course introduces the students into the various terminologies used in Indian musicology and their explanations, like Nadam, Sruti, Svaram – svara nomenclature, Stayi, Graha, Nyasa, Amsa, Thala,- Saptatalas and their angas, Shadangas, Vadi, Samavadi, Anuvadi. The course takes the students through Carnatic as well as Hindustani classical styles.

Insights into Traditional Indian Painting

The course introduces traditional Indian paintings in the light of ancient Indian wisdom in the fields of aesthetics, the Shadanga (Six limbs of Indian paintings) and the contextual stories from ancient texts from where the paintings originated. The course introduces the painting styles such as Madhubani, Kerala Mural, Pahari, Cheriyal, Rajput, Tanjore etc.

Insights into Indian Classical Dance

The course takes the students through the ancient Indian text on aesthetics the Natyasastra and its commentary the AbhinavaBharati. The course introduces various styles of Indian classical dance such as Bharatanatyan, Mohiniyatton, Kuchipudi, Odissy, Katak etc. The course takes the students through both contextual theory as well as practice time.

Indian Martial Arts and Self Defense

The course introduces the students to the ancient Indian system of self-defense and the combat through various martial art forms and focuses more on traditional Kerala's traditional Kalari Payattu. The course introduces the various exercise technique to make the body supple and flexible before going into the steps and techniques of the martial art. The advanced level of this course introduces the technique of weaponry.

Social Awareness Campaign

The course introduces the students into the concept of public social awareness and how to transmit the messages of social awareness through various media, both traditional and modern. The course goes through the theoretical aspects of campaign planning and execution.

Temple Mural Arts in Kerala

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The mural painting specially area visual counterpart of myth, legend, gods, dirties, and demons of the theatrical world, Identical myths are popular the birth of Rama, the story of Bhīma and Hanuman, Shiva, as Kirata, and the

Jealousy of Uma and ganga the mural painting in Kerala appear to be closely related to, and influenced by this theatrical activity the art historians on temple planes, wood carving and painting the architectural plane of the Kerala temples are built largely on the pan-Indians almost universal model of the vasthupurusha.

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Organic agriculture is the   application of a set of cultural, biological, and mechanical practices that support the cycling of farm resources, promote ecological balance, and conserve biodiversity. These include maintaining and enhancing soil and water quality; conserving wetlands, woodlands, and wildlife; and avoiding use of synthetic fertilizers, sewage sludge, irradiation, and genetic engineering. This factsheet provides an overview of some common farming practices that ensure organic integrity and operation sustainability.

Ayurveda for Lifestyle Modification:
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Life Style and Therapy using Yoga
Yoga therapy is the adaptation of yogic principles, methods, and techniques to specific human ailments. In its ideal application, Yoga therapy is preventive in nature, as is Yoga itself, but it is also restorative in many instances, palliative in others, and curative in many others. The therapeutic effect comes to force when we practice daily and the body starts removing toxins and the rest is done by nature.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17)

15CUL101	CULTURAL EDUCATION I	2 0 0 2

Description
The student will be introduced to the foundational concepts of Indian culture and heritage.

Course Outcomes: After the completion of the course the student will be able to

CO1: Gain a positive appreciation of Indian culture, traditions, customs and practices

CO2: Understand the foundational concepts of Indian civilization like purusharthas, law of karma, etc, which contributes towards personality growth.

CO3: Understand the cultural ethos of Amrita Vishwa Vidyapeetham, and Amma's life and vision of holistic education

CO4: Imbibe spirit of living in harmony with nature

CO5: Get guidelines for healthy and happy living from the great spiritual masters.

Unit 1
Introduction to Indian Culture - Introduction to Amma's life and Teachings - Symbols
of Indian Culture.
Unit 2
Science and Technology in Ancient India - Education in Ancient India - Goals of Life
– Purusharthas - Introduction to Vedanta and Bhagavad Gita.
Unit 3
Introduction to Yoga - Nature and Indian Culture - Values from Indian History - Life
and work of Great Seers of India.

TEXTBOOKS:
1. The Glory of India (in-house publication)
2. The Mother of Sweet Bliss, (Amma's Life & Teachings)

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17)

15CUL111	CULTURAL EDUCATION II	2 0 0 2

Objectives
The students will be able to deepen their understanding and further their knowledge about the different aspects of Indian culture and heritage

Course Outcomes: After the completion of the course the student will be able to

CO1: Get an overview of India and her contribution to the world in the field of science and literature

CO2: Understand the foundational concepts of ancient Indian education system and practices associated with them

CO3: Learn the important concepts of Vedas, Bhagavad-Gita and Yogasutras and their relevance to daily life

CO4: Familiarize themselves with the inspirational characters and anecdotes from the epics and Indian history

CO5: Gain a rational understanding of the underlying principles of Indian spirituality.

Unit 1
1. Relevance of Sri Rama and Sri Krishna in this Scientific Age
2. Lessons from the Epics of India
3. Ramayana & Mahabharata
Unit 2
4. Who is a Wise Man?
5. A Ruler's Dharma
6. The Story of King Shibi
Unit 3
7. Introduction to the Bhagavad Gita
8. Bhagavad Gita – Action without Desire
Unit 4
9. Role and Position of Women in India
10. The Awakening of Universal Motherhood
Unit 5
11. Patanjali'sA stanga - Yoga System for Personality Refinement
12. Examples of Heroism and Patriotism in Modern India

TEXTBOOKS:
Common Resource Material II (in-house publication)
Sanatana Dharma - The Eternal Truth (A compilation of Amma's teachings on Indian Culture)

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17)

LANGUAGES

15ENG101	Communicative English	2-0-2-3

Objectives:
To help students obtain an ability to communicate fluently in English; to enable and enhance the students skills in reading, writing, listening and speaking; to impart an aesthetic sense and enhance creativity. By the end of the course, the students will be able to:

CO1 – Demonstrate competency in all the four linguistic skills, viz. listening, speaking, reading and writing.

CO2 – Apply different styles of communication in professional context.

CO3 – Participate in different planned & extempore communicative activities.

CO4 - Interpret and discuss facts and information in a given context.

CO5 - Develop an appreciation for human values.

Course Contents:
Unit 1
Parts of Speech, Tenses, Prepositions, Determiners - Agreement (Subject – Verb, Pronoun - Antecedent), Phrasal Verbs, Modifiers, Linkers/ Discourse Markers, Question Tags.

Unit 2
Paragraph writing – Cohesion - Development: definition, comparison, classification, contrast, cause and effect - Essay writing: Descriptive and Narrative.

Unit 3
Letter Writing - Personal (congratulation, invitation, felicitation, gratitude, condolence etc.) Official (Principal/ Head of the department/ College authorities, Bank Manager, Editors of newspapers and magazines).

Unit 4
Reading Comprehension – Skimming and scanning - inference and deduction – Reading different kinds of material – Graphical Representation – Speaking**:** Narration of incidents / stories/ anecdotes - Current News Awareness.

Unit 5
Prose: R. K. Narayan's *Fifteen Years* - A.P.J. Abdul Kalam's *Wings of Fire (Part I - 3)*

Short Stories: Katherine Mansfield's *A Cup of Tea* – Kishori Charan Das's *Death of an Indian*,

Poems: Maya Angelou's *I Know Why the Caged Bird Sings* - Sri Aurobindo's *The Tiger and the Deer*

CORE READING:
1. Ruskin Bond, Time Stops at Shamli and Other Stories, Penguin Books India Pvt Ltd, 1989
2. Syamala, V. Speak English in Four Easy Steps, Improve English Foundation Trivandrum: 2006
3. Beerbohm, Max, The Prince of Minor Writers: The Selected Essays of Max Beerbohm (NYRB Classics), Phillip Lopate (Introduction, Editor), The New York Review of Book Publishers.
4. Edger Allan Poe. The Selected Works of Edger Allan Poe. A Running Press, 2014.
5. Online sources

References:
1. Ruskin Bond, Time Stops at Shamli and Other Stories, Penguin Books India Pvt Ltd, 1989
2. Martinet, Thomson, A Practical English Grammar, IV Ed. OUP, 1986.
3. Murphy, Raymond, Murphy's English Grammar, CUP, 2004
4. Online sources

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17)

15ENG121	Professional Communication	1- 0-2-2

Objectives:

To convey and document information in a formal environment; to acquire the skill of self projection in professional circles; to inculcate critical and analytical thinking. By the end of the course, the students will be able to:

CO1 – Demonstrate competency in oral and written communication.

CO2 – Apply different styles of communication in professional context.

CO3 – Participate in different planned & extempore communicative activities

CO4 – Interpret and discuss facts and information in a given context

CO5 – Develop critical and analytical thinking.

Unit I
Vocabulary Building: Prefixes and Suffixes; One word substitutes, Modal auxiliaries, Error Analysis: Position of Adverbs, Redundancy, misplaced modifiers**,** Dangling modifiers – Reported Speech
Unit II
 Instruction, Suggestion & Recommendation - Sounds of English: Stress, Intonation
 - Essay writing: Analytical and Argumentative
Unit III
Circulars, Memos – Business Letters - e - mails
Unit IV
Reports: Trip report, incident report, event report - Situational Dialogue - Group Discussion
Unit V
Listening and Reading Practice - Book Review

References
1. FelixaEskey. Tech Talk, University of Michigan. 2005
2. Michael Swan. Practical English Usage, Oxford University Press. 2005
3. Anderson, Paul. Technical Communication: A Reader Centered Approach, V Edition, Hercourt, 2003.
4. Raymond V. Lesikar and Marie E. Flatley. Basic Business Communication, Tata   Mc Graw   Hill Pub. Co. New Delhi. 2005. Tenth Edition.
5. Thampi, G. Balamohan. Meeting the World: Writings on Contemporary Issues. Pearson, 2013.
6. Lynch, Tony. Study Listening. New Delhi: CUP, 2008.
7. Kenneth, Anderson, Tony Lynch, Joan Mac Lean. Study Speaking. New Delhi: CUP, 2008.
8. Marks, Jonathan. English Pronunciation in Use. New Delhi: CUP, 2007.
9. Syamala, V. Effective English Communication For You (Functional Grammar, Oral and Written Communication): Emerald, 2002.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17)

15HIN101	**HINDI I**	**1-0-2[2cr]**

Objectives: To teach Hindi for effective communication in different spheres of life: Social context, Education, governance, Media, Business, Profession and Mass communication.

By the end of the course, the students will be able to:

CO1 – To understand the nature & culture of the language

CO2 – Ability to understand the structure of the language in different context.

CO3 – To understand the functional skills of the language

CO4 - Enhance the social contribution of modern literature

CO5 - Develop research and secondary reading ability

Unit 1
Introduction to Hindi Language - National Language, Official Language, link Language etc. Introduction to Hindi language, Devanagari script and Hindi alphabet.

Shabda Bhed, Roopanthar ki Drishti se - Bhasha – Paribhasha aur Bhed - Sangya - Paribhasha Aur Bhed - Sangya ke Roopanthar - kriya.

Unit 2
Common errors and error corrections in Parts of Speech with emphasis on use of pronouns, Adjective and verb in different tenses – Special usage of adverbs, changing voice and conjunctions in sentences, gender & number - General vocabulary for conversations in given context – understanding proper pronunciation – Conversations, Interviews, Short speeches.

Unit 3

Poems –Kabir Ist 8 Dohas, Surdas 1st 1 Pada; Tulsidas 1st 1 Pada; Meera 1st 1 Pada.

Unit 4
Letter writing – personal and Formal – Translation from English to Hindi.

Unit 5
Kahani – Premchand: Kafan, Abhilasha, Vidroh, Poos ki rath, Juloos.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17)

15HIN111	HINDI II	1-0-2[2cr]

Objectives: *Appreciation and assimilation of Hindi Literature both drisya & shravya using the best specimens provided as anthology.*

By the end of the course, the students will be able to:

CO1 – Develop the creativity & language competence.

CO2 – To improve the writing and analytical skills

CO3 –Enhancing critical thinking.

CO4 –A good exposure with the different styles of literary writing.

CO5 – To understand the post modern trends of literature.

Unit 1
Kavya Tarang; Dhumil ke Anthim Kavitha [Poet - Dhumil], Dhabba [Poet - Kedarnath Singh], Proxy [Poet - Venugopal] Vakth [Poet - Arun Kamal], Maachis [Poet - Suneeta Jain].

Unit 2
Communicative Hindi - Moukhik Abhivyakthi.

Unit 3
Audio-Visual – Media in Hindi – Movies like Tare Zameen par, Paa, Black etc., appreciation and evaluation. News reading and presentations in Radio and TV channels in Hindi.

Unit 4
Gadya Manjusha – Budhapa, Kheesa, Sadachar ka Thavis.

Unit 5
Translation: Theory and Practice - Letter writing: Formal and Personal – Introduction to Hindi Software.

TEXTBOOKS:
Kavay Tarang: Dr. Niranjan, Jawahar Pusthakalay, Mathura.
Gadya Manjusha: Editor: Govind, Jawahar Pusthakalay, Mathura

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17)

15KAN101	KANNADA I	1-0-2[2cr]

CO-1: To enable the students to acquire basic skills in functional language.
CO-2: To develop independent reading skills and reading for appreciating literary works.
CO-3: To analyse language in context to gain an understanding of vocabulary, spelling,   punctuation and speech

Objectives: *To enable the students to acquire basic skills in functional language; to develop independent reading skills and reading for appreciating literary works; to analyse language in context to gain an understanding of vocabulary, spelling, punctuation and speech.*

Unit 1
Adalitha Kannada: bhashe, swaroopa, belavanigeya kiru parichaya
Paaribhaashika padagalu
Vocabulary Building

Unit 2

Prabhandha – Vyaaghra Geethe - A. N. Murthy Rao
Prabhandha – Baredidi…baredidi, Baduku mugiyuvudilla allige… - Nemi Chandra
Paragraph writing – Development: comparison, definition, cause & effect
Essay – Descriptive & Narrative

Unit 3
Mochi – Bharateepriya
Mosarina Mangamma – Maasti Venkatesh Iyengar
Kamalaapurada Hotelnalli – Panje Mangesh Rao
Kaanike – B. M. Shree
Geleyanobbanige bareda Kaagada – Dr. G. S. Shivarudrappa
Moodala Mane – Da. Ra. Bendre
Swathantryada Hanate – K. S. Nissaar Ahmed

Unit 4
Letter Writing - Personal: Congratulation, thanks giving, invitation, condolence

Unit 5
Reading Comprehension; nudigattu, gaadegalu

Speaking Skills: Prepared speech, pick and speak

REFERENCES:
1. *H. S. Krishna Swami Iyangar – Adalitha Kannada – Chetana Publication, Mysuru*
2. *A. N. Murthy Rao – Aleyuva Mana – Kuvempu Kannada Adyayana Samste*
3. *Nemi Chandra – Badhuku Badalisabahudu – Navakarnataka Publication*
4. *Sanna Kathegalu - Prasaranga, Mysuru University , Mysuru*
5. *B. M. Shree – Kannadada Bavuta – Kannada Sahitya Parishattu*
6. *K. S. Nissar Ahmed – 75 Bhaavageetegalu – Sapna Book House (P) Ltd.*
7. *Dr. G. S. Shivarudrappa – Samagra Kavya – Kamadhenu Pustaka Bhavana*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17)

15KAN111	**KANNADA II**	**1-0-2[2cr]**

Description: *To enable the students to acquire basic skills in functional language; to develop independent reading skills and reading for appreciating literary works; to develop functional and creative skills in language; to enable the students to plan, draft, edit & present a piece of writing.*

Objectives:

CO-1: To enable the students to acquire basic skills in functional language.

CO-2: To develop independent reading skills and reading for appreciating literary works.

CO-3: To develop functional and creative skills in language.

CO-4: To enable the students to plan, draft, edit & present a piece of writing.

Unit 1
Official Correspondence: Adhikrutha patra, prakatane, manavi patra, vanijya patra

Unit 2
Nanna Hanate - Dr. G. S. Shivarudrappa
Mankuthimmana Kaggada Ayda bhagagalu – D. V. Gundappa (Padya Sankhye 5, 20, 22, 23, 25, 44, 344, 345, 346, 601)
Ella Marethiruvaga - K. S. Nissaar Ahmed
Saviraru Nadigalu – S Siddalingayya

Unit 3
Sayo Aata – Da. Ra. Bendre

Unit 4
Sarva Sollegala turtu Maha Samelana - Beechi
Swarthakkaagi Tyaga - Beechi

Unit 5

Essay writing: Argumentative & Analytical
Précis writing

REFERENCES:
1. *H. S. Krishnaswami Iyangar – Adalitha Kannada – Chetan Publication, Mysuru*
2. *Dr. G. S. Shivarudrappa – Samagra Kavya. - Kamadhenu Pustaka Bhavana*
3. *Shrikanth - Mankuthimmana Kagga – Taatparya – Sri Ranga Printers & Binders*
4. *K. S. Nissar Ahmed – 75 Bhaavageetegalu – Sapna book house*
5. *Dr. Da. Ra. Bendre – Saayo Aata – Shri Maata Publication*
6. *Beechi – Sahukara Subbamma – Sahitya Prakashana*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17)

15MAL101	Malayalam I

Objectives: By the end of the course, the students will be able to
To appreciate the aesthetics & cultural implications; to enhance creative thinking in mother-tongue; to learn our culture & values; to equip students read & write correct Malayalam; to correct the mistakes in pronunciation; to create awareness that good language is the sign of complete personality.

Unit 1
Ancient poet trio: *Adhyatmaramayanam*,
Lakshmana Swanthanam (valsa soumitre… mungikidakayal), Ezhuthachan- Medieval period classics – *Jnanappana (kalaminnu… vilasangalingane*), Poonthanam.

Unit 2
Modern Poet trio: *Ente Gurunathan,* Vallathol Narayana Menon - Critical analysis of the poem.

Unit 3
Short stories from period 1/2/3, *Poovanpazham* - Vaikaom Muhammed Basheer - Literary & Cultural figures of Kerala and about their literary contributions.

Unit 4
Literary Criticism: Ithihasa studies - *Bharatha Paryadanam - Vyasante Chiri* - Kuttikrishna Mararu - Outline of literary Criticism in Malayalam Literature - Introduction to Kutti Krishna Mararu & his outlook towards literature & life.

Unit 5
Error-free Malayalam: **1**. Language; **2**. Clarity of expression; **3**. Punctuation.

Thettillatha Malayalam – Writing - **a**. Expansion of ideas; **b**. Precis Writing; **c**. Essay Writing; **d**. Letter writing; **e**. Radio Speech; **f**. Script/ Feature/ Script Writing; **g**. News Editing; **h**. Advertising; **i**. Editing; **j**. Editorial Writing; **k**. Critical appreciation of literary works (Any one or two as an assignment).

REFERENCES:
1. *P. K. Balakrishnanan, Thunjan padhanangal, D. C. Books, 2007.*
2. *G. Balakrishnan Nair,.Jnanappanayum Harinama Keerthanavum, N.B.S, 2005.*
3. *M. N. Karasseri, Basheerinte Poonkavanam, D. C. Books, 2008.*
4 *M. N. Vijayan, Marubhoomikal Pookkumbol, D. C. Books, 2010.*
5. *M. Thomas Mathew, Lavanyanubhavathinte Yukthisasthram, National Book Stall, 2009.*
6. *M. Leelavathy, Kavitha Sahityacharitram, National Book Stall, 1998.*
7. *Thayattu Sankaran, Vallathol Kavithapadhanam, D. C. Books, 2004.*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17)

15MAL111	Malayalam II	(102 2)

Objectives: *To appreciate the aesthetics & cultural implications; to enhance creative thinking in mother-tongue; to learn our culture & values; to equip students read & write correct Malayalam; to correct the mistakes in pronunciation; to create awareness that good language is the sign of complete personality.*

Unit 1

Ancient poet trio: *Kalayanasougandhikam, (kallum marangalun… namukkennarika vrikodara)* Kunjan Nambiar - Critical analysis of his poetry - Ancient Drama: *Kerala Sakunthalam* (Act 1), Kalidasan (Transilated by Attor Krishna Pisharody).

Unit 2
Modern/ romantic/ contemporary poetry: *Manaswini,* Changampuzha Krishna Pillai – Romanticism – modernism.

Unit 3
Anthology of short stories from period 3/4/5: *Ninte Ormmayku*, M. T. Vasudevan Nair - literary contributions of his time.

Unit 4
Part of an autobiography/ travelogue: *Kannerum Kinavum*, V. T. Bhattathirippadu - Socio-cultural literature - historical importance.

Unit 5
Error-free Malayalam: 1. Language; 2. Clarity of expression; 3. Punctuation.

Thettillatha Malayalam – Writing - a. Expansion of ideas; b. Precis Writing; c. Essay Writing; d. Letter writing; e. Radio Speech; f. Script/ Feature/ Script Writing; g. News Editing; h. Advertising; i. Editing; j. Editorial Writing; k. Critical appreciation of literary works (Any one or two as an assignment).

REFERENCES:
1. Narayana Pillai. P. K, Sahitya Panchanan. Vimarsanathrayam, Kerala Sahitya Academy, 2000
2. Sankunni Nair. M. P, Chathravum Chamaravum, D. C. Books, 2010.
3. Gupthan Nair. S, Asthiyude Pookkal, D. C Books.2005
4. Panmana Ramachandran Nair, Thettillatha Malayalam, Sariyum thettum etc., D. C. Book, 2006.
5. M. Achuthan, Cherukatha-Innale, innu, National Book Stall, 1998.
6. N. Krishna Pillai, Kairaliyude Katha, National Book Stall, 2001.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15SAN101	SANSKRIT I	1-0-2[2cr]

Objectives
1. To familiarize students with Sanskrit language and literature.
2. To enable them to read and understand Sanskrit verses and sentences.
3. To help them acquire expertise for self-study of Sanskrit texts and communication in Sanskrit.
4. To help the students imbibe values of life and Indian culture as propounded in scriptures.

Unit 1
Introduction to Sanskrit language, Devanagari script - Vowels and consonants, pronunciation, classification of consonants, conjunct consonants, words – nouns and verbs, cases – introduction, numbers, Pronouns, communicating time in Sanskrit. Practical classes in spoken Sanskrit

Unit 2
Verbs - Singular, Dual and plural – First person, Second person, Third person.
Tenses – Past, Present and Future – Atmanepadi and Parasmaipadi-karthariprayoga

Unit 3
Words for communication, slokas, moral stories, subhashithas, riddles (from the books prescribed)

Unit 4
Selected slokas from Valmiki Ramayana, Kalidasa's works and Bhagavad Gita .
Ramayana – chapter VIII - verse 5, Mahabharata - chapter 174, verse-16, Bhagavad Gita –chapter -IV verse 8, Kalidasa's Sakuntalam Act IV – verse 4

Unit 5
Translation of simple sentences from Sanskrit to English and vice versa.

Essential Reading:
1. Praveshaha; Publisher: Samskrita bharati, Aksharam, 8th cross, 2nd phase, girinagar, Bangalore -560 085
2. Sanskrit Reader I, II and III, R.S. Vadhyar and Sons, Kalpathi, Palakkad
3. PrakriyaBhashyam written and published by Fr. John Kunnappally
4. Sanskrit Primer by Edward Delavan Perry, published by Ginn and Company Boston

5,.Sabdamanjari, R.S. Vadyar and Sons, Kalpathi, Palakkad
6. Namalinganusasanam by Amarasimha published by Travancore Sanskrit series
7. Subhashita Ratna Bhandakara by Kashinath Sharma, published by Nirnayasagarpress

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15SAN111	**SANSKRIT II**	**1-0-2[2cr]**

Course Outcomes:

CO-1: To familiarize students with Sanskrit language and literature.

CO-2: To read and understand Sanskrit verses and sentences.

CO-3: Self-study of Sanskrit texts and to practice communication in Sanskrit.

CO-4: To help the students imbibe values of life and Indian traditions propounded by the scriptures.

CO-5: To be able to speak in Sanskrit.

Module I
Seven cases, Avyayas, sentence making with Avyayas, Saptha kakaras. **(5hrs)**

Module II
Kthavathu' Prathyayam, Upasargas, Kthvatha,Thumunnantha, Lyabantha Prathyayam. Three Lakaras – brief introduction, Lot lakara **(5hrs)**

Module III
New words and sentences for the communication, Slokas, moral stories(panchathanthra) Subhashithas, riddles (Selected from the Pravesha Book) **(5hrs)**

Module IV
Introduction to classical literature, classification of Kavyas, classification of Dramas - Important five Maha kavyas **(5hrs)**

Module V
Translation of paragraphs from Sanskrit to English and wise -verse **(5hrs)**

Module VI
Bhagavad - Geeta fourteenth chapter (all 27 Shlokas) **(5hrs)**

Essential Reading:
1, Praveshaha; Publisher : Samskrita bharati, Aksharam, 8th cross, 2nd phase, girinagar, Bangalore -560 085
2, Sanskrit Reader I, II and III, R.S. Vadhyar and Sons, Kalpathi, Palakkad
3, PrakriyaBhashyamwritten and published by Fr. John Kunnappally
4, Sanskrit Primer by Edward Delavan Perry, published by Ginn and Company Boston
5, Sabdamanjari, R.S. Vadyar and Sons, Kalpathi, Palakkad
6, Namalinganusasanam by Amarasimha published by Travancore Sanskrit series
7, SubhashitaRatnaBhandakara by Kashinath Sharma, published by Nirnayasagarpress

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15TAM101	**TAMIL I**	**1 0 2 2**

Objectives:
1. To introduce the students to different literature - Sangam literature, Epics, Bhakthi literature and modern literature.
2. To improve their ability to communicate with creative concepts, and also to introduce them to the usefulness of basic grammatical components in Tamil.

Unit 1
Sangam literature: Kuṟuntokai; (2, 6,8,40 pāṭalkaḷ) – puṟanāṉūṟu (74,112,184,192 pāṭalkaḷ) – tirukkuṟaḷ (iṟaimāṭci, amaiccu)

Unit 2
Epic literature: cilappatikāram maturaik kāṇṭam (vaḻakkuṟaikkātai 50-55)
Spiritual Literature: tiruppāvai(3,4) – tēvāram (mācilvīṇaiyum)
Medieval Literature: bāratiyar kaṇṇaṉ pāṭṭu (eṉ viḷaiyāṭṭu piḷḷai) – bāratitacaṉ kuṭumpaviḷakku (tāyiṉ tālāṭṭu).

Unit 3
Novel: Jeyakāntaṉ "kuru pīṭam"
Essay: Aṇṇā "ē tāḻnta tamiḻakamē"

Unit 4
Tiruñāṉa campantar – tirunāvukkaracar – cuntarar – māṇikka vācakar – āṇṭāḷ – tirumūlar – kulacēkara āḻvār – cīttalaic cāttaṉār toṭarpāṉa ceytikaḷ, mēṟkōḷkaḷ maṟrum cirappup peyarkaḷ

Unit 5
Tamil Grammar: Col vakaikaḷ - vēṟrumai urupukaḷ - valliṉam mikumiṭam mikāyiṭam - canti(puṇarcci) - ilakkaṇakkuṟippu.
Practical skills: Listening, speaking, writing and reading

TEXTBOOKS:
1. Aṇṇā "ē tāḻnta tamiḻakamē" nakkīraṉ papḷikēṣaṉs.
2. Caktitācaṉ cupramaṇiyaṉ "nalla kuṟuntokai mūlamum uraiyum" mullai patippakam, 2008.
3. http:/Www.Tamilvu.Org/libirary/libindex.Htm.
4. jeyakāntaṉ "kuru pīṭam" mīṉāṭci puttaka nilaiyam, 1971.
5. Nā.Pārttacārati "puṟanāṉūṟuc ciṟukataikaḷ" tamiḻp puttakālayam, 1978, 2001
6. Poṉ maṇimāṟaṉ "aṭōṉ tamiḻ ilakkaṇam "aṭōṉ papḷiṣiṅ kurūp, vañciyūr, tiruvaṉantapuram, 2007.
7. puliyūrk kēcikaṉ "kuṟuntokai mūlamum uraiyum" cārāta patippakam, 2010.
8. Puliyūrk kēcikaṉ "puṟanāṉūṟu" srīceṉpakā patippakam, 2010

| 15TAM111 | TAMIL II | 1 0 2 2 |

Objectives: To learn the history of Tamil literature. To analyze different styles, language training, to strengthen the creativity in communication, Tamil basic grammar, Computer and its use in Tamil language.

Unit 1
The history of Tamil literature: Nāṭṭupuṟap pāṭalkaḷ, kataikkaḷ, paḻamoḻikaḷ - cirukataikaḷ tōṟramum vaḷarcciyum, ciṟṟilakkiyaṅkaḷ: Kaliṅkattup paraṇi (pōrpāṭiyatu) - mukkūṭar paḷḷu 35.
Kāppiyaṅkaḷ: Cilappatikāram – maṇimēkalai naṭaiyiyal āyvu maṟrum aimperum – aiñciṟuṅ kāppiyaṅkaḷ toṭarpāṉa ceytikaḷ.

Unit 2
tiṇai ilakkiyamum nītiyilakkiyamum - patiṉeṇkīḻkkaṇakku nūlkaḷ toṭarpāṉa piṟa ceytikaḷ - tirukkuṟaḷ (aṉpu, paṇpu, kalvi, oḷukkam, naṭpu, vāymai, kēḷvi, ceynaṉri, periyāraittuṇakkōṭal, viḷippuṇarvu pēṉra atikārattil uḷḷa ceytikaḷ).
Aṟanūlkaḷ: Ulakanīti (1-5) – ēlāti (1,3,6). - Cittarkaḷ: Kaṭuveḷi cittar pāṭalkaḷ (āṉantak kaḷippu –1, 4, 6, 7, 8), maṟrum akappēy cittar pāṭalkaḷ (1-5).

Unit 3
tamiḻ ilakkaṇam: Vākkiya vakaikaḷ – taṉviṉai piṟaviṉai – nērkkūṟru ayaṟkūṟru

Unit 4
tamiḻaka aṟiñarkaḷiṉ tamiḻ toṇṭum camutāya toṇṭum: Pāratiyār, pāratitācaṉ, paṭṭukkōṭṭai kalyāṇacuntaram, curatā, cujātā, ciṟpi, mēttā, aptul rakumāṉ, na.Piccaimūrtti, akilaṉ, kalki, jī.Yū.Pōp, vīramāmuṉivar, aṇṇā, paritimāṟ kalaiñar, maṟaimalaiyaṭikaḷ.

Unit 5
tamiḻ moḻi āyvil kaṇiṉi payaṉpāṭu. - Karuttu parimāṟram - viḷampara moḻiyamaippu – pēccu – nāṭakam paṭaippu - cirukatai, katai, putiṉam paṭaippu.

TEXTBOOKS:
1. http:/Www.tamilvu.trg/libirary/libindex.htm.
2. http:/Www.tunathamizh.tom/2013/07/blog0post_24.html
3. Mu.Varatarācaṉ "tamiḻ ilakkiya varalāṟu" cāhitya akaṭemi papḷikēṣaṉs, 2012
4. Nā.Vāṇamāmalai "paḻaṅkataikaḷum, paḻamoḻikaḷum" niyū ceñcuri puttaka veḷiyīṭṭakam, 1980,2008
5. Nā.Vāṇamāmalai, "tamiḻar nāṭṭuppāṭalkaḷ" niyū ceñcuri puttaka veḷiyīṭṭakam 1964,2006
6. Poṉ maṇimāṟaṉ "aṭōṉ tamiḻ ilakkaṇam "aṭōṉ papḷiṣiṅ kurūp, vañciyūr, tiruvaṉantapuram, 2007.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

25

Life Skills

15SSK201	LIFE SKILLS I	1 0 2 2

Course Outcomes: After successful completion of the course, students
CO1: will have develop self-confidence and positive attitude necessary to compete and challenge themselves, analyse and manage their emotions to face real life situations (Soft Skill**)**
CO2: will have honed their presentation skills by understanding the nuances of content creation, effective delivery, use of appropriate body language and the art of overcoming nervousness to create an impact in the minds of a target audience. (Soft Skill)
CO3: will have acquired the ability to analyse, understand and classify questions under arithmetic, algebra and logical reasoning and solve them employing the most suitable methods; will be able to analyse, compare and arrive at conclusions for data analysis questions. (Aptitude**)**
CO4: will have the ability to dissect polysyllabic words, infer the meaning, inspect, classify, contextualise and use them effectively (Verbal**).**
CO5: will have the ability to understand the nuances of English grammar and apply them effectively (Verbal).
CO6: will have the ability to identify, analyse and interpret relationship between words and use the process of elimination to arrive at the answer (Verbal).

Soft skills and its importance: Pleasure and pains of transition from an academic environment to work-environment. Need for change. Fears, stress and competition in the professional world. Importance of positive attitude, self motivation and continuous knowledge upgradation.

Self Confidence: Characteristics of the person perceived, characteristics of the situation, Characteristics of the Perceiver. Attitude, Values, Motivation, Emotion Management, Steps to like yourself, Positive Mental Attitude, Assertiveness.

Presentations: Preparations, Outlining, Hints for efficient practice, Last minute tasks, means of effective presentation, language, Gestures, Posture, Facial expressions, Professional attire.

Vocabulary building: A brief introduction into the methods and practices of learning vocabulary. Learning how to face questions on antonyms, synonyms, spelling error, analogy etc. Faulty comparison, wrong form of words and confused words like understanding the nuances of spelling changes and wrong use of words.

Listening Skills: The importance of listening in communication and how to listen actively.

Prepositions and Articles: A experiential method of learning the uses of articles and prepositions in sentences is provided.

Problem solving; Number System; LCM &HCF; Divisibility Test; Surds and Indices; Logarithms; Ratio, Proportions and Variations; Partnership; Time speed and distance; work time problems;

Data Interpretation: Numerical Data Tables; Line Graphs; Bar Charts and Pie charts; Caselet Forms; Mix Diagrams; Geometrical Diagrams and other forms of Data Representation.

Logical Reasoning: Family Tree; Linear Arrangements; Circular and Complex Arrangement; Conditionalities and Grouping; Sequencing and Scheduling; Selections; Networks; Codes; Cubes; Venn Diagram in Logical Reasoning.

TEXTBOOKS:
1. *A Communicative Grammar of English: Geoffrey Leech and Jan Svartvik. Longman, London.*
2. *Adair J (1986) - "Effective Team Building: How to make a winning team", London, U.K: Pan Books.*
3. *Gulati S (2006) - "Corporate Soft Skills", New Delhi, India: Rupa & Co.*
4. *The Hard Truth about Soft Skills, by Amazone Publication.*

REFERENCES:
1. *Quantitative Aptitude, by R S Aggarwal, S Chand Publ.*
2. *Verbal and Non-verbal Reasoning, R S Aggarwal, S Chand Publ.*
3. *Data Interpretation, R S Aggarwal, S Chand Publ.*
4. *Nova GRE, KAPAL GRE, Barrons GRE books;*
5. *Quantitative Aptitude, The Institute of Chartered Accountants of India.*
6. *More Games Teams Play, by Leslie Bendaly, McGraw-Hill Ryerson.*
7. *The BBC and British Council online resources*
8. *Owl Purdue University online teaching resources*

9. *www.thegrammarbook.com online teaching resources*
10. *www.englishpage.com online teaching resources and other useful websites.*

Skills: Recognizing transition from an academic environment to work-environment, in class hands on practice sessions, tutorials, help development of self confidence, skills of giving presentations, expanding listening and comminication skills, problem solving, data interpretation, and logical reasoning. Employability: Any work environment.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15SSK211	LIFE SKILLS II	1 0 2 2

Course Outcomes: After successful completion of the course, students will be able to
1) communicate convincingly and negotiate diplomatically while working in a team to arrive at a win-win situation, would further develop their inter-personal and leadership skills (Soft Skill).
2) examine the context of a Group Discussion topic and develop new perspectives and ideas through brainstorming and arrive at a consensus (Soft Skills).
3) identify, recall and arrive at appropriate strategies to solve questions on geometry; will be able to investigate, interpret and select suitable methods to solve questions on arithmetic, probability and combinatorics (Aptitude).
4) relate, choose, conclude and determine the usage of right vocabulary (Verbal).
5) utilise prior knowledge of grammar to recognise structural instabilities and modify them (Verbal).
6) comprehend, interpret, deduce and logically categorise words, phrases and sentences; will also have the ability to theorise, discuss, elaborate, criticise and defend their ideas (Verbal).

Professional Grooming and Practices: Basics of Corporate culture, Key pillars of Business Etiquette. Basics of Etiquette: Etiquette – Socially acceptable ways of behaviour, Personal hygiene, Professional attire, Cultural Adaptability. Introductions and Greetings: Rules of the handshake, Earning respect, Business manners. Telephone Etiquette: activities during the conversation, Conclude the call, To take a message. Body Language: Components, Undesirable body language, Desirable body language. Adapting to Corporate life: Dealing with people.

Group Discussions: Advantages of Group Discussions, Structured GD – Roles, Negative roles to be avoided, Personality traits to do well in a GD, Initiation techniques, How to perform in a group discussion, Summarization techniques.

Listening Comprehension advanced: Exercise on improving listening skills, Grammar basics: Topics like clauses, punctuation, capitalization, number agreement, pronouns, tenses etc.

Reading Comprehension advanced: A course on how to approach middle level reading comprehension passages.

Problem solving – Money Related problems; Mixtures; Symbol Based problems; Clocks and Calendars; Simple, Linear, Quadratic and Polynomial Equations; Special Equations; Inequalities; Functions and Graphs; Sequence and Series; Set Theory; Permutations and Combinations; Probability; Statistics.

Data Sufficiency: Concepts and Problem Solving.

Non-Verbal Reasoning and Simple Engineering Aptitude: Mirror Image; Water Image; Paper Folding; Paper Cutting; Grouping Of Figures; Figure Formation and Analysis; Completion of Incomplete Pattern; Figure Matrix; Miscellaneous.

Special Aptitude: Cloth, Leather, 2D and 3D Objects, Coin, Match Sticks, Stubs, Chalk, Chess Board , Land and geodesic problems etc., Related Problems

TEXTBOOKS:
1. *A Communicative Grammar of English: Geoffrey Leech and Jan Svartvik. Longman, London.*
2. *Adair J (1986) - "Effective Team Building: How to make a winning team", London, U.K: Pan Books.*
3. *Gulati S (2006) - "Corporate Soft Skills", New Delhi, India: Rupa & Co.*
4. *The Hard Truth about Soft Skills, by Amazone Publication.*

REFERENCES:
1. *Quantitative Aptitude, by R S Aggarwal, S Chand Publ.*
2. *Verbal and Non-verbal Reasoning, R S Aggarwal, S Chand Publ.*
3. *Quantitative Aptitude by Abjith Guha, Tata McGraw hill Publ..*

4. *More Games Teams Play, by Leslie Bendaly, McGraw-Hill Ryerson.*
5. *The BBC and British Council online resources*
6. *Owl Purdue University online teaching resources*
7. *www.the grammarbook.com online teaching resources*
8. *www.englishpage.com online teaching resources and other useful websites.*

Skills: In class hands on practice sessions and tutorials help development of professional grooming and practices, group discussions, advanced reading, listening and comprehension, non-verbal reasoning and engineering aptitude, and problem solving skills. Employability: Any work environment.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15SSK301	LIFE SKILLS III	1 0 2 2

Course Outcomes: After successful completion of the course, students will be able to
1) prepare a suitable resume (including video resume), present themselves confidently, introduce themselves and face interviews in a sure-footed manner (Soft Skills).
2) analyse every question asked by the interviewer, compose correct responses and respond in the right manner to justify and convince the interviewer of one's right candidature through displaying etiquette, positive attitude and courteous communication (Soft Skills).
3) interpret, critically analyse and solve logical reasoning questions; manage time while applying methods to solve questions on arithmetic, algebra, logical reasoning, and statistics and data analysis and arrive at appropriate conclusions (Aptitude).
4) understand and use words, idioms and phrases, interpret the meaning of standard expressions and compose sentences using the same (Verbal).
5) decide, conclude, identify and choose the right grammatical construction (Verbal)..
6) examine, interpret and investigate arguments, use inductive and deductive reasoning to support, defend, prove or disprove them; create, generate and relate facts / ideas / opinions and share / express the same convincingly to the audience / recipient using their communication skills in English (Verbal).

Team Work: Value of Team work in organisations, Definition of a Team, Why Team, Elements of leadership, Disadvantages of a team, Stages of Team formation. Group Development Activities: Orientation, Internal Problem Solving, Growth and Productivity, Evaluation and Control. Effective Team Building: Basics of Team Building, Teamwork Parameters, Roles, Empowerment, Communication, Effective Team working, Team Effectiveness Criteria, Common characteristics of Effective Teams, Factors affecting Team Effectiveness, Personal characteristics of members, Team Structure, Team Process, Team Outcomes.

Facing an Interview: Foundation in core subject, Industry Orientation/Knowledge about the company, Professional Personality, Communication Skills, activities before interview, upon entering interview room, during the interview and at the end. Mock interviews.

Advanced Grammar: Topics like parallel construction, dangling modifiers, active and passive voices, etc.

Syllogisms, Critical reasoning: A course on verbal reasoning. Listening Comprehension advanced: An exercise on improving listening skills.

Reading Comprehension advanced: A course on how to approach advanced level of reading, comprehension passages. Exercises on competitive exam questions.

Specific Training: Solving campus recruitment papers, National level and state level competitive examination papers; Speed mathematics; Tackling aptitude problems asked in interview; Techniques to remember (In Mathematics). Lateral Thinking problems. Quick checking of answers techniques; Techniques on elimination of options, Estimating and predicting correct answer; Time management in aptitude tests; Test taking strategies.

