UNIVERSITY OF CALICUT

Abstract

General & Academic - CCSS PG Regulations 2019 - Scheme and Syllabus of M.Sc Physics Programme, w.e.f 2020 Admission -Incorporating Outcome Based Education - Implemented - Subject to ratification by the Academic Council - Orders Issued.

G & A - IV - J

U.O.No. 5812/2021/Admn   Dated, Calicut University.P.O, 31.05.2021

Read:-1) U.O.No. 9201/2019/Admn, Dated 12.07.2019.
2) Email Dated 30.05.2021, from the Chairperson, Board of Studies in Physics PG.
3) Remarks of the Dean, Faculty of Science, Dated 31.05.2021.
4) Orders of the Vice Chancellor in the file of even no, Dated 31.05.2021.

ORDER

1. The Scheme and Syllabus of M.Sc Physics Programme under CCSS PG Regulations 2019 in the Teaching Department of the University, w.e.f 2019 admission, has been implemented, vide paper read (1) above.
2. The Chairman, Board of Studies in Physics PG, vide paper read (2) above, has forwarded the Scheme and Syllabus of M.Sc Physics Programme , incorporating Outcome Based Education(OBE) in the existing syllabus in accordance with CCSS PG Regulations 2019, w.e.f 2020 admission ,after circulating among the members of the board , as per Chapter 3(34) of Calicut University First Statute, 1976.
3. The Scheme and Syllabus of M.Sc Physics Programme (CCSS-PG-2019), incorporating Outcome Based Education(OBE), has been approved by the Dean, Faculty of Science, vide paper read (3) above and by the Vice Chancellor, subject to ratification by the Academic Council, vide paper read (4) above.
4. The Scheme and Syllabus of M.Sc Physics (CCSS) programme incorporating Outcome Based Education (OBE) in the existing syllabus, in tune with CCSS PG Regulations 2019, is therefore implemented with effect from 2020 Admission onwards under Teaching Department of the University, subject to ratification by the Academic Council.
5. Orders are issued accordingly.
6. U.O.No. 9201/2019/Admn Dated,12.07.2019 stands modified to this extend.(syllabus appended).

Ajitha P.P

Joint Registrar

To

The HoD, Department of Physics
Copy to: PS to VC/PA to PVC/ PA to Registrar/PA to CE/JCE I/JCE V/JCE VIII/DoA/EX and EG Sections/GA I F/CHMK Library/Information Centres/SF/DF/FC

Forwarded / By Order

Section Officer

UNIVERSITY OF CALICUT

Scheme and Syllabus for
M.Sc. (Physics) Programme (CCSS-PG-2020)
for the University Physics Department (w.e.f. 2020 admission)

Programme objective :

Physics is ultimately mechanics and it furnishes the official framework. It encompasses classical mechanics, quantum mechanics, electrodynamics and statistical mechanics. These are the four pillars upon which the structure of physics is built. In spite of having large number of branches and specializations in physics, the driving source that keeps them united under a common umbrella is mechanics. Any branch of physics which has its roots in the soil of mechanics grows as physics, otherwise it becomes nonphysics. The above mentioned four branches are the foundation subjects in physics. Frontier subjects are those in which current research is going on, such as atomic physics, molecular physics, nuclear physics, plasma physics, solid state physics, materials science, astrophysics etc. Frontier subjects are always rooted in the foundation subjects. Mathematical physics is the theoretical tool and electronics is the experimental tool for exploring physics. In this programme, all the foundation subjects and few frontier subjects are offered as core courses. Because of the time constraint, few other frontier subjects are offered as elective courses. Practicals include general physics, electronics, modern physics and computational physics. A project work also has to be carried out as part of the masters programme. The programme objective is to provide quality education with a firm foundation in physics.

Programme specific outcomes:

On successful completion of the M.Sc Physics programme, students will

P.O.1 aquire a comprehensive knowledge in physics.

P.O.2 will develop a broad understanding of the physical principles of the universe.

P.O.3 acquire laboratory skills to design advanced experiments and high precision measurements.

P.O.4 be proficient in computing and interfacing techniques.

P.O.5 be empowered for critical thinking and innovation in dealing with scientific problems and experiments.

P.O.6 develop advanced laboratory techniques and instrumentation skills for a career in research.

P.O.7 develop independent research skills through projects.

P.O.8 be provided with opportunities to further their knowledge in frontier areas through elective courses.

P.O.9 be empowered for planning career in physical sciences and also in taking up jobs in other fields in the contemporary society.

P.O.10 be able to communicate effectively and participate actively in team work.

The duration of the M.Sc (Physics) programme shall be 2 years, split into 4 semesters. The programme shall include three types of courses, viz. Core courses, Elective courses and Audited courses. The total credits for the entire programme (Core and elective) is 80. The credit for two audit courses together is 4. Indirect grading pattern with 20% internal and 80% external marks will be followed. The practical examinations will be of three hours duration. The scheme and syllabus of the programme, consisting of sections (a) Programme structure (b) Courses in various semesters (c) Marks and credit distribution summary (d) Evaluation and Grading (e) Pattern of question paper and (f) Detailed Syllabus are as follows.

. (a) **PROGRAMME STRUCTURE**

1. The programme shall include three types of courses, viz. Core courses, Elective courses and Audited Courses.
2. There shall be a compulsory Project/Dissertation to be undertaken by all students. There shall also be a viva-voce in the final semester.
3. Total credit for the program shall be 80 (eighty). The audit courses carry a total of 4 credits and it is over and above 80. The pattern of distribution of the 80 credits is as detailed below :

   i)Total credits for the core courses (theory, practicals, Viva-voce and project) shall be 64. Out of this the total credits for comprehensive viva-voce and project work combined together shall be 8 (eight) subject to a minimum of 4 (four) credit for project work.

   ii)Total credits for Elective courses shall be 16.
4. A student is free to register for as many courses as she/he can manage if facilities permit, meeting the minimum credit requirements.

Table 1. Structure of the Programme

Programme Duration	M.Sc Physics
Accumulated minimum credits required for successful completion of programme	80 (+4 Credits of the audit course)
Minimum credits required from Core courses (including project and viva-voce)	64
Minimum credits required from Elective courses	16
Minimum and maximum credits to be registered in a semester	20 to 22 (including audit courses)
Minimum attendance required	75%

5. **Audit courses** :

In addition to the above courses for the mandatory requirement of a programme, there will be two compulsory courses - **Ability Enhancement Course** (AEC) & **Professional Competency Course** (PCC), each with 2 credits, and these courses are to be done within the first two semesters. The credits will not be counted for computing the overall SGPA/CGPA of the student. The concerned department shall conduct examination for these courses and shall intimate /upload the results of the same to the University on the stipulated date during the III Semester. The student has to obtain only minimum pass requirements in these two courses. The broad framework of the compulsory audited courses are given hereunder.

Table 2. Guidelines for Audit Courses

Semester	Course Title	Suggested Area	Details
I	Ability Enhancement Course (AEC)	Internship/Seminar Presentation/Publications/Industrial or Practical Training/Community linkage programme/Book reviews etc.	Concerned Department Council/BoS can design appropriate AEC & PCC and evaluation criteria by considering the relevant aspects in the core areas.
II	Professional Competency Course	To test the skill level of students like testing the application level of different softwares such as Latex/ Data visualization/ Python/ Any software relevant to the programme of study/ Translations etc.	

(b) COURSES IN VARIOUS SEMESTERS

Semester -I (20C)

(PHY1C01) Classical Mechanics and Chaos (4C)
(PHY1C02) Mathematical Physics – I (4C)
(PHY1C03) Electrodynamics and Plasma Physics (4C)
(PHY1C04) Electronics (4C)
(PHY1C05) General Physics Practical -I (2C)
(PHY1C06) Electronics Practical (2C)
(PHY1A01 Ability Enhancement Course (AEC) (2C)

Semester -II (20C)

(PHY2C07) Quantum Mechanics -I (4C)
(PHY2C08) Mathematical Physics -II (4C)
(PHY2C09) Statistical Mechanics (4C)
Elective **-I** (4C)

(PHY2C10) General Physics Practical -II (2C)
(PHY2C11) Computational Physics Practical (2C)
PHY2A02 Professional Competency Course (PCC) (2C)

Semester -III (20C)

(PHY3C12) Quantum Mechanics -II (4C)
(PHY3C13) Nuclear and Particle Physics (4C)
(PHY3C14) Solid State Physics (4C)

Elective **-II** (4C)

(PHY3C15) Modern Physics Practical I (2C)
(PHY3C16) Modern Physics Practical II (2C)

Semester -IV (20C)
(PHY4C17) Spectroscopy (4C)
Elective **-III** (4C)
Elective **-IV** (4C)
(PHY4C18) **Project** (4C) + Comprehensive **Viva Voce** (4C)

ELECTIVES IN DIFFERENT CLUSTERS

Elective – I cluster
(PHY2E01) Computational Techniques and Python programming (4C)
(PHY2E02) Computational Techniques and C programming (4C)
(PHY2E03) Computational Techniques and Fortran programming (4C)

Elective -II cluster:
(PHY3E04) Experimental Techniques (4C)
(PHY3E05) Elementary Astrophysics (4C)
(PHY3E06) Plasma Physics (4C)

Elective -III cluster:
(PHY4E07) Advanced Nuclear Physics (4C)
(PHY4E08) Advanced Astrophysics (4C)
(PHY4E09) Information Theory and Quantum Computing (4C)
(PHY4E10) Advanced Materials Science (4C)

Elective -IV cluster:
(PHY4E11) Radiation Physics (4C)
(PHY4E12) Nano Materials and Technology (4C)
(PHY4E13) Quantum Field Theory (4C)
(PHY4E14) Advanced Electronics (4C)

(c) Table 3. MARKS AND CREDIT DISTRIBUTION SUMMARY

Course Code	**Course Title**	**Credits**	**Marks**		
			Internal	**External**	**Total**
Semester I					
PHY1C01	Classical Mechanics and Chaos	4	20	80	100
PHY1C02	Mathematical Physics – I	4	20	80	100
PHY1C03	Electrodynamics and Plasma Physics	4	20	80	100
PHY1C04	Electronics	4	20	80	100

PHY1C05	General Physics Practical -I	2	20	80	100
PHY1C06	Electronics Practical	2	20	80	100
PHY1A01	Ability Enhancement course (AEC*)*	*2**			
	Total for Semester I	**20**			**600**
Semester II					
PHY2C07	Quantum Mechanics -I	4	20	80	100
PHY2C08	Mathematical Physics -II	4	20	80	100
PHY2C09	Statistical Mechanics	4	20	80	100
	Elective I	4	20	80	100
PHY2C10	General Physics Practical -II	2	20	80	100
PHY2C11	Computational Physics Practical	2	20	80	100
PHY2A02	Professional Competancy course (PCC)	*2**			
	Total for Semester II	**20**			**600**
Semester III					
PHY3C12	Quantum Mechanics -II	4	20	80	100
PHY3C13	Nuclear and Particle Physics	4	20	80	100
PHY3C14	Solid State Physics	4	20	80	100
	Elective II	4	20	80	100
PHY3C15	Modern Physics Practical I	2	20	80	100
PHY3C16	Modern Physics Practical II	2	20	80	100
	Total for Semester III	**20**			**600**
Semester IV					
PHY4C17	Spectroscopy	4	20	80	100
	Elective -III	4	20	80	100
	Elective -IV	4	20	80	100
PHY4C18	Project + Comprehensive Viva Voce on theory	8	20	80	100
	Total for Semester IV	**20**			**400**
	Total for the course	**80**			**2200**

The credits for the audit courses (PHY1A01 & PHY2A02)*** will not be counted for computing the SGPA/CGPA of the student. Students have to obtain only pass minimum requirements in the audit courses.**

(d) EVALUATION AND GRADING

(i)Credit (C) of a course is a measure of the weekly unit of work assigned for the course. A theory class of one hour per week or a practical class of three hours per week shall be counted as one credit.

(ii)'Grade point' (G) of a student in a course is the value obtained by dividing her/his % marks in the course by 10. Grade point is expressed on a 10.0 point scale rounded off to the first decimal place and varies from 0.0 to 10.0. Grade point indicates the exact level of performance of a student in a course.

(iii)'Letter Grade' or simply 'Grade' in a course is a letter symbol (e.g., O, A+, A, B+, B, etc.), which indicates a particular range of grade points (e.g., 8.0 to 10.0, 7.0 to 7.99, 6.0 to 6.99, 5.5 to 5.99, 5.0 to 5.49 etc.) and is used to refer to the broad level of performance of a student in a course.

(iv)'Credit point' (P) of a course is the value obtained by multiplying the grade point (G) by the credit (C) of the course: P = G x C.

(v)Semester Grade Point Average' (SGPA) is the value obtained by dividing the sum of credit points (P) obtained by a student in the various courses studied in a semester by the total number of credits taken by him/her in that semester. The grade point shall be rounded off to the first decimal place. SGPA determines the overall performance of a student at the end of a semester.

For instance, if a student has registered for 'n' courses of credits C_1, C_2, …,C_n in a semester and if she/he has scored credit points P_1, P_2 , …, P_n respectively in these courses, then SGPA of the student in that semester is calculated using the formula

$$SGPA = \frac{P_1 + P_2 + \ldots + P_n}{C_1 + C_2 + \ldots + C_n}$$

(v)Cumulative Grade Point Average' (CGPA) is the value obtained by dividing the sum of credit points in all the courses opted by the student for the entire programme by the total number of credits and is calculated based on the same formula given above. CGPA shall be rounded off to the first decimal place. CGPA determines the academic level of the student in a programme and is the index for ranking students.

An overall letter grade (Cumulative Grade) for the entire programme shall be awarded to a student depending on the CGPA using the same criterion used for awarding Grade in a course based on the grade point.

1. Evaluation

(i)The evaluation scheme for each paper shall contain two parts

(1) internal evaluation

(2) external evaluation

20% weight shall be given to the internal evaluation. The remaining **80%** weight shall be for the end semester external evaluation.

(ii)Internal Evaluation:

The internal evaluation shall be based on a predetermined transparent system involving periodic written tests, viva-voce, seminars and attendance in respect of theory courses and based on written tests, viva-voce and lab skill/records in respect of practical courses as detailed below in Table 4:

Table 4: Internal Evaluation

Theory Paper	Marks	Practical Paper	Marks
a. Attendance /Classroom presentation*	3	**a.** Lab skill/ Quality of Records	5
b. Seminar	5	**b.** Practical Test	10
c. Test Paper	8	**c.** Viva-voce	5
d. Viva-Voce / Field work	4	**d.** Total marks	**20**
e. Total marks	**20**		

*90% & above: 3 marks, 80 to 89%: 2 marks, 75 to 79%: 1 mark, below 75%: nil

The details of executing the internal evaluation shall be decided by the concerned Departmental Council. To ensure transparency of the evaluation process, photocopies of the answer scripts of the test papers shall be returned to the students within a week of the conduct of the tests. Any dispute regarding the internal evaluation shall be taken up with the concerned teacher within 48 hours. The internal assessment marks awarded to the students in each course in a semester shall be notified on the notice board at least one week before the commencement of external examination.

(iii)External Evaluation:

The external examination in theory courses is to be conducted with question papers set by external examiners. The evaluation of the answer scripts shall be done by the teacher offering the course and an external expert based on a well-defined scheme of valuation framed by them.

The external examination in practical courses shall be conducted and evaluated by two examiners - one internal and an external.

The valuation scheme for Project/Dissertation:

The valuation shall be jointly done by the supervisor of the project in the department and an External Expert from the approved panel, based on a well-defined scheme of valuation framed by them. The following break-up is suggested for the valuation:

Table 5. Valuation scheme for project

Sl.No.	Particulars	Weightage %
1	Review of Literature and Formulation of the Research Problem/Objective	20
2	Methods and Description of the techniques used	15
3	Analysis and Discussion of results	30
4	Presentation of the report, organization, linguistics style, references etc.	15
5	Viva Voce examination based on the Project work/Dissertation	20

		Total	**100**

(iv) The external evaluation shall be done in a Centralized Valuation Camp, to be held in the Department/School of Chemical and Physical Sciences, immediately after the examination under the supervision /control of the Academic Committee. It is desirable to have the semester results announced within 10 days of the conduct of the last examination of the semester.

(v) The course teacher(s) shall maintain the academic record of each student registered for the course, which shall be forwarded to the Academic Committee through the Head of the Department/School.

(vi)The Academic Committee is empowered to lay down the procedure for the conduct of examinations from time to time.

2. GRADING SYSTEM

(i) The indirect absolute grading system where the marks are compounded to grades based on pre-determined class intervals and letter grades based on 10-point grading system as recommended by UGC shall be followed.

(ii) Based on the % marks scored (internal and external marks put together), the students are graded in each course applying the following grading system given in Table 6:

Table 6. Letter Grades with Grade Points and Marks Equivalence

Range of Marks (%)	Grade Point	Letter Grade
80-100	8.0 - 10.0	**O** (Outstanding)
70 - 79	7.0 - 7.99	**A+** (Excellent)
60 - 69	6.0 - 6.99	**A** (Very Good)
55 - 59	5.5 - 5.99	**B+** (Good)
50 - 54	5.0 - 5.49	**B** (Above Average)
45 - 49	4.5 - 4.99	**C** (Average)
40 - 44	4.0 – 4.49	**P** (Pass)
0 - 39	0 – 3.99	**F** (Failed)/ RA(Reappear)
-	0	**Ab** (Absent)

-	0	**I** (Incomplete)

Remarks:

*(1) The cut-off mark for **Grade B+ (Good)** is **55% marks** and the cut-off mark for **Grade B (Above Average)** is **50% marks** under this grading system.*

*(2) **Conversion Formula**: Percentage of Marks = Grade point x 10*

(iii) Each student shall be assigned a grade point and a letter grade in each course on the basis of the % marks scored in the course (internal and external marks taken together) as shown above. The minimum grade point required for passing a course is **4.0**.

