ST. TERESA'S COLLEGE
(AUTONOMOUS)
ERNAKULAM

CURRICULUM FOR
Master's Programme in
PHYSICS

Under Choice based Credit & Semester System

(2015 Admissions Onwards)

ST. TERESA'S COLLEGE (AUTONOMOUS), ERNAKULAM
DEPARTMENT OF PHYSICS

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9. Dr. Mariyam Thomas, Assistant Professor, Dept. of Physics, St Teresa's College, Ernakulam.

FACULTY MEMBERS WHO HAVE CONTRIBUTED TOWARDS CURRICULUM AND SYLLABUS IN PHYSICS

- **Dr Sajimol Augustine M Controller of Examinations & Head of the Dept. of Physics, St. Teresa's College Ernakulam**
- **Smt. Tessy Joseph, Associate Professor, Dept. of Physics, St. Teresa's College Ernakulam**
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- **Dr. Mariyam Thomas , Assistant Professor, Dept. of Physics, St. Teresa's College Ernakulam**
- **Ms Sreevidya T M, Guest Lecturer, Dept. of Physics, St. Teresa's College, Ernakulam**

ACKNOWLEDGEMENT

Research experience opens the door to many careers, not just further research. The maturity and experience gained during a research project provide an extra dimension to the qualification beyond that of a conventional two-year Masters programme. With this view the masters program in Physics is designed with equal emphasis on both classroom lectures and laboratory training with modern equipments. The prime objective is to frame a dynamic curriculum to accommodate the fast paced development in the knowledge of Physics.

Our principal Dr Sr Vinitha has always rendered motivation and help in all our ventures and she was the driving force behind this new curriculum. On behalf of Physics department, St Teresas college , I am happy to express my sense of gratitude to her.

In the preparation of this syllabi for Master's programme in Physics, we have received cheerful cooperation and many helpful comments from the members of Board of studies. It is a special pleasure to thank them for their remarks have been of great benefit to us in shaping the syllabus.

I wish to express my sincere thanks to Dr. N. J. Rao, Visiting Professor, International Institute of Information Technology, Bangalore in expressing and Dr. Rajan Gurukal, Former Vice-Chancellor, M.G. University, currently Visiting Professor, Centre for Contemporary Studies, Indian Institute of Science, for their selfless and timely service and for giving us all the help and guidance we needed . I also acknowledge my thanks to Dr. Achuthshankar S. Nair, Professor & Head, Department of Computational Biology and Bio Informatics, University of Kerala, for his invaluable suggestions.

At this juncture I feel deeply honoured in expressing my sincere thanks to Dr Sajimol Augustine M. Controller of examinations & Head of Department of Physics and Smt. Tessy Joseph, St Teresas college Ernakulam for coordinating the efforts to finalise the syllabus.

I would like to express my special appreciation and thanks to all the faculty members of our department whose collective work and fruitful discussions only enabled us to structure the syllabus into its final version.

I wish to record my gratitude to our students for their active participation in the discussions we had on various aspects of curricula.

I take this opportunity to express my profound gratitude and deep regards to the former faculty members of the Department Rev. Sr. Merita, Smt. Daisy A Punnose, Smt. K A Anne, Smt. Lucy V J, Dr. Annie Joseph Vallamattom and Smt. Shalini Rose who moulded us to face any challenge successfully in the academic realm.

The suggestions of Dr. Beena Job Associate Professor, Department of English and IQAC Co-ordinator and Dr. Latha Nair, Associate Professor, Department of English and member of the Governing Council helped to give shape to the overall structure.

Dr Rose P Ignatius,

Chairperson, Board of Studies in Physics
St. Teresa's College (Autonomous)

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ST. TERESA'S COLLEGE (AUTONOMOUS) ERNAKULAM
DEPARTMENT OF PHYSICS

M.Sc. PROGRAMME IN PHYSICS

Under Choice based Credit & Semester System

(2015 admissions onwards)

PREAMBLE

The aim of the post graduate education is to provide high quality education as well as a supportive learning environment for the students to reach their full academic potential. The higher education has to inculcate in students the spirit of hard work and research aptitude to pursue further studies in the nationally/internationally reputed institutions and laboratories as well as prepare them for a wider range of career opportunities in industry and commerce.

Board of Studies in Physics has designed the curriculum for M.Sc. Physics so as to monitor, review and enhance educational provision which ensures the Post Graduate Education remains intellectually demanding and relevant to current needs of physics graduates. The thrust is given in fostering a friendly and stimulating learning environment which will motivate the students to reach high standards, enable them to acquire real insight into physics and become self-confident, committed and adaptable graduates. With this in mind, we aim to provide a firm foundation in every aspect of Physics and to explain a broad spectrum of modern trends in Physics and to develop analytical, experimental, computational and mathematical skills of students.

Department of Physics, St. Teresa's College has always played a key role in designing the curriculum and syllabus of Mahatma Gandhi University and of various other Universities. The Board of Studies acknowledges and appreciates the good effort put in by the faculty members of Physics Department to frame the syllabus for M.Sc. Programme in Physics in the institution which will be implemented for the admissions from 2015 onwards.

GRADUATE ATTRIBUTES

Students on completion of the Master's programme in Physics should be able to demonstrate the following attributes

- Knowledge and understanding of the techniques of Physics at advanced levels that are internationally recognized.
- The ability to locate, analyse, evaluate and synthesise information from a wide variety of sources in a planned and timely manner.
- Global in outlook and competence.
- Commitment to the highest standards of professional endeavour and the ability to take a leadership role in the community.
- Ability to be a self - directed and active life long learner, fostering a healthy intellectual curiosity in Physics as well as in other disciplines and the ability to determine one's own learning needs and to organise one's own learning.
- Commitment to continuous learning and the capacity to maintain intellectual curiosity.
- Professional skills of team work with a high order in interpersonal understanding and communication.
- Confidence and readiness to the work using principles of Physics.
- Innovative with local and international perspective.
- Ability to acquire knowledge through research.
- Commitment to the pursuit of truth and academic freedom.

Also the course enables graduates to be ethically informed and be able to

- Demonstrate respect for the dignity of each individual and for human diversity.
- Have fundamental concern for justice and equity.
- Describe values, knowledge, skills and attitudes appropriate to the discipline and profession.
- Utilise information and communication and other technologies effectively for the betterment of society especially for uplifting weaker sections.

Objectives:

By the end of the first year (2nd semester),

1) The students should have attained a common level understanding in mathematical methods employed in Physics
2) A secure foundation in fundamentals of classical, quantum and statistical mechanics
3) A clear understanding of principles and techniques of condensed matter physics, thermodynamics, electronics and electrodynamics.
4) Developed their experimental and data analysis skills through a wide range of lab experiments.

By the end of the second year (4th semester),

1) The students should have been introduced to a broad spectrum of topics in Computational Physics and familiarised with additional relevant quantum mechanical techniques.
2) The students will be equipped with the knowledge of atomic, molecular, nuclear and particle physics.
3) Developed their experimental skills through a series of experiments supplementing major themes of the lecture courses.
4) Specialised in one of the frontier area of Physics via Choice Based learning of topics in one of elective bunches.
5) The student will be familiarized with one of the open elective course Optoelectronics, Software Engineering or Nanophotonics.
6) Undergone through the experience of independent work such as projects; seminars and assignments.
7) Obtained effective communication skills.

STRUTCURE OF MASTER'S PROGRAMME IN PHYSICS

Theory Courses

There are sixteen theory courses spread equally in allfour semesters in the M.Sc. Programme. Distribution of theory courses is as follows: There are twelve compulsory courses common to all students. Semester I and Semester II will have **four** core courses each and Semester III and Semester IV will have **two** core courses each. **Two** elective courses each will be done in Semester III and Semester IV. The fourth Elective course appearing in Semester IV is the Open Elective Course. There are three Elective Bunches and an Open Elective Bunch offered in the syllabus. Each bunch consists of three theory courses. The department can offer one Elective Bunch and any one course from the Open Elective Bunch in one academic year according to the interest of students. Total credits for the Master's programme in Physics is 80.

Practicals

All four semesters will have a course on laboratorypractical. The laboratory practical of Semesters I, II and III are compulsory courses. The Semester IV laboratory practical course will change, subjected to the Elective Bunch opted by the student. A minimum of 12 experiments should be done and a minimum of 8 experiments should be recorded in each semester. The practical examinations will be conducted at the end of even semesters only evaluated by one external and one internal examiner. The first and second semester examinations of laboratory practical courses will be conducted at the end of Semester II while the third and fourth semester practical examinations will be conducted at the end of Semester IV.

Project

The project of the PG programmme should be very relevant and innovative in nature. The type of project can be decided by the student and the guide (a faculty of the department or other department/college/university/institution). The project work should be taken up seriously by the student and the guide. The project should be aimed to motivate the inquisitive and research aptitude of the students. The students may be encouraged to present the results of the project in seminars/symposia. The conduct of the project may be started at the beginning of Semester III, with its evaluation scheduled at the end of Semester IV along with the practical examination. The project is evaluated by one externaland one internal examiner.

Viva Voce

A viva voce examination will be conducted by one external examiner along with the internal examiner at the time of evaluation of the project. The components of viva consists of subject of special interest, fundamental physics, topics covering all semesters and awareness of current and advanced topics with separate marks.

Course Code

The 12 core courses in the programmme are coded according to the following criteria. The first two letters of the code indicates the name of programme, ie. PH stands for Physics. Next digit is to indicate the semester. i.e., PH1 (Physics, 1st semester) followed by the letter C, E or OEindicating whether the course is core course or elective course or open elective course as the case may be. Next digits indicate course number. The letter/letters T/ P / PR/V follows it and is used to indicate theory/ practical/ project/viva. The last letter will be M which indicates whether the programme is for masters.

The elective courses are coded in similar pattern except the letters denoting the name of the course is replaced by letter E for elective and letter A/ B/ C indicating Elective bunch A/ B/ C. This is followed by one digit to indicate the course number in the bunch.

The lone Open Elective course appearing in Semester IV is coded as PH4OET1M. The letter OE stand for Open Elective and the digit 1 stands for the 1^{st} course of the Open Elective Bunch.

Laboratory Practical courses are coded as PH2CP01M indicating 2nd semester practical 1 course in M.Sc. Physics programme.

DISTRIBUTION OF COURSES AND CREDITS – a. CORE COURSES

SEM	Name of the course with course code	No.of Hrs/ week	No. of credits	Total Hrs/ SEM.	Exam Duration Hrs	Total marks	
						Sessional	Final
I	**PH1C01TM** Mathematical Methods in Physics- I	4	4	72	3	25	75
	PH1C02TM Classical Mechanics	4	4	72	3	25	75
	PH1C03TM Electrodynamics	4	4	72	3	25	75
	PH1C04TM Electronics	4	4	72	3	25	75
	PH2C01PM General Physics Practical	5	*	90	*	*	*
	PH2C02PM Electronics Practical	4	*	72	*	*	*
II	**PH2C05TM** MathematicalMethodsin Physics- II	4	4	72	3	25	75
	PH2C06TM Quantum Mechanics – I	4	4	72	3	25	75
	PH2C07TM Thermodynamics and Statistical Mechanics	4	4	72	3	25	75
	PH2C08TM Condensed Matter Physics	4	4	72	3	25	75

	PH2C01PM General Physics Practical	5	3	90	5	25	75
	PH2C02PM Electronics Practical	4	3	72	5	25	75
III	**PH3C09TM** Quantum Mechanics – II	4	4	72	3	25	75
	PH3C10TM Computational Physics	4	4	72	3	25	75
	PH4C03PM Computational Physics Practical	4	*	72	*	*	*
	PH4C1PRM Project/Dissertation	1	*	18	*	*	*
IV	**PH4C11TM**Atomic and Molecular Physics	4	4	72	3	25	75
	PH4C12TM Nuclear and Particle Physics	4	4	72	3	25	75
	PH4C03PM Computational Physics Practical	4	3	72	5	25	75
	PH4C1PRM Project/Dissertation	1	2	18	45 minute	25	75
	PH4C01VM Viva Voce	Nil	2	Nil		Nil	100

Table: ***Structure of PG CSS Physics M.Sc. Common Courses***

*Four/five hours will be allotted for each Practical course in all semesters. The practical examination will be conducted only in even semesters.

*One hour will be allotted for doing Project each in third and fourth semesters and project evaluation will be done at the end of fourth semester.

b.<u>ELECTIVE BUNCHES</u>

There are three Electives Bunches offered in this PGCSS Programme. Each elective consists of a bunch of **three** theory courses and **one** laboratory course. The first two theory courses of a bunch are placed in the Semester III, while the third theory course and the laboratory course will be done in Semester IV. The student can do only one Elective Bunch in an academic year. The course structure of the Electives Bunches is given below.

The Electives Bunches are named as,

(i) Bunch A : Electronics(ii) Bunch B : Material Science
(iii) Bunch C : Theoretical Physics

Elective	Semester	Name of the Course with Course Code	No. of hours per week	No. of Credits	No. of hrs per Sem.	Exam Duration	Total Marks	
							Sessional	Final
Bunch A: Electronics	III	**PH3EA1TM** Optoelectronics and Digital Signal Processing	4	4	72	3	25	75
	III	**PH3EA2TM**Microelectronics and Semiconductor Devices	4	4	72	3	25	75
	III	**PH4EA1PM** Advanced Electronics Practical	4	*	72	*	*	*
	IV	**PH4EA3TM**Instrumentation and Communication	4	4	72	3	25	75
	IV	**PH4EA1PM**Advanced Electronics Practical	4	3	72	5	25	75
Bunch B: Material	III	**PH3EB1TM**Solid State Physics	4	4	72	3	25	75

Science	III	**PH3EB2TM** Crystal Growth Techniques	4	4	72	3	25	75
	III	**PH4EB1PM** Material Science Practical	4	*	72	*	*	*
	IV	**PH4EB3TM** Nanostructures and Characterization	4	4	72	3	25	75
	IV	**PH4EB1PM**Material Science Practical	4	3	72	5	25	75
Bunch C : Theoretical Physics	III	**PH3EC1TM**Astrophysics	4	4	72	3	25	75
	III	**PH3EC2TM** Nonlinear Dynamics	4	4	72	3	25	75
	III	**PH4EC1PM** Special Computational Practical	4	*	72	*	*	*
	IV	**PH4EC3TM**Quantum Field Theory	4	4	72	3	25	75
	IV	**PH4EC1PM**Special Computational Practical	4	3	72	5	25	75

*Four hours will be allotted for elective Practical course in third and fourth semesters. The practical examination will be conducted only in even semesters.

c. OPEN ELECTIVES

The Open Elective Bunch has three specialized theory courses. The department will offer any one of these courses according to the interest of students. The 4th theory course of the Semester IV comes from the open elective bunch. The course structure of Open Elective Bunch is given in table below.

SEM	Name of the course with course code	No. of Hrs/ Week	No. of Credits	Total Hrs./ Sem.	Exam Duration Hrs.	Total Marks	
						Sessional	Final
IV	**PH4OE1TM** Optoelectronics & Optical Fiber Communication	4	4	72	3	25	75
	PH4OE2TM Software Engineeringand Web design	4	4	72	3	25	75
	PH4OE3TM Nanophotonics	4	4	72	3	25	75

Distribution of Credits

The total credit for the programme is fixed at 80.The distribution of credit points in each semester and allocation of the number of credit for theory courses, practicals, project and viva is as follows. The credit of theory courses is 4 per course, while that of laboratory practical course is 3 per course. The project and viva voce will have a credit of 2 each. The distribution of credit is shown below.

Semester	Courses	Credit	Total Credit
I	4 Theory Courses	$4 \times 4 = 16$	16
II	4 Theory Courses 2 Laboratory Practical	$4 \times 4 = 16$ $2 \times 3 = 6$	22
III	4 Theory Courses	$4 \times 4 = 16$	16
IV	4 Theory Courses 2 Laboratory Practical 1 Project / Dissertation 1 Viva- Voce	$4 \times 4 = 16$ $2 \times 3 = 6$ $1 \times 2 = 2$ $1 \times 2 = 2$	26
Total Credit of the M.Sc. Programme			**80**

EVALUATION

The evaluation of each course shall contain two parts such as Sessional Assessment and Final assessment. The ratio between Sessional and Final shall be 1:3. The mark distribution for Sessional and Final is 25 and 75. The Sessional and Final assessment shall be made using Mark based Grading system based on 7-point scale.

a.SESSIONAL ASSESSMENT

The Sessional evaluation is to be done by continuous assessments of the following components. Pass minimum for sessional assessment for each course is 10 marks.The components of the sessional for theory and practical and their mark distributions are given in the table below.

THEORY		**PRACTICALS**	
Component	***Marks***	***Component***	***Marks***
Attendance	5	Attendance	5
Assignments	5		
Seminar	5	Test Papers (Average of 2)	10
Test Papers (Average of 2)	10	Record	10
Total	**25**	**Total**	**25**

Attendance, Assignment and Seminar

Monitoring of attendance is very important in the credit and semester system. All the teachers handling the respective courses are to document the attendance in each semester. Students with attendance less than 75% in a course are not eligible to attend external examination of that course. The performance of students in the seminar and assignment should also be documented.

Distribution of marks for attendance

A student should have a minimum of 75% attendance. Those who do not have the minimum requirement for attendance will not be allowed to appear for the Final Examinations.

<table>
<tr><th colspan="2">Attendance</th><th colspan="2">Assignments</th><th colspan="2">Seminar</th></tr>
<tr><td>% of Attendance</td><td>Marks</td><td>Components</td><td>Marks</td><td>Components</td><td>Marks</td></tr>
<tr><td>≥ 90%</td><td>5</td><td rowspan="2">Punctuality</td><td rowspan="2">2</td><td rowspan="2">Content</td><td rowspan="2">2</td></tr>
<tr><td>≥ 85% and ≤ 90%</td><td>4</td></tr>
<tr><td>≥ 80% and ≤ 85%</td><td>3</td><td rowspan="3">Content</td><td rowspan="3">3</td><td rowspan="3">Presentation</td><td rowspan="3">3</td></tr>
<tr><td>≥ 75% and ≤ 80%</td><td>2</td></tr>
<tr><td>< 75%</td><td>0</td></tr>
</table>

Table: split up of marks for attendance and components of Seminar & Assignment

Test Paper

- Average mark of two sessional examinations shall be taken.

Project Evaluation

The sessional evaluation of the project is done by the supervising guide of the department or the member of the faculty decided by the head of the department. The project work may be started at the beginning of the Semester III. The supervising guide should keenly and sincerely observe the performance of the student during the course of project work. The supervising guide is expected to inculcate in student(s), the research aptitude and aspiration to learn and aim high in the realm of research and development. A maximum of three students may be allowed to perform one project work if the volume of the work demands it.

Project evaluation begins with (i) the selection of problem, (ii) literature survey, (iii) work plan, (iv) experimental / theoretical setup/data collection,(v) characterization techniques/computation/analysis (vi) use of modern software for data analysis/experiments (Origin, LABView, MATLAB, and other computational techniques) and (vi) preparation of dissertation. The project internal marks are to be submitted at the end of Semester IV. The internal evaluation is to done as per the following general criteria given in below.