TEXTBOOKS:
1. *A Communicative Grammar of English: Geoffrey Leech and Jan Svartvik. Longman, London.*
2. *Adair J (1986) - "Effective Team Building: How to make a winning team", London, U.K: Pan Books.*
3. *Gulati S (2006) - "Corporate Soft Skills", New Delhi, India: Rupa & Co.*
4. *The Hard Truth about Soft Skills, by Amazon Publication.*

REFERENCES:
1. *Speed Mathematics, Secrets of Lightning Mental Calculations, by Bill Handley, Master Mind books;*
2. *The Trachtenberg Speed System of Basic Mathematics, Rupa & Co., Publishers;*
3. *Vedic Mathematics, by Jagadguru Swami Sri Bharati Krsna Tirthayi Maharaja, Motilal Banarsidass Publ.;*
4. *How to Ace the Brainteaser Interview, by John Kador, Mc Graw Hill Publishers.*

5. *Quick Arithmetics, by Ashish Agarwal, S Chand Publ.;*
6. *Quicker Maths, by M tyra & K Kundan, BSC Publishing Co. Pvt. Ltd., Delhi;*
7. *More Games Teams Play, by Leslie Bendaly, McGraw-Hill Ryerson.*
8. *The BBC and British Council online resources*
9. *Owl Purdue University online teaching resources*
10. *www.thegrammarbook.com online teaching resources*
11. *www.englishpage.com online teaching resources and other useful websites.*

Skills: In class hands on practice sessions and tutorials help development of aptitude of team work spirit, facing interviews, advanced reading, listening and language skills, specific training involving solving campus recruitment papers for preparedness. Employability: Any work environment.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Chemistry and Computer Science Courses

15CHY102	CHEMISTRY I	(3 0 0 3)

Course Outcomes:
1) Gain an understanding and describe basic aspects of various chemical bonding.
2) Gain an understanding of basics of thermochemistry and apply to solve problems in chemical reactions.
3) Gain an understanding of concepts of chemical kinetics, reaction rates, to explain the rates of certain reactions and how to control their rates.
4) Gain an understanding of basic concepts in electrochemistry, electrolytes, associated fundamentals and theories.
5) Gain an understanding of law of photochemistry and apply them to explain photochemical processes, including fluorescence, phosphorescence, chemiluminescence.

Unit 1 Chemical Bonding
Review of orbital concept and electronic configuration, electrovalency and ionic bond formation, ionic compounds and their properties, lattice energy, solvation enthalpy and solubility of ionic compounds, covalent bond, covalency, orbital theory of covalency - sigma and pi bonds - formation of covalent compounds and their properties. Hybridization and geometry of covalent molecules - VSEPR theory – polar and non-polar covalent bonds, polarization of covalent bond - polarizing power, polarisability of ions and Fajan's rule, dipole moment, percentage ionic character from dipole moment, dipole moment and structure of molecules, co-ordinate covalent compounds and their characteristics, molecular orbital theory for H_2, N_2, O_2 and CO, metallic bond - free electron, valence bond and band theories, weak chemical bonds – inter and intra molecular hydrogen bond - van der Waals forces.

Unit 2 Thermodynamic Parameters
Stoichiometry - mole concept, significance of balanced chemical equation – simple calculations - Conditions for occurrence of chemical reactions - enthapy, entropy and free changes – spontaneity – Thermochemistry - heats of reactions - (formation, combustion, neutralization) - specific heats - variation of enthalpy change
with temperature - Kirchhoff' relation (integrated form) - bond enthalpy and bond order - Problems based on the above.

Unit 3 Kinetics
Review of molecularity and order of a reaction, rate law expression and rate constant - first, second, third and zeroorder reactions, pseudo-first order reactions. (pseudo-unimolecular reactions) - complex reactions - equilibrium and steady state approximations - mechanism of these reactions - effect of temperature on reaction rates - Arrhenius equation and its significance, Michaelis Menden kinetics-enzyme catalysis.

Unit 4 Electrochemistry
Electrolytes - strong and weak, dilution law, Debye-Huckel theory, faraday's laws, origin of potential, single electrode potential, electrochemical series, electrochemical cells, Nernst equation and its application, reference electrodes - SHE, Ag/AgCl, Calomel.

Unit 5 Photochemistry
Photochemistry, laws of photochemistry - Stark-Eistein law, Beer-Lamberts law, quantum efficiency-determination, photochemical processes - Jablonsky diagram, internal conversion, inter-system crossing, fluorescence, phosphorescence, chemiluminescence and photo sensitization, photopolymerization.

REFERENCE BOOKS:
1. Principles of Physical Chemistry, B.R. Puri, L.R. Sharma & M.S. Pathania, Vishal Publications,
46th, 2013.

2. Principles of Inorganic Chemistry, B R. Puri, L. R. Sharma, Vishal Publications, 2008

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: The entire contents of this course, with exercises and tutorials provides foundations for use of chemistry concepts and use of chemicals for research in universities.

15CHY112	CHEMISTRY II	(3 0 0 3)

Course Outcomes:
1) Gain an understanding and explain ionic equilibrium in electrolytes, electrical conductance in dilute solutions, concepts related to pH, apply them to solve problems.
2) Gain an understanding of concepts in chemical equilibria, law of mass action, temperature dependence, Le-Chatelier's principle and its application.
3) Gain familiarity with concepts in organic chemistry, organic compounds, their dominant physical and chemical characteristics and describe them.
4) Gain an understanding of acids, bases, and non-aqueous solvents, describe their general physical and chemical characteristics with examples.
5) Gain an understanding of concepts in coordination chemistry, Weiner's theory, coordination numbers, ligands, nomenclature, isomerism, use of such compounds in qualitative and quantitative analysis, theory of boding in coordination.

Unit 1 Ionic equilibria
Electrolytes, strong and weak - specific, equivalent and molar conductances, equivalent conductance at infinite dilution and their measurement - Kohlrausch's law and its applications - calculation of equivalent conductance at infinite dilution for weak Electrolytes and solubility of sparingly soluble salts - applications of conductivity measurement - conductometric titrations - acid-base precipitation and complexometric titrations, Common ion effect and its application, concept of pH, indicators, theories of indicators – buffers and their pH - Henderson equation.

Unit 2 Chemical equilibria
Law of mass action - equilibrium constant – Relation between Kp and Kc - Temperature dependence – The van't Hoffs equation – Pressure dependence of the equilibrium constant Kp and Kc – Factors that change the state of equilibrium - Le-chatelier's principle and its application to chemical equilibria.

Unit 3 Basic concepts in Organic Chemistry
Composition of organic compounds – detection and estimation of elements – carbon – hydrogen - nitrogen, oxygen, sulphur, phosphorous, halogens – Calculation of empirical and molecular formula - determination of molecular weights – physical and chemical methods - empirical formula and molecular formula – Classification and Nomenclature of organic compounds. Organic reactions and their mechanisms: Electron displacement effects – inductive, electromeric, mesomeric and hyperconjugative. Reactive intermediates – carbocations, carbanions, free radicals and carbenes

Unit 4 Acids, Bases and Non-aqueous solvents
Concepts of acids and bases – hard and soft acids and bases - Pearson's concept, HSAB principle and its application - basis for hard-hard and soft-soft interactions - non-aqueous solvents - general characteristics of non-aqueous solvent - melting point, boiling point, latent heat of fusion and vaporization, and dielectric constant - reactions such as complex formation, redox, precipitation and acid base type in non-aqueous solvents like liquid ammonia, liquid SO2 and liquid HF.

Unit 5 Coordination chemistry
Werner's theory – Electronic interpretation of co-ordination compounds - EAN rule – types of ligands – Nomenclature, isomerism – stability of complexes – factors influencing stability – Application of coordination compounds in qualitative and quantitative analysis. Theories of bonding in coordination.

TEXTBOOKS:
1. Puri, Sharma & Pathania, 'Principles of Physical Chemistry', 42nd edition, Vishal Publishing Co, Delhi, 2007.
2. Morrison and R.N. Boyd, 'Organic Chemistry', 6th Edition, Prentice Hall, 1992.
3. Puri BR, Sharma LR, Kalia KK. 'Principles of Inorganic Chemistry', 23rd Edition, Shoban Lal Nagin Chand & Co, New Delhi, 1993.

REFERENCES:
1. S.F.A. Kettle, 'Physical Inorganic Chemistry', Spectrum, 1996
2. J. Clayden, N. Greeves, S. Warren and P. Wothers, 'Organic Chemistry', 2nd edition, Oxford

University Press, 2012.
3. R. Stephen Berry, Stuart A. Rice & John Ross, 'Physical Chemistry', 2nd edition, Oxford
University press, 2000.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: The entire contents of this course, with exercises and tutorials provides foundations for use of chemistry concepts and use of chemicals for research in universities.

15CHY182	CHEMISTRY LAB	(0 0 2 1)

Course Outcomes:
1) Understand and apply principles of use basic experimentation in chemistry.
2) Gain and demonstrate skill in using chemicals
3) Gain skill and demonstrate performing chemical synthesis
4) Demonstrate a knowledge of safe precautions.

1. Acid base titration (double titration)
2. Complexometric titration (double titration)
3. Redox (permanganimetry) titration (double titration)
4. Conductometric titration
5. Potentiometric titration
6. Colourimetric titration

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: Lab sessions provide practical foundation for use of chemistry concepts and use of chemicals for research in universities.

16CSA107	Introduction to Programming in C	(3 0 0 3)

Course Outcomes:
1) Understanding foundation concepts of information and information processing in computer systems: a matter of information, data representation, coding systems, history of computing.
2) Problem solving using flowcharts
3) Define an algorithm and use the principles to write programs to solve problems.
4) Demonstrate an understanding of a programming language syntax and its definition by example of C language, data types, assignment rules.
5) Demonstrate ability to write simple programs in C language by using basic control structures (conditional statements, loops, switches, branching, etc.).
6) Demonstrate the basic use of a function concept and how to deal with function arguments and parameters.
7) Demonstrate the use of one and multi-dimensional arrays, string operations, and structures.

Unit 1
Computer - History, Generations, classifications, applications, input output devices, hardware units, Introduction to problem soving – algorithm development, flowcharting, program, programming language. Fundamentals of Programming Language, Different Programming Techniques - Procedural Programming, Modular Programming, Object Oriented Programming.

Unit 2
Introduction to C, Program structure – Header and Body, use of comments, construction of the Program, /*Comments */, Body braces, File names. Getting started with compiler, Alphabets in C, Keywords in C, Rules of forming Words, Data Variables, Data Types and Rules for naming and declaring data variables.

Unit 3
Basic Data Types in C, variables, Constants, and Data Types. Type Definitions, Input/Output Instructions. Operators, Decision Control Instructions: -If, If-else, If-else-if, Nested if-else, Conditions, Switch case. Loop Control Instructions: While Loop, Do While, For Loop, continue, break, goto. Storage Classes and Scoping: Auto, Register, Extern, Static.

Unit 4
Arrays: Array Declaration, array Initialization, processing an Array. Two-Dimensional arrays, Multidimensional arrays, Strings, string i/o, String handling functions.

Unit 5
Functions: Why use Function, Components of Function, Name, Body, Local variables, Parameters Arguments, Return Value, Prototype of a function, Rules of using a function. Structure: Declaration, Initialisation, Accessing a Structure, Uses of Structures.

TEXTBOOKS:
1. Byron S Gottfried, "Schaum's Outline of Tehory and problems of Programming with C", 2nd ed., TMH Publishers, 1996.
2. Yaswant Kanitker, "Let us C", 2nd Ed., TMH, 1996.

REFERENCES:
1. Computer Programming in C – V Rajaraman
2. Mastering C, K R Venugopal, S R Prasad
3. Cooper Herbert, "Spirit of C: Introduction to Modern programming" TMH, 1983.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: Entire course contents with tutorials and assignments help build foundations and develops computational thinking, programming skills – design and implementation of software for scientific, engineering and industrial computing applications in universities, industries and research labs/organisations.

16CSA118	**Advanced Programming in C**	**(3 0 0 3)**

Course Outcomes:
1) Demonstrate an understanding of basic principles of structural programming, understand and apply advanced uses of functions, scope of a variable.
2) Demonstrate advanced uses of structure, array of structures, pointers to structures, self-referential structures.
3) Demonstrate and understanding ideas and applications of pointers, pointers functions.
4) Demonstrate skill in using basics of advanced data structures.
5) Save and read data from files, formatting data output, use preprocessors, macros, bitwise operations.
6) Elementary knowledge of programming code style.

Unit 1 Functions
Types of functions - User defined functions - Structure of a function – Execution Process of a function - Nesting of Functions - Sending arrays to functions – Recursion

Unit 2 Structures
Structure Definition - Structure Initialization - Nesting of Structure - Arrays and Structures - Structure to functions, Array of structures, pointers to structures, self-referential strucures.

Unit 3 Pointers
Accessing the address of a variable - Declaring and initializing a pointer – Pointer to Pointer - Pointers and functions – Functions returning pointer, Pointers and Arrays – pointer to array, array of pointers, Dynamic memory allocation – malloc(), calloc(0, free().

Unit 4 Data Structures in C
Overview of Data Structures - Primary Forms - Linked List, Queue, Stack

Unit 5 File Management in C
File Operations - I/O Operations on files - General Formats for declaring and opening a File. The Pre Processor: Preprocessor Directives - Macro Substitution directives - Command Line Arguments - Bitwise Operators

TEXTBOOKS:
1. Schaums's Outline of Theory and problems of Programming with C, by Byron Gottfried, 2nd ed., TMH Publishers, 1996.
2. C Programming Langauge by Kenninghan, Brian, W & Ritchie Dennis M, 2nd ed., TMH, 1992.

REFERENCES:
1. Let us c by Yashawant Kanetkar, 2nd ed., TMH 1996
2. Programming in ANSI C by E balagururswamy, 2nd.
3. C; the complete Reference, Herbert Schildt, 4th ed., TMH 2002.
4. Understanding pointers in C, Yashwant Kanetkar, 3rd ed., BPB Publication.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: Entire course contents with tutorials and assignments help build foundations and develops computational thinking, programming skills – design and implementation of software for scientific, engineering and industrial computing applications in universities, industries and research labs/organisations.

16CSA192   **Introduction to Programming Lab**   **(0 0 2 1)**

Course Outcomes:
1) Gain knowledge to problem solving using programming
2) Demonstrate programming in C to solve problems using various programs structs.
3) Demonstrate use of writing and reading formatted data files, and generate outputs of results and plots.

1. Programs using various input/ output statements (scanf, printf, getchar, gets, puts, putchar)
2. Programs using operatos and enumerated data types
3. Programs using control structures (if, if else, switch, & loops)
4. Programs using one-dimensional array
5. Programs using multidimensional array
6. Programs using strings and string handling functions
7. Functions using static, external and auto-variables
8. Programs using functions
9. Programs using structures, structure within structure.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: Entire course contents with tutorials and assignments help build foundations and develops computational thinking, programming skills – design and implementation of software for scientific, engineering and industrial computing applications in universities, industries and research labs/organisations.

Other Allied Courses and Open Electives

15ENV300   **Environmental Science and Sustainability**   **3 0 0 3**

Course outcomes:

CO1: Integrate facts and concepts from ecological, physical and social sciences to characterize some common socio-environmental problems.

CO2: Develop simple integrated systems and frameworks for solving common interconnected socio-environmental problems.

CO3: Reflect critically about their roles and identities as citizens, consumers and environmental actors in a complex, interconnected world.

CO4: Identify the ethical underpinnings of socio-environmental issues in general.

Unit 1
State of Environment and Unsustainability, Need for Sustainable Development, Traditional conservation systems in India, People in Environment, Need for an attitudinal change and ethics, Need for Environmental Education, Overview of International Treaties and Conventions, Overview of Legal and Regulatory Frameworks.

Environment: Abiotic and biotic factors, Segments of the Environment, Biogeochemical Cycles, Ecosystems (associations, community adaptations, ecological succession, Food webs, Food chain, ecological pyramids), Types of Ecosystems – Terrestrial ecosystems, Ecosystem Services, Economic value of ecosystem services, Threats to ecosystems and conservation strategies.

Biodiversity: Species, Genetic & Ecosystem Diversity, Origin of life and significance of biodiversity, Value of Biodiversity, Biodiversity at Global, National and Local Levels, India as a Mega-Diversity Nation (Hotspots) & Protected Area Network, Community Biodiversity Registers. Threats to Biodiversity, Red Data book, Rare, Endangered and Endemic Species of India. Conservation of Biodiversity. People's action.

Impacts, causes, effects, control measures, international, legal and regulatory frameworks of: Climate Change, Ozone depletion, Air pollution, Water pollution, Noise pollution, Soil/ land degradation/ pollution

Unit 2

Linear vs. cyclical resource management systems, need for systems thinking and design of cyclical systems, circular economy, industrial ecology, green technology. Specifically apply these concepts to: Water Resources, Energy Resources, Food Resources, Land & Forests, Waste management.

Discuss the interrelation of environmental issues with social issues such as:
Population, Illiteracy, Poverty, Gender equality, Class discrimination, Social impacts of development on the poor and tribal communities, Conservation movements: people's movements and activism, Indigenous knowledge systems and traditions of conservation.

Unit 3
Common goods and public goods, natural capital/ tragedy of commons, Cost benefit analysis of development projects, Environment Impact Assessment (EIA), Environment Management Plan (EMP), Green business, Eco-labeling, Problems and solutions with case studies.

Global and national state of housing and shelter, Urbanization, Effects of unplanned development case studies, Impacts of the building and road construction industry on the environment, Eco-homes/ Green buildings, Sustainable communities, Sustainable Cities.

Ethical issues related to resource consumption, Intergenerational ethics, Need for investigation and resolution of the root cause of unsustainability, Traditional value systems of India, Significance of holistic value-based education for true sustainability.

TEXTBOOKS/ REFERENCES:
1. R. Rajagopalan, Environmental Studies: From Crisis to Cure. Oxford University Press, 2011, 358 pages. ISBN: 9780198072089.
2. Daniel D. Chiras, Environmental Science. Jones & Bartlett Publishers, 01-Feb-2012, 669
pages. ISBN: 9781449645311.
3. Andy Jones, Michel Pimbert and Janice Jiggins, 2011. Virtuous Circles: Values, Systems,
Sustainability. IIED and IUCN CEESP, London. URL:http://pubs.iied.org/pdfs/G03177.pdf
4. Annenberg Learner, The Habitable Planet, Annenberg Foundation 2015.
URL: http://www.learner.org/courses/envsci/unit/pdfs/textbook.pdf.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills: The entire course and assignments help students become more aware about environmental issues and imparts knowledge about some methods and techniques of responsible use of natural resources.

16BUS306	FUNDAMENTALS OF MANAGEMENT	(2 0 0 2)

Course Outcomes: On successful completion, students will be able to

CO 1: demonstrate familiarity with the basic concepts of management and managerial roles.
CO 2: gain ides about of various functions of management such as planning, organizing, staffing, directing and controlling and describe them.
CO 3: gain ideas about different decision-making tools and strategic planning in an organization and to create awareness about effective communication and performance appraisal and describe them.
CO 4: gain ideas about various functional units in an organization such as marketing, finance, human resource management and production, and describe them in detail.
CO5: gain familiarity about the role of information technology in managing the activities in an organization and describe them.

Unit 1
Introduction to management, definition, nature and importance, role and skills of a manager, Planning, nature and purpose of planning, objectives of planning, steps in planning.

Unit 2
Strategic policy, goal setting, decision making, SW OT analysis, organization structure, Departmentalization, line staff authority, principles of staffing.

Unit 3
Performance appraisal, career strategy, Leading, managing human factor, leadership, communication, controlling the system and the process.

Unit 4

Introduction to management functional areas - Marketing, HR, Production and specialization, finance,

Unit 5

Management Information System - managerial functional areas.

TEXTBOOK:
Harold & Heinz Weihrich, Principles of Management, Tata McGraw Hill, 2007
REFERENCE:
T.N. Chhaabra, Principles of Management, 9/e Dhanpath Rai & Co. Pvt Ltd.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15OEL231 – 2xx	OPEN ELECTIVES	3 0 0 3

Two Open Elective courses are to be taken by each student, one each at the **4th and the 5th** semesters, from the list of Open electives offered by the School. Students undertaking and registering for a Live-in-Lab project, can be exempted from registering for an Open Elective course in the fifth semester.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

UG Project

16MPJ399	PROJECT (for exit-option students)	6 cr

Course Outcomes: After successful completion of the project, students will be able to
1) Gain deeper insights into the chosen areas of research.
2) Gain experience in research methodologies in the chosen area.
3) Develop theoretical/experimental/computational skills in helping explore the research goals.
4) Communicate one's efforts in the form of a well reference scientific report with illustrations, tables, equations, organization conforming to current publication standards leading to Bachelor's thesis.
5) Hone and demonstrate research and communication skills by submitting a research article to a conference or journal.

Students interested in exercising the exit-option at the end of the sixth semester, shall decide on it at the end of the fourth semester. Such students should do an additional six-credit project.

The proposed project work shall get started at the beginning of the fifth semester and is to be credited during the sixth semester. The project work should be done under the supervision of the faculty members from the respective disciplines. Projects can be something like learning a chapter in a text book and writing it elaborately or it can be some survey projects and interpreting the results or making working models in Physics or developing Mathematical models for engineering and science problems.

At the end of the fifth semester, there shall be a review of the ongoing project. The students should give a presentation of the project at the end of the sixth semester.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills: Training during the course of the project work help develop theoretical/ experimental/ computational skills and help communicate one's efforts in the form of a well referenced scientific report.

MATHEMATICSUG Courses (for Semesters 1 – 6)

SEMESTER 1

16MAT107	Calculus	3 1 0 4

Course Outcomes(CO)

CO1: An ability to understand the basic concepts of Derivative.
CO2: An ability to understand the concept of extreme values and apply the derivative test to identify concavity and extreme values.
CO3: Understand the concept of integration and apply them to evaluate the area between curves.
CO4: Apply the different techniques of integration to evaluate the integrals. Also understand the nature of numerical and improper integrals.
CO5: Apply the concept of integration to applications in science and engineering.

Unit-I

Limits and continuity: Rates of Change and Limits – Calculating Limits using Limiting Laws – The Precise definition of Limit – One-Sided Limits and Limits at Infinity – Continuity – Tangents and Derivatives.
Chapter 2- Sec: 2.1 to 2.4, 2.6 to 2.7

Unit-II

Differentiation: The Derivative as a Function – Differentiation Rules – The Derivative as a Rate of Change – Derivatives of Trigonometric Functions – The Chain Rule and Parametric Equations – Implicit Differentiation.
Chapter 3- Sec: 3.1 to 3.6

Unit-III

Application of Derivatives: Extreme values of Functions – The Mean Value Theorem – Monotonic Functions and the First Derivative Test – Concavity and Curve Sketching
 Chapter 4- Sec: 4.1 to 4.4

Unit-IV

Integration: Estimating with Finite Sums – Sigma Notation and Limits of Finite Sums – The Definite Integral – The Fundamental Theorem of Calculus – Indefinite Integrals and the Substitution Rule – Substitution and Area between Curves.
Chapter 5- Sec: 5.1 to 5.6

Unit-V

Techniques of Integration: Basic Integration Formulas – Integration by Parts – Integration of Rational Functions by Partial Fractions – Trigonometric Integrals – Trigonometric Substitutions– Improper Integrals.
Chapter 8: 8.1 to 8.5, 8.8

TEXT BOOK: Calculus by Finney and Thomas, Pearson, Eleventh Edition, 2008.

REFERENCE BOOKS:

1. M. J. Strauss, G. L. Bradley and K. J. Smith, *Calculus*, 3rd Edition, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), 2007.
2. S Balachandra Rao, *Differential Calculus*, New Age Publications, 2005.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: Mathematics being a language of all physical sciences and being a speciality in itself, the entire contents of this course, tutorials and assignments lays mathematical foundation for many mathematics, physics and engineering courses and builds skills required for a career as an educator in schools, colleges and universities, as a researcher, and as a communicator of mathematics in general.

SEMESTER2

16MAT118	Vector Calculus	3 1 0 4

Course Outcomes:
CO-1: Understand the basic concepts of vector valued functions, their limits, derivatives and integrals and its geometrical and physical interpretations.
CO-2: Understand the concepts of scalar and vector fields, their limits, derivatives and their applications.
CO-3: Understand the concepts of line integrals and its path independence.
CO-4: Understand and apply the concepts of double integrals to various problems including Green's theorem for plane..
CO-5: Understand the concepts of surface integrals, divergence theorem and Stoke's theorem.

Unit-I

Motion in Space: Lines and Planes in space, Cylinders and Quadric Surfaces, Vector Functions, Arc length and the unit tangent vector, Curvature and the unit normal vector , Torsion and the unit binormal vectors,
Text Book 1: Sections 12.5, 12.6, 13.1, 13.3, 13.4, 13.5

Unit-II

Multivariate Calculus: Functions of Several Variables – Limits and Continuity in Higher Dimensions – Partial Derivatives – The Chain rule, Multiple Integrals- Double Integrals in Cartesian and Polar Coordinates, Triple Integrals in Cartesian, Spherical and Cylindrical Coordinates.
Text Book 1: Sec. Sec. 14.1 to 14.4, 15.1, 15.3, 15.4 and 15.6

Unit-III

Vector Differentiation: Gradient, divergence and curl, identities, invariant scalar and vector fields, invariance of gradient, divergence and curl.
 Text Book 2: Chapter 4

Unit-IV

Line integrals, Vector Fields, Work, Circulation an ,and Flux, Path Independence, Potential Functions, and Conservative Fields, Green's Theorem in the plane.
Text Book 1: Sec. 16.1,16.2,16.3,16.4.

Unit -V

Surface area and surface integrals ,Parametrized surfaces, Stokes Theorem,The divergence Theorem and a unified theory

Text Book 1: Sec. 16.5,16.6,16.7,16.8

TEXT BOOKS:
1. Maurice D Wier, Joel Hass, Frank R Giordano, Thomas' Calculus, 11th Edition, Pearson, 2009.
2. Murray R Spiegel, Theory and problems of vector analysis, Schaum's outline series, McGraw-Hill Book Compnay 1974.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: Mathematics being a language of all physical sciences and being a speciality in itself, the entire contents of this course, tutorials and assignments lays mathematical foundation for many mathematics, physics and engineering courses and builds skills required for a career as an educator in schools, colleges and universities, as a researcher, and as a communicator of mathematics in general.

SEMESTER3

15MAT222	Differential Equations	3 1 0 4

Course Outcomes:
 CO1: Understand the basic concepts of differential equations and solve the various forms of differential equations.
 CO2: Understand the concepts and solve the linear homogeneous/non homogeneous differential equations with constants and variable coefficients.

CO3: Understand the concepts and solve the nth order differential equation and simultaneous linear differential equations with constant and variable coefficients.
CO4: Understand the concepts of partial differential equations and solve the first order PDE.
CO5: Understand the concepts and solve the linear homogeneous/non homogeneous parital differential equations with constants coefficients.

Unit 1: Review of differential equations. Exactness. Rules for finding Integrating factors. Equations of first order but of higher degree. Equations solvable for $\frac{dy}{dx}$, y, x. Methods for solving $\frac{dx}{P} = \frac{dy}{Q} = \frac{dz}{R}$ where P, Q and R are functions of x, y and z. Clairut's equation. Simultaneous linear differential equations with constant coefficients.

Unit 2: Second order linear homogeneous differential equations with constant coefficients. Second order linear nonhomogeneous differential equations. Method of undetermined coefficients. Method of variation of parameters. Method of reduction of order of linear second order differential equations with variable coefficients. Solving equations of the forms f(x, y'') = 0, f(y, y'') = 0, f(x, y', y'') = 0 and f(y, y', y'') = 0.

Partial Differential Equations

Unit 3: Formation of equations by eliminating arbitrary constants and arbitrary functions. Solutions of partial differential equations. General, particular and complete integrals. Solution of partial differential equations by direct integration. Methods to solve the first order partial differential equations of the forms f(p,q) = 0, f(x,p,q) = 0, f(y,p,q) = 0, f(z,p,q) = 0, f_1(x,p) = f_2(p,q) and Clairut's form z = px + qy + f(p,q) where $p = \frac{\partial z}{\partial x}$ and $q = \frac{\partial z}{\partial y}$. Equations reducible to standard forms. Lagrange's linear equation. Charpit's method. Solution of subsidiary equation by the method of multipliers.

Unit 4: Classification of partial differential equations of second order. Homogeneous linear partial differential equations of higher order.

Unit 5: Non homogeneous linear partial differential equations of higher order. Non homogeneous linear differential equation f(D, D') z = F(x, y) where f(D, D') is factorisable into linear factors.

Text Book

1. A First Course in Differential Equations, Dennis Zill, Cengage Learning, 2009.

References

1. Ordinary and Partial Differential Equations, M.D. Raisinghanian, S.Chand, 2001.
2. Ordinary and Partial Differential Equations : Theory and Applications Nita H. Shah, PHI learning, 2010.
3. Introduction to partial differential equations ; Sankar Rao, PHI Learning Pvt. Ltd., 2010.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: Mathematics being a language of all physical sciences and being a speciality in itself, the entire contents of this course, tutorials and assignments lays mathematical foundation for many mathematics, physics and engineering courses and builds skills required for a career as an educator in schools, colleges and universities, as a researcher, and as a communicator of mathematics in general.

16MAT229	Introduction to Linear Algebra	3-1-0-4

Course Outcomes:

CO1: To understand inner products and compute the angle/length of a vector. To construct the orthonormal basis.
CO2: To familiarize the concept of characteristic roots/ vectors and related properties. To understand a link between linear transformation and matrix.
CO3: To understand the construction of matrices for a linear transformation in the triangular/Jordan form.
CO4: To familiarize the types of matrices, understand their properties and apply them in the real quadratic forms.
CO5: To understand the process of diagonalizing and identify Conic Sections using diagonalization.

Unit – I

System of linear equations and Matrices, Determinants,(Sec 1.1-1.7, 2.1-2.3)

Unit – II
Euclidian Vector Spaces (Sec 3.1-4.4)

Unit – III
General Vector Spaces (Sec 5.1-5.6)

Unit – IV
Inner product spaces (Sec 6.1-6.6)

Unit – V
Eigenvalues and eigenvectors (Sec 7.1-7.3)

TEXTBOOKS:

1.   Howard Anton and Chris Rorres, 'Elementary Linear Algebra', John Wiley & Sons, 1994, ninth Edition.

REFERENCES

1.   Serge Lang, 'Introduction to Linear Algebra', Second Edition, Springer-Verlag, 1986.
2.   Kenneth Hoffmann and Ray Kunze, 'Linear Algebra', Second Edition, Prentice Hall, 1971.
3.   Gilbert Strang, 'Linear Algebra and Applications', Third Edition Wellesley Publishers, Indian Edition (Thompson Learning), 2001.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: Mathematics being a language of all physical sciences and being a speciality in itself, the entire contents of this course, tutorials and assignments lays mathematical foundation for many mathematics, physics and engineering courses and builds skills required for a career as an educator in schools, colleges and universities, as a researcher, and as a communicator of mathematics in general.

SEMESTER4

15MAT201	**Discrete Mathematics**	**3 1 0 4**

Course Outcomes

CO1: Understand how to write an argument using logical notation and determine if the argument is or is not valid.

CO2 : Ability to demonstrate an understanding of relations and functions and be able to determine their properties and counting principles.

CO3 Ability to demonstrate different traversal methods for trees and graphs

CO4: Ability to Model problems in Computer Science using graphs and tree.

Unit – I
Logic, Mathematical Reasoning and Counting: Logic, Prepositional Equivalence, Predicate and Quantifiers, Theorem Proving, Functions, Mathematical Induction. Recursive Definitions, Recursive Algorithms, Basics of Counting, Pigeonhole Principle, Permutation and Combinations. *(Sections: 1.1 -1.3, 1.5 -1.7, 2.3, 4.1 - 4.4, 5.1 - 5.3 and 5.5)*

Unit – II
Relations and Their Properties: Representing Relations, Closure of Relations, Partial Ordering, Equivalence Relations and partitions. *(Sections: 7.1, 7.3 - 7.6)*

Advanced Counting Techniques and Relations: Recurrence Relations, Solving Recurrence Relations, Generating Functions, Solutions of Homogeneous Recurrence Relations, Divide and Conquer Relations, Inclusion-Exclusion. *(Sections: 6.1 - 6.6)*

Unit – III

Graph Theory: Introduction to Graphs, Graph Operations, Graph and Matrices, Graph Isomorphism, Connectivity, Euler and Hamilton Paths, Shortest Path Problem, Planar Graph, Graph Colorings and Chromatic Polynomials. *(Sections: 8.1 - 8.8)*

TEXTBOOK:

Kenneth H. Rosen, "Discrete Mathematics and its Applications", Tata McGraw-Hill Publishing Company Limited, New Delhi, 6th Edition, 2007.
REFERENCES:
1. *R.P. Grimaldi, "Discrete and Combinatorial Mathematics", Pearson Education, 5th Edition, 2007.*
2. *Thomas Koshy, "Discrete Mathematics with Applications", Academic Press, 2005.*
3. *Liu, "Elements of Discrete Mathematics", Tata McGraw Hill Publishing Company Limited, 2004.*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: Entire course contents with tutorials and lab exercises help build foundations and develops computational thinking leading to scientific computing and software applications in research labs, and prepare students as an educator in schools, colleges and universities..

15MAT224	Probability and Statistics	3 1 0 4

Course Outcomes(CO)
CO1: Understand the basic concepts of probability and probability modeling.
CO2: Gain in-depth knowledge about statistical distributions and their properties
CO3: To apply one and two dimensional statistical distributions.
CO4: To study and apply statistical methods such as correlation and regression to real life problems
CO5: To understand statistical inference and apply in real life problems.

Unit – I
Probability Concepts:
Important definitions- random experiment, trial, sample space, mutually exclusive events, independent events, dependent events, equally likely events, exhausitive events – approaches to measuring probability – mathematical approach, statistical approach, axiomatic approach to probability, law of addition and multiplication of probability, conditional probability - Bayes Theorem definition and proof.

Unit – II
Random Variable and Distributions:
Discrete and continuous random variables – discrete and continuous distribution functions- mathematical expectation, moment generating function and characteristic function, standard distributions- discrete distributions Binomial, Poisson and Geometric- continuous distributions uniform, exponential, Gamma, Normal distributions - Chebyshev's theorem and central limit theorem.

Unit – III
Two dimensional random variables:
Joint, marginal and conditional probability distributions for discrete and continuous cases, stochastic independence, expectation of two dimensional random variables, conditional mean and variance, transformation of one and two random variables.

Unit – IV
Correlation and Regression:
Introduction to simple correlation - scatter plot and correlation coefficient, properties of correlation coefficient, rank correlation coefficient, introduction to simple regression, regression lines- least squares method for estimation of regression coefficients.

Unit – V
Theory of Estimation and Testing of Hypothesis:

Population and sample — sampling distributions – determination of sample size – t, F and Chi-square distributions – theory of estimation – types of estimation- point estimation and properties of point estimator - interval estimation methods based on normal, t, F and chi-square distributions and hypothesis tests.

TEXT BOOK
1. Douglas C. Montgomery and George C. Runger, Applied Statistics and Probability for Engineers, John Wiley and Sons Inc., 2005
REFERENCES:
1. Ronald E. Walpole, Raymond H. Myers, Sharon L. Myers and Keying Ye, Probability and Statistics for Engineers and Scientists, 8th Edition, Pearson Education Asia, 2007.
2. Ravichandran, J. Probability and Statistics for engineers, First Reprint Edition, Wiley India, 2012.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: In class practice sessions, tutorials and assignments help build foundations and develops computational thinking and programming skills leading to industrial computing and engineering software applications in industries and research labs, and prepare students as an educator in schools, colleges and universities.

| **16MAT238** | **Introduction to Modern Algebra** | **3** | **1** | **0** | **4** |

Course Outcomes
CO1: Understand fundamental concepts of algebra which include groups, subgroups, permutations, cosets.
CO2: Understand the theorem of Lagrange, homomorphism, isomorphism of groups.
CO3: Applications of Factor Groups, Internal Direct Products and Group Homomorphisms.
CO4: Understand the concepts of Rings ,Subrings ,Intergral domain and Fields.
CO5: Understand tje properties of Ideals and Ring Homomorphisms,

Unit – I
Introduction to Groups. Symmetries of a Square. The Dihedral Groups. Definition and Examples of Groups. Elementary Properties of Groups Finite Groups; Subgroups, Terminology and Notation. Subgroup Tests, Examples of Subgroups,

Unit – II
Cyclic Groups, Properties of Cyclic Groups. Classification of Subgroups of Cyclic Groups, Permutation Groups, Properties of Permutations, Isomorphisms, Definition and Examples. Cayley's Theorem, Properties of Isomorphisms,Automorphisms, Cosets and Lagrange"s Theorem, Application of Cosets to Permutation Groups.

Unit- III
External Direct Products, Properties of External Direct Products, Normal Subgroups, Factor Groups, Applications of Factor Groups, Internal Direct Products, Group Homomorphisms, Definition and Examples,Properties of Homomorphisms, The First Isomorphism Theorem.

Unit – IV
Rings-Motivation and Definition, Examples of Rings. Properties of Rings. Subrings. Integral Domains-Definition and Examples, Fields, Characteristic of a Ring.

Unit – V
Ideals, Factor Rings, Prime Ideals and Maximal Ideals. Ring Homomorphisms-Definition and Examples. Properties of Ring Homomorphisms. The Field of Quotients

Text Book:
1. Contemporary Abstract Algebra, Joseph Gallian, Ninth edition, Cengage Learning India, 2013.

References
1. Garrett Birkoff and Saunders Mac Lane, 'A Survey of Modern Algebra', Universities Press, 2003.
2. I. N. Herstein, 'Topics in Algebra', Second Edition, John Wiley and Sons, 2000.
3. M.Artin, 'Algebra', Prentice Hall inc., 1994.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: Mathematics being a language of all physical sciences and being a speciality in itself, the entire contents of this course, tutorials and assignments lays mathematical foundation for many mathematics, physics and engineering courses and builds skills required for a career as an educator in schools, colleges and universities, as a researcher, and as a communicator of mathematics in general.

SEMESTER5

15MAT234	Numerical Methods	3 1 0 4

Course Outcomes:
CO1: Understand the basic concepts of root finding methods, system of equations and their solutions.
CO2: Understand the concepts of interpolation and construction of polynomials.
CO3: Application of numerical methods to understand the concept of Calculus (Differentiation and Integration).
CO4: Application of numerical concepts to solve ODEs and PDEs.
CO5: Usage of software tools to solve various problems numerically.

Unit – I Roots of Transcendental and Polynomial Equations: Bisection method, Iteration methods based on first degree equation, Rate of convergence, System of nonlinear equations.
Solution of System of Linear Algebraic Equations: Iteration Methods.
Eigenvalues and Eigenvectors: Jacobi Method for symmetric matrices, Power Method for arbitrary matrices.

Unit – II Interpolation and Approximation: Lagrange and Newton interpolation for unequal intervals, Finite difference operators, Interpolating polynomials using finite differences.

Unit – III Differentiation and integration: Numerical differentiation-Methods based on Interpolation, Numerical integration-Methods Based on Interpolation, Methods Based on Undetermined Coefficients.

Unit – IV Solutions of Ordinary Differential Equations: Initial value problems- Single step methods- Taylor Series Method, Second, Third and Fourth order Runge-Kutta Methods.

Unit – V Solutions of Partial Differential Equations: Elliptic partial differential equations, Parabolic partial differential equations, Hyperbolic partial differential equations.

TEXT BOOKS:
1. M.K.Jain, S.R.K. Iyengar and R.K.jain, Numerical methods for Scientific and Engineering Computation, New Age International Publishers, 2007, Fifth edition.

REFERENCE BOOK:
1. S.D Conte and Carl de Boor,' Elementary Numerical Analysis; an Algorithmic Approach', International Series in Pure and Applied Mathematics, Mcgraw Hill Book Co., 1980.
2. Richard L. Burden and J. Douglas Faires, Numerical Analysis, 8th Edition.
3. Kandasamy. P, Thilagavathi. K and Gunavathi. K "Numerical methods" – S. Chand and Company Ltd, New Delhi – Revised Edition 2007.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: Entire course contents with tutorials and assignments help build foundations and develops computational thinking, programming skills – design and implementation of software for scientific, engineering and industrial computing applications in universities, industries and research labs/organisations, and prepare students as an educator in schools, colleges and universities.

16MAT326	Introduction to Real Analysis	3 1 0 4

Course Outcomes

CO1: Understanding the set theoretic statements and the completeness property of R.
CO2: Understanding the concepts of sequences, series and Limits. Apply the tests for convergence, absolute convergence and analyzing the convergence criteria.

CO3: Defining Limits, continuity and monotonicity of a function and understanding the theorems related to them.
CO4: Understanding the concepts of extreme values, Mean value theorem and applying Taylor's theorem for approximating functions.
CO5: Understanding Riemann Sum and apply it to approximate integrations.

Unit I
Preliminaries-Sets and Functions, Mathematical Induction, Finite and Infinite Sets.
The Real Numbers-The Algebraic and Order Properties of R, Absolute Value and the Real Line, The Completeness Property of R, Applications of the Supremum Property, Intervals.

Unit II
Sequences and Series-Sequences and Their Limits, Limit Theorems, Monotone Sequences, Subsequences and the Bolzano-Weierstrass Theorem, The Cauchy Criterion, Properly Divergent Sequences, Introduction to Infinite Series.
Limits-Limits of Functions, Limit Theorems.

Unit III
Continuous Functions-Continuous Functions, Combinations of Continuous Functions,Continuous Functions on Intervals, Uniform Continuity.
Differentiation-The Derivative, The Mean Value Theorem, L'Hospital's Rules, Taylor's Theorem.

Unit IV
The Riemann Integral- Riemann Integral, Riemann Integrable Functions, The Fundamental Theorem.
Sequences of Functions-Pointwise and Uniform Convergence, Interchange of Limits.

Unit V
The Exponential and Logarithmic Functions, The Trigonometric Functions.
Infinite Series-Absolute Convergence, Tests for Absolute Convergence, Tests for Non absolute Convergence,Series of Functions

Text Book:
1. Introduction to Real Analysis, by Robert Gardner Bartle, Donald R. Sherbert, , Fourth Edition, John Wiley and Sons, 2011.

Reference Books:
1. Mathematical Analysis by Tom M. Apostol, Second Edition, Narosa publishing house, New Delhi,1989.
2. Principles of Mathematical Analysis by Rudin.W, Third Edition, McGraw-Hill International Editions, 1976.
3. Real Analysis by H.L. Royden and P.M.Fitzpatrick. Fourth Edition. Pearson Education Asia Limited, 2010.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: Mathematics being a language of all physical sciences and being a speciality in itself, the entire contents of this course, tutorials and assignments lays mathematical foundation for many mathematics, physics and engineering courses and builds skills required for a career as an educator in schools, colleges and universities, as a researcher, and as a communicator of mathematics in general.

16MAT380   **MATLAB – MATHEMATICAL SOFTWARE**   **0 0 2 1**
Course Outcomes

CO1: Understand the basics of MATLAB.
CO2: Application of MATLAB software for basic matrix computation problems through loops.
CO3: Application of MATLAB software to solve various Linear algebra problems numerically.
CO4: Understand the concepts of ODE and PDE using MATLAB .

Mathematical package MATLAB will be introduced to solve problems in Linear Algebra, Differential Equations, Numerical Analysis, Combinatorics etc.