If 2 students score 78% and 73% marks in a course, then their grade points

are 7.8 and 7.3 respectively, but both will be assigned the same letter grade A+. If the course carries 4 credits, then the credit points of these students will be 31.2 and 29.2 respectively.

(iv)The student is required to pass all the core courses and the stipulated minimum

number of elective courses in order to complete the programme successfully.

(v) After the completion of a semester, the Semester Grade Point Average (SGPA) of a student in that semester is calculated using the formula given under its definition. The minimum SGPA required for the successful completion of a semester is **5.0**. However, a student with SGPA less than 5.0 in a semester is permitted to proceed to the next semester.

(vi) The Cumulative Grade Point Average (CGPA) of the student is calculated at the end of a programme. For the CGPA computation only the best performed courses with maximum credit points (P) alone shall be taken subject to the restrictions on the credits of Core and Elective courses prescribed for a specific degree. The CGPA of a student determines the academic level of the student in a programme and is the criterion for ranking the students.

An overall letter grade (Cumulative Grade) for the whole programme shall be awarded to the student based on the value of CGPA using the same criterion given in Table 6 for assigning letter grade for a course on the basis of the grade point. For instance, if the CGPA of a student turns out to be 6.6, then the Cumulative Grade of that student will be A (Very Good).

(vii) The minimum CGPA required for the successful completion of a programme is **5.0**, which corresponds to **50%** marks.

(viii) A student who secures zero grade point (F grade) in a course (for want of sufficient marks and/or attendance) is permitted to register for repeating the course when the course is offered to the next batch. The student registered for repeat course need not attend the classes if she/he has satisfied the requirements regarding attendance.

(ix) A student who does not complete the stipulated requirements of a course gets I Grade (Course Incomplete). However, such a student shall be permitted by the Academic Committee, with the concurrence of the Department Council, to complete the course at a later time along with the respective semester batch.

(x) Any student in a course is permitted to register within the time limit

specified by the University after the declaration of results for the improvement examination for improving the performance if she/he desires so and can appear for the improvement examination in the subsequent semester for external examination. However there shall be no improvement chance for internal assessment. The student need not attend classes for improvement examination course. On registering for an improvement examination course, the marks obtained under regular registration or new registration, which one is higher will be awarded to the candidate. However, the internal marks will be carried forward to determine the new grade point in the improvement examination course. In case the student fails to appear for the improvement examination for any reason, the marks obtained under the original registration will be retained.

(e) CCSS-PG-2019 – Pattern of Question Paper for

Reg. No: **Code:**

Name:

1^{st} / 2^{nd} / 3^{rd} / 4^{th} Semester M.Sc. Degree Examination – w.e.f 2019,
CCSS – M.Sc. Programme

Code: (e.g. PHY1C01:) Subject (e.g. CLASSICAL MECHANICS AND CHAOS)

Time : 3 hours **Total Marks = 80**

Section A
(12 Short questions answerable within 5 minutes)
(Answer **ALL** questions, each carry 2 Marks)

Question Numbers 1 to 12 Total Marks 12 x 2= 24

Section B
(4 essay questions answerable within 30 minutes)
(Answer **ANY TWO** questions, each carry 14 Marks)

Question Numbers 13 to 16 Total Marks 2 x 14= 28

Section C
(6 problems answerable within 15 minutes)
(Answer **ANY FOUR** questions, each carry 7 Marks)

Question Numbers 17 to 22 Total Marks 4 x 7= 28

Note: Section A - **2** questions from each module **plus** one each from the modules which has more lecture hours.
Section B **– One** each from **important 4** modules.
Section C **– One** each from each modules **plus** one from the module **left out** in Section B.

(f) DETAILED SYLLABUS

FIRST SEMESTER

PHY1C01 : CLASSICAL MECHANICS AND CHAOS (4 Credits, 72 hrs)

Objectives

- Define and interpret the concepts of Lagrangian and Hamiltonian

  mechanics.

- Explain the generating function, canonical transformation and Poisson brackets
- Illustrate the dynamics of a rigid body in different frames of references.
-
- Formulate the concepts of coupled oscillators.
- Understand the basic features of non-linear dynamics

Course outcome: **After completion of the full course the student should be able to**	Cognitive level
C.O.1: Apply the Lagrangian and Hamiltonian formalisms to simple classical systems and compare with Newtonian systems.	Apply
C.O.2: Solve problems like motion under central force, rigid body dynamics and periodic motions using Lagrangian and Hamiltonian mechanisms using appropriate mathematical equations	Analyse
C.O.3: Analyze non linear nature of many of the simple systems.	Analyse

1. **Lagrangian and Hamiltonian Formulation** : Preliminary ideas about Constraints and Generalized coordinates, D'Alemberts principle and Lagrange's equation, Velocity dependent potentials, Simple applications of Lagrangian formulation, Hamilton's Principle, Conservation theorems and symmetries, Lagrange's equation from Hamilton's principle, Two- body central force problems, Equivalent one - body and one dimensional problem, Kepler problem, Inverse square law of force, Laplace-Lenz vector, Scattering in a central force field, Transformation to lab coordinates. (17 hours)
   Text : Goldstein et al.

2. **Hamiltonian Formulations:** Legendre Transformation and Hamilton's equations, Cyclic co-ordinates and conservation theorems, Principle of least action, Canonical transformations and examples, Infinitesimal canonical transformations, Poisson brackets and other canonical invariants, Equation of motion in Poisson bracket

form, Angular momentum Poisson brackets, Hamilton-Jacobi equation, Hamilton's principal and characteristic function, H-J equation for the linear harmonic oscillator, Separation of variables, Action-angle variables, H-J formulation of the Kepler problem, H-J equation and the Schrodinger equation. (19 hours)
Text : Goldstein et al.

3. **Kinematics of Rigid Bodies** : Independent co-ordinates, orthogonal transformation, Transformation matrix, Euler angles, Euler theorem, Infinitesimal rotation, Rate of change of a vector, Centrifugal and Coriolis forces, Inertia tensor, Euler's equation of motion, Torque-free motion of a rigid body, Precession of Equinoxes and satellite orbits. (14 hours)
Text : Goldstein et al.

4 **Small Oscillations** : Formulation of the problem, Eigenvalue equation, Eigenvectors and Eigenvalues, Orthogonality, Principal axis transformation, Frequencies of free vibrations, Normal coordinates, Free vibrations of a linear triatomic molecule, Forced vibration and Dissipative forces. (9 hours)
Text : Goldstein et al.

5. **Nonlinear Equations and Chaos** : Introduction, Singular points of trajectories, Nonlinear oscillations, Limit cycles, Chaos : Logistic map, Definitions, Fixed points, Period doubling, Universality. (13 hours)
Text : Bhatia

Text Books :

1. Herbert Goldstein, Charles P.Poole and John Safko : "Classical Mechanics" (3rd Edition, Pearson Education, 2011)
2. V.B.Bhatia : "Classical Mechanics" (Narosa Publications, 1997)

Books for Reference :

1. Michael Tabor : "Chaos and Integrability in Nonlinear Dynamics" (Wiley, 1989)
2. N.C.Rana and P.S.Joag : "Classical Mechanics" (Tata McGraw Hill, 2011)
3. R.G.Takwale and P.S.Puranik : "Introduction to Classical Mechanics" (Tata McGraw Hill, 1978)
4. Atam P. Arya : "Introduction to Classical Mechanics, " (2nd Edition, Addison Wesley, 1998)
5. Muthusamy Lakshmanan, Shanmuganathan Rajaseekar : "Nonlinear Dynamics" (Springer Verlag, 2002)

PHY1C02: MATHEMATICAL PHYSICS – I (4 Credits,72 hrs)

Objectives:

- Mathematics is the language of nature. Physics addresses fundamental questions in nature. Mathematical tools used for solving physical problems constitute mathematical physics. Mathematical Physics I, offered as a core course, delivers an entry level exposure to the fundamentals of this subject.

Course outcome: **After completion of the full course the student should be able to**	Cognitive level
C.O.1: Describe coordinate systems appropriate for different physical problems. Applies it to solve Laplace's equation in different coordinate systems.	Analyse
C.O.2: Distinguish the class of objects called tensors, their classifications and use. Peform transformation operations and get the corresponding transformation matrices. Learns procedures for matrix diagonalisation.	Evaluate
IC.O..3: Identify differential equations of special nature and the ways to solve them.	Analyse
C.O.4: Illustrate special functions as solutions to problems in atomic, molecular nuclear, and solid state physics etc. and will put them in use.	Analyse
C.O..5: Distinguish Fourier series and integral transforms of different types and their properties. This will enable him/her to analyse or solve different mathematical problems in physical sciences.	Analyse

1. **Vectors** : Rotation of coordinates, Orthogonal curvilinear coordinates, Gradient, Divergence and Curl in orthogonal curvilinear coordinates, Rectangular, cylindrical and spherical polarcoordinates, Laplacianoperator, Laplace's equation – application to electrostatic field and wave equations, Vector integration (11 hours).
   Text : Arfken & Weber

2. **Matrices and Tensors** : Basic properties of matrices (Review only), Orthogonal matrices, Hermitian and Unitary matrices, Similarity and unitary transformations, Diagonalization of matrices, Definition of Tensors, Contraction, Direct products,, ' quotient rule, Pseudo tensors, Dual tensors, Levi Cevita symbol, irreducible tensors. (11 hours)
Text : Arfken & Weber

3. **Second Order Differential Equations** : Partial differential equations of Physics, Separation of variables, Singular points, Ordinary series solution, Frobenius method, A second solution, Self-adjoint differential equation, eigen functions and values, Boundary conditions, Hermitian operators and their properties, Schmidt orthogonalization, Completeness of functions. (14 hours)
Text : Arfken & Weber

4. **Special functions** : Gamma function, Beta function, Delta function, Dirac delta function, Bessel functions of the first and second kinds, Generating function, Recurrence relation, Orthogonality, Neumann function, Spherical Bessel function, Legendre polynomials, Generating function, Recurrence relation, Rodrigues' formula, Orthogonality, Associated Legendre polynomials, Spherical harmonics, Hermite polynomials, Laguerre polynomials. (24 hours)
Text : Arfken & Weber

5. **Integral Transforms:** Fourier Series, General properties, Advantages, Uses of Fourier series, Properties of Fourier series, Fourier integral, Fourier transform, Properties, Inverse transform, Transform of the derivative, Convolution theorem, Laplace transform, Inverse Transform and Convolution theorem.(12 hours)
Text : Arfken & Weber

Text Book:

1. G.B.Arfken and H.J.Weber : "Mathematical Methods for Physicists" (6th Edition, Academic Press, 2005)

Books for Reference:

(1) J.Mathews and R.Walker : "Mathematical Methods for Physics" (2nd Edition, Benjamin)
(2) L.I.Pipes and L.R.Harvill : "Applied Mathematics for Engineers and Physicists" (3rd Edition, McGrawHill)
(4)Erwin Kreyzig : "Advanced Engineering Mathematics"(8th edition, Wiley)
(5)M. Greenberg : "Advanced Engineering Mathematics" (2nd edition, Pearson India, 2002)
(6)A.W. Joshi : "Matrices and tensors in Physics"(New Age International Publishers)
(7) Nazrul Islam: "Tensors and Their Applications" (New Age International, 2006)

PHY1C03: ELECTRODYNAMICS AND PLASMA PHYSICS (4 Credits,72 hrs)

Objective:

- To provide a firm understanding of electrostatics and magnetostatics in a more general perspective. Maxwell's equations and and their applications will be emphasized.
- Analyse the propagation of electromagnetic waves through conducting and nonconducting media.
- To understands the propagation of electromagnetic waves through confined media. Also learns the sources of electromagnetic radiations such as antennas.
- To understand special theory of relativity and the relativistic formulation of electrodynamics.
- To learn the basics of elementary plasma physics.

Course Outcome: **After completion of the full course the student should be able to**	Cognitive level
C.O.1: Solve boundary value problems and wave equations. Carry out multipole expansions and interpret the results.	Apply
C.O.2: Understand basic concepts related to wave propagation and few of their applications.	Understand
C.O.3: Develop a firm understanding on the propagation of electromagnetic waves through waveguides and their storage in cavity resonators. The specific field patterns from antennas will be analysed.	analyse
C.O.4: Enables to appreciate the magnificent results of the blending of relativity and electrodynamics and motivates to take up a course on quantum field theory, the study of fields, interactions and symmetries.	Analyse
C.O.5: Understand the criteria for a medium to be called plasma and the various properties of it.	Understand

1. **Electrostatics, Magnetostatics and Time varying fields**: Coulomb's law, Gauss's law, Laplace and Poisson equations, Solutions, Boundary value problems, Green's

identities and Green's function, uniqueness theorem, Method of images with simple examples, Multipole expansion, Ponderable media, Dielectrics. Biot-Savart law, Ampere's law, Boundary value problems, Ampere's theorem, Multipoles, Electromagnetic induction, Maxwell's equations, Potential functions, Gauge transformations and gauge fixing, Wave equations and their solutions. (19 hours)
Text : J. D. Jackson

2. **Plane electromagnetic waves** : Plane waves in nonconducting medium, Polarization, Reflection and Refraction, Dispersion in dielectrics, conductors and plasma, Superposition of waves, Group velocity, Kramers-Kronig relations. (12 hours)
Text : J. D. Jackson

3. **Wave guides and cavity resonators**: Penetration of fields into the conductors, Wave guides, Cylindrical, Rectangular, Energy flow and attenuation, Resonance cavities, Power losses, Fields and radiation of localized oscillating source, Electric dipole fields and radiation. (13 hours)
Text : J. D. Jackson

4. **Relativistic electrodynamics:** Special theory of relativity, Lorentz transformations, Addition of velocities, 4-vectors, Covariance of electrodynamics, Transformations of electromagnetic fields, Lienard-Wiechert potentials, Larmors formula and its relativistic generalization. (13 hours)
Text : J. D. Jackson

5. **Plasma Physics** : Plasma -Definition, concepts of plasma parameter, Debye shielding, Motion of charged particles in an electromagnetic field -Uniform electric and magnetic fields, Distribution function, Boltzmann and Vlasov equations, Derivation of moment equation, Fluid theory, Plasma oscillations, Hydromagnetic waves, Magnetosonic waves and Alfven waves.(15 hours)
Text : F. F. Chen

Text Books :

1. J.D.Jackson : "Classical Electrodynamics" (3rd Ed., Wiley,1999)
2. F. F. Chen :" Introduction to Plasma Physics and Controlled Fusion", Volume I :Plasma Physics, (Springer Verlag, 2006).

Books for Reference:

1. David K. Cheng : " Field and Wave Electromagnetics" (2nd Ed., Addisson Wesley)
2. David Griffiths : " Introductory Electrodynamics" (4th Ed.,Prentice Hall of India, 2012)
3. K.L. Goswami, Introduction to Plasma Physics – Central Book House, Kolkata

PHY1C04**: ELECTRONICS** (4 Credits, 72 hrs)

Objectives:

- To understand bi-junction uni-junction transistors based amplifiers and their frequency performances and applications.
- To understand the architecture and performance of various semiconductor based components for microwave and photonic devices.
- To understand the architecture and working of an Op-Amp and its characteristics from its equivalent circuit.
- To understand the working of an Op-Amp based circuits for practical applications
- To understand the architecture and working digital components needed for building a digital computer

Course outcome: **After completion of the full course the student should be able to**	Cognitive level
C.O.1: Analyse the performance and differentiate voltage and current amplifiers, design a public address system with transistors.	Anaalyse
C.O.2: Understand the operations of LEDs, explain the working semiconductor lasers	Understand
C.O..3 : Students are able to analyse the frequency response, input and output impedances of an Op-Amp.	Analyse
IC.O..4: Students are able to analyse the frequency response, input and output impedances of various Op-Amp based circuits for practical applications.	Apply
C.O.5: Students are able to analyse arithmetic logic circuits, differentiate between: A/D and D/A convertors, microprocessor and microcontroller, explain the working of various counters and registers, design a microprocessor based circuit for practical applications	Analyse

1. Transistor Amplifiers

BJT: Biasing and ac models (EP 8:3, 8:4, 9:1, 9:6, 9:7), Voltage amplifiers (EP 10:1– 10:4), Power amplifiers (EP 11:3 – 11-5), Emitter follower (EP 12:1 – 12:4). FET: h-parameters, FET small signal model, Biasing FET, Analysis of common source and common drain amplifiers at low and high frequencies, FET as VVR and its applications. MOSFET: Circuit symbol and equations, small signal model, CMOS and Digital MOSFET gates. (IE 8:3, 10:1-10:10) (17 hours)

Texts:

1. Malvino, "Electronic Principles" 6th Edition, TMH India.
2. Millman and Halkias, "Integrated Electronics" TMH India

2. Microwave and Photonic Devices: Tunnel diode, Transferred electron devices, Negative differential resistance and devise operation, Radiative transitions and optical absorption, Light emitting diodes (LED) –Visible and IR, Semiconductor lasers - materials, operation (population inversion, carrier and optical confinement, optical cavity and feedback, threshold current density), Photo-detectors, Photoconductor (Light dependent resistor- LDR) and photodiode, p-n junction solar cells - short circuit current, fill factor and efficiency. (12 hours)

Text:

1. S. M. Sze.,"Semiconductor Devices- Physics and Technology" (John Wiley and Sons.

3. Operational Amplifier:

Dual input differential amplifier DC and AC analysis (OA 1:4, 1:5), Op-Amp block diagram representation, analysis of a typical Op-Amp equivalent circuit (OA 2:1 – 2:6), ideal Op-Amp characteristics, equivalent circuit, open loop configurations (OA 3:3 – 3:6), Op-Amp parameters: input offset voltage & current, input bias current, output offset voltage, CMRR (OA 5), Op-Amp with negative feedback: voltage series feedback amplifier: gain, input & output impedances (4:3), Frequency response, compensating networks (OA 6:1–6:7) (14 hours)

Text:

R. A. Gayakwad, "Op-Amps and Linear Integrated Circuits" 3rd Edition, PHI.

4. OPAMP Applications:

Summing, scaling and averaging amplifiers (OA 7:5), Analog integrator and differentiator (OA 7:12-7:13), Electronic analog computation (IE 16:5), Active filters: Low pass, High pass, band pass, Butterworth filters (OA 8:1-8:9), Oscillators: Phase shift, Wein bridge, Quadrature oscillators, Square, triangular and saw-tooth wave generators (OA 8:11-8:17), comparators, zero crossing detectors, Schmitt trigger (OA 9:1-9:4) (12 hours)

Texts:

1 R. A. Gayakwad : "Op-Amps and Linear Integrated Circuits"(3rd Edition, PHI)
2 Millman and Halkias :"Integrated Electronics" (TMH India)

5. Digital Electronics:

Arithmetic circuits: adder, adder/subtracter, ALU (ML 6:7- 6:10) RS, JK and JK

MS flip-flops (ML 8.7), Registers: types of registers, SISO & 7491, SIPO &74164, PIPO & 74198, applications of shift registers. Counters: asynchronous counter & 7493A, decoding gates, synchronous counters & 7490 A, decade counters (ML10), D/A-A/D converters (ML 12:1–12:8)

Microprocessors and Microcontrollers: Microprocessor, architecture of 8085: Bus organization, Registers, memory, block diagram of 4 bit register, memory map, tri-state buffer (MA 2:1-2:3), 8085 functional pin diagram, control & status signals, microprocessor communication and bus timing (memory read/write operations), address data de-multiplexing (MA 3:1). Microcontrollers, architectural overview and block diagram of microcontrollers (MC 1:1-1:3). (17 hours)

Texts:

1. Leach, Malvino and Saha : "Digital Principles and Applications" 6th Edition, TMH.
2. Ramesh S. Gaonkar: "Microprocessor Architecture, Programming and Applications with the 8085", New Age Publishers.
3. The 8051 Microcontroller: 2nd Edition, Kenneth J. Ayala, Thomson, Delmar Learning.
4. Atmega16 microcontroller data sheet available from Atmel website.