Component	**Marks**
Literature Survey Test Paper/ Oral Viva	10
Experimental/Theoretical setup/Data Collection/Result and Discussion and Presentation	10
Punctuality	5
Total	25

General Instructions for sessional assessment

(i) One teacher appointed by the Head of the Department will act as a coordinator for consolidating score sheet for internal evaluation in the department in the format supplied by the controller of the examination. The consolidated score sheets are to be published in the department notice board, one week before the closing of the classes for final examinations. The score sheet should be signed by the coordinator and counter signed by the Head of the Department and the college Principal.

(ii) The consolidated score sheets in specific format are to be kept in the college for future references. The consolidated marks in each course should be uploaded to the Institution Portal at the end of each semester as directed by the Controller of Examination.

(iii) A candidate who fails to register for the examination in a particular semester is not eligible to continue in the subsequent semester.

(iv) Grievance Redressal Mechanism for Internal evaluation: There will be provision for grievance redress at four levels, viz,

a) at the level of teacher concerned, at the level of departmental committee consisting of Head of the Department, Coordinator and teacher concerned,

b) at the level of college committee consisting of the Principal, Controller of Examination and Head of the Department

College level complaints should be filed within one week of the publication of results.

b.FINAL ASSESSMENT

The final examinationof all semesters shall be conducted by the institution on the close of each semester. Pass minimum for final assessment of each course is 30 marks. For reappearance/ improvement, students may appear along with the next batch.

Question Paper Pattern for Theory Courses

All the theory question papers are of three hour duration. All question papers will have three parts. Total marks for both theory and practical is 75.

Part A: Questions from this part are very short answer type. Five questions have to be answered from among seven questions. Each question will have 3 marks and the Part A will have total marks of 15.

Part B: Part B is fully dedicated to solving problems from the course concerned. Six problems out of nine given have to be answered. Each question has 5 marks making the Part B to have total marks of 30. A minimum of two problems from each module is required. The problems need not always be of numerical in nature.

Part C: Part C will have four questions. One question must be asked from each module. Two questions have to be answered out of four questions. Each question will have 15 marks making the total marks 30 in Part C.

Model Blue Print of the Question Paper

Module	Hours *(Total 72 hours)*	3 Marks *(5 questions out of 7)*	5 Marks *(6 questions out of 9)*	15 Marks *(2 questions out of 4)*	Total Marks *(75 marks out of 126)*
I	**18**	**2**	**2**	**1**	**31**
II	**18**	**2**	**2**	**1**	**31**
III	**18**	**2**	**2**	**1**	**31**
IV	**18**	**1**	**3**	**1**	**33**

Questions from all the modules of the syllabus shall be included in Parts A, B and C of the question paper. Not more than 2 questions can be included in Part A from each module whereas in part B, a minimum of two questions has to be there from each module. In Part C, one question from each module is to be included.

Maximum marks allocated to a module is 33

Directions for question setters

(i) Follow the as far as possible the text book specified in the syllabus.
(ii) The question paper should cover uniformly the entire syllabus. For that the pattern

of question paper mentioned above must be strictly followed.

(iii) Set Part A questions to be answered in six minutes each, Part B questions in twelve minutes each and Part C questions in thirty five minutes each.

Weightage to objectives and difficulty levels in the question paper should be as given in the Table below.

Weightage to Objectives		*Weightage to Difficulty Levels*	
Objective	%	Level of Difficulty	%
Information	20	Easy	30
Understanding	60	Average	50
Application	20	Difficult	20

Practical, Project and Viva Voce Examinations

Practical Examination: Practical examinations are conducted at the end of Semester II and at the end of Semester IV. All practical examinations will be of five hours duration. One external examiner will be selected from the panel of examiners and one internal examiner will be selected by the department.

Evaluation of Practical Examinations: The scheme of evaluation of the practical examination will be decided by the Board of Examiners.

Project Evaluation: The project is evaluated by one external and one internal examiner deputed from the board of practical examination. The dissertation of the project is examined along with the oral presentation of the project by the candidate. The examiners should ascertain that the project and report are genuine. Innovative projects or the results/findings of the project presented in national seminars may be given maximum advantage. The different marks for assessment of different components of project are as shown in the following table.

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Component	**Weights**
Quality of project under study	10
Theses /Presentation of the project	10
Experimental/Theoretical setup/Data Collection	20
Result and Dissertation layout	10
Total marks for Dissertation	50
Oral presentation and Viva on Project	25
Total marks for final assessment of project	75

Table : Components and marks of Project

Viva Voce Examination: Viva voce examination is conducted only in the final examination by the internal and the external examiner. The viva voce examination is given a credit two. The marks for different components should be awarded in the following format shown below.

Type of Questions	Percentage	Weightage to Difficulty Level	
B.Sc/ + 2 level	20	Level of Difficulty	%
M.Sc. Syllabus Based	40	Easy	30
Subject of Interest	30	Average	50
Advanced Level	10	Difficult	20

Table 2.6: Format for viva voce Examination

Both project evaluation and viva voce examination are to be conducted in batches of students formed for the practical examinations.

Reappearance/Improvement: For reappearance / improvement , students can appear along with the next regular batch of students of their particular semester. A maximum of two chances will be given for each failed paper. Only those papers in which candidate have failed need be repeated. Chances of reappearance will be available only during eight continuous semesters starting with the semester in which admission/readmission is given to the candidate.

COMPUTATION OF CCPA

Grade and Grade Point is given to each course based on the percentage of marks obtained as follows:

Percentage of Marks	**Grade**	**Grade Point**
90 and above	A+ - Outstanding	10
80-89	A - Excellent	9
70-79	B - Very Good	8
60-69	C - Good	7
50-59	D - Satisfactory	6
40-49	E - Adequate	5
Below 40	F - Failure	4

Note: Decimal are to be rounded to the next whole number

CREDIT POINT AND CREDIT POINT AVERAGE

Credit Point (CP) of a course is calculated using the formula ***CP = C* x *GP*,**

*where**C** = Credit for the course; **GP** = Grade point*

Semester Credit Point Average (SCPA) is calculated as**SCPA**= $\frac{\boldsymbol{TotalCreditPoints}\ (\boldsymbol{TCP})}{\boldsymbol{TotalCredits}(\boldsymbol{TC})}$

Grades for the different semesters / programme are given based on the corresponding SCPA on a 7-point scale as shown below:

SCPA	Grade
Above 9	A+ - Outstanding
Above 8, but below or equal to 9	A - Excellent
Above 7, but below or equal to 8	B -Very Good
Above 6, but below or equal to 7	C - Good
Above 5, but below or equal to 6	D - Satisfactory
Above 4, but below or equal to 5	E - Adequate
4 or below	F - Failure

Cumulative Credit Point Average for the programme is calculated as follows:

$$\textbf{CCPA} = \frac{(TCP)_1 + \dots\dots\dots + (TCP)_4}{TC_1 + \dots + TC_4}$$

where **TCP_1……., TCP_4** are the **Total Credit Points** in each semester and **TC_1……., TC_4** are the **Total Credits** in each semester

Note: A separate minimum of 4**0% marks** each for Sessionals and Finals (for both theory and practical) is required for pass for a course. For a pass in a programme, a separate minimum of Grade E is required for all the individual courses. If a candidate secures **F** Grade for any one of the courses offered in a Semester/Programme only **F** grade will be awarded for that Semester/Programme until he/she improves this to **E** grade or above within the permitted period. Candidate who secures **E** grade and above will be eligible for higher studies.

SYLLABI OF COURSES

CORE COURSES

Semester I

PH1C01MT Mathematical Methods in Physics – I

Credit-4

Total Lecture hours- 72

Aim

The aim of this course is to expose the student to the indispensable role that mathematics plays in modern physics**.** It is intended to provide students with a firm grounding in mathematical concepts, tools and techniques that are essential to the solution of problems they encounter in advanced courses of Physics.

Course Overview and context

Mathematical Physics refers to the application of mathematics to problems in physics and the development of mathematical methods suitable for such applications and for the formulation of physical theories. It examines the mathematical basis underlying in theoretical physics and provides a strong conceptual understanding of physics as a wider discipline. This course covers the fundamental and advanced topics such as vectors, tensors, matrices, probability theory, special functions and differential equations. It is expected to help the student to acquire mathematical skills needed for a postgraduate course in Physics.

Module I

Vectors and Vector Spaces (18 Hrs)

Integral forms of gradient, divergence and curl - Equation of continuity , Line, surface and volume integrals – Stoke's, Gauss's and Green's theorems - Potential theory - scalar, gravitational and centrifugal potentials. Orthogonal curvilinear coordinates - gradient, divergence and curl in Cartesian, spherical and cylindrical co ordinates. Linear vector spaces - Hermitian, unitary and projection operators with their properties- inner product space – Schmidt orthogonalization - Hilbert space - Schwartz inequality.

Text Books

1. ***Mathematical Methods for Physicists, G.B. Arfken & H.J. Weber 4th Edition, Academic Press.***
2. ***Mathematical Physics, P.K Chattopadhyay, New Age International.***
3. ***Theory and problems of vector analysis, Murray R. Spiegel (Schaum's outline series).***

Module II

Matrices (12 Hrs)

Direct sum and direct product of matrices - diagonal matrices, Orthogonal, unitary and Hermitian matrices, normal matrices, Pauli spin matrices- Characteristic equation - Cayley-Hamilton theorem - Eigen values and eigenvectors – Diagonalisation - Solution of simultaneous linear equation-Gauss elimination method – Matrix inversion by Gauss-Jordan inversion method – Application – Normal modes of vibrations.

Text Books

1. ***Mathematical Methods for Physicists, G.B. Arfken &H.J. Weber 4th Edition, Academic Press***
2. ***Mathematical Physics, P.K Chattopadhyay, New Age International***
3. ***Mathematical Physics, B.D. Gupta, Vikas Pub.House, New Delhi***

Probability theory and distributions (6 Hrs)

Elementary probability theory, Random variables, Binomial, Poisson and Gaussian distributions-central limit theorem.

Text Books

1. ***Mathematical methods for Physics and Engineering, K.F. Riley, M.P Hobson, S. J. Bence, Cambridge University Press***
2. ***Mathematical Methods for Physicists, G.B. Arfken &H.J. Weber 4th Edition, Academic Press.***

Module III

Differential Geometry (16 hrs)

Occurrence of tensors in physics – Contravariant vector – Covariant vector – Contravariant tensor – Covariant tensor General definition – rank of a tensor - Tensor of second rank – Definition of tensor in three dimension - Definition of tensor in four dimension – Invariant tensor – Epsilon tensor – Krutkov tensor - The algebra of tensor – Addition and subtraction, Outer product of tensors, inner product of tensors & Contraction of tensor. Symmetric & antisymmetric tensors – Quotient law - Metric tensor and its properties –

Contravariant metric tensor – Associate tensors – Covariant differentiation of a tensor – Christoffel symbols & their transformation laws – Geodesics - Tensors in nonrelativistic physics – Stress, strain and strain, piezoelectricity and dielectric susceptibility & moment of inertia tensor.

Text books

1. ***Matrices and Tensors in Physics – A.W. Joshi, Publications: Wiley Eastern Limited, New Delhi.***
2. ***Mathematical Physics – B.S Rajput, Yog Prakash, Publications: Pragati Prakashan, P. B. No:62, Meerut, India.***
3. ***Vector Analysis & Tensors, Schaum's outline series, M.R. Spiegel, Seymour Lipschutz, Dennis Spellman, McGraw Hill.***

Module IV

Special functions and Differential equations (20 Hrs)

Gamma and Beta functions, Dirac delta function, Kronecker Delta function - properties and applications.

Bessel's differential equation – Bessel and Neumann functions – Generating function, recurrence relations and orthogonality property – Representation as trigonometric functions - Legendre differential equation – Legendre polynomials - Generating function, recurrence relations, Rodrigue's formula and orthogonality property -Associated Legendre polynomials - Hermite differential equation – Hermite polynomials - Generating function, recurrence relations, and orthogonality property - Laguerre differential equation – Laguerre polynomials - Generating function, recurrence relations, and orthogonality property - Associated Laguerre polynomials.

Text Books

1. ***Mathematical Methods for Physicists, G.B. Arfken &H.J. Weber 4th Edition, Academic Press***
2. ***Mathematical Physics, B.S Rajput, Pragati Prakashan***

References

1. Mathematical Physics, B.D. Gupta, Vikas Pub.House, New Delhi
2. Advanced Engineering Mathematics, E. Kreyszig, 7th Ed., John Wiley
3. Introduction to mathematical methods in physics, G.Fletcher, Tata McGraw Hill
4. Advanced engineering mathematics, C.R. Wylie, & L C Barrett, Tata McGraw Hill

5. Advanced Mathematics for Engineering and Physics, L.A. Pipes & L.R. Harvill, Tata McGraw Hill

6. Mathematical Methods in Physics, J. Mathew & R.L. Walker, India Book House.

7. Mathematical Physics, H.K. Dass, S. Chand & Co. New Delhi.

Competencies

C1. Identify different vector differentiation operators and understand their physical significance.

C2. Extend the knowledge of differentiation to vector integrations and classifying different integrals.

C3. State the theorems connecting different vector integrals.

C4. Differentiate types of potential.

C5. Identify the need for a generalized co ordinate system and express various operators in the same.

C6. Generalizing the co ordinate space and understand linear vector space in detail.

C7. Define direct sum and direct product of matrices with examples.

C8. Explain the different types of matrices with examples.

C9. Explain the properties of Pauli spin matrices.

C10. State and prove Cayley – Hamilton theorem.

C11. Apply the principle of similarity transformation to diagonalise square matrices.

C12. Discuss two methods to solve simultaneous linear equations.

C13. Apply matrix methods to find the normal modes of vibration of a molecule.

C14. Discuss elementary probability theory. Apply it to solve problems.

C15. Classify the different distributions in statistics and discuss them in detail.

C16. State and prove central limit theorem.

C17. Discuss the importance of tensor in physics.

C18. Categorize vectors & tensors.

C19. Discuss fundamental operations of tensors.

C20. Discuss metric tensor and determine metric tensor in different coordinate system.

C21. Discuss the transformation laws of Christoffel symbols.

C22. Set up Geodesic equation.

C23. Discuss different types of tensors in nonrelativistic physics.

C24. Discuss the various definitions and properties of gamma and beta functions.

C25. Solve definite integrals using gamma and beta functions.

C26. Discuss the properties and applications of Dirac and Kronecker delta functions.

C27. Obtain the solution of Bessel, Legendre, Hermite and Laguerre differential equations by Frobenius method.

C28. Derive the generating function, recurrence relations and orthogonality property of Bessel, Legendre, Hermite and Laguerre functions.

C29. Derive Rodrigues formula for Legendre and Laguerre polynomials.

C30. Obtain Associated Legendre and Laguerre equations.

Model Question Paper

PH1C01TMMathematical Methods in Physics – I

Time: Three Hours Maximum Marks: 75

Part A

(Answer **any five** questions. *Each question carries 3 marks*)

1. State Green's theorem.
2. Define Unitary operator with an example.
3. What are the properties of Pauli spin matrices?
4. Define Dirac delta function. State one situation where it finds application
5. Define outer product of tensors.
6. Write down the associated Legendre equation.
7. Explain what is meant by a Neumann function.

(5×3 =15)

Part B

(Answer **any six** questions. *Each question carries 5 marks*)

8. State and prove Schwartz inequality.

9. Determine unit vectors in Spherical coordinates and prove that they are orthogonal.
10. Diagonalise the matrix A = $\begin{bmatrix} 3 & 1 & 1 \\ 1 & 3 & 2 \\ 2 & 2 & 3 \end{bmatrix}$
11. Solve the following system of equations by Gauss elimination method.

$$3x + 2y + z = 11$$
$$2x + 3y + z = 13$$
$$x + y + 4z = 12$$

12. Explain elementary probability theory. In a box, there are 8 red, 7 blue and 6 green balls. One ball is picked up randomly. What is the probability that it is neither red nor green?
13. Prove that single contraction of a tensor A_{lm}^{ijk} is a tensor of rank 3
14. Explain moment of inertia tensor.

15. Evaluate the following integrals using beta and gamma functions.

    i)$\int_a^b (b-x)^{m-1}\,(x-a)^{n-1}dx$, where m and n are positive integers

    ii)$\int_0^1 x^4\ (1-x^2)^{-1/2}$ dx

16. Prove that $J_{1/2}(x) = \sqrt{\frac{2}{\pi x}} sinx$

(6×5 =30)

Part C

(Answer **any two** questions. *Each question carries 15 marks*)

17. Define line, surface and volume integrals. Explain the theorems connecting these integrals
18. Illustrate the application of the matrix technique in finding the normal modes of vibration of a CO_2 molecule.
19. Define Christoffel symbols and derive their transformation equations.
20. Derive the Rodrigues Formula for Legendre polynomial of order n.

(2×15 =30)

Semester I

PH1C02TMClassical Mechanics

Credits – 4

Total lecture hours – 72

Aim

To introduce the techniques of classical mechanics to students so that they are familiarized with Lagrangian and Hamiltonian formulation, Rigid body dynamics, Non linear systems and General theory of relativity.

Course overview and Context

The extension of Lagrangian formulation to velocity dependent potentials and introduction to Hamiltonian dynamics is given in module I. The techniques of small oscillations, canonical transformations and Hamilton Jacobi Theory are described in module II. Module III deals with the motion in central forces and rigid body dynamics. Module IV is dedicated for nonlinear dynamics, chaos and general theory of relativity. Since classical mechanics forms the basic theory for motions without mastering the subject the study of physical systems is not possible.

Module I

Hamiltonian Mechanics (10 Hrs)

Review of Newtonian and Lagrangian formalisms - cyclic co-ordinates -conservation theorems and symmetry properties - velocity dependentpotentials and dissipation function - Hamilton's equations of motion – Leastaction principle - physical significance.

Text Book:*Classical Mechanics, H. Goldstein, C.P. Poole & J.L. Safko, Pearson, 3rd Edn.*

Variational Principle and Lagrange's equations (6 Hrs)

Hamilton's principle - calculus of variations – examples - Lagrange's equations from Hamilton's principle.

Text Book:*Classical Mechanics, H. Goldstein, C.P. Poole & J.L. Safko, Pearson,3rd Ed.*

Module II

Mechanics of Small Oscillations (6 Hrs)

Stable and unstable equilibrium-General theory of small oscillation– Lagrange's equations of motion for small oscillations - normal co-ordinates and normal modes - oscillations of linear tri-atomic molecules.

Text Book:*Classical Mechanics, J.C. Upadhyaya, Himalaya, 2010*.

Canonical Transformations (7 Hrs)

Equations of canonical transformation- examples of canonical transformation- harmonic oscillator.

Text Book:*Classical Mechanics, H. Goldstein, C.P. Poole & J.L. Safko, Pearson, 3rd Ed.*

Poisson brackets - Lagrange brackets - properties- equations of motion in Poisson bracket form - angular momentum Poisson brackets - invariance under canonical transformations.