Linear Algebra : Solution of linear systems by elimination, least squares problems, eigenvalue problem. Euler's Method , Runge Kutta Methods.

Combinatorics: Making lists of combinatorial objects, generating random combinatorial objects (like sets, permutations, partitions etc.), Tree Search, Graph search: Breadth and depth first search.

TEXT BOOKS
1. Chapman, *MATLAB Programming for Engineers*, Thomson Learning (3rd Edition – 2005).
2. Rudra Pratap *Getting Started with MATLAB 7: A Quick Introduction for Scientists and Engineers*, Oxford University Press.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: Entire course contents with tutorials and lab exercises help build foundations and develops computational thinking and programming skills leading to scientific computing and software applications in research organizations and universities.

SEMESTER 6

16MAT327	Introduction to Complex Analysis	3-1-0-4

Course Outcomes

CO1: Understand the concepts of the complex numbers analyticity, series expansions and some elementary complex functions
CO2:Understand about complex integrations
CO3:Understand about the singularities and Residues
CO4:Understand the evaluation of different type integrals
CO5:Understand the concept of complex mappings and Linear transformations some basic mappings.

Unit 1
Definition, Algebra of complex numbers, polar forms, regions, Limits, continuity, differentiability Analyticity, CR equations, Harmonic Functions, Exponential, trigonometric, logarithmic and hyperbolic functions, complex exponentials and Inverse trigonometric functions

Unit 2
Conformal mappings, bilinear transformations, Special bilinear transformations, fixed points

Unit 3
Contour integral, Cauchy-Goursat theorem, Cauchy's integral formula, winding number, Primitives

Unit 4
Sequences, series, power series, uniform convergence of power series, Taylor's series, Laurent's series, Integration and differentiation of Power series.

Unit 5
Zeros and singularities of analytic functions, types of singularities, poles, residue theorem.

TEXT BOOK
1. H S Kasana, Complex variables, Theory and Applications, second edition, Prentice Hall India

REFERENCES
1. S. Ponnusamy, *Foundations of Complex Analysis*, 2nd Edition, Narosa Publishing House, 2005.
2. J.W. Brown and R.V. Churchil, *Complex Variable and Applications*, McGraw Hill, 2008
3. R. Roopkumar, Complex Analysis, Pearson Education, 2014, Chennai.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: Mathematics being a language of all physical sciences and being a speciality in itself, the entire contents of this course, tutorials and assignments lays mathematical foundation for many mathematics, physics and engineering courses and builds skills required for a career as an educator in schools, colleges and universities, as a researcher, and as a communicator of mathematics in general.

15MAT328	**Introduction to Number Theory**	3	1	0	4

Course Outcomes

CO1: Understand integers with divisibility properties and realize the group structure in integers using modular operations.
CO2: Apply division algorithm and factorization techniques in Cryptography.
CO3: Study arithmetic functions and its applications in Number Theory
CO4: Understand quadratic residue, primitive roots and solve Diophantine equations.

Unit – I
Divisibility: Definition, properties, division algorithm, greatest integer function (Sec 1.1)

Primes: Definition, Euclid's Theorem, Prime Number Theorem (statement only), Goldbach and Twin Primes conjectures, Fermat primes, Mersenne primes.The greatest common divisor: Definition, properties, Euclid's algorithm, linear combinations and the GCD - The least common multiple: Definition and properties.The Fundamental Theorem of Arithmetic: Euclid's Lemma, canonical prime factorization, divisibility, gcd, and lcm in terms of prime factorizations. Primes in arithmetic progressions: Dirichlet's Theorem on primes in arithmetic progressions (statement only) (Sec 1.2 to 1.5)

Unit – II Congruences:
Definitions and basic properties, residue classes, complete residue systems, reduced residue systems - Linear congruences in one variable, Euclid's algorithm - Simultaneous linear congruences, Chinese Remainder Theorem - Wilson's Theorem - Fermat's Theorem, pseudoprimes and Carmichael numbers - Euler's Theorem (Sec 2.1 to 2.6)

Unit – III Arithmetic functions:
Arithmetic function, multiplicative functions: definitions and basic examples - The Moebius function, Moebius inversion formula - The Euler phi function, Carmichael conjecture -The number-of-divisors and sum-of-divisors functions - Perfect numbers, characterization of even perfect numbers (Sec 3.1 to 3.6)

Unit – IV Quadratic residues:
Quadratic residues and nonresidues - The Legendre symbol: Definition and basic properties, Euler's Criterion, Gauss' Lemma - The law of quadratic reciprocity (Sec 4.1 to 4.3)

Unit – V Primitive roots:
The order of an integer - Primitive roots: Definition and properties - The Primitive Root Theorem: Characterization of integers for which a primitive root exists(Sec 5.1 to 5.3)

Diophantine Equations
Linear Diophantine Equations- Pythagorean triples – Representation of an integer as a Sum of squares (Sec 6.1, 6.3, 6.5)

TEXT BOOK:
1.   James Strayer, 'Elementary Number Theory', Waveland Press, 1994/2002, ISBN 1-57766-224-5

REFERENCE BOOK:
1.   Tom M. Apostol,' Introduction to Analytic Number Theory', Springer, Under Graduate Studies in Mathematics, 1976.
2.   Kenneth Rosen, *Elementary Number Theory and its Applications*, 5th Edition, McGraw Hill.
3.   I. Niven, H. Zuckerman, H. Montgomery, *An Introduction to the Theory of Numbers*, 5th Edition, Wiley.
4.   Burton, David M. *Elementary Number Theory*. Allyn and Bacon, 1976.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: Mathematics being a language of all physical sciences and being a speciality in itself, the entire contents of this course, tutorials and assignments lays mathematical foundation for many mathematics, physics and engineering courses and builds skills required for a career as an educator in schools, colleges and universities, as a researcher, and as a communicator of mathematics in general.

16MAT391	MathematicsSeminar	0-0-2-1

Course Outcomes
CO1: Earn awareness about general mathematics, history, culture etc.
CO2: Get knowledge about special topics not given in the syllabus
CO3: Acquire presentation skills and also get writing skills of mathematics

Seminars shall be given in the area of Mathematics. In this one-credit course, students present and discuss the subject matter with faculty guidance. Topics presented by the students include fundamental topics. Students are exposed to areas not covered in courses and the students take turns in giving lectures. The objective of these seminars is to provide the students with training in the verbal and written communication of topics in Mathematics.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Mathematics UG Elective courses

15MAT337	Linear and Nonlinear optimization	3 1 0 4

Course Outcomes:

CO1.   Understand different types of Optimization Techniques in engineering problems. Learn Optimization methods such as Bracketing methods, Region elimination methods, Point estimation methods.
CO2.   Learn gradient based Optimizations Techniques in single variables as well as multi-variables (non-linear).
CO3.   Understand the Optimality criteria for functions in several variables and learn to apply OT methods like unidirectional search and direct search methods.
CO4.   Learn constrained optimization techniques. Learn to verify Kuhn-Tucker conditions and Lagrangian Method.

Unit-I Optimization - optimal problem formulation, engineering optimization problems, optimization algorithms, numerical search for optimal solution.

Single Variable optimization
Unit-II Optimality criteria, bracketing methods - exhaustive search method, bounding phase method- region elimination methods - interval halving, Fibonacci search, golden section search methods.
Unit-III Point estimation method- successive quadratic search, gradient based methods, Newton Raphson, bisection method, secant method and cubic search method.

Multivariable Optimization
Unit-IV Optimality criteria, unconstrained optimization - solution by direct substitution, unidirectional search – direct search methods evolutionary search method, simplex search method, Hook-Jeeves pattern search method, gradient based methods – steepest descent, Cauchy's steepest descent method, Newton's method, conjugate gradient method.
Unit-V Constrained optimization –Kuhn-Tucker conditions-transformation methods – penalty function method, method of multipliers, cutting plane method, feasible direction method – gradient projection method, Indirect methods – transformation techniques, penalty function method , branch and bound method – Lagrangian method.

TEXTBOOKS:

1. S.S. Rao, "Optimization Theory and Applications", Second Edition, New Age International (P) Limited Publishers, 1995.

REFERENCES:

1. Kalyanmoy Deb, "Optimization for Engineering Design Algorithms and Examples", Prentice Hall of India, New Delhi, 2004.
2. Edwin K.P. Chong and Stanislaw H. Zak, "An Introduction to Optimization", Second Edition, Wiley-Interscience Series in Discrete Mathematics and Optimization, 2004.
3. M. Asghar Bhatti, "Practical Optimization Methods: with Mathematics Applications", Springer Verlag Publishers, 2000.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT338	**Introduction to Special Functions**	**3-1-0-4**

Course Outcomes

CO-1: Understand and apply the concept of gamma and beta and elliptic functions in engineering and sciences.
CO-2: Model various engineering nonlinear systems as differential equations and solve using the knowledge of series solutions.
CO-3: Understand the concept of recurrence relation and apply to solve engineering problems using the knowledge of Bessel's equation.
CO-4: Understand the concept of recurrence relation and apply to solve engineering problems using the knowledge of Legendre Polynomial.
CO-5: Understand and apply the concepts of Legendre, Bessel's and Greens functions to solve integral equations..

Unit-I Definition ofLegendre's Equation, Solution of Legendre's Equation, Definition of $P_n(x)$ and $Q_n(x)$, General solution of Legendre's equation. Orthogonal properties of Legendre's Polynomials, Recurrence formulae, Rodrigues formula.
Unit-II Legendre's functions of the Second Kind, Recurrence formulae for $Q_n(x)$, Relation between $P_n(x)$ and $Q_n(x)$. Orthogonality of Legendre Polynomials.
Unit-III Bessel's equation (Def.) , Solution of Bessel's General Differential Equations, General Solution of Bessel's Equation, Definition of $J_n(x)$, Recurrence formulae for $J_n(x)$, Orthogonality of Bessel Functions.
Unit-IV Periodic Functions, Elliptic Functions, Order of an Elliptic Function, Properties of an Elliptic Function, Weierstrass's function, Weierstrass's Elliptic Function, The differential equation satisfied by two Weierstrass's elliptic function $p(z)$. Euler's Integrals
Unit-V Beta and Gamma Functions, Elementary properties of Gamma Functions, Transformation of Gamma Functions, Another form of Beta Function, Relation between Beta and Gamma Functions, To find the value of $\Gamma\left(\frac{1}{n}\right) \Gamma\left(\frac{2}{n}\right) ... \Gamma\left(\frac{n-1}{n}\right)$.

TEXT BOOK:

1. Special Functions by J. N. Sharma, Dr. R. K. Gupta, Krishna Prakashan Media,   26th Edition, 2006.

 REFERENCES:
1. I. N. Sneddon - Special Functions of Mathematical Physics & Chemistry, 3 Oliver & Boyd, London.
2.   N. N. Lebedev - Special Functions and Their Applications , PHI.
3.   Special Functions, R. Askey and R. Roy, Cambridge.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT339	**Testing of hypotheses and Analysis of Variance**	**3**	**1**	**0**	**4**

CO1: To understand the concept and types of hypothesis testing and its applications
CO2: To apply normal and t-distribution based tests for two-mean problems

CO3: To understand the concept of ANOVA and DoE and their applications
CO4: To understand the concept of Latin Square and Factorial designs and applications
CO5: To study types of control charts, their constructions and applications

Unit – I
Hypothesis Testing:
Introduction - relation between confidence intervals and testing of hypothesis – level of significance, critical region and p-value – test statistics and steps for testing of hypothesis – classification of hypothesis tests - large sample tests based on normal distribution – tests for single mean, difference of two means, single proportion, two proportions.

Unit – II
Small sample tests - tests for single mean and difference of two means, F – test for equality of two variances - Chi-square based tests – test for independence of attributes and test for goodness - of- fit - nonparametric tests – sign test, signed rank test and run test.

Unit – III
Analysis of Variance:
Introduction- analysis of variance – single factor analysis of variance – one-way analysis of variance, fixed and random effects models – computation of sum of squares - two way analysis of variance (completely randomized block designs) - fixed and random effects models, computation of sum of squares, estimation of variance components.

Unit – IV
Design of Experiments:
Introduction – Latin Square Design – statistical model for LSD, computation of sum of squares – two factor factorial experiment – main and interaction effects, data and statistical model- computation of sum of squares – estimation of variance components.

Unit –V
Statistical Quality Control
Introduction - relation between confidence limits and control limits - control charts for variables – X-bar chart, R-chart, S chart for individual observations- control charts for attributes p and C charts.

TEXT BOOKS:
1. Ronald E. Walpole, Raymond H. Myers, Sharon L. Myers and Keying Ye, Probability and Statistics for Engineers and Scientists, 8th Edition, Pearson Education Asia, 2007.

REFERENCES:
1. Douglas C. Montgomery and George C.Runger, Applied Statistics and Probability for Engineers, John Wiley and Sons Inc. , 2005
2. Ravichandran, J. Probability and Statistics for engineers, First Reprint Edition, Wiley India, 2012.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT340	Integral Transforms and Fourier series	3 1 0 4

Course Outcomes:

CO1: Understand the basic concepts of Fourier series for periodic functions and extension to aperiodic functions.
CO2: Understand the concepts of Complex Fourier transform, Fourier cosine and sine transform.
CO3: Model mathematically the one dimensional wave and heat equations and solve using the Fourier series.
CO4: Understand the concept of Laplace transform and its properties.
CO5: Apply Laplace transform to solve linear ordinary differential equations with initial conditions.

Unit – I Fourier Analysis: Fourier series, Complex Form of Fourier Series, Parseval's Identity, Fourier Integrals, Fourier integral theorem. Gibbs Phenomenon, Sine and Cosine Integrals.

Unit – II Infinite Complex Fourier Transforms, Sine and Cosine Transforms, Properties, Convolution theorem and Parseval's theorem**.**

Unit – III Applications to Partial Differential Equations: Modeling: Vibrating String, Solution by Separation of Variables, and Solution of one dimensional Wave Equation. Solution of one dimensional Heat Equation.

Unit – IV Laplace Transforms: Laplace Transforms, Inverse Transforms, Properties, Transforms of Derivatives and Integrals, Second Shifting Theorem, Unit Step Function and Dirac-Delta Function, Differentiation and Integration of Transforms.

Unit – V Convolution, Initial and Final Value Theorems, Periodic Functions, Solving Linear Ordinary Differential Equations with Constant Coefficients, System of Differential Equations and Integral Equations.

Text Book
1. E Kreyszig, Advanced Engineering Mathematics, John Wiley and Sons, 2002, Eighth Edition.

Reference Book
1. Larry C. Andrews and Bhimson. K. Shivamoggi, The Integral Transforms for Engineers, Spie Press, Washington, 1999.
2. J. L. Schiff, The Laplace Transform, Springer, 1999.
3. Stanley J Farlow,' Partial Differential Equations for Scientists and Engineers' Dover Book on Mathematics, 1993

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT341	Introduction to Operations Research	3 1 0 4

Course Outcomes

CO1.   Understand the basic concepts of linear programming, duality and methods for solving linear programming problem.

CO2.   Understand the mathematical formulation of transportation and assignment problems and solution methods.

CO3.   Understand the network representation of project works and computation of PERT and CPM.

CO4.   Understand the basic concepts of sequencing problem, integer programing algorithms and solution methods.

Unit – ILinear Programming Problem:
Introduction to Operations Research, necessity of Operations Research in modern management- models in Operations Research, Introduction to Linear Programming Problems, Formulation of Linear Programming Problems, solutions to Linear Programming Problems based on graphical method, solutions based on simplex algorithm, penalty method, two phase method- solutions based on dual simplex method- duality in Linear Programming Problem – primal-dual problems.

Unit – II Transportation and Assignment Problems:

Introduction to transportation - mathematical formulation of transportation problem, methods for initial basic feasible solution methods, MODI method for optimal solution – unbalanced transportation problems, degeneracy in transportation problem - introduction to assignment problem, mathematical formulation of assignment problem, comparison between assignment problem and transportation problem, optimal solution based on Hungarian method, Traveling Salesman Problem.

Unit – III Queuing Theory:

Introduction to queuing theory, characteristics of queuing theory, single channel queuing models with finite and infinite size, solution to single channel queuing models, application of queuing theory.

Unit – IV Simulation: Introduction to simulation, advantages and limitations, generation of random numbers, Monte Carlo simulation, and computer aided simulation, application in inventory management and queuing.

Unit – V CPM and PERT: Network logic, concepts and definition, network scheduling by critical path method, program evaluation and review technique- slack and float.

TEXT BOOKS and REFERENCES:

1. Hamadi A. Taha, "Operations Research - An Introduction", Seventh Edition, Pearson Education, 2014.

2. Kanti Swarup, P.K. Gupta and Man Mohan, "Operations Research", Ninth Edition, Sultan Chand and Sons, 2001

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

PG Courses(MATHEMATICS Stream) (Semesters 7 – 10)

SEMESTER 7

15MAT501	Advanced Algebra	3 1 0 4

Course Outcomes

CO1: To derive the class equation and use it in various counting problems. To derive Cauchy's/ Sylow's theorem for general groups.
CO2: To understand direct product and to apply Sylow's theorem to Classify finite Abelian Groups.
CO3: To understand polynomial rings over rational fields and identify irreducible polynomials through standard theorems.
CO4: To study in details special cases of integral domains. To familiarize the concept of Grobner Bases and its applications.
CO5: To familiarize Galois Theory and its use in analyzing the solvability by radicals of polynomial equations.

Unit-I

Review: Groups and Rings

Rings: Euclidean Rings, Polynomial Rings, Polynomial Rings over the Rational Field, Polynomial Rings over

Commutative Rings. (Sec. 3.7 to 3.11)

Unit-II
Fields: Definition of Fields, Field Extensions, Finite, Algebraic Field Extensions and Their Properties. The

Transcendence of 'e'. (Sec. 5.1 to 5.2)

Unit-III
Fields(cont.): Roots of Polynomials, Remainder Theorem, Splitting Field and its Uniqueness, Classical Ruler and Compass Constructions, Distinct and Multiple Roots, Simple Extension of a Field. (Sec. 5.3 to 5.5).
Unit-IV
Fields(cont.): The Elements of Galois Theory, Solvability by Radicals, Galois Groups over the Rationals. (Sec. 5.6 to 5.8).
Unit-V

Groups: Direct products, Finite Abelian Groups. (Sec. 2.13 and 2.14).
(Seminar/self-study topics)

Text Books:
1. I. N. Herstein, 'Topics in Algebra', Second Edition, John Wiley and Sons, 2000.

References
1. Garrett Birkoff and Saunders Mac Lane, 'A Survey of Modern Algebra', Universities Press, 2003.
2. M.Artin, 'Algebra', Prentice Hall inc 1994.
3. D.S. Dummit and R. M. Foote, 'Abstract Algebra', 2nd Ed., John Wiley, 2002.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT502	Advanced Real Analysis	4 0 0 4

CO1- Understanding Riemann-Stieltjes Integral and applying it to evaluate length of the Rectifiable curves
CO2- Understanding Equi continuous Families of Functions and The Stone-Weierstrass Theorem.
CO3- Understanding special functions and algebraic completeness of the complex field
CO4- Applying the concept of derivatives in functions of several variables.
CO5- Understanding Contraction principle, The inverse function theorem, The implicit function theorem.

Unit 1: Functions of Bounded Variation and Rectifiable Curves:
Introduction, Properties of monotonic functions, Functions of bounded variation, Total Variation, Additive property of total variation, Total variation on $[a, x]$ as a function of x.

Unit-II Functions of bounded variation expressed as the difference of increasing functions, Continuous functions of bounded variation.(Chapter 6 : 6.1-6.8)

Unit III Riemann-Stieltjes Integral: Definition and Existence of the Integral, Properties of the Integral, Integration and Differentiation, Integration of vector-valued functions, Rectifiable curves.

Unit-IV Sequences and Series of Functions: Sequence of functions and its point-wise limit, Discussion of main problems, Uniform convergence, Uniform convergence and continuity, Uniform convergence and Integration, Uniform convergence and Differentiation, Equicontinuous Families of Functions, The Stone-Weierstrass Theorem.

Unit-V Some Special Functions: Introduction to power series, The Exponential and Logarithmic Functions, The Trigonometric Functions, The Algebraic Completeness of the Complex Field, Fourier series, Gamma function and its properties.

Text Book:

1. **Mathematical Analysis** by Tom M. Apostol, Second Edition, Narosa publishing house, New Delhi,1989.

Reference Books:

1. **Introduction to Real Analysis**, by Robert Gardner Bartle, Donald R. Sherbert, ,Fourth Edition, John Wiley and Sons, 2011.
2. **Principles of Mathematical Analysis** by Rudin.W, Third Edition, McGraw-HillInternational Editions, 1976.
3. **Real Analysis** by H.L. Royden and P.M.Fitzpatrick. Fourth Edition. Pearson Education Asia Limited, 2010.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT504	Ordinary Differential Equations	4 0 0 4

Course Outcomes:

CO1: Understand the existence - uniqueness conditions of solutions to first order equations and apply various methods to solve the initial value problems.
CO2: Understand the concepts of the existence and uniqueness theorem, fundamental matrix, homogenous/nonhomogenous linear systems with constant coefficients and solve the problems involving central forces, planetary motion and some special equations.
CO3: Understand the concepts of a complex n-dimensional space, the systems as vector equations, existence and uniqueness of solutions to systems.
CO4: Understand the concepts of nonlinear equations, autonomous systems, the phase plane and its phenomena and stability for linear and nonlinear systems.
CO5: Understand the concepts of periodic and oscillatory behaviours of a differential equation.

Unit-I Existence-Uniqueness of Solutions to First Order Equations: Equations with variable separated, Exact equations, the method of successive approximations, Lipschitz condition, Convergence of successive approximations, Non–local existence of solutions, Approximations to and uniqueness of solutions.

Unit-II Existence and Uniqueness of Solutions to Systems and n-th Order Equations: Introduction, An example – central forces and planetary motion, Some special equations.

Unit-III Complex n-dimensional space, Systems as vector equations, Existence and uniqueness of solutions to systems, Existence and Uniqueness of linear systems, Equations of order n.

Unit-IV Nonlinear equations: Autonomous Systems, The Phase plane and its phenomena, Types of critical points, Stability, critical points and stability, for linear systems, Stability by Liapunov's Direct method, Simple critical points of nonlinear systems.

Unit-V Nonlinear mechanics, Conservative systems, Periodic solutions, The Poincaré –Bendixson theorem.

Oscillations and the Sturm Separation theorem, The Sturm comparison theorem.

TEXTBOOK:
1. Differential equations with applications and historical notes, George F. Simmons and John S Robertson, Tata McGraw Hill Education Private Limited, 2003, Second Edition.

2. An introduction to ordinary differential equations, E.A. Coddington, PHI learning, 1999.

REFERENCES:

Ordinary differential equations and stability theory, S. G. Deo and V Raghavendra

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT511	Advanced Complex Analysis	4-0-0-4

CO1: Understand the concept of the Schwarz Reflection by complex conjugation, and its Applications
CO2:Understand the Riemann Mapping theorem
CO3:Understand the Analytic Continuation
CO4:To understand about the entire function and meromorphic function
CO5:Understand about the Elliptic functions

Unit-I Analytic Continuation: Direct Analytic Continuation, Monodromy Theorem, Poisson Integral Formula, Analytic Continuation via Reflection.

Unit-II Representations for Meromorphic and Entire Functions: Infinite Sums and Meromorphic functions, Infinite Product of Complex Numbers, Infinite Products of Analytic Functions.

Unit-III Factorization of Entire Functions, The Gamma Function, The Zeta Function Jensen's Formula, The Order and the Genus of Entire Functions.

Unit-IV Mapping Theorems: Open Mapping Theorem and Hurwitz' Theorem, Basic Results on Univalent Functions, Normal Families.

Unit-V The Riemann Mapping Theorem, Bieberbach Conjecture, The Bloch-Landau Theorems Picard's Theorem.

TEXT BOOK
1. L. Ahlfors, *Complex Analysis, 2nd Ed.*, McGraw-Hill,New York, 1966.

REFERENCES
1. T.W. Gamelin, *Complex Analysis*, Springer-Verlag, 2001
2. S. Ponnusamy and H. Silverman, *Complex Variables with Applications*, Springer, 2006.
3. R. Roopkumar, Complex Analysis, Pearson Education, 2014, Chennai.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

SEMESTER 8

15MAT503	Topology	3	1	0	4

Course Outcomes

- CO1: To understand the basic definitions of infinite sets, countable set, uncountable sets and axiom of choice through examples.
- CO2: To understand the definitions of metric space, convergence, continuity and completeness through examples this leads to the study of more abstract topological spaces.
- CO3: To study the basic properties of compact metric spaces. To understand the concepts of compact metric space and separable metric space through examples.
- CO4: Understand and apply the concepts of completeness and compactness to prove the existence and uniqueness of solutions to certain ordinary differential equations.
- CO5: To understand the basic definitions of topological spaces, limits, closed set, open set and basis for a topology through examples. To construct new topology from given topology such as subspace topology, product topology etc.

Unit 1: Metric Spaces: General Properties: Examples of Metric Spaces – Open Sets, Closed Sets and Convergence Sequences – Continuous Mappings between Metric Spaces – Complete Metric Spaces – Compact Metric Spaces – Separable Metric Spaces.
Chapter 9: Sec 9.1 to 9.6 (Text Book 1)

Unit II : Metric Spaces: Three Fundamental Theorems: The Arzelas-Ascoli Theorem – The Baire Category Theorem – The Banach Contraction Principle.
Chapter 10: Sec 10.1 to 10.3 (Text Book 1)

Unit 3: Topological Spaces and Continuous Function: Topological Spaces- Basics for a Topology – The Order Topology – The Product Topology on X ×Y – The Subspace Topology – Closed Sets and Limit Points – Continuous Functions – Product Topology – The Metric Topology.Chapter 2: Sec 12 to 21 (Text Book 2)

Unit 4: Connectedness and Compactness: Connected Spaces – Connected Subspaces of the Real Line – Compact Spaces – Compact Subspaces of the Real Line.
Chapter 3: Sec 23, 24, 26, 27 (Text Book 2)
Unit 5: Countability and Separation Axioms: The Countability Axioms – The Separation Axioms – Normal Spaces – Te Urysohn Lemma – The Urysohn Metrization Theorem.
Chapter 4: Sec 30 to 34 (Text Book 2)

TEXT BOOK :
1. **Real Analysis** by H.L. Royden and P.M.Fitzpatrick. Fourth Edition. Pearson Education Asia Limited, 2010.
2. **Topology** by J.R. Munkers, Second Edition, Prentice Hall of India, New Delhi, 2004.

REFERENCE BOOKS :
1. J. Dugundji : Topology (Allyn and Bacon, Boston, 1966.)

2. 2. K. D. Joshi: Introduction to General Topology (Wiley Eastern Limited).
3. M. A. Armstrong, Basic Topology, Springer (India), 2004.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT512	Functional Analysis	4	0	0	4

Course Outcomes

CO1: To understand the concepts of linear space, metric space and normed linear space. To analyze the spaces which has both linear structure and metric structure. To apply this new structure on set of all transformations and operators, so that continuity and boundedness becomes equivalent. By applying these results, we obtain a new normed spaces of all bounded linear transformations.

CO2: To understand and review the concepts from real analysis such as Integration and Differentiation, Compact Spaces and separability of compact metric Spaces. To apply and evaluate the corresponding results in this normed spaces.

CO3: To understand finite dimensional normed spaces and operators on it. To understand and apply Stone Weierstrass Theorem, Ascoli-Arzela Theorem and Peano's Theorem.

CO4: To understand dual spaces and reflexive spaces. To understand and apply Hahn Banach Theorem.

CO5: To understand convex sets. To understand and apply The Riesz Representation Theorem and Hergoltz's Theorem.

Unit – I: **Normed Linear Spaces:** Linear Spaces – Normed Linear Spaces – The Metric on a Normed Linear Space – Linear Subspaces – Bounded Linear Transformations.
Sections: 3.1 to 3.5 (Text Book – 1)

Unit – II : **Linear Homeomorphisms** – An Elementary Integral – Regulated Mappings – Integration and Differentiation - Review of Compact Metric Spaces – Basic Results on Compact Subsets of a Metric Space – Separability of Compact Metric Spaces – Conditions Equivalent to Compactness - Borel – Lebesgue Theorem
Sections: 3.7 to 3.9   and 4.1 to 4.2 (Text Book – 1)

Unit – III : - Compactness and Continuity – Dini's Theorem- Finite Dimensional Normed Linear Spaces – Completeness – Stone Weierstrass Theorem – Weierstrass Theorem on approximation of periodic functions by trigonometric polynomials – Extension of Stone-Weirstrass Theorem to $C_c(X)$ - Separability of $C_K(X)$ - Ascoli-Arzela Theorem – Peano's Theorem
Sections: 4.3 to 4.6 (Text Book – 1)

Unit – IV: **Bounded Linear Functionals** – Some Dual Spaces – The Hahn-Banach Theorem – The Existence of Bounded Linear Functionals – Reflexivity of the Banach Space l^p - Annihilators.
Sections: 5.1 to 5.4 (Text Book – 1)

Unit 5: A Theorem on Convex Sets – The Riesz Representation Theorem – Hergoltz's Theorem
Sections 5.5 to 5.7 (Text Book – 1)

Text Books:

1. Elements of Functional Analysis by A.L. Brown and A. Page, Van Norstrand Reinhold Company, London, 1970.
2. Functional Analysis by Balmohan V Limaye, New Age International Publishers, Third Edition, Reprint 2014.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT513   **Graph Theory**   **4 0 0 4**
Course outcomes

   CO-1: Understand the basic concepts of graphs and trees.
   CO-2: Understand and apply the concepts of graph connectivity and shortest path problems.
   CO-3: Understand and apply the concepts of matching problems in job assignments.
   CO-4: Understand the concepts of vertex and edge colorings.
   CO-5: Understand the concepts of planar graphs and dual graphs.

Unit-I Review of Graphs: Graphs and Sub graphs, isomorphism, matrices associated with graphs, degrees, walks, connected graphs, shortest path algorithm.

Trees: Trees, cut-edges and cut-vertices, spanning trees, minimum spanning trees, DFS, BFS algorithms.

Unit-II Connectivity: Graph connectivity, k-connected graphs and blocks.

Euler and Hamilton Graphs: Euler graphs, Euler's theorem. Fleury's algorithm for Eulerian trails. Necessary / sufficient conditions for the existence of Hamilton cycles, Chinese-postman-problem, approximate solutions of traveling salesman problem

Unit-III Matching: Matchings, maximal matchings. Coverings and minimal coverings. Berge's theorem, Hall's theorem, Tutte's perfect matching theorem, Job assignment problem.

Coverings, Independent Sets and Cliques; Basic Relations.

Unit-IV Colorings: Vertex colorings, greedy algorithm and its consequences, Brooks' theorem. Edge-colorings, Vizing theorem on edge-colorings.

Unit-V Planar graphs: Euler formula. Dual graphs. Kuratowaski's Characterization, Planarity testing algorithm.

TEXT BOOKS
1. J.A. Bondy and U.S.R. Murty, *Graph Theory and Applications*, Springer, 2008.

REFERENCES BOOKS
1. D.B. West, *Introduction to Graph Theory*, P.H.I. 2010.

2. Frank Harary, Graph Theory, New York Academy of Sciences, 1979.

3. Russel Merris, Graph Theory, John Wiley, 2011.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT514	Partial Differential Equations	3-1-0-4

Course Outcomes:

CO-1: Understand the geometrical interpretation, characteristics and general solutions of a first-order p.d.e, and solve it by various methods.
CO-2: Understand the concepts of a second-order p.d.e, its canonical forms and the procedure for obtaining the general solutions.
CO-3: Understand the concepts of the Cauchy problem, initial & boundary-value problems and homogeneous/ nonhomogeneous wave equations.
CO-4: Understand the various types of boundary-value problems, maximum/minimum principles and uniqueness and continuity theorems.
CO-5: Understand the concepts of the heat equation, its solutions and the initial and boundary value problems with time- dependent and time-independent boundary conditions.

Unit-I First order PDE - Geometrical Interpretation of a First-Order Equation, Method of Characteristics and General Solutions, Canonical Forms of First-Order Linear Equations

Unit-II Second-Order Linear Equations - Second-Order Equations in Two Independent Variables, Canonical Forms, Equations with Constant Coefficients.

Unit-III Cauchy Problem and Wave Equations - The Cauchy Problem, The Cauchy-Kowalewskaya Theorem, Homogeneous Wave Equations, Initial Boundary-Value Problems, Equations with Nonhomogeneous Boundary Conditions, Vibration of Finite String with Fixed Ends,(review) Nonhomogeneous Wave Equations.

Unit-IV Boundary-Value Problems - Boundary-Value Problems, Maximum and Minimum Principles, Uniqueness and Continuity Theorems.

Unit-V Dirichlet Problem for a Circle, Dirichlet Problem for a Circular Annulus, Neumann Problem for a Circle, Dirichlet Problem for a Rectangle, Dirichlet Problem Involving the Poisson Equation, The Neumann Problem for a Rectangle.

TEXTBOOK:
1. Tyn Myint-U, Lokenath Debnath Linear Partial Differential Equations for Scientists and Engineers, Birkhauser, Boston, Fourth Edition, 2007.

REFERENCES:
1. L.C. Evans, Partial Differrential Equations, Graduate Studies in Mathematics, Vol. 19, AMS, Providence, 1998.
2. I.N. Sneddon, Elements of partial differential equations, McGraw Hill, New York, 1986.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

SEMESTER 9

15MAT601	Advanced Topology	4 0 0 4

CO1: To understand the basic definition of continuity in topological space and its properties through examples. To study the rules for constructing continuous functions and topological spaces. To understand the relationship between two topological spaces.
CO2: To understand the concepts of connected spaces, separation, path connectedness and locally connected through examples.
CO3: To study the basic properties of compact spaces. To understand the concepts of limit point compactness, sequentially compact, local compactness, compactification, one point compactification through examples.
CO4: To understand countability axioms, separation axioms and its properties.
CO5: To understand the behaviour of compactness in product topology and properties of completeness through Tychonoff's theorem and Baire category theorem respectively.

Unit-I Countability and Separation Axioms: Urysohn lemma, Metrization theorem and Tietze extension theorem. Tychonoff theorem. Stone-Cech campactification.

Unit-II Metrization and Paracompactness: Local finiteness. Nagata-Smirnov Metrization theorem. Paracompactness. Smirnov Metrization theorem.

Unit-III Complete metric spaces. Compactness in metric spaces. Pointwise and compact convergence. And Ascoli's theorem.

Unit-IV Baire spaces. Introduction to dimension theory.

Unit-V Introduction to Fundamental group: Homotopy of paths. Fundamental group. Covering spaces. Fundamental group of cycle. Retractions and fixed points.

TEXT BOOK: J.R. Munkers : Topology A first Course , Prentice Hall of India.

REFERENCE BOOKS:
1. J. Dugundji : Topology (Allyn and Bacon, Boston, 1966.)

2. 2. K. D. Joshi : Introduction to General Topology (Wiley Eastern Limited).
3. M. A. Armstrong, Basic Topology, Springer (India), 2004.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT603	Measure and Integration	4 0 0 4

CO 1: To understand the notion of measure of a set on the real line and the measurable sets and functions
CO2: To understand the notion of Lebesgue Integrals as a generalization of Riemann Integrals
CO3: To understand abstract measure spaces and integration with respect to a measure
CO4: To understand and apply various inequalities to establish the completeness of $L^p(\mu)$
CO5: To understand Raydon-Nikodym Theorem its Applications

Unit 1: Measure on the Real Line: Lebesgue Outer Measure - Measurable Sets – Regularity -Measurable Functions - Borel and Lebesgue Measurability.(sections 2.1 to 2.5)

Unit 2: Integration of Functions of a Real Variable: Integration of Non-Negative Functions - The General Integral - Integration of Series - Riemann and Lebesgue Integrals.(sections 3.1 to 3.4)

Unit 3: Abstract Measure Spaces: Measures and Outer Measures - Extension of a Measure -Uniqueness of the Extension - Completion of a Measure - Measure Spaces - Integration with Respect to a Measure (sections 5.1 to 5.6).

Unit IV : Inequalities and the L ^{P} Spaces: The L ^{P} Spaces - Convex Functions - Jensen's Inequality - The Inequalities of Holder and Minkowski - Completeness of L $^P(\mu)$.(sections 6.1 to 6.5)

Unit 5: Signed Measures and their Derivatives: Signed Measures and the Decomposition - The Jordan Decomposition - The Radon-Nikodym Theorem - Some Applications of the Radon-Nikodym Theorem (sections 8.1 to 8.4)

Text Book:

1.   Measure Theory and Integration by G.de Barra, First Edition, New Age International Publishers, Reprint 2000.

Reference Book:
1.   Real Analysis by H.L. Royden and P.M.Fitzpatrick, Fourth Edition, Pearson Education Asia Limited, 2010.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT604	Operator Theory	4 0 0 4

CO1: To understand compact operators and apply in Fredholm Theory and $C*$- algebras.
CO2: To understand and apply Gelfand-Neumark representation theorem.
CO3: To understand and apply projections, Toeplitz operators.

Unit 1: Bounded Linear Operators – Examples – The Algebra of Bounded Linear Operators – The Spectrum of a Bounded Linear Operator – The Adjoint of a Bounded Linear Transformation.
Sections: 6.1 to 6.4 (Text Book – 1)

Unit 2: Compact Linear Operators – The Riesz-Schauder Theory of Compact Linear Operators – The Spectrum of a Compact linear Operator – Fredholm Integral Equations
Sections: 6.5 to 6.8 (Text Book – 1)

Unit 3: Baire's Theorem – Nowhere Differentiable Continuous Functions – Pointwise Limits of Continuous Functions – The Principle of Uniform Boundedness – The Open Mapping Theorem – The Closes Graph Theorem
Sections: 8.1 to 8.5 and 8.8 (Text Book – 1)

Unit 4: Spectral Theory in Hilbert Spaces: Hermitian Symmetric Forms – Orthogonality – The Hilbert Space Adjoint – Self-adoint Bounded Linear Operators
Sections: 9.1 to 9.4 (Text Book – 1)

Unit 5: (Spectral Theory in Hilbert Spaces continued): Self-adjoint Compact Linear Operators – Positive Linear Operators - Orthogonal Projections – Functions of Self-adjoint Bounded Linear Operators – The Spectral Theorem.
Sections: 9.5 to 9.9

Text Book:

1.   Elements of Functional Analysis by A.L. Brown and A. Page, Van Norstrand Reinhold Company, London, 1970.
2.   Introduction to Functional Analysis with Applications by A.H. Siddiqi, Khalil Ahmad and P. Manchanda. Anamaya Publishers New Delhi 2007.
3.   Functional Analysis by Balmohan V Limaye, New Age International Publishers, Third Edition, Reprint 2014.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT605	Differential Geometry	4 0 0 4

Course outcomes

 CO1: Explain the concepts and language of differential geometry and its role in modern mathematics.

CO2: Analyze and solve complex problems using appropriate techniques from differentia geometry

CO3: Develop the ability to compute quantities of geometric interest such as curvature, as well as develop a facility to compute in various specialized systems, such as semi geodesic coordinates or ones representing asymptotic lines or principal curvatures.

CO4: Familiarize the method of the moving frame and overdetermined systems of differential equations as they arise in surface theory.

CO5: Apply differential geometry to specific research problems in mathematics and other fields.

Unit-I

Curves in the plane and in space, arc-length, re-parametrization, level curves Vs parametrized curves.

Unit-II

Curvature, plane curves, space curve-global properties of curves, the isoperimetric inequality, and the four vertex theorem.

Unit-III

Surfaces in the three dimension, smooth surfaces, tangents, normals and orientability, quadratic surfaces, triply orthogonal systems, applications of inverse function theorem, the first fundamental form, lengths of curves on surfaces, isometric surfaces.

Unit-IV

Conformal mapping of surfaces, surfaces area, equiareal mapss and a theorem of Archimedes, curvature of surfaces, the second fundamental form, the curvature of curves on a surface, the normal and principal curvatures, geometric interpretation of principal curvatures.

Unit-V

The Gaussian curvature and the mean curvatures, the pseudoshere, flat surfaces, surfaces of a constant mean curvature, Gaussian curvature of a compance surfaces, the Gauss map.

Textbook:

1.   Andreq Pressley, Elementary Differential Geometry, Springer, 2006.

Reference Books:
1.   Thierry Aubin, A Course in Differential Geometry, American Mathematical Society, 2007.
2.   K. L. Wardle, Differential Geometry, Dover, 2008.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

SEMESTER 10

15MAT696	DISSERTATION	10 cr

Every   student   is   required   to   register   for   a   project   under   a   faculty   member,   within oroutsidetheDepartment.AtthecompletionoftheProjectwork,thestudent

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills: Training during the course of the project work help develop theoretical/ computational skills and help communicate one's efforts in the form of a well referenced scientific report.

Elective Courses - Algebra Stream

15MAT631	ALGEBRAIC GEOMETRY	3-0-0-3

Course Outcomes

CO 1: To understand the various structures introduced in Algebraic geometry and to prove the standard theorems due to Hilbert/Krull/Noether which give correspondence between algebraic varieties and ideals, rings and fields.
CO 2: To understands properties of morphisms and its applications
CO 3: To familiarize the concept of rational maps
CO 4: To identify non singularity through various criteria and understand the process of   desingularisation
CO 5: To familiarize the idea of multiplicity and intersection with examples

Unit-I AFFINE AND PROJECTIVE VARIETIES: Noetherian rings and modules; Emmy Noether's theorem and Hilbert's Basissatz; Hilbert's Nullstellensatz; Affine and Projective algebraic sets; Krull's Hauptidealsatz; topological irreducibility, Noetherian decomposition; local ring, function field, transcendence degree and dimension theory; Quasi-Compactness and Hausdorffness; Prime and maximal spectra; Example: linear varieties, hypersurfaces, curves.

Unit-II MORPHISMS: Morphisms in the category of commutative algebras over a commutative ring; behaviour under localization; morphisms of local rings; tensor products; Product varieties; standard embedding like the segre- and the d-uple embedding.

Unit-III RATIONAL MAPS: Relevance to function fields and birational classification; Example: Classification of curves; blowing-up.

Unit-IV NONSINGULAR VARIETIES: Nonsingularity; Jacobian Criterion; singular locus; Regular local rings; Normal rings; normal varieties; Normalization; concept of desingularisation and its relevance to Classification Problems; Jacobian Conjecture; relationships between a ring and its completion; non-singular curves.

Unit-V INTERSECTIONS IN PROJECTIVE SPACE: Notions of multiplicity and intersection with examples.