Books for Reference:

1. Robert L. Boylstead & L. Nashelsky: "Electronic devices and circuit theory" (Pearson Education.)
2. Floyd:"Electronic devices"(5th Edition, Pearson Education)
3. Alen Motorshed, Microelectronic Circuits: Analysis & Design, M. H. Rashid, PWS Publishing Company.
4. Linear Integrated circuits, D. R. Choudhuri, S. Jain, New Age International Publishers.
5. Fundamentals of Microprocessors and Microcomputers, 2nd Edition, B.Ram, Dhanapathi Rai & Sons.
6. Embedded C Programming and the Atmel AVR, Barnett, O'cull, Cox, Cengate Learning.

PHY1C05 : GENERAL PHYSICS PRACTICAL – I (2 Credits)

Notes:

1. At least 10 experiments should be done . All the experiments should involve error analysis. Practical observation book to be submitted to the examiners at the time of external examination. One mark is to be deducted from internal marks for each experiment not done by the student if a total of 10 experiments are not done in each semester.

2. The PHOENIX Experimental Kit developed at the Inter University Accelerator Centre, New Delhi, may be used for the experiments wherever possible.

Experiments:

1. Y and σ - Interference method (a) elliptical (b) hyperbolic fringes. To determine Y and σ of the material of the given specimen by observing the elliptical and hyperbolic fringes formed in an interference set up

2. Y and σ by Koenig's method

3. Viscosity of a liquid - Oscillating disc method. To determine the viscosity of the given liquid by measurements on the time period of oscillation of the disc in air and in the liquid

4. Variation of surface tension with temperature - Jaegar's method. To determine the surface tension of water at different temperatures by Jaeger's method of observing the air bubble

5. Mode constants of a vibrating strip. To determine the first and second mode constants of a steel vibrating strip; Y to be measured by the Cantilever method and frequency of vibration by the Melde's string method

6. AC bridge circuits: Maxwell's, De Sauty's and Anderson's bridges (any two).

7. Calibration of Silicon Diode.

8. Stefan's constant of radiation

9. Thermal diffusivity of brass

10. High resistance by leakage

11. Temperature coefficient of resistance of copper

12. Measurement of Self Inductance of a coil
13. Dielectric constant of a non polar liquid
14. Magnetic field variation along the axis of a solenoid

15. Mutual Inductance with Lock-in amplifier
16. Band gap of semiconductor using diode
17. Optical fibre – evaluation of numerical aperture
18. Design of passive filter (first and second order) RC circuit

Laser experiments.

19. Wavelength determination using grating
20. Intensity distribution
21. Diameter of a thin wire
22. Diffraction at a slit - determination of slit width
23. Fraunhoffer Diffraction at Single Slit
24. Young's Double slit experiment.

Books for Reference:

1. A.C. Melissinos, J.Napolitano : "Experiments in Modern Physics" (Academic Press, 2003)
2. B.L. Worsnop and H.T. Flint :"Advanced Practical Physics for students" (Methusen & Co., 1950)
3. E.V. Smith :" Manual of experiments in applied Physics" (Butterworth 1970)
4. R.A. Dunlap :"Experimental Physics - Modern methods"(Oxford University Press, 1988)
5. D. Malacara (ed) : " Methods of experimental Physics - series of volumes " (Academic Press Inc., 1988)
6. S.P. Singh : "Advanced Practical Physics – Vol I & II (13th Edition, Pragati Prakasan, Meerut , 2003)

PHY1C06 : ELECTRONICS PRACTICAL (2 Credis)

Notes : Students have to do 10 experiments from the list. They have to carry out a minor electronic project under the supervision of the teacher as a partial fulfilment of the course. From each module, one has to do at least one experiment and at the most 3 experiments.

I Voltage Regulator

1. Voltage regulation using transistors with feedback (regulation characteristics with load for different input voltages and variation of ripple factor with load)

2. Voltage regulation using Op Amp with feedback (regulation characteristics with load for different input voltages and variation of ripple factor with load

II BJT Amplifiers

1. Single stage RC coupled amplifier with and without Negative feedback (input, output resistance, frequency response)
2. Two stage RC coupled amplifier (input and output resistance and frequency response including Bode plots)
3. Complementary symmetry Class B push-pull power amplifier (transformerless) (I/O impedances, efficiency and frequency response)
4. Darlington pair amplifier (gain, frequency response, input &output resistances)
5. Differential amplifier using transistors (I/O impedances, frequency response, CMRR)
6. Bootstrap Amplifier (frequency response, input & output resistance)
7. Two stage IF amplifier (Gain and frequency response, bandwidth)
8. Amplitude modulation and detection using transistors (modulation index & recovery of modulating signal)

III FET and MOSFET

1. RC coupled FET amplifier - common source (frequency response, input & output impedances).
2. MOSFET amplifier (frequency response, input & output impedances)
3. UJT characteristics and relaxation oscillator (construct relaxation oscillator & sharp pulse generator)
4. Characteristics of a Silicon controlled rectifier (Half wave and full wave) Negative resistance oscillator. (for different frequencies)

IV Operational Amplifiers

1. Use of IC 741 - Determination of input offset voltage, current, CMRR, slew rate, and use as Inverting and non-inverting amplifier and difference amplifier, summing amplifier and comparator.
2. Sawtooth generator using transistors and Miller sweep circuit using OPAMPS

(for different frequencies)
3. Schmidt trigger using transistors and OPAMPS - Trace hysteresis curve , determine LTP and UTP
4. Analog integration and differentiation using OPAMPS (study the integrator characteristics & differentiator)
5. Analog computation using OPAMPS (LM324) – Differential equations / Simultaneous equations
6. Second order Low pass, High Pass and Band Pass filters using OPAMP.(study the frequency response)
7. Square, Triangular and Saw tooth generator, Voltage controlled oscillator using Op Amp (Refer R. A. Gayakwad, Ch.8)
8. IC 555 Timer circuit- Astable and monostable multi vibrators,
9. IC 555 Timer circuit -VCO missing pulse detector and sawtooth generator.

V Oscillators

1. Wien bridge oscillator using OP AMP (For different frequencies, distortion due to feedback resistor, compare with design values)
2. Phase shift and Quadrature oscillator with OP AMP (Refer R. A. Gayakwad)
3. Crystal Oscillator (For different frequencies & evaluation of frequency stability)

VI Digital Circuits, Microprocessors and Microcontrollers

1. Operation and working of Arithmetic and Logic circuits IC 7483, IC 74181
2. Shift registers IC 74166 and IC 74198
3. Counters IC 7490 A, IC 7493 A, IC 74193
4. Organize M X N random access memory with basic memory unit (Verify the READ and WRITE operations)
5. Microprocessors experiments (simple experiments) addition, subtraction, multiplication and division using 8085
6. Square wave generation using Microprocessor 8085 and programmable peripheral interface 8255.
7. Programming Atmel microcontroller (square wave generation, sine wave generation with inbuilt D/A converter)

Mini-Project

(Students have to do a mini electronic project leading to understanding and applications of the theory. Examples are given below, they can choose other projects in consultation with the teacher.)

1. Construction of a complete power supply circuit
2. Construction of a simple Operational Amplifier with transistors like MC 1435 and study the performance and compare with the IC (Refer R. A. Gayakwad)
3. Study the frequency response of an Operational Amplifier and study the poles

4. Construction of a Digital to Analog Convertor and supporting circuitry using MC1408 (Refer R. A. Gayakwad)
5. Optical fibre communication
6. A/D and D/A convertors using OpAmp (Refer R. A. Gayakwad, Ch. 9-11)
7. Power Supply circuit for various ranges (Refer R. A. Gayakwad Ch. 11-2)
8. Audio Function Generator (Refer R. A. Gayakwad Ch. 11-5)
9. Construction of digital clock
10. Programming of Atmel microcontroller
    Example Programming Atmel microcontroller for different wave forms (square wave generation, sine wave with inbuilt D/A converter, triangular etc.)
11. Signal processing and circuit designing using Matlab
12. Circuit designing, Simulation using PSPICE
13. Data Acquisition using Virtual Lab
14. Printed Circuit designing and optimisation using WinQCad

Text Books & References

1. Electronic devices and circuit theory, R. L. Boylestad, L. Nashelsky, Pearson Education 7th ed.
2. Electronic principles, Malvino, Tata McGraw-Hill, 6th ed.
3. Amps and Linear Integrated Circuits, R. A. Gayakwad, P.H.I, 3rd ed.
4. Fundamentals of microprocessors and microcomputers, B. Ram, Dhanapathi Rai & Sons
5. Malvino and Leach, Digital Principles and Application, Tata McGraw Hill, 6th ed.
6. Embedded C programming and Atmel AVR, R. Barnett, L. O’cull, S. Cox, Cengate Learning IE, 2004.

PHY1A01: ABILITY ENHANCEMENT COURSE (AEC) (2C)

This course will be in the form of a seminar on a topic in physics. Each student has to prepare for and present a seminar on a topic in physics, which will be evaluated based on its content, report and presentation. The student also has to write an essay on this topic and present it at the end of the first semester.

SECOND SEMESTER

PHY2C07: QUANTUM MECHANICS I (4 Credits, 72 hrs**)**

Objectives:

- Acquire basic ideas of linear vector spaces, operations, transformations and representations
- Understand the basis postulates of quantum mechanics
- Discuss the quantum theory of angular momenta
- Understand the quantum dynamics of hydrogen atom, identical particles and quantum mechanical scattering, etc.
- Enhance the knowledge about symmetry and conservation laws

After completion of the full course the student should be able to	**Cognitive level**
Understand the importance of Hilbert space in quantum mechanics and identify them	Apply
Understand the basic postulates of quantum mechanics	Understand
Perform angular momenta additions	Apply
Solve Schrödinger equation in different situations	Apply
Apply commutational algebra in order to understand the simultaneous events	Apply
Calculate the differential cross section of a scattering process	Analyse

1. Origin of Quantum Mechanics and Mathematical Tools

Essential structure of Classical Mechanics and its Inadequacy. Linear Vector Spaces- Hilbert Space; Dimension and Basis of a Vector Space; Square-Integrable Functions; Wave Functions; Dirac's Bra and Ket notation; Schwarz Inequality.
Operators- Adjoint of an Operator; Hermitian Operators; Unitary Operators; Commutator Algebra; Commutator of Operators and Uncertainty Relation; Functions of Operators; Eigenvalues and Eigenvectors of an Operator.
Representation in Discrete Bases- Matrix Representation of Bras, Kets and Operators; Change of Bases and Unitary Transformations; Matrix Representation of the Eigenvalue Problem. Representation in Continuous Bases- Position and Momemtum Representations and relation between them. (12 hours)

2.Postulates of Quantum Mechanics and Exactly Solvable Problems in one Dimension

The State of a System; Probability Density; The Superposition Principle, Observables and Operators.
Measurement in Quantum Mechanics- How Measurements Disturb Systems; Expectation Values; Complete Sets of Commuting Operators; Measurement and the Uncertainty

Relations.
Time Evolution of the System's State- Time Evolution Operator; Schrodinger Equation and Wave Packets; The Conservation of Probability; Time Evolution of Expectation Values.
Connecting Quantum to Classical Mechanics- Poisson Brackets and Commutators; The Ehrenfest Theorem.
Time-independent Schrodinger equation- Stationary States; Infinite square well; Delta-function Potential; Finite square well; Finite Potential Barrier; Harmonic Oscillator.
The Free particle- Wave Packets; Localized Wave Packets; Wave Packets and the Uncertainty Relations; Motion of Wave Packets. (12 hours)

3.Quantum Dynamics and Angular Momentum
The equation of motion.
Schrodinger, Heisenberg and the Interaction pictures of time development.
The linear harmonic oscillator in the Schrodinger and Heisenberg pictures.
Orbital Angular Momentum- Angular Momentum Opeartors; Angular Momentum Algebra; Simultaneous Eigenfunctions of L_z and L^2; Properties of the Spherical Harmonics; Matrix Representation of Angular Momentum Operators; Addition of angular momenta; Clebsh-Gordon coefficients.
Spin Angular Momentum- Spin 1/2 and the Pauli Matrices.
Coupling of Orbital and Spin Angular Momenta. (17hours)

4. Exactly Solvable Problems in three Dimensions & Symmetry and Conservation Laws
The Free Particle in Spherical Coordinates; The Spherical Square Well Potential; The Isotropic Harmonic Oscillator; The Hydrogen Atom; Effect of Magnetic Fields on Central Potentials.
Space-time symmetries- Space translation and conservation of linear momentum; Time translation and conservation of energy; Space rotation and conservation of angular momentum; Space inversion and time reversal.
Identical particles- Identical Particles in Classical and Quantum Mechanics; Exchange Degeneracy; Construction of symmetric and antisymmetric wave functions; Slater determinant; Pauli exclusion principle; Bosons and Fermions; Spin wave functions for two electrons; The ground state of He atom. (19 hours)

5. Scattering
Scattering cross section and scattering amplitude; Low energy scattering by a central potential; The method of partial waves; Phase shifts; Optical theorem, Convergence of partial wave series; Scattering by a rigid sphere; Scattering by a square well potential; High energy scattering; Scattering integral equation and Born approximation. (12 hours)

Text books

1. Nouredine Zettili, *Quantum Mechanics: Concepts and Applications,* Second Edition, John Wily & Sons Ltd, 2009
2. V. K. Thankappan, *Quantum Mechanics, Second Edition,* New Age International

Publishers, 1993.
3. David J. Griffiths, *Introduction to Quantum Mechanics, Second Edition*, Pearson education International, 2005
4. R. Shankar, *Principles of Quantum Mechanics, Second Edition*, Kluwer Academic/ Plenum Publishers, 1994

Reference books

1. Thomas E Jordan, *Quantum Mechanics in Simple Matrix Form*, John Wiley & Sons Ltd, 1986
2. Claude Cohen Tannoudji, Bernard Diu and Frank Laloe, *Quantum Mechanics, Volumes I and II*, 1996
3. L. I. Schiff, *Quantum Mechanics*, McGraw Hill, 1968
4. J. J. Sakurai, *Modern Quantum Mechanics*, Addison-Wesley, 2010
5. J. D. Bjorken and S. D. Drell, *Relativistic Quantum Mechanics*, McGraw Hill, 1998
6. P. M. Mathews and K. Venkatesan, *A Textbook of Quantum Mechanics,* TataMcGraw Hill, 1978
7. Albert Messiah, *Quantum Mechanics,* Dover Publications, 2014
8. Amit Goswami, Quantum Mechanics, 2nd Ed., Waveland Press, 2003.
9. G. Aruldhas, Quantum Mechanics, 2nd Ed., PHI Learning, 2009
10. Stephen Gasiorowicz, Quantum Physics, 3rd Ed.,Wiley, 2003

PHY2C08: MATHEMATICAL PHYSICS II (4 Credits, 72 hrs**)**

Objectives:

Mathematics is the language of nature. Physics addresses fundamental questions in nature. Mathematical tools used for solving physical problems constitute mathematical physics. Mathematical Physics I, offered as a core course, delivers an entry level exposure to the fundamentals of this subject.