Text Book:*Classical Mechanics, J.C. Upadhyaya, Himalaya, 2010.*

Hamilton-Jacobi Theory (7 Hrs)

Hamilton-Jacobi equation for Hamilton's principal function - harmonic oscillator problem - Hamilton - Jacobi equation for Hamilton's characteristic function- action angle variables in systems of one degree of freedom –Harmonic oscillator, Kepler's Problem.

Text Books:

1. ***Classical Mechanics, H. Goldstein, C.P. Poole & J.L. Safko, Pearson, 3rd Edn.***
2. ***Classical Mechanics, J.C. Upadhyaya, Himalaya, 2010***

Module III

Central Force Problem (9 Hrs)

Reduction to the equivalent one body problem - equations of motion and first integrals - equivalent one-dimensional problem and classification of orbits - differential equation for the orbits – virial theorem - Kepler problem: Inverse square law of force

Text Book:*Classical Mechanics, H. Goldstein, C.P. Poole & J.L. Safko, Pearson, 3rd Ed.*

Rigid Body Dynamics (9 Hrs)

Angular momentum - kinetic energy - inertia tensor - principal axes - Euler's angles- infinitesimal rotations - rate of change of a vector - Coriolis force - Euler's equations of motion of a symmetric top - heavy symmetric top with one point fixed.

Text Book:*Classical Mechanics, G. Aruldhas, Prentice Hall, 2009*

Module IV

General Theory of Relativity (9 Hrs)

General theory of relativity-Principle of equivalence and applications-ideas of Riemannian geometry-space time curvature –geodesics- Einsteins equations of general theory of relativity-Schwarzchild solutions – observational evidences to General Relativity.

Text Books

1. K D Krori Fundamentals of Special and General Relativity, PHI Learning Pvt. Ltd (2010), Chapter 7 to 10

2. ***S K Srivastava General Relativity and Cosmology (2008, Chapter 8***

Classical Chaos (9 Hrs)

Linear and non-linear systems - integration of linear equation: Quadrature method - the pendulum equation – phase plane analysis of dynamical systems

– phase curve of simple harmonic oscillator and damped oscillator- phase portrait of the pendulum - bifurcation - logistic map – attractors - universality of chaos - Lyapunov exponent - fractals - fractal dimension.

Text Book:*Classical Mechanics, G. Aruldhas, Prentice Hall (2009)*

Reference Books:

1. Classical Mechanics, N.C. Rana and P.S. Joag, Tata Mc Graw Hill
2. Introduction to Classical Mechanics, R.G. Takwale and P.S. Puranik, TMGH.
3. Langrangian and Hamiltonian Mechanics, M.G. Calkin, World Scientific Pub.Co Ltd
4. Introduction to General Relativity, R. Adler, M. Bazin, M. Schiffer, TMGH.
5. An introduction to general relativity, S. K. Bose, Wiley Eastern.
6. Relativistic Mechanics, Satya Prakash, Pragathi prakashan Pub.
7. Chaos in Classical and Quantum Mechanics, M.C.Gutzwiller, Springer, 1990.

8. Deterministic Chaos, N. Kumar, University Press,
9. Chaotic Dynamics, G.L.Baker & J.P.Gollub, Cambridge Uni. Press, 1996
10. Mathematical Methods for Physicists, G.B. Arfken &H.J. Weber 4th Edition

Competencies

C1. Compare Newtonian and Lagrangian mechanisms to analyze the motion of single and a group of particles.

C2. Understand the relative merits and demerits of differential and integral principle in setting up the equations of motion.

C3. Describe various concepts mentioned in the syllabus.

C4. Bring out the correspondence between conservation theorem and symmetry properties.

C5. State conservation theorems in terms of cyclic coordinates.

C6. Set up equations of motion, when the potentials are velocity dependent.

C7. Describe the physical significance of least action principle.

C8. Obtain the Lagrangian equations of motion of various systems.

C9. Derive Lagrange's equations from Hamilton's principle.

C10. Recognise the different types of equilibrium.

C11. Discuss the theory of small oscillation in terms of displacement and also in terms of normal co ordinates

C12. Obtain the normal modes of linear triatomic molecule.

C13. Discuss conditions for Canonical transformation and obtain the relation among the generating functions.

C14. Apply the method of canonical transformation in solving one dimensional harmonic oscillator.

C15. Introduce different classical bracket formalisms.

C16. Establish the invariance of Poisson Bracket under canonical transformation.

C17. Describe Hamilton Jacobi Theory to solve mechanical problems.

C18. Distinguish Hamilton's principal function and Hamilton's characteristic function.

C19. Investigate the significance of action angle variables in mechanical systems.

C20. Examine reduction of two body problem to the equivalent one body problem and extend it to central forces to find equations of motion and first integrals

C21. Apply the method of first integrals to study the motion in general central force motion using equation of motion and conservation theorems

C22. Summarize the classification of orbits with respect to potential and nature of orbits

C23. Recognize the differential equation of orbits for integrable power-law potentials

C24. State and establish virial theorem and apply the same to derive Boyles law for gases

C25. Kepler problem: Inverse square law of force

C26. Illustrate the central force motion with the Kepler problem

C27. Describe Rigid body motion with respect to angular momentum and kinetic energy

C28. Introduce the concept of inertia tensor to rigid bodies and the principal axes

C29. Describe Euler's angles and infinitesimal rotations

C30. Find the rate of change of a vector with respect to body fixed axis and space fixed axis

C31. Illustrate Coriolis force with its effect in specific example

C32. Describe Euler's equations of motion of a symmetric top and examine the motion ofheavy symmetric top with one point fixed.

C33. Introduce the concept of General theory of relativity

C34. State Principle of equivalence and applications

C35. Describe Riemannian geometry and space time curvature

C36. Explain geodesics

C37. Derive Einsteins equations of general theory of relativity and find the Schwarzchild solutions.

C38. Give the observational evidences to General Relativity.

C39. Compare linear and non-linear systems

C40. Describe the quadrature method for integration of linear equation

C41. Apply the method of quadruture to the pendulum equation

C42. Analyse the behaviour of dynamical systems in the phase plane and exemplify with phase curve of simple harmonic oscillator and damped oscillator

C43. Describe phase portrait of the pendulum

C44. Examine the logistic map with respect to bifurcation, attractors, universality of chaos, Lyapunov exponent

C45. Discuss fractals and the concept of fractal dimension with the help of typical example.

Model Question Paper

PH1C02TM Classical Mechanics

Time : 3 hrs　　　　Max. Marks: 75

Part A

(Answer any **5** questions. Each question carries 3 marks)

1. Define constraints. How do they simplify the equations of motion?
2. What are cyclic coordinates? Give two examples.
3. Define Poisson Brackets. Discuss its properties.
4. What is fictitious potential energy? Illustrate with an example.
5. Describe Inertia tensor with respect to a rigid body.
6. What is fractal dimension? How is it computed?
7. What is curvature tensor? What is its relevance in general theory of relativity?

(5 x 3 = 15)

Part B

(Answer any 6 questions. Each questioncarries 5 marks)

8. Describe the motion of a particle of mass m constrained to move on the surface of a cylinder of radius a and attracted towards the origin by a force which is proportional to the distance of the particle from the origin.

9. Obtain the equation of motion of a particle falling vertically under the influence of gravity when frictional forces obtainable from dissipation function, ½ kv^2 are present. Integrate the equation to obtain velocity as a function of time and show that the maximum possible velocity for fall from rest is mg/k.
10. Obtain the relation between Poisson and Lagrange's Brackets.
11. Show that the transformation $P = \frac{1}{2}(p^2 + q^2)$, $Q=\tan^{-1}\frac{q}{p}$ is canonical.
12. Solve the harmonic oscillator problem using action angle variables.
13. Consider a particle falling freely from a height *h*at latitude *a*. Find its deflection from the vertical due to Coriolis force.
14. For a system representing perfect gas prove that $\frac{3}{2}NK_BT=\frac{3}{2}PV$.
15. Find the gravitational field of Sun. Assume that the gravitational field of earth can be neglected compared to that of Sun. The fractional change in frequency of a photon as it enters from gravitational field of sun to that of earth is 2.12×10^{-6}.
16. Solve the equation $\ddot{x} + \omega^2 x = 0$ using the Quadrature method.

(6 x 5 = 30)

Part C

(Answer any 2 question. Each question carries 15 marks)

17. Derive Lagrange's equation from Hamilton's principle. Extend this to nonholonomic systems.
18. Solve Kepler's Problem using Hamilton Jacobi Method.
19. Derive the elliptical orbit equation for a particle moving in a central force which obeys inverse square law.
20. Derive Einstien's field equations with the help of Poisson approximation.

(2 x 15 = 30)

Semester I

PH1C03TMElectrodynamics

Credits – 4

Total lecture hours – 72

Aim

Electrodynamics has become an integral part of the foundations of Physics and has a permanent place in Physics curriculum. This course aims to provide a comprehensive introduction to the subject of Electrodynamics and to cater the needs of students who intend to go for further studies and research.

Course Overview and Context

This course intends to familiarize the student with electrostatic fields, theories that discuss the propagation of electromagnetic waves in materials, Maxwell's equations, relativistic fields and their transformations thereof. It also provides an insight into time varying fields, electromagnetic radiation, antennas, guided transport of electromagnetic waves and energy through waveguides and transmission lines.

Module I

Review of electrostatics and magnetostatics (3 hrs)

Coulomb's law – electric field –Gauss's law – divergence and curl of E – electric potential – Lorentz force law – Biot-Savart law – divergence and curl of B.

Electrodynamics (5 hrs)

Maxwell's equations – displacement current – Maxwell's equations in matter – boundary conditions – continuity equation – Poynting's theorem – Newton's third law in Electrodynamics – Maxwell's stress tensor.

Electromagnetic waves (10 hrs)

Wave equation – boundary conditions for reflection and transmission – electromagnetic waves in vacuum – monochromatic plane waves – energy and momentum in electromagnetic waves – electromagnetic waves in matter – reflection and transmission at normal incidence – reflection and transmission at oblique incidence – Fresnel's equations – absorption of electromagnetic waves in conductors – reflection at conducting surface.

Text Book: ***Introduction to Electrodynamics, D. J. Griffiths, PHI***

Module II

Relativistic Electrodynamics (18 hrs)

Structure of space time : four vectors, proper time and proper velocity, relativistic dynamics – Minkowski force, magnetism as a relativistic phenomena, transformation rules for electric and magnetic fields, electromagnetic field tensor, electrodynamics in tensor notation, relativistic potentials.

Text Book:*Introduction to Electrodynamics – D. J. Griffiths, PHI*

Module III

Potential & Fields (8 hrs)

Scalar & vector potentials-Retarded potentials-Jefimenkos equations- point charges - Lienard-Wiechert potential- fields of a moving point charge

Text Book: *Introduction to Electrodynamics, D. J. Griffiths, PHI*

Radiation (12 hrs)

Electric dipole radiation-magnetic dipole radiation- power radiated by point charge in motion. radiation reaction-physical basis of radiation reaction

Text Book: *Introduction to Electrodynamics, D. J. Griffiths, PHI*

Module IV

Wave guides (5 hrs)

Rectangular wave guides- TE & TM waves in rectangular wave guides – cut off frequency -impossibility of TEM waves in rectangular wave guides

Text Book:*Electromagnetic waves and radiating systems, E.C. Jordan &K.G. Balmain, PHI*

Antennas (5 hrs)

Hertzian dipole- quarter wave monopole antenna- antenna characteristics- antenna patterns, radiation intensity, directive gain, power gain.

Text Book: *Elements of electromagnetic- Matthew N O Sadiku,Oxford UniversityPress*

Transmission lines (6 hrs)

Transmission Lines- transmission line parameters - transmission line equations- for lossless line, distortionless line- input impedance, SWR and power

Text Book: ***Elements of electromagnetic, Matthew N O Sadiku, Oxford University Press***

References:

1. Classical Electrodynamics, J. D. Jackson, Wiley Eastern Ltd.
2. Introduction to Classical electrodynamics, Y. K. Lim, World Scientific, 1986.
3. The Feymann Lectures in Physics, Vol. 2, R.P. Feymann, R.B. Leighton & M. Sands.
4. Electromagnetic Waves and Fields, V.V. Sarwate, Wiley Eastern Ltd, New AgeInernational
5. Antenna and wave guide propagation, K. D Prasad, SatyaPrakashan
6. Electronic Communication Systems, G. Kennedy & B. Davis, TMH.

Competencies:

C1. State Coulomb's law, Gauss's law, Lorentz law and Biot-Savart law.

C2. List Maxwell's equations.

C3. Define displacement current.

C4. Discuss boundary conditions of electromagnetic waves in vacuum and matter.

C5. Discuss Poynting's vector and Maxwell's stress tensor

C6. Derive Fresnel's equations.

C7. Discuss four vectors in electrodynamics.

C8. Identify magnetism as a relativistic phenomenon.

C9. Derive the transformation rules for electric and magnetic fields.

C10. Discuss electromagnetic field tensor.

C11. Discuss relativistic potentials.

C12. Associate retarded potentials and discussJefimenkos equations

C13. Investigate the power radiated by a pointcharge in motion.

C14. Examine the power radiated by electric & magnetic dipoles.

C15. Discuss the wave propagation in a rectangular wave guides.

C16.Compute the radiation resistance for Hertzian dipole and quarter wave monopole antenna.

C17. Recognize directive gain and power gain.

C18.Calculate the propagation constant and characteristic impedance of transmission lines.

Model Question Paper

PH1C03TM Electrodynamics

Time : 3 hours Total Marks : 75

Part A

(Answer any five questions, each carries 3 marks)

1. Explain the conservation of momentum in electrodynamics.
2. What is meant by gauge transformation? Explain Coulomb gauge.
3. Show that current density 4-vector is divergenceless.
4. Define Minkowski force. Interpret physically its zeroth component.
5. Write down the Jefimenkos equation.
6. What is meant by radiative reaction?
7. What do you mean by SWR of a transmission line?

$(5 \times 3 \ = 15\, marks\ )$

Part B

(Answer any six questions, each carries 5 marks)

8. Calculate the reflection coefficient for light at an air-to-silver interface ($\mu_1 = \mu_2 = \mu_0$, $\varepsilon_1 = \varepsilon_0$, $\sigma = 6 \times 10^7\ (\Omega m)^{-1}$, at optical frequencies ($\omega = 4 \times 10^{15}$ /s).

9. An electromagnetic wave propagates in free space along the Z-direction. The electric field vector is given by $\vec{E} = \hat{\imath}\ E_0 \cos \omega(\frac{Z}{c} - t) + \hat{\jmath}\ E_0 \tan \omega(\frac{Z}{c} - t)$. Obtain the direction and magnitude of Poynting's vector.
10. Obtain the relativistic continuity equation directly from Maxwell's equations.
11. Show that $\vec{E}.\vec{B}$ is relativistically invariant.
12. Show that the retarded potential V satisfies the inhomogeneous wave equation $\Box^2 V = (-\rho/\varepsilon_0)$.
13. Show that power radiated by a point charge is proportional to the square of its acceleration.
14. Find the characteristic impedance of a transmission line.
15. A standard air filled rectangular waveguide with dimensions a = 8.636 cm, b = 4.318 cm is fed by a 4 GHz carrier from a coaxial cable. Determine if a TE_{10} mode will be propagated. If so, calculate the phase velocity and the group velocity.
16. A coaxial cable, having an inner diameter of 0.025 mm and using an insulator with a dielectric constant of 2.56, is to have a characteristic impedance of 2000 Ω. What must be outer conductor diameter?

.$(6 \times 5 = 30\ marks)$

Part C

(Answer two questions, each carries 15 marks)

17. Discuss the reflection and transmission of electromagnetic waves at a dielectric surface at normal incidence. Show that R + T = 1.

18. Derive the relativistic transformation rules for electric and magnetic fields.

19. Discuss the radiation from an oscillating magnetic dipole.

20. Obtain the expressions for the field and power radiated by a quarter wave monopole antenna. Calculate its radiation resistance.

$(2 \times 15 = 30\ marks)$

Semester I
PH1C04TMElectronics

Credit-4

Total Lecture hours- 72

Aim

The aim of this course is to develop practical understanding of various electronic components and enable students to adapt to the changing technology.

Course overview and Context

The first session of this course deals with field effect transistors- its working and characteristics. The details of operational amplifiers feedback and its effect on various parameters is included. The second session gives primary focus on the practical op amp circuits and its linear applications. The factors that influence performance of a practical op amp and the frequency response of op amp are illustrated. Next session covers active filters and different types of oscillators. The theory of various electronic devices such as converters, comparators, voltage regulators are included further. The details of analog communication are mentioned in the last session. In nutshell, this course provided a link to the practical aspect of various electronic components and enables students to cope with the changing technologies.

Module I

Field Effect Transistors (5 Hrs)

Types of FET- junction FET-formation of depletion region in JFET-characteristics of JFET-JFET parameters-comparison between FET and bipolar transistor- types of MOSFET-depletion type MOSFET- working and characteristics-Enhancement type MOSFET- characteristics.

Text Book:*Applied Electronics, R. S Sedha, S Chand publications.*

Op-amp with Negative Feedback (13 Hrs)

Differential amplifier – Inverting amplifier – Non-inverting amplifier –Block diagram representations – Voltage series feedback: Negative feedback – closed loop voltage gain – Difference input voltage ideally zero – Input and output resistance with feedback – Bandwidth with feedback – Total output offset voltage with feedback – Voltage follower. Voltage shunt feedback amplifier: Closed loop voltage gain – inverting input terminal and virtual ground - input and output resistance with feedback – Bandwidth with feedback - Total output offset voltage with feedback – Current to voltage converter- Inverter. Differential amplifier with one op-amp and two op-amps.

Text Book:*Op-amps and linear integrated circuits, R.A. Gayakwad,PHI, 4th Ed.*

Module II

The Practical Op-amp (6 Hrs)

Input offset voltage –Input bias current – input offset current – Total output offset voltage- Thermal drift – Effect of variation in power supply voltage on offset voltage – Change in input offset voltage and input offset current with time - Noise – Common mode configuration and CMRR.

Text Book:*Op-amps and linear integrated circuits, R.A. Gayakwad, PHI, 4th Ed.*

General Linear Applications (with design) (12 Hrs)

DC and AC amplifiers – AC amplifier with single supply voltage – Peaking amplifier – Summing , Scaling, averaging amplifiers – Instrumentation amplifier using transducer bridge – Differential input and differential output amplifier – Low voltage DC and AC voltmeter - Voltage to current converter with grounded load – Current to voltage converter – Very high input impedance circuit – integrator and differentiator**.**

Text Book:*Op-amps and linear integrated circuits, R.A. Gayakwad, PHI, 4th Ed.*

Module III

Frequency Response of an Op-amp (6 Hrs)

Frequency response –Compensating networks – Frequency response of internally compensated and non compensated op-amps – High frequency opamp equivalent circuit – Open loop gain as a function of frequency – Closed loop frequency response – Circuit stability - slew rate**.**

Text Book:*Op-amps and linear integrated circuits, R.A. Gayakwad, PHI, 4th Ed.*

Active Filters and Oscillators. (with design) (12 Hrs)

Active filters – First order and second order low pass Butterworth filter – First order and second order high pass Butterworth filter- wide and narrow band pass filter - wide and narrow band reject filter- All pass filter – Oscillators: Phase shift and Wien-bridge oscillators – square, triangular and sawtooth wave generators- Voltage controlled oscillator.