TEXT BOOKS / REFERENCES BOOKS

1. Robin Hartshorne, Algebraic Geometry, *Graduate Texts in Mathematics (GTM)* 8th Printing, Springer, 1997.
2. C. Musili, *Algebraic Geometry for Beginners, Texts and Readings in Mathematics20*, Hindustan Book Agency, 2001.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT632	ALGEBRAIC TOPOLOGY	3-0-0-3

Course outcomes

CO1:Understand the basic concepts of set-theoretic topology and continuous mappings and construct new topologies from given topologies; to know special classes of topological spaces and their special characteristics like CW complexes, simplicial complexes and manifolds

CO2: Apply basic concepts of category theory to topological spaces and use concepts of functors to obtain algebraic invariants of topological spaces and mappings.

CO3: Acquire the knowledge of fundamental group and the covering theory as well as the basic methods for the computation of fundamental groups and mappings between them, homology and cohomology, and calculate those for important examples and with the aid of these deduce non-existence of mappings as well as fixed-point theorems.

CO4: calculate homology and cohomology with the aid of chain complexes and deduce algebraic characteristics of homology and cohomology with the aid of homological algebra.

CO5: Get acquainted with connections between analysis and topology, apply algebraic structures to deduce special global characteristics of the cohomology of a local structure of manifolds.

Unit-I Geometric Complexes and Polyhedra: Introduction. Examples. Geometric Complexes and Polyhedra; Orientation of geometric complexes.
Simplicial Homology Groups: Chains, cycles, Boundaries and homology groups, Examples of homology groups; The structure of homology groups.

Unit-II The Euler Poincare's Theorem; Pseudomanifolds and the homology groups of Sn.[Chapter 1 Sections 1.1 to 1.4 & Chapter 2 Sections 2.1 to 2.5 from the text].

Unit-III Simplicial Approximation: Introduction; Simplicial approximatin; Induced homomorphisms on the Homology groups; The Brouwer fixed point theorem and related results;

Unit-IV The Fundamental Group: Introduction; Homotopic Paths and the Fundamental Group; The Covering Homotopy Property for S1;
[Chapter 3 Sectins 3.1 to 3.4; Chapter 4 Sections 4.1 to 4.3]

Unit-V Examples of Fundamental Groups; The Relation between H1 (K) and p1 (iKi); Covering Spaces: The definition and some examples. Basic properties of covering spaces. Classification of covering spaces. Universal covering spaces. Applications.
[Chapter 4: Sections 4.4, 4.5; Chapter 5 Sections 5.1 to 5.5 from the text]

TEXT BOOK
1. Fred H. Croom: *Basic Concepts of Algebraic Topology*, UTM, Springer, NY, 1978.

REFERENCES
1. Eilenberg S and Steenrod N: *Foundations of Algebraic Topology*, Princetion Univ. Press, 1952.
2. S.T. Hu: *Homology Theory*, Holden-Day, 1965.
3. S.T. Hu: *Homology Theory*, Academic Press, 1959.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT633	CODING THEORY	3-0-0-3

CO-1: To understand the basic concepts of linear/error correcting codes and apply the concepts to encode and decode the information.
CO-2: To understand the concepts of dual /hamming codes and apply the concept to find the parameters of given codes and their dual codes using standard matrix and polynomial operations**.**
CO-3: To familiarize the concepts of cyclic/BCH codes with required properties.
CO-4: To understand the concepts of weight enumerators and apply to find the weight information of the code. To familiarize the concept of MDS code.
CO-5: Apply the basic concepts of linear codes to solve problems

Unit I
Introduction to linear codes and error correcting codes, Encoding and decoding of a linear code

Unit-II
Dual codes. Hamming codes and perfect codes.

Unit-III
Cyclic codes. Codes with Latin Squares, Introduction to BCH codes, Reed Solomon Codes

Unit-IV
Weight Enumerators and MDS codes.

Unit-V
Linear coding theory problems and conclusions.

TEXT BOOKS
1. Raymond Hill, *A first course in Coding Theory*, Clarandon Press, Oxford (1986).
2. J.H. Van Lint, *Introduction to Coding Theory*, Springer (1998).

REFERENCES
1. W. Cary Huffman and Versa Pless, *Fundamentals of Error Correcting Codes*, Cambridge University Press(2003).
2. W.W. Peterson, *Error Correcting Codes*, Cambridge, MA MIT Press (1961).
3. V. Pless, W.C. Huffman and R.A. Brualdi, *An Introduction to Algebraic Codes*, in Hand book of coding theory, Eds. Amsterdam Elsevier (1998).

15MAT634	COMMUTATIVE ALGEBRA	3-0-0-3

CO1: To understand the basic definitions of rings, ideals and modules through examples; To construct new modules by tensor product, Hom, direct sum/product.

CO2: To understand the fractions of modules and apply the fractions to construct the field from integral domain. To familiarize the decomposition of rings/modules.

CO3: To familiarize the concept of integral dependence of extension ring and chain conditions of modules. To understand the definitions of valuations / Noetherian / Artin rings through examples.

CO4: To study the basic properties of Noetherian/Artin rings; use the basic properties to characterize/decompose the Noetherian/Artin rings.

CO5: To understand the basic definitions of discrete valuation rings and Dedekind domains. To familiarize the concept of dimension theory of rings/modules.

Unit I
Rings and ideals, modules and operations on them (tensor product, Hom, direct sum and product).
Unit II
Rings and modules of Fractions, primary decomposition.
Unit III
Integral dependence and Valuations, Chain Conditions.
Unit IV
Noetherian Rings and Artin Rings.
Unit V
Discrete valuation Rings and Dedekind Domains, Dimension theory.

TEXT BOOKS / REFERENCES

1. Atiyah-Macdonald, *Commutative Algebra*, Westview Press, 1994.
2. Zariski and Samuel, *Commutative Algebra I, II* , Springer, 1991.
3. Eisenbud, *Commutative Algebra with a View Towards Algebraic Geometry*, Springer, 1995.
4. Bourbaki, *Commutative Algebra*, Springer, 1989.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT635	LIE ALGEBRA	3-0-0-3

CO 1: To understand the concept of Lie algebra and to know the substructures and operations on them.

CO 2: To familiarize nilpotent and solvable Lie algebras and prove the Engel's theorem

CO 3: To understand theorems on Semi simple Lie algebras and their applications .

CO 4: To derive various decomposition theorems on Lie algebras

Co 5: To understand the classification of Lie algebras through Dynkin diagrams.

Unit I
Basic Concepts – Definition and Examples, Lie Algebra of Derivations, Adjoint Representation, Structure Constants, Direct Sums, Homomorphism and Isomorphisms, Ideals, Centre and Derived Algebra of a Lie Algebra, Simple Lie Algebras, The Normalizer of a Subalgebra and Centralizer of a Subset in Lie Algebras, Automorphism and Inner Automorphism of a Lie Algebra.(Book 1, Chapters 1 and 2)

Unit II
Descending Central Series of a Lie Algebra, Nilpotent Lie Algebras. Derived Series of a Lie Algebra, Radical of a Lie Algebra, Solvable Lie Algebras, Engel's Theorem.
(Book 1, Chapter 3)

Unit III
Semisimple Lie Algebras – Theorems of Lie and Cartan, Jordan- Chevalley Decomposition, Cartan's Criterion. (Book 1, Chapter 4)

Unit IV
Killing Form, Inner Derivations, Abstarct Jordan Decomposition, Complete Reducibility of Lie algebras.. (Book 1, Chapter 5)

Unit V
The Weyl Group, Root Systems. (Book 1, Chapter 10)

TEXT BOOKS / REFERENCES BOOKS
1. J.E. Humphreys, *Introduction to Lie Algebras and Representation Theory*, Springer-Verlag, 1980.
2. Jacobson, *Lie Algebras*, Dover, 1979.
3. J.P. Serre, *Lie Algebras and Lie Groups*, Benjamin, 1965 (Translated from French).

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT636	THEORY OF MANIFOLDS	3-0-0-3

CO 1: To familiarize the concept of manifolds and learn their properties
CO 2: To understand the concept of tangent spaces and its properties
CO 3: To generalize the ideas of curves/derivatives to manifolds
CO 4: To prove the inverse /implicit function theorems in manifolds
Co 5: To understand Riemannian manifolds and their relevance

Unit I

Definition of Manifolds, Differentiable and Analytic Manifolds, Examples of Manifolds, Product of Manifolds, Mappings between Manifolds, Submanifolds, Tangent Vectors.

Unit II
Differentials, The Differential of a Function, Infinitesimal Transformation, Tangent Space, Tangent Vector.

Unit III
Cotangent Space, Vector Fields, Smooth Curve in a Manifold. Differential Forms– k-forms, Exterior Differential, its Existence and Uniqueness.

Unit IV

Exact Differential Forms. De Rham Cohomology Group, Betti Number, Poincare's Lemma, Inverse Function Theorem, Implicit Function Theorem and its Applications, Integral Curve of a Smooth Vector Field.

Unit V

Orientable Manifolds–Definition and Examples. Smooth Partition of Unity– Definition and Existence. Riemannian Manifolds– Definition and Examples.

TEXT BOOKS / REFERENCES:
1. M.Singer., J.A. Thorpe*, "Lecture Notes on Elementary Topology and Geometry",* Undergraduate Texts in Mathematics, 2008.
2. P.M.Cohn*, "Lie Groups",* Cambridge University Press, 1965*.*
3. Claude Chevalley*, "Theory of Lie Groups",* Fifteenth Reprint, Princeton University Press, 1999*.*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

<div align="center">

Analysis Stream

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Elective Courses - Analysis Stream

15MAT641	FIXED POINT THEORY	3-0-0-3

CO-1: Understand and apply the concepts of fixed point theorems to prove the existence and uniqueness of solution to certain ordinary differential equations.
CO-2: To understand the existence and uniqueness of fixed point for non expansive and set valued mappings.
CO-3: To understand the existence of best approximation point for non expansive mapping and its applications.
CO-4: To understand the existence and uniqueness of fixed point for partially ordered metric space.
As an application, to prove the existence and uniqueness of solution for a periodic boundary value problem.
CO-5: Applying the fixed point theorems of multivalued mappings to demonstrate the conditions for existence of Nash equilibria in strategic games

Unit-I Contraction Principle, and its variants and applications.

Unit-II Fixed points of non-expansive maps and set valued maps, Brouwer -Schauder fixed point theorems.

Unit-III Ky Fan Best Approximation Theorem, Principle and Applications of KKM -maps, their variants and applications.

Unit-IV Fixed Point Theorems in partially ordered spaces and other abstract spaces.

Unit-V Application of fixed point theory to Game theory and Mathematical Economics.

TEXT BOOKS / REFERENCES BOOKS

1. M.A.Khamsi and W.A.Kirk, *An Introduction to Metric Spaces and Fixed Point Theory*, Wiley - Inter Sci. (2001).
2. Sankatha Singh, *Bruce Watson and Pramila Srivastava, Fixed Point Theory and Best Approximation: The KKM - map Principle*, Kluwer Academic Publishers, 1997.
3. Kim C. Border, *Fixed Point Theorems with Applications to Economics and Game Theory*, Cambridge University Press, 1985.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT642	FRACTALS	3-0-0-3

CO1. Understand the basic concepts and structure of fractals .
CO2. Understand the space of fractals and transformation on metric spaces.
CO3. Understand the iterated function system with contraction mapping theorem.
CO4.   Apply fractal concepts to compute fractal dimension of sets and construct fractal interpolation functions.

Understand the hidden variable fractal interpolation function, fractal splines and fractal surfaces

Unit-I Classical Fractals, Self-similarity, Metric Spaces, Equivalent Spaces.

Unit-II The Space of Fractals, Transformation on Metric Spaces.

Unit-III Contraction Mapping and Construction of fractals from IFS.

Unit-IV Fractal Dimension, Hausdorff measure and dimension, fractal Interpolation Functions.

Unit-V Hidden Variable FIF, Fractal Splines, Fractal Surfaces, Measures on Fractals.

TEXT /REFERENCES BOOKS
1. M.F. Barnsley, *Fractals Everywhere*, Academic Press, 1993.
2. P.R. Massopust, *Interpolation and Approximation with Splines and Fractals*, Oxford University Press, 2009.
3. K. Falconer, *Fractal Geometry (Mathematical Foundations and Applications),* John Wiley & Sons, 2003.
4. P.R. Massopust, *Fractal Functions, Fractal Surfaces and Wavelets*, Academic Press, 1994.
5. Richard M. Crownover, *Introduction to Chaos and Fractals*, Jones and Bartlett Publishers, 1995.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT643	Harmonic Analysis	3 0 0 3

Unit 1:   Fourier series and integrals – Definitions and easy results – The Fourier transform – Convolution – Approximate identities – Fejer's theorem – Unicity theorem – Parselval relation – Fourier Stieltjes Coefficients – The classical kernels.

Unit 2:   Summability – Metric theorems – Pointwise summability – Positive definite sequences – Herglotz;s theorem – The inequality of Hausdorff and Young.

Unit 3:   The Fourier integral – Kernels on R. The Plancherel theorem – Another convergence theorem – Poisson summation formula – Bachner's theorem – Continuity theorem.

Unit 4:   Characters of discrete groups and compact groups – Bochners' theorem – Minkowski's theorem.

Unit 5:   Hardy spaces- Invariant subspaces – Factoring F and M. Rieza theorem – Theorems of   Szego and Beuoling.

Text Book:

Henry Helson, Harmonic Analysis, Hindustan Book Agency, Chapters 1.1 to 1.9, 2.1 to 3.5 and 4.1 to 4.3.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT644	NONLINEAR PARTIAL DIFFERENTIAL EQUATIONS	3-0-0-3

Course Outcomes

Review of first order equations and characteristics.

Unit-I Weak solutions to hyperbolic equations- discontinuous solutions, shock formation, a formal approach to weak solutions, asymptotic behaviour of shocks.

Unit-II Diffusion Processes-Similarity methods, Fisher's equation, Burgers' equation, asymptotic solutions to Burgers' equations.

Unit-III Reaction diffusion equations-traveling wave solutions, existence of solutions, maximum principles and comparison theorem, asymptotic behaviour.

Unit-IV Elliptic equations-Basic results for elliptic operators, eigenvalue problems, stability and bifurcation.

Unit-V Hyperbolic system.

TEXT BOOK : J David Logan, *An Introduction to Nonlinear Partial Differential Equations*, John Wiley and Sons, Inc., 1994

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT645	WAVELETS ANALYSIS	3 0 0 3

CO1: Understand and apply the concepts of DFT and its significance in engineering problems
CO2: Understand and apply the concept of first stage wavelet basis and iterative stages of wavelet bases in finite dimensional space.
CO3: Understand and apply the concept of first stage wavelet basis and iterative stages of wavelet bases   in infinite dimensional space.
CO4: Understand the concepts of Fourier transform and MRA and the construction of wavelets and its applications.

Unit-I Basic Properties of the Discrete Fourier Transform, Translation-Invariant Linear Transformations. The Fast Fourier Transform.

Unit-II Construction of Wavelets on Z_N, The First Stage Construction of Wavelets on Z_N, The Iteration Step`s. Examples and Applications.
Unit-III Complete Orthonormal Sets in Hilbert Spaces, $L_2([-\pi,\pi))$ and Fourier Series, The Fourier Transform and Convolution on $l_2(Z)$, First-Stage Wavelets on Z .
The Iteration Step for Wavelets on Z , Implementation and Examples.

Unit-IV $L_2(R)$ and Approximate Identities, The Fourier Transform on R, Multiresolution Analysis and Wavelets.
Unit-V Construction of Multiresolution Analyses, Wavelets with Compact Support and Their Computation.

Text Books:
1. Michael W. Frazier, An Introduction to Wavelets Through Linear Algebra, Springer,1999.

References:
1. Daubechis, Ten Lectures on Wavelets, SIAM, 1992.
2. S. Mallat, A Wavelet Tour of Signal Processing, Elsevier, 2008.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Electives - Statistics Stream

15MAT651	QUEUING THEORY AND INVENTORY CONTROL THEORY	3-0-0-3

Course Outcomes
CO1: Understand about general stochastic processes and their applications in various fields
CO2: Acquire knowledge about queueing models, network of queues and their applications
CO3: Acquire knowledge about inventory control and their applications in industry
CO4: Get knowledge about various deterministic inventory models and their analysis
CO5: Apply the concept of queueing and inventory models in real life situations

Unit 1: Introduction to stochastic processes, Markov chains and Markov processes and queueing models,single server and multi-server Markovian Queues and network of queues

Unit II Inventory concept – Components of Inventory model.
Deterministic Continuous Review model - Deterministic Periodic Review model.
Unit III
The classical EOQ – Non zero lead time – EOQ with and without shortages.
Unit IV
Deterministic Multi echelon Inventory models for supply chain management.
Unit V
A stochastic continuous review model – A stochastic single period model for perishable products.

TEXT BOOKS
1. F S Hillier and Gerald J Lieberman, Introduction to Operations research, 8th edition, McGraw Hill.
2. Ravindran , Phillips and Solberg, Operations research Principles and Practice, 2nd Edition, John Wiley & Sons.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT652 Random Processes	4 0 0 4

Course Outcomes
  CO1.   Understand the concepts of stochastic process, markov chains and classifical of states and chains.
  CO2.   Understand the markov process with discrete state space as poisson process and its properties with related theorems.
  CO3. Understand the markov process with continuous state space as wiener process and   its properties.
  CO4. Understand the renewal process and related theorems.
  CO5. Understand the concepts of branching process and Bellman-Harris process.

Probability and Statistics:
Unit I
Review of one and two random variables, stochastic independence of random variables, Poisson, uniform, exponential and normal distributions, Chebyshev's theorem central limit theorem, transformation of random variables, covariance and correlation, bivariate normal distribution function.

Random Processes:
Unit II
Random variable and random function – definition of random process – probability distributions and statistical averages Stationarity of random process- Types of stationarity – strict sense and wide sense stationary processes - autocorrelation – properties of autocorrelation and cross-correlation functions – correlation coefficient of stationary process.

Special Processes:
Unit III
Binomial and Poisson processes - Poisson points, properties and theorems on Poisson process - Gaussian processes- description of normal processes, first and second order normal processes, standard normal process, processes depending on Gaussian process, random walk and Wiener process
Spectrum estimation:
Unit IV
Introduction- Ergodicity, ensemble and time averages, types of ergodic processes - mean ergodic theorem,-Power spectrum – power spectral density function and properties, Wiener-Khinchine theorem, systems with stochastic inputs –
Markov process –Markov chains:
Unit V
Introduction,   transition diagram, transition probability matrix, Chapman-Kolmogorov theorem, – steady state probabilities, limiting distributions– classification of states.
TEXT BOOKS

1. A. Papoulis and Unnikrishna Pillai, "Probability, Random Variables and Stochastic processes", Fourth Edition, McGraw Hill, 2002.

2. J. Ravichandran, "Probability and Random Processes for Engineers", First Edition, IK International, 2015

REFERENCES:

1. Douglas C.Montgomery and George C. Runger, "Applied Statistics and probability for Engineers", Third Edition, John Wiley and Sons Inc., 2003.

2. Ravichandran, J. Probability and Statistics for Engineers, First Reprint Edition, Wiley India, 2012.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT653	STATISTICAL PATTERN CLASSIFICATIONS	3-0-0-3

Course Outcomes
CO1: To gain knowledge about pattern classification and dimensionality reduction method
CO2: To understand the use of Maximum-likelihood and Bayesian Parameter Estimation
CO3:To understand and apply Nonparametric Techniques and Linear Discriminant Functions
CO4: To apply Nonmetric methods and Algorithm-independent Machine Learning
CO5: To implement clustering methods under unsupervised learning

Unit 1:

Introduction and Bayesian Decision Theory

Introduction – Pattern recognition systems – the design cycle – learning and adaptation – Bayesian decision theory – continuous features – Minimum error rate classification – discriminant functions and decision surfaces – the normal density based discriminant functions.

Unit 2:
Maximum-likelihood and Bayesian Parameter Estimation
Maximum likelihood estimation – Bayesian estimation - Bayesian parameter estimation – Gaussian case and general theory – problems of dimensionality – components analysis and discriminants – hidden Markov models.

Unit 3:
Nonparametric Techniques and Linear Discriminant Functions
Nonparametric techniques – density estimation – Parzen windows – nearest neighborhood estimation – rules and metrics – linear discriminant functions and decision surfaces – generalized linear discriminant functions – two-category linearly separable case – minimizing the perception criterion function.

Unit 4:
Nonmetric methods and Algorithm-independent Machine Learning
Nonmetric methods – decision trees – CART methods – algorithm-independent machine learning – lack of inherent superiority of any classifier – bias and variance for regression and classification – resampling or estimating statistics – estimating and comparing classifiers.

Unit 5:
Unsupervised Learning and Clustering
Unsupervised learning and clustering – mixture densities and identifiability – maximum likelihood estimates – application to normal mixtures – unsupervised Bayesian learning – data description and clustering – criterion functions for clustering – hierarchical clustering – component analysis – low-dimensional representations and multi-dimensional scaling.

TEXT AND REFERENCE BOOKS:
1. Richard O. Duda, Peter E. Hart and David G. Stork*, Pattern Classification,* Second Edition, 2003, John Wily & Sons.

2. Earl Gose, Richard Johnsonbaugh and Steve Jost, *Pattern Recognition and Image Analysis,* 2002, Prentice Hall of India.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT654 STATISTICAL QUALITY CONTROL AND SIX SIGMA QUALITY ANALYSIS   3-0-0-3

Course Outcomes
CO1: To develop basic knowledge about TQM
CO2 :To understand old and new quality improvement tools
CO3: To understand the aspects of project planning and capability analysis
CO4 :To understand the concept of Six Sigma and Lean methods
CO5: To apply Taguchi methods

Unit I

Introduction to Quality Management – Japanese System of Total Quality Management

Unit II

Quality Circles - 7 Quality Control tools - 7 New Quality Control tools

Unit III

 ISO 9000 Quality system Standards - Project Planning, Process and measurement system capability analysis- Area properties of Normal distribution -

Unit IV

Metrics of Six sigma, The DMAIC cycle - Design for Six Sigma - Lean Sigma – Statistical tools for Six Sigma

Unit V

 Taguchi methods, Loss functions and orthogonal arrays and experiments

TEXT AND REFERENCE BOOKS

1. Ravichandran. J,, *Probability and Statistics for Engineers*, 1st Edition 2012 (Reprint), Wiley India.
2. Montgomery Douglas C., *Introduction to Statistical Quality Control*, Sixth Edition. John Wiley & Sons, (2008).
3. Ishikawa K., *Guide to Quality Control*, 2nd Edition.: Asian Productivity Organization, Tokyo(1983).
4. Taguchi G, *Introduction to Quality Engineering: Designing Quality into Products and Processes* Second Edition. (1991).
5. Harry, M and Schroeder R., *Six Sigma: The Breakthrough Management Strategy*. Currency Publishers, USA. (2000).

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT655   THEORY OF SAMPLING AND DESIGNS OF EXPERIMENTS   3-0-0-3

Course Outcomes
CO1: To study different types of basic sampling methods
CO2 :To understand the types of estimators and their applications
CO3: To understand with and without replacement sampling methods
CO4: To understand the use of sampling in experimental designs
CO5: To apply factorial experiments

Unit I

Stratified random sampling, estimation of the population mean, total and proportion, properties of estimators, various methods of allocation of a sample, comparison of the precisions of estimators under proportional allocation, optimum allocation and srs. Systematic sampling. Comparison of systematic sampling, srs and stratified random sampling for a population with a linear trend.

Unit II

Unbiased ratio type estimators- Hartly- Ross estimator, regression method of estimation. Cluster sampling, single stage cluster sampling with equal and unequal cluster sizes, estimation of the population mean and its standard error. Two- stage cluster sampling with equal and unequal cluster sizes, estimation of the population mean and its standard error.

Unit III

Unequal probability sampling, PPS sampling with and without replacement, cumulative total method, Lahiris method, Midzuno-Zen method, estimation of the population total and its estimated variance under PPS wr sampling, ordered and unordered estimators of the population total under PPS wor, Horwitz – Thomson estimator.

Unit IV

Elementary concepts (one and 2 way classified data) Review of elementary design (CRD, RBD, LSD) Missing plot technique in RBD and LSD with one and two missing values, Gauss- Markov theorem, BIBD : Elementary parametric relations, Analysis , PBIBD.

Unit V

General factorial experiments, factorial effects, best estimates and testing the significance of factorial effects, study of 2^3 and 2^4 factorial experiments.

TEXT AND REFERENCE BOOKS

1. Cochran, W.C. *Sampling Techniques*, Third Edition, Wiley Eastern, (1977).
2. Des Raj, *Sampling Theory*, Tata McGraw Hill, New Delhi, (1976).
3. Murthy, M.N., *Sampling Theory*, Tata McGraw Hill, New Delhi, (1967).

15MAT656	TIME SERIES ANALYSIS	3-0-0-3

Course Outcomes
CO1: To gain in-depth knowledge about time series and its components
CO2: To understand the smoothening concepts and the relevant tests.
CO3: To understand and apply the concepts of autocorrelation and auto-covariance
CO4: To apply various types of autoregressive models
CO5: To understand the estimation procedures in time series

Unit I

Time series, components of time series, additive and multiplicative models, determination of trend, analysis of seasonal fluctuations

Unit II

Test for trend and seasonality, exponential and moving average smoothing, holt-winter smoothing, forecasting based on smoothing.

Unit III

Time series as a discrete parameter stochastic process, auto covariance and auto correlation functions and their properties, stationary processes, test for stationarity, unit root test, stationary processes in the frequency domain, spectral analysis of time series.

Unit IV

Detailed study of the stationary processes: moving average (MA), autoregressive (AR), autoregressive moving average (ARMA) and autoregressive integrated moving average (ARIMA) models.

Unit V

Estimation of ARMA models, maximum likelihood method (the likelihood function for a Gaussian AR(1) and a Gaussian MA(1)) and Least squares, Yule-Walker estimation for AR Processes, choice of AR and MA periods, forecasting, residual analysis and diagnostic checking.

TEXT BOOKS

1. Anderson, T.W. *The Statistical Analysis of Time Series*, John Wiley, New York, 1971.
2. Box, G.E.P. and Jenkins, G.M. *Time Series Analysis*- Forecasting and Control,
   Holden-day, San Francisco,1976.
3. Kendall, Sir Maurice and Ord, J.K., *Time Series*, Edward Arnold, London, 1990.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Electives - Fluid Mechanics Stream

15MAT661	ADVANCED BOUNDARY LAYER THEORY	3-0-0-3

Unit-I Introduction – limitations of ideal fluid dynamics – Importance of Prandtl's boundary layer theory - boundary layer equations in two dimensional flows – boundary layer flow over a flat plate – Blasius solution – Boundary layer over a wedge.

Unit-II Energy integral equation for two-dimensional laminar boundary layers in incompressible flow – application of Von Karman's integral equations to boundary layer with pressure gradient

Unit-III Displacement, momentum, energy thickness – axially symmetric flows – momentum equation for laminar boundary layer by von Karman – Wall shear and drag force on a flat plate due to boundary layer – coefficient of drag. Boundary layer equations for a 2D viscous incompressible fluid over a plane wall – Similar solutions – Separation of boundary layer flow.

Unit-IV Hydromagnetic Boundary layers – Hartman Layer – MHD Blasius flow. Thermal boundary layers – thermal boundary layer equation in two dimensional flow – Thermal boundary layers with and without coupling of velocity and temperature field – forced convection in a laminar boundary on a flat plate.

Unit-V Polhausen's method of exact solution for the velocity and thermal boundary layers in free convection from a heated plate – thermal energy integral equation. Boundary layer control using suction and injection.

TEXT BOOKS /REFERENCES:

1. H.Schlichting and K.Gersten, *"Boundary Layer Theory",* Eighth Edition, Springer,2000.
2. L. Rosenhead*, "Laminar Boundary Layers",* Dover, 1988.
3. G.K.Batchelor, "*An Introduction to Fluid Dynamics"*, Cambridge University Press,1993.
4. P.H.Roberts *, "An Introduction to MHD"* , Longmans, 1967.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT662	Computational Fluid Dynamics	3-0-0-3

Course Outcomes
CO-01: To review the conservation laws and to understand the Eulerian and Lagrangian approach to fluid flow problems

CO-02: To understand the classification of PDEs and to review Finite Difference, Integral, Weighted Residual and Finite Element and Finite Volume and Least Square Methods
CO-03: To understand the finite volume discretization method and to develop computational methods for compressible flows
CO-04: To learn advance notions of finite volume methods and apply SIMPLE algorithm for flow and model and solve turbulent flows
CO-05 : To learn CFD methods for compressible and turbulent flows

Unit-I Review of Conservation equations for mass, momentum and energy; coordinate systems; Eulerian and Lagrangian approach, Conservative and non-conservative forms of the equations, rotating co-ordinates.

Unit-II Classification of system of PDEs: parabolic elliptic and hyperbolic; Boundary and initial conditions; Overview of numerical methods; Review of Finite Difference Method, Introduction to integral method, method of weighted residuals, finite elements finite volume method & least square method.

Unit-III Numerical Grid Generation: Basic ideas, transformation and mapping, unstructured grid generation, moving grids, unmatched meshes. Finite Volume Method: Basic methodology, finite volume discretization, approximation of surface and volume integrals, interpolation methods - central, upwind and hybrid formulations and comparison for convection-diffusion problem; Basic computational
methods for compressible flows.

Unit-IV Advanced Finite Volume methods: FV discretization in two and three dimensions, SIMPLE algorithm and flow field calculations, variants of SIMPLE, Turbulence and turbulence modelling, illustrative flow computations.

Unit-V Introduction to turbulence modelling, CFD methods for compressible flows.

Text Books / Reference Books:
1.   Anderson D A, Tannehill J C, and Pletcher R H, Computational Fluid Mechanics and Heat Transfer, 2nd edition, Taylor & Francis, 1997.
2.   Ferziger, J. H. and Peric, M., Computational Methods for Fluid Dynamics, 3rd edition, Springer. 2003.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT663	FINITE ELEMENT METHOD	3-0-0-3

Course Outcomes:
CO-1: Understand the basic concepts of weighted residue and energy methods.
CO-2: Understand the concepts of global and local finite element models and its derivations.
CO-3: Application of interpolation and various polynomials to model stiffness matrices.
CO-4: Application of global and local finite element models with boundary conditions in a steady state problem.
CO-5: Usage of finite element concept for one dimensional heat and wave equations.

Unit-I Finite Element Method : Variational formulation - Rayleigh-Ritz minimization - weighted residuals - Galerkin method applied to boundary value problems.

Unit-II Global and local finite element models in one dimension - derivation of finite element equation.

Unit-III Finite element interpolation - polynomial elements in one dimension, two dimensional elements, natural coordinates, triangular elements, rectangular elements, Lagrangian and Hermite elements for rectangular elements - global interpolation functions.

Unit-IV Local and global forms of finite element equations - boundary conditions - methods of solution for a steady state problem - Newton-Raphson continuation.

Unit-V One dimensional heat and wave equations.

TEXT AND REFERENCE BOOKS

   1.   J.N.Reddy, *An introduction to the Finite Element Method, McGraw Hill, NY.*
   2.   Chung, *Finite Element Analysis in Fluid Dynamics*, McGraw Hill Inc.

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Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT664	Magneto-Hydrodynamics	3-0-0-3

Unit-I Electromagnetic field equations – Maxwell's equations - Electromagnetic effects and the magnetic Reynolds number – induction equation. Alfven's Theorem – Ferraro's Law of irrotation – Electromagnetic stresses.

Unit-II Magnetohydrostatics and steady states – Hydromagnetic equilibria and Force free magnetic fields –– Chandrasekhar's theorem – General solution of force free magnetic field when$\alpha$is constant – Some examples of force free fields.

Unit-III Steady laminar motion – Hartmann flow. Tensor electrical conductivity, Hall current and ion slip – simple flow problems with tensor electrical conductivity.

Unit-IV Magnetohydrodynamic waves - Alfven waves –Stability of hydromagnetic systems - Normal mode analysis - Squire's theorem – Orr-Sommerfield equation-Instability of linear pinch – Flute instability – A general criterion for stability.

Unit-V Bernstein's method of small oscillations – Jeans Criterion for Gravitational stability – Chandrasekhar's generalization for MHD and rotating fluids.

TEXT BOOKS / REFERENCES:

1. Ferraro, V.C.A and Plumpton, C., "*An Introduction to Magneto-Fluid Mechanics*", Clarendon Press, Oxford, 1966.

2. M.R.Crammer, and Shi-I Pai, *"Magneto-Fluid Dynamics for Engineers and Applied Physicists"*, Scripta Publishing Company, Washington, 1973.

3. P.H. Roberts, *"An Introduction to Magnetohydrodynamics"*, Longmans, Green and Co, London, 1967.

4. S.Chandrasekhar, "*Hydrodynamic and Hydromagnetic Stability*", Dover Publications, 1981.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT665	Mathematical Foundations of Incompressible Fluid Flow	3-0-0-3

Unit-I Kinematics of Fluids in motion – Lagrangian and Eulerian methods – Equation of continuity – Boundary conditions – Kinematic and physical – steam line, path line and streak line – velocity potential – vorticity-rotational and irrotational motion.

Unit-II Equation of Motion of Compressible Viscous Fluid (Navier-Stokes Equations)-General Properties – Equation of motion of inviscid fluid – Euler's equation – impulsive force –physical meaning of velocity potential-energy equation.

Unit-III Lagrange's hydrodynamical equations –– Bernoulli's equation and its applications-Motion in two-dimensions and sources and sinks – irrotational motion – complex potential-Milne-Thomson circle theorem – Blasius theorem.

Unit-IV General theory of irrotational motion – flow and circulation – Stoke's theorem – Kelvin's Circulation theorem –Permanence of irrotational motion - Kelvin's minimum energy theorem Viscous Incompressible flow - Dimensional Analysis – BuckingamΠtheorem.

Unit-V Exact Solutions of Navier Stokes Equations – Small Reynold's number flows – flow past a sphere –Stokes flow – Whitehead's paradox- Flow past a circular cylinder – Stoke's Paradox.

TEXT BOOKS / REFERENCES:
1. G.K.Batchelor, "*An Introduction to Fluid Dynamics*", Cambridge University Press, 1997.
2. L.M. Milne-Thompson, "*Theoretical Hydrodynamics*", Dover Publications, 1968.
3. Victor L. Streeter and E.Benjamin Wylie, "*Fluid Mechanics*",Mc Graw Hill, 1983.
4. S.W. Yuan, "*Foundations of Fluid Mechanics*", Prentice Hall, New Jersey, 1970.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Electives - Computer Science Stream

15MAT671	DATA STRUCTURES AND ALGORITHMS	3-0-0-3

Pre-requisite: Data Structures and Algorithms.

Unit-I Introduction: growth functions – recurrence relation – methods – master method. Sorting: bubble – insertion sort – selection sort.

Unit-II Divide and conquer: quick sort – merge sort – bucket sort – lower bounds – heap sort – comparisons of sorting.

Unit-III Greedy algorithm: fractional knapsack problem – task scheduling problem. Dynamic programming: matrix multiplication problem – 0-1 knapsack.

Unit-IV Graph algorithms: graph traversal (DFS, BFS with analysis) – biconnected components – strong connectivity; shortest path algorithms (along with analysis) – Dijkstra – Bellman Ford – Floyd Warshall. All pairs shortest path algorithm – minimum spanning tree (with analysis) – Kruskal – Prim's – Baruvka's.

Unit-V NP problems: definition, P, NP, NP complete, NP hard & co-NP, examples – P, NP.

TEXT BOOK
1. Goodrich M T and Tamassia R, *Algorithm Design Foundations, Analysis, and Internet Examples*, John Wiley and Sons, 2002.

REFERENCES
1. Baase S and Gelder A V, ``*Computer Algorithms – Introduction to Design and Analysis*, Pearson Education Asia, 2002.

2. Cormen T H, Leiserson C E, Rivest R L and Stein C, *Introduction to Algorithms*, Prentice Hall of India Private Limited, 2001.

3. Dasgupta S, Papadimitriou C and Vazirani U, *Algorithms,* Tata McGraw-Hill, 2009.

4. Horowitz E, Sahni S and Rajasekaran S, *Fundamentals of Computer Algorithms*, Galgotia, 1998.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT672	Advanced Graph Theory	3 0 0 3

Course Outcomes:
CO-1: Understand the basic concepts of graphs and trees.
CO-2: Understand and apply the concepts of graph connectivity and shortest path problems.
CO-3: Understand and apply the concepts of matching problems in job assignments.
CO-4: Understand the concepts of vertex and edge colorings.
CO-5: Understand the concepts of planar graphs and dual graphs.

Unit-I Binomial coefficients, convexity. Inequalities: Jensen's, AM-GM, Cauchy Schwarz. Graphs, subgraphs, connectedness.

Unit-II Euler circuits, cycles, trees, bipartite graphs and other basic concepts.

Unit-III Vertex colourings. Graphs with large girth and large chromatic number.

Unit-IV Extremal graph theory: Dirac's theorem. Ore's theorem. Mantel's theorem. Turan's

theorem (several proofs including probabilistic and analytic).

Unit-V Kovari- Sosuran theorem with applications to geometry. Erdos Stone theorem. Stability. Andrasfai-Erdos-Sos theorem.

TEXT AND REFERENCE BOOKS
1. B Bollobas, Modern Graph Theory, Springer

2. D.B. West, *Introduction to Graph Theory*, P.H.I. 2010

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT673	**Computer Aided Design of VLSI Circuits**	**3-0-0- 0**

Course Outcomes:
   CO-1: Understand the basic concepts of VLSI design problems.
   CO-2: Understand various definitions of graphs and apply to some algorithms.
   CO-3: Understand and apply the placement and partitioning algorithms.
   CO-4: Understand and apply the routing algorithms.
   CO-5: Understand the concepts of 1D and 2D compactions.
Unit-I Introduction of Design Methodologies and Graph Theory: The VLSI Design Problems- Design Methods – Design Cycle – Physical Design Cycle-Design Styles.

Unit-II Algorithmic and System Design-Structural and Logic Design-Layout Design. Graph terminologies – Data structures for the representation of Graphs – Algorithms: DFS-BFS-Dijkstra's shortest path algorithm – Prim's algorithm for minimum spanning trees. Combinatorial Optimization Problems – Complexity Class-P-NP Completeness and NP Hardness problems.

Unit-III Placement, Partitioning and Floor Planning: Types of Placement Problems – Placement Algorithms – K-L Partitioning Algorithm. Optimization Problems in Floor planning - Shape Function and Floor plan Sizing

Unit-IV Routing and Compaction: Types of Routing Problems – Area Routing – Channel Routing – Global Routings.
Unit-V1D and 2D Compaction. Gete level – Switch level Modeling and Simulations.

TEXT BOOK / REFERENCES:

1. Gerez, *"Algorithms for VLSI Design Automation"*, John Wiley & Sons, 2000.
2. Naveed Sherwani, *"Algorithms for VLSI Physical Design Automation"*, SecondEdition, Kluwer AcademicPublishers, 1995.
3. Sadiq M Sait and Habib Youssef, *"VLSI Physical Design Automation: Theory and Practice"*, IEET, 1999.
4. M. Sarrafzadeh and C. K. Wong, *An Introduction to VLSI Physical Design*,McGraw-Hill, New York, NY, 1996.
5. Giovanni De Micheli, *Synthesis and Optimization of Digital Circuits*, Tata McGraw Hill, 1994

15MAT674	**Cryptography**	**3 0 0 3**

Course Outcomes:
   CO-1: Understand the basic concepts of classical ciphers.
   CO-2: Understand the concepts of encryptions and pseudorandomness.
   CO-3: Understand the concepts private-key encryption.
   CO-4: Understand the concepts of ElGamal encryption.
   CO-5: Understand the concepts of RSA and DSA signatures.

Unit-I Classical ciphers: Cryptanalysis of classical ciphers, Probability theory, Perfect security

Block ciphers: DES, AES, Block cipher modes of operation.

Unit-II Private-key encryption: Chosen plaintext attacks, Randomised encryption, Pseudorandomness, Chosen cyphertext attacks.

Unit-III Message authentication codes: Private-key authentication, CBC-MAC, Pseudorandom functions, CCA-secure private-key encryption.

Unit-IV Hash function: Integrity, Pre-image resistance, 2nd pre-image resistance, Collision freeness.
Key distribution: Key distribution centres, Modular arithmetic and group theory, Diffie-Hellman key exchange.

Unit-V Public-key Distribution: ElGamal encryption, Cramer-Shoup encryption, Discrete logarithm problem.

Digital Signatures: RSA signatures, RSA-FDH and RSA-PSS signatures, DSA signatures.

Text / Reference Books:

1. Katz and Lindell, Introduction to Modern Cryptography. Second Edition, Chapman & Hall/ CRC Press, 2014.
2. Jonathan Katz and Yehuda Lindell, Introduction to Modern Cryptography, CRC Press.

3. Hans Delfs, Helmut Knebl, "Introduction to Cryptography, Principles and Applications", Springer Verlag.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT 675	FUZZY SETS AND ITS APPLICATIONS	3-0-0-3

Course Outcomes:
    CO-1: Understand the basic concepts of Fuzzy sets
    CO-2: Understand the concepts of arithmetci operations on fuzzy numbers.
    CO-3: Understand the concepts Fuzzy relations.
    CO-4: Understand the concepts of Fuzzy logic.
    CO-5: Understand the concepts of uncertainty and crisp sets.

Unit-IFuzzy Sets: Crisp Sets- an Overview, Fuzzy Sets-Definition and Examples, α-Cuts and its Properties, Representations of Fuzzy Sets, Extension Principles of Fuzzy Sets, Operations on Fuzzy Sets-Fuzzy Complements, Fuzzy Intersections, Fuzzy Unions, Combinations of Operations, Aggregation Operations.

Unit-IIFuzzy Arithmetic: Fuzzy Numbers, Arithmetic Operations on Intervals, Arithmetic Operations on Fuzzy Numbers.

Unit-IIIFuzzy Relations: Binary Fuzzy relations, Fuzzy Equivalence Relations, Fuzzy Compatibility Relations.

Unit-IVFuzzy Logic: Classical Logic, Multivalued Logic, Fuzzy Propositions, Fuzzy Quantifiers, Linguistic Hedges, Inference from Conditional Fuzzy Propositions, Conditional and Qualified Propositions and Quantified Propositions,.

Unit-VUncertainty-Based Information: Information and Uncertainty, Non Specificity of Crisp Sets – Non Specificity of Fuzzy Sets, Fuzziness of Fuzzy Sets, Uncertainty In Evidence Theory, Principles of Uncertainty.