Course outcome: **After completion of the full course the student should be able to**	Cognitive level
C.O.1: In general, physical phenomena are expressed in equations involving complex quantities. Some times we get complex solutions to equations. Solving such problems requires special procedures. On completing this module he/she will be gain the skill for solving and interpreting such problems.	Analyse
C.O.2: Address the class of objects called groups and the symmetry operations expressed as group elements. Understand group properties.	Evaluate
C.O..3 : Group representations provide the understanding of applications of group theory in quantum mechanics. Different discrete and continuous groups and gauge principles are introduced here.	Apply
IC.O..4: Understand calculus of variation in a level suitable for application in various physical problems in physics.	Understand
C.O.5: Understand various integral transforms and Greens functions and their applications in physical problems obeying causality conditions,	Understand

1. **Functions of Complex Variables** : Introduction, Analyticity, Cauchy-Reimann conditions, Cauchy's integral theorem and integral formula, Laurent expansion, Singularities, Calculus of residues and applications (13 hours)
   Text : Arfken and Weber

2. **Group Theory** : Groups, Multiplication Table, Conjugate elements and classes, Subgroups, Direct product groups, Isomorphism and homomorphism, Permutation groups, Distinct groups of given order,Exercises. (14 hours)
   Text : Joshi

3. **Group Representation Theory** : Unitary representations, Schur's lemmas, orthogonality theorem and interpretations, Character of a representation, Character Tables and examples, Irreducible representations of Abelian and non-Abelian

groups, Connection with quantum numbers, Symmetry group of the Schrodinger equation, Symmetry and degeneracy, Basis functions of irreducible representations, SU(2) group, SU(3) group, applications (Qualitative only) to Nuclear and Particle Physics , Qualitative ideas of Lie groups,Exercises. (19 hours)
Texts : Tinkham, Joshi

4. **Calculus of Variations** : One dependent and one independent variable, Applications of the Euler equation, Generalization to several independent variables, Several dependent and independent variables, Lagrange Multipliers, Variation subject to constraints, Rayleigh-Ritz variational technique, Exercises. (11 hours)
Text : Arfken and Weber

5. **Integral equations and Green's function** : Integral equations – introduction, Integral transforms and generating functions, Neumann series, separable kernel, Green's function – Non homogeneous equations, Green's function, Symmetry of Green's function, form of Green's function, Example – Quantum mechanical scattering,Exercises. (15 hours)
Text : Arfken and Weber

Text Books :

1. G.B.Arfken and H.J. Weber : "Mathematical Methods For Physicists" (5th Edition, Academic Press, 2001)
2. A.W.Joshi : "Elements of Group Theory For Physicists" (New Age International Publishers New Delhi, 2002)
3. M.Tinkham : "Group Theory and Quantum Mechanics" (Tata-McGraw-Hill)

B**ooks for Reference** :

1.A.K. Ghatak, I.C. Goyal and S.J. Chua: "Mathematical Physics"(Laxmi Publications Private Limited; First edition, 2017)
2.Wu- ki Tung "Group Theory in Physics - An Introduction to Symmetry Principles, Group Representations, and Special Functions in Classical and Quantum Physics" (World Scientific)
3. Wu-Ki Tung : "Group Theory in Physics"(World Scientific)

PHY2C09 : STATISTICAL MECHANICS (4 Credits, 72 hrs**)**

Objectives:

- Understand the statistical foundations of thermodynamics
- Introduce the fundamental principles of equilibrium statistical physics
- Analyse the connection and dichotomy between classical and quantum statistics
- Learn the behaviour of Bose and Fermi gases based on quantum statistical physics
- Familiarise phase transitions and non-equilibrium statistical mechanics

Course Outcomes:

After completion of the full course, the student should be able to	Cognitive leve
Discuss the connection between statistics and thermodynamics	Analyse
Demonstrate an understanding of the terminology, concepts and principles of describing equilibrium properties of physical systems in a statistical mechanical framework	Apply
Derive partition function and compute thermodynamics relations for various real-world physical systems	Create
Comprehend the statistical behaviour of ideal Bose and Fermi systems	Analyse
Explain aspects of the statistical physics of systems with an interaction between its constituent components	Analyse

1. **Foundations of statistical mechanics**: Specification of states of a system, Contact between statistics and Thermodynamics, Classical Ideal gas, Entropy of mixing and Gibbs paradox, Sackur-Tetrode Equation. (13 hrs)

Text book: Pathria

2. **Ensemble Theory**: Microcanonical ensemble, phase space, trajectories and density of states, Liouville's theorem, canonical and grand canonical ensembles, partition function, Equipartition Theorem, calculation of statistical quantities. (17 hrs)

Text book: Pathria

3. Quantum Statistical Mechanics: Density matrix, statistics of Microcanonical, Canonical and Grand canonical Ensemble, Example: Electron in a magnetic field, Free Particle in a box, Statistics of indistinguishable particles. (15 hrs)

Text book: Pathria

4. I**deal Systems**: Density matrix of a system of non-interacting particles. Ideal gas in quantum mechanical ensembles, Maxwell-Boltzman, Fermi-Dirac and Bose-Einstein statistics, Thermodynamics of ideal Bose and Fermi gases, Bose-Einstein condensation.

(17 hrs)

Text book: Pathria

5. Phase Transitions and Fluctuations: Problem of condensation, Yang and Lee Theory, Dynamical model of Phase transitions, Ising Model in Zeroth approximation, Equilibrium thermodynamic Fluctuations, Brownian motion and Langevin theory, Exercises. (10 hrs)

Text book: Pathria

Text Book: R. K. Pathria. "Statistical Mechanics" (3rd Edition, Elsevier, 2011)

Books for Reference:

(1)K Huang : "Statistical Mechanics" (2nd Edition, John Wiley(NY), 1987).
(2)F. Reif : "Statistical and Thermal Physics" (Tata McGraw Hill(ND), 2008).
(3) Landau and Lifshitz : "Statistical Physics Part 1" (3rd edition, Elsevier, 2011).

ELECTIVE – I

(Any one of the following PHY2E01 or PHY2E02 or PHY2E03)

PHY2E01 : COMPUTATIONAL TECHNIQUES AND PYTHON PROGRAMMING

(4 Credits, 72 hrs**)**

Objectives:

- To develop a bsic understanding of python programming language.
- To understand the modular approach in programming. Understand important modules and their use in python.
- To understand data visualisation methods in python.
- To understand basic numerical methods for interpolation, integration, curve fitting etc.
- To understand the need for numerical methods to solve problems in physics, apply this to solve some specific problems in physics.

Course outcome: **After completion of the full course, the student should be able to**	**Cognitive level**
C.O.1:Understand the syntax and other special features of python programming language.	Understand
C.O.2: Use modules in python for practical applications.	Apply
C.O.3: Achieve data visualisation by making use of matplotlib module.	Create
C.O.4: arry out interpolation by cubic slpine method. Do integration by importance sampling etc. Follow numerical methods to find eigen values and eigen functions.	Apply
C.O.5: Study the evolution of physical systems by developing simulation programs using C.	Create

1. **Introduction to Python language**: (15 hours) Inputs and Output methods, Variables, operators, expressions and statements, Strings, Lists, list functions and methods (len, append, insert, del, remove, reverse, sort, +, *, max, min, count, in, not in, sum), sets, set functions and methods(set, add, remove, in, not in, union, intersection, symmetric difference)-Tuples and Dictionaries, Conditionals, Iteration and looping - Functions and Modules - File input and file output, Exercises.

Ref: (1) Python for Education, Ajith Kumar B.P., (2) Python tutorials available on the net (http://www.altaway.com/resources/python/tutorial.pdf)

2. **Numpy module-Arrays and Matrices:** (14 hours) Creation of arrays and matrices (arrange, linspace, zeros, ones, random, reshape, copying arrays), Arithmetic operations, cross product, dot product , Saving and Restoring, Matrix inversion, solution of simultaneous equations(use functions in linalg module).

Ref: Guide to NumPy, Travis E. Oliphant

3. Data visualization-The Matplotlib, Module: (13 hours) Methods defined in matplotlib, Plotting graphs, Multiple plots, Polar plots-, Pie Charts, Plotting Sine, Log, Exponential, Bessel, Legendre, Gaussian and Gamma functions, Parametric plots.

Ref: Matplotlib for python developers, Sandro Tosi

4. Numerical methods: (15 hours) Inverse of a function, Interpolation with Cubic Spline, Zeros of polynomials, Monte Carlo Methods: simple integration, integration by Importance Sampling, Eigenvalues and eigen functions shooting and relaxation methods, Sampled Data: Sampling Theorem, Discrete Fourier Transform, Fast Fourier Transform (FFT).

Ref: 1. Numerical Recipes in C, W.H.Press,S.A.Teukolsky et al.
2. Introductory methods of numerical analysis, S.S. Shastry , (Prentice Hall of India,1983)

5. Introduction to Computational approach in Physics*: (15 hrs) Formulation: from Analytical methods to Numerical Methods - Oscillatory motion – Ideal Simple Harmonic Oscillator (Euler method), Driven LCR circuit (R-K method), circuit analysis using Kirchoff‟s laws, central field motion, simulations of standing waves, Monte-Carlo simulations- value of π,simulation of radioactivity, Logistic maps.

(*Programs are to be discussed in Python, Visualisation can be done with matplotlib/pylab)

Text book: Computational Physics-An Introduction,R.C.Verma, P.K.Ahluwalia & K.C.Sharma, New Age International Publishers

Reference: Computational Physics, V.K.Mittal, R.C.Verma & S.C.Gupta, Ane's Student Edition.

More References: (For Python any book can be used as reference. Moreover a number of open articles are available freely in internet. Python is included in default in all GNU/Linux platforms and it is freely downloadable for Windows platform as well. However use of GNU/Linux may be encouraged).

1. www.python.org

2. Python Essential Reference, David M. Beazley, Pearson Education
3. Core Python Programming, Wesley J Chun, Pearson Education
4. Python Tutorial Release 2.6.1 by Guido van Rossum, Fred L. Drake, Jr., editor. This tutorial can be obtained from website http://www.altaway.com/resources/python/tutorial.pdf
5. How to Think Like a Computer Scientist: Learning with Python, Allen Downey , Jeffrey Elkner , Chris Meyers, http://www.greenteapress.com/thinkpython/thinkpython.pdf
6. Numerical Recipes in C, second Edition(1992), Cambridge University Press
7. Numerical Recipes in Fortran 77, second Edition(1992), Cambridge University Press
8. Numpy reference guide, http://docs.scipy.org/doc/numpy/numpy-ref.pdf (and other free resources available on net)
9. Matplotlib , http://matplotlib.sf.net/Matplotlib.pdf (and other free resources available on net)
10. Numerical Methods, E Balagurusamy, Tata McGraw-Hill
11. Numerical Methods , T Veerarajan, T Ramachandran, Tat MCGraw-Hill
12. Numerical Methods with Programs I BASIC, Fortran & Pascal, S Balachandra Rao, C K Shantha. Universities Press
13. Numerical methods for scientists and engineers, K. Sankara Rao, PHI
14. Numerical Methods in Engineering with Python by Jaan Kiusalaas

For further reference:

1. Computational Techniques - Video - http://nptel.iitm.ac.in/courses/103106074/
2. Numerical Analysis Web Prof. Vittal Rao IISc Bangalore http://nptel.iitm.ac.in/courses/Webcourse-contents/IISc-BANG/Numerical Analysis/New_index1.html
3. Numerical Analysis and Computer Programming Video Prof. P.B. Sunil Kumar IIT Madras http://nptel.iitm.ac.in/video.php?subjectId=122106033
4. Numerical Analysis in Computer Programming Web Prof. Rathish Kumar,Prof. V. Raghavendra,Prof. M.K. Kadalbajoo, Prof. P.B. Sunil KumarIIT Kanpur, IIT Madras http://nptel.iitm.ac.in/courses/Webcourse-contents/IIT-KANPUR/NumericalAnalysis/front.htm
5. Numerical Methods and Computation Video Prof. S. R. K. Iyengar IIT Delhi http://nptel.iitm.ac.in/video.php?subjectId=122102009

PHY2E02: COMPUTATIONAL TECHNIQUES AND C PROGRAMMING

(4 Credits,72 hrs**)**

Objectives:

- To understand root finding methods and choose the best strategy for finding the roots of a transcendental equation and apply it in physics problems

- To understand interpolation and curve fitting methods and choose the appropriate technique for physics problems involving interpolation, curve-fitting and adopt Fortran language for solving.

- To get a clear cut idea on various methods for numerical integration, numerical solutions of Ordinary and Partial differential equations and apply it in various physics problems using C language.

- To understand different methods adopted in solving linear equations, Eigen value problems using matrices and adopt various computationally less expensive methods and strategies using C language.
- To understand C programming fundamentals and its syntax essential for translating problems involving arithmetic and logical entities, branching, iterations and repeated sub-modules etc. to frame an algorithm for finding numerical solution.

Course Outcomes:

After completion of the full course, the student should be able to	Cognitive leve
C.O.1:Learn different methods of root findings of transcendental equations involved in physical problem and choose the best method among to find the root with required accuracy using a computer by computationally less expensive method.	Apply
C.O.2: Learn different methods for interpolation and curve fitting involved in physical problem and choose the best method among to find the solution with required accuracy using a computationally profitable algorithm.	Understand
C.O.3:Familiarize with different approaches for numerical integration, methods for solving ordinary and partial differential equations and their graphical representations apply the method in various physics problems using C language. Compare the results with analytically solvable problems to find the goodness of the method.	Apply
C.O.4:Familiarizing with different numerical methods adopted in solving linear equations, evaluating determinants, solving Eigen value problems using matrices and implementing various computationally less expensive methods and strategies using C language.	Understand
C.O.5: To split a numerically solvable problem into	Analyse

subunits involving arithmetic and logical entities, iterations, branching, repeated sub-modules etc. and frame a systematic algorithm to solve it and translate it into C language and numerically solve via computationally less expensive route with needed accuracy	

1. **Roots of transcendental equations** : Location theorem, Bisection (half interval) method- Method of false position (Regula Falsi), Graphical Method, Newton-Raphson method, Geometric significance, inherent error, convergence of Newton Raphson method, Special procedure for Algebraic equations, Iteration Method, Geometry and convergence of iteration process. (12 hours)
2. **Interpolation and curve fitting :** Difference calculus, Detection of error, Forward, backward, Central & divided difference, Newtons forward, backward, general interpolation formula, Lagrange's Interpolation formula. Least square fitting (Linear & Non-linear). (12 hours)
3. **Numerical integration and Ordinary differential equations :** Trapezoidal and Simpson's methods, Newton-Cote's method, Gauss quadrature, Solution of ordinary differential equations - Euler's method, Milne's method, Runge-Kutta methods, Enough exercises. (14 hours)
4. **Determinents and Matrices:** Evaluation of numerical determinants, Cramer's rule, Successive elimination of unknowns: division by the leading coefficients, Gauss method, Solution by Inversion of Matrices: solution of equation by matrix methods, Systems solvable by iteration and condition for convergence. The Eigen value problem – Eigen values of a symmetric tridiagonal matrix- Householder's method – QR method. (15 hours
5. **C Programming fundamentals :** Constants and variables, Data types, Type declaration of variables, Symbolic constants, Arithmetic operators, Increment and decrement operators, Conditional operator, Bitwise operators, Hierarchy, Arithmetic expressions, Logical operators and expressions, Assignment operators, Arithmetical and assignment statements, Mathematical functions, Input/output statements, Formatted I/O, Relational operators, Decision making and branching, Go to, if, if…else, switch statements, Looping, While, do and for, Arrays, Handling characters and strings, Functions and voids, structures, Pointers (elementary ideas only), File operations(defining and opening, reading, writing, updating and closing of files. (19 hours)

Text Books :

1. J.B.Scarborough : "Numerical mathematical analysis" (Oxford and IBH, 6th edition)
2. S.S.Shastry : "Introductory methods of numerical analysis" (Prentice Hall of India,1983)
3. V.Rajaraman : "Programming in C"
4. E.Balaguruswamy : "Programming in ANSI C" (Tata-McGraw Hill, 1992)

Books for Reference:

1. J.H.Rice : "Numerical methods-software and analysis" (McGraw Hill, 1983)
2. Hildebrand : "Introduction to Numerical analysis" (2nd Ed., Dover Publications

Inc., 1987)

3. W.H.Press, et al., “Numerical Recipes in C, The art of scientific computing,, (Cambridge University Press, 2007)

PHY2E03: COMPUTATIONAL TECHNIQUES AND FORTRAN

PROGRAMMING (4 Credits, 72 hrs**)**

Objectives:

- To understand root finding methods and choose the best strategy for finding the roots of a transcendental equation and apply it in physics problems

- To understand interpolation and curve fitting methods and choose the appropriate technique for physics problems involving interpolation, curve-fitting and adopt Fortran language for solving.

- To get a clear cut idea on various methods for numerical integration, numerical solutions of Ordinary and Partial differential equations and apply it in various physics problems using Fortran language.

- To understand different methods adopted in solving linear equations, Eigen value problems using matrices and adopt various computationally less expensive methods and strategies using Fortran language.
- To understand Fortran programming fundamentals and its syntax essential for translating problems involving arithmetic and logical entities, branching, iterations and repeated sub-modules etc. to frame an algorithm for finding numerical solution.