Text Book:*Op-amps and linear integrated circuits, R.A. Gayakwad, PHI, 4th Ed.*

Module IV

Comparators and Converters (8 Hrs)

Basic comparator- Zero crossing detector- Schmitt Trigger – Comparator characteristics- Limitations of op-amp as comparators- Voltage to frequencyand frequency to voltage converters - D/A and A/D converters- Peak detector – Sample and Hold circuit.

Text Book:*Op-amps and linear integrated circuits, R.A. Gayakwad, PHI, 4th Ed.*

Voltage Regulators (3Hrs)

Voltage Regulators-fixed regulators-adjustable voltage regulators-switching regulators.

Text Book:*Op-amps and linear integrated circuits, R.A. Gayakwad, PHI, 4th Ed.*

Analog Communication (7 Hrs)

Review of analog modulation – Radio receivers – AM receivers – superhetrodyne receiver – detection and automatic gain control – communication receiver – FM receiver – phase discriminators – ratio detector – stereo FM reception.

Text Book:*Electronic Communication Systems, Kennedy & Davis 4thEd., TMH.*

References:

1. Electronic Devices (Electron Flow Version), 9/E TThomas L. Floyd, Pearson.

2. Fundamentals of Electronic Devices and Circuits 5Pth P Ed. David A. Bell, Cambridge.

3. Electronic Communications Dennis Roddy and John Coolen, 4th Ed. Pearson.

4. Modern digital and analog communication systems, B.P. Lathi & Zhi Ding, Oxford University Press.

5. Linear Integrated Circuits and Op Amps, T. S Bali, TMH

Competencies:

C1. Classify FET.

C2. Discuss the working and characteristics of JFET and MOSFET.

C3. Explain Differential, Inverting amplifier and Non-inverting amplifier.

C4. Represent the amplifiers using block diagrams.

C5. Identify different feedback in amplifiers and associated terms.

C6. Understand variation of different parameters of amplifiers with feedback.

C7. Mention Current to voltage converter and Inverter.

C8. Identify the factors related to offset in a practical op amp.

C9. Explain the effect of variation in power supply voltage on offset voltage

C10. Understand thermal drift and noise

C11. Discuss the various linear applications of op amp.

C12. Exemplify instrumentation amplifier

C13. Classify and understand the working of integrator and differentiator.

C14. Explain frequency response of amplifiers.

C15. Compare the frequency response of compensated and non compensated op-amps.

C16. Determine the open loop gain of an op-amp using the high frequency equivalent Circuit. .

C17. Discuss closed loop frequency response, circuit stability and slew rate.

C18. Discuss first order and second order low pass Butterworth filters.

C19. Discuss first order and secondorder high pass Butterworth filters.

C20. Distinguish between wide and narrow band pass filters.

C21. Distinguish between wide and narrow band reject filters.

C22. Describe phase shift and Wein bridge oscillators.

C23. Describe square, triangular and saw tooth wave generators.

C24. Describe voltage controlled oscillators.

C25. Explain comparators.

C26. Discuss voltage to frequency and frequency to voltage converters.

C27. Discuss D/A and A/D converters

C28. Describe peak detector, sample and hold circuit.

C29. Explain voltage regulators.

C30. Explain super heterodyne AM and FM radio receivers.

C31. Explain stereo FM reception.

Model question paper

PH1C04TM Electronics

Time: Three Hours Maximum Marks: 75

Part A

*(Answer any **five**questions, Each question carries **3** marks)*

1. Explain how the bandwidth with feedback is related to bandwidth without feedback in an op-amp
2. Discuss the effect of negative feedback in non-inverting amplifiers.
3. What is noise? Discuss in detail the different types of noises.
4. How does high frequency model of an op-amp differ from the equivalent circuit of an op-amp?
5. What are the two requirements for oscillation?
6. Distinguish between selectivity and sensitivity of a radio receiver .
7. Comparators are also called a voltage level detector. Why?

Part B

*(Answer any **Six**questions, Each question carries **5** marks)*

8. An inverting amplifier with $R_1 = 470\ \Omega$ and $R_F = 2\ R_1$. Assume that the Op-amp is a 741C having A = 200,000, $R_i = 2M\Omega$, $R_0 = 75\ \Omega$, $F_0 = 5$ Hz, Supply voltage = ± 15 V, Output voltage swing = ± 13 V. Compute the values of A_F, R_{iF}, R_{oF} and f_F.
9. What is a current to voltage converter? With a proper circuit, derive an expression for output voltage in terms of feedback resistance and input current. What is the output voltage for an input current of 10 mA and a feedback resistance of 2 kΩ.

10. For an op-amp used as an inverting amplifier, determine the maximum possible output offset voltage due to Input offset voltage V_{io} and input bias current I_B. Given V_{io} max =6 mV dc, I_B max = 500 nA at T_A = 25°C , V_S =±15 V, R_F =47 KΩ, R_1 = 470 Ω.
11. (a) Design a differentiator to differentiate an input signal that varies in frequency from 10 Hz to about 1 KHz. (b) If a sine wave of 1 V peak at 1000 Hz is applied to the differentiator of part (a), draw its output waveform.
12. Determine the valueof ROM needed to reduce the effect of input bias current in an op-amp circuit used as an amplifier.Given V_{io}max =6 mV dc,I_B max = 500 nA at T_A = 25°C , V_S =±15 V, R_F =47 KΩ, R_1 = 470 Ω.

13. For a V.C.O, determine the change in output frequency if V_C is varied between 9 V and 11V. Assume that +V=12V, R_2 =15kΩ, R_3=100kΩ, R_1=6.8kΩ and C_1=75PF.

14. What are band pass filters? For a wide band pass filter F_L =400 Hz, F_H = 1 KHz and pass band gain =1. Calculate the value of Q for the filter.

15. In the Schmitt trigger R_1=100Ω, R_2=56KΩ, V_{in}=1 V_{pp} sine wave and the op-amp is type 741 with supply voltages=± 15V. Determine the threshold voltages V_{ut} and V_{lt} and draw the output waveform.

16. What is a voltage regulator? Explain the performance parameters for a regulator?

Part C

*(Answer any **two** questions, Each question carries **15** marks)*

17.(i) Draw the block diagram of a voltage – series feedback amplifier. Identify each block, and state its function. (ii) Derive the expression for closed- loop voltage gain in terms of open-loop voltage gain with the help of circuit diagram.

18. Explain the instrumentation amplifier and give an account of its applications.

19. What is meant by heterodyning? Give the block diagram of a super heterodyne radio receiver and explain the function of each unit in it?

20. What are active filters? With the help of a circuit diagram ,explain first order low pass and high pass filters.

Semester II

PH2C05TMMathematical Methods in Physics – II

Credit-4

Total Lecture hours- 72

Aim

The aim of this course is to acclimatize the methods of mathematics to study physical problems. Further it enables students to learn Mathematical Physics in the advanced level.

Course overview and Context

Complex Analysis is a basic analytical method to solve mathematical integrals and functions. In the first session, evaluation of integrals using complex analysis is included. Further the Residue theorem and Cauchy's integral formula are also discussed. It is important to understand the representation of periodic and aperiodic functions as a series of sines and cosines, which will simplify real life problems and is discussed under topic of Integral transforms. In the next session the introductory definitions of group and its representations are included. Basic understanding of character table for different groups and the concept of generators are inevitable for advanced level learning. In the last session primary focus is on partial differential equations and its solution methods. Green functions its application on the scattering problem is specifically incorporated.

Module I

Complex Analysis (18 Hrs)

Functions of a complex variable - Analytic functions - Cauchy-Riemann equation - integration in a complex plane – Cauchy's theorem-deformation of contours - Cauchy's integral formula - Taylor and Laurent expansion- Poles, residue and residue theorem – Cauchy's Principle value theorem - Evaluation of integrals.

Text Books:

1. ***Introduction to Mathematical physics, Charlie Harper, PHI.***
2. ***Mathematical Physics, B.D. Gupta, Vikas Pub.House, New Delhi.***
3. ***Mathematical Physics, P.K Chattopadhyay, New Age International.***

Module II

Integral Transforms (18 Hrs)

Introduction to Fourier series and Fourier integral form - Fourier transform - square wave, full wave rectifier and finite wave train – momentum representation of hydrogen atom ground state - harmonic oscillator.

Laplace transform –inverse Laplace transform-properties and applications – Earth's nutation, LCR circuit, wave equation in a dispersive medium, damped, driven oscillator, solution of differential equations.

Text Books:

1. Mathematical Methods for Physicists, G.B. Arfken &H.J. Weber 4th Edition, Academic Press.

2. Mathematical Physics, H.K Dass & Dr. Rama Verma, S. Chand &Co.

Module III

Group theory (18 Hrs)

Introductory definition and concepts of group - point group, cyclic group, homomorphism and isomorphism-classes, reducible and irreducible representations- Schur's Lemmas and Great Orthogonality theorem. Group character table- C_{2V}, C_{3V} and C_{4V} groups, Lie group, concept ofgenerators- rotation group SO(2), SO(3), Unitary Group SU(2) and SU(3)-Homomorphism between SU(2) and SO(3).

Text Books:

1. Elements of Group Theory for Physicists, A.W. Joshi, New Age India

2. Mathematical Physics, Sathyaprakash, Sultan Chand & Sons, New Delhi.

3. Mathematical Physics, P.K Chattopadhyay, New Age International.

Module IV

Partial Differential Equation (18 Hrs)

Partial differential equations – homogeneous and non homogeneous differential equations – Linear and nonlinear differential equations - boundary conditions – Initial condition – Separation of variables in Cartesian, cylindrical and spherical polar coordinates – Heat equation and Laplace equations – Green's function – Symmetry of Green's function - Green's function for Poisson's equation and Helmholtz equation – Application of Green's function in scattering problem.

Text Books:

1. ***Mathematical Physics, B.S Rajput, Yog Prakash, Publications: Pragati Prakashan.***
2. ***Mathematical Methods for Physicists, G.B. Arfken &H.J. Weber 4th Edition, Academic Press.***

References:

1. Mathematical Physics, B.D. Gupta, Vikas Pub.House, New Delhi
2. Advanced Engineering Mathematics, E. Kreyszig, 7th P Ed., John Wiley
3. Introduction to mathematical methods in physics, G.Fletcher, Tata McGraw Hill
4. Advanced engineering mathematics, C.R. Wylie, & L C Barrett, Tata McGraw Hill
5. Advanced Mathematics for Engineering and Physics, L.A. Pipes & L.R. Harvill, Tata McGraw Hill
6. Mathematical Methods in Physics, J. Mathew & R.L. Walker, India Book House.
7. Mathematical Physics, H.K. Dass, S. Chand & Co. New Delhi.
8. Essential Mathematical Methods for the Physical Sciences, K. F. Riley and M. P. Hobson.
9. Group theory- Schaum's series, Benjamin Baumslag & Bruce Chandler, MGH.

Competencies

C1. Introduce complex variable and standard representation of complex variable.

C2. Discuss conditions for Analytic Function.

C3. Apply Cauchy's Integral Theorem in simply and multiply connected region.

C4. Obtain Cauchy's Integral formula.

C5. Explain Taylor and Laurent expansion.

C6. Discuss different types of poles.

C7. Apply residue theorem in evaluating integrals.

C8. Discuss Fourier series and Fourier transform.

C9. Solve problems using Fourier series and Fourier transform.

C10. Discuss Laplace transform and inverse Laplace transform

C11. Mention the properties and applications of integral transforms.

C12. Understand introductory definition and concepts of group.

C13. State and prove Schur's Lemmas and Great Orthogonality theorem.

C14. Explain Group character table.

C15. Classify rotation group and Unitary Group.

C16. Categorize partial differential equations.

C17. Discuss the method of separation of variables for solving homogeneous partial differential equations.

C18. Discuss & solve homogeneous partial differential equations.

C19. Discussthe general method for solving non-homogeneous partial differential equations.

C20. Discuss & solve non-homogeneous partial differential equations.

C21. Apply Green's function in scattering problem.

Model Question Paper

PH2C05TM Mathematical Methods in Physics – II

Time: Three Hours Maximum Marks: 75

Part A

(Answer **any five** questions. *Each question carries 3 marks*)

1. Define residue of a function. Give the different ways of evaluating the residue.
2. State the condition for a function f(Z) of a complex variable Z to be continuous at $Z=Z_0$.
3. Explain sine and cosine Fourier series?
4. Write translation or shifting property of Laplace transform.
5. What is a SU(2) group?
6. State and Explain Schur's lemma1.
7. Check whether the equation is linear or nonlinear. $\nabla^2 U = \sqrt{U}$

(5 x 3 = 15)

Part B

(Answer **any six** questions. *Each question carries 5 marks*)

8. Given w(x,y) = u(x,y)+ i v(x,y). If u and v are real functions and w is analytic show that $\nabla^2 u = \nabla^2 v = 0$.
9. Find Laurent's expansion for f(Z) = $\frac{1}{Z(Z-2)}$ in the region a) 0<$|Z|$< 2 and b) 2<$|Z|$< ∞.
10. Solve $y'' + 4y' + 4y = e^{-t}$ using Laplace transform, given y(0) = 0 and $y'(0)$= 0.
11. Find the Fourier series of $f(x) = \begin{cases} 0, & -2 < t < -1 \\ k, & -1 < t < 1 \\ 0, & 1 < t < 2 \end{cases}$
12. Show that the group of order two and three are always cyclic.
13. Write brief notes on the following with examples:
    (a) Conjugate elements and classes
    (b) Subgroups
    (c) Isomorphism and Homomorphism
    (d) Representation of a group
14. Find the potential inside and outside the sphere using zonal surface harmonics.
15. Find the solution of heat equation in two dimensional Cartesian coordinate system by taking a rectangular bar bounded by x = 0, x=l and y=0 y=b which are kept at constant temperature and initial temperature is f(x,y)
16. Write any three partial differential equation in Physics and discuss its significances.

(6 x 5 = 30)

Part C

(Answer **any two**questions. *Each question carries 15 marks*)

17. Obtain Laurent's expansion of a function f(Z) about $Z=Z_0$ and hence deduce Taylor expansion form it.
18. What is Convolution theorem of Fourier transform. Find the Fourier transform of

$f(x) = \begin{cases} 1, & -a < x < a, |x| < a \\ 0, & |x| > a > 0 \end{cases}$ then deduce $\int_0^\infty \sin t/t \ \ dt = \frac{\pi}{2}$ and

$$\int_0^\infty (\sin t/t)^2 \, dt = \frac{\pi}{2}$$

19. Discuss the character table of C_{4v} group.
20. Solve Laplace's equation in spherical polar coordinates.

(2 x 15 = 30)

Semester II

PH2C06TMQuantum Mechanics - I

Credits – 4

Total lecture hours – 72

Aim

This course aims to provide a comprehensive introduction to the subject of quantum mechanics. It intends to familiarize the student with the physical concepts and the mathematical basis of quantum mechanics. It also aims at cultivating the learner's skill at formulating and solving Physics problems.

Course Overview and Context

Quantum physics is the foundation for much of modern technology, provides the framework for understanding light and matter from the subatomic to macroscopic domains, and makes possible the most precise measurements ever made. More than just a theory, it offers a way of looking at the world that grows richer with experience and practice. This course is intended to initiate the student into the quantum world.

Module I contains basics of quantum mechanics such as Hilbert's space, observables, operators, matrix representations, position and momentum basis and Gaussian wave packet. Module II deals with time evolution of quantum systems. It also discusses the linear harmonic problem and identical particles. In module III, angular momentum, infinitesimal rotations, spherical harmonics etc are discussed whereas in module IV, learner is familiarized with variational method, Hydrogen atom problem, anharmonic oscillator and Zeeman effect.

Module I

Basics of Quantum Mechanics (14 hrs)

Stern-Gerlach experiment leading to vector space concept, Dirac notation for state vectors– ket space, bra space, inner products, algebraic manipulation of operators, eigenkets and eigenvalues, Hermitian operator and its expectation values, generalized uncertainty relation, change of basis – transformation operator – orthonormal basis and unitary matrix

– transformation matrix – diagonalization – unitary equivalent observables, eigenkets of position, infinitesimal translation operator and its properties, linear momentum as generator of translation, canonicalcommutation relations, position space wave function – momentum operator in position basis, momentum space wave function – relation between position space and momentum space wave functions, Gaussian wave packet – computation of expectation values x, x^2, p and p^2 for a Gaussian wave packet.

Text Book: ***Modern Quantum Mechanics, J. J. Sakurai, Pearson Education.***

Module II

Quantum Dynamics (14 hrs)

Time evolution operator and its properties – Schrodinger equation for the time evolution operator, energy eigenkets– time dependence of expectation values –correlation amplitude – time energy uncertainty relation, Schrodinger picture and Heisenberg picture – behavior of state kets and observables in Schrodinger picture and Heisenberg picture – Heisenberg equation of motion –Ehrenfest's theorem, time evolution of base kets– transition amplitude, energy eigenket and eigen values of a simple harmonic oscillator using creation and annihilation operators.

Text Book: ***Modern Quantum Mechanics, J. J. Sakurai, Pearson Education***

Identical particles (4hrs)

Two-particle systems – Bosons and Fermions – Pauli exclusion Principle – exchange forces – Helium atom.

Text Book: ***Introduction to Quantum Mechanics, D. J. Griffiths, Pearson Education.***

Module III

Angular momentum (20 Hrs)

Rotation and Angular momentum– Commutation relations, relation between finite versus infinitesimal rotations–infinitesimal rotations in quantum mechanics–fundamental commutation relations of angular momentum – rotation operator for spin ½ system – Pauli two component formalism – Pauli spin matrices – 2×2 matrix representation of rotation operator –commutation relations for J^2, J_z , ladder operators– eigen values of J^2 and J_z, matrix elements of angular momentum operators– representation of the rotation operator – rotation matrix–orbital angular momentum as a rotation generator –Spherical Harmonics, addition of angular momentum – addition of spin angular momenta and Clebsch-Gordon coefficients for two spin ½ particles.

Text Book: ***Modern Quantum Mechanics, J. J. Sakurai, Pearson Education***

Module IV

Solutions of Schrodinger equation and Approximation Methods (20 Hrs)

Motion in a central potential – Hydrogen atom, WKB approximation – WKB wave function – validity of the approximation – connection formula (proof not needed) potential well - barrier penetration, Variational methods – hydrogen molecule ion – stationary state perturbation theory – nondegenerate case – anharmonic oscillator – degenerate case – applications – first order Stark effect and Zeeman effect in hydrogen.