TEXT AND REFERENCE BOOKS:
1. George J. Klir and Bo Yuan, *Fuzzy Sets and Fuzzy Logic- Theory and Applications,* Prentice Hall of India, 1997.
2. Timothy J. Ross, *Fuzzy Logic with Engineering Applications*, McGraw Hill, 1997.
3. H.J. Zimmermann, *Fuzzy Sets and its Applications*, Allied publishers, 1991.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT676	INTRODUCTION TO SOFT COMPUTING	3-0-0-3

Course Outcomes:
- CO-1: Understand the various types of soft computing techniques
- CO-2: Understand the concepts of artificial intelligence.
- CO-3: Understand and apply the concepts fuzzy logic in optimization problems.
- CO-4: Understand the concepts of neural networks.
- CO-5: Understand the concepts of genetic algorithms.

Unit-ISoft Computing: Introduction of soft computing, soft computing vs. hard computing, various types of soft computing techniques, applications of soft computing.

Unit-IIArtificial Intelligence: Introduction, Various types of production systems, characteristics of production systems, breadth first search, depth first search techniques, other Search Techniques like hill Climbing, Best first Search, A* algorithm, AO* Algorithms and various types of control strategies.

Unit-IIIFuzzy Logic: Crisp set and Fuzzy set, basic concepts of fuzzy sets, membership functions. Basic operations on fuzzy sets, Properties of fuzzy sets, Fuzzy relations. Propositional logic and Predicate logic, fuzzy If – Then rules, fuzzy mapping rules and fuzzy implication functions, Applications.

Unit-IVNeural Networks: Basic concepts of neural networks, Neural network architectures, Learning methods, Architecture of a back propagation network, Applications.

Unit-VGenetic Algorithms: Basic concepts of genetic algorithms, encoding, genetic modeling.

Hybrid Systems: Integration of neural networks, fuzzy logic and genetic algorithms.

TEXT AND REFERENCE BOOKS

1. S. Rajasekaran and G.A.Vijaylakshmi Pai.. *Neural Networks Fuzzy Logic, and Genetic Algorithms,* Prentice Hall of India.
2. K.H.Lee.. *First Course on Fuzzy Theory and Applications,* Springer-Verlag.
3. J. Yen and R. Langari.. *Fuzzy Logic, Intelligence, Control and Information*, Pearson Education.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15MAT677	Object Oriented Programming and Python	3 0 0 3

Unit I
Object oriented programming concepts –objects –classes –methods and messages –abstraction and encapsulation –inheritance –abstract classes –polymorphism.

Introduction to C++ –classes –access specifiers –function and data members –default arguments –function overloading –friend functions –const and volatile functions -static members–Objects
–pointers and objects –constant objects –nested classes –local classes

Unit II
Constructors –default constructor –Parameterized constructors –Constructor with dynamic allocation –copy constructor –destructors–operator overloading –overloading through friend functions –overloading the assignment operator –type conversion –explicit constructor.

Unit III
Function and class templates -Exception handling–try-catch-throw paradigm –exception specification –terminate and Unexpected functions–Uncaughtexception.

Unit IV
Inheritance –public, private, and protected derivations –multiple inheritance-virtual base class –abstract class – composite objects Runtime polymorphism –virtual functions –pure virtual functions –RTTI –typeid –dynamic casting –RTTI and templates –cross casting –down casting.

Unit V

Python Programming.

TEXT BOOKS:

1. B. Trivedi, "Programming with ANSI C++", Oxford University Press, 2007.

REFERENCES:

1. Ira Pohl, "Object Oriented Programming using C++", Pearson Education, Second Edition Reprint 2004.
2. S. B. Lippman, Josee Lajoie, Barbara E. Moo, "C++ Primer", Fourth Edition, Pearson Education, 2005.
3. B. Stroustrup, "The C++ Programming language", Third edition, PearsonEducation, 2004.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

PHYSICS UG Courses (Semesters 1 – 6)

Semester 1

15PHY103	MECHANICS	3 1 0 4

Course Outcomes: After successful completion of the course, students will be able to

CO1: apply to the concepts of measurements, estimating order of magnitudes, vectors, kinematics in one dimension, projectile and circular, and relative motions.

CO2: apply Newton's law of motion to solve, with the help of a free-body diagram, for forces of equilibrium or acceleration, under contact forces, uniform gravity, for rectilinear and circular motions.

CO3: apply the concepts of kinetic energy, work – dot product of force and displacement, work-kinetic energy theorem, power, potential energy and relation to conservative forces, conservation energy, identify types of equilibrium.

CO4: apply Newton's law for center of mass motion, linear momentum and its conservation for collision problems.

CO5: apply concepts of rotation – angle, angular velocity, angular acceleration, torque, inertia, angular oscillations, angular momentum and its conservation, describe gyroscope motion.

CO6: apply Hooke's law, simple harmonic motion, free, damped and forced oscillations, resonance.

Unit 1 Motion
Motion in 1D; vectors, motion in 2D & 3D, projectile and uniform circular motion; relative motion and relative velocity.

Unit 2 Forces and dynamics
Force, mass, Newton's laws, inertial mass, examples of forces, free body diagram analysis for simple applications; friction and contact forces, drag force and terminal speed, uniform circular motion.

Unit 3 Work, Energy, Collisions
Work, kinetic energy, work-kinetic energy theorem, work done by gravitational and spring forces, power; Work and potential energy, conservative forces, conservation of mechanical energy, potential energy curve; Center of mass, Newton's law for system of particles, linear momentum and its conservation, Impulse forces, collisions - elastic and inelastic collisions in 1D and 2D; systems with variable mass - rockets.

Unit 4 Rotational Motion
Rotational variables, linear and angular variables, rotational kinetic energy, rotational inertia; torque, Newton's law for rotation, work, rolling – combined translation and rotation, angular momentum, Newton's law in angular form, system of particles, conservation of angular momentum.

Unit 5 Oscillatory motion
Small oscillations in physical systems; determination of frequency; simple harmonic motion; damped oscillations, resonance.

TEXTBOOK:
Halliday, Resnick, and Walker, Fundamentals of Physics, 8th Extended Ed., Wiley Indian Reprint, 2008, Chap. 1-12, 15
REFERENCES:
1. *Young and Freedman, University Physics, 11th Ed, Dorling Kindersley India, 2006*
2. *Halliday, Resnick, and Krane, Physics, Vol. 1, 5th Ed., Wiley Indian Reprint, 2007*
3. *Feynamn, Leighton and Sands, "The Feynman Lectures on Physics", Narosa, 1E, 2008*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: The entire contents of this course, tutorials and assignments lays conceptual/theoretical foundation for application of laws of physics to problems of scientific interest and builds skills required for a career as an educator/academician in schools, colleges, universities and coaching centres, as a professional researcher in government/industrial research organizations, and as a communicator of science in general.

Semester 2

15PHY113	**ELECTRICITY AND MAGNETISM**	**3 1 0 4**

Course Outcomes: By the end of the course students will be able to develop an understanding, and

CO1: describe and apply electrostatic forces laws in vector form, superposition of forces, calculate electric fields, potentials, potential energies for basic charge distributions, electric flux, apply Gauss' law for symmetric charge distributions, electric potential from electric field and vice-versa, dipoles, work and potential energy.

CO2: describe Gauss' law and divergence, curl and rotation, gradient of potentials, capacitors, conductors, electric current, electrical resistance and Ohm's law, capacitor, resistor networks, RC circuit concepts, apply for problems therein.

CO3: describe magnetism, magnetic fields, determine forces due to magnetic field on moving charges and current carrying wires and their consequences, determine magnetic field due to current distributions, solenoids.

CO4: apply Faraday's laws for induced emf, induced electric field, describe laws in induction in integral form, mutual and self-induction, inductors and LRC ac-circuits, resonance and tuning.

CO5: describe displacement current and Maxwell's equation, Maxwell's equation and electromagnetic waves in vacuum, electric polarization, dipoles, and fields in dielectric media, magnetic fields in matter, magnetic dipoles.

UNIT 1: Electric forces and fields
Electric forces, charges, conservation of charge, superposition of electric forces; electric fields, calculation of electric fields of static discrete and continuous charge distributions; Gauss' law and determination of electric fields of simple symmetric charge distributions.

UNIT 2: Electric potential and Capacitors
Electrical potential energy and electric potential of discrete and continuous distributions of charges; calculating electric field from potential; potential energy of system of point charges; capacitors and dielectrics.

UNIT 3: Magnetostatics
Force due to magnetic fields, Hall effect, circular and helical orbits, magnetic force on a current carrying wire, torque on a current loop, magnetic dipole moment; calculation of magnetic field from current sources using Biot-Savart's law and Ampere's law; solenoids and toroids.

UNIT 4: Changing magnetic fields
Faraday's law, Electromagnetic Induction, Self & mutual inductance; Magnetism in matter and Maxwell's equations.

UNIT 5: DC and AC Circuits
Electric current, resistance, resistivity, microscopic view; DC circuits involving resistance and capacitance; AC Circuits, RLC circuits, transformers.

TEXTBOOK:
Halliday, Resnick, and Walker, Fundamentals of Physics, 8th Ed., Wiley Indian Reprint, 2008, Chapters 22-33.
REFERENCES:
1. *Halliday, Resnick, and Krane, Physics, Vol. 1, 5th Ed., Wiley Indian Reprint, 2007*
2. *Young and Freedman, University Physics, 11th Ed, Dorling Kindersley India, 2006*
3. *Edward Purcell, Electricity and Magnetism, 2e, Tata-McGraw Hill, 2011.*
4. *Feynamn, Leighton and Sands, "The Feynman Lectures on Physics", Narosa, 1E, 2008*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: The entire contents of this course, tutorials and assignments lays conceptual/theoretical foundation for application of laws of physics to problems of scientific interest and builds skills required for a career as an educator/academician in schools, colleges, universities and coaching centres, as a professional researcher in government/industrial research organizations, and as a communicator of science in general.

15PHY184	**PHYSICS LAB I**	**0 0 2 1**

Course Outcomes: After successful complete of the course, students will be able to

CO1: perform basic experiments in physics

CO2: apply the measurement techniques and analyze data and infer physics

CO3: apply the basic classical physics theories

CO4: calculate errors in measurements

CO5: through experiments infer basic material properties such as elasticity moduli, fluid properties and some topics from heat and thermodynamics, optics and rigid body.

List of experiments:
1. Surface Tension – Capillary Rise Method.
2. Coefficient of Viscosity - Stoke's Method.
3. The Torsion Pendulum.
a. Moment of Inertia of the Disc.
b. The Rigidity Modules of the Material of Wire.
4. Young's Modulus – Uniform Bending.
5. Spectrometer – Dispersive Power.
6. Liquid Lens – Refractive index of liquid.
7. Laser - Wave length of Laser beam.
8. Laser - Slit Width of the given slit.
9. Magnetometer – Measurement of magnetic flux.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: Lab sessions and experimentation help develop intuition for lab equipment and builds practical knowledge of using lab instruments, measurement techniques and experimental techniques needed for work involving communication of science such as lab instructor/ demonstrator, technical staff, educator or a scientist in schools, colleges, universities, industries and research labs/organizations.

Semester 3

15PHY186	PHYSICS LAB II	0 0 2 1

Course Outcomes: After successful complete of the course, students will be able to

CO1:   perform basic experiments in electrical measurements in physics

CO2:   apply measurement techniques, collect data, analyze data and draw interferences.

CO3:   apply the basic electricity laws in physics and different circuit theories, bridges etc. and their applications

CO4:   calculate errors in measurements

CO5:   infer specified the basic electrical properties of matter and applications through experiments.

CO6:   gain skills in using basic electrical instruments such as ammeter, voltmeter and galvanometer, etc., for various measurements.

List of experiments
1. Lee's disc – Thermal Conductivity of a bad conductor.
2. Solar cell characteristics.
3. Potentio meter – Comparison of emfs.
4. Conversion of galvanometer to Voltmeter.
5. Field along the axis of a coil.
6. Measurement of Laser beam divergence.
7. Spectrometer - i – d – curve.
8. Newton's rings.
9. Meter bridge - Resistance measurement.
10. Ref. index of a Transport bar.
11. Elective field distribution.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: Lab sessions and experimentation help develop intuition for lab equipment and builds practical knowledge of using lab instruments, measurement techniques and experimental techniques needed for work involving communication of science such as lab instructor/ demonstrator, technical staff, educator or a scientist in schools, colleges, universities, industries and research labs/organizations.

16PHY200	HISTORY AND PHILOSOPHY OF SCIENCE	2 0 0 2

Course Outcomes: After successful completion of the course, students will be able to
1) Describe the Indian and world history of science starting from Copernican revolution and the rise of modern science in a nutshell.
2) Identify the ancient Indian contribution to science, technology, architecture, Mathematics and Medicine, Astronomy etc.
3) Describe the ancient revolutionary work and writings of Euclid, Aryabhata, Brahmagupta, Jyestadeva, Newton etc.

4) Analyze the aims or goals and philosophy of science to utilize their knowledge and talent to serve society at large.

Unit 1
Why History of Science?
Astronomy in the ancient world - people, theory and instruments (4 hours) - Astronomy across civilizations of the old world, main discoveries, their contribution and instruments during those times.

Unit 2
The Dark ages in Europe - the Arabian influence - The Islamic science, translations and original contributions of Arabians, dark ages Europe, logic, literature and scientific method, early universities of Europe.

Unit 3
Indian tradition in Science and Technology - an overview - Indian contributions in science and technology - mathematics, astronomy and other sciences.

Unit 4
Texts that changed the course of history science - Elements of Euclid, Aryabhatiya of Aryabhata, Brahmasputa Sidhanta of Brahmagupta, Yuktibhasa of Jyestadeva, Philosophiae Natturalis Principia Mathematica.

Unit 5
The Copernican revolution and the rise of modern science - The background of Copernican revolution, interaction between civilizations, the rise of modern sciences - when and why?

Text And Background Literature:
History and philosophy of science is yet to be established as full-fledged discipline. A suggested anthology of reading materials:
1. Essential reading on history of sciences (in-house publication)
2. http://www.Open2.net/whattheancients/ (Documentaries)

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15PHY203	BASIC ELECTRONICS	2 1 0 3

Course Outcomes: After successful completion of the course, students will be able to develop an understanding, and be able to
1) Describe basic concepts regarding semiconductor p-n junction devices and identify their unique properties for device applications.
2) solve different electrical networks based on theorems
3) To develop the knowledge regarding the use of transistors and diodes for different scientific and household applications
4) To analyse and troubleshoot an amplifier circuit.

UNIT 1
Voltage and current - resistors, voltage dividers, voltage and current sources, Thevenin's theorem, sinusoidal signals, signal amplitudes and decibels, other signals, logic levels, signal sources.

UNIT 2
Conduction in metals, semiconductors and insulators, intrinsic semiconductors, n and p materials, conduction by drift and diffusion, The p-n junction, Fermi level of pn junction, diode equation, Hall effect, diode characteristics, capacitance of a p-n junction, rectification, rectifier configurations for power supplies, circuit applications of a diode-as a switch, clipping, clamping, different types of diodes - Zener diodes, LEDs, diode lasers, photodiodes, etc.

UNIT 3
Transistors - npn and pnp, transistor characteristics - CB, CE and CC configurations, relation between a, b and g, transistor switch, transistor biasing. Feedback circuits. Transistor action, emitter follower, Transistor applications as amplifier. RC coupled amplifier.

UNIT 4
Transistor as an oscillator, FET, JFET, MOSFET, etc.

Operational amplifiers; differential amplifier, inverting and non-inverting amplifiers ers. Op-amp applications-integrator, differentiator, adder etc. ICs – examples.

UNIT 5
Digital electronics: Digital versus analog, logic gates, truth table, discrete circuits for gates, logic identities, minimization and Karnaugh maps.

TEXTBOOK:
Bernar Grob and Mitchel.E.Schultz, Basic Electronics (9th Edition), Tata Mc.Graw Hill, New Delhi (2003)
REFERENCES:
1. *John D. Ryder, Electronic Fundamentals and Applications, Prentice Hall of India Pvt. Ltd. New Delhi (1983).*
2. *Albert Paul Malvino, Digital Computer Electronics Tata McGraw Hill Pub. Co. Ltd New Delhi (1983*
3. *Horowitz and Hill, The art of Electronics (Cambridge University press)*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: The entire contents of this course, tutorials and assignments lays conceptual and theoretical foundation in electronics required for basic physics lab equipment and instrumentation and builds skills required for a career as an educator in physics in schools, colleges and universities, and as a researcher in experimental physics, and as a communicator of science in general.

16PHY204	HEAT AND THERMODYNAMICS	3 1 0 4

Course Outcomes:
CO1: Study zeroth law of thermodynamics to find thermodynamic properties and units.

CO2: Understand concepts of heat, work, and energy in order to apply those in phase change processes.

CO3: Theoretical assessment of ideal gases, heat engines etc for effective thermo dynamical processes.

CO4: Investigate the entropy through 2nd law of thermodynamics.

CO5: Experimental phenomenon in support of the theoretical expiations.

Unit 1
Thermodynamic systems: Microscopic and macroscopic views, measureable properties, thermal equilibrium, temperature, and the zeroth law; ideal gas and other temperature scales, thermometers. Simple thermodynamic systems: thermodynamic equilibrium & state, hydrostatic, dielectric, elastic, electrochemical, magnetic & surface-interface systems.

Unit 2
Work: change of state and processes, P-V work, P-V diagram, path dependence; work in hydrostatic, elastic, magnetic systems; Heat & its equivalence to work, internal energy function; the I Law of thermodynamics & its differential form, concept of heat & work as boundary interactions, heat capacities & measurement, calorie, application to hydrostatic systems; heat reservoirs, heat transfer by conduction, convection & radiation; thermodynamics of radiation – Kirchoff, Planck, Stefan-Boltzmann laws.

Unit 3
Ideal gases: Equation of state, internal energy, heat capacities; Microscopic point of view - kinetic theory of ideal gases. The II Law of Thermodynamics: conversion of energy & efficiency - heat engines & heat pumps, Kelvin-Planck & Clausius statements, irreversibility & its forms, loss of useful work & efficiency, Carnot cycles, Carnot engines & refrigerators, Carnot theorem, thermodynamic temperature scale, absolute zero, Carnot efficiency.

Unit 4
Entropy & the II law: mathematical formulation - Clausius inequality, concept of entropy, differential form of the II law, entropy of ideal gases, TS diagram, heat & entropy in reversible and irreversible processes, principle of increase of entropy; Pure substances: PV, PT & phase diagrams, PVT surface, equation of state, molar heat capacities, coefficient of expansion & compressibility.

Unit 5
Thermodynamic potentials - internal energy, enthalpy, Helmholtz and Gibbs free energies, TdS & Maxwell's relations; heat capacity & compressibility equations; Joule-Thomson effect; Open systems and chemical potential; maximum entropy & minimum energy principles, equilibrium & stability; Phase transition: first- & second- order transitions, conditions for phase coexistence, Clapeyron equation.

Textbook
M.W. Zemansky and R.H. Dittman: Heat and Thermodynamics, 8th Ed., McGraw-Hill, 2011
References

1. *K. Huang, Introduction to Statistical Physics, 2nd Ed., CRC Press, 2009 (Ch. 1-4)*
2. *J. Walker, D. Halliday, & R. Resnick, Principles of Physics, 10th Ed., Wiley (2015).*
3. *R.P. Feynman, R.B. Leighton and M. Sands, The Feynman Lectures on Physics, Vol.1, Pearson, 2012*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: The entire contents of this course, tutorials and assignments lays conceptual/theoretical foundation for application of laws of physics to problems of scientific interest and builds skills required for a career as an educator/academician in schools, colleges, universities and coaching centres, as a professional researcher in government/industrial research organizations, and as a communicator of science in general.

16PHY282	BASIC ELECTRONICS LAB	0 0 2 1

Course Outcomes:

1) perform the experiments using different p-n junction devices and its analysis

2) identify the characteristics of transistor and operational amplifiers.

3) design circuits using transistors for different applications and its analysis

4) develop basic skill in using op-amp, apply, design circuits for different applications

Experiment List
Familiarization of devices and equipment; Diode Characteristics; Rectifiers – Half-wave and Bridge Rectifiers; Clipper and Clamper circuits; Zener Diode; Transistor Characteristics in Common Emitter mode; RC Coupled amplifier; Oscillators / Multi vibrators; Integrator/ Differentiator / Adder / Subtractor;   Operational Amplifier; Introduction to Logic Gates

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: Lab sessions and experimentation help develop intuition for lab equipment and builds practical knowledge of using lab instruments, measurement techniques and experimental techniques needed for work involving communication of science such as lab instructor/ demonstrator, technical staff, educator or a scientist in schools, colleges, universities, industries and research labs/organizations.

Semester 4

16PHY215	OSCILLATIONS, WAVES AND OPTICS	3 1 0 4

Course Outcomes: After successful completion of the course, students will be able to

1) Describe and apply concepts in oscillations in 1D and 2D, polarization, many coupled oscillations, mechanical and electrical filters,

2) Describe the concepts involved in transverse wave motion on a string and apply to obtain dispersion, phase and group velocities, energy transport, characteristic impedance in forces oscillations, reflection and transmission at a boundary, apply boundary conditions to deduce standing waves and quantized frequencies.

3) Describe concepts in sound waves and apply to explain Doppler effect, characterize intensities with decibels, shock waves

4) Describe basic ideas of waves in 2D and 3D, wave vector, cylindrical and spherical waves and apply, electromagnetic waves and its origin from Maxwell's equation, energy and momentum transport, radiation pressure.

5) Describe and apply electromagnetic waves in dielectric media and arrive at dispersion relations, refractive index, reflection and transmission at boundary, concepts in polarization, method of polarizing a light, and applications.

6) Describe and apply concepts in interference, multi-beam interference for Fabry-Perot interferometer, concepts in single and double slit diffraction, gratings, resolution of images.

7) Describe and apply basics of fiber optics.

Unit 1

Oscillations & Waves: Simple harmonic oscillations in physical systems, damped & driven oscillations, resonance; Superposition of two oscillations, Lissajous figures. Wave equation in 1D, standing and travelling waves, energy density and transmission; superposition, group and phase velocities; characteristics of waves in 2D & 3D; sound waves in media; Basics of electromagnetic waves, EM spectrum, light & photons.

Unit 2

Geometrical optics: Propagation light and dispersion in matter, Rayleigh scattering, index of refraction; Fermat's principle, laws of reflection and refraction from Fermat's principle; total internal reflection, evanescent wave, beam splitters; Lenses: refraction at spherical surfaces, thin lenses, lateral and longitudinal magnifications, combination of thin lenses; thick lenses and lens systems, cardinal points.

Unit 3

Mirrors: plane & spherical mirrors; Prisms: dispersing and reflecting types; Aberrations; A selection of topics in optical systems: Eyes, microscopes, camera and telescopes; Basic ideas on fibre-optics, transmission of light in fibres, coherent bundle, numerical aperture, fibre-optic communications.

Unit 4

Interference: spatial and temporal coherence; interference by division of wave front: Young's double slit, Fresnel's biprism; interference by division of amplitude: thin films and air wedges, fringes of equal inclination and thickness, Newton's rings, Michelson' interferometer; Multiple beam interference, application to Fabry-Perot interferometer, AR and HR coatings.

Unit 5

Basic diffraction theory: Fresnel and Fraunhoffer diffraction; diffraction by circular aperture, single & double slits, diffraction grating; Rayleigh criterion and revolving power. Polarisation: linear, circular and elliptic polarizations; polarization by double refraction (birefringence) & reflection; Wave plates (quarter, half, full), circular polarizers; optical activity.

Textbooks/References

1. *E. Hecht and Ganesan A R, Optics, 4E, Pearson, 2008*
2. *A.P. French, Vibrations and Waves, CRC Press, 1971*
3. *Walker, Halliday & Resnick: Principles of Physics, 10E, Wiley (2015) (Ch. 15-17 & 33-36)*
4. *Ajoy Ghatak, Optics, 5E, Tata-McGraw Hill, 2012*
5. *R.P. Feynman, R.B. Leighton and M. Sands, The Feynman Lectures on Physics, Vol.1, Pearson, 2012*
6. *G.R. Fowles, Introduction to Modern Optics, 2E, Dover, 1989*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: The entire contents of this course, tutorials and assignments lays conceptual/theoretical foundation for application of laws of physics to problems of scientific interest and builds skills required for a career as an educator/academician in schools, colleges, universities and coaching centres, as a professional researcher in government/industrial research organizations, and as a communicator of science in general.

15PHY312	**INTERMEDIATE MECHANICS**	**3 1 0 4**

Course Outcomes: After successful completion of this course, students shall be able to

1) Set up vector relations for most kinematic systems and identify the appropriate vector system for the problem at hand.

2) Distinguish between inertial and non-inertial frames, and successfully solve important dynamical problems using Fictitious forces.

3) Define and describe the significance of the Least action principle, and set up Lagrangians and Hamiltonians for simple systems, and solve them.

4) Distinguish what dynamical problems are more easily solved by the Work-Energy theorem than by Newtons laws and apply them successfully to obtain solutions.

5) Apply appropriate conservation laws for elastic and inelastic collisions.

6) Resolve the general motion of a rigid body system into translational and rotational motion; apply the ideas of central force motion and solve basic problems in planetary systems.

7) Set up differential equations for various types of oscillations and solve them; use the results to explain the observed oscillatory phenomena in nature.

UNIT 1

Galilean transformation, absolute and relative velocities, inertial and non-inertial frames, rotating frames, centrifugal and coriolis forces; Foucault pendulum.

UNIT 2

Conservative forces; contact forces – friction, stress, viscous drag, etc. Pseudo forces and fundamental forces. Mathematical aside: work as a line integral, collisions and conservation laws; potential energy and conservation of energy in gravitational and electric field; stokes theorem, curl, irrotational force fields.

UNIT 3

Motion under a centre force, Kepler's laws, Gravitational law and field, conservative and non-conservative forces, system of particles, centre of mass, equations of motion for centre of mass and relative motion, Angular momentum about centre of mass elastic and inelastic collision, conservation of linear and angular momentum. Variable mass systems.

UNIT 4

Fixed axis rotations, rotation and translation, moments of inertia and products of inertia. Principal moments and axes. Behaviour of angular momentum vector.

UNIT 5

Mechanics of particles, Mechanics of system of particles, Constraints, D'Alembert's Principle and Lagrange's equation, Simple applications of the Lagrange's formulation,

TEXTBOOKS:
1. *David Halliday, Robert Resnick, and Jearl Walker, Fundamentals of Physics, 6th Ed, John-Wiley, 2000*
2. *H. Goldstein, Charles Poole, John Safko, Classical Mechanics,3rd Ed., Pearson education, 2002*
REFERENCE BOOKS:
1. *D. A. Walls, Lagrangian mechanics, Schaum Series, 1st Ed., McGraw-Hill, 1967.*
2. *J. B. Marion and S. T. Thornton, Classical dynamics of particles and systems, 4th Ed., Harcourt College Publishers, 1995.*
3. *Howard D. Curtis, Orbital Mechanics for Engineering Students, Elsevier, pp.475 – 543*
4. *John David Anderson, Modern Compressible flow, 1st Ed., McGraw–Hill,2004.*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: The entire contents of this course, tutorials and assignments lays conceptual/theoretical foundation for application of laws of physics to problems of scientific interest and builds skills required for a career as an educator/academician in schools, colleges, universities and coaching centres, as a professional researcher in government/industrial research organizations, and as a communicator of science in general.

16PHY286	PHYSICS LAB III	0 0 2 1

Course Outcomes: After successful complete of the course, students will be able to

CO1: perform basic experiments in optical measurements in physics

CO2: apply measurement techniques, gather data, and develop skills and analyze data, and draw inferences.

CO3: apply the basic wave theories in physics and their dependence with different mediums or properties of matter

CO4: calculate errors in measurements

CO5: infer specified the basic properties of laser, light and sound waves through different experimental phenomena associated in optics

CO6: gain skills to use basic electrical instruments such as spectrometer, grating, light sources etc.

List of Experiments

Field along the axis of coil; Determine the Cauchy's constant using Spectrometer; Conservation of Galvanometer to Ammeter; Measurement of Laser beam divergence; Refractive index of transparent bar using diode Laser; Stefan-Boltzmann Constant determination; Emissivity Measurement; Thermal Conductivity of Solids; Natural Convention heat transfer; Moment of inertia of Disc & Ring; Gyroscope couple determination; Hartnell Governor – Speed vs sleeve displacement; Young's and rigidity modulus of brass by driven vibrations (Dr.R. Srinivasan's Kit).

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: Lab sessions and experimentation help develop intuition for lab equipment and builds practical knowledge of using lab instruments, measurement techniques and experimental techniques needed for work involving communication of science such as lab instructor/ demonstrator, technical staff, educator or a scientist in schools, colleges, universities, industries and research labs/organizations.

Semester 5

16PHY305	INTERMEDIATE ELECTRODYNAMICS	3 1 0 4

Course Outcomes: On successful completion of the course, students will be able to

1) apply techniques of vector calculus to problems in electrodynamics
2) apply Gauss' law to symmetric charge distributions, calculate potential and potential energies of charge distributions
3) solve Laplace's equation with boundary conditions for electrostatic problems
4) apply electrostatic principles to dielectric media
5) calculate magnetic fields due to current sources, demonstrate use of Ampere's law, vector potential concept
6) investigate and apply formalism of magnetic fields in materials.
7) Understand electromagnetic induction to derive electromagnetic waves and its properties.

Unit 1
Brief review of Vector Calculus: gradient, divergence, curl and their fundamental theorems; line, surface, and volume integrals, curvilinear coordinates, Dirac delta function, Helmholtz theorem and potentials.

Unit 2
Electric field: discrete and continuous charge distributions, electric flux, Gauss's law, divergence of E, applications; Poisson's and Laplace's equations; curl of E; Potential and energy of charge distributions; conductors, induced charge; capacitors.

Unit 3
Solution to Laplace's equation in simple cases; method of images; multipole expansion, diploe moment and field; electric fields in matter: dielectrics, induced dipoles, polarization, bound charges, electric displacement, linear dielectrics.

Unit 4
Magnetic forces and fields: Current densities, calculating magnetic fields from current sources using Biot-Savart's and Ampere's laws, curl and divergence of **B**; magnetic vector potential; magnetic fields in matter: torques and forces on magnetic dipoles, magnetization, bound currents; fields H and B.

Unit 5
Electromagnetic induction & EM waves: Faraday's law and induced **E** field, Maxwell's equations and EM waves in vacuum, momentum and energy density, plane wave solutions.

Textbooks/References
1. D. Griffiths, Electrodynamics, 4E, Pearson, 2015
2. E.M Purcell, Berkeley Physics Vol.2: Electricity and Magnetism, 2ⁿᵈ Ed., TMH India, 2011
3. R. Feynman, R.B. Leighton and M. Sands, The Feynman Lectures on Physics, Vol.2, Pearson, 2012

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: The entire contents of this course, tutorials and assignments lays conceptual/theoretical foundation for application of laws of physics to problems of scientific interest and builds skills required for a career as an educator/academician in schools, colleges, universities and coaching centres, as a professional researcher in government/industrial research organizations, and as a communicator of science in general.

16PHY306	RELATIVITY AND MODERN PHYSICS	3 1 0 4

Course Outcomes: After successful completion of the course, students will be able to

1) Write down Einstein's laws special theory of relativity and apply to elementary problems of relativistic kinematics and dynamics
2) Identify physical significance of relativity and compare with Newtonian mechanics
3) Identify the limitations of classical physics through different phenomena

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4) Describe the formulation of quantum mechanics, its significance and its mathematical formulation.

5) apply quantum mechanics in simple problems/applications

6) apply physical laws based on both classical and quantum theories on large number systems with a statistical approach

7) apply different statistical distribution pertaining to classical and quantum mechanical systems and their applications.

Unit 1
Relativity: Inertial frames and Galilean transformations; postulates of special relativity; length contraction and time dilation; Lorenz transformations; relativistic velocity addition; relativistic momentum and energy, conservation of energy - momentum.

Unit 2
Invitation to Quantum Physics: Specific heat of molecules and solids, Blackbody radiation, Photoelectric & Compton effects, wave-particle duality in light; structure and stability of atoms and the Bohr's atomic model.

Unit 3
Wave-particle duality in matter, Uncertainty principle, Schrodinger equation, wave-function and its interpretation, stationary states and eigenvalues, expectation values; application to simples systems: Solution to Schrodinger equation for one, two and three dimensional boxes; reflection and transmission at a step potential, tunnelling through a barrier.

Unit 4
Semiclassical quantization and quantum levels of a simple harmonic oscillator and other periodic motion; degeneracy of energy levels; Statistical Mechanics: Microstates, Macro states, density of states, Boltzmann factor and simple examples.

Unit 5
Statistics of Quantum Systems: distinguishable and indistinguishable particles, Maxwell-Boltzmann, Fermi-Dirac and Bose-Einstein statistics; some applications, elementary ideas on white dwarfs and neutron stars, super-fluids and superconductors.

Textbooks/References
1. *Kenneth Krane, Modern Physics, Wiley-India, 2E, 2006*
2. *Eisberg and Resnick, Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles, 2E, Wiley-India, 2006*
3. *Bemstein, Fishbane and Gasiorowic, Modern Physics, Pearson-India*
4. *Arthur Beiser, Concepts of Modern Physics, TMH, 6E, 2006*
5. *Eyvind Wichman, Quantum Physics, Berkeley Physics Vol.4, TMH, 2011*
6. *Robert Resnick, Introduction to Special Relativity, Wiley-India,1E,2007*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: The entire contents of this course, tutorials and assignments lays conceptual/theoretical foundation for application of laws of physics to problems of scientific interest and builds skills required for a career as an educator/academician in schools, colleges, universities and coaching centres, as a professional researcher in government/industrial research organizations, and as a communicator of science in general.

15OEL231 – 2xx	**OPEN ELECTIVES**	**3 0 0 3**

Open electives syllabi – see at the end of the booklet.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Semester 6

16PHY315	**ATOMIC, MOLECULAR AND NUCLEAR PHYSICS**	**3 1 0 4**

Course Outcomes:

CO1: Review hydrogen atom to discuss its spectral outputs.

CO2: Explain the observed dependence of atomic spectral lines on externally applied electric and magnetic fields

CO3: State and justify the selection rules for various optical spectroscopy in terms of the symmetries of molecular vibrations

CO4: Discuss modern spectroscopic instruments with theoretical support.

CO5: Describe basis nuclear properties.

CO6: Classify elementary particles and describe standard model.

Unit 1
Hydrogen atom: angular momentum, wave functions, energy levels; intrinsic spin, magnetic dipole moment, basic ideas of addition of angular momenta, Landég-factor, Zeeman Effect, spin-orbit coupling and fine structure, hyperfine structure, NMR & imaging; Many-electron systems, Pauli's principle, Helium atom – singlet and triplet states.

Unit 2
Periodic table, Hund's rules, spectroscopic notation; Excited atomic sates, autoionization, Auger effect; Molecules: Hydrogen molecule, molecular binding – ionic and covalent bonds, bonding and anti-bonding orbitals, hybridized orbitals, electronic, vibrational, rotational energy spectra, Raman effect & spectroscopy.

Unit 3
Aspects of radiation, transition rates and selection rules, spontaneous & stimulated emissions; lifetime of excited states and linewidths, Doppler broadening; X-rays: Bremsstrahlung, characteristic X-ray radiation, scattering, absorption, Moseley's law; Lasers; An overview of experimental techniques and modern developments in atomic & molecular physics.

Unit 4
Structure and properties of atomic nucleus, mass and binding energy, nuclear forces, nuclear models - liquid drop and shell models, radioactivity, nuclear fission and fusion.

Unit 5
Fundamental forces, elementary particles, quarks and leptons, selected topics from astrophysics.

References
1. *Kenneth Krane, Modern Physics, Wiley-India, 2E 2006*
2. *Bemstein, Fishbane and Gasiorowic, Modern Physics, 1E, Pearson-India, 2003*
3. *Eisberg and Resnick, Quantum Physics of Atoms, molecules, solids, Nuclei and particles, Wiley-India,2E, 2006*
4. *Arther Beiser, Concepts of Modern Physics, TMH, 6E, 2006*
5. *Wolfgang Demtroder, Atoms, Molecules, Photons, Springer, 2006*
6. *C.J. Foot, Atomic Physics, Oxford University Press, 2005*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: The entire contents of this course, tutorials and assignments lays conceptual/theoretical foundation for application of laws of physics to problems of scientific interest and builds skills required for a career as an educator/academician in schools, colleges, universities and coaching centres, as a professional researcher in government/industrial research organizations, and as a communicator of science in general.

16PHY316	SOLID STATE PHYSICS AND DEVICES	3 1 0 4

Course Outcomes: After successful completion of this course, students shall be able to

1) Associate X-ray diffraction patterns and Bravais lattices.
2) Identify thermal properties from the the bonding of solids. Calculate the Debye specific heat for 1,2,3D model lattices.
3) Calculate basic transport parameters in the framework of Drude theory for various metals.
4) Perform simple Tight-binding calculations; Associate Fermi surfaces of FCC and BCC metals.
5) Calculate basic properties of semiconductor; relate transistor action to underlying semiconductor theory.

Unit 1
Crystal Structure: Bravais lattices, unit cells, basis, packing fraction, crystal symmetries and classification of crystal systems, crystal structures; crystal planes, Miller indices, reciprocal lattices; Bragg's law, X-ray diffraction,Laue conditions, Bragg planes, diffraction patterns of FCC and BCC structures.

Unit 2
Crystal Binding and Thermal Properties: Binding in molecular solids, Van der Walls forces and Lennard-Jones potential, binding in ionic solids; Vibrations and elastic waves in solids (1D); Einstein and Debye's theory of specific heat of solids.

Unit 3
Theory of Free Electrons in Metals: Free electron theory, density of states, Fermi energy, elementary discussion of specific heat of electrons; transport in electric magnetic fields, Hall effect.

Unit 4
Band energy structure of electrons in crystals: origin of energy bands, elementary discussion of tight-binding approximation, Fermi surfaces, Brillouin zones; semiclassical motion, acceleration theorem; concept of holes and effective mass.

Unit 5
Semiconductors: Band structure, Intrinsic and extrinsic semiconductors, impurity levels, carrier concentrations, elementary ideas of p-n junctions, and transistors; Magnetism: Elementary ideas about dia- para-and ferromagnetism, Langevin's theory of paramagnetism, Curie's law; Elementary ideas of superconductivity.

Textbooks/Reference
1. *Kittel: Solid State Physics, 8E, Wiley India, 2014*
2. *S.O. Pillai: Solid State Physics, New Age, 6E, 2010*
3. *M. Ali Omar: Elementary Solid State Physics: Principles and Applications, Pearson, 1975*
4. *Ibach and Luth, Solid State Physics, 3E, Springer India,*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: The entire contents of this course, tutorials and assignments lays conceptual/theoretical foundation for application of laws of physics to problems of scientific interest and builds skills required for a career as an educator/academician in schools, colleges, universities and coaching centres, as a professional researcher in government/industrial research organizations, and as a communicator of science in general.

16PHY391	PHYSICS SEMINAR	0 0 2 1

A topic from a selection of topics from different branches of physics with the assistance of the instructor of the course may be chosen for a 30 minutes presentation.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Physics UG Electives

15PHY331	ASTRONOMY	3 0 0 3

Course Outcomes: After successful completion of the course, students will be able to

CO1: Present a brief historic perspective of Indian and Western astronomy starting from Aryabhata and Tycho Brahe.

CO2: Solve problems of celestial mechanics with of Kepler's laws and equations.

CO3: Give an overall view of Sun and Solar system and relatively nearer celestial objects

CO4: Describe various observational components like different telescopes and spectroscopic techniques covering the entire electromagnetic spectrum.

CO5: Explain the stellar evolution and their classification by employing the H-R diagram.

CO6: Apply various distance measurement techniques like parallax method, Cepheid variable method, Red shift etc. for different ranges and distances.

CO7: Describe various type of galaxies and their structures and classify them by Hubble's tuning fork morphological classification.

CO8: Describe Big Bang Cosmology to explain the observed expansion of the universe, the verified prediction of CMBR.

Unit 1
Galileo's proof of the Copernican theory; stellar magnitudes, celestial coordinate system, precession, solar & sidereal time, laws of planetary motion, Newton's law of gravity, Einstein's theories of relativity. Formation of the solar system. Sun's properties: nuclear fusion, sun's atmosphere, solar wind, magnetic field & sunspots, eclipses.

Unit 2
Planetary orbits, properties & atmospheres; individual planetary properties; comets.

Unit 3

Extra-solar planets: detection methods, types discovered; sun-like systems. Observation methods & instruments: optics and optical instruments; radio telescopes, arrays and interferometry; instruments for other wavebands; observing without using electromagnetic radiation.

Unit 4
Stars: luminosity, distances, proper motion, absolute magnitude, colour and surface temperature, photometry, spectra, spectroscopic parallax, Hertzsprung-Russell diagram, size measurement, masses and densities, stellar mass-luminosity relationship, stellar lifetimes. Evolution of stars: low & mid mass stars, variable stars, planetary nebulas, white & black dwarfs, sun-like stars, close binary systems, high mass stars, type II supernovas, neutron stars and black holes, pulsars.

Unit 5
Galaxies: the Milky Way, other types of galaxies, mass of a galaxy, Hubble classification, galactic distance scales and measurement methods, starburst and active galaxies, groups and clusters, superclusters, structure of the universe. Cosmology: Einstein's contribution, big bang models, blueshifts and redshifts, expansion of the universe, steady state model, cosmic microwave background, inflation, formation of primeval elements, ripples in the cosmic microwave background, dark matter and dark energy, makeup of the universe, intelligent life in the universe, future of the universe.

TEXTBOOK:
Ian Morison: Introduction to Astronomy and Cosmology, Wiley (UK), October 2008.
REFERENCE:
D. C. Clarke, A. E. Roy: Astronomy: Principles and Practice, 4th Edition (Paperback)

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

16PHY341	INTRODUCTION TO NONLINEAR DYNAMICS	3 0 0 3

Course Outcomes: After successful completion of the course, students will be able to develop an understanding, and be able to
   1) Classify non-linear dynamical systems, types and features of chaos, describe continuous and discrete systems, perform linear stability analysis and determine fixed-points, stability and flows, bifurcations, apply to population dynamics and other examples.
   2) Describe, analyse and characterise 2D and higher-dimensional systems and determine limit cycles, bifurcations, attractors, chaos, Lorenz, Rossler, and pendulum systems.
   3) Describe, analyse and characterise discrete dynamical systems and analyse logistic and circles maps and characterize bifurcations, period doubling, Lyapunov exponent.
   4) Describe, analyse and characterise maps, quasiperiodicity, measures of chaos, basin boundary, Lyapunov exponents, fractals and fractal dimensions.
   5) Explore, analyse and characterize time series.