Course Outcomes: **After completion of the full course, the student should be able to**	**Cognitive leve**
C.O.1:Learn different methods of root findings of transcendental equations involved in physical problem and choose the best method among to find the root with required accuracy using a computer by computationally less expensive method.	Apply
C.O.2: Learn different methods for interpolation and curve fitting involved in physical problem and choose the best method among to find the solution with required accuracy using a computationally profitable algorithm.	Understand
C.O.3:Familiarize with different approaches for numerical integration, methods for solving ordinary and partial differential equations and their graphical representations apply the method in various physics problems using Fortran language. Compare the results with analytically solvable problems to find the goodness of the method.	Apply
C.O.4:Familiarizing with different numerical methods adopted in solving linear equations, evaluating determinants, solving Eigen value problems using matrices	Understand

and implementing various computationally less expensive methods and strategies using Fortran language.	
C.O.5:To split a numerically solvable problem into subunits involving arithmetic and logical entities, iterations, branching, repeated sub-modules etc. and frame a systematic algorithm to solve it and translate it into Fortran language and numerically solve via computationally less expensive route with needed accuracy	Analyse

1. **Roots of transcendental equations** : Location theorem, Bisection (half interval) method, Method of false position (Regula Falsi), Iteration Method, Geometry and convergence of iteration process, Newton - Raphson method, Geometrical significance, inherent error, convergence of Newton Raphson method (12 hours)
2. **Interpolation and curve fitting :** Difference calculus, Detection of error, Forward, backward, Central & divided difference, Newtons forward, backward, general interpolation formula, Lagrange's Interpolation formula. Least square fitting (Linear & Non-linear). (12 hours)
3. **Numerical integration and differential equations :** Trapezoidal and Simpson's methods, Gauss quadrature, Solution of ordinary differential equations - Euler's and modified Euler's methods, Runge-Kutta methods, Solving higher order differential equations, Partial differential equations, Finite difference Approximations, Laplace equation, ADI method, Parabolic equations, Hyperbolic equations(14 hours)
4. **Determinants and Matrices:** Evaluation of numerical determinants, Cramer's rule, Successive elimination of unknowns: division by the leading coefficients, Gauss method, Solution by Inversion of Matrices: solution of equation by matrix methods, Systems solvable by iteration and condition for convergence. The Eigen value problem – Eigen values of a symmetric tridiagonal matrix-Householder's method. (15 hours)
5. **Fortran Programming fundamentals**: (Fortran 90/95) Fortran constants and variables, Type declarations, Arithmetic operators, Hierarchy, Arithmetic expressions, Logical operators and expressions, Arithmetical and assignment statements, Special functions, Input/output statements, Relational operators, Control statements(go to, arithmetic and logical if), Do loop, repeat while, Dimensioned variables, Formats, Subprograms, Functions and subroutines, Common declaration, File operations (creating, reading, writing, updating and merging of sequential files), Complex Arithmetic,Exercises. (19 hours)

Text Books :

1. J.B.Scarborough : "Numerical mathematical analysis" (Oxford and IBH, 6th edition)
2. S.S.Shastry : "Introductory methods of numerical analysis" (Prentice Hall of India,1983)
3.Computer Programming in Fortran 90, V. Rajaraman, PHI
4. Programming with Fortran 77 – Schaum's Outline Series, McGraw Hill

Reference Books :

1. J.H.Rice : “Numerical methods-software and analysis” (McGraw Hill, 1983)
2. Hildebrand : “Numerical analysis”
3. Numerical Recipes in C, The art of scientific computing, Press, Teukolsky, Vellerling & Flannery Cambridge University Press
4. Numerical Recipes in Fortran, The art of Scientific Computing, W. H. Press et al., Cambridge.

PHY2C10 : GENERAL PHYSICS PRACTICAL – II (2 Credits)

Note :

1. *At least 10 experiments should be done . All the experiments should involve error analysis. Practical observation book to be submitted to the examiners at the time of external examination. One mark is to be deducted from internal marks for each experiment not done by the student if a total of 10 experiments are not done in each semester. The Practical examination is of 3 hours duration.*

   2. *The PHOENIX Experimental Kit developed at the Inter University Accelerator Centre, New Delhi, may be used for the experiments wherever possible*.

Experiments

1. Study of magnetic hysteresis - B-H Curve.
2. Dielectric constant by Lecher Wire - To determine the wavelength of the waves from the given RF oscillator and the dielectric constant of the given oil by measurement of a suitable capacitance by using Lecher wire setup.
3. Young's modulus- vibrating strip
4. Cauchy's constants. – Liquid prism (different concentrations)
5. Michelson's interferometer - (a) dλ and *** (b) and the thickness of mica sheet.
6. Measurement of electrical and thermal conductivity of copper.
7. Band gap of a semiconductor.
8. Thermal conductivity of a liquid and air (poor conductor) by Lee's Disc Method.
9. Temperature of sodium flame. - To determine the temperature of the sodium flame by comparison with an incandescent lamp using a spectrometer
10. Dipole moment of an organic molecule
11. Verification of Curie-Weiss law.
12. B-H curve of a ferromagnetic material.
13. Measurement of a low resistance.
14. Time constant of a serial light bulb.

15. Mode constants of a vibrating strip.
16. Measurement of magnetic susceptibility – Quincke's method
17. e/m Millikan oil drop experiment
18. Frequency estimation using EXPEYES

Elementary experiments using Laser :

19. Laser beam parameters.
20. Diffraction Grating.
21. Diffraction at Circular aperture
22. Refractive Index of liquids.
23. Magneto-striction.
24. Diffraction at rectangular aperture.
25. Diffraction at two circular apertures.
26. Evaluation of beam profile, half divergence and beam waist of the laser

Books for Reference:

1. B.L. Worsnop and H.T. Flint - Advanced Practical Physics for students - Methusen & Co (1950)
2. E.V. Smith - Manual of experiments in applied Physics - Butterworth (1970)
3. R.A. Dunlap - Experimental Physics - Modern methods - Oxford University Press (1988)
4. D. Malacara (ed) - Methods of experimental Physics - series of volumes - Academic Press Inc (1988)
5. S.P. Singh –Advanced Practical Physics – Vol I & II – Pragati Prakasan, Meerut (2003) – 13th Edition

PHY2C11 : COMPUTATIONAL PHYSICS PRACTICAL (2 Credis)

Students have to do 12 experiments from the list given below. The programs are to be written and executed in Fortran / C /Python. The Practical examination is of 3 Hours duration. Further, they have to carry out a small project of two weeks' duration under the supervision of the teacher in charge as a partial fulfilment of the course.

General Programs

1. Find the roots of a quadratic equation which can give even complex roots.

2. List the prime numbers between two integers specified.

3. Write a program for finding the determinant and inverse of a 3 x 3 matrix

4. Write a program for plotting square wave using Fourier series coefficients.

5. Find the roots of a transcendental equation using Bisection / Regula Falsi/ Newton-Raphson method with an accuracy specified.

6. Interpolate from the list of data given using Newton's forward / backward interpolation formula and visualize the curve.

7. Interpolate from the list of data given using Newton's general / Lagrange interpolation formula and visualize the curve.

8. Fit the set of data to a straight line using least square curve fitting formula and visualize it.

9. Fit the set of data to a polynomial of degree 2 or 3 using least square curve fitting formula and visualize it.

10. Find the integral of the given function between the limits supplied using Trapezoidal formula

11. Find the integral of the given function between the limits supplied using Simpson's 1/3 or 3/8 rule and find the error in evaluation.

12. Evaluate the indefinite integral Exp[$-x^2$] between the limits 0 to infinity.

13. Solve the first order differential equation using Euler's formula or modified Euler's formula.

14. Solve the first order differential equation using second /fourth order Runge-

Kutta formula.

15. Solve the simple harmonic oscillator problem with /without damping and visualize the phase-space diagram.

16. Write a program for finding the inverse of a 3 x 3 matrix using Gauss / Gauss-Jordan method.

17. Find the Eigen values & Eigen vectors of a 3 x 3 symmetric matrix by Householder method.

18. Solving wave equation (parabolic PDE) using finite difference/Crank-Nicolson method

19. Solving Laplace equation (elliptic PDE) using finite difference method

20. Solving Hyperbolic PDE using difference approximation approach.

21. Evaluation of Pi using Monte Carlo method

22. Random walk simulation in 2D

Mini-Project

Students have to do a mini project leading to understanding and applications of the theory in consultation with the teacher in charge.

Text Books :

1. Computational Physics -An introduction., R.C.Varma, P.K.Ahluwalia and K.C.Sharma, New Age International Publishers
2. Numpy Reference guide, http://docs.scipy.org/doc/numpy/numpy-ref.pdf (also, free resources available on net)
3. Matplotlib , http://matplotlib.sf.net/Matplotlib.pdf (and other free resources available on net)
4. Numerical Methods in Engineering and Science, Dr. B S Grewal, Khanna Publishers, New Delhi (or any other book)
5. Numerical Methods, E Balagurusamy, Tata McGraw-Hill

6. Numerical Methods , T Veerarajan, T Ramachandran, Tat MCGraw-Hill
7. Numerical Methods with Programs I BASIC, Fortran & Pascal, S Balachandra Rao, C K Shantha. Universities Press
8. Numerical methods for scientists and engineers, K. Sankara Rao, PHI
9. Introductory methods of numerical analysis, S.S.Shastry , (Prentice Hall of India,1983)
10. Numerical Methods in Engineering with Python by Jaan Kiusalaas

PHY2A02 Professional Competency Course (PCC) (2C)

This audit course for the second semester shall be a course designed by the supervisor (faculty of the department) in experimental physics/theoretical physics/computational physics/software or related fields in physics with two credit points and it will be evaluated based on the documents prepared.

THIRD SEMESTER

PHY3C12 : QUANTUM MECHANICS - II (4 Credits, 72 hrs)

Objectives:

- To understand time-independent perturbation theory with applications.
- To understand variational method to solve quantum mechanical problems.
- To understand time dependent perturbation theory.
- To understand relativistic quantum mechanics.
- To understand canonical quantisation of fields.

Course outcome: **After completion of the full course, the student should be able to**	**Cognitive level**
C.O.1:Apply time-independent perturbation theory to unharmonic oscillator, Stark effect and Zeeman effect.	Apply
C.O.2: Solve hydrogen and helium atom problems using variational method.	Apply
C.O.3: Apply time dependent perturbation theory. To explain interaction of atoms with electromagnetic waves leading to emission and absorption. Explain Born approximation.	Apply
C.O.4: Appreciate relativistic quantum mechanics as a stepping stone to quantum field theory. Obtain Klein-Gordon, Dirac and Weyl equations.	Analyse
C.O.5: Quantise electromagnetic field and Schrodinger field .	Apply

1. **Perturbation Theory**: The WKB approximation, Connection formulae, Barrier tunneling, Application to decay- bound states, Penetration of a potential barrier, Time- independent perturbation theory, Non-degenerate and generate cases, Anharmonic oscillator, Stark and Zeeman effects in hydrogen. (14 hours)

2. **Variational method**: The variational equation, ground state and excited states, the variation method for bound states, Application to ground state of the hydrogen and helium atoms. (7 hours)

3. **Time dependent perturbation theory** : Transition probability, Harmonic

perturbation, Interaction of an atom with the electromagnetic field, Induced emission and absorption, The dipole approximation, The Born approximation and scattering amplitude. (14 hours)

4. **Relativistic Quantum Mechanics** : The Dirac equation, Dirac matrices, Solution of the free-particle Dirac equation, Equation of continuity, Spin of the electron, Non realistic limit, Spin-orbit coupling, Covariance of the Dirac equation, Bilinear covariants, Hole theory, The Weyl equation equation for the neutrino, Non-conservation of parity, The Klein Gordon equation, Charge and current densities, The Klein- Gordon equation, Charge and current densities, The Klein -Gordon equation equation with potentials, Wave equation for the photon,Charge conjugation for the Dirac, Weyl and Klein Gordon equation. (20 hours)

5. **Quantization of fields:** The principles of canonical quantization of fields, Lagrangian density and Hamiltonian density, Second quantization of the Schrodinger wave field for bosons and fermions, Classical field theory of electrodynamics and gauge symmetry. (11 hours)

6. **Quantum Interpretation** : Quantum measurement- Entanglement- EPR paradox, Hidden variables, Bell's theorem-Experimental test of Bell's Inequality. (6 hours)

Textbooks:

1. V.K. Thankappan : “Quantum Mechanics” (Wiley Eastern)
2. N.Zettili: “Quantum Mechanics – Concepts and applications” (John Wiley & Sons, 2004)
3. J.D.Bjorken and D.Drell: “Relativistic Quantum Mechanics” (McGraw Hill , 1998)

Reference books :

1. L.I.Schiff : “Quantum Mechanics” (McGraw Hill)
2. J.J.Sakurai :” Advanced Quantum Mechanics “ (Addition Wesley)
3. P.M. Mathews and K.Venkatesan : “ A Text Book of Quantum Mechanics”(Tata McGrawHill)
4. Stephen Gasiorowicz :” Quantum Physics”, (3 edition, Wiley, 2003)
5. D.A. Bromley, W. Greiner, “Relativistic Qunatum Mechanics, Wave Equations”, : (3rd ed. , Springer)
6. Amit Goswami, Quantum Mechanics, 2nd Ed., Waveland Press, 2003.
7. G. Aruldhas, Quantum Mechanics, 2nd Ed., PHI Learning, 2009

PHY3C13 : NUCLEAR AND PARTICLE PHYSICS (4 credits, 72 hrs**)**

Objectives:

- Understand the basic properties of the nucleus and nuclear force.
- Learn how to develop models for nucleus on the basis of observation of the properties of the nucleus.
- Understand the physics and mechanism of radioactive decay of nuclei and explain the physics involved. Acquire the basic understanding of morphological classification of galaxies.
- Learn the basic principle and working of commonly used nuclear radiation detectors.
- To familiarize the fundamental particles and their classification in terms of conservation and symmetry.

After completion of the full course the student should be able to	Cognitive level
Explain the interaction between the nucleons and explain the observed data	Analyse
Explain the basic properties of the nuclei and predict the behaviour of new nuclei.	Apply
Predict the decay probability of radiation from any nucleus	Apply
Use radiation detectors for detection and monitoring radiations	Apply
Identify the elementary particle from their basic properties	Analyse

1. **Nuclear Forces:** Properties of the nucleus, size, binding energy, angular momentum , The deuteron and two-nucleon scattering experimental data, Simple theory of the deuteron structure, Low energy n-p scattering, characteristics of nuclear forces, Spin dependence,Tensor force, Scattering cross sections, Partial waves, Phase shift, Singlet and triplet potentials, Effective range theory, p-p scattering. (12 hours)
   Text: K.S.Krane : "Introductory Nuclear Physics" (Wiley)

2. **Nuclear Decay:** Basics of alpha decay and theory of alpha emission, Beta decay, Energetics of beta decay, Fermi theory of beta decay, Comparative half-life, Allowed and forbidden transitions, Selection rules, Parity violation in beta decay. Neutrino. Energetics of Gamma Decay, Multipole moments, Decay rate, Angular momentum and parity selection rules, Internal conversion, Lifetimes. (12 hours)
   Text: K.S.Krane : "Introductory Nuclear Physics" (Wiley)

3. **Nuclear Models, Fission and Fusion:** Shell model potential, Spin-orbit potential, Magnetic dipole moments, Electric quadruple moments, Valence Nucleons, Collective structure, Nuclear vibrations, Nuclear rotations, Liquid drop Model, Semiempirical Mass formula, Energetics of Fission process, Controlled Fission reactions. Fusion process, Characteristics of fusion, solar fusion, Controlled fusion reactors. (19 hours)
Text: K.S.Krane : "Introductory Nuclear Physics" (Wiley)

4. **Nuclear Radiation Detectors and Nuclear Electronics:** Gas detectors – Ionization chamber, Proportional counter and G M counter, Scintillation detector, Photo Multiplier Tube (PMT), Semiconductor detectors – Ge(Li), Si(Li) and surface barrier detectors, Preamplifiers, Amplifiers, Single channel analyzers, Multi- channel analyzers, counting statistics, energy measurements. (12 hours)
Text: S S Kapoor and V S Ramamurthy: "Nuclear Radiation Detectors" (Wiley)

5. **Particle Physics:** Four basic forces - Gravitational, Electromagnetic, Weak and Strong - Relative strengths, Classification of particles, Yukawa's theory, Conservation of energy and masses, Electric charges, Conservation of angular momentum, Baryon and lepton numbers, Conservation of strangeness, Conservation of isospin and its components, Conservation of parity, Charge conjugation, CP violation, time reversal and CPT theorem. Extremely short lived particles, Resonances - detecting methods and experiments, Internal symmetry, The Sakata model, SU (3), The eight fold way, Gellmann and Okubo mass formula, Quarks and quark model, Confined quarks, Experimental evidence, Coloured quarks. (17 hours)
Text Book: Y.Neeman and Y.Kirsh: "The particle hunters' (Cambridge University Press)

Books for Reference :

1. H.S.Hans : "Nuclear Physics – Experimental and theoretical" (New Age International, 2001).
2. G.F.Knoll : "Radiation Detection and Measurement, (Fourth Edition, Wiley , 2011)
3. G.D.Couoghlan, J.E.Dodd and B.M.Gripalos "The ideas of particle physics – an introduction for scientists", (Cambridge Press)
4. David Griffiths – "Introduction to elementary particles" – Wiley (1989)
5. S.B.Patel : "An Introduction to Nuclear Physics" (New Ag e International Publishers)
6. Samuel S.M.Wong: "Introductory Nuclear Physics" (Prentice Hall,India)
7. B.L.Cohen : "Concepts of Nuclear Physics" (Tata McGraw Hill)
8. E.Segre : "Nuclei and Particles" (Benjamin, 1967)
9. K Muraleedhara Varier: "Nuclear Radiation Detection: Measurement and Analysis" (Narosa).

PHY3C14 : SOLID STATE PHYSICS (4 Credits, 72 hrs**)**

Objectives:

- To understand the reciprocal lattice, Brillouine zone, crystal structures and various bondings in crystals.
- To understand different excitations in crystals and their after effects.
- To understand free electron model and the explanation for the properties of metals. To have a deeper understanding of band gaps in different situations.
- To understand the thermal, electrical and magnetic properties of materials.
- To understand electron pairing and superconductivity.