Text Books:

1. ***Quantum mechanics, V.K. Thankappan New Age International, 1996.***
2. ***Quantum Mechanics, G Aruldhas, PHI, 2002.***

References

1. Introduction to Quantum mechanics, David J Griffiths, Pearson
2. Quantum Mechanics, Concepts and Applications, N. Zettily, John Wiley & Sons.
3. A Modern approach to quantum mechanics, John S. Townsend, Viva Books MGH.
4. Basic Quantum Mechanics, A. Ghatak, Macmillan India 1996
5. Quantum Mechanics, an Introduction, W Greiner, Springer Verlag
6. Quantum Mechanics, E. Merzbacher, John Wiley, 1996
7. Quantum Mechanics, B H Bransden, CJ Joachain, Pearson
8. Quantum Mechanics, L.I. Schiff, Tata McGraw Hill
9. A Text Book of Quantum Mechanics, P.M. Mathews & K. Venkatesan, TMGH.
10. Fundamentals of Quantum Mechanics Y.R. Waghmare, S Chand & Co.

Competencies

C1. Discuss the need of complex abstract space in quantum mechanics

C2. Describe eigenkets and eigen values

C3. Represent operators in matrix form
C4. Identify different types of quantum mechanical operators
C5. Relate the position basis with momentum basis
C6. Compute the expectation values of x, x^2, p and p^2 for a Gaussian wavepacket
C7. Discuss the time evolution operator
C8. Examine different pictures of quantum mechanics
C9. Describe Ehrenfest's theorem
C10. Compute the eigen values and eigenkets of linear harmonic oscillator
C11. Compute the fundamental commutation relations of angular momentum
C12. Recognize rotation operator for spin ½ system
C13. Illustrate Pauli the two component formalism and Pauli spin matrices with 2x2 matrix representation of rotation operator
C14. Determine the commutation relations for J^2, $J_z$and ladder operators and hence find the eigen values of J^2 and J_z
C15. Discuss the matrix elements of angular momentum operators and their role in the representation of the rotation operator
C16. Evaluate the orbital angular momentum as a rotation generator
C17. Examine Spherical Harmonics in the context of rotation operator
C18. Evaluate the Clebsch-Gordon coefficients for two spin ½ particles
C19. Illustrate Motion in a central potential and apply the method to find the energy states and wave functions for Hydrogen atom
C20. Describe the method of WKB approximation and examine WKB wave function
C21. Find the validity criterion for WKB the approximation
C22. State the connection formula for classical and non classical states
C23. Apply the WKB approximation method to potential well and for barrier penetration
C24. Discuss the Variational method in the context of hydrogen molecule ion
C25. Outline the techniques of stationary state perturbation theory for non degenerate cases and extend it to find the wave function and energy states of anharmonic

oscillator

C26. Investigate the stationary perturbation theory with respect to degenerate case and apply the same to explain first order Stark effect and Zeeman effect in hydrogen

Model Question Paper

PH2C06TMQuantum Mechanics - I

Time: Three Hours Maximum Marks: 75

Part A

*(Answerany **five**questions, Each question carries **3** marks)*

1. Briefly discuss the momentum wave functions.
2. What is a unitary operator? Explain its properties.
3. What are identical particles?
4. Discuss properties of time evolution operator.
5. Give the general expression for matrix elements of J_+ and J_-.
6. Explain why WKB approximations can only be applied to one - dimensional problems.
7. What are the energy levels which become non degenerate as first order corrections are included to explain Zeeman effect?

(5 × 3 = 15)

Part B

*(Answer any **six**questions, Each question carries **5** marks)*

8. If the Hamiltonian of a system is H = $\frac{p_x^2}{2m}$+ V(x), obtain the value of the commutator [x, H]. Hence, find the uncertainty product (Δx) (ΔH).
9. Calculate the expectation value of momentum for a Gaussian wave packet.

10. For the number operator N_k of a linear harmonic oscillator, show that (i) the commutator $[N_k, N_l] = 0$, and (ii) all positive integers including zero are the eigen values of N_k .
11. Discuss the time dependence of expectation values of stationary and non-stationary states.
12. Compute $(\sigma.a)(\sigma.b)$ and hence evaluate $(\sigma.a)^2$.
13. Find the 3×3 matrix representation of J_y for j=1.
14. Find the Clebch Gordon coefficients for spin ½ system.
15. Apply WKB approximation method to find out the wave functions in the presence of potential well.
16. Using Variational principle find the ground state energy for Hydrogen molecule ion.

(6 ×5 = 30)

Part C

(Answer any ***two****questions, Each question carries* ***15*** *marks)*

17. Discuss how Stern – Gerlach experiment shows the need of a complex abstract vector space to describe a quantum mechanical system.
18. Differentiate between Schrodinger picture and Heisenberg picture of quantum mechanics. Also derive the equations of motion in both pictures.
19. Discuss the formal theory of addition of angular momentum. Discuss the relevant commutation relations.
20. Describe the Schrodinger equation for motion in central potential and hence describe Hydrogen atom.

(2 × 15=30)

Semester II

PH2C07TMThermodynamics and Statistical Mechanics

Credit – 4

Total lecture hours – 72

Aim

The fundamental theories such as Classical Mechanics, Electrodynamics and Quantum Mechanics have given a reductionist approach in understanding the world in terms of elementary particles and the four known type of interactions. However, in order to explain complex systems, comprising of numerous number of such particles, we resort to Statistical Physics which concentrates on bulk properties taking into consideration the average distribution of these particles. Therefore it is high time to give a strong foundation in Thermodynamics and Statistical Mechanics in post graduate education to understand the real world systems.

Course Overview and Context

The course intends to present a solid foundation in thermodynamics and statistical mechanics in analyzing complex systems. These basic concepts will applied in the context of understanding various kinds of ensembles and hence the system of identical particles. Also the different aspects of phase transition will be dealt with.

Module I

Fundamental of Thermodynamics (10 Hrs)

Fundamental definitions – different aspects of equilibrium – functions of state – internal energy – reversible changes – enthalpy – heat capacities – reversible adiabatic changes in an ideal gas – second law of thermodynamics– the Carnot cycle - equivalence of the absolute and the perfect gas scale of temperature – definition of entropy- measuring the entropy – law of increase of entropy – calculations of the increase in the entropy in irreversible processes – the approach to equilibrium.

Foundations of Statistical Mechanics (8 Hrs)

Ideas of probability – classical probability – statistical probability – the axioms of probability theory – independent events – counting the number of events – statistics and distributions – basic ideas of statistical mechanics - definition of the quantum state of the system – simple model of spins on lattice sites – equations of state – the second law of thermodynamics.

Module II

The Canonical Ensemble (12 Hrs)

A system in contact with a heat bath – the partition function – definition of the entropy in the canonical ensemble – the bridge to thermodynamics through partition function – condition for thermal equilibrium – thermodynamic quantities from partition function – case of a two level system – single particle in a one dimensional box – single particle in a three dimensional box –expression for heat and work – rotational energy levels for diatomic molecules – vibrational energy levels for diatomic molecules – factorizing the partition function – equipartition theorem – minimizing the free energy.

Statistics of Identical Particles (4 Hrs)

Identical particles – symmetric and antisymmetricwave functions - bosons – fermions – calculating the partition function for identical particles – spin – identical particles localized on lattice sites.

Module III

Maxwell Distribution and Planck's Distribution (12 Hrs)

The probability that a particle is in a quantum state – density of states in k space – single particle density of states in energy – distribution of speeds of particles in a classical gas – blackbody radiation – Rayleigh-Jeans theory -Planck's distribution – derivation of the Planck distribution – the free energy – Einstein's model vibrations in a solid – Debye's model of vibrations in a solid.

Grand Canonical Ensemble (8 Hrs)

Systems with variable number of particles – the condition for chemical equilibrium – the approach to chemical equilibrium – chemical potential –reactions – external chemical potential – grand canonical ensemble –partition function – adsorption of atoms on surface sites – grand potential.

Module IV

Fermi and Bose Particles (6 Hrs)

Statistical mechanics of identical particles – thermodynamic properties of a Fermi gas – examples of Fermi systems – non-interacting Bose gas.

Phase Transitions (12 Hrs)

Phases – thermodynamic potential – approximation – first order phase transition - Clapeyron equation – phase separation – phase separation inmixtures – liquid gas system –

Ising model – order parameter – Landau theory- symmetry breaking field – critical exponents.

Text Book:*Introductory Statistical Mechanics, R. Bowley&M.Sanchez, 2ndEdn., 2007, Oxford University Press.*

Reference Books

1. Statistical Mechanics, R.K. Pathria, & P.D. Beale, 2ndEdn, B-H (Elsevier) (2004).
2. Introductory Statistical Physics, S.R.A. Salinas, Springer (2000).
3. Fundamentals of Statistical and Thermal Physics, F. Rief, McGraw Hill (1986).
4. Statistical Mechanics, Kerson Huang, John Wiley and Sons (2003).
5. Statistical Mechanics, Satyaprakash& Agarwal, KedarNath Ram Nath Pub. (2004).
6. Problems and solutions on Thermodynamics and Statistical mechanics, Yung Kuo Lim, World Scientific Pub. (1990)
7. Fundamentals of Statistical Mechanics, A.K. Dasgupta, New Central Book Agency Pub. (2005)
8. Statistical Mechanics: a survival guide, A.M. Glazer and J.S. Wark, Oxford University Press. (2001).

Competencies

C1. Discuss fundamental definitions of thermodynamics.

C2. Define different aspects of equilibrium.

C3. Derive the functions of state.

C4. Explain reversible changes

C5. Explain and derive enthalpy, internal energy and heat capacities.

C6. Explain second law of thermodynamics and Carnot cycle.

C7. Define entropy.

C8. Discuss law of increase of entropy.

C9. Explain the ideas of classical and statisticalprobability.

C10. Discuss the axioms of probability theory.

C11. Recognize independent events.

C12. Define quantum state of the system.
C13. Discuss the simple model of spins on the lattice sites.
C14. Define partition function for a canonical ensemble.
C15. Understand the relation between various thermodynamic quantities andpartition Function.
C16. Obtain the expression for heat capacity at constant volume of a single particle in a 3D box.
C17. Compute the heat capacity at constant volume for a diatomic molecule due to rotational and vibrational energy levels .
C18. Explain equipartition theorem.
C19. Distinguish between bosons and fermions.
C20. Starting from the partition function of N particle system, obtain Sackur-Tetrode formula for entropy of an ideal gas.
C21. Extend density of states in k space to calculate single particle density of states in energy.
C22. Compute the average speed, average kinetic energy and root mean square speed of a particle.
C23. State various laws related to blackbody radiation.
C24. Discuss the heat capacity of solids based on Einstein's &Debye's model of vibrations.
C25. Discuss the various methods of calculating chemical potential.
C26. Represent the thermodynamics of a system in terms of grand potential.
C27. Discuss the statistical mechanics of identical particles.
C28. Investigate the thermodynamic properties of Fermi Gas.
C29. Investigate the some examples of Fermi system.
C30. Explain the properties of non interacting Bose gas.
C31. Distinguish between first order and continuous phase transitions.
C32. Obtain the Clapeyron equation.

C33. Discuss the phase separation in mixtures and liquid gas systems.

C34. Explain Ising model.

C35. Define Order parameter.

C36. Explain Landau Theory.

C37. Introduce critical exponents.

Model Question Paper
PH2C07TMThermodynamics and Statistical Mechanics

Time: Three Hours Maximum Marks: 75

Part A

(Answer **any five** questions. *Each question carries 3 marks*)

1. What are the qualities of a good thermometer?
2. What are the axioms of probability?
3. What is partition function? Why is it called so?
4. Write down Wien's scaling law and obtain Wien's displacement law.
5. Define Gibb's free energy. How is it related to the chemical potential?
6. Give the distribution functions for fermions and bosons. Substantiate the difference between them.
7. Define thermodynamic potential. Give some examples.

(5 x 3 = 15)

Part B

(Answer **any six** questions. *Each question carries 5 marks*)

8. What is the maximum possible efficiency of an engine that obtains heat at 250^0C and loses the waste heat at 60^0C?
9. Explain a simple model of spins on lattice sites.
10. Obtain the unnormalized symmetrized wavefunctions for three particle system of bosons and fermions.

11. Calculate the free energy of a system with N particles, each with spin 3/2 with one particle per site. Given that the levels associated with the four spin states have energies $\frac{3}{2}\varepsilon$, $\frac{1}{2}\varepsilon$, $-\frac{1}{2}\varepsilon$ and $-\frac{3}{2}\varepsilon$ and degeneracies 1, 3, 3, and 1 respectively.
12. The partition function of a system is given by

$$Z = e^{aVT^3}$$

where a is a constant. Calculate the pressure, entropy and internal energy of the system
13. Calculate the single particle density of states in energy of a free particle in two dimensions.
14. Show that the internal energy density of black body radiation is proportional to the fourth power of temperature.
15. Calculate the Fermi temperature of electrons in Lithium with number density 4.6×10^{28} m^{-3}.
16. Write a short note on continuous phase transition citing examples.

(6 x 5 = 30)

Part C

(Answer **any two** questions. *Each question carries 15 marks*)

17. Explain the concept of increase in entropy and show that entropy depends on internal energy, volume and number of particles.
18. Considering the translational motion of N non interacting particles in three dimensions show that the contribution to specific heat capacity , $C_v = (3/2)\, Nk_BT$
19. What is grand partition function? Obtain expressions for entropy, pressure and the average number of particles of a grand canonical ensemble in terms of grand partition function.
20. Obtain the thermodynamic properties of Fermi gas at absolute zero of temperature.

(2 x 15 = 30)

Semester II

PH2C08TMCondensed Matter Physics

Credit-4

Total Lecture hours- 72

Aim

The condensed matter physics is one of the largest and most versatile sub-fields of study in physics. It is an area where extended research is going on which has resulted in the discovery and use of several thin film technology devices, nanodevices and composite materials. Therefore it is essential that a post graduate student in physics learn the basics and possibilities of this branch of physics.

Course overview and Context

Condensed matter physics explores the properties of matter, both macroscopic and microscopic. It enables us to learn how matter arises from a large number of interacting atoms, and what physical properties it has as a result of these interactions. This course starts with the basics of reciprocal lattice and equips the student to appreciate the symmetries in the crystal structure and its correspondence to the Bragg patterns.

The electron behavior in crystals is analyzed using the tools of quantum mechanics and a comparison of metals, semiconductors and insulators is drawn using this technique. The students proceed to learn the formation of band gap and the consequences of the presence of the band gap. A small introduction to semiconducting nanoparticles is also provided at the end.

Module I

Elements of Crystal Structure (6 Hrs)

Review of crystal lattice fundamentals and interpretation of Bragg's equation, Ewald construction, the reciprocal lattice, reciprocal lattice to SC,BCC and FCC lattices, properties of reciprocal lattice, diffraction intensity -atomic, geometrical and crystal structure factors- physical significance.

Text Books:

1. ***Introduction to Solid State Physics, C. Kittel, 3rd Edn. Wiley India.***
2. ***Solid State Physics: Structure and properties of materials, M.A.Wahab, Narosa 2nd Edn. 2010***

Free Electron Theory of Metals (12 Hrs)

Review of Drude-Lorentz model - electrons moving in a one dimensionalpotential well - three dimensional well - quantum state and degeneracy -density of states - Fermi-Dirac statistics - effect of temperature on Fermi-Dirac distribution - electronic specific heat - electrical conductivity of metals -relaxation time and mean free path - electrical conductivity and Ohm's law -Widemann-Franz-Lorentz law - electrical resistivity of metals.

Text Book:*Solid State Physics: Structure and properties of materials, M.A. Wahab, Narosa 2nd Edn. 2010.*

Module II

Band Theory of Metals (6 Hrs)

Bloch theorem - Kronig-Penney model - Brillouin zone construction ofBrillouin zone in one and two dimensions – extended, reduced and periodic zone scheme of Brillouin zone (qualitative idea only) - effective mass ofelectron - nearly free electron model – conductors - semiconductors -insulators.

Text Book:*Solid State Physics: Structure and properties of materials, M.A. Wahab, Narosa 2nd Edn. 2010.*

Band theory of semiconductors (10 Hrs)

Generation and recombination - minority carrier life-time - mobility of current carriers - drift and diffusion - general study of excess carrier movement- diffusion length. Free carrier concentration in semiconductors - Fermi level and carrier concentration in semiconductors - mobility of charge carriers - effect oftemperature on mobility - electrical conductivity of semiconductors –Hall effect in semiconductors - junction properties- metal-metal, metal semiconductor and semiconductor-semiconductor junctions.

Text Books:

1. ***Solid State Physics, S.O. Pillai, New Age International 6th Edn.2010.***
2. ***Solid State Physics: Structure and properties of materials, M.A.Wahab, Narosa 2nd Edn. 2010***

Module III

Lattice Dynamics (14 Hrs)

Vibrations of crystals with monatomic basis – diatomic lattice – quantizationof elastic waves – phonon momentum.

Text Book:*Introduction to Solid State Physics, C. Kittel, 3rd Edn. Wiley India.*

Anharmonicity and thermal expansion - specific heat of a solid – classicalmodel - Einstein model - density of states - Debye model – thermalconductivity of solids - thermal conductivity due to electrons and phonons -thermal resistance of solids.

Text Book:*Solid State Physics: Structure and properties of materials, M.A.Wahab,*

Narosa 2nd Edn. 2010.

Dielectric Properties of Solids (6 Hrs)

Review of basic terms and relations, ferroelectricity, hysteresis, dipole theory- Curie-Weiss law, classification of ferroelectric materials andpiezoelectricity.

Text Book:*Solid State Physics, S.O. Pillai, New Age International 6th Edn.2010.*

Ferroelectric domain, antiferroelectricity and ferrielectricity.

Text Book:*Solid State Physics: Structure and properties of materials, M.A.Wahab, Narosa 2nd Edn. 2010.*

Module IV

Magnetic properties of solids (10 hrs)

Review of basic terms and relations, Quantum theory of paramagnetism -cooling by adiabatic demagnetization – Hund's rule – ferromagnetism -spontaneous magnetization in ferromagnetic materials - Quantum theory of ferromagnetism –Weiss molecular field - Curie- Weiss law- spontaneous magnetism - internal field and exchange interaction – magnetization curve –saturation magnetization - domain model.

Text Book:*Solid State Physics, S.O. Pillai, New Age International 6th Edn.2010.*

Superconductivity (4 Hrs)

Thermodynamics and electrodynamics of superconductors- BCS theory- flux quantization- single particle tunneling- Josephson superconductor tunnelingmacroscopicquantum interference

Text Books:

1. ***Introduction to Solid State Physics, C. Kittel, 3rd Edn. WileyIndia.***
2. ***Solid State Physics, S.O. Pillai, New Age International 6th Edn.2010.***

Quantum Confined Structures (Qualitative) (4 Hrs)

Q-well, Q-wires and Q-dots, comparison of density of states, conduction electrons and dimensionality effects, size effects, fermi gas and density of states, properties dependent on density of states

Text Book:*Introduction to Nanotechnology, Charles P Poole and Frank JOwens, Wiley India*

Reference Books

1.Solid State Physics, N.W. Ashcroft & N.D. Mermin, Cengage Learning Pub.11th Indian Reprint (2011).

2.Solid State Physics, R.L. Singhal, Kedar Nath Ram Nath & Co (1981)

3.Elementary Solid State Physics, M. Ali Omar, Pearson, 4th Indian Reprint (2004).