Unit 1
Introduction: Examples of dynamical systems, discrete and continuous dynamical systems; Maps: 1- and 2- dimensional maps; Logistic map, bifurcations in the logistic map, period doubling, fixed points and their stability; Henon map.

Unit 2
Dynamical system described by ODEs: Logistic differential equation, Harmonic Oscillator (simple, damped, driven and damped), Van der Pol oscillator, Duffing oscillator, phase space, phase space trajectories, conservative systems.

Unit 3
Dynamical system theory: Stability of fixed points in 2- Dimensional systems. Stability matrix, types of fixed points. Attractors: 0-, 1- and 2-dimensional attractors; strange attractors, basins of attractions.

Unit 4
Origin and measures of chaos: Sensitivity to initial conditions, Lyapaunov exponents (LE), LE for one and two dimensional maps; calculation of largest Lyapunov exponent; Fractals: Cantor set, Koch curve, Sierpinski gasket, fractal dimensions.

Unit 5
Time Series: Time delay embedding; Lyapunov exponents from time series; Fractals and Multifractals, Capacity, similarity and correlation dimensions.

Reference
1. M. Lakshmaman and S. Rajasekar, Nonlinear Dynamics, Springer, 2003

2. *Strogatz, S.H., Nonlinear Dynamics and Chaos, Westview Press, 2001*
3. *Hilbom, R.C., Chaos and Nonlinear Dynamics, OUP, 2000*
4. *Sprott, J.C., Chaos and Time-series Analysis, OUP, 2003*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

16PHY342	MATHEMATICAL ASPECTS OF MECHANICS	3 0 0 3

Course Outcomes: After successful completion of this course, students shall be able to

1) Check equations for dimensional consistency; appreciate the art od estimation

2) Solve various first and second order differential equations; set up equations for constrained motion.

3) Set up inhomogeneous differential equations and apply them to forced and damped periodic motions

4) Solve problems in collision in lab and centre-of-mass frames.

5) Use the theorems in vector calculus to solve problems involving various forces.

6) Appreciate any general motion as a combination of translation and rotation.

Unit 1
Basics: Art of estimation and approximations, the concept of scaling, dimensional analysis and the nature of functional relationship among physical quantities as imposed by their dimensions (units).
Second order differential equations. Linear and non- linear, with initial conditions and applications to motion in one dimension: changes, rates, graphs of motions; mathematical statements of Newton's laws; mathematical models of some forces in nature-gravitational, electrostatics, frictional, spring forces and forces that occur in constrained motion.

Unit 2
Inhomogeneous differential equations and applications to forced and damped periodic motions
First integral invariant and integral of motion: concepts of kinetic energy, work, potential and potential energy, conservation of mechanical energy, and power; phase-space description of motion: Phase-space trajectories, flows, separatrices, and elementary stability theory.

Unit 3
Mathematics of motion of systems of particles: centre of mass coordinates and centre of mass frame; models of contact forces, impulses and collisions; integral invariants and conservation of momentum.

Unit 4
Vector calculus and motion in 2 and 3 dimensions: trajectories in Cartesian, cylindrical and spherical polar coordinates; models of forces in 3 dimensions: vector fields - rotational, irrotational and conservative vector fields, Gauss divergences theorem and fields in a continuous distribution of matter, scalar fields and potentials; symmetry, cyclic coordinates and conservations laws; spherically symmetric force fields; inverse square and linear forces; integral invariants: energy, angular momentum, Laplace-Runge-Lenz vector.

Unit 5
Rotating coordinates systems and the rigid body motion: pure rotations. Moment-of-inertia-tensor, combined translation and rotation, instantaneous axis of rotation, Chasles' theorem, Euler's equations. Some Mathematical aspects of the Special Theory of Relativity.

Textbook
1. *Kleppner & Kollenkow, Introduction to Mechanics, TMH India*
2. *Kittel, Berkeley Physics Series Vol 1: Mechanics, 2nd Ed, TMH India*
References
1. *Phill Dyke & Ronger Whitworth, Guide to Mechanics, Palgrave mathematical Guides (2001)*
2. *David Morin, Introduction to Classical Mechanics, CUP, 2009*
3. *A.I. Borisenko & I.E. Tarapov, Vector and Tensor Analysis with Applications, Dover (1980)*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

16PHY343	PHYSICS OF SEMICONDUCTOR	3 0 0 3

Course Outcomes:

1. To understand the fundamental crystal structure and to use Miller indices to describe crystal planes

2. To describe different theory related to electrical conductivity of semiconductors

3. To identify and describe the working of different semiconductor devices.

4. To introduce the basic knowledge in hetero junction semiconductor devices

Unit 1

Crystal Structure: Crystal and non-crystalline materials, Bravais lattices, crystal systems, symmetry elements, crystal structures, Miller Indices, imperfections.

Unit 2

Electrical Conductivity: Classical Free electron theory of metals, expression for electrical conductivity, quantum free electron theory of metals, Fermi energy, origin of bad gap, effective mass.

Unit 3

Semiconductors: Elemental and Compound Semiconductors, intrinsic and extrinsic carrier concentrations, variation of fermi level with carrier concentration and temperature, Hall Effect.

Unit 4

Semiconducting Devices: Photo diodes, PIN diodes, frequency response silicon photo diodes, high speed long wavelength photo diodes.

Unit 5

Quantum Wells, heterojunction semiconductor devices, electro-optic modulators, electro absorption modulators, optical switching and logic ices; Modern semiconducting Devices: CCD – Introduction to Nano devices, fundamentals of tunnelling devices, design considerations, physics of tunnelling devices.

Textbook
S.M. Sze, Physics of Semiconductor Devices, Wiley India, 1966.
References
1. *P. Bhattacharya, Semiconductor Opto-electronic Devices, Prentice. Hall,1996(1ˢᵗ edition)*
2. *J. Allison, Electronic Engineering Materials and Devices, TMG Hill,1990*
3. *A.J. Decker, Electrical Engineering Materials, PHI, 1957*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

16PHY344	LASERS AND ITS APPLICATIONS	3 0 0 3

Course Outcomes:

CO1: Find the interrelations between Einstein coefficients and to apply it for laser production.

CO2: Determine the laser behaviour depending on the line broadening mechanism

CO3: To study the principle and working of different types of lasers.

CO4: Quantitatively describe the key characteristics of laser communication system.

CO5: Describe concrete major example laser systems in different fields of applications

Unit 1

Laser - concepts of ordinary and monochromatic light, coherent and incoherent light, interaction of radiation with matter-induced absorption, spontaneous and stimulated emission, metastable state and pumping, active material, Einstein coefficients, population inversion - concepts and discussion of different techniques, resonant cavity.

Unit 2

Gain mechanism, threshold condition for population inversion, emission broadening- line width, Dw FWHM natural emission line width as deduced by quantum mechanics - additional broadening process: collision broadening, broadening due to de-phasing collisions, amorphous crystal broadening, Doppler broadening in laser and broadening in gases due to isotope shifts; Saturation intensity of laser, condition to attain saturation intensity.

Unit 3

Properties of laser – coherency, intensity, directionality, monochromatically and focusability; Laser transition- role of electrons in laser transitions, 2, 3 and 4 level laser system; Types of Lasers - Ruby, Neodymium, He-Ne, carbon dioxide lasers(principle, working and application), liquid chemical and dye Lasers, semiconductor diode lasers, homo- and hetero-junction lasers, high power semiconductor, diode lasers etc.

Unit 4

Applications - Laser communications: principle, construction, types, modes of propagation, degradation of signal, Analog communication system, digital transmission, fiber optic communication.

Unit 5

Application in other areas: Laser in Medicine - Effects of laser radiation on tissues, surgical uses, ophthalmic uses, laser hazards - biological effects, photo thermal effects, photochemical effects, laser hazards to the eye, to skin, safe exposure; Laser in industry drilling cutting and welding; Holography – principle, types, intensity distribution and applications.

References
1. *S O Pillai, Solid State Physics, New Age 6E 2010*
2. *William T Silfvast, Laser Fundamentals, Cambridge University Press UK(2003)*
3. *A Ghatak, Lasers: Theory and Applications, McMillan India 1E 2009*
4. *BB Laud, Lasers and Non-Linear Optics, New Age 2011*
5. *Kr Nambiar, Lasers: Principles, types and applications, New Age 2006*
6. *T Suhara, Semiconductor Laser Fundamentals, Marcel Dekker (2004)*
7. *R W Wayanant, Lasers in Medicine, Plenum Publishing*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

PG Courses (PHYSICS Stream) (Semesters 7 – 10)

Semester 7

15PHY501	CLASSICAL MECHANICS	3 1 0 4

Course Outcomes: After successful completion of the course, students will be able to develop an understanding, and be able to

CO1: describe the fundamental concept of dynamics of a system of particles.

CO2: apply the Lagrangian and the Hamiltonian formalism for solving the equations of motion for any reasonable mechanical system.

CO3: describe basic ideas of motion in central potential, small oscillations, kinematics and dynamics of rigid bodies, and charged particles in magnetic field, relativistic particles, solve problems of reasonable complexity.

CO4: Describe and apply Poisson-bracket formalism, derive various Poisson brackets and equations of motion.

CO5: State and derive conditions for Canonical transformations, apply them to symmetry transformations, deduce invariants.

CO6: describe and explain Hamilton-Jacobi and Action-Angle formalisms, apply them for 1D oscillators, describe motion for other important problems in this formalism.

Unit 1 Elementary Principles
Review of mechanics of a particle and systems of particles; constraints and generalized coordinates; D'Alembert's principle and Lagrange's equations of motions, applications to simple systems, velocity-dependent potentials and dissipation function.

Unit 2 Variational Principle & Lagrangian Formulation
Hamilton's principle, calculus of variations, Lagrange's equations from Hamilton's principle; symmetries, conservation theorems and cyclic coordinates, energy function; Two-body central force problem: equivalent 1D problem, classification of orbits, integrable power law potentials, the Kepler problem; scattering in a central force field, Rutherford scattering.

Unit 3 Hamiltonian Formulation
Legendre transformations, Hamiltonian, Hamilton's equations; cyclic coordinates and conservation theorems, Hamilton's equations from a variational principle, the principle of least action; Canonical Transformations (CT): equations of CT, examples, generating functions; Poisson brackets (PB), equations of motion and conservation theorems in PB form, infinitesimal CTs &generators, fundamental &angular momentum PB relations; Liouville's theorem.

Unit 4 Hamilton-Jacobi (HJ) Theory
Hamilton-Jacobi equation, harmonic oscillator using HJ method, Hamilton's characteristic function; the action-angle variables; harmonic oscillator using action- angle variable; Small oscillations: eigenvalue

equation, principal axis transformation, normal coordinates, vibrations of a linear tri-atomic molecule.

Unit 5 Rigid Body Dynamics

Degrees of freedom, rotations - orthogonal transformation and its properties, Euler angles, Euler's theorem, infinitesimal rotations; Rotating frames: rates of change of position and velocity, Coriolis-effect; angular momentum, energy, inertia and Euler equations of motion; torque-free motion of rigid body; symmetrical top.

TEXTBOOKS:
1. *H. Goldstein, C. Poole and J. Safko: Classical Mechanics, 2E, Pearson, 2011*
2. *Kleppner and Kolenknow: An Introduction to Mechanics, TMH, 2007*

REFERENCES:
1. *Landau and Lifshitz, Mechanics, 3E, Butterworth–Heinemann, 1976.*
2. *S.T.Thomtonand J.BMarion,ClassicalDynamicsofParticlesandSystems,5E,Cengage,2012.*
3. *Walter Greiner, Classical Mechanics: systems of particle and Hamiltonian Dynamics, 2nd Ed., Springer,2010.*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: The entire contents of this course, tutorials and assignments lays conceptual/theoretical foundation for application of laws of physics to problems of scientific interest and builds skills required for a career as an educator/academician in schools, colleges, universities and coaching centres, as a professional researcher in government/industrial research organizations, and as a communicator of science in general.

15PHY503	MATHEMATICAL PHYSICS I	3 1 0 4

Course Outcomes: After successful completion of the course, students will be able to develop an understanding, and be able to

1) recall vector analysis and apply to electrostatics, magnetostatics, and other applications.
2) solve problems involving vector and function spaces
3) tackle problems involving eigenvalue, change of basis, transformations, diagonalization and spectral decompositions of matrices
4) formulate elementary physical phenomena as Ordinary Differential Equations up to 2nd order and solve them
5) Use curvilinear coordinates to solve problems in electrodynamics
6) describe physical problems in hydrodynamics, material science and general theory of relativity using tensors
7) Solve problems in acoustics and other branches of physics using Fourier techniques
8) Review probability concepts and apply them to a few physics applications.

UNIT 1
Vector Analysis: Scalar and vectorfields,gradient, divergence, curl and Laplacian,vector identities; Line, surface and volume integrals– Gauss, Stokes& Green's theorems, applications; Orthogonal curvilinear coordinates - expression for gradient, divergence, curl and Laplacian in cylindrical and spherical coordinates.

UNIT 2
Linear Algebra& Matrices: Definitions, linear independence of vectors, dimension, inner product, Schwartz inequality, Schmidt's orthogonalization, orthonormal basis; linear transformations, change of basis;Algebra of matrices, special matrices, eigenvalues and eigenvectors, diagonalization, simultaneous diagonalization of matrices.

UNIT 3
Second order differential equations: ordinary differential equations, singular points, series solutions – Frobenius' method; Bessel & modified Bessel functions of different kinds, orthogonality.

UNIT 4
Legendre Polynomials:recurrence relations, Rodrigue's formula, orthogonality;associated Legendre polynomials.

UNIT 5

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Fourier series and function spaces: Examples and applications; sine, cosine and complex series; *Basic ideas in function spaces:generalized series of orthogonal functions and polynomials –Legendre,and Bessel series; convergence in the mean, Parseval identity & Bessel inequality, completeness (statement only).

* Optional topics to be covered if time permits.

TEXTBOOK:
Arfken & Weber, Mathematical Methods for Physicists, Elsevier Indian Reprint, 7E, 2013.
REFERENCE BOOKS:
1. *Riley K F, Hobson M P, Bence S J, Mathematical Methods for Physics and Engineering, CUP, 3E, 2010*
2. *M.L. Boas, Mathematical Methods in Physical Sciences, Wiley Indian Reprint 3E, 2006*
3. *Mathews J and Walker R L, Mathematical Methods of Physics, Pearson India, 2E, 2004*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: Mathematics being a language of physical sciences, the entire contents of this course, tutorials and assignments lays mathematical foundation for physics courses and builds skills required for a career as an educator in physics in schools, colleges and universities, and as a researcher in physical sciences, and as a communicator of science in general.

15PHY504	QUANTUM MECHANICS I	3 1 0 4

Course Outcomes: After successful completion of the course students will be able to

CO1: identify inadequacy of classical mechanics and need for quantum model, wave function, Schrodinger equation, probabilities, apply probability conservation, describe classical-quantum correspondence, wave-packets, uncertainty relations.

CO2: apply Schrodinger equation for simple one-dimensional potentials to obtain energy spectrum, identify scattering and bound states, calculate reflection, transmission coefficients of steps and barriers.

CO3:   describe and apply of concepts of vector spaces, Hilbert spaces, inner products, orthogonality, completeness.

CO4: describe postulates of QM, precisely describe quantum states, observables and operators, commutators, eigenvalues, measurements, uncertainties, orthonormal bases and representations, matrices.

CO5: describe quantum dynamics, propagator and unitary transformation, operator methods, apply them two and many level systems.

CO6: apply Schrodinger equation to three-dimensional rectangular and spherical infinite potential wells, Coulomb potential, angular momentum eigenvalue problems, apply properties of special functions for wave functions, identify and characterize simultaneous eigenstates of L_z, L^2, and H with respective quantum numbers.

CO7: describe scattering process, apply scattering theory and Born approximation to calculate scattering cross-section for simple potentials.

Unit 1
Origins and Schrödinger equation: Summary of experiments & inferences, inadequacy of classical physics, DeBroglie's hypothesis, wave-particle duality; Wave function and Schrödinger equation, probability density, probability current density, Ehrenfest's theorem, classical-quantum correspondence; expectation values anduncertainties, position, momentum and Hamiltonian operators; wave packets, position-momentum uncertainty principle, classical physics as a limiting case of quantum physics.

Unit 2
Stationary states, energy spectrum and eigenfunctions: time-independent Schrödinger equation and stationary states; bound statesin infinite square well,linear harmonic oscillator – Heisenberg and Schrodinger's treatments;bound and scattering states in finite square wellsand barriers, tunnelling, scattering resonances – Ramsauer-Townsend effect;free particle solutions–Gaussian wave packet; Three dimensional and spherically symmetric potentials: spherical potential well and hydrogen atom, radial wave functions and spherical harmonics, degeneracy of levels.

Unit 3
Postulates and principles: Quantum states,wave functions, and linear vector spaces, bra and ket vectors; Observables and hermitian operators, measurements, eigenvalues, eigenstates, collapse postulate; discrete and continuous spectra; generalized statistical interpretation, expectation values, generalized uncertainty relations; position and momentum representations.

Unit 4

Quantum dynamics: postulate of time evolution of a quantum state and Schrodinger equation, calculation of evolution of linearly superposed states and expectation values invarious potentials, quantum oscillations,two-level systems;motion and spread of free Gaussian wave packet; Heisenberg picture of quantum dynamics of observables; energy-time uncertainty relation; introduction to unstable states - decay lifetimes - natural line-widths of spectral lines; coherent-states.

Unit 5
Scattering theory: incident and scattered waves, scattering amplitude and cross section, Integral equation and Greens functions, Born approximation and its validity, partial wave analysis, optical theorem, calculation of phase shifts, scattering by hard sphere and Coulomb potentials.

TEXTBOOKS:
1. *David Griffiths, Introduction to Quantum Mechanics, Pearson India (LPE), 2E, 2005*
2. *R Shankar, Principles of Quantum Mechanics, Pearson India (LPE), 2E 2005*
REFERENCE BOOKS:
1. *L I Schiff, Quantum Mechanics, TMH, 3E, 2010*
2. *J.S. Townsend, A Modern Approach to Quantum Mechanics, 1E, Viva Books, 2010*
3. *S Gasiorowicsz, Quantum Physics, Wiley India, 2E*
4. *JJ Sakurai, Modern Quantum Mechanics, Pearson, 1E, 1994*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: The entire contents of this course, tutorials and assignments lays conceptual/theoretical foundation for application of laws of physics to problems of scientific interest and builds skills required for a career as an educator/academician in schools, colleges, universities and coaching centres, as a professional researcher in government/industrial research organizations, and as a communicator of science in general.

15PHY506	**COMPUTATIONAL PHYSICS**	**4 0 0 4**

Course Outcomes:

CO-1   Familiarize with the basics of computer programming using Python/MATLAB.

CO-2   Solve ordinary differential equations using numerical methods. Utilize the concepts of numerical stability and convergence to analyze each of the methods.

CO-3   Utilize Python/MATLAB codes to solve nonlinear equations.

CO-4   Learn how to numerically approximate functions as well as data.

CO-5   Approximate function derivatives and estimate integrals using numerical methods.

CO-6   Apply numerical methods to solve a system of linear equations.

CO-7   Understand the concepts of optimization.

CO-8   Apply finite difference and finite element methods to approximate boundary value problems

Unit 1   Beginning programming: description of programming, procedure for writing a program, basic programming elements. MATLAB tutorial: Vectors, matrices, vector operations, loops, plots, executable files, functions, if statements and real-time plotting, data files. Basic concepts: Real and complex numbers, matrices, real functions, errors.

Unit 2   Ordinary differential equations: Cauchy problem, Euler methods, convergence analysis, the Crank-Nicolson method, zero-stability, stability on unbounded intervals, high-order methods, predictor-corrector methods, systems of differential equations. Eigenvalues and eigenvectors: power method, convergence analysis, inverse power method with shift, computing the shift, computation of all eigenvalues.

Unit 3   Nonlinear equations: Bisection method, Newton's method, secant method, systems of nonlinear equations, fixed-point iterations, acceleration using Aitken method, Newton-Hörner method for polynomial roots. Approximation of functions and data: Taylor's polynomials, interpolation – Lagrangian, stability of polynomial, Chebyshev, trigonometric, barycentric, piecewise linear; spline functions; least squares method.

Unit 4   Numerical differentiations and integration: Approximation of function derivatives; numerical integration – midpoint, trapezoidal and Simpson methods; interpolatory quadratures; Simpson adaptive formula. Linear Systems: linear system complexity, LU factorization method, pivoting, accuracy of LU factorization, tridiagonal systems, over-determined systems, how the MATLAB backslash operator works, iterative methods, Richardson and gradient methods, conjugate gradient method, when to stop iterating, direct methods *vs*. iterative methods.

Unit 5   Unconstrained optimization: derivative-free methods, Newton method, descent methods, trust region methods, nonlinear least-squares method; constrained optimization. Approximation of boundary value problems

by finite differences and finite elements, finite differences in 2 dimensions, consistency and convergence, heat and wave equations.

Textbook
Quarteroni, A., and Saleri, F., Scientific Computing with MATLAB and Octave, 4E, Springer-Verlag Berlin Heidelberg, 2014
Additional References:
1. Hunt, B.R., Lipsman, R.L., Rosenberg, J.M., A Guide to MATALB for Beginners and Experienced Users, Cambridge University Press, New York, 2001
2. Quarteroni, A., Sacco, R., and Saleri, F., Numerical Mathematics, Springer-Verlag, New York, 2000
3. Press, W.H., Teukolsky, S.A., Vetterling, W.T., and Flannery, B.P., Numerical Recipes, The Art of Scientific Computing, Third Edition, Cambridge University Press, New York, 2007

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: Entire course contents with tutorials and assignments help build foundations and develops computational thinking, programming skills – design and implementation of software for scientific, engineering and industrial computing applications in universities, industries and research labs/organisations.

15PHY547	OPTICS	3 1 0 4

Description: This course describes optical phenomena in nature at the graduate level, dealing mainly with wave optics.

Course Outcomes: After successful completion of the course, students will be able to
1) Summarize and apply results on interaction of electromagnetic radiation with matter, and calculate parameters in reflection, transmission, dispersion in metals and dielectrics.
2) Describe and apply concepts of polarization, relate to angular momentum, polarization using scattering and reflection, quantify using Stokes' and related parameters.
3) Describe and apply complex representations and phasors to deduce conditions for interference, apply to interferometers, thin films, coatings.
4) Describe and apply Huygens-Fresnel principle and Kirchhoff's scalar diffraction theory, Fraunhofer diffraction analysis to single and double slits and other problems.
5) Describe and apply Fourier methods in diffraction, basics of coherence theory, basic ideas in lasers and nonlinear optics.

Unit 1   Review of basics: Wave motion in 1D: harmonic waves, phase and phase velocity, superposition principle, complex representation; Wave equation: plane, cylindrical and spherical waves and wave-fronts; Maxwell equations, EM waves, photons, and light, energy and momentum transport, radiation pressure; Propagation of light in matter, Rayleigh scattering, origin of refractive index.

Unit 2   Review of (a selection of topics in) geometric optics: reflection, refraction, total internal reflection, beam splitting; Lenses, Stops, Mirrors, Prisms, Lens & Optical systems; Introduction to wave front shaping, analytical ray tracing, aberrations; Wave optics: superposition of waves having same and different frequencies, group and phase velocities; anharmonic periodic and aperiodic waves; pulses and wave packets, natural linewidth, coherence time and length.

Unit 3   Polarization: linear, elliptical and circular polarizations; Dichroism, Birefringence, polarization by scattering and reflection; Retarders; Circular polarizers; Basics of optical activity, induced optical effects, modulators, and liquid crystals; Mathematical theory of polarization: polarization ellipse, Poincare sphere, Stokes parameters, Jones vectors & matrices.

Unit 4   Interference: **I**ntroduction, conditions for interference, wavefront splitting and amplitude splitting interferometers, types and location of interference fringes, multiple beam interference, interferometry, applications; Diffraction: Introduction, Fraunhoffer and Fresnel diffraction, Kirchoff's scalar diffraction theory; diffraction by circular aperture, single, double and multiple slits, diffraction grating, resolving power.

Unit 5 Fourier Optics: Fourier transforms, optical applications; Basics of Coherence Theory - introduction, visibility, mutual coherence function, degree of coherence, stellar interferometry; Basic ideas on nonlinear optics: harmonic generation, optical rectification, frequency mixing, self-focusing.

Textbooks/References
1. E. Hecht and A.R. Ganesan, Optics, 4E, Pearson, 2008 (Prescribed)
2. Ajoy Ghatak, Optics, 5E, Tata-McGraw Hill, 2012
3. J. Peatross & M. Ware, Physics of Light and Optics (Available online at:http://optics.byu.edu/BYUOpticsBook_2013.pdf)
4. G.R. Fowles, Introduction to Modern Optics, 2E, Dover, 1989

5. *M. Born M & E. Wolf, Principles of Optics, 7ᵗʰ Expanded Ed., CUP, 1999 (Reference)*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: The entire contents of this course, tutorials and assignments lays conceptual/theoretical foundation for application of laws of physics to problems of scientific interest and builds skills required for a career as an educator/academician in schools, colleges, universities and coaching centres, as a professional researcher in government/industrial research organizations, and as a communicator of science in general.

15PHY581	**PHYSICS LAB A**	**0 0 6 2**

Course Outcomes: After successful completion of the course, students will be able to

CO1: perform some advanced experiments in physics

CO2: apply the measurement techniques and develop skill and analyze data, and draw inferences

CO3: infer some specified properties standard atomic and molecular physics related experiments based on electromagnetic absorptions

CO4: use skillfully modern equipment such as Michelson and Fraby-Pero interferometers

CO5: link some of the modern concepts and advanced experiments in electrical, dielectric and magnetic properties of matter and their applications

CO6: perform some of the advanced level experiments to strengthen students' caliber towards research and development

A selection of experiments from the following list:
Michelson's interferometer; Ultrasonic interferometer; Photoelectric effect; Fourier Analysis Kit; Four Probe and measurement of band gap of Ge; Hall effect of doped semiconductors; Magneto-resistance of Ge; Quincke's tube experiment for measurement of magnetic susceptibility; Electron-spin resonance.

Experiments from Dr. R.Srinivasan's kit:
Calibration of Cu-Constantan thermocouples as temperature sensors, Stefan's constant of radiation, Thermal and electrical conductivities of Cu and its Lorenz number, Thermal conductivity of a poor conductor, Thermal diffusivity of brass; Temperature coefficient of resistance of Cu, Energy band gap of Si, Determination of k/e using a transistor; Dielectric constant of a non-polar liquid, Dipole moment of an organic molecule – acetone, Verification of Curie-Weiss law for a ferroelectric material – temperature dependence of a ceramic capacitor; Magnetic hysteresis and B-H curve of a ferromagnetic material; Principle of phase sensitive detection and the calibration of a lock-in amplifier, Measurement of mutual inductance and low resistance with a lock-in amplifier; Experiments in non-linear dynamics: Chua circuit, Feigenbaum circuit for period doubling.

References
1. R. Srinivasan, K.R. Kriolkar, Instruction Manual for Kit Developed for Doing Experiments in Physics, Indian Academy of Sciences.
2. Other Lab manuals and Handouts.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: Lab sessions and experimentation help develop intuition for lab equipment and builds practical knowledge of using lab instruments, measurement techniques and experimental techniques needed for work involving communication of science such as lab instructor/ demonstrator, technical staff, educator or a scientist in schools, colleges, universities, industries and research labs/organizations.

15PHY582	**SIMULATION LAB**	**0 0 3 1**

Course Outcomes:
1) Learn the basics of MATLAB.
2) Apply numerical methods to solve ordinary differential equations using MATLAB. Write programs to simulate projectile motion, pendulum, electron motion in crossed electric and magnetic fields etc.
3) Solve system of equations using computational methods.
4) Familiarize data analysis using the concepts of curve fitting and spectral analysis.
5) Understand the concepts behind explicit and implicit methods to solve partial differential equations like Laplace and Poisson equations. Solve the Schrodinger equation to portray the evolution of a Gaussian wave packet.
6) Utilize the basics of numerical integration and special functions and compute the Legendre polynomials and Bessel function.

Preliminaries – Programming, Basic elements of MATLAB, Numerical errors; *Basic Projects*: Basic MATLAB (i/o, computing, graphics etc.), Doing Math with Computers – Vectors, Interpolation etc.

Ordinary Differential Equations (ODEs – Basic & Advanced methods): Basic – Projects: Projectile motion, Pendulum; Advanced – Runge-Kutta & Adaptive methods – *Projects*: Cometary Orbits, Electron motion in crossed electric and magnetic fields, Double pendulum.

Solving systems of equations – Linear systems of equations, Matrix inverse, Non-linear system of equations; *Projects*: Gaussian Elimination, Coupled Harmonic Oscillators, Potential well problem.

Data analysis – Curve fitting, Spectral analysis; *Projects*: Least square fit, Fourier Transforms, Fourier Spectrum, Coupled Spring Mass systems.

Partial Differential Equations (PDEs) – Foundations and explicit methods: Introduction to PDEs; Advanced explicit methods: Relaxation and Spectral methods; Stability and implicit methods; *Projects*: Solving Diffusion and Advection equations using various schemes, Solving Laplace and Poisson equations, Evolution of a Gaussian Wave packet by Solving the Schrödinger equation.

Special functions and quadrature – Special functions and basic numerical integration, Gaussian quadrature; *Projects*: Computing Legendre Polynomials and Bessel functions
[# If time doesn't permit, we will stop with Intro to PDE – Foundations and Explicit methods]

Textbooks/References*:*
1. *Alejandro Garcia, "Numerical methods for Physics", 2E, Prentice-Hall, 2000*
2. *Paul L DeVries & Javier Hasbun, "A First Course in Computational Physics", 2E, Jones & Bartlett, 2011*
3. *Mark Newman, "Computational Physics", Create Space Publishing, 2012*
4. *NJ Giordano & H Nakanishi, "Computational Physics", Pearson India, 2012*
5. *Press, W.H., Teukolsky, S.A., Vetterling, W.T., Flannery, B.P., Numerical Recipes3rd Edition: The Art of Scientific Computing, CUP, 3E, 2007*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills: Entire course contents with tutorials and assignments help build foundations and develops computational thinking and programming skills leading to industrial computing and engineering software applications in industries and research labs. Employability: Design and implementation of Applications in Scientific Computing.

Semester 8

15PHY511	QUANTUM MECHANICS II	3 1 0 4

Course Outcomes: After successful completion of the course students will be able to

CO1: describe the effect of transformations on wave functions and observables, symmetry-invariance connection, behaviour of generators, apply to symmetric potentials.

CO2: deduce angular momentum spectrum by algebraic method, describe Stern-Gerlach experiment, spin states and operators, apply to spin dynamics in magnetic fields, Describe and calculate Clebsch-Gordan coefficients for addition of angular momenta in simple cases.

CO3: Describe many particle systems, symmetry of wave functions, Pauli's principle and statistics of identical particles, and write down wave functions and product states for simple cases.

CO4: apply time-dependent perturbation theory to obtain approximate energy system of complex problems, Hydrogen atom under various approximations.

CO5: Apply variational methods to estimate ground state and 1st excited states.

CO6: Apply WKB method to obtain energy spectrum and tunnelling properties.

CO7: apply time-dependent perturbation theory to describe level transitions, calculate transition rates and radiation characteristics.

CO8: Apply Dirac equation to describe phenomena at the relativistic speeds, like particle creation, etc.

Unit 1Angular momentum, spin and identical particles: Angular momentum, various commutation relations, eigenvalues and eigenfunctions of the angular momentum, maximal set of commuting operators and levels of hydrogen atom; Spin, spin operators, Pauli's spin matrices, spin in magnetic field; Addition of angular momenta –

Clebsch-Gordan Coefficients. Many particle systems,identical particles spin and statistics, symmetric and anti-symmetric wavefunctions, Pauli's exclusion principle.

Unit 2Variational and WKB methods: Variational estimate of ground state energies in simple systems; WKB (semiclassical) approximation of wave functions, tunnelling amplitudes, application to theory of alpha decay, bound states and Bohr-Sommerfeld quantization rule.

Unit 3Time independent perturbation theory: non-degenerate and degenerate cases, application to simple systems; Elementary discussion of corrections to energy levels of Hydrogen atom: Zeeman and Stark effects, fine and hyperfine structures.

Unit 4Time-dependent perturbation theory: first order correction, constant, sudden, adiabatic and sinusoidal perturbations; transition rates& Fermi golden rule, lifetime of an excited state; selection rules, interaction of an atom with electromagnetic radiation, the Einstein's A & B coefficients; Schrodinger, Heisenberg, and Interaction Pictures.

Unit 5Elements of relativistic quantum mechanics: Klein-Gordon equation for a free particles and particle in electromagnetic (EM)fields; Dirac Hamiltonian and relativisticwave equation, free particle solutions, negative energy states; *Dirac equation in EM fields – nonrelativistic limit and spin.

TEXTBOOKS:
1. *R Shankar, Principles of Quantum Mechanics, Pearson India (LPE), 2E 2005*
2. *David Griffiths, Introduction to Quantum Mechanics, Pearson India (LPE), 2E, 2005*
3. *L I Schiff, Quantum Mechanics, TMH, 3E, 2010*
REFERENCE BOOKS:
1. *S Gasiorowicsz, Quantum Physics, Wiley India, 2E*
2. *JJ Sakurai, Modern Quantum Mechanics, Pearson, 1E, 1994*
3. *David Griffiths, Introduction to Quantum Mechanics, Pearson India (LPE), 2E, 2005*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: The entire contents of this course, tutorials and assignments lays conceptual/theoretical foundation for application of laws of physics to problems of scientific interest and builds skills required for a career as an educator/academician in schools, colleges, universities and coaching centres, as a professional researcher in government/industrial research organizations, and as a communicator of science in general.

15PHY512	**MATHEMATICAL PHYSICS II**	**3 1 0 4**

Course Outcomes: After successful completion of the course, students will be able to develop an understanding, and be able to

1) Apply techniques of complex analysis like the concept of singularity, Cauchy's theorem, multiple value functions, branch points etc. to solve problems in contour integration.

2) Solve problems related applications in Fourier and Laplace transforms, convolution and other theorems.

3) Solve problems in vector and function and Hilbert spaces, including Parseval's theorem, Bessel inequality etc.

4) Recognize how physical phenomena are modelled using PDEs and solve problems related to PDEs using methods of separation of variables, transforms, eigenfunction expansions.

5) Apply concepts in group theory like discrete groups and continuous (Lie) groups, rotation group in 2-D and 3-D, U(1) and SU(2), SO(3) identify their use in physics.

Unit 1
Complex variables: Analytic functions, Cauchy-Riemann conditions, Cauchy's Integraltheorem and Integral formula, Laurent expansion, Singularities, Residue theorem, evaluation of integrals.

Unit 2
Complex variables II: Singularities, branch cuts, Riemann surfaces, analytic continuation, principal value, dispersion relations; Integral representations of special functions; saddle point approximation, asymptotic expansions.
Special Functions: Gamma and Beta functions, Sterling's formula, Error function.

Unit 3
Integral Transforms: Laplace transforms, Inversion, convolution theorem, application to initial value problems; Fourier transforms, Inversion, Fourier sine and cosine transforms, convolution theorem, Fourier transforms of derivatives, applications to ODEs.

Unit 4

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Partial differential equations: selected examples of partial differential equations of theoretical physics,solution by the methods of separation of variables, eigenfunction expansions and transform techniques.

Unit 5

Linear integral equations (a selection of topics): classification of integral equations, separable kernels, Neumann and Fredholm's series solutions, Hilbert-Schmidt theory for symmetric kernels; **Group Theory (a selection of topics)**: Elementary introduction and examples fromtheory of groups and representations in physics, symmetries and groupsin physics.

TEXTBOOKS:
Arfken & Weber, Mathematical Methods for Physicists, Elsevier Indian Reprint, 7E, 2013

REFERENCE BOOKS:
1. Riley K F, Hobson M P, Bence S J, Mathematical Methods for Physics and Engineering, CUP, 3E, 2010
2. M.L. Boas, Mathematical Methods in Physical Sciences, Wiley Indian Reprint 3E, 2006
3. Mathews J and Walker R L, Mathematical Methods of Physics, Pearson India, 2E, 2004

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: Mathematics being a language of physical sciences, the entire contents of this course, tutorials and assignments lays mathematical foundation for physics courses and builds skills required for a career as an educator in physics in schools, colleges and universities, and as a researcher in physical sciences, and as a communicator of science in general.

15PHY513	**STATISTICAL PHYSICS**	**3 1 0 4**

Course Outcomes: After successful completion of the course students will be able to develop an understanding, and be able to

1) describe and apply principles of macroscopic thermodynamic properties of systems.

2) summarize and apply laws of probability for random walk, density fluctuations in gas.

3) describe micro and macro states and fundamental postulates, statistical approach to thermodynamics – statistical mechanics, apply to ideal gas and other systems.

4) describe and apply the formalism to systems that can exchange energy and particles, and systems containing identical particles to explain from more advanced perspective electrons in metals, black-body radiation, specific heat of atoms, molecules, electrons in solids.

5) describe interacting statistical mechanics of interacting spins and phase transitions, and phenomenology of liquid-gas transitions and universality, apply to estimate parameters of the theory.

UNIT 1
Foundations of statistical mechanics:specification of states of a system -micro and macrostates in quantum and classical systems - phase space - trajectories and density of states; Liouville's theorem, ergodic theorem, fundamental postulate; Ensembles: Microcanonical ensemble – postulate of equal a priori probabilities –contact between statistics and thermodynamics–spin system – classical ideal gas-entropy of mixing and Gibb's paradox.

UNIT 2
Canonical and grand canonical ensembles-partition function – connection with thermodynamics - calculation of thermodynamic quantities - energy and density fluctuations.

UNIT 3
Statistics of indistinguishable particles - Maxwell-Boltzman,Fermi dirac and Bose Einstein statistics– properties of ideal Bose and Fermi gases – Bose-Einstein condensation. Density matrix formalism.

UNIT 4
Interacting systems and phase transitions:thermodynamics of magnetic systems, paramagnetism; Ising model – exact solution in one dimension, spin-spin correlations, mean field theory of Ising model, ferromagnetic phase transition; Liquid-gas system - cluster expansion of classical gas, virial equation of state, liquid-gas transition - critical exponents; Landau theory of phase transition – order parameter, scaling, dimensional analysis, universality.

UNIT 5
Basics ideas onfluctuations and dissipation: Nyquist noise–Brownian motion –diffusion& dissipation – Einstein's relation –fluctuations and spatial and time correlations – power spectrum& white noise - Langevin theory-fluctuation dissipation theorem - The Fokker-Planck equation –approach to Maxwell-Boltzmann distribution.

TEXTBOOKS/ REFERENCES:
1. *F Reif, Foundations of Statistical and Thermal Physics, TMH, 1E, 2011*
2. *Silivio Salinas, Introduction to Statistical Physics, Springer Indain Reprint, IE, 2006.*
3. *Tobochnik and Gould, Thermal and Statistical Physics, Princeton University Press, 2010*
4. *Kerson Huang, Introduction to Statistical Physics, 2E, CRC Press (Indian Reprint), 2010.*
5. *R.K. Pathria, Statistical Mechanics, 3E, Elsevier India,*
6. *Landau and Lifshitz, Statistical Physics,Pergaman Press.*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: The entire contents of this course, tutorials and assignments lays conceptual/theoretical foundation for application of laws of physics to problems of scientific interest and builds skills required for a career as an educator/academician in schools, colleges, universities and coaching centres, as a professional researcher in government/industrial research organizations, and as a communicator of science in general.

15PHY513	**STATISTICAL PHYSICS**	**3 1 0 4**

Course Outcomes: After successful completion of the course students will be able to develop an understanding, and be able to

6) describe and apply principles of macroscopic thermodynamic properties of systems.

7) summarize and apply laws of probability for random walk, density fluctuations in gas.

8) describe micro and macro states and fundamental postulates, statistical approach to thermodynamics – statistical mechanics, apply to ideal gas and other systems.

9) describe and apply the formalism to systems that can exchange energy and particles, and systems containing identical particles to explain from more advanced perspective electrons in metals, black-body radiation, specific heat of atoms, molecules, electrons in solids.

10) describe interacting statistical mechanics of interacting spins and phase transitions, and phenomenology of liquid-gas transitions and universality, apply to estimate parameters of the theory.

UNIT 1
Foundations of statistical mechanics: specification of states of a system - micro and macrostates in quantum and classical systems - phase space - trajectories and density of states; Liouville's theorem, ergodic theorem, fundamental postulate; Ensembles: Microcanonical ensemble – postulate of equal a priori probabilities – contact between statistics and thermodynamics – spin system – classical ideal gas - entropy of mixing and Gibb's paradox.

UNIT 2
Canonical and grand canonical ensembles - partition function – connection with thermodynamics - calculation of thermodynamic quantities - energy and density fluctuations.

UNIT 3
Statistics of indistinguishable particles - Maxwell-Boltzman, Fermi dirac and Bose Einstein statistics – properties of ideal Bose and Fermi gases – Bose-Einstein condensation. Density matrix formalism.

UNIT 4
Interacting systems and phase transitions: thermodynamics of magnetic systems, paramagnetism; Ising model – exact solution in one dimension, spin-spin correlations, mean field theory of Ising model, ferromagnetic phase transition; Liquid-gas system - cluster expansion of classical gas, virial equation of state, liquid-gas transition - critical exponents; Landau theory of phase transition – order parameter, scaling, dimensional analysis, universality.

UNIT 5
Basics ideas on fluctuations and dissipation: Nyquist noise – Brownian motion – diffusion & dissipation – Einstein's relation – fluctuations and spatial and time correlations – power spectrum & white noise - Langevin theory - fluctuation dissipation theorem - The Fokker-Planck equation – approach to Maxwell-Boltzmann distribution.