Course Outcome: **After completion of the full course the student should be able to**	Cognitive level
C.O.1: Analyse the structure of materials based on X-ray diffraction and interpret it on the basis of the theory understood.	Analyse
C.O.2: Distinguish different excitations in crystals. Properties of quasiparticles could be explained. Arrive at proper explanation of for specific heat.	Analyse
C.O.3: Explain free electron model and interpret the properties of metals. Gain a deeper understanding of the energy bands based on the properties of carriers.	Understand
C.O.4: Interpret properly the thermal, electrical and magnetic properties of materials. Will enable the student to understand the current research going on in the related areas.	Analyse
C.O.5: Illustrate using phase diagrams, phase transitions in materials leading to superconductivity and different types of superconductors.	Analyse

1. **Crystal Structure, binding and nanostructure**s: Symmetry elements of a crystal, Types of space lattices, Miller indices, Diamond structure, NaCl structure, BCC, FCC, HCP structures with examples, Description of X-Ray diffraction using reciprocal lattice, Brillouin zones, Van der Waals interaction, Cohesive energy of inert gas crystals, Madelung interaction, Cohesive energy of ionic crystals, Covalent bonding, Metallic bonding, Hydrogen-bonded crystals. Nanomaterials: Definition, Synthesis and properties of nanostructured materials (14 hours)
2. **Lattice Vibrations**: Vibrations of monatomic and diatomic lattices, Quantization

of lattice vibrations, Inelastic scattering of neutrons, Einstein and Debye models of specific heat, Thermal conductivity. (9 hours)

3. **Electron States and semiconductors**: Free electron gas in three dimensions, heat capacity of electron gas, electrical conductivity and Ohm's law, Experimental electrical resistivity of metals, Motion in magnetic fields, Hall effect, Thermal conductivity of metals (Wiedemann-Franz law), Nearly free electron model-origin of energy bands, Magnitude of energy gap, Bloch functions, Kronig Penny model, Semiconductor crystals: band gap, direct/indirect bad gap SCs, Equation of motion, Holes, Effective masses in semiconductors, Intrinsic carrier concentration, Impurity conductivity, Thermoelectric effects. (15 hours)

4. **Dielectric, Ferroelectric and magnetic properties**: Theory of Dielectrics: Polarisation, Dielectric constant, Local Electric field, Dielectric polarisability, Clausius- Mossotti relation, Polarisation from dipole orientation, Dielectric losses, Ferroelectric crystals, Order-disorder type ferroelectrics, Properties of BaTiO3, Polarisation catastrophe, Displacive type ferroelectrics, Landau theory of ferroelectric phase transitions, Ferroelectric domain, Antiferroelectricity, Piezoelectricity, Applications of Piezoelectric Crystals ; Diamagnetism and Paramagnetism: Langevin's diamagnetism equation, Quantum theory of diamagnetism of mononuclear systems, Quantum theory of paramagnetism, Hund's rule, Paramagnetic susceptibility of conduction electrons, Ferro, Anti and Ferri magnetism: Curie point and the exchange integral, Magnons, Ferrimagnetic order, Curie temperature and susceptibility of ferrimagnets, Antiferromagnetic order. Weiss theory of ferromagnetism, Ferromagnetic domain s, Bloch walls, Origin of domains, Novel magnetic materials: GMR-CMR materials (qualitative) Pu. (22 hours)

5. **Superconductivity** : Meissner effect, Type I and Type II superconductors, Heat capacity, Microwave absorption, Energy gap, Isotope effect, Free energy of superconductor in magnetic field and the stabilization energy, London equation and penetration of magnetic field, Cooper pairs and the B C S ground state (qualitative), Flux quantization, Single particle tunneling, DC and AC Josephson effects, High Tc superconductors (Qualitative) - description of the cuprates). (12 hours)

Textbooks :

1.C.Kittel : "Introduction to Solid State Physics" (5th or 7 th Ed., Wiley Eastern)
2.A.J.Dekker : "Solid State Physics" (Macmillan, 1958)
3.N.W.Ashcroft and Mermin, "Solid State Physics", Brooks Cole, 1976)
4. Srivastava J.P.: "Elements of Solid State Physics", (2nd Edition, Prentice Hall of India)
5.Ziman J.H. : "Principles of the Theory of Solids" (Cambridge, 1964)
6. Hari Singh Nalwa, Ed., "Nanoclusters and Nanocrystals" (American Scientific Publishers, 2003)

ELECTIVE II

(Any ONE of PHY3E04 or PHY3E05 or PHY3E06)

PHY3E04 : EXPERIMENTAL TECHNIQUES (4 Credits, 72 hrs)

Objectives :

- To impart knowledge on vacuum techniques, pumps and measuring gauges.
- To learn the different thin film fabrication techniques, thickness measurement and application.
- Knowledge on different types of particle accelerators and their uses
- Learn the methods of different materials analysis by nuclear techniques
- Understand different X-Ray techniques to characterize materials.

Course Outcome: **After completion of the full course the student should be able to**	Cognitive level
C.O.1: Explain vacuum, Gauges to measure vacuum, types of pumps and their utility, cryogenics etc.	Understand
C.O.2:Explain and demonstrate different thin film fabrication techniques, thickness measurement and application of thin films	Apply
C.O.3: Explain different types of particle accelerators, their working and specific applications	Understand
C.O.4: Explain methods of materials analysis by different nuclear techniques.	Understand
C.O.5: Be trained on defining X-ray techniques to characterise materials.	Apply

1. **Vacuum Techniques** : Units and basic definitions, Roughing pumps - Oil sealed rotary vacuum pump and Sorption pump, High vacuum pumps – Turbo molecular pump, Diffusion pump, Oil vapour booster pump, Ion pumps - Sputter ion pump and Getter ion pump, Cryo pump, Vacuum guages - Pirani gauge, Thermocouple gauge, penning guage (Cold cathode Ionization guage) and Hot filament ionization gauge, Vacuum accessories – Diaphragm, Gate valve, Butterfly valve, Baffle and isolation valves, magnetic valves, adjustable valves, air inlet valves, Traps - Liquid nitrogen trap, Sorption traps, and gaskets and O rings (19 hours)
Text : Varier et al.

2. **Thin film techniques** : Introduction, Fabrication of thin films, Thermal evaporation in vacuum – Resistive heating, Electron beam evaporation and laser evaporation techniques,

Sputter deposition, Glow discharge, Thickness measurement by quartz crystal monitor, optical interference method, electrical conductivity measurement, Thermo electric power, Interference filters - Multi layer optical filters, Technological Applications of thin films. (14 hours)

Text : Varier, et al.

4 **Accelerator techniques** : High voltage DC accelerators, Cascade generator, Van de Graaff accelerator, Tandem Van de Graaff accelerator, Linear accelerator, Cyclotron, Synchrotron (Electron and proton), Ion sources – Ionization processes, simple ion source, ion plasma source and RF ion source, Ion implantation – techniques and profiles, Ion beam sputtering– principles and applications. (14 hours)

Text :Varier, et al.

4. Materials Analysis by nuclear techniques: Introduction, Basic principles and requirements, General experimental setup, mathematical basis and nuclear reaction kinematics, Rutherford backscattering – introduction, Theoretical background – classical and quantum mechanical, experimental set up, energy loss and straggling and applications. Neutron activation analysis – principles and experimental arrangement, applications, Proton induced X-ray Emission – principle and experimental set up, applications to water samples, human hair samples and forensic samples, limitations of PIXE. (15 hours)

Text: Varier et al.

5. X- Ray Diffraction Technique : Introduction, Lattice planes and Bragg's Law, Diffractometer - Instrumentation, Single crystal and Powder diffraction, Scherrer equation, Structure factor, Applications of XRD - Crystallinity, Unit Cell Parameters, Phase transition studies, thin film studies, Awareness on Powder Diffraction File (PDF) of the International Centre for Diffraction Data. (10 hours)

Text: Jens Als Nielsen and Des McMorrow

Text Books:

1. Muraleedhara Varier, Antony Joseph and P.P.Pradyumnan : "Advanced Experimental Techniques in Modern Physics" (Pragati Prakashan, 2006)

2. Elements of Modern X-ray Physics, Jens Als Nielsen and Des McMorrow, (John Wiley and Sons 2000)

Books for Reference:

1. Scientific foundations of vacuum techniques – S. Dushman and J.M. Laffer, John Wiley New York (1962)
2. Thin film phenomena – K.L. Chopra, Mc Graw Hill (1983)
3. R. Sreenivasan – Approach to absolute zero - Resonance magazine Vol 1 no 12 , vol 2 nos 2, 6 and 10

4. R. Berry, P.M. Hall and M.T. Harris – Thin film technology – Van Nostrand (1968)
5. Dennis and Heppel – Vacuum system design
6. Nuclear Micro analysis – V. Valkovic
7. B.D. Cullity, Elements of X-ray diffraction, Addison Wesley Inc (1978)
8. Useful Link for XRD-http://pd.chem.ucl.ac.uk/pdnn/powintro/whatdiff.htm

PHY3E05 : ELEMENTARY ASTROPHYSICS (4 Credits, 72 hrs)

Objectives

- Identify celestial objects from their celestial co-ordinates
- Understand photometric and spectroscopic measuring techniques
- Understand stellar evolution
- Understand how to make astronomical observations from ground in optical and radio wavelengths. Also understand the tools and techniques used to study celestial objects in multi-wavelengths.
- Learn space observation techniques carried out using satellites.

Course Outcome: **After completion of the full course the student should be able to**	Cognitive level
C.O.1: Plan the observation, given co-ordinates of a celestial source.	Apply
C.O.2: Use the results of photometric and spectroscopic observation to study the properties of stars.	Analyse
C.O.3: Apply the principles of physics to understand stellar evolution	Apply
C.O.4:Understand various techniques involved in ground based observations.	Understand
C.O.5: Describe the techniques involved in the observation of celestial objects using space satellites.	Analyse

1. **The Celestial Co-ordinate systems**: Identification of stars- spherical co-ordinates- the Altazimuth system – Local equatorial system – the universal equatorial system – aspects of sky at a given place- Other systems- Stellar parallax and units of stellar distance. (14 hours)

2. **Stellar magnitude sequence:** Absolute magnitude and distance modulus, Colour index of a star, Luminosities of stars. Spectral classification of stars, Boltzmanns formula, Saha's equation of thermal ionization, Harward system of classification, Luminosity effect of stellar spectra, Importance of ionization theory, Spectroscopic parallax. (15 hours)

3. **Hertzsprung - Russel diagram**. Structure and evolution of stars, Observational basis, Equation of state for stellar interior, Mechanical and thermal equilibrium in stars, Energy transport in stellar interior, Energy generation in stars (thermonuclear reactions), Stellar evolution, White dwarfs Neutron stars, pulsars and black holes. (15 hours)

4. **Astronomical Instruments**: Optical properties of telescopes - aberrations – Special purpose telescopes – photometry, photographic & photo-electric - instruments and techniques – radio telescopes. (14 hours)

5. **Space Astronomy**: Infrared Astronomy, detection and measurement – Ultra-violet astronomy, range and importance – X-ray astronomy – Gamma ray astronomy. (14 hours)

Text Books:

1. K. D. Abhyankar: "Astrophysics – stars and galaxies", (Universities press) Relevant sections from Chapters 2, 19 and 20.
2. Baidyanath Basusu M : "An introduction to Astrophysics" (Prentice Hall of India) Relevant sections of Chapters 3,4, 14 and 15.

Book for Reference:

1. Gerald North: "Astronomy explained", (Springer, 2011)

PHY3E06 : PLASMA PHYSICS (4 Credits, 72 hrs)

Objective

- To understand the basic requirements for a medium to be called plasma.
- To understand the principle behind the production of plasma waves.
- To understand different instabilities likely to arise in a plasma medium.
- To apply the kinetic theory principles to derive the fluid equations in plasma.
- To understand the principles behind plasma confinement and subsequent achievement of nuclear fusion.

Course Outcome: **After completion of the full course the student should be able to**	Cognitive level
C.O.1: explore the motion of plasma particles in electric and magnetic fields. Enable to identify adiabatic invariants.	Analyse
C.O.2: Apply the principles of electrodynamics to understand the production and propagation of waves in plasma	Apply.
C.O.3: Understands the factors affecting instability of plasma.	Understand
C.O.4: Analyse Landau damping and its effects in plasma.	Analyse
C.O.5: Understand free electron laser action in plasma. Analyses the hurdles in plasma confinement.	Analyse.

1 **Introduction to Plasma Physics** : Existence of plasma,Definition of Plasma, Debye shielding 1D and 3D, Criteria for plasma,Applications of Plasma Physics (in brief), Single Particle motions -Uniform E & B fields, Non uniform B field, Non uniform E field, Time varying E field, Adiabatic invariants and applications. (15 hours)
Text : Chen

2. **Plasma as Fluids and waves in plasma**s : Introduction –The set of fluid equations, Maxwell's equations, Fluid drifts perpendicular to B, Fluid drifts parallel to B, The plasma approximations , Waves in Plasma - Waves, Group velocity, Phase velocity, Plasma oscillations, Electron Plasma Waves, Sound waves, Ion waves, Validity of Plasma approximations, Comparison of ion and electron waves, Electrostatic electron oscillations with B, Electrostatic ion

waves with B, The lower hybrid frequency, Electromagnetic waves with B0 , Cutoffs and Resonances, Electromagnetic waves parallel to B0, Experimental consequences, Hydromagnetic waves, Magnetosonic waves, The CMA diagrams. (20 hours)
Text : Chen

3. **Equilibrium and stability** : Hydro magnetic equilibrium, The concept of , Diffusion of magnetic field into plasma, Classification of instability, Two stream instability, the gravitational instability, Resistive drift waves, the Weibel instability. (13 hours)
Text : Chen

4. **Kinetic Theory** : The meaning of f(v), Equations of kinetic theory, Derivation of the fluid equations, Plasma oscillations and Landau damping, the meaning of Landau damping, Physical derivation of Landau damping, Ion Landau damping, Kinetic effects in a magnetic field, Exercises. (12 hours)
Text : Chen

5. **Introduction to Controlled Fusio**n : The problem of controlled fusion, Magnetic confinements such as Toruses, Mirrors, Pinches, Laser Fusion, Plasma heating, Fusion Technology, Exercises. (12 hours)
Text : Chen

Text Book : .

F. F. Chen : "Introduction to Plasma Physics and Controlled Fusion", Volume I and II (Springer, 2006).

Books for **Reference :**

1. J. D. Jackson, Classical Electrodynamics, Wiley Eastern, 1978.
2. D. R. Nicholson, Introduction to Plasma Theory.
3. N. A. Krall and A. W. Trivelpiece, Principles of Plasma Physics, McGraw-Hill, recent edition.

PHY3C15 : MODERN PHYSICS PRACTICAL I (2 Credits)

(Any 8 experiments to be done. Examination will be of 3 hours duration))

1. Zener voltage characteristics at low and ambient temperatures - To study the variation of the Zener voltage of the given Zener diode with temperature.

2. Ultrasonic interferometer – velocity of sound in liquids - To determine the velocity of ultra sonic waves in the given liquid and hence the compressibility.

3. Determination of band gap energy in Si and Ge by Four probe method.

4. Absorption spectrum of KMnO4 - To determine the wavelengths of the absorption bands for KMnO4 solution.

5. Hall effect in semiconductors - To determine the carrier concentration in the given specimen of semiconducting material by means of the Hall effect.

6. Photoelectric effect - Determination of Planck's constant (White light and filters or LEDs of different colours may be used)

7. Study of LED characteristics - Determination of wavelength of emission, I-V characteristics and variation with temperature, variation of output power vs. applied voltage.

8. Millikan's oil drop method - To measure the charge on the electron by means of the Millikan's oil drop apparatus.

9. Thomson's e/m measurement - To determine the charge to mass ratio of the electron by Thomson's method using a CRT.

10. Thermionic work function - To determine the thermionic work function of the material of the cathode of the given vacuum diode/triode from the characteristics at different filament currents.

11. Optical fibre characteristics - To determine the numerical aperture, attenuation and band width of the given optical fibre specimen

12. Frank-Hertz experiment - To measure the critical ionization potentials of Mercury by drawing current vs. applied voltage in a discharge tube

13. Fabry Perot etalon - Determination of wavelength and thickness of air film

14. Thermo emf of bulk samples – Al, Cu, Brass etc.

15. Determine the thermal conductivity of the given bulk specimen using the given setup.

PHY3C16 : MODERN PHYSICS PRACTICAL II (2 Credits)

(Any 8 experiments to be done. Examination will be of 3 hours duration)

1. G.M. Counter plateau and statistics of counting - To obtain the plateau, operating voltage and to verify the distribution law satisfied by the radioactive decay.

2. Absorption coefficient for gamma rays -To determine the absorption coefficient of the given material for Cs-137 gamma rays using a G.M. Counter.

3. Absorption coefficient for beta rays -To determine the absorption coefficient of the given material for beta rays from beta sources using a G.M. Counter.

4. Feather analysis – End point energy - To determine the end point energy of the beta particles from a given source using Feather analysis.

5. Scintillation counter - To calibrate the given gamma ray (scintillation) spectrometer using standard gamma sources and to determine the energy of an unknown gamma ray source.

6. Compton scattering - To verify the theoretical expression for the energy of the Compton scattered gamma rays at a given angle using a Scintillation gamma spectrometer / determine the rest mass energy of the electron.

7. To verify the inverse square law in the emission of gamma rays from a radioactive source.

8. Half life of Indium – thermal neutron absorption - To determine the half life of In-116 by irradiation of In foil with neutron and beta counting using a GM counter.

9. Alpha spectrometer - To calibrate the given alpha spectrometer and determine the resolution.

10. Photoelectric effect in lead - To get the spectrum of X rays emitted from lead target by photo electric effect using Cs-137 gammas

11. Band gap energy of the given thin film sample by four probe method.

12. ESR spectrometer – Determination of g factor

13. Find the thermal conductivity of the given crystal sample.

14. Obtain the uv-visible absorption spectra of the given liquid/solid.

15. Determine the dielectric constant of the given material using LCR high tester.

16. Obtain the powder diffraction data of the given sample and study its crystalline behaviour. Compare the values with ICDD.