4.Solid State Physics, C.M. Kachhava, Tata McGraw-Hill (1990).

5.Elements of Solid State Physics, J. P. Srivastava, PHI (2004)

6.Solid State Physics, Dan Wei, Cengage Learning (2008)

7.Solid State Physics, A.J. Dekker, Macmillan & Co Ltd. (1967)

Competencies

C1. Revise the basics of crystalline structure and classifications of crystal lattices.

C2. Illustrate the importance of Ewald sphere.

C3. Describe each of the concepts outlined in the syllabus.

C4. Apply equations to evaluate various crystal properties.

C5. Illustrate the realignment of Fermi level in various types of junctions.

C6. Apply the basics f XRD to interpret an XRD pattern.

C7. Compare the vibrations of crystals with monoatomic and diatomic basis.

C8. Explain the concept of phonons and phonon momentum.

C9. Analyse the reason for thermal expansion in solids.

C10. Discuss and compare the classical, Einstein's and Debye models of specific heat.

C11. Explain thermal conductivity of a solid and analyse the contributions from electrons and phonons.

C12. What are ferroelectric materials? Give examples.

C13. Derive the Curie – Weiss law for ferroelectric materials.

C14. Classify ferroelectric materials.

C15. Explain piezoelectricity with examples.

C16. Distinguish between anti ferroelectricity and ferrielectricity.

C17. Discuss quantum theory of paramagnetism.

C18. Explain how cooling can be produced with adiabatic demagnetization.

C19. Apply Hund's rules to find the electronic configuration of elements.

C20. Discuss quantum theory of ferromagnetism and arrive at Curie – Weiss law.

C21. Apply the domain model to explain the hysteresis in ferromagnetic materials.

C22. Derive London equations and discuss the significance.

C23. Discuss qualitative ideas of BCS theory.

C24. Show that the total flux passing through a superconducting ring is quantized.

C25. Discuss different Josephson tunneling and explain macroscopic quantum interference.

C26. Compare the density of states in Q –well, Q – wires and Q –dots.

C27. Discuss the dimensionality and size effects quantum structures.

C28. Explain the properties of quantum structures dependent on density of states.

Model Question Paper

PH2C08TM Condensed Matter Physics

Time : 3 hrs | Max. Marks : 75

Part A

(Answer any 5 questions. Each question carries three marks)

21. What is the significance of geometrical structure factor?
22. What is the Drude model of metals?
23. What is diffusion length in a semiconductor?
24. Write a short note on phonon momentum.
25. Explain how anharmonicity explains thermal expansion in solids

26. How is cooling produced by adiabatic demagnetization?
27. Describe the significance of London equations.

(5 x 3 = 15)

Part B

(Answer any 6 questions. Each question carries 5 marks)

28. State the properties of a reciprocal lattice. Prove that the fcc lattice is reciprocal to bcc lattice.
29. If a dust particle of 1 microgram requires 100 s to cross a distance of 1 mm which is the separation between two rigid walls of the potential, determine the quantum number described by this motion.
30. Using the Kronig – Penney model, show that for P << 1, the energy of the lowest energy band is $E = \hbar^2P/ma^2$.
31. The intrinsic carrier density at 300 K in silicon is 1.5×10^{16} /m^3. If the electron and hole mobilities are 0.13 and 0.05 $m^2V^{-1}s^{-1}$ respectively, calculate the conductivity of intrinsic silicon.
32. The visible light of wavelength 4000A^o undergoes scattering from a diamond crystal of refractive index 2.42. Calculate the maximum frequency of the phonon generated and the fractional change in frequency of incident radiation, given the velocity of sound in diamond as 1.2×10^4m/s
33. The Debye temperature of diamond is 2000K. Calculate the mean velocity of sound in diamond, given the density and atomic mass of diamond as 3500 Kgm^{-3} and 12 amu respectively. If the interatomic spacing is 1.54A^o, estimate the frequency of the dominant mode of lattice vibration
34. State Hunds' rules. Apply these rules to find out the electronic configuration of Dy^{3+} with configuration$4f^9$, $5s^2$, $5p^6$.
35. A ferromagnetic material with J = 3/2 and g =2 has a Curie temperature of 125K. Calculate the intrinsic flux density near 0K. Also calculate the ratio of the magnetisation at 300K in the presence of an external field of 1mT to the spontaneous magnetisation at 0K.
36. Derive the expression for density of states in a quantum well.

(6 x 5 = 30)

Part C

(Answer any 2 questions. Each question carries 15 marks)

37. Derive Bragg's law in reciprocal space. Explain the significance of Laue equations and Ewald sphere.
38. Discuss – How are materials classified into metals, semiconductors and insulators based on Kronig – Penney model?
39. Discuss the Einstein's model of specific heat. What were the drawbacks of the theory?
40. S.T. the current flowing across a Josephson junction is oscillatory when a voltage is applied across the junction.

(15 x 2 = 30)

Semester I& II

PH2C01PMGeneral Physics Practicals

Minimum of 12 Experiments may be chosen from the list. Error analysis of the experiments is to be done.

1. Y, n, σ Cornu's method (a) Elliptical fringes and (b) Hyperbolic fringes.
2. Y & σ by Koenig's method
3. Absorption spectrum –$KMnO_4$ solution / Iodine vapour – telescope and scale arrangement – Hartmann's formula or photographic method
4. Hall Effect (a) carrier concentration (b) Mobility & (c) Hall coefficient.
5. Resistivity of semiconductor specimen–Four Probe Method
6. Band gap energy measurement of silicon.
7. Acousto-optic technique-elastic property of a liquid
8. B - H Curve-Hysteresis.
9. Oscillating Disc-Viscosity of a liquid
10. e/m of the electron-Thomson's method
11. Characteristic of a thermistor - Determination of the relevant parameters.
12. Dielectric constant of a non-polar liquid.
13. Dipole moment of an organic molecule (acetone).
14. Young's modulus of steel using the flexural vibrations of a bar.
15. Verification of Stefan's law and determination of Stefan's constant of radiation
16. Photoelectric effect – determination of Plank's constant.
17. Calibration of Silicon diode as a temperature sensor.
18. Electrical and thermal conductivity of copper and determination of Lorentz number.
19. Elementary experiments using Laser: (a) Study of Gaussian nature of laser beam (b) Evaluation of beam spot size (c) Measurement of divergence
20. Cauchy's constants using liquid prism
21. Constants of a thermocouple and temperature of inversion.
22. Thermal conductivity of liquid / air by Lee's disc method.

23. LED experiments (a) wavelength determination (b) I-V characteristics (c) outputpower variations with applied voltage etc.
24. Surface tension of a liquid using Jaeger's method
25. Michelson's interferometer - (a) λ and (b) d λ and thickness of mica sheet.

Reference Books

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

4. D. Malacara (ed) - Methods of experimental Physics - series of volumes – Academic Press Inc (1988)

Semester I &II

PH2C02PMElectronics Practicals

Minimum of 12 Experiments may be chosen from the list.

1. R C Coupled CE amplifier - Two stages with feedback –Frequency response and voltage gain.
2. Differential amplifiers using transistors and constant current source Frequency response, CMRR.
3. Complementary -symmetry Class B Push-pull amplifier using transistors. Power gain and frequency response.
4. Voltage controlled oscillator using transistors.
5. Voltage controlled oscillator using IC 555.
6. Differential amplifier - using op-amp.
7. Active filters – low pass and high pass-first and second order frequency response and roll off rate.
8. Band pass filter using single op-amp -frequency response andBand width.
9. Wein-bridge Oscillator – using op-amp with amplitude stabilization.
10. Op-amp-measurement of parameters such as open loop gain –offset voltage – open loop response.
11. Crystal Oscillator.
12. R F amplifier - frequency response & band width - Effect of damping.
13. R F Oscillator - above 1 MHz frequency measurement.
14. MOSFET amplifier (frequency response, input & output impedances)
15. RC phase shift oscillator
16. AM generation and demodulation.
17. Voltage regulation using op-amp with feedback.
18. Op-amp-triangular wave generator with specified amplitude. .
19. Solving simultaneous equation using IC 741
20. Analog to digital and digital to analog converter ADC0800 & DAC0800

21. µp - stepper motor control.
22. µp- measurement of analog voltage.
23. µp-Digital synthesis of wave form using D/A Converter

References

1. Electronic devices and circuit theory, R. L. Boylestad, L. Nashelsky, Pearson Education10thed.
2. Electronic principles, Malvino, Tata McGraw-Hill, 6th ed.
3. Op Amps and Linear Integrated Circuits, R. A. Gayakwad, P.H.I, 3rded.
4. Fundamentals of microprocessors and microcomputers, B. Ram, Dhanapathi Rai & Sons
5. Malvino and Leach, Digital Principles and Application, Tata McGraw Hill ed.

Semester III

PH3C09TMQuantum Mechanics - II

Credits – 4

Total lecture hours – 72

Aim

This course aims to provide the learner the knowledge of how to deal with time dependent problems in quantum mechanics. It introduces the students to quantum field theory and to the techniques of quantum mechanics underlining the scattering problem. It familiarizes them with the concepts of relativistic quantum mechanics.

Course Overview and Context

This course deals with time dependent perturbation theory, scattering, relativistic quantum mechanics and introduction to quantum field theory. In Module I, time evolution of the quantum system in the interaction picture is discussed. Theory and application of constant and harmonic perturbations are dealt with. Module II is devoted to the quantum mechanical treatment of the scattering of a particle by a potential. Much of our understanding is gained from the scattering of particles. It is only through the scattering experiments the nucleus, nucleons and quarks have been discovered. So it is relevant to examine the quantum mechanics behind these experiments.Module IIIintroduces the relativistic quantum mechanics with Klein Gordon and Dirac equations. These theories describe spin zero particles and spin ½ particles which are relevant for mesons and fermions. In Module IV, field theory is introduced. Quantizations of relativistic and non-relativistic field are described.

Module I

Time dependent perturbation theory (16 hrs)

Time dependent potentials – interaction picture – time evolution operator in the interaction picture – Dyson series, transition probability, constant perturbation, Fermi golden rule, harmonic perturbation, interaction with classical radiation field, absorption and stimulated emission, electric dipole approximation, photoelectric effect, energy shiftand decay width, sudden and adiabatic approximations (qualitative).

Text Books:

1. ***Modern Quantum Mechanics, J. J. Sakurai, Pearson Education.***
2. ***Quantum Mechanics, Concepts and Applications, N. Zettily, John Wiley & Sons.***

Module II

Scattering (18 hrs)

The integral equation, Asymptotic wave function, Green's function, differential cross section,Born approximation, Yukawa potential, Rutherford scattering. The partial wave expansion, Unitarity and phase shifts, hard sphere scattering, S-wave scattering for the finite potential well, resonances – Ramsaur- Townsend effect.

Text Books:

1. ***Modern Quantum Mechanics, J.J Sakurai , Pearson Education.***
2. ***Principles of Quantum Mechanics, R Shankar, Plenum Press.***

Module III

Relativistic Quantum Mechanics (18 hrs)

Need for relativistic wave equation – Klein-Gordon equation – Probability conservation – covariant notation – derivation of Dirac equation – conserved current representation – large and small components – approximate Hamiltonian for electrostatic problem – free particle at rest –plane wave solutions – gamma matrices – bilinear covariant – relativistic covariance of Dirac equation – angular momentum as constant of motion.

Text Book:*Advanced Quantum Mechanics, J.J. Sakurai, Pearson Education*

Module IV

Elements of quantum field theory (20 hrs)

Euler-Lagrange equation for the fields – Hamiltonian formulation, functional derivatives, conservation laws for classical field theory, Noether's theorem (qualitative), non relativistic quantum field theory, quantization rules for bosons and fermions, relativistic quantum field theory, quantization of neutral Klein Gordon field, canonical quantization of Dirac field - plane wave expansion of field operator - positive definite Hamiltonian.

Text Book:*Field quantization, W. Greiner, J. Reinhardt, Springer.*

References

1. A Text Book of Quantum Mechanics, P.M. Mathews & K. Venkatesan, TMGH.
2. Introduction to Quantum mechanics, David J Griffiths, Pearson.

3. Quantum Field theory, L. H. Ryder, Cambridge University Press.
4. A Modern approach to quantum mechanics, John S. Townsend, Viva Books MGH.
5. Basic Quantum Mechanics, A. Ghatak, Macmillan India 1996
6. Quantum Mechanics, an Introduction, W Greiner, Springer Verlag
7. Quantum Mechanics, E. Merzbacher, John Wiley, 1996
8. Quantum Mechanics, B H Bransden, CJ Joachain, Pearson
9. Quantum Mechanics, L.I. Schiff, Tata McGraw Hill
10. Quantum Mechanics, G Aruldhas, PHI, 2002
11. Fundamentals of Quantum Mechanics Y.R. Waghmare, S Chand & Co.
12. Quantum mechanics, V.K. Thankappan, New Age International 1996

Competencies

C1. Discuss the time dependent perturbation

C2. Illustrate Fermi Golden rule

C3. Apply time dependent perturbation theory to charged particle in electromagnetic field

C4. Examine photoelectric emission on the basis of perturbation theory

C5. Discuss adiabatic and sudden approximation

C6. Find the integral equation for scattering problem

C7. Illustrate the asymptotic wave function for scattering.

C8. Examine the role of Green's function with respect to the wave function in scattering

C9. Define differential cross section cross section and recognize its physical significance

C10. Describe the Born approximation for scattering and apply the same for Yukawa potential and Rutherford scattering.

C11. Describe the partial wave expansion in scattering and hence evaluate derive Unitarityrelation

C12. Determine the phase shifts in scattering

C13. Examine the hard sphere and S-wave scattering for the finite potential well

C14. Illustrate resonances and Ramsaur- Townsend effect in scattering

C15. Recognize the need for relativistic wave equation

C16. Derive Klein-Gordon equation and evaluate the Probability conservation with respect to Klein Gordon equation

C17. Express Klein Gordon equation in covariant notation

C18. Derive Dirac equation and hence find conserved current representation

C19. Find the large and small components of Dirac wave function

C20. Evaluate approximate Hamiltonian for electrostatic problem

C21. Examine the plane wave solutions for Dirac equation

C22. Give the representation of gamma matrices

C23. Summarise the representation and properties of bilinear covariants

C24. Examine relativistic covariance of Dirac equation

C25. Check the angular momentum as constant of motion

C26. Discuss functional derivatives

C27. State Noether's theorem

C28. Discuss the quantization of bosons and fermions

C29. Describe the quantization of Klein Gordon and Dirac fields.

Semester III

PH3C10TMComputational Physics

Credits – 4

Total lecture hours – 72

Aim

This course is intended to introduce the concept of numerical computing to students since mathematical computations are essential in every field of Physics. It expects to help the student in choosing the correct method for solving a numerical problem and in understanding its limitations.

Course Overview and Context

Mathematical computations are an essential component of modern research in every field of science. Large-scale numerical computations have become necessary whenever the complexity of the physical systems investigated does not allow the derivation of an analytical solution. Module I deals with least squares methods of curve fitting and the study of finite differences and interpolation. Module II contains numerical differentiation and integration Trapezoidal Rule, Simpson's 1/3 and 3/8 Rule and error associated with each. A discussion on numerical double integration is also included. Module III provides an introduction to numerical solution of ordinary differential equations by different methods like Euler method, Runga – Kutta 4thorder method, predictor - corrector methods etc. Numerical solution of a system of equations by elimination methods and iterative methods are also introduced. Module IV covers solutions of second order partial differential equations especially elliptical and parabolic equations.

Module I

Curve Fitting and Interpolation (20Hrs)

The least squares method for fitting a straight line, parabola, power and exponential curves with the help of principle of least square fit. Interpolation - Introduction to finite difference operators- Newton's forward and backward difference interpolation formulae- Lagrange's interpolation formula- Newton's divided difference formula with error term- interpolation in two dimensions. Cubic spline interpolation- end conditions. Statistical Ψ^2 test

Text Book: ***Numerical methods for Scientists and Engineers - K Sankara Rao, Prentice Hall of India***

Module II

Numerical Differentiation and Integration (16 Hrs)

Numerical differentiation, errors in numerical differentiation, cubic spline method - finding maxima and minima of a tabulated function - Integration of a function with Trapezoidal Rule, Simpson's 1/3 and 3/8 Rule and error associated with each. Romberg's integration-Gaussian integration method- numerical double integration

Text Book: ***Introductory Methods of Numerical Analysis, S.S. Sastry, PHI Pvt. Ltd.***

Module III

Numerical Solution of Ordinary Differential Equations (20Hrs)

Euler method - modified Euler method and Runge - Kutta 4^{th} order methods - predictor - corrector methods - Milne's method and Adam-Mouton method.

Numerical Solution of System of Equations

Elimination methods – Gauss elimination with pivoting and Gauss-Jordan elimination Method – Iteration methods – Jacobi's method and Gauss-Seidel iteration method – Gauss elimination method and Gauss-Jordan method to find inverse of a matrix - Power method and Jacobi's method to solve eigen value problems

Text Books:

1. ***Numerical methods for Scientists and Engineers - K Sankara Rao, Prentice Hall of India***
2. ***Introductory Methods of Numerical Analysis, S.S. Sastry, PHI Pvt. Ltd.***

Module IV

Numerical solutions of partial differential equations (16Hrs)

Classification of second order partial differential equations - finite difference approximations to derivatives. Laplace's equation- Jacobi's method, Gauss-Seidel method, successive over relaxation method. Parabolic equations- iterative methods for the solution of equations- Hyperbolic equations

Text Books:

1. ***Introductory Methods of Numerical Analysis, S.S. Sastry, PHI Pvt. Ltd.***

2. Numerical Methods, E.Balaguruswamy, Tata McGraw Hill,2009

Reference Books

1. Numerical methods for Scientists and Engineers - K Sankara Rao, Prentice Hall of India
2. An Introduction to Computational Physics-Tao Pang, Cambridge University Press
3. Numerical methods for scientific and Engineering computation -M.K Jain, S.R.K Iyengar, R.K. Jain, New Age International Publishers
4. Computer Oriented Numerical Methods- V. Rajaraman, PHI,2004
5. Numerical Methods -E. Balagurusami, Tata McGraw Hill ,2009
6. Numerical Mathematical Analysis, J.B. Scarborough, 4th Edn, 1958

Competencies

C1. Explain least squares methods of curve fitting.

C2. Discuss Newton's forward and backward difference interpolation formula.

C3. Explain Lagrange's and Newton's divided difference interpolation formula.

C4. Discuss cubic spline interpolation formula.

C5. Explain Ψ^2 test.

C6. Explain numerical differentiation.

C7. Discuss Trapezoidal, Simpson's 1/3 and 3/8 rule for numerical integration.

C8. Discuss numerical double integration

C9. Discuss the theory of Euler method, modified Euler method and Runga – Kutta 4^{th} order method to find numerical solution of ordinary differential equations.

C10. Apply Euler method, modified Euler method and Runga – Kutta 4^{th} order method to solve ordinary differential equations numerically.

C11. Discuss the theory of predictor – corrector methods for solving ordinary differential equations.