TEXTBOOKS/ REFERENCES:
7. *F Reif, Foundations of Statistical and Thermal Physics, TMH, 1E, 2011*
8. *Silivio Salinas, Introduction to Statistical Physics, Springer Indain Reprint, IE, 2006.*
9. *Tobochnik and Gould, Thermal and Statistical Physics, Princeton University Press, 2010*
10. *Kerson Huang, Introduction to Statistical Physics, 2E, CRC Press (Indian Reprint), 2010.*

11. R.K. Pathria, Statistical Mechanics, 3E, Elsevier India,
12. Landau and Lifshitz, Statistical Physics, Pergaman Press.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: The entire contents of this course, tutorials and assignments lays conceptual/theoretical foundation for application of laws of physics to problems of scientific interest and builds skills required for a career as an educator/academician in schools, colleges, universities and coaching centres, as a professional researcher in government/industrial research organizations, and as a communicator of science in general.

15PHY514	**ADVANCED ELECTRODYNAMICS**	**(3 1 0 4)**

Course Outcomes: On successful completion of the course, students will be able to

1) Apply basic principles to determine electric field, potential, potential energies of charge distributions.

2) Determine magnetic field due to charge distributions using Biot-Savart and Ampere's laws, describe and apply magnetostatics in matter.

3) Investigate and apply concepts in electromagnetic induction, changing electric fields, and their consequences, arrive at electromagnetic wave equation, electromagnetic waves, and their properties.

4) Describe conservation laws, energy and momentum transport by electromagnetic waves

5) Study the behaviour electromagnetic waves at the boundary of metals and dielectric and explain reflection and transmission properties, dispersion in dielectrics.

6) Apply principles of electromagnetic wave propagation in wave guides and explain modes of propagation.

7) Apply principles and explain electromagnetic fields of moving charged particles, Apply principle to explain different types of electromagnetic radiations, describe and apply basics of relativistic electrodynamic phenomena.

Unit 1
Electrostatics: Gauss' law and its applications; Laplace and Poisson equations, boundary value problems – basics, multipoles; macroscopic electrostatics in dielectrics.

Unit 2
Magnetostatics: Biot- Savart's law, Ampere's theorem, vector potential, magnetic multipole expansion, macroscopic magnetostatics in matter.

Unit 3
Changing Fields: electromagnetic induction, electrodynamics in free space and linear isotropic media, Maxwell's equations; boundary conditions on fields at interfaces; Poynting vector, conservations laws; gauge transformation and gauge invariance.

Unit 4
Electromagnetic Waves: Propagation in free space, dielectrics, conductors, and plasma; transmission lines and wave guides; reflection, refraction, Fresnel's laws; states of polarization

Unit 5
Radiation from moving charges, retarded potentials; dipole radiation; power radiated; Relativity of electromagnetic fields: Lorentz invariance of Maxwell's equations, transformation of electromagnetic fields.

Textbooks/References
1. J.D. Jackson, Classical Electrodynamics, 3E, Wiley, 2007
2. D. Griffiths, Electrodynamics, 4E, Pearson, 2015
3. W. Greiner, Classical Electrodynamics, 1E, Springer, 2006
4. E.M. Purcell, Berkeley Physics, Vol 2, 2E, TMH India, 2011
5. R.P. Feyman, R.B. Leighton, M. Sands, Feyman Lectures in Physics, Vol 2, Narosa, 2010

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15PHY515	**EXPERIMENTAL TECHNIQUES**	**3 1 0 4**

Course Outcomes:

1) Classify, explain and apply the basic concept of errors and noise in measurements

2) Explain different kinds of techniques in measurements and transducers.

3) Explain different spectroscopic techniques (IR, FTIR, Raman, NMR and ESR) used for characterization, distinguish places of applications.,

4) To analyse the IR and Raman spectrum to predict the molecular structure of simple molecules

5) To understand about different characterisation techniques

Unit 1
Data analysis: Date interpretation and analysis; Precision and accuracy, error analysis, propagation of error, least squares fitting, linear and non-linear curve fitting, chi-square test.

Unit 2
Transducers: Temperature, pressure/vacuum, magnetic field, vibration, optical, and particle detectors.

Unit 3
Electronics: Nyquist noise in electronic measurements, filtering and noise reduction, shielding and grouping; Fourier transforms; lock-in detector, box-car integrator, modulation techniques; Data acquisition through computers.

Unit 4
Spectroscopic techniques I: ESR, NMR, FTNMR, X-ray diffraction (Power, Laue), SEM TEM, AFM.

Unit 5
Spectroscopic techniques II: IR, FTIR, Raman.

Textbooks
1. P.R. Bevington, D.K. Robinson, Data reduction and Error Analysis for the Physical Sciences, 3E, McGraw Hill (2002)
2. N.C. Barford, Experimental Measurements: Precision, Error, and Truth, Addison-Wesley (1968)
3. Paul Horowitz, The Art of Electronics, 2E, CUP (2006)
4. Colin Banwell, Elaine McCash, Fundamentals of Molecular Spectroscopy, TMH (2011)
5. T. Pradeep, NANO: The Essentials: Understanding Nanoscience and Nanotechnology, Mcgraw Hill India (2007)

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: The entire contents of this course, tutorials and assignments lays conceptual/theoretical foundation for application of laws of physics to problems of scientific interest and builds skills required for a career as an educator/academician in schools, colleges, universities and coaching centres, as a professional researcher in government/industrial research organizations, and as a communicator of science in general.

15PHY585	**PHYSICS LAB B**	**0 0 6 2**

Course Outcomes: After successful completion of the course, students will be able to

CO1: perform some more advanced experiments in modern physics viz. Michelson interferometer.

CO2: apply measurement techniques and develop skills for efficient data collection, data and error analyzing skills, and draw inferences

CO3: perform condensed matter physics related experiments

CO4: understand and analyze some of the basic as well as advanced concepts of properties of matter and electronics related topics

CO5: perform some of the advanced level experiments to strengthen students' caliber towards research and development

A selection of experiments from the following list:
Michelson's interferometer; Ultrasonic interferometer; Photoelectric effect; Fourier Analysis Kit; Four Probe and measurement of band gap of Ge; Hall effect of doped semiconductors; Magneto-resistance of Ge; Quincke's tube experiment for measurement of magnetic susceptibility; Electron-spin resonance.

Experiments from Dr. R.Srinivasan's kit:
Calibration of Cu-Constantan thermocouples as temperature sensors, Stefan's constant of radiation, Thermal and electrical conductivities of Cu and its Lorenz number, Thermal conductivity of a poor conductor, Thermal diffusivity of brass; Temperature coefficient of resistance of Cu, Energy band gap of Si, Determination of k/e using a transistor; Dielectric constant of a non-polar liquid, Dipole moment of an organic molecule – acetone, Verification of Curie-Weiss law for a ferroelectric material – temperature dependence of a ceramic capacitor;

Magnetic hysteresis and B-H curve of a ferromagnetic material; Principle of phase sensitive detection and the calibration of a lock-in amplifier, Measurement of mutual inductance and low resistance with a lock-in amplifier; Experiments in non-linear dynamics: Chua circuit, Feigenbaum circuit for period doubling.

References
1. *R. Srinivasan, K.R. Kriolkar, Instruction Manual for Kit Developed for Doing Experiments in Physics, Indian Academy of Sciences.*
2. *Other Lab manuals and Handouts.*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: Lab sessions and experimentation help develop intuition for lab equipment and builds practical knowledge of using lab instruments, measurement techniques and experimental techniques needed for work involving communication of science such as lab instructor/ demonstrator, technical staff, educator or a scientist in schools, colleges, universities, industries and research labs/organizations.

15PHY591	SEMINAR A	0 0 2 1

Course Outcomes: After successful completion of the course, students will be able to
1) Research seminar material
2) Gain experience communicating with peers.
3) Comprehend and present confidently within the time limitation.

A topic from a selection of topics from different branches of physics with the assistance of the instructor of the course may be chosen for a 30 – 45 minutes presentation.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: Seminars train students in presentation methods to prepare students as a science communicator, physics resource person in journalism and administrative services, instructor/researcher in schools, colleges and universities, research labs.

Semester 9

15PHY602	CONDENSED MATTER PHYSICS	3 1 0 4

Course Outcomes: After successful completion of the course, students will be able to
1) Differentiate between different Lattice types and explain the concepts of reciprocal lattice and crystal diffraction.
2) Predict electrical and thermal properties of solids and explain their origin.
3) Explain the concept of energy bands and effect of the same on electrical properties.
4) Describe the dielectric properties of insulators.
5) Explain various types of magnetic phenomenon, physics behind them, their properties and applications.
6) Explain superconductivity, its properties, important parameters related to possible applications.

Unit 1
Basic Concepts: Review of free electron theory of metals, thermal and electrical transport properties; inadequacies; Brief review of crystal structure & symmetry, crystal planes, reciprocal lattices and X-ray diffraction pattern, Bragg planes & Brillouin zones.

Unit 2
Electrons in periodic potentials: Bloch theorem, band energy spectrum; nearly free electron and Tight binding models, Fermi surface, energy spectrum of selected solids.

Unit 3
Electron transport: semiclassical dynamics in electric and magnetic fields, band insulators and metals, Bloch oscillations, effective mass and concepts of holes; Hall effect and magneto-resistance; Landau levels, de-Hass van Alfen oscillations; quantum Hall effect.

Unit 4

Semiconductors: energy band structure & parameters – direct and indirect energy gaps and effective masses, photo-absorption, cyclotron resonance; intrinsic and extrinsic semiconductors, equilibrium carrier concentrations; p-n junctions, Schottky-barrier.

Superconductivity: persistent currents, Meissner effect, London's equations, introduction to BCS theory and its predictions, Ginzburg-Landau theory, flux quantization, Josephson effects, SQUID.

Unit 5

Magnetism in solids: dia- and paramagnetism, quenching of orbital angular momentum, Pauli paramegnetism and Landau diamagnetism in metals and semiconductors; exchange interactions, Heisenberg model,ferro- and anti-ferromagnetism.

TEXTBOOKS/ REFERENCES:
1. *N.W. Ashcroft and N.D. Mermin, Solid Satate Physics, Cengage Learning, 2003.*
2. *C.Kittel, Introduction to Solid State Physics, Wiley India, 7E, 2007.*
3. *Ibach and Luth, Soil State Physics, Springer India, 3E, 2002.*
4. *M.Marder, Condensesd Matter Physics, Wiley Intersciences, 1E, 2000.*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: The entire contents of this course, tutorials and assignments lays conceptual/theoretical foundation for application of laws of physics to problems of scientific interest and builds skills required for a career as an educator/academician in schools, colleges, universities and coaching centres, as a professional researcher in government/industrial research organizations, and as a communicator of science in general.

15PHY603	**NUCLEAR AND PARTICLE PHYSICS**	**3 1 0 4**

CO1: Understand basic concepts in nuclear physics with experimental and theoretical explanations, and describe them.

CO2: study the nuclear structure with ideas of liquid drop model and shell model and their application to solve various problems.

CO3: explain the different forms of radioactivity and account for their occurrence in order to   study the theoretical background of alpha, beta and gamma decay.

CO4: assess various nuclear reactions theoretically and numerically for their applications in field of nuclear energy.

CO5: Investigate the properties of nuclear forces and scattering processes.

CO6: Classify of elementary particles and standard model to do numerical problems on quantum numbers.

Unit 1

Nuclear Structure: Basic nuclear properties, Rutherford's scattering, charge distribution, spin and parity, magnetic moment, binding energy – stable & unstable nuclei, packing fraction; liquid drop model – semi empirical mass & binding energy formula, mass parabolas, shell model – validity & limitations.

Unit 2

Nuclear Decay and Radioactivity: Radioactive decays, decay law, radioactive dating; Alpha decay: tunnel theory, angular momentum & parity selection rules, formula for decay constant; Beta decay: energetics, Fermi theory, comparative half-life, allowed & forbidden transitions, selection rules, Parity violation in beta decay, negatron & positron emissions, electron capture, inverse beta decay and the discovery of neutrino; Gamma decay: energetics, decay rates, selection rules; Basic ideas of nuclear isomerism and conversion, interaction of radiation with matter – heavy charged particles, electrons, electromagnetic radiation, relativistic kinematics.

Unit 3

Nuclear reactions Fission and Fusion: Nuclear reactions & mechanisms, compound nuclei and direct reactions – Q value; nuclear fission, neutron capture cross section – reaction rate, controlled fission reactions, nuclear reactors; fusion reactions, energy production, nuclear fusion in stars – p-p & C-N cycles – formation of heavier elements, controlled fusion.

Unit 4

Nuclear Forces: Nucleon-nucleon potential, effective range theory, p-p & n-p scattering, and simple theory of the deuteron structure, characteristics of nuclear forces, charge symmetry of nuclear forces, Isospin - Meson theory of nuclear forces - pions.

Unit 5

Particle Physics: Classification of fundamental forces and elementary particles, elementary particle quantum numbers, symmetries and conversation Laws, Gell-Mann–Nishijima formula, parity non-conservation in weak interactions, CPT theorem, CP violation, applications of conservation laws to particle reactions; extremely short lived particles, quarks – color and flavor, quark model: field bosons, basic ideas of quantum chromo dynamics, colored quarks; history of the universe – dark matter.

REFERENCE BOOKS:
1. *Nuclear Physics: D.G. Tayal*
2. *Nuclear Physics: S.N.Ghoshal*
3. *R.Murugeshan and Er. K, Sivaprasath – Modern Physics – S.Chand(2010)*
4. *K.S.Krane:"Introductory Nuclear Physics" (Wiley)*
5. *David Griffiths – "Introduction to elementary particles" – Wiley (1989)*
6. *S.B.Patel: "An Introduction to Nuclear Physics" (New age international publishers).*
7. *I.Kaplan: " Nuclear Physics"(Addison Wesley, 1962)*
8. *E.Segre: "Nuclei and Particules" (Benjamin, 1967)*
9. *Arthur Beiser: "Concepts of Modern Physics" (5th edition)*
10. *W.E. Burcham and M.Jobes: "Nuclear and Particle Physics" (Longman, 1995)*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: The entire contents of this course, tutorials and assignments lays conceptual/theoretical foundation for application of laws of physics to problems of scientific interest and builds skills required for a career as an educator/academician in schools, colleges, universities and coaching centres, as a professional researcher in government/industrial research organizations, and as a communicator of science in general.

15PHY604	**ADVANCED ELECTRONICS**	**4 0 0 4**

Course Outcomes:

1. To introduce the basic concepts regarding semiconductor optoelectronic devices and its applications
2. To design and analyse op-amp based circuits for different applications
3. To understand the frequency response of different filter circuits
4. To introduce the basic concepts of microprocessor programming

Unit 1
Optoelectronic devices, solar cells, photodetectors, and LEDs.

Unit 2
Digital technique and applications: registers, counters, comparators and similar circuits.

Unit 3
Introduction to operational amplifiers, concept of negative feedback and virtual short, analysis of simple operational amplifier circuits, frequency response of amplifiers, feedback topologies and analysis of discrete transistor amplifiers; signal conditioning and recovery in measurement and control systems.

Unit 4
Active filters and switched capacitor filters; Wave form generators, A/D instruction set, programmable peripheral devices.

Unit 5
Introduction to 8086 microprocessor and its instruction set Assembly level programming, Introduction to microcontrollers and embedded systems.

References:
1. *Malvino & Leech Digital principles and applications, TMH,2003*
2. *John D. Ryder, Electronic Fundamentals and applications PHI, 1999*
3. *Gayakwad, operational Amplifiers & Linear Integrated Circuits, 4E, Pearson India, 2015*
4. *Millman & Halkias, Integrated Electronics, TMH,1991*
5. *Gaonkar, Microprocessor Architecture Programming and Applications with the 8085, penram international, 1999*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: The entire contents of this course, tutorials and assignments lays conceptual and theoretical foundation in electronics required for basic physics lab equipment and instrumentation and builds skills required for a career as an educator in physics in schools, colleges and universities, and as a researcher in experimental physics, and as a communicator of science in general.

15PHY682	ADVANCED ELECTRONICS LAB	0 0 6 2

Course Outcomes:
1. To design and analyse different amplifiers with and without feedback
2. To design different basic logic gates and flip-flops
3. To develop experimental skill in using op-amp and 555 timer for different applications.
4. To develop basic skill in microprocessor programming.

Design and study of CE amplifier with and without feedback, two stage amplifier, Power amplifier, Differential amplifier, Voltage regulated power supplies with Zener diodes and transistors, Design of basic DL. TI and TTL logic gates, RS and JK flip flops using NOR-NAND gates, Schmitt trigger using op-amp, Uses of IC 741, Phase shift oscillator, 555 timer, three terminal IC voltage regulator, Familiarization of 8085 kit and programming, A/D and D/A converters, control of stepper motor.

Textbook/References
Paul B. Zbar & Alert P Malvino, Basic electronics - A text-Lab Manual.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills: Lab sessions and experimentation help develop intuition for lab equipment and builds practical knowledge of using lab instruments, measurement techniques and experimental techniques needed for work involving communication of science such as lab instructor/ demonstrator, educator in schools, colleges and universities, technical staff and scientist in research labs, and builds skills needed for higher studies.

15PHY691	SEMINAR B	0 0 2 1

Course Outcomes: After successful completion of the course, students will be able to
1) Research seminar material
2) Gain experience communicating with peers.
3) Comprehend and present confidently within the time limitation.

A topic from a selection of topics from different branches of physics with the assistance of the instructor of the course may be chosen for a 30 – 45 minutes presentation. Topics relevant to the final semester project are encouraged.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: Seminars train students in presentation methods to prepare students as a science communicator, physics resource person in journalism and administrative services, instructor/researcher in schools, colleges and universities, research labs.

Semester 10

15PHY696	PROJECT	10cr

Course Outcomes: After successful completion of the project, students will be able to

1) Gain deeper insights into the chosen areas of research.
2) Gain experience in research methodologies in the chosen area.
3) Develop theoretical/experimental/computational skills in helping explore the research goals.
4) Communicate one's efforts in the form of a well reference scientific report with illustrations, tables, equations, organization conforming to current publication standards leading to master's thesis.
5) Hone and demonstrate research and communication skills by submitting a research article to a conference or journal.

The aim of the project work is to give more detailed exposure to the student for research methodology. This can include literature survey, review, data collection, and theoretical/experimental work on small parts of research in area chosen by the faculty guiding the project work. If the project to be carried out at other institutions/ laboratories, the experts from these institutions are to be associated in choosing the research topic and its execution.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: Training during the course of the project work help develop theoretical/ experimental/ computational skills and help communicate one's efforts in the form of a well referenced scientific report. These skills form essential part of learning for higher studies and for teaching and research positions in universities and research organizations.

Physics PG Electives

15PHY531	ANTENNAS AND WAVE PROPAGATION	3 0 0 3

UNIT 1
Review of electromagnetic theory: Vector potential, Solution of wave equation, retardedcase, Hertzian dipole. Antenna characteristics: Radiation pattern, Beam solid angle,Directivity, Gain, Input impedance, Polarization, Bandwidth, Reciprocity, Equivalence of Radiation patterns, Equivalence of Impedances, Effective aperture, Vector effectivelength, Antenna temperature.

UNIT 2
Wire antennas: Short dipole, Radiation resistance and Directivity, Half wave Dipole,Monopole, Small loop antennas. Antenna Arrays: Linear Array and Pattern Multiplication,Two-element Array, Uniform Array, Polynomial representation, Array with non-uniformExcitation-Binomial Array.

UNIT 3
Aperture Antennas: Magnetic Current and its fields, Uniqueness theorem, Fieldequivalence principle, Duality principle, Method of Images, Pattern properties, Slotantenna, Horn Antenna, Pyramidal Horn Antenna, Reflector Antenna-Flat reflector,Corner Reflector, Common curved reflector shapes, Lens Antenna.

UNIT 4
Special Antennas: Long wire, V and Rhombic Antenna, Yagi-Uda Antenna, TurnstileAntenna, Helical Antenna- Axial mode helix, Normal mode helix, Biconical Antenna, Logperiodic Dipole Array, Spiral Antenna, Microstrip Patch Antennas.Antenna Measurements: Radiation Pattern measurement, Gain and DirectivityMeasurements

UNIT 5
Calculation of Great Circle Distance between any two points on earth, Ground WavePropagation, Free-space Propagation, Ground Reflection, Surface waves, Diffraction,Wave propagation in complex Environments, Tropospheric Propagation, TroposphericScatter. Ionospheric propagation: Structure of ionosphere, Sky waves, skip distance. Virtual height, Critical frequency, MUF, Electrical properties of ionosphere, Effects ofearth's magnetic fields, Faraday rotation.

TEXTBOOKS:
1. E.C.Jordan and Balmain, "Electromagnetic waves and Radiating Systems", Pearson Education / PHI, 2006
2. A.R.Harish, M.Sachidanada, "Antennas and Wave propagation", Oxford University Press, 2007.
REFERENCE BOOKS:
1. John D.Kraus, Ronald J Marhefka and Ahmad S Khan, "Antennas for all Applications", Tata McGraw-Hill Book Company, 3 ed, 2007.
2. G.S.N.Raju, Antenna Wave Propagation, Pearson Education, 2004.
3. Constantine A. Balanis, Antenna Theory Analysis and Desin, John Wiley, 2nd Edition,2007.
4. R.E.Collins, "Antenna and Radiowave propagation", W.L Stutzman and G.A. Thiele, "Antenna analysis and design", John Wiley, 2000.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15PHY533	BIOPHOTONICS	3 0 0 3

Description:
The course introduces to the students the basic concepts of optical physics required to explain life on earth. This course should help students to do research in biophotonics, and also to develop advanced equipment for medical industry.

Course Outcomes: After successful completion of the course, students will be able to

1) Explain optics of eye, photosynthesis, fluorescence and optical imaging systems.
2) Understand the physics of Photo-excitation, Optical coherence tomography, special and time-resolved imaging, fluorescence resonance energy transfer, nonlinear optical imaging, Bio-imaging and multi- photon microscopy.

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3) Develop articulated arm delivery, hollow tube wave-guides, and fiber optic delivery systems.
4) Design and develop optical biosensors, microscopes and Bio-imaging probes, devices for tissue engineering using light.
5) Understand and explain Phot-dynamic therapy, photo–sensitizers for photodynamic therapy, Contouring and restructuring of tissues using laser, laser tissue regeneration, and femto-second laser surgery.
6) Understand and describe various tools for Flow cytometry, DNA analysis, biomaterials and medicine.

Unit 1
Photobiology: Interaction of light with cells and tissues, Photo–processes in Biopolymers, human eye and vision, photosynthesis. Photo-excitation: free space propagation, optical fiber delivery system, articulated arm delivery, hollow tube wave-guides. Optical coherence tomography, special and time-resolved imaging, fluorescence resonance energy transfer(FRET) imaging, nonlinear optical imaging, Bio-imaging:

Unit 2
Transmission microscopy, Kohler illumination, microscopy based on phase contrast, dark-field and differential interference contract microscopy, fluorescence, confocal and multi-photon microscopy. Applications of bio-imaging: Bio-imaging probes and fluorophores, imaging of microbes, cellular imaging and tissue imaging.

Unit 3
Optical biosensors: Fluorescence and energy transfer sensing, molecular beacons and optical geometries of bio-sensing, biosensors based on fibre optics planar waveguides, evanescent waves, interferometry and surface Plasmon resonance. Flow cytometry: Basics, fluorochromes for flow cytometry, DNA analysis.

Unit 4
Laser activated therapy: Photdynamic therapy, photo–sensitizers for photodynamic therapy, applications of photodynamic therapy, two photon phoyodynamic therapy. Tissue engineering using light: Contouring and restructuring of tissues using laser, laser tissue regeneration, femto-second laser surgery.

Unit 5
Laser tweezers and laser scissors, design of laser tweezers and laser scissors, optical trapping using non Gaussian optical beam, manipulation of single DNA molecules, molecular motors, lasers for genonmocs and proteomics, semiconductor quantum dots for bio imaging, metallic nano-particles and nano-rods for bio-sensing. Photonics and biomaterials: Bacteria as bio-synthesizers for photonic polymers.

TEXTS:
1. Introduction to Bio-photonics- V N Prasad (Wiley-Interscience April 2003)
2. Biomedical photonics: A Handbook-Tu Vo Dinh (CRC Press,Boca Raton,FL 2003)
REFERENCES:
1. A Handbook of Optical Biomedical diagnostics,SPIE press monograph vol pm 107
2. Biomedical Optics-Principles and Imaging-Lihong V and Hsin-IWU, Wiley Intersceince 1sted, 2007
3. Optical coherence Tomography-Principles and Applications –Mark E.Brezinski, (Academic press 1st ed, 2006)
4. Biophysics-An Introduction-Rodney cotterill, (John Wiley Student edition)

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15PHY534	**BIOPHYSICS**	**3 0 0 3**

Course Outcomes: After successful completion of the course, students will be able to

1. Describe application of crystallography, chromatography, electrophoresis, hydration, osmosis, sedimentation, light and x-ray scattering, mass spectrometry applications in biophysics
2. Describe applications of various spectroscopic techniques such as UV, Fluorescence, IR, Raman, ESR, and NMR spectroscopy for biophysical applications.
3. Gain an understanding of molecular structures and modeling techniques related to DNA molecules.
4. Describe energy pathways in biology
5. Gain an understanding and describe aspects of physics of nervous system.

UNIT 1
Introduction: Laws of Physics and Chemistry, introduction to crystallography, Introduction to chromatorgraphy, electrophoresis Physico-Chemical Techniques to study Biomolecules: hydration of macromolecules, diffusion of osmosis, sedimentation, ultracentrifuge, rotational dissusion, light scattering, small angle X-ray scattering, Mass spectrometry.

UNIT 2

Spectroscopy: UV spectroscopy, circular dichroism, Fluorescence spectroscopy, IR, Raman and Electron spin spectroscopy, NMR spectroscopy.

UNIT 3
Molecular Modeling & Macromolecular Structure: building the structure of H2O2, nucleic acid structure, monomers, polymers, double helical structure of DNA, Polymorphism andnanostructure of DNA, structure of RNA, protein structure: amino acids, virus structure.

UNIT 4
Energy Pathways in Biology: free energy, couple reactions, group transfer potential, pyridinenucleotides, photosynthesis, energy conversion pathways, membrane transport. Biomechanics: strained muscles, mechanical properties of muscles, cardiovascular system.

UNIT 5
Neurobiophysics: nervous system, physics of membrane potentials, sensory mechanisms. Origin and evolution of life: prebiotic earth, theories of origin and evolution of life, laboratory experiments on formation of small molecules.

TEXTBOOKS:
1. "Cell and Molecular Biology-Concepts and Experiments" by G.Karp, 2nd ed. John Wiley & Sons, Inc. Singapore, 1999.
2. "Principles of Physical Biochemistry" by K.van Holde, W.C. Johnson, and P.S.Ho.Prentice Hall, 1998.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15PHY535	**EARTH'S ATMOSPHERE**	**3 0 0 3**

Course Outcomes:

1) Identify and describe the basics of the structure of the atmosphere, the variations of temperature and humidity, the fundamentals of processes involving moisture transport and condensation.
2) Describe the fundamentals of cloud formation and precipitation, the basics of atmospheric circulation patterns.
3) Explain the formation of weather systems, the physics behind the formation and evolution of thunderstorms and tornadoes.
4) Explain the basics of tropical weather systems.
5) Explain the concepts of global climate patterns.
6) Explain the basics of climate change.
7) Describe the fundamentals of atmospheric optics.

Unit 1
Earth's atmosphere: overview and vertical structure. Warming the earth and the atmosphere: temperature and heat transfer; absorption, emission, and equilibrium; incoming solar energy. Air temperature: daily variations, controls, data, human comfort, measurement. Humidity, condensation, and clouds: circulation of water in the atmosphere; evaporation, condensation, and saturation; dew and frost; fog.

Unit 2
Cloud development and precipitation: atmospheric stability & determining stability, cloud development and stability, precipitation processes, collision and coalescence, precipitation types, measuring precipitation. Air pressure and winds: atmospheric pressure, pressure measurement, surface and upper-air charts, surface winds, winds and vertical air motions, measuring and determining winds. Atmospheric circulations: scales of atmospheric motion, eddies, local wind systems, global winds, global wind patterns and the oceans.

Unit 3
Air masses, fronts, and mid-latitude cyclones. Weather forecasting: acquisition of weather information, forecasting methods and tools, forecasting using surface charts. Thunderstorms: ordinary (air-mass) thunderstorms, mesoscale convective complexes, floods and flash floods, distribution of thunderstorms, lightning and thunder. Tornadoes: severe weather and Doppler radar, waterspouts.

Unit 4
Hurricanes (cyclones, typhoons): tropical weather; anatomy, formation, dissipation and naming of hurricanes. Air pollution: a brief history, types and sources, factors that affect air pollution, the urban environment, acid deposition. Global climate: climatic classification; global pattern of climate.

Unit 5

Climate change: possible causes; carbon dioxide, the greenhouse effect, and recent global warming. Light, color, and atmospheric optics: white and colors, white clouds and scattered light; blue skies and hazy days, red suns and blue moons; twinkling, twilight, and the green flash; the mirage; halos, sundogs, and sun pillars; rainbows; coronas and cloud iridescence.

TEXTBOOK:
C. Donald Ahrens: Essentials of Meteorology: An Invitation to the Atmosphere (6thedition), Brooks-Cole, 2010.

REFERENCE:
Frederick K. Lutgens & Edward J. Tarbuck: The Atmosphere, An Introduction to Meteorology (11thEdition), Prentice Hall, 19 January, 2009

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15PHY536	EARTH'S STRUCTURE AND EVOLUTION	3 0 0 3

Unit 1

Introduction: geologic time; earth as a system, the rock cycle, early evolution, internal structure & face of earth, dynamic earth. Matter and minerals: atoms, isotopes and radioactive decay; physical properties & groups of minerals; silicates, important nonsilicate minerals, resources. Igneous rocks: magma, igneous processes, compositions & textures; naming igneous rocks; origin and evolution of magma, intrusive igneous activity, mineral resources and igneous processes.

Unit 2

Volcanoes and volcanic hazards: materials extruded, structures and eruptive styles, composite cones and other volcanic landforms, plate tectonics and volcanic activity. Weathering and soils: earth's external processes; mechanical & chemical weathering, rates; soils, controls of formation, profile, classification, human impact, erosion, weathering and ore deposits. Sedimentary rocks: the importance and origins of sedimentary rocks; detrital & chemical sedimentary rocks, coal, converting sediment into sedimentary rock; classification & structures, nonmetallic mineral & energy resources. Metamorphism and metamorphic rocks: metamorphic textures, common metamorphic rocks, metamorphic environments & zones.

Unit 3

Mass wasting: gravity, mass wasting and landform development, controls and triggers, classification of mass-wasting processes, slump, rockslide, debris flow, earthflow, slow movements. Running water: hydrologic cycle, running water, streamflow, work of running water, stream channels, base level and graded streams, shaping stream valleys, depositional landforms, drainage patterns, floods and flood control. Groundwater: importance and distribution, water table, factors influencing storage and movement, springs, wells, artesian wells, environmental problems, hot springs and geysers, geothermal energy, geologic work. Glaciers and glaciation: formation and movement, erosion & landforms, deposits, other effects, causes. Deserts and wind: distribution and causes, geologic processes, basin and range, wind transport, erosion & deposits.

Unit 4

Shorelines: coastal zone, waves & erosion, sand movement, shoreline features & stabilization; erosion problems along U.S. coasts, hurricanes, coastal classification, tides. Earthquakes and earth's interior: faults, seismology, locating the source of an earthquake, measuring intensity, belts and plate boundaries, destruction, damage east of the Rocky Mountains, earthquake prediction, earth's interior. Plate tectonics: continental drift, divergent boundaries, convergent boundaries, transform fault boundaries, testing the plate tectonics model, the breakup of Pangaea, measuring plate motion, what drives plate motions, plate tectonics in the future.

Unit 5

Origin and evolution of the ocean floor: continental margins, features of deep-ocean basins, anatomy of oceanic ridge, oceanic ridges and seafloor spreading, nature of oceanic crust, continental rifting, destruction of oceanic lithosphere. Crustal deformation and mountain building: structures formed by ductile & brittle deformation, mountain building at subduction zones, collisional mountain belts, fault-block mountains, vertical movements of the crust. Geologic time: time scales, relative dating, correlation of rock layers; dating with radioactivity, the geologic time scale, difficulties in dating. Earth's evolution: birth of a planet, origin of the atmosphere and oceans, Precambrian (formation of continents); Phanerozoic (formation of modern continents & earth's first life); Paleozoic (life explodes); the Mesozoic (dinosaurs); Cenozoic era (mammals). Global climate change: climate & geology, climate system, detecting change; atmospheric basics & heating the atmosphere; natural & human causes; carbon dioxide, trace gases, and climate change; climate-feedback mechanisms, aerosols, some possible consequences.

TEXTBOOK:

Frederick K. Lutgens, Edward J. Tarbuck &Dennis G. Tasa: Essentials of Geology (11th edition), Prentice Hall, 8 March, 2012.
REFERENCE:
Graham R. Thompson&Jonathan Turk: Introduction to Physical Geology (2nd Edition), Brooks Cole, 23 June, 1997.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15PHY537	FIBER OPTIC SENSORS AND APPLICATIONS	3 0 0 3

Description:
The course introduces to the students the concepts of various optical fibers and their applications to sensor technology. This course should help students to do research in sensors in presence of harsh electromagnetic fields and to develop advanced equipment for industry.

Course Outcomes: After successful completion of the course, students will be able to

1) Understand Explain principle and technology of fiber optics, electro optic and integrated optic modulators.
2) Understand the basic concepts and specifications of optical fiber sensors, micro-bend, evanescent fiber sensors, and polarization modulated sensors.
3) Explain the principle of temperature and strain sensing, multiplexing. FBG, Long period fiber grating sensors and refractive index sensing.
4) Design and develop Interferometric, Mach-Zehnder and Michelson types optical fiber sensors.
5) Understand and explain physics and technology of temperature, pressure and strain measurements, encoded sensors, and fiber optic biosensors.
6) Understand and describe of fiber optic gyroscopes, Faraday effect sensors, Magnetostriction and Lorentz force sensors, applications in industrial and environmental monitoring.

Unit 1
MM and SM fibers for sensing, Lasers & LEDs suitable for sensing, PIN & APDs for fiber optic sensing. Principles of electro optic modulators bulk & integrated optic modulators. Optical sensor types, advantages and disadvantages of fiber optic sensors, Senser system performance: basic specifications, Intensity modulated sensors, reflective concept, micro-bend concept, evanescent fiber sensors, polarization modulated sensors.

Unit 2
In-fiber Bragg grating based sensors – sensing principles – temperature and strain sensing, integration techniques, cross sensitivity, FBG multiplexing techniques. Long period fiber grating sensors-temperature and stain sensing, refractive index sensing, optical load sensors and optical bend sensors.

Unit 3
Interferometric sensors, Mach-Zehnder & Michelson interferometric sensors, Theory-expression for fringe visibility, Fabry-perot fiber optic sensors – theory and configurations, optical integration methods and multiplication techniques, application – temperature, pressure and strain measurements, encoded sensors.

Unit 4
Sagnac interferometers for rotation sensing fiber gyroscope sensors – Sagnac effect – open loop biasing scheme – closed loop signal processing scheme – fundamental limit – performance accuracy and parasitic effects – phase-type bias error – shupe effect – anti-shupe winding methods – applications of fiber optic gyroscopes. Faraday effect sensors. Magnetostriction sensors- Lorentz force sensors.

Unit 5
Biomedical sensors, sensors for physical parameters, pressure, temperature, blood flow, humidity and radiation loss, sensors for chemical parameters. pH, oxygen, carbon, dioxide, spectral sensors. Distributed fiber optic sensors – intrinsic distributed fiber optic sensor – optical time domain reflectometry based Rayleigh scattering – optical time domain reflectometry based Raman scattering – optical time domain reflectometry – quasi – distributed fiber optic sensors. An overview on the optical fiber sensors in nuclear power industry, fly-by light aircraft, oil field services, civil and electrical engineering, industrial and environmental monitoring.

TEXTBOOKS
1. Francis T. S Yu, Shizhuo Yin (Eds), Fiber Optic Sensors, Marcel Dekker Inc., New York, 2002
2. Dakin J and Culshow B., (Ed), Optical fiber sensors, Vol I, II, III, Artech House, 1998
3. Pal B. P, Fundamentals of fiber optics in telecommunication and sensor systems, Wiley Eastern, 1994
REFERENCES
1. Jose Miguel Lopez-Higuera(Ed), Handbook of optical fiber sensing technology, John Wiley and Sons Ltd.,2001
2. Eric Udd (Ed), Fiber optic sensors: An introduction for engineers and scientists, John Wiley and Sons Ltd., 1991
3. B. D Gupta, Fiber optic Sensors: Principles and applications, New India Publishing Agency, New Delhi., 2006
4. Bio-medical sensors using optical fibers, Report on progress in physics Vol 59.1,1996

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15PHY538	**FIBER OPTICS AND TECHNOLOGY**	3 0 0 3

Description:
The course introduces to the students an in depth understanding of various optical fibers, classification of fibers based on refractive index profiles, modes guided and materials. This course help students to do research in fiber optics technology for communication and sensing.

Course Outcomes: After successful completion of the course, students will be able to
1. Understand Explain principle and technology of fiber optics, classification, and its applications.
2. Understand and explain the basic concepts and specifications of optical fibers, types of optical fibers, losses in fibers, polarization, attenuation and propagation of light through optical fibers.
3. Explain dispersion phenomenon in optical fibers, waveguide and modal dispersion, attenuation and noise reduction.
4. Understand and explain optical sources, characteristics and coupling of light into the optical fibers
5. Understand and describe Fiber drawing and fabrication methods, measurement of attenuation, dispersion, group velocity delay, and refractive index profile.
6. Understand and describe Optical Amplifiers, EDFA and applications of fibers in industry, medicine, communication and sensing.

Unit 1
Classification of fibers: based on refractive index profiles, modes guided applications and materials. Fibers for specific applications: polarization maintaining fibers (PMF), dispersion shifted and dispersion flattened fibers, doped fibers. Photonic crystal fibers, holly fibers.
Fiber specifications: Numerical aperture of SI and GI fibers, Fractional refractive index difference, V – parameter, Cut off wavelength, dispersion parameter, bandwidth , rise time and Non linearity coefficient.

Unit 2
Impairment in fibers: group velocity dispersion (GVD), wave guide and modal dispersions. Polarization mode dispersion (PMD), Birefringence – liner and circular.
Fiber drawing and fabrication methods: modified chemical vapor deposition(MCVD) and VAD techniques.

Unit 3
Mode theory of fibers – different modes in fibers. Dominant mode, Derivations for modal equations for SI and GI fibers. Approximate number of guided modes in a fiber (SI and GI fibers). Comparison of single mode and multimode fibers for optical communications.LED and LD modulators. Coupling of light sources to fibers – (LED and LD) – Derivations required. Theory and applications of passive optical components: connectors, couplers, splices, Directional couplers, gratings: FBGs and AWGs, reflecting stars: Optical add drop multiplexers and SLMs.

Unit 4
Active components: Optical Amplifiers (OAS)- Comparative study of OAS-SLAs, FRAs, FBAs EDFAs and PDFAs based on signal gain, pump efficiency, Noise Figure, Insertion loss and bandwidth. Design and Characterization of forward pumped EDFAs.

Unit 5
Fiber measurements: Attenuation measurement – cut back method. Measurement of dispersion – differential group delay, Refractive index profile measurement.
Numerical aperture (NA) measurement, diameter measurement, mode field diameter (MFD) measurement, V-Parameter, Cut off wavelength Measurement, splicing and insertion losses, OTDR – working principle and applications. OSA- Basic block schematic and applications in measurements.(John M senior)

TEXTBOOKS:
1. Gerd Keiser, Ooptical Fiber communications, MC Graw Hill,200
2. Maynbav, Optical Fiber Technology, Pearson Education, 2001
3. John M senior, Optical fiber communications, PHI, 1992
REFERENCES:
1. Joseph C Palais, Optical Fiber communications, Pearson Education.1998.
2. Dennis Deriikson, Fiber optic test and measurement, Prentice hall,1998.
3. 3 David Bailey and Edwin wright, practical Fiber optics, Elsevier 2003.
4. Franz and Jain, optical Fiber communication systems and Components, Narosa Publishers, 2004.
5. Ajoy Ghatak and K.Thyagarajan, Introduction to Fiber optics: Cambridge university press,1999.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15PHY539	**NANOPHOTONICS**	3 0 0 3

Course Outcomes: Upon the successful completion of the course, students will be able:

CO1: To understand the basics of photonics, building blocks of photonic circuits and its effects
CO2: To understand the physics and application of photonic crystals, plasmonic nanostructures and metamaterials
CO3: To be aware of the techniques available in nano-fabrication and nano-characterization.
CO4: To describe broadly about the impact of nanophotonics in biomedical research.
CO5: To design and develop theoretical models of a basic plasmonic and photonic structures using finite-difference time-domain (FDTD) simulation and study the behavior.

Unit 1
Introduction to nanoscale interaction of photons and electrons. Near field interaction and microscopy-near field optics and microscopy-single molecule spectroscopy-nonlinear optical process.

Unit 2
Materials for nanophotonics-quantum confinement-optical properties with examples-dielectric confinement-super lattices-organic quantum confined structures.

Unit 3
Plasmonics-metallic nanoparticles and nanorods-metallic nanoshells-local field enhancement-plasmonic wave guiding-applications of metallic nanostructures.

Unit 4
Nanocontrol of excitation dynamics-nanostructure and excited states-rare earth doped nanostructures-up converting nanophores-quantum cutting. Growth and characterization of nanomaterials – epitaxial – PLD – nanochemistry-XRD-XPS-SEM-TEM-SPM.

Unit 5
Concept of photonic band gap – photonic crystals – theoretical modeling – features-optical circuitry-photonic crystal in optical communication-nonlinear photonic crystal-applications. Nanoelectronic devices – Introduction-single electron transistor. Basic ideas of nanolithography and biomaterials-nanophotonics for Biotechnology and Nanomedicine – nanophotonics and the market place.

TEXTBOOKS:
1. Paras N. Prasad, Nanophotonics, Wiley Interscience, 2004
2. Lukas Novotny and Bert Hecht, Principles of Nano-Optics, Cambridge University Press, 2006
REFERENCE:
1. Herve Rigneault, jean-Michel Lourtioz, Claude Delalande, Juan Ariel Levenson, Nanophotonics, ISTE Publishing Company, 2006.
2. Surface Plasmon Nanophotonics, Mark L. Brongersma, Pieter G. Kik, Springer-Verlag, 2006.
3. Photonic Crystals, by John D. Joannopoulos, Robert D. Meade, Joshua N. Winn Prienceton University Press.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15PHY541	**NUCLEAR PHYSICS**	3 0 0 3

CO1: Examine scattering processes through quantum mechanical analysis.