17. Obtain the surface features of a thin film sample using AFM.

18. Find the etched pattern of the given crystal using optical microscope.

FOURTH SEMESTER

PHY4C17 : SPECTROSCOPY (4 Credits, 72 hrs)

Objectives:

- Understand the rotational energy states of various types of molecule and the interaction of electromagnetic radiation with molecules
- Understand vibrational energy state of molecules and interaction of electromagnetic radiations in IR region
- Understand the phenominon of raman scattering and nature of raman spetra
- Understand the electronic excitation states of the molecule and interaction of UV-visible radiation with molecules L
- To understand the mechanism of spin resonances and interaction of electromagnetic radiations under resonance conditions of spin reorientation

After completion of the full course the student should be able to	Cognitive level
Able to interpret the microwave spectra of the molecule and deduce various parameters	Apply
Able interpret the IR spectra of molecule and deduce information about the molecule	Apply
Able to deduce molecular structure from combined analsis of raman and IR spectra	Apply
Able to interpret the UV-visible spectra and deduce properties of the molecules in ground and excited states	Apply
Able to identify the chemical environment of the molecule and apply the concept for imaging internal anatomy of samples	Analyse

1. **Microwave Spectroscopy** : Introduction, The Spectrum of a non rigid rotator, Example of HF, Spectrum of a symmetric top molecule, Examples, Instrumentation for Microwave Spectroscopy-Information derived from rotational spectra. (12 hours)
   Text : Relevant sections of Banwell and McCash and Barrow

2. **Infrared Spectroscopy** : Vibrational energy of an anharmonic oscillator – diatomic molecule (Morse Curve), IR spectra - Spectral Transitions and Selection Rules, The Vibration – Rotation Spectra of diatomic molecule, Born-Oppenheimer Approximation, Effect of Break down of Born-Oppenheimer Approximation, Normal modes of vibration of H2O and CO2, Spectra of symmetric top molecules, Examples, Instrumentation for Infrared Spectroscopy, Fourier transform IR spectroscopy. (14 hours)
   Text : Relevant sections of Aruldas, Banwell

3. **Raman Spectroscopy** : Introduction, Rotational Raman Spectrum of diatomic and poly atomic molecules- linear and Symmetric top molecules, Vibrational Raman Spectrum of a Symmetric top molecule, Combined use of Raman and Infrared Spectroscopy in structure determination, Examples, Instrumentation for Raman Spectroscopy, Laser Raman Spectroscopy, Non linear Raman effects, Hyper Raman Effect, Stimulated Raman effect and inverse Raman effect. (14 hours)
Text : Relevant sections of Aruldas, Banwell & McCash and Straughan & Walker
Book for reference : Raman spectroscopy by Long D.A., Mc Graw Hill (1977)

4. **Electronic Spectroscopy of molecules** : Vibrational coarse structure of electronic spectra, Vibrational analysis of band systems, Deslander's table, Progressions and sequences, Information derived from vibrational analysis, Franck-Condon Principle, Rotational fine structure and the R, P and Q branches, Fortrat Diagram, Dissociation Energy, Example of iodine molecule. (13 hours)
Text : Relevant sections of Aruldas, Banwell & McCash

5. **Spin Resonance Spectroscopy** : Interaction between nuclear spin and magnetic field, Level population, Larmour Precession, Resonance condition, Bloch equations, Relaxation times, Spin-Spin and spin-lattice relaxation, The Chemical shift, Instrumentation for NMR spectroscopy, CWNMR and FTNMR, Imaging, Electron Spin Spectroscopy of the unpaired electron, Total Hamiltonian, Fine structure, Electron-Nucleus coupling and hyperfine structure, ESR spectrometer, Mossbauer Spectroscopy : Resonance Fluorescence of gamma - rays, Recoilless emission of gamma - rays and Mossbauer Effect, Chemical shift, Effect of electric and magnetic fields, Example of Fe57, Experimental techniques. (19 hours)
Text : For ESR & NMR : Relevant sections of Aruldas, Banwell & McCash and Straughan & Walker; For Mossbauer Effect : Aruldas and G.K. Wertheim

Text book :

1. G Aruldas : "Molecular structure and Spectroscopy" (Prentice Hall of India ,2002)
2. C.N.Banwell and E.M. McCash : "Fundamentals of Molecular Spectroscopy", (Tata McGrow Hill (1994)
3. Gunther K. Wertheim : "Mossbauer Effect : Principles and applications, (Academic Press)
4. Straughan and Walker (Eds): " Spectroscopy"- Vol. I and II (Chapman and Hall)
5. G.M. Barrow : "Introduction to molecular Spectroscopy", (McGraw Hill)

Books for Reference:

Long D.A : "Raman spectroscopy " (Mc Graw Hill (1977)

ELECTIVE III

(Any one among PHY4E07 to PHY4E10)

PHY4E07: ADVANCED NUCLEAR PHYSICS (4 Credits, 72 hrs)

Objectives

- The course enables the student to:
- Strengthen the fundamentals of the nuclear models and the necessity of shell model
- Understand the nuclear deformation, properties and nuclear models for understanding the structure of nuclei and reaction mechanism
- Learn more of the collective models and application to rotational and vibrational nuclei.
- Illuminate on nuclear reactions such as fusion and fission
- Demonstrate the mechanism of particle accelerators and detector technologies

Course Outcome: **After completion of the full course the student should be able to**	Cognitive level
C.O.1: Explain the basics of nucleus, nuclear properties and necessity of shell model and collective models.	Analyse
C.O.2: Apply these models to explain the filling up of neutron and protons inside shells and explain the properties of the nuclei.	Apply
C.O.3: Calculate the moment of inertia of any rotational nuclei, energy levels of vibrational nuclei	Evaluate
C.O.4:Explain the different models of particle accelerators and their use.	Analyse

1. **Nuclear Shell Model**: Shell structure and magic numbers, The nuclear one particle potential, spin orbit term, realistic one body potentials, Nuclear volume parameter, single particle spectra of closed shell + 1 nuclei, Harmonic oscillator and infinite square well potentials in 3- dimensions, coupling of spin and orbital angular momentum, magnetic dipole moment and electric quadrupole moment, Schmidt diagram; Single particle orbitals in deformed nuclei, perturbation treatment, asymptotic wave functions, single particle orbitals in an axially symmetric modified oscillator potential. (19 Hours)

Text :S.G. Nilsson and I. Ragnarsson: “Shapes and Shells in Nuclear Structure”, **(**Cambridge University Press; Revised ed. Edition, 2005)

2. **Nuclear Collective Models**: Nuclear rotational motion- rotational energy spectrum and wave functions for even-even and odd A nuclei - Nuclear moments- collective vibrational excitations, Rotational Bands – The particle rotor model, strong coupling- deformation

alignment, Decoupled bands - rotational alignment; two particle excitations and back-bending; Fast nuclear rotation- the cranking model; Rotating harmonic oscillator. (13 Hours)

Text : 1. R.R. Roy and B.P. Nigam :“Nuclear Physics- Theory and Experiment”, (Wiley Eastern)
2. S.G. Nilsson and I. Ragnarsson: “Shapes and Shells in Nuclear Structure”, **(**Cambridge University Press; Revised ed. Edition, 2005)
3. M K Pal : “Theory of Nuclear Structure”,(East West Press Pvt. Ltd).

3. **Nuclear Reactions**: Reactions and Cross-sections, Resonances, Breit-Wigner formula for l = 0, Compound Nucleus formation, continuum theory, statistical theory, evaporation probability, Heavy ion reactions. (12 Hours)
Text : 1. R.R. Roy and B.P. Nigam :“Nuclear Physics- Theory and Experiment”, (Wiley Eastern)
2. Kenneth S. Krane : “ Introductory Nuclear Physics”, (Wiley)

4. **Nuclear Fission**: The semi-empirical mass formula , The stability peninsula, nuclear fission and the liquid drop model, some basic fission phenomena, fission barrier. Nuclear Fission- cross- section, spontaneous fission, Mass and energy distribution of fragments, Statistical model of Fission. (14 Hours)
Text : R.R. Roy and B.P. Nigam :“Nuclear Physics- Theory and Experiment”, (Wiley Eastern)

5. **Accelerators**: Electrostatic accelerator, cyclotrons, synchrotrons, linear accelerators , colliding beam accelerators. (14 Hours)
Text: R.R. Roy and B.P. Nigam :“Nuclear Physics- Theory and Experiment”, (Wiley Eastern)
1. Samuel M. Wong : “Introductory Nuclear Physics”, (Prentice Hall India 1996)

2. H.S. Hans : “Nuclear Physics – Experimental and theoretical”, (New Age International, 2001)

PHY4E08 : ADVANCED ASTROPHYSICS (4 Credits, 72 hrs)

Objectives:

- Understand various radiative process involved in Astrophysics
- Understand different types of variable stars.
- Acquire the basic understanding of morphological classification of galaxies.
- Understand general relativistic formulation for the study of Universe
- Compare different Cosmological models.

Course Outcome: **After completion of the full course the student should be able to**	Cognitive level
C.O.1: Connect the observation of radiation in a particular wavelength from a celestial source to its possible nature and state.	Apply
C.O.2: Understand the physics involved in the formation of variable stars.	Understand
C.O.3: Compare various models involved in the formation and evolution of galaxies.	Analyse
C.O.4: Explain how to develop cosmological models.	Apply

1. **Radiative Process**: Theory of Black Body Radiation-Photoelectric Effect-Pressure of Radiation -Absorption and Emission spectra - Doppler Effect - Zeeman Effect-Bremsstrahlung – Synchrotron Radiation - Scattering of Radiation - Compton Effect - and Inverse Compton effect. (10 Hours)
   Text : Baidyanath Basu, Ch 2

2. **Variable stars**: Classification of Variable stars – Cepheid variables – RV Tauri variables - Mira variables - Red Irregular and Semi-regular variables – Beta Canis Majoris Variables–U Geminorum and Flare stars– Theory of Variable stars. (10 hours)
   Text : Baidyanath Basu, Ch 8

3. G**alaxies**: The Milkyway galaxy - Kinematics of the Milkyway – Morphology – Galactic Centre – Morphological classification of galaxies – Effects of environment – Galaxy luminosity function – The local group – Surface photometry of galaxies - ellipticals and disk galaxies – Globular cluster systems – Abnormal galaxies- Active galactic nuclei. (24 Hours)
   Text : Binney & Merrifield, Ch 4

4. **General Relativity**: General Considerations - Connection Between Gravity and Geometry - Metric Tensorand Gravity - Particle Trajectories in Gravitational field - Physics in curved space- time – Curvature -Properties of Energy and momentum

Tensor - Scwarzchild Metric - Gravitational Collapse and Black Holes-
Gravitational Waves. (16 Hours)
Text : Padmanabhan, Vol 2, Ch 11

5. **Cosmology**: Cosmological Principle - Cosmic Standard Coordinates - Equivalent Coordinates –Robertson-Walker Metric - The Red Shift - Measures of Distance – Red Shift Versus Distance Relation -Steady State Cosmology. (12 Hours)
Text : Narlikar, Sections 3.1-3.8

Books for Reference :

1. Steven Weinberg : "Gravitation & Cosmology", (John Wiley (1972)
2. T. Padmanabhan : "Theoretical Astro Physics", Vol 1 and 2 (Cambridge University Press, 2000)
3. Ajit K Kembhavi and Jayat V Narlikar: "Quasars and Active Galactic Nuclei", (Cambridge University Press, 1999)
4. F. Shu : "The Physical Universe, An Introduction to Astronomy", (Oxford University Press, 1982)
5. Fred Hoyle, Geoffrey, Jayant V Narlikar :"A Different Approach to Cosmology", (Cambridge University Press, 2000)
6. Baidyanath Basu :"An Introduction to Astro Physics", (Prentice Hall India , 1997)
7. R.C. Bless : "Discovering the Cosmos", (University Science Books,1996)
8. V.B. Bhatia : "Text Book of Astronomy and Astrophysics with Elements of Cosmology", (Narosa publications, 2001)
9. B.W. Carroll & D.A. Ostille : "Modern Astrophysics", (Addison Wesley, 1996)
10. J. Binney & M. Merrifield :"Galactic Astronomy",(Princeton University Press)
11. J. Binney & S. Tremaine :"Galactic Dynamics", (Princeton University Press)
12. J. V. Narlikar,:"An Introduction to Cosmology", (Third Edition, Cambridge University Press, 2002)

PHY4E09 : INFORMATION THEORY AND QUANTUM COMPUTING
(4 Credits, 72 hrs**)**

1. **Basics of Quantum Theory**: Fundamental postulates-Dual vectors- Spectral theorem- Tensor products- Entangled state - Schmidt decomposition theorem- Pure state and Mixed state, Density matrices. (12 hrs)

2. **Qubits and Quantum Measurement**: Qubits- Bloch Sphere-Multi Qubit systems-Bell state-time evolution of a closed system- measurement - EPR Paradox-mixed states and general quantum operations-partial trace- general quantum operations. (15hrs)

3. **Quantum Gates and Quantum Computation :** Quantum Computation definitions - Simple gates-CNOT- CCNOT- Walsh-Hadamard Transformation SWAP Gate and Fredkin gate- Correspondence with logc gates-No-Cloning Theorem-Dense Coding and Quantum Teleportation- Universal Quantum Gates-Quantum Parallelism and entanglement. (19 hrs)

4. **Quantum Algorithms:** Probabilistic versus quantum algorithms - Deuths Algorithm- Deuths -Jozsa Algorithm - Simon' Algorithms. (12 hrs)

5. **Quantum Information :** Classical versus Quantum information-quantum entropy-relative and conditional entropies- quantum mutual information- fidelity and coherent information-quantum channels- quantum channel capacities-quantum communication complexity. (14 hrs)

Text Books

1. Philip Kaye, Raymond Laflamme and Michele Mosca :"An Introduction to Quantum Computing",(Oxford University Press, 2007)
2. Mikio Nakahara and Tetsuo Ohmi :"Quantum Computing: From Linear Algebra to Physical Realizations", (CRC Press, 2008)
3. Gregg Jaeger :"Quantum Information: An Overview",(Springer, 2007)

Books for Reference:

1. VK Shrivastava :"Quantum Physics and Measurement",(ABD Pub., 2007)
2. George Greenstein & Arthur G Zajonc :"The Quantum Challenge",(Narosa, 2006)
3. Daniel Bes : "Quantum Mechanics", (Springer; 2007)
4. Kenichi Konishi & Giampiero Paffuti : "Quantum Mechanics: A New Introduction",(Oxford, 2009).
5. Kurt Gottfried & Tung-Mow Yan :"Quantum Mechanics: Fundamentals", (Springer, 2004)

PHY4E10 : ADVANCED MATERIALS SCIENCE (4 Credits, 72 hrs**)**

Objectives:

- To impart knowledge on various imperfections in solids.
- To learn the phase diagrams, surface of thin films and morphology.
- To gain knowledge on structure of ceramic materials and their features.
- Learn the importance of unsaturated hydrocarbons, polymers and their applications.
- To understand iquid crystals, nanomaterials and quasi crystals

Course Outcome: **After completion of the full course the student should be able to**	Cognitive level
C.O.1: Define different types of imperfections in crystals.	Understand
C.O.2: Analyse different phase diagrams and elucidate the expected properties.	Apply
C.O.3:Identify different types of silicates and understand the importance and application of ceramic materials.	Analyse
C.O.4:Explain unsaturated hydrocarbons, different types of polymerization and its application.	Analyse
C,O,5:Define types of liquid crystals, quasi crystals, fullerenes, nano structures and their applications.	Understand

1. **Imperfections in Crystals** : Thermodynamics of Schottky and Frenkel Defects, Equilibrium number of Point Defects as a function of temperature, Interstitial Diffusion, Self-diffusion, Determination of Diffusion constant, Edge and Screw Dislocations, Energy of Dislocation, Dislocation motion, Dislocation Multiplication: Frank-Read mechanism, Work Hardening of Metals, Exercises. (12 Hours)

2. **Alloys, films and surfaces** : Binary phase diagrams from Free energy considerations, case of complete miscibility, Gibbs phase rule, The lever rule, Rules of solid solubility, Hume-Rothery Electron compounds, case of limited solid solubility, the Eutectic temperature. Study of surface topography by multiple beam interferometry, Determination of film thicknesses, Qualitative ideas of surface crystallography, scanning, tunneling and atomic force microscopy, Electrical conductivity of thin films, Exercises. (20 Hours)

3. **Ceramic Materials** : Silicate structure, Polymorphism, Solid solution, Non-ductile fracture, Plastic deformation of layered structures, Viscous deformation of glass, Electrical properties of ceramics, Application of ceramic materials, Exercises(9 hours)

4. **Polymers: -** Unsaturated hydrocarbons, Polymer size, Addition polymerization, Copolymerization, Condensation polymerization, Thermoplastic and thermosetting resins, Elastomers, Cross-linking, Branching, Application of polymers, Exercises. (12 Hours)

5. **Liquid crystals, Quasi crystals and Nanomaterials**: Structure and symmetries of liquids, Liquid crystals and amorphous solids, Application of liquid crystals, Aperiodic crystals and quasicrystals, Formation and characterization of Fullerenes and tubules, Carbon nanotube based electronic devices, Synthesis and properties of nanostructured materials, Experimental techniques for characterizing nanostructured materials, Quantum size effect and its applications, Exercises. (19 Hours)

Books for Reference:

1.“Solid State Physics”, A.J. Dekker (MacMillan, 1958)
2.“Introduction to Solid State Physics”, C. Kittel(Wiley Eastern, 1977).
3.“Elements of Materials Science”, L.H. Van Vlack (Addison Wesley)
4.“Physics of Thin Films”, K.L.Chopra
5.“Thin Films”, O.S.Heavens
6.“Multiple Beam Interferometry”, Tolansky
7.“Transmission Electron Microscopy”, Thomas
8.“The Physics of Quasicrystals”, Ed. Steinhardt and Ostulond
9.“Handbook of Nanostructured Materials and Nanotechnology”, Ed. Harisingh Nalwa

ELECTIVE IV

(Any one among : PHY4E11 to PHY4E14)

PHY4E11 : RADIATION PHYSICS (4 Credits, 72 hrs)

Objectives:

- To classify radiations as ionising and nonionising and find the sources of each category.
- To identify the unique interaction mechanisms of each category of radiation,
- To quantify the radiation and understand the various units used in dosimetry, radiotherapy and environmental radioactivity studies.
- To understand the effect of radiation exposure to biological cells at a microscopic level.
- To identify the appropriate shielding materials and mechanisms to protect man and materials from damage due to excess exposure.