C12. Solve numerically the ordinary differential equations using Milne's method and Adam - Mouton methods.

C13. Explain the theory of elimination methods and apply them to solve a system of equations.

C14. Apply iterative methods to find numerical solution of a system of equations.

C15. Discuss different methods to find the inverse of a matrix and apply them to solve numerical problems.

C16. Solve eigen value problems using Power method and Jacobi's method.

C17. Classify the general second order partial differential equations

C18. Derive finite difference equations and set up the standard five point and Diagonal formula

C19. Solve Laplace's equation through different methods.

C20. Execute Bender Schmidt recurrence relation and Crank –Nicolson formula to

C21. Solve parabolic type heat equation.

Semester IV

PH4C11TMAtomic and Molecular Physics

Credits- 4

No- of lecture hours- 72

Aim

Spectroscopy plays most important tool in the development of modern physics, particularly in the understanding of atomic structure which lead to quantum theory. In present day, the technique of spectroscopy remains important for the study of atoms and molecules, and has become a basic technique in many other fields such as plasma physics. It's for this reason that a course in Spectroscopy is essential part of physics education at postgraduate level. This course is designed to provide a strong foundation in Spectroscopy.

Course overview

This course envisages to cover atomic spectrum of one electron system, different magneto and electro optical phenomena, microwave spectroscopy, infrared spectroscopy, Raman effect, electronic spectrum of diatomic molecules and spin resonance spectroscopy.

Module I

Atomic Spectra (18 Hrs)

Vector atom model and quantum numbers - spectroscopic terms - Spin-orbit interaction- derivation of spin-orbit interaction energy, fine structure in sodium atom &selection rules. Lande g factor - normal and anomalous Zeeman effects, Paschen–Back effect and Stark effect in one electron system. Coupling schemes - L S and j j coupling, vector diagram, examples, derivation of interaction energy, Hund's rule &Lande interval rule. Hyperfine structure and width of spectral lines(Qualitative ideas only).

Text Books:

1. ***Spectroscopy, B.P. Straughan& S. Walker, Vol. 1, John Wiley & Sons.***
2. ***Introduction of Atomic Spectra, H.E. White, McGraw Hill***

Module II

Microwave and Infra Red Spectroscopy (18 Hrs)

Introduction: Molecular spectroscopy**-** characterization of electromagnetic radiation- quantization of energy-regions of spectrum – Fourier transform spectroscopy.

Microwave Spectroscopy: Rotational spectra of diatomic molecules - intensity of spectral lines - effect of isotopic substitution. Non–rigid rotor - rotational spectra of polyatomic molecules - linear and symmetric top –Chemical analysis by microwave spectroscopy-Microwave oven.

IR Spectroscopy: Vibrating diatomic molecule as simple harmonic and anharmonic oscillator, diatomic vibrating rotor – break down of Born-Oppenheimer approximation - vibrations of polyatomic molecules –fundamental vibrations and symmetry, overtone and combination frequencies - influence of rotation on the spectra of polyatomic molecules - linear and symmetric top - analysis by IR technique - Fourier transform IR spectroscopy.

Text Books:

1. Fundamentals of Molecular Spectroscopy, C.N. Banwell, Tata McGraw Hill

2. Molecular Structure and Spectroscopy, G. Aruldhas, PHI Learning Pvt. Ltd.

Module III

Raman and Electronic Spectroscopy (18 Hrs)

Raman Spectroscopy: Pure rotational Raman spectra - linear and symmetric top molecules - vibrational Raman spectra – Raman activity of vibrations - mutual exclusion principle - rotational fine structure - structure determination from Raman and IR spectroscopy. Non- linear Raman effects - hyper Raman effect - classical treatment - stimulated Raman effect - CARS, PARS - inverse Raman effect

Electronic Spectroscopy: Electronic spectra of diatomic molecules - progressions and sequences - intensity of spectral lines- Franck – Condon principle - dissociation energy and dissociation products - Rotational fine structure of electronic-vibrational transition - Fortrat parabola - Predissociation.

Text books:

1. Fundamentals of molecular spectroscopy, C.N. Banwell, MGH

2. Molecular structure and spectroscopy, G. Aruldhas, PHI Learning Pvt. Ltd.

3. Lasers and Non-Linear Optics, B.B Laud, Wiley Eastern

Module IV

Spin Resonance Spectroscopy (18 Hrs)

Nuclear Magnetic Resonance (NMR): Quantum mechanical descriptions - Bloch equations - relaxation processes - chemical shift - spin–spin coupling – CW&FTNMR spectrometer - applications of NMR.

Electron Spin Resonance (ESR): Theory of ESR - thermal equilibrium and relaxation - g- factor - hyperfine structure -applications.

Mossbauer spectroscopy: Mossbauer effect - recoilless emission and absorption - hyperfine interactions – chemical isomer shift – magnetic hyperfine and electronic quadrupole interactions - applications.

Text Books:

1. Molecular structure and spectroscopy, G. Aruldhas, PHI Learning Pvt. Ltd.

2. Spectroscopy, B.P. Straughan& S. Walker, Vol. 1, John Wiley & Sons

3 Fundamentals of molecular spectroscopy, C.N. Banwell, MGH

References

1. Spectroscopy (Vol. 2 & 3), B.P. Straughan& S. Walker, Science paperbacks 1976
2. Raman Spectroscopy, D.A. Long, McGraw Hill international, 1977
3. Introduction to Molecular Spectroscopy, G.M. Barrow, McGraw Hill
4. Molecular Spectra and Molecular Structure, Vol. 1, 2 & 3. G. Herzberg, Van Nostard,London.
5. Elements of Spectroscopy, Gupta, Kumar & Sharma, PragathiPrakshan
6. The Infra Red Spectra of Complex Molecules, L.J. Bellamy, Chapman & Hall. Vol.1
7. Laser Spectroscopy techniques and applications, E.R. Menzel, CRC Press, India

Competencies

C1. Discuss the vector atom model and associated quantum numbers with examples.

C2. Calculate spin orbit interaction energy and discuss the fine structure of sodium.

C3. Discuss Different magneto- optical and electro-optical phenomena on the basis of vector atom model.

C4. Calculate interaction energies in coupling schemes and illustrate with examples.

C5. Describe Hyperfine structure and width of spectral lines.

C6. Introduce Molecular spectroscopy and significance of Fourier transform spectroscopy.

C7. Describe the rotational spectrum of rigid and non-rigid diatomic rotator.

C8. Discuss the rotational spectra of polyatomic molecule.
C9. Recognise the principle behind microwave oven.
C10. Discuss the vibrational spectra of diatomic molecule as simple harmonic and unharmonic oscillator.
C11. Discuss diatomic vibrating rotator.
C12. Understand the breakdown of Born Oppenheimer approximation.
C13. Explain the vibrational spectra of polyatomic molecule.
C14. Understand Fourier transform Infrared Spectroscopy.
C15. Explain Rotational Raman spectrum for different types of molecule.
C16. Generalize Raman activity and deduce the Mutual exclusion principle.
C17. Apply Raman and IR spectroscopy to determine the structure of molecules.
C18. Identify various nonlinear and stimulated Raman effects.
C19. Discuss vibrational transitions in electronic spectrum of diatomic molecules
C20. Discuss Franck – Condon principle and analyze intensity of vibrational transitions & dissociation on the basis of Franck – Condon principle
C21. Discuss Rotational fine structure of electronic spectrum of diatomic molecules.
C22. Describe how to draw Fortrat parabola.
C23. Mention Predissociation.
C24. Discuss the theory of nuclear magnetic resonance.
C25. Derive Bloch equations.
C26. Discuss different factors affecting NMR spectrum.
C27. Discuss setup & working of CW&FTNMR spectrometer.
C28. Mention applications of NMR.
C29. Discuss the theory of electron spin resonance.
C30. Describe hyperfine structure of electron spin resonance
C31. Mention applications of ESR.
C32. Illustrate Mossbauer spectroscopy with its applications.

Semester IV

PH4C12TMNuclear and Particle Physics

Credit-4

Total Lecture hours- 72

Aim

The course is aimed to provide an introductory account of nuclear physics and elementary particle physics. Nuclear physics course is intended to give the student an in depth knowledge about the structure and properties of nuclei and about the various models that describe the properties; while the Particle physics course aims to give a coherent description of the basic building blocks of matter such as quarks and leptons.

Course Overview and context

Nuclear physics is the field of physics that studies the constituents and interactions of atomic nuclei. The most commonly known applications of nuclear physics are nuclear power generation but the research has provided application in many fields, including those in nuclear medicine, magnetic resonance imaging and nuclear weapons. The course covers fundamental topics in Nuclear Physics such as nuclear properties, decay, reactions, models, fission and fusion. The last module is on Particle physics which describes the forces involved in elementary particle interactions, the types of elementary particles and their relationships, and the reaction and conservation laws applying to them.

Module I

Nuclear properties and Force between nucleons (18 hrs)

Nuclear radius - mass and abundance of nuclides -nuclear binding energy-nuclear angular momentum and parity, nuclear electromagnetic moments - Deuteron - nucleon-nucleon scattering - properties of nuclear forces- exchange force model

Text Books:

1. ***Introductory Nuclear Physics, K. S. Krane, Wiley India Pvt. Ltd.(Chapter 3&4)***
2. ***Nuclear Physics- D.C. Tayal, Himalaya Publishing House***

Module II

Nuclear Decay and Nuclear Reactions (18 Hrs)

Elementary ideas of α, β, γ decay - Beta decay- energy release- Fermi theory- angular momentum and parity selection rules, Comparative half lives and forbidden decays- neutrino physics- non conservation of parity - Types of reactions and conservation laws- energetics of nuclear reactions - isospin. Reaction cross sections- Coulomb scattering, nuclear scattering - scattering and reaction cross sections- compound-nucleus reactions, direct Reactions

Text Books

1. ***Introductory Nuclear Physics, K. S. Krane Wiley, (Chapter 9&11).***
2. ***Nuclear Physics, S. N. Ghoshal, S.Chand Ltd.***

Module III

Nuclear Models, Fission and Fusion (18 Hrs)

Shell model - Spin-orbit potential - Magnetic dipole moments, Electric quadrupole moments - Valence Nucleons - Collective structure - Nuclear vibrations, Nuclear rotations

Liquid drop Model, Bethe – Weizsacker formula - Application of semi empirical formula - Alpha decay

Nuclear fission – characteristics - energy in fission - Controlled fission reactions - Fission reactors

Nuclear Fusion - Characteristics - Controlled fusion reactors

Text Books:
1.Introductory Nuclear Physics, K. S. Krane Wiley, (Chapter 5, 13&14)
2.Nuclear Physics, S. N. Ghoshal, S. Chand Ltd.

Module IV

Particle Physics (18 Hrs)

Classification of elementary particles - Types of interactions - The four basic forces – symmetries and conservation laws - Conservation of energy, mass, linear and angular momentum, electric charge, Baryon and lepton numbers, strangeness, isospin and parity - C, P , T theorem - Gell-Mann-Nishijima formula - applications of symmetry arguments to particle reactions - Quark model, confined quarks, coloured quarks, experimental evidences for quark model – Gluons - quark-gluon interaction - Grand unified theories.

Text Books:
1. Introductory Nuclear Physics, K. S. Krane Wiley, (Chapter 18)
2. Nuclear Physics, D. C. Tayal, Himalaya Publishing House

Reference Books

1. Introduction to Elementary Particle, D.J. Griffiths, Harper and Row, NY
2. Nuclear Physics, R.R. Roy and B.P. Nigam, New Age International, NewDelhi
3. The particle Hunters - Yuval Ne'eman & Yoram kirsh CUP
4. Concepts of Nuclear Physics, B.L. Cohen, TMH, New Delhi
5. Theory of Nuclear Structure, M.K. Pal, East-West, Chennai
6. Atomic Nucleus, R.D. Evans, McGraw-Hill, New York.
7. Nuclear Physics, I. Kaplan, 2nd Edn, Narosa, New Delhi
8. Introduction to Nuclear Physics, H.A. Enge, Addison Wesley, London
9. Introductory Nuclear Physics, Y.R. Waghmare,Oxford-IBH, New Delhi
10. Atomic and Nuclear Physics, Ghoshal, Vol. 2, S. Chand & Company
11. Fundamentals of Elementary Particle Physics, J.M. Longo, MGH, New York
12. Nuclear and Particle Physics, W.E. Burcham and M. Jobes, Addison-Wesley, Tokyo
13. Subatomic Physics, Frauenfelder and Henley, Prentice-Hall.
14. Particles and Nuclei: An Introduction to Physical Concepts, B. Povh, K. Rith, C. Scholz and Zetche, Springer
15. Elementary Particles and Symmetries, L.H. Ryder, Gordon and Breach, Science Publishers, NY

Competencies

C1 Identify the static properties of nuclei

C2 Extend the idea of binding energy to clarify semiempirical mass formula

C3 Discuss the nucleon-nucleon scattering at low energies

C4 Summarize the main features of internucleon force.

C5 Recognize the elementary ideas of different nuclear decays.

C6 Discuss the energy process and theory associated with β decay.

C7 Instantiate the selection rule for β decay.

C8 Classify nuclear reactions and conservation laws.

C9 Associate reaction cross sections and discuss different scattering.

C10 Discuss the shell model of nucleus taking into account the spin – orbit interaction.

C11 Explain the magnetic dipole moment and electric quadrupole moments of nucleus.

C12 Explain the collective structure of nucleus.

C13 Bring out the differences between nuclear vibrations and rotations.

C14 Discuss the Liquid drop model of nucleus.

C15 Derive the semi empirical mass formula and discuss its application to alpha decay.

C16 Differentiate between nuclear fission and fusion and discuss their characteristics.

C17 Explain controlled fission and fusion reactors.

C18 Classify the elementary particles.

C19 Discuss the types of interactions and the basic forces.

C20 Discuss the symmetries and conservation laws in particle physics.

C21 State and explain C, P, T theorem.

C22 Discuss Gellmann – Nishijima formula.

C23 Discuss quark model and give experimental evidence for the same.

C24 Explain the quark – gluon interaction.

C25 Discuss grand unified theories.

Semester III& IV

PH4C03PMComputational Physics Practicals

(Minimum of 12 Experiments should be done with C++ as the programming language)

1. Study the motion of a spherical body falling through a viscous medium and observe the changes in critical velocity with radius, viscosity of the medium.
2. Study the path of a projectile for different angles of projection. From graph find the variation in range and maximum height with angle of projection.
3. Study graphically the variation of magnetic field B(T) with critical temperature in superconductivity using the relationship $B(T) = B_0 [1 - (T/T_c)^2]$, for different substances.
4. Discuss the charging /discharging of a capacitor through an inductor and resistor, by plotting time –charge graphs for a) non oscillatory, b) critical) oscillatory charging.
5. Analyze a Wheatstone's bridge with three known resistances. Find the voltage across the galvanometer when the bridge is balanced.
6. Study the variation in phase relation between applied voltage and current of a series LCR circuit with given values of L and C. Find the resonant frequency and maximum current.
7. A set of observations of π meson disintegration is given. Fit the values to a graph based on appropriate theory and hence calculate the life time τ of π mesons
8. Draw graphs for radioactive disintegrations with different decay rates for different substances. Also calculate the half-life's in each case.
9. Half-life period of a Radium sample is 1620 years. Analytically calculate amount of radium remaining in a sample of 5gm after 1000 years. Verify your answer by plotting a graph between time of decay and amount of substance of the same sample.
10. Plot the trajectory of a α-particle in Rutherford scattering and ditermine the values of the impact parameter.
11. Draw the phase plots for the following systems
    a. A conservative case(simple pendulum)
    b. A dissipative case(damped pendulum)
    c. A nonlinear case(coupled pendulum
12. Two masses m_1BB and m_2BB are connected to each other by a spring of spring constant k and the system is made to oscillate as a two coupled pendulum. . Plot the

positions of the masses as a function of time.

13. Plot the motion of an electron in (i) in uniform electric field perpendicular to initial velocity (ii) uniform magnetic field at an angle with the velocity. and (iii) simultaneous electric and magnetic fields in perpendicular directions with different field strengths.
14. A proton is incident on a rectangular barrier, calculate the probability of transmission for fixed values of V_0 and E (V_0> E) for the width of barrier ranges from 5 to 10 Fermi, and plot the same.
15. Generate the interference pattern in Young's double slit-interference and study the variation of intensity with variation of distance of the screen from the slit.
16. Analyze the Elliptically and circularly polarized light based on two vibrations emerging out of a polarizer represented by two simple harmonic motions at right angles to each other and having a phase difference. Plot the nature of vibrations of the emergent light for different values of phase difference
17. Generate the pattern of electric field due to a point charge
18. Sketch the ground state wave function and corresponding probability distribution function for different values of displacements of the harmonic oscillator.
19. Gauss elimination method for solving a system of linear equations.
20. Solving a second order differential equation using 4^{th} order Runge- Kutta method.
21. Finding the roots of a nonlinear equation by bisection method.
22. Monte Carlo method for simulation
23. Integration using Simpson's 1/3 or 3/8 rule
24. Numerical integration by Rectangle rule
25. Generation of standing wave
26. Solution of algebraic and transcendental equations using Newton Raphson method
27. Evaluation of Bessel and Legendre functions using series expansion and recurrence relations.
28. Least square fitting: to obtain slope and intercept by linear and non-linear fitting
29. Simulation of wave function and probability density of a particle in a box;

Schrodinger equation is to be solved and eigen value must be calculated numerically.

30. Logistic map-solution and bifurcation diagram.

Reference Books:

1. Computational physics, An Introduction, R.C. Verma, P.K. Ahluwalia & K.C. Sharma, New Age India, Pvt. Ltd.
2. An Introduction to computational Physics, Tao Pang, Cambridge University Press.
3. Simulations for Solid State Physics: An Interactive Resource for Students and Teachers, R.H. Silsbee & J. Drager, Cambridge University Press.
4. Numerical Recipes: the Art of Scientific Computing, W.H. Press, B.P. Flannery, S.A. Teukolsky& W.T.Vettering, Cambridge University Press.

SYLLABI OF COURSES – ELECTIVE BUNCH

ELECTIVE BUNCH A: ELECTRONICS

Semester III

PH3EA1TMOptoelectronics & Digital Signal Processing.

Credits- 4

No- of lecture hours- 72

Aim

Optoelectronics is based on the quantum mechanical effects of light on electronic materials, especially semiconductors, sometimes in the presence of electric fields. This field is a growth area, and is strongly dependent on the science underpinning the topics. It's for this reason that a course in Optoelectronics is essential part of physics education at postgraduate level. This course is designed to provide a strong foundation in Optoelectronics.

Course overview and context.

This course envisages covering different display devices, different types of lasers, generation of high power laser pulse through Q switching, non linear optics, photo detectors, modulators and digital signal processing.

Module I

Display devices (6 hrs)

Light emitting diode – Principle, materials, structures, Characteristics, Response time & Drive circuitry. Heterojunction high intensity LEDs – Double hetero junction LED - Plasma displays – Liquid crystal display – Numeric display.