CO2: To illustrate nuclear reactions with supporting theories

CO3: To investigate the detection methods of various particles.

UNIT 1
Two-nucleon scattering-partial wave analysis, effective range theory, coherent scattering, spin-flip and polarization, comparison of n-n and p-p scattering.

UNIT 2
Nuclear reactions-reaction and scattering cross sections, compound nuclear reactions, resonance reactions, Breit-Weigner formula, experimental determination of resonance widths and shapes, statistical theory, optical model, transfer reactions, pick-up and stripping reactions, spectroscopic factors.

UNIT 3
Heavy ion reactions-salient features at low, intermediate and high energies, classical dynamical model, heavy ion fusion, fusion excitation function, deep inelastic collision.

UNIT 4

Some aspects of nuclear measurement techniques: (i) Detectors and electronics for high resolution gamma and charge particle spectroscopy; (ii) Fast neutron, detection (iii)Neutrino detection, (iv) Drift chambers, RICH, calorimeter.

BOOKS RECOMMENDED:
1. Nuclear Physics: L.R.B Elton
2. Nuclear reactions: Blatt and Weisskopf
3. Nuclear Theory- Roy and Nigam
4. Nuclear Physics- B. Cohen
5. Nuclear Physics- Preston and Bhaduri
6. Nuclear structure- Bohr and Mottelson
7. Nuclear structure- M. K. Pal
8. Techniques in experimental nuclear physics- Leo
9. Techniques in experimental nuclear physics- Knoll
10. Techniques in experimental nuclear physics-S. S. Kapur

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15PHY543	PHYSICS OF COLD ATOMS AND IONS	3 0 0 3

Course Outcomes: After completing the course, students should be able to
CO1. Understand, describe, and perform basic calculations on the behaviour of two-level atoms in a radiation field, apply selection rules.
CO2. Understand and describe concepts associated with laser cooling.
CO3. Understand and describe optical molasses and atomic beam collimation and related concepts and experiments.
CO4. Understand and describe concepts of cooling below doppler limit, magnetic and optical traps, evaporative cooling.
CO5. Understand and describe concepts related atom mirrors and lenses, basics of nonlinear optics, optical lattices, Bose-Einstein condensation, quantum entanglement and quantum computing.

UNIT 1

Two level atom in a radiation field, Laser light pressure, Atoms in motion, Travelling wave and standing wave - Multilevel atoms, Alkali metal atoms, metastable noble gas atoms, Polarization and interference, Angular momentum and selection rules and Optical transitions in Multilevel atoms.

UNIT 2

Temperature and Thermodynamics in Laser Cooling, Kinetic Theory and the Maxwell-Boltzmann Distribution, Random Walks, The Fokker-Planck Equation and Cooling Limits, Phase Space and Liouville's Theorem.

UNIT 3

Optical Molasses: Introduction, Low-Intensity Theory for a Two-Level Atom in One Dimension, Atomic Beam Collimation, Low-Intensity Case, Experiments in One and Two Dimensions, Experiments in Three-Dimensional Optical Molasses.

UNIT 4

Cooling below the Doppler limit - Magnetic trapping of neutral atoms. Optical Traps – Magneto optical traps - Evaporative cooling.

UNIT5

Applications to atom mirrors, lenses, atomic fountain, nano fabrication, atomic clocks and nonlinear optics - Optical lattices - Bose Einstein condensation Entangled states and quantum computing.

TEXTBOOKS:
1.   Laser cooling and trapping by H J Metcalf and Peter Van der Straten Springer VerlagNew York 1999.
2.   Laser Manipulation of atoms and ions – Proceedings of the international school of Physics "Enrico Fermi" Course CXVII,Amsterdam (1993) North Holland.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15PHY544	QUANTUM ELECTRODYNAMICS	3 0 0 3

Course Outcomes: After completing the course, students should be able to
CO1. Understand and do basic calculations on Lorentz covariance and Dirac equation of relativistic particles, and their symmetry properties.

CO2. Understand concepts related to transformations properties, negative energy solutions, vacuum polarization, and relativistic theory of Hydrogen atom.
CO3. Understand general formulation of quantum field theory and description in terms of local fields, canonical quantization of fields for charged scalar field, Feynman propagator.
CO4. Understand the concepts of second quantization of Dirac field and associated theoretical concepts, Propagators and perform basic calculations.
CO5. Understand and describe and perform basic calculations on quantization of electromagnetic fields.

Unit 1   Lorentz covariance of the Dirac equation: covariant form of the Dirac equation, proof of covariance, space reflection, bilinear covariants, solution of the Dirac equation for a free particle: plane wave solutions, projection operators for energy and spin, physical interpretations of free-particle solutions and packets.

Unit 2 The Foldy-Wouthuysen transformation: introduction, free-particle transformation, the Hydrogen atom hole theory: the problem of negative energy solutions, charge conjugation, vacuum polarization, the time reversal and other symmetries.

Unit 3 General formulation of the quantum field theory: implication of the description in terms of local fields, canonical formulation and quantization procedure for particles, canonical formulation and quantization for fields, the Klein-Gordon field: quantization and particle interpretation, symmetry of the states, measurability of the field and microscopic causality, vacuum fluctuations, the charged scalar field, Feynman propagator.

Unit 4 Second quantization of the field: quantum mechanics of N-identical particles, The number representation for fermions, the Dirac theory, momentum expansions, relativistic covariance, Feynman propagator.

Unit 5   Quantization of the electromagnetic field: introduction, quantization, covariance of the quantization procedure, momentum expansions, spin of the photon, the Feynman propagator for transverse photons.

TEXTBOOKS:
1. *Bjorken & Drell: "Relativistic Quantum Mechanics"*
2. *Bjorken & Drell: "Relativistic Quantum Fields"*
REFERENCE BOOKS:
1. *Schweber, Bethe and Hoffmann: Mesons and Fields*
2. *Sakural: Advanced Quantum Mechanics*
3. *Lee: Particle Physics and Introduction to Field Theory*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15PHY545	**QUANTUM OPTICS**	**3 0 0 3**

Course Outcomes: After completing the course, students should be able to
CO1. Understand and describe optical coherence and correlation functions, spectral representations, theory of partial coherence.
CO2. Describe quantization and quantized states of radiation field, coherent state of photons.
CO3. Understand and describe quantum theory of lasers and related phenomena.
CO4. Understand and describe photon counting statistics and related concepts.
CO5. Understand and describe collective cooperative spontaneous radiation and related phenomena, squeezed states.

UNIT 1
Correlation functions of light waves. Spectral representation of mutual coherence function.
Calculation of mutual intensity and degree of coherence, propagation of mutual intensity.
Rigorous theory of partial coherence. Coherency matrix of a quasi-monochromatic plane wave. Stochastic description of light and higher order coherence effects.

UNIT 2
Quantization of the radiation field, Quantum mechanical harmonic oscillator, the zero point energy, states of the quantized radiation field, single mode number states and phase states, coherent photon states.

UNIT 3
Quantum theory of the laser: photon rate equations, time dependence of photon coherence, laser threshold condition, rate equations for atoms and laser photons, laser photon distribution, fluctuations in laser light and laser phase diffusion.

UNIT 4
Statistical optics of photons: Photon coherence properties, photon counting, photon distribution for coherent and chaotic light, quantum mechanical photon counting distribution.

UNIT 5

Super radiance: collective cooperative spontaneous radiation. Diecke's theory. Photon echoes. Quantum beats. Quantum chaos and instability hierarchies of laser light, chaos and its routes. Squeezed states of light.

REFERENCES:
1. L. Mandel and E. Wolf, Coherence and Quantum Optics, Plenum (1973).41
2. H. Haken, Light. Vol. 1 & 2, North Holland (1981).
3. S.M. Kay and A. Maitland, Quantum Optics. Academic Press (1970).
4. R. Loudon, Quantum Theory of Light, Clarendon Press (1979).
5. J. Fox, (Ed.), Optical Masers, Interscience Publishers (1963).
6. R.G. Brewer and A. Mooradian, Laser Spectroscopy, Plenum (1974).
7. Laser Theory: Encyl. of Phy. Vol. 25/2C, SpringerVerlag (1976).
8. M.O. Scully, W.E. Lamb and M. Sargent III, Laser Physics, Addison Wesley (1974).
9. J. Jacob, M. Sargent III, Laser Applications to Optics and Spectroscopy, Addison Wesley (1975).
10. R.H. Pantell and H.E. Puthoff, Fundamentals of Quantum Electronics Wiley (1969).

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15PHY546	THIN FILM TECHNOLOGY	3 0 0 3

Course Outcomes:

1) Recognize the importance of thin films in varied applications in science and technology.

2) Classify and describe methods of thin film fabrication - thermal evaporation, cathodic sputtering, Molecular beam epitaxy and laser ablation, electrolytic deposition, and physical and chemical vapour deposition.

3) Explain thickness measurements using electrical, mechanical, optical interference, micro balance, quartz crystal methods.

4) Describe the analytical techniques of characterization such as X-ray diffraction, electron microscopy, high and low energy electron diffraction, Auger emission spectroscopy.

5) Describe and explain using theories the growth of thin films, the post nucleation growth, epitaxial growth, structural defects in thin films, the elastic and plastic nature of thin films.

6) Describe and explain with illustrations the optical properties of thin films such as reflectance, transmittance and absorbance, Categorize the Anisotropic and isotropic thin film.

7) Describe the electronic properties and applications of semiconductor, insulating-dielectric and superconducting films.

8) Describe and apply the molecular-field and spin-wave theories in magnetic thin films to explain magnetic phenomena.

9) Describe applications of thin films for thin film device fabrication.

UNIT 1

Preparation methods: Physical methods: thermal evaporation, cathodic sputtering, Molecular beam epitaxy and laser ablation methods.Chemical methods: electrolytic deposition, chemical vapour deposition.

UNIT 2

Thickness measurement and Characterisation: electrical, mechanical, optical interference, microbalane, quartz crystal methods. Analytical techniques of characterization: X-ray diffraction, electron microscopy, high and low energy electron diffraction, Auger emission spectroscopy.

UNIT 3

Growth and structure of films: General features-Nucleation theories- Effect of electron bombardment on film structure-Post nucleation growth- Epitaxial film growth- Structural defects.

UNIT 4

Properties of films: elastic and plastic behaviour. Optical properties- Reflectance and transmittance spectra-Absorbing films-Optical constants of film material- Multilayer films- Anisotropic and isotropic films. Electric properties to films: Conductivity in metal, semiconductor and insulating films- Discontinuous films-Superconducting films.

UNIT 5

Magnetism of films: Molecular field theory- Spin wave theory- Anisotropy in magnetic films-Domains in films-Applications of magnetic films.
Thin film devices: fabrication and applications.

TEXTBOOKS:
1. *K.L. Chopra, Thin Film Phenomena, McGrawHill (1983),*
2. *George Hass. Physics of Thin Films: Volumes 1':12. Academic Press (1963).*

REFERENCE BOOKS:
1. *K.L. Chopra and I.J. Kaur, Thin Film Soalr Cells, Plenum Press (1983).*
2. *L.I. Maissel and Giang (Eds.), Handbook of Thin film Technology, McGrawHill (1970).*
3. *J.C. Anderson, The Use of Thin Films in Physical Investigation, Academic Press (1966).*
4. *J.J. Coutts, Active and Passive Thin Film Devices, Academic Press (1978).*
5. *R.W. Berry, P.M. Hall and M.T. Harris, Thin Film Technology, Van Nostrand (1968). 47*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15PHY548	FUNDAMENTALS OF PLASMA PHYSICS	3 0 0 3

(Pre-requisites: Intermediate and Advanced Electrodynamics)

Course Outcomes: After successful completion of the course, students will be able to know

1. Know the basic concepts of plasma physics.
2. Understand the physics behind plasma and various forms of plasma
3. Calculate the amount of energy transfers in e-atomic/molecules collisions and collision cross-section.
4. Understand the plasma characteristics; energy distribution function, plasma Sheath, Debye shielding, plasma frequency.
5. Understand the physics of modeling plasmas as fluid.
6. Acquire knowledge of the wave propagation in plasmas

Unit 1
Introduction – Spatial scale of an unmagnetized plasma – Debye Length, time scale - plasma period, gyroradius and gyrofrequency of magnetized plasma, single particle motion in prescribed fields- ExB, grad-B, Curvature and polarization drifts, magnetic moment, adiabatic invariants of particle motion, magnetic mirror.

Unit 2
Kinetic theory of plasmas, Boltzmann equation, Maxwell-Boltzmann distribution, Vlasov description of collisionless plasmas, Moments of the Boltzmann equation, Systems of macroscopic equations: Cold and Warm plasma models.

Unit 3
Plasmas as fluids - Two fluid description, equation of motion, Drifts perpendicular to B, parallel pressure balance.

Unit 4
Single fluid theory of plasmas: Magneto hydrodynamics (Hydromagnetic, MHD).

Unit 5
Introduction to waves in plasmas, waves in cold magnetized and unmagnetized plasma, Fourier representation, Dispersion relation, Waves in hot (magnetized) plasmas, Landau Damping, CMA diagram, Instabilities, MHD Waves, Alfven Waves, MHD discontinuities.

Textbooks/References
1. *Umran S. Inan & Marek Golkowski, Principles of Plasma Physics for Engineers and Scientists, Cambridge, 2011*
2. *Francis F. Chen, Introduction to Plasma Physics and controlled fusion, Springer, 2006*
3. *D.A. Gumett & A. Bhattacharjee, Introduction to Plasma Physics, CUP, 2006*
4. *Boyd, T.J.M., and Sanderson, J.J.: The Physics of plasmas, CUP,2003*
5. *Krall, N.A, Trivelpiece, A.W., Principles of plasma physics, McGraw Hill,1973*
6. *Stix, T.H., Waves in plasmas, Springer, 1992*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15PHY549	SPACE PHYSICS	3 0 0 3

(Pre-requisites:PHY322, PHY420, preferably PHY555)

Course Outcomes:

1) Define what is meant by a plasma, the criteria that an ionized gas must satisfy in order to be called a plasma, different types of plasma and their classification
2) Describe the plasma environment in space, with focus on near-Earth environment, Classify the main domains where Space Physics applies and enumerate their properties, giving specific details
3) Describe and define the relevant key physical theories (particularly from plasma physics) that control the qualitative properties of different space plasma phenomena – Explain how certain important plasma populations in the solar system, e.g. the Earth's ionosphere and magnetosphere, get their basic properties, and how these properties may differ between the planets
4) Calculate the quantitative behaviour of different space physics phenomena using plasma physics analysis methods. Make order of magnitude estimates of some properties in space plasmas and space phenomena, e.g. the power dissipated in the aurora, or the amount of current floating from Earth's Magnetosphere to Ionosphere
5) Demonstrate an understanding of how Space Physics has a practical impact on everyday life in the field of Space Weather. Identify ways in which experimental studies of Space Physics phenomena have advanced our understanding of basic plasma physics
6) Model certain Space Physics phenomena by applying basic physical laws, using simple Mathematics (e.g. model the form of the ionosphere/magnetosphere or estimate the temperature of a sunspot)
7) Describe current research within space physics and explain it to an interested layman

Unit 1
Brief history of solar-terrestrial physics – The variables Sun and the heliosphere, Earth's space environment and upper atmosphere.

Unit 2
Space plasma physics - single particle motion, plasma state, Fluid description, MHD & kinetic theory, Applications

Unit 3
Solid wind & Interplanetary Magnetic field (IMF), Shocks and Instabilities in space

Unit 4
Solar wind interactions with magnetized planets-Introduction, planetary magnetic fields, spherical harmonic expansions, geomagnetic field and its measurements, variations in Earth's field.

Unit 5
Magnetosphere - Dynamics, SW-magnetosphere interactions; Ionospheres, Currents in space and Ionosphere; Neutral atmosphere-Dynamics.

Textbooks/References:
1. *Hannu E.J. Koskinen, Physics of Space Storms, Springer, 2011*
2. *Molwin, M., An Introduction to Space Weather, CUP, 2008*
3. *Kallenrode, M.B., Space Physics: An introduction to plasmas and particles in the Heliosphere and Magnetosphers, Springer, 3e, 2004*
4. *Baumjohann, W. & Treumann, R.A., Basic Space Plasma Physics, Imperial College Press, 1997*
5. *Kivelson & Russell, Introduction to Space Physics, CUP, 1995*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

| **15PHY550** | **Applied Quantum Mechanics and Material Modeling** | **3 0 0 3** |

Course Outcomes: After successful completion of this course, students shall be able to

1) Solve and obtain energies of various cyclic and linear molecular systems using Huckel/EHT theory.

2) Perform very simple but conceptually deep HF calculation for a very simple molecules. Appreciate the significance of J and K integrals.

3) Select an appropriate level of Basis Sets for a given problem. Perform a sample calculation on small molecular cluster with and without BSSE correction.

4) See how the various extension of HF theory like CI, MBPT go closer to the full QM result, but at great cost of computing power.

5) Choose appropriate DFT functionals for appropriate molecular/solid state properties like Energies, Spectra.

Unit 1

Hückel molecular orbital theory – approximations-The Born-Oppenheimer, independent particle, Pi-electron-expectation energy and Hückel M.O., Hückel Molecular Orbital and symmetry - the extended Hückel method.

Unit 2
Hartree – Fock theory - Bosons and Fermions, Slater determinant- energy calculation from STO function, energy calculation of multi-electron systems. Gaussian type orbitals (GTOs), Hartree-Fock equation, Restricted and unrestricted Hartree-Fock models, Roothan-Hall Equations, Koopman's theorem.

Unit 3
Basis sets: classification - contracted Gaussian type orbitals (CGTO), double- and triple-zeta, split-valence, polarized, double, triple-zeta, split-valence and polarized basis sets. Gaussian type and contracted Gaussian orbitals. Truncation and basis set superposition errors.

Unit 4
Ab initio method - Computation of correlation energy and Slater determinant of the excited states- Configuration Interaction, Many-body perturbation theory (MBPT), Semi empirical methods. Möller-Plesset Perturbation, The Coupled Cluster method.

Unit 5
Density functional theory - Electron density, Pair density, Functional, Hohenberg and Kohn (H.K.) theorems, Kohn and Sham Method and its Implementations common functionals and potentials.
Applications of modeling and simulation – Transition states, charge, electron density, population analysis.

REFERENCES/ TEXT BOOK
1. Tamar Schlick, "Molecular modeling and simulation-an inter-disciplinary guide", springer Verlag, 2002.
2. K.I.Ramachandran, G.Deepa and Krishnan Namboori P.K.," Computational chemistry and Molecular Modeling-Principles and applications", Springer-Verlag Berlin Heidelberg, 2008.
3. Daan Frenkel and Berend Smith, "Understanding molecular simulation-from algorithms to applications", Academic press, California, USA, 2002.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15PHY551   **Epistemological Foundations Of Quantum Mechanics**   **3 0 0 3**

Description: The main objective of this course is to impart and inculcate an epistemological vision that quantum physics imply and can afford.
Course Outcomes: After successful completion of the course, students will be able to

CO1: Identify failure of classical mechanics and origin of QM starting from Planck to Schrodinger and later to Bell with a historic and philosophical perspective.

CO2: formulate quantum mechanical problems in Dirac's Ket and Bra and Hilbert space representation

CO3: Analyse the concepts of reality and trajectory of a particle with the experimental paradigms using Mach-Zehnder type interferometers.

CO4: Distinguish between Fermions and Bosons and be able to connect it to Pauli Exclusion Principle, indistinguishability and symmetry.

CO5: Identify the paradoxes of QM like de Broglie, Schrödinger's cat, Wigner's friend, EPR paradox, etc. and describe measurement problem using State-vector reduction and justify the same by the concept of decoherence.

CO6**:** Analyse Bell type of inequalities (like CHSH inequality) using the notions of Entanglement, Hidden variables and the like using Mermin's Reality machine and Aspects Experiments

CO7**:** Describe a variety of interpretations of quantum mechanics like, Statistical, Copenhagen, Bohm's formulation, Transactional, Wheeler's Participatory Universe, Many World, Transactional Interpretation, Consciousness interpretation.

CO8: Apply the quantum concepts to some modern technological applications like, Vaidman bomb detector, Quantum teleportation, Quantum Erasing, Quantum cryptography and Quantum Computing, dense coding, Quantum Information.

Unit 1
Historical & epistemological Perspective: Quick review of the failure of classical mechanics and origin of QM: Planck-Einstein, Bohr atom, de Broglie, Heisenberg's uncertainty principle, Experimental verifications – wave-particle duality and Young's double-slit experiment, polarization experiments, Stern-Gerlach experiments, Schrödinger equation - particle in a box, tunnel effect.

Unit 2

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Dirac's Ket and Bra formulations and Hilbert space representation, Mach-Zhender type interferometers; Reality and trajectory of a particle, Fermions and Bosons, Pauli Exclusion Principle and indistinguishability, symmetry; State-vector reduction and measurement problem, decoherence.

Unit 3
Paradoxes of QM: de Broglie paradox, Schrödinger's cat, Wigner's friend paradox, Entanglement, Hidden variables, EPR paradox, Bell-type Inequalities, Mermin's Reality machine, Aspects Experiments, CHSH inequality, Kohen-Specker theorem.

Unit 4
Various interpretations of QM: Statistical, Copenhagen, Bohm's formulation, Transactional, Wheeler's Participatory Universe, Many World, Transactional Interpretation, Consciousness interpretation – Philosophical implications.

Unit 5
Modern applications of quantum entanglement: Quantum teleportation, Quantum Erasing, Introduction to Quantum cryptography and Quantum Computing, dense coding, Quantum Information.

Reference Books:
Since the subject is rather unconventional, there are no affordable, tailor-made text book is available. Hence the following reference books are suggested for reading. Separate additional lecture notes will be provided.

Suggested Reading:
1. John von Neumann, Mathematical Foundations of Quantum Mechanics, Reprint, PUP, 1996.
2. M. Bell, K. Gottfried and M.Veltman (Eds.), John S. Bell on the Foundations of Quantum Mechanics, World Scientific, 2001.
3. George Greenstein and Arthur G. Zajonc, The Quantum Challenge: Modern Research on the Foundations of Quantum Mechanics, 2nd Ed., Jones & Bartlett Learning, 2005.
4. Bruce Rosenblum and Fred Kuttner, Quantum Enigma: Physics Encounters Consciousness, 2nd Ed., Oxford University Press, 2011.
5. Bernard D'Espagnat, Conceptual Foundations of Quantum Mechanics:, 2nd Ed., Westview Press, 1999.
6. Tarja Kallio-Tamminen, Quantum Metaphysics (dissertation, e-copy), University of Helsinki, 2004 (http://ethesis.helsinki.fi/julkaisut/hum/filos/vk/kallio-tamminen/quantumm.pdf)

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15PHY552	INTRODUCTION TO FOURIER OPTICS	3 0 03

(Pre-requisite: 15PHY547 Optics)

Course Outcomes:

1. Introduction to the discipline of Optics and its role in the modern society
2. Introduction to the realm of Computational Fourier Optics and review analytic Fourier Theory
3. Physical understanding of Sampling and Shannon-Nyquist Sampling theorem. Student will learn about sampling of functions and their Discrete Fourier Transform
4. Programming of functions, vectors, arrays and Fourier Transforms
5. Understand Scalar Diffraction theory, Monochromatic fields and irradiance & analytic diffraction solution with Fraunhofer diffraction as example. Student will learn about propagation simulation – Fresnel propagation and sampling & Fraunhofer propagation
6. Understand transmittance functions – Tilt, Lens, Grating and other periodic functions
7. Learn fundamentals of imaging & simulation of diffraction limited imaging; Basics of Wavefront aberrations – Optical Path Difference, Primary aberrations, Pupil and Transfer functions, Image quality and Wavefront sampling

Unit 1: Analytic Fourier Theory Review
Analysis of two dimensional signals and systems – Fourier analysis in 2D, LocalSpatial Frequency and Spatial Frequency localization, Linear systems, Two dimensional sampling.

Unit 2: Scalar diffraction & propagation solutions, Simulations
Scalar diffraction theory – Introduction, vector to scalar theory, mathematical preliminaries, Kirchoff formulation of diffraction by a planar screen, Rayleigh-Sommerfeld formulation, Huygen-Fresnel principle, Angular spectrum of plane waves.

Unit 3: Diffraction
Fresnel and Fraunhoffer diffraction – Background, Fresnel and Fraunhofer approximations, Examples of Fraunhofer diffraction patterns and Fresnel diffraction calculations.

Unit 4: Transmittance functions, Lenses & Gratings
Wave optics analysis of coherent optical systems – thin lens as a phasetransformation, Fourier transforming properties of lenses, image formation:monochromatic illumination.

Unit 5: Imaging and diffraction limited imaging, wavefront aberrations and modulation, simulations
Frequency analysis of optical imaging systems – generalized treatment, frequency response for diffraction limited coherent and incoherent imaging; Aberrations and their effects on frequency response, comparisons of coherent andincoherent imaging, resolution beyond classical diffraction limit; Wavefront modulation – incoherent image and coherent optical information processing systems, applications.

Textbook/References
1. *J.W. Goodman, Introduction to Fourier Optics, 3E, Roberts & Company Publishers, 2005 (Prescribed)*
2. *E.G. Steward, Fourier Optics – An Introduction, Dover, 2004*
3. *J.D. Gaskill, Linear systems, Fourier Transforms, and Optics, Wiley, 1978*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: Entire course centents with tutorials, assignments and computational projects help build foundations develops skills in optical physics and will students will find useful in optics industry and optical software development.

15PHY553	INTRODUCTION TO NANOPHYSICS AND APPLICATIONS	3 0 0 3

Course Outcomes: After successful completion of the course, students will be able to
1) Relate nano to other branches of science such as biology, chemistry, physics and nano in nature.
2) Describe the properties of nanomaterials – size, shape, density, melting point, surface tension, wettability, surface area and pore size and classify them.
3) Describe the mechanical, thermal, optical, electrical and magnetic properties of nano materials.
4) Describe the Synthesis of nanomaterials through physical, chemical and biological methods, top-down and bottom-up approaches of nanofabrication, distinguish physical and chemical methods.
5) Describe quantum wells, wires and dots and derive their energy spectra, density of states, and describe their electronic properties
6) Describe the nanomaterial analysis techniques such as XRD, SEM, TEM, STM and AFM and distinguish their uses in characterization.
7) Describe the carbon nano structures such as Fullerenes and CNTs, MEMs and NEMs devices, spintronics, GMR and CMR.

Unit 1
Introduction: relation of nano to other sciences - chemistry, biology, astronomy, geology, nano in nature.

Unit 2
Properties of nanomaterials: size effect, particle's size, shape, and density, melting point, surface tension, wettability, surface area and pore, composite structure, crystal structure, surface characteristics; mechanical, electrical, properties, and optical properties.

Unit 3
Synthesis of nanoparticles: Classification of fabrication methods – top-to-bottom and bottom-to-top approaches, physical and chemical methods of preparation: CVD, controlled precipitation, sol-gel method, PLD etc; Confinement of particles - low dimensional structures - quantum wells, wires and dots.

Unit 4
Characterisation of nanoparticles: X-Ray diffraction, examples of XRD, Debye-Scherrer formula; FTIR: principle, methodologies and accessories; SEM: basics and primary mode of operation, applications; TEM: basic principles; STM: basic principles and instrumentation; AFM: basics, modes of operation and applications; Photoluminescence: basic principles.

Unit 5
Application of nanophysics: Carbon nanostructures: Fullerenes, CNTs and their applications; MEMS and NEMS devices; Quantum Cascade Lasers, Smart materials, GMR and Spintronic, multiferroics.

References:
1. *Charles P Poole Jr. & Frank J Owens, Introduction to Nanotechnology, 1E, Wiley, 2007*

2. *W.R Fahner (Ed.), Nanotechnology and Nano electronics, Springer, 2006*
3. *M Hosokawa, et al, Nanoparticle Technology Handbook, Elsevier Publishers, 2007*
4. *S.V. Gaponenko, P.L Knight & A. Miller, Optical Properties of Semiconductor Nanocrystals, CUP, 1E, 2005*
5. *T Pradeep, Nano: The Essentials, TMH, 1E, 2007*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15PHY554	OPTOELECTRONICS	3 0 0 3

Course outcomes: On successful completion of this course, student should be able:

CO-1.   To explain the processes of excess electron and hole generation and recombination.

CO-2.   To describe the basics of p-n junction diode and apply ambipolar transport equation in deriving the device electrical properties.

CO-3.   To construct energy band diagrams of basic p-n junction as well as complex heterojunctions to describe the carrier transport phenomenon in the semiconductor junctions

CO-4.   To demonstrate a knowledge of fundamental properties of optical processes in semiconductor optical sources and the operation principles of basic optical components.

CO-5.   To draw schematically and describe the operation and design architecture of 1st generation solar cells and to outline the basics concepts of 2nd and 3rd generation solar cells

CO-6.   To describe the structures and the operation of LEDs and lasers

CO-7.   To demonstrate familiarity with the operation and designs of photodetectors

CO-8.   To compare operation principles, basic designs and challenges of optical detectors and modulators of light.

Unit 1
Electronic and Optical processes in semiconductors.

Unit 2
P-n junction theory. Light emitting diodes.

Unit 3
Laser diodes: structures, properties and operating principles.

Unit 4
Photodetectors, Solar cells; Optoelectronic modulators and switching devices.

Unit 5
Systems needs and new device challenges.

Textbooks/References:
1. *Semiconductor Optoelectronic Devices, by P.Bhattacharya (2nd Edition, Prentice Hall,Upper Saddle River,1997)*
2. *Physics of Semiconductor Devices, by S.M. Sze (2nd Edition,Wiley, Newyork,1981)*
3. *Introduction to Solid State Physics,by C.Kittel (7th Edition,Wiley,Newyork,1996)*
4. *J. Singh, Optoelectronics: An Introduction to materials and devices, McGraw-Hill*
5. *Optional Suppliment: J.I. Pankove, Optical processess in Semiconductor, Dover, 1975.*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15PHY555	PHYSICS OF THE ATMOSPHERE	3 0 1 4

Course Outcomes: On successful completion of the course, students will be able to

1.   Gain a basic understanding of the Earth's atmospheric system – its structure and composition as well as the energy transfer and general circulation within it.

2.   Apply the basics of thermodynamics to the atmospheric system, explain the basics of cloud formation.

3.   describe the principle of radiative transfer in the atmosphere, the basic spectroscopy as applied to the atmospheric molecules, scattering of radiation in the atmosphere through the use of a simple scattering model.

4.   describe the fundamentals of fluid dynamics, apply them to the atmospheric system, derive the equations of motion in the rotating frame of reference, describe the basic dynamics of weather systems.

5. describe the basic chemical kinetics and Ozone chemistry, apply the basics of thermodynamics, dynamics and chemical reactions to explain the processes and dynamics of air pollution.

6.   describe the basics of atmospheric remote sensing.

7. describe the basics of atmospheric modeling and explain a few of numerical models.

8. Describe the basics of climate change.

9. Apply the basics of dynamics/thermodynamics/numerical modeling/remote sensing and successfully finish a small project by reading and reproducing the results of a published article.

Unit 1
Earth-Atmosphere system – Introduction, Composition and structure, Radiative equilibrium, Energy budget, General circulation, Historical perspectives, Weather & Climate

Unit 2
Atmospheric thermodynamics – Ideal gas law, First law of thermodynamics, Atmospheric composition, Hydrostatic balance, Entropy & potential temperature, Parcel concepts, Available potential energy, Moisture in the atmosphere, Saturated adiabatic lapse rate, Tephigram, Cloud formation

Atmospheric radiation – Basic physical concepts, Radiative transfer equation, basic spectroscopy of molecules, Transmittance, Absorption by atmospheric gases, Heating rates, Greenhouse effect revisited, Simple scattering model

Unit 3
Basic fluid dynamics – Mass conservation, material derivative, alternative form of continuity equation, equation of state for the atmosphere, Navier-Stokes equation, Rotating frames of reference, equations of motion in coordinate form, geostrophic and hydrostatic approximation, Pressure coordinates and geopotential, Thermodynamic energy equation; Atmospheric fluid dynamics – vorticity and potential vorticity, Boussinesq approximation, Quasi-geostrophic motion, Gravity waves, Rossby waves, Boundary layers, Instability

Unit 4
Stratospheric chemistry – Thermodynamics and chemical reactions, Chemical kinetics, Bimolecular reactions, Photo-dissociation, Stratospheric ozone, Transport of chemicals, Antarctic ozone hole

Atmospheric remote sounding – Observations, remote sounding from space and ground; Atmospheric modeling – Hierarchy of models, Numerical methods, Uses of complex numerical models, Lab models

Unit 5
Climate change – Introduction, energy balance model, some solutions of the linearised energy balance model, Climatic feedbacks, Radiative forcing due to increase in Carbon dioxide.

Projects based on Modules 5, 6 and 7 (Reading a journal paper & reproducing calculations, Numerical modeling and / or data analyses)

Textbooks/References
1. *Andrews DG: An introduction to atmospheric physics, 2E, CUP, 2010*
2. *Salby ML: Physics of the Atmosphere and Climate, CUP, 2012*
3. *Holton JR: An introduction to Dynamic Meteorology, 4E, AP, 2004*
4. *Wallace JM & Hobbs PV: Atmospheric Science-An introductory Survey, 2E, AP, 2006*
5. *Chandrasekar A: Basics of Atmospheric Science, PHI, 2010*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15PHY556	PYTHON FOR SCIENTIFIC COMPUTING	3 0 0 3

(*Prerequisite: 15PHY506 Computational Physics and 15PHY582 Simulation Lab)

Course Outcomes:

1) Develop skill in installing Linux OS and work in shell environment and use shell commands.
2) Develop skill in using various Python modules for scientific applications
3) Develop skill in storing date and using data structures for computing in physics
4) Develop skill in modelling and solving problems numerically using computing techniques.

Unit 1: Installing and running the *GNU/Linux* OS, *BASH* shell environment

Unit 2: Programming in Python – Introduction, *Ipython*, *NumPy* library, *Matplotlib* and others, *SciPy* and numerical methods, *SymPy*, *Pandas* and data frame, GUI, Extending *Python* and *FORTRAN* and sysops, Building *Python* applications and packaging

Unit 3: Storing data, HDF5, Basic data structures in Physics

Unit 4: Any other topic(s) of interest, if time permits. Physics projects based on student interest.

Textbooks/References:
The course will make use of various excellent web resources and text books. All such information will be made available on the course site.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

Skills and Employability: Entire course contents with tutorials and assignments help build foundations and develops computational thinking, programming skills – design and implementation of software for scientific, engineering and industrial computing applications in universities, industries and research labs/organisations.

15PHY557	**ASTROPHYSICS**	**3 0 0 3**

Description: This course is meant to satisfy the urge of those students who have very good aptitude astronomy and astrophysics.

Course Outcomes: After successful completion of the course, students will be able to

CO1: Provide a brief historical perspective of Indian and Western astronomy.

CO2 Apply classical mechanics of Newton and Kepler to solve problems in Celestial mechanics related to distance, mass period, orbit parameters etc.

CO3: Describe the structure of Sun and Solar system and explain sunspot activities.

CO4: Apply various distance measurement techniques (viz trigonometric, spectroscopic, moving cluster, statistical parallax, Cepheid variable method and Red shift method (Hubble's law)) for different ranges.

CO5: Using Hertzsprung -Russel diagram and describe stellar evolution and classification of stars.

CO6: Describe various type of galaxies and their structures and classify them by Hubble's tuning fork morphological classification.

CO7: Apply general relativity and space-time curvature to explain various cosmological models.

UNIT 1
Stellar dynamics, types of forces on a star in the stellar system, Tidal radii, star-star encounter, time of relaxation determination of time of relaxation, application to Galaxy & star cluster.
Masses of double galaxies, Masses of cluster of galaxies by virial theorem observational determination of masses, clusters of galaxies, Missing mass problem.

UNIT 2
Cosmology, cosmological principle, Newtonian cosmology, deceleration parameters critical density, Robertson walker equation and its properties, solution of Robertson-Walker equations. Einstein field equation in cosmology, Energy tensor of Universe, solution of Friedman's equation, Einstein de-sitter model, open model, particle horizon, Event horizon.

UNIT 3
The formation of structures in the Universe: Jean's equation derivation from fluid dynamics and General relativity; evolution of Jean mass, Growth in the Post recombination era; Einstein-do Sitter model; closed model; open model; observation constraints; small angle anisotropy, horizon problem, the scale – invariant spectrum, Hierarchy of structures, Age distribution.

UNIT 5
Thermal History of the Universe, Temperature red shift relation, distribution in the early Universe, relativistic and non-relativistic limits, decoupling of matter and radiation, Cosmic microwave background radiation (CMBR), isotropy and anisotropy of CMBR.

TEXT AND REFERENCE BOOKS:
1. *Introduction to Cosmology By J.V.Narliker*
2. *Structure Formation in the Universe by T. Padmanabhan, Cambridge University*
3. *Stellar Dynamics by S.Chandersakher*
4. *Stellar Evolution by Kippenhahn*
5. *Quassars and Active Galactic Nuclei by A.K.Kembehavia & G.V.Narliker, Cambridge University Press*
6. *Modern Astrophysics by B.W.Carroll and D.A.Ostlie, Addison-Wesley Publishing Co.*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15PHY558	NONLINEAR DYNAMICSANDCHAOS	3 0 0 3

Course Outcomes: After completing the course students should be able to
CO1. Analyse, understand, describe and classify linear systems, their solutions, fixed points, linearization methods, stability of systems about fixed points for simple dynamical systems.
CO2. Understand and describe limit cycles in simple dynamical systems such as van der Pol oscillator and a few other systems.
CO3. Understand and describe bifurcation phenomena in linear systems
CO4: understand and describe and perform calculations on nonlinear normal modes in multi-degree of freedom systems.
CO5: understand and describe the concepts of chaotic dynamics using Lorentz system, logistic map, Lyapunov exponents, fractal sets and fractal dimensions, strange attractors.

Unit 1 Introduction, Phase Space, and Phase Portraits

Linear systems and their classification; Existence and uniqueness of solutions; Fixed points and linearization; Stability of equilibria; Pendulum and Duffing oscillator, Lindstedt's method; Conservative and reversiblesystems.

Unit 2 Limit Cycles

The van der Pol oscillator, Method of Averaging; Relaxation oscillators; Weakly nonlinear oscillators; Forced Duffing oscillator, Method of Multiple Scales; Forced van der Pol oscillator, Entrainment; Mathieu's equation, Floquet Theory, Harmonic Balance.

Unit 3 Bifurcations

Saddle-node, **transcritical**, and pitchfork bifurcations; Center manifold theory; Hopf bifurcation; Global bifurcations; and Poincaré maps.

Unit 4 Nonlinear Normal Modes

Nonlinear Normal Mode manifolds **of** multidegree-of-freedom systems; external and internal resonances; and Energy transfer through nonlinear interactions.

Unit 5 Chaotic Dynamics

Lorentz equations; Lorentz **map**; Logistics map; Lyapunov Exponents; fractal sets and their dimensions; box, pointwise and correlation dimensions; strange attractors; and forced two-well oscillator.

TEXTBOOKS:

1. Richard H. Rand, Lecture Notes on Nonlinear Vibrations, version 52, 2005. Available online at
   http://audiophile.tam.cornell.edu/randpdf/nlvibe52.pdf
2. S.H.Strogatz,NonlinearDynamicsandChaoswithApplicationstoPhysics,Biology,Chemistry and Engineering, Perseus Books Publishing, 2000.

REFERENCE BOOKS:

1. J.C. Sprott, Chaos and Time-Series Analysis, Oxford University Press,   2003.
2. G.L. Baker and J.P. Gollub, Chaotic Dynamics, 2nd edition, Cambridge University Press, New York,1996.
3. Edward Ott, Chaos in Dynamical Systems, Cambridge,1993.
4. K.T. Alligood, T.D. Sauer, and J.A. Yorke, CHAOS - An Introduction to Dynamical Systems, Springer,1996.
5. D.KaplanandL.Glass,Understandingnonlineardynamics,Springer-Verlag,NewYork,1995.
6. J.M.T. Thompson and H.B. Stewart, Nonlinear dynamics and chaos, John Wiley and Sons, New York,1986.

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).

15PHY559	PHYSICS OFOPTOELECTRONICDEVICES	3 0 03

Course Outcomes: After completing the course, students should be able to
CO1. Develop understanding and describe basics of semiconducting materials, crystalline lattice and crystal growth techniques.
CO2. Understand and describe the concepts of energy bands, concentration of charge carriers in thermal equilibrium, and their drift under electric and magnetic fields.

CO3.   Understand, describe and perform calculations related to a few optical properties, PN junction and heterojunction characteristics.
CO4. Understand and describe operation and characteristics of LEDs, lasers, photo detectors, solar cells, and relevance of III-V and II-IV semiconductors.
CO5. Understand and describe integrated optics devices including optical wave guides, switches and storage devices.

Unit 1 Introduction
Semiconductor materials; Crystal lattices; Bulk Crystal growth, epitaxial growth.

Unit 2 Energy bands and Charge carriers in Semiconductors
Direct and indirect semiconductors; variation of Energy bands with alloy composition. Charge carriers in semi-conductors-electrons, holes, effective mass; intrinsic and extrinsic materials. Drift of carriers in electric and magnetic   fields.

Unit 3 Excess carries in Semiconductors
Optical absorption; luminescence – photoluminescence, electroluminescence. Carrier lifetime and photoconductivity, diffusion of carriers. P-N Junction Diode: Current- Voltage Characteristics; hetrojunctions.

Unit 4 Optoelectronic Devices
Principle of operation and characteristics; Light emitting diodes, lasers, photo detectors, solar cells. Relevance of III-V and IV-VI material-systems in optoelectronic devices.

Unit 5 Integrated Optics
Optical waveguides - passive, electro-optical; optical modulators and switches; optical storage devices.

TEXTBOOK:

Pallab Bhattacharya, "Semiconductor Optoelectronic Devices", 2nd Edition.

REFERENCE BOOKS:

1. *StreetBGandBanerjeeS,"SolidStateElectronicDevices",PHINewDelhi,(2004)*
2. *Sze S M, "Physics of Semiconductors Devices", Wiley Eastern Limited, New Delhi.*
3. *Wilson and Hawkes, "Optoelectronics; An Introduction", 2nd Ed.,   PHI.*
4. *Hummel R E, "Electronic Properties of Materials", Narosa Publishing House, New Delhi.*

Evaluation Pattern: As in the rules for *Assessment Procedure* (R.13 or R.14) &*Grading System* (R.16 or R.17).