Course Outcome: **After completion of the full course the student should be able to**	Cognitive level
C.O.1: Verify through experiments that radiations are primarily divided into ionising and nonionising. Also understand different sources under each category. Production methods of each will also be identified.	Analyse
C.O.2: Anaalyse the interaction mechanism of each category, giving emphasize to scattering and absorption.	Analyse
C.O.3: Exposure leads to beneficial or harmful effects. Understands details of both.	Understand
C.O.4: Both stochastic and deterministic effects will be analysed and will be useful in planning for diagnosis and treatment.	Analyse
C.O.5: Implement proper shielding in laboratory where sources are stored and in transportation.	Analyse`
C.O.6: After M.Sc Physics, if PG Diploma courses of BARC or other recognised institutions are carried out, there are plenty of opportunities for radiation physicists in an outside the country.	Apply

1. **Radiation source : Types of radiations**, ionizing, non ionizing, electromagnetic, particles, neutral -gamma-neutrino-neutron, charged alpha, beta, gamma, and heavy ion sources, radioactive sources – naturally occurring production of artificial isotopes, accelerators–cyclotrons, nuclear reactors. **(12 hours) {Ref 1, 2}**

2. **Interaction of radiations with matter :** Electrons – classical theory of inelastic

collisions with atomic electrons, energy loss per ion pair by primary and secondary ionization, specific energy loss, bremsstrahlung, range energy relation, energy and range straggling Heavy charged particles – stopping power, energy loss, range and range – energy relations, Bragg curve, specific ionization, Gamma rays – Interaction mechanism – Photoelectric absorption, Compton scattering, Pair production, gamma ray attenuation, attenuation coefficients, Elastic and inelastic scattering, Cross sections, linear and mass absorption coefficients, stopping power, LET,Neutrons – General properties, fast neutron interactions, slowing down and moderation. **(17 hours)** **{Ref 1,2}**

3. **Radiation quantities, Units and Dosimeters :** Particle flux and fluence, calculation of energy flux and fluence, curie, becquerel, exposure and its measurements, absorbed dose and its relation to exposure, KERMA, Biological effectiveness, wighting factors, (W_R and W_T), Equivalent dose, Effective dose, Dosimeters, Primary and secondary dosimeters, Pocket dosimeter, Films and solid dosimeter (TLD and RPL), Clincal and calorimetric devices , Radiation survey meter for area monitoring. **(15 hours)** **{Ref 2,3}**

4. **Biological effects :** Basic concepts of cell biology, Effects of ionizing radiations at molecular, sub molecular and cellular levels, secondary effects, free radicals, deterministic effects, stochastic effects,,, Effects on tissues and organs, genetic effects, Mutation and chromosomal aberrations, applications in cancer therapy, food preservation, radiation and sterilization. (12 hours) **{Ref 3,4}**

5. **Radiation protection, shielding and transport** : Effective radiation protection, need to safeguard against continuing radiation exposure, justification and responsibility, ALARA, concept of radiologic practice. time distance and shielding, safety specifications. method of radiation control, Shielding factor for radiations, Choice of material, Primary and secondary radiations, Source geometry, Beta shielding, Gamma shielding, neutron shielding, Shielding requirements for medical, industrial and research facilities, handling of the source, sealing, transport and storage of sealed and unsealed sources. records, spills. waste disposal. (16 hours) **{Ref 3,4,5}**

Books for Reference:

1. .G.F.Knoll : "Radiation detection and measurement",(John Wiley & sons, Newyork, 2000)
2. K.Thayalan :"Basic radiological physics",(Jaypee brothers medical Publishers, New Delhi, 2003)
3. W.J. Meredith and J.B. Masse: " Fundamental Physics of radiology", (Varghese publishing house , Bombay, 1992)
4. M.A.S. Sherer, P.J.Visconti, E.R Ritenour :"Radiation Protection in medical radiography",(Mosbey Elsevier,2006)
5. Lowenthal G.C and Airey P.L.:" Practical applications of radioactivity and nuclear radiation sources",(Cambridge University Press, 2005)

PHY4E12: NANO MATERIALS AND TECHNOLOGY (4 Credits, 72 hrs**)**

Objectives:

- To gain a detailed understanding of nanoparticle systems.
- To understand the quantum properties of nanomaterials.
- To understand different methods for the synthesis of nanomaterials
- To understand how to design advanced nanomaterials.
- To familiarize various characterization techniques.

Course Outcome: **After completion of the full course the student should be able to**	Cognitive level
C.O.1: To understand 0-d,1-d,2-d,3-d nanosystems and to identify the specific properties of nanosized alloys, metals, semiconductors etc.	Analyse
C.O.2: To correlate the optical, electronic, photonic, dielectric, magnetic etc. behaviour of nanomaterials with their quantum properties.	Apply
C.O.3: To learn different synthesis methods based on physical and chemical principles.	Understand
C.O.4: Gain the know-how to design advanced nanomaterials like integrated nanocomposites, functional materials etc.	Analyse
C.O.5: Develop skills to use XRD, SEM,AFM,SPM,SIMS etc.	apply

1. **Nanomaterials an overview :** Natural and classical nanosystems. Low dimensional materials. Zero -, one -, two - and three dimensional nanostructures-quantum dots, quantum wells, quantum rods, quantum wires. Nanosized metals and alloys, semiconductors, ceramics. Fullerens, Nanotubes. Comparison with bulk materials. Application in electronics, communication, medicine etc., Exercises. (12 Hrs)

2. **Quantum states of nanoparticles** - Quantum confinement in semiconductors-particle in a box like model for quantum dots, effective mass approximation, weak confinement, strong confinement, Size and shape dependency in optical, emission, electronic, transport, photonic, refractive index, dielectric, mechanical, magnetic, non-linear optical; catalytic and photocatalytic properties, Exercises. (17 Hrs)

3. Synthesis of nanomaterials

Physical techniques (bottom up approach) - Physical vapour deposition, electron beam evaporation, sputter deposition, laser ablation, ion beam mixing, plasma deposition. Physical methods-mechanical milling, laser ablation, sputtering, microwave plasma etc. Chemical methods-chemical reduction and oxidation, sol-gel processes, photolysis, radiolysis, metal-organic chemical vapor deposition.

molecular self-assemblies, surface engineering, Exercises. (15 Hrs)

4 **Designing of advanced nanomaterials-** Integrated nanocomposites, functional nanomaterials and nanostructured thin films. Development of nanoscale catalysts, sensitizers, sensors, composites, polymers, ceramics, biomaterials, pharmaceuticals, nanopaints, nanofluids, optical, fluorescent, electronic, magnetic and photonic devices, future perspectives of nanotechnolgy, Exercises. (14Hrs)

5 **Characterization techniques**: X-ray diffraction technique, Scanning Electron Microscopy - environmental techniques, Transmission Electron Microscopy including high-resolution imaging, Surface Analysis techniques -AFM, SPM, STM, SNOM, ESCA, SIMS- Nanoindentation, Small-angle X-ray and neutron scattering, DLS, Ellipsometer, Confocal microscopy, Exercises. (14 Hrs)

Text Books

1. Physics of Low Dimensional Structures, J. H. Davis, (Cambridge Press), 1998.
2. Semiconductor Quantum Dots, L. Banjaj and S. W. Koch.
3. Low Dimensional Semiconductors, M. J. Kelly, Clarendon,1955.
4. NanoTechnology:Principles and Practices, Sulabha Kulkarni, CPC-New Delhi 2007
5. Nano:The essentials:Understanding nanoscience and Nanotechnology, Pradeep T TMCGH, New Delhi 2007
6. Characterization of Materials, J. B. Wachtman and Z. H. Kalman, Butterworth-Heinmann, USA, 1993.
7. Experimental Physics, Modern Methods, R. A. Dunlop.
8 Instrumental Methods of Analysis, H. H. Willard, L. L. Merritt, J. A. Dean and F. A. Settle ,(CBS Pub.), 1986.

PHY4E13 : QUANTUM FIELD THEORY (4 Credits, 72 hrs)

Objectives:

- To classify fields as classical fields and quantum fields and also as relativistic and nonrelativistic.
- To analyse in detail the procedure for quantisation.
- To illustrate the procedure for quantising spin-1/2 field, i.e. Dirac field.
- To analyse various interactions as corrent-current interactions.
- To introduce path integral formalism in quantum mechanics.

Course Outcome: **After completion of the full course the student should be able to**	
C.O.1: Understand the key concept of the use of harmonic oscillators as oscillatory quanta is introduced. Can carry out the canonical quantisation of electromagnetic and Schrodinger field.	Understan d
C.O.2: Substantiate that for studying the behaviour of identtical many particle system, like atoms, molecules, nuclei, quantisation is a must. Quasi particles are also introduced.	Apply
C.O.3: Understand electron-photon interaction at a more fundamental level.	Understan d
C.O.4: All types of interactions can be analysed as current-current interactions. Nuclear decays can also be explained using this assumption.	Analyse
C.O.5: Tools like Feynman propagator and Greens functions can be made use of here.	Apply

1. **Classical Field Theory** : Harmonic oscillator, The linear chain- classical treatment, the linear chain – quantum treatment, classical field theory, Hamiltonian formalism, Functional derivatives , Canonical quantization of non-relativistic fields, Lagrangian and Hamiltonian for the Schroedinger field, Quantization of fermions and bosons, Normalization of Fock states. (14 hours)
Text Book : "Field Quantization" Greiner and Reinhardt (Spinger-Verlag -1996)

2 – **Canonical quantization of Klein Gordon and photon fields** : The neutral Klein Gordon field Commutation relation for creation and annihilation operators, Charged Klein – Gordon field, Invariant commutation relations, Scalar Feyman propagator, Canonical quantization of photon field – Maxwells equations,

Larangian density for the Maxwell field, Electromagnetic field in the Lorentz gauge, Canonical quantization of the Lorentz gauge – Gupta-Bleuler method, Canonical quantization in the Coulomb gauge. (20 hours)
Text Book : "Field Quantization" Greiner and Reinhardt (Spinger-Verlag -1996)

3. **Canonical quantization of spin ½ fields** : Lagrangian and Hamiltonian densities for the Dirac field, Canonical quantization of the Dirac field, Plane wave expansion of the field operator, Feyman propagatorn for the Dirac field. (12 hours)
Text Book : "Field Quantization" Greiner and Reinhardt (Spinger-Verlag -1996)

4. **Interacting quantum fields and Quantum Electrodynamics** : The interaction picture, Time evolution operator, Scattering matrix, Wick's theorem, Feynman rules for QED, Moller scattering and Compton scattering.
(12 hours)
Text Book : "Field Quantization" Greiner and Reinhardt (Spinger-Verlag -1996)

5. **The path integral method** : Path integrals in non-relativistic Quantum Mechanics, Feynman path integral, Multidimensional path integral, Time ordered product and n-point functions, Path integrals for scalar quantum fields, The Euclidian field theory, The Feynman propagator, Generating functional and Green's function, Generating functional for interacting fields, Exercises. (14 hours)
Text Book : "Field Quantization" Greiner and Reinhardt (Spinger-Verlag -1996)

References :

1."Quantum Field theory", Lewis H. Ryder (Cambridge University Press -1995)
2."Field Theory – A modern primer" – Pierre Ramond (Bengamin – 1996)
3."Quantum Field theory", Itzyskon and Zuber (McGraw Hill – 1989)
4."Quantum Field theory", Karson Huang (Wiley)

PHY4E14 : ADVANCED ELECTRONICS (4 Credits, 72 hrs)

Objectives:

- To understand evolution of microprocessors and its architecture giving reference to Intel-8085
- To understand the basics of microprocessor interfacing with different general purpose programmable peripheral devices and their architecture and working.
- To understand the basics of assembly language programming for arithmetic and logical operations and transferring data to and fro to the peripheral devices.
- To understand the architecture and working of a typical microcontroller in comparison with a microprocessor.
- To understand the basics of assembly language programming of a microcontroller for arithmetic and logical operations and transferring data to and fro to the peripheral devices.

Course Outcome: **After completion of the full course the student should be able to**	
C.O.1: Students are able to design and explain the method of solving a problem with different operations of a microprocessor.	Analyse
C.O.2: Students are able to write simple codes for simple general purpose operations which involve data flow between different peripheral devices.	Apply
C.O.3: Students are able to write simpler programs for series arithmetic and logical operations and data transfer to and fro from the microprocessor to the peripheral devices.	Apply
C.O.4: Students are able to design and explain the method of solving a problem with different operations of a microcontroller and distinguishes it from a microprocessor.	Analyse
C.O.5: .Students are able to write simpler programs for series arithmetic and logical operations and data transfer to and fro from the microcontroller to the peripheral devices.	Apply

1 **Microprocessors Architecture:** Evolution of microprocessors, 4,8,16,32 bit microprocessors, Organization and architecture of microcomputer of Intel 8085:operations, Pin-diagram, Registers, Flags, Memory operations (R/W), Tri-stage buffer, Bus (Address, Data and control, I/O operations, Address data demultiplexing using 74LS373, machine cycles and bus timings, memory read/write machine cycles. **(14 Hours)**
(Text: R.S. Gaonkar)

2. **Peripheral Devices and Interfacing:** Generation of control signals for memory and I/O devices, I/O Ports-Intel 8212, 8155, Programmable peripheral interface-8255, Programmable DMA controller 8257, Programmable interrupt Controller 8259, Programmable communication interface 8251, Programmable interval timer/counter 8253. Special Purpose devices: The 8279 Programmable Keyboard/Display interface. **(14 Hours)**
(Text: B. Ram)

3. **Assembly Language Programming and Applications:** Machine language and assembly language programming, Simple arithmetic operations: addition, subtraction, multiplication and division, finding largest and smallest, sorting etc. Applications: Microprocessor based data acquisition system: A/D converter, Sample and Hold circuit, Analog multiplexer, ADC 0800, D/A Converter, DAC 0800, Realization of A/D Converter using D/A Converter. Delay subroutine, 7 segment LED display, decoders/drivers-7448, Interfacing of 7 segment display, Display of decimal and alphanumeric characters, Measurement of frequency, Voltage, Generation of square wave/pulse. Traffic control system. **(15 Hours)**
(Text: B. Ram)

4. **Microcontrollers:** Comparisons of Microprocessors and Microcontrollers, Microcontroller survey 4-32 bits (Z80, 8051, PIC, Atmel AVR) Microcontroller (Atmega16) Architecture: block diagram, Ports, Registers, ALU, Stack Pointer, Instruction execution timings, Interrupt handling, Memories (Flash, SRAM, EPROM), System Clock, Power management, A/D convertor, JTAG interface and Debug system, Interrupts, I/O ports, Data transfer schemes: programmed, DMA, Serial data transfer. **(15 Hours)**
(Text: Atmega 16 datasheet)

5. **Microcontroller programming and applications:** Hardware and software concepts, machine language assembly language and high level languages, C programming, moving data, logical operations, arithmetic operations, jump and call instructions, Interrupts and returns, JTAG interfacing and on chip debug system, Programming and debugging tools (STK 500, AVR dragon), C compilers (AVR studio), C program examples: controlling multiple LEDs, Traffic control system, Stepper motor, Temperature measurement and controlling. **(14 hours)**
(Text: R. Barnet et al; K. J. Ayala; Web resources from Atmel AVR)

Text Books:

1.Fundamentals of Microprocessors and Microcomputers, B. Ram, Dhanapati Rai & Sons. 3rd / Recent Edition.
2.Microprocessor Architecture, Programming and Applications: R. S. Gaokar, New Age International
3.Embedded C programming and the Atmel AVR, R. Barnet, L. O'cull, S. Cox,

Cengate Learning India.
4. 8051 Microcontroller: Kenneth J. Ayala, 2nd Edition, Thomson Delmar Learning, India.
5. Atmel AVR web resources. Atmega16, www.atmel.com

Books for Reference :

1. Microprocessors and Microcomputer system design, M. Rafiquazzaman , Universal Book Stall, New Delhi.
2. Microprocessor 8085 and its applications, 2nd Edition, A.Nagoor Kani, RBA Publications.
3. Embedded C programming and the Atmel AVR, R. Barnet, L. O'cull, S. Cox, Cengate Learning India.
4. PIC Microcontroller, an introduction to software and Hardware interfacing: H. W. Huang, Cengate Learning.
5. Embedded system design using C8051: H. W. Huang, Cengate Learning.
6. 8051 Microcontroller and embedded systems2nd Edition: Kenneth J. Ayala, Dhananjay V. Gadre, Cengate Learning, India.
7. Embedded systems and Robots: S. Ghoshal, Cengate Learning, India.

7.

PHY4C18 : PROJECT AND VIVA VOCE (8 Credits)

The project can be experimental or theoretical. The projects may be carried out either utilizing the facilities in the Department or elsewhere. In case they carry out the projects outside the Department, this shall in no way affect their minimum attendance for the theory papers. Also, they should obtain an attendance certificate from the outside institution where the work is carried out and also a certificate in the Project Report that the work had been carried out by the concerned student at that institution. The students shall prepare a detailed report on their work. This shall be attested by the teacher-in-charge concerned at the centre (and the relevant authority at the external institution, if the work had been carried out at some other centre). The students shall submit the project report before the commencement of the theory examinations. The same will be evaluated by a committee consisting of one external expert and the internal supervisor. A presentation of the project and a comprehensive viva voce on the project and the theory papers will be held and evaluated jointly by the external expert and the supervisor. (See Table 5). The Project shall also carry an internal evaluation to the extent of 20%.)