Photo detectors (14 hrs)

Photodiode – Principle, Ramo's theorem and external photocurrent, Photovoltaic and photoconductive mode & Quantum efficiency and responsivity. Pin Photodiode – Avalanche photodiode – Phototransistor – Photoconductive detectors - Noise in photodetectors – Photovoltaic device principles – Solar cell – Series resistance and equivalent circuit & Temperature effects.

Text books:

1. ***Optoelectronics An introduction, J. Wilson & J.F.B Hawkes, Prentice Hall of India Pvt. Ltd.***
2. ***Optoelectronics & Photonics, S.O. Kasap. Publication: Dorling Kindersley India Pvt. Ltd.***

Module II

Modulators (10 hrs)

Light propagation in an anisotropic medium – Optical anisotropy, Uniaxial crystals, Birefringence of calcite and Dichorism. Electro-optic effect – Pockels effect – Kerr modulators – Scanning and switching – Magneto – optic effect –Faraday effect – Acousto – optic modulator.

Text books:

1. Optoelectronics An introduction, J. Wilson & J.F.B Hawkes. Publication: Prentice Hall of India Private Limited, New Delhi - 110001

2. Optoelectronics & Photonics, S.O. Kasap. Publication: Dorling Kindersley India Pvt Ltd.

Nonlinear Optics (8 hrs)

Wave propagation in an anisotropic crystal- polarization response of materials to light-second order nonlinear optical process- second harmonic generation- sum and difference frequency generation- optical parametric oscillation- third order nonlinear optical process-third harmonic generation- intensity dependent refractive index- self focusing- nonlinear optical materials- phase matching- angle tuning- saturable absorption- optical bistability-two photon absorption.

Text books:

1. ***Laser fundamentals, William Silfvast, CUP, 2nd edition***
2. ***Nonlinear Optics, B B Laud, New Age International***

Module III

Laser Principle (8 hrs)

Thermal equilibrium - Absorption - spontaneous and stimulated emissions - Absorption and stimulated emission coefficients- Absorption and gain on homogeneously and inhomogeneously broadened radiative transitions - Population inversion and saturation intensity - exponential growth factor,

Laser Output Control (8hrs)

Generation of high power pulses- Q-factor- Q-switching for giant pulses-methods of Q-switching- mode locking and techniques for mode locking.

Text book: ***Laser fundamentals, William T. Silfvast, CUP 2nd Edn. (2009).***

Module IV

Digital Signal Processing (16 hrs)

Signals – Continuous time (CT) and discrete time (DT), periodic and aperiodic & eve and odd signals. Energy and power in signals – Standard DT and CT signals – Analysis of CT signals – Fourier series & Fourier transform. Analysis of DT signals – Discrete Fourier transform, Fast Fourier transform & Z-transform. Digital filtering in time domain – Linear filters – Finite impulse response filters & Infinite impulse response filters.

Text books:

1 ***Digital Signal Processing: Theor, Analysis and Digital-Filter Design, B.Somanathan Nair, PHI (2004)***
2 ***Digital Signal Processing, P. Ramesh Babu, Scitech***
3 ***Digital Signal Processing, Alan V. Oppenheim & R.W. Schafer, PHI***

Reference Books:

1. Semiconductor optoelectronic devices: Pallab Bhattacharya, Pearson(2008).
2. Optoelectronics: An introduction to materials and devices, Jasprit Singh, Mc Graw Hill International Edn., (1996).
3. Optical waves in crystals: Propagation and Control of Laser Radiation, A. Yariv and P. Yeh, John Wiley and Sons Pub. (2003).
4. Digital Signal Processing, S. Salivahanan, A. Vallavaraj, C. Gnanapriya, TMH .
5. Signals and Systems, Allan V. Oppenheim, Alan S. Willsky, S.H. Nawab, PHI.
6. Digital Signal Processing, John G. Proakis, Dimitris G. Manolakis, PHI.

Competencies

C1. The students master all the topics outlined in the syllabus and become able to describe each concept.

C2. Discuss the principle, working, materials, structures, characteristics, response time and drive circuitry of LED

C3. Discuss the principle and working of Plasma displays.

C4. Discuss the principle and working of Liquid crystal display.

C5. Describe numeric display.

C6. Discuss the principle, working, efficiency and responsivity of photodiode.

C7. Discuss the principle, working and advantages of PIN diode over of photodiode.

C8. Discuss the principle, working and advantages of avalanche photo diode.

C9. Discuss the principle and working of phototransistor.

C10. Discuss the principle and working of photoconductive detectors and determine photoconductive gain.

C11. Discuss the principle, working, characteristics and equivalent circuit of solar cell.

C12. Discuss the temperature dependence on the output of solar cell.

C13. Discuss light propagation in an anisotropic medium.

C14. Discuss the principle and working of longitudinal and transverse electro-optic modulators.

C15. Describe Kerr effect.

C16. Describe scanning and switching

C17. Discuss Faraday effect.

C18. Discuss the principle and working of acousto-optic modulator.

C19. Apply the knowledge to identify the type of nonlinear optical process in various situations.

C20. Identify various materials in terms of their order of nonlinear optical coefficients.

C21. Understand the applications of various nonlinear optical materials.

C22. Describe with illustrations various concepts mentioned in the syllabus.

C23. Understand the differences between line broadening mechanisms.

C24. Evaluate various parameters relevant to the laser using the concerned equations.

C25. List and describe various techniques for mode locking and Q switching.

C26. Analyse different types of signals.

C27. Discuss the representation of continuous time periodic and aperiodic signals in frequency domain. (Continuous time Fourier series and Fourier transform)

C28. Discuss the representation of discrete time aperiodic signals in frequency domain.

C29. Discuss decimation in time fast Fourier transform and its algorithm.

C30. Discuss representation of discrete time signals in complex domain.

C31. Discuss linear finite impulse response filters and infinite impulse response filters.

Semester III

PH3EA2TMMicroelectronics and Semiconductor Devices

Credit – 4

Total lecture hours – 72

Aim

The boom in microelectronic technology, owing to the emergence and evolution of microprocessor and microcontroller, has paved way to the concept of real time monitoring and control systems. The course on "Microelectronics and Semiconductor devices" is designed so as to impart knowledge on the fundamental architecture and system design concept of microelectronics as well as an overview of semiconductor devices.

Course Overview and Context

The course is centered around the hardware and software aspects of typical 8 bit and 16 bit microprocessors. A comparison of microprocessor and microcontroller is sought to introduce the role of microcontroller in real time applications and embedded systems. The course also imparts an overview of characteristics, operations and limitations of various semiconductor devices.

Module I

Basics of Digital Techniques (18 Hrs)

Review of 8085 microprocessor - General organization of a microprocessor based microcomputer system – memory organization – main memory array – memory management – cache memory – virtual memory - input/output - standard I/O – memory mapped I/O – microcomputer I/O circuits – interrupt driven I/O –DMA – RAM - hard disk - CD – Flash memory.

Text Book:*Microprocessors and Microcomputer based system design, H.Rafiquizzaman, Universal Book stall, New Delhi*

Module II

8086 Microprocessor (19 Hrs)

The Intel 8086 - architecture - MN/MX modes - 8086 addressing modes - instruction set-instruction format - assembler directives and operators - Programming with 8086 –Pins and signals-Basic system concepts- Comparison of 8086 and 8088 - Coprocessors , Intel 8087 - Familiarization with Debug utility(elementary idea)

Text Books:

1. Microprocessors and Microcomputer based system design, H. Rafiquizzaman, Universal Book stall, New Delhi
2. Microprocessor- The 8086/8088, 80186/80286, 80386/80486 and Pentium Family- Nilesh B Bahadure

Module III

Microcontrollers (19 Hrs)

Introduction to microcontrollers and Embedded systems - comparison of microprocessors and microcontrollers - The 8051 architecture - Register setof 8051 - important operational features - I/O pins, ports and circuits - external memory - counters and timers – interrupts - Instruction set of 8051 - Basic programming concepts - Applications of microcontrollers - (basic ideas) – Embedded systems(basic ideas)

Text Book:*The 8051 microcontroller, Architecture Programming andApplications, Kenneth J Ayala- Penram Int. Pub. Mumbai.*

Module IV

Semiconductor Devices (16 hrs)

Schottky barrier diode - qualitative characteristics – ideal junction properties– nonlinear effects on barrier height – current voltage relationship – comparison with junction diode – metal semiconductor ohmic contact – ideal non rectifying barriers – tunnelling barrier – specific contact resistances – hetro-junctions – hetro junction materials – energy band diagram – two dimensional electron gas – equilibrium electrostatics – current voltage characteristics.

Text Book:*Semiconductor Physics and Devices, Donald A. Neamen, McGraw Hill*

References:

1. Microprocessor and Peripherals, S.P. Chowdhury & S. Chowdhury-SCITECH Publications
2. Microprocessor Architecture Programming and Applications with 8085, R.S. Gaonkar – Penram int. Pub. Mumbai
3. 0000 to 8085 Introduction to Microprocessors for Engineers and Scientists.- P.K. Gosh & P.R. Sridhar, PHI

4. Advanced microprocessors and peripherals, A.K. Ray & K.M. Burchandi –TMH.
5. Microprocessor and microcontroller, R. Theagarajan- SCITECH Publications India Pvt. Ltd.
6. Operating system Principles, Abraham Silberschatz & Peter Baer Galvin & Greg Gagne, John Wiley
7. Microprocessors and Microcontrollers – Architecture, Progamming and System Design using 8085,8086,8051 and 8096, Krishna Kant, PHI 2007

Competencies

C1. Discuss the architecture of 8085 microprocessor.
C2. Explain organization of microprocessor based microcomputer system.
C3. Discuss the memory organization of microprocessor.
C4. Differentiate standard I/O and memory mapped I/O.
C5. Discuss microcomputer I/O circuits.
C6. Explain interrupt driven I/O.
C7. Define DMA, RAM, CD and flash memory.
C8. Explain the architecture of 8086 microprocessor.
C9. Discuss various addressing modes of 8086 microprocessor.
C10. Recognize the instruction sets of 8086 microprocessor.
C11. Demonstrate basic programming concept of 8086 microprocessor.
C12. Explain pins and signals of 8086 microprocessor.
C13. Compare 8088 and 8086 microprocessor qualitatively.
C14. Introduce coprocessor 8087.
C15. Introduce the concept of debug utility.
C16. Distinguish between microprocessor and microcontroller.
C17. Explain various registers of 8051 microcontroller.
C18. Explain various operational features of 8051 microcontroller.
C19. Sketch and explain pin out diagram of 8051 microcontroller.

C20. Recognise the instruction sets of 8051 microcontroller.
C21. Introduce the various applications of microcontroller and embedded systems.
C22. Discuss schottky barrier diode.
C23. Discuss the ideal junction properties.
C24. Illustrate the current voltage relationship.
C25. Discuss metal semiconductor ohmic contact.
C26. Explain hetro- junctions.
C27. Draw and explain energy band diagram.
C28. Discuss two dimensional electron gas.
C29. Define equilibrium electrostatics.

SemesterIV

PH4EA3TMInstrumentation and communication Electronics

Credit – 4

Total lecture hours – 72

Aim

The importance of technical education in general and training in specific areas in particular has been recognized by people all over the world. This course makes the students get introduced to electronic instrumentation and communication.

Course overview and context

This course introduces various kinds of transducers and instruments for digital measurements in module I. The measuring instruments for basic parameters and various kinds of recorders are described in module II. The students get familiarized with different types of wave propagation, Television fundamentals and digital communication techniques in modules III and IV. Study of measuring instruments, recorders and communication technology is very relevant with respect to the Physics scenario. This course provides an elaborate foundation for the topics.

Module I

Transducers and Digital Instrumentation (20 Hrs)

Transducers: Classification of transducers - electrical transducer –resistive transducer - strain gauges –thermistor-inductive transducer - differential output transducers –linear variable differential transducer-rotational variable differential transducer-capacitive transducer – load cell -- piezo-electrical transducer- photoelectric transducer – photoconductive cells-photo voltaic cell – semi conductor photo diode –the photo transistor- thermo electric transducers– Mechanical transducers, ionization transducers, Hall effect transducers, digital transducers and electro chemical transducers(Basic idea only).

Digital Instrumentation: Digital counters and timers - digital voltmeter –RAMP technique –Dual slope integrating type DVM-integrating type DVM- digital multimeters. Digital frequency- meter - digital measurement of time-digital measurement of frequency– digital tachometer -digital pH meter - digital phase meter.

Module II

Measurement of Basic Parameters and Recorders (18 Hrs)

Transistor Voltmeter - amplified DC meter – A.C voltmeters using rectifiers– precision rectifier – true RMS responding voltmeter – chopper type DC amplifier voltmeter - milli voltmeter using operational amplifier – differential voltmeter – Ohm meter – electronic multimeter – commercial multimeter – output power meters - stroboscope – phase meter – vector impedance meter – Q meter – RF measurement – transistor testers – CRO (Basic ideas) Recorders: Strip chart recorders - XY recorders - digital XY plotters - magnetic recorders -digital data recording - Storage oscilloscope – Digital storage oscilloscope

Module III

Introduction to Communication (18 Hrs)

Bandwidth requirements − SSB technique – radio wave propagation −Ionosphere − Ionosphere variations − Space waves – Extraterrestrial communication - Transmission lines − Basic principles – Characteristic impedance − Losses − Standing waves − Quarter and half wavelength lines. Television fundamentals − Monochrome transmission − Scanning −Composite TV video wave form − Monochrome reception – Deflection circuits − Colour Television. Basic ideas of high definition TV – LCD & LED TV

Module IV

Digital Communication (16 hrs)

Pulse Communication – Information theory – Coding – Noise – Pulse modulation – PAM – PTM – PCM – PPM. Digital communication –Fundamentals ofdata Communications systems – Digital codes – Data Sets and interconnection requirements. Multiplexing techniques – Frequency division and time division multiplexing. Microwave generators – Klystron and Magnetron – Satellite communication. Digital cellular systems GSM, TDMA, CDMA and GPS (basic idea only)

Text Books:

1. Electronic Instrumentation, H.S. Kalsi, TMH (1995)

2. Electronic communication systems, George Kennedy, TMMGH

Reference Books:

1. Transducers and instrumentation, D.V.S. Murty, PHI (1995)

2. Monochrome and Colour Television R.R. Gulati, New Age India
3. Mobile Cellular Telecommunication Systems, William C.Y. Lee,
4. Modern electronic Instrumentation and Measurement Techniques, A.D. Helfric & W.D. Cooper,PHI, (1997)
5. Instrumentation-Devices and Systems 2nd Edn. C.S. Rangan, G.R. Sarma, V.S.V. Mani, TMH, (1998) 73
6. Electronic Measurements and Instrumentation, M.B. Olive & J.M. Cage, MGH, (1975)
7. Digital Instrumentation, A.J. Bouwens,TMH, (1998)
8. Elements of Electronic Instrumentation, J. Jha, M. Puri, K.R. Sukesh, &M.Kovar., Narosa, (1996)
9. Instrumentation Measurement and Analysis, B.C. Nakra & K.K. Chaudhry, TMH, (1998)
10. Op-amps and Linear Integrated Circuits, R.A. Gaykward, PHI, (1989)
11. Electronic fundamentals and Applications, John D. Ryder, PHI.
12. Satellite communication, Robert M.Gagliardi, CBS Publishers, Delhi.
13. Electric and electronic measurements and instrumentation 10th Edn. A.K. Sawhney, Dhanpath Rai & Company.

Competencies

C1. Classify different types of transducers.

C2. Illustrate electrical and resistive transducers.

C3. Categorize and explain strain gauges.

C4. Categorize and explain differential output transistors.

C5. Explain capacitive transducer and load cell.

C6. Discuss different types of photoelectric transducers.

C7. Discuss thermoelectric transducers.

C8. Define mechanical transducers , ionization transducers , Hall effect transducers, digital transducers and electro chemical transducers.

C9. Discuss dual slope and single slope integrating type digital voltmeters.

C10. Explain digital measurement of time and frequency.

C11. Discuss digital meters.

C12. Construct different ac and dc voltmeter using basic meter

C13. Design and construct Ohm meter, multimeter, output power meters, stroboscope, phase meter, vector impedance meter, Q meter

C14. Discuss CRO

C15. Define different types of recorders

C16. Explain SSB techniques.

C17. Define radio wave propagation and its variations

C18. Define space waves

C19. Discuss transmission lines

C20. Define standing waves

C21. Describe television.

C22. Categorize and explain different types of pulse communication.

C23. Explain digital codes, data sets and inter connection requirements.

C24. Explain multiplexing techniques

C25. Discuss microwave generators, satellite communication and different digital cellular systems.

Semester III &IV

PH4EA1PMAdvanced Electronics Practicals

(Minimum of 12 Experiments should be done choosing at least 2experiments from each group)

[A] Microprocessors and Micro Controllers (use a PC or 8086-µp kit)

1. Sorting of numbers in ascending/descending order.
2. Find the largest and smallest of numbers in array of memory.
3. Conversion of Hexadecimal number to ASCII and ASCII to Hexadecimal number.
4. Multi channel analog voltage measurements using AC card. 74
5. Generation of square wave of different periods using a microcontroller.
6. Measurement of frequency, current and voltage using microprocessors.

[B] Communication Electronics

1. Generation PAM and PWM
2. Frequency modulation and demodulation using IC –CD4046.
3. Multiplexer and demultiplexer using digital IC 7432.
4. Radiation characteristics of a horn antenna.
5. Measurement of characteristic impedance and transmission lineparameters of a coaxial cable.

[C] Electronic Instrumentation

1. DC and AC milli-voltmeter construction and calibration.
2. Amplified DC voltmeter using FET.
3. Instrumentation amplifier using a transducer.
4. Generation of BH curve and diode characteristics on CRO.
5. Voltage to frequency and frequency to voltage conversion.
6. Construction of digital frequency meter.
7. Characterization of PLL and frequency multiplier and FM detector.

[D] Optoelectronics

1. Characteristic of a photo diode - Determination of the relevant parameters.
2. Beam Profile of laser, spot size and divergence.
3. Temperature co-efficient of resistance of copper.
4. Data transmission and reception through optical fiber link.

ELECTIVE BUNCH B: MATERIAL SCIENCE

Semester III

PH3EB1TMSolid State Physics

Credit-4

Total Lecture hours- 72

Aim

This course aims to provide a sound foundation of basic and some of the advanced topics in solid state physics. It is intended to show how the study of solid state plays a vital role in many branches such as material Science and engineering.

Course Overview and context

Solid-state physics, the largest branch of condensed matter physics provides the theoretical basis for the study of Material science. It is the study of solids, using quantum mechanics, crystallography, electromagnetism, metallurgy etc. and studies how the large-scale properties of solid materials result from their atomic-scale properties. This course aims to provide an introduction to crystal structure and symmetry properties, imperfections and dislocations in crystals, Optical properties, Lasers and semiconductor crystals through the four modules.

Module I

Crystals and Symmetry Properties (20 Hrs)

Crystalline state – Anisotropy - Symmetry elements – Translational, Rotational, Reflection – Restrictions on Symmetry elements – Possible combinations of Rotational Symmetries - Crystal systems - 14 Bravais lattices.

Stereographic projection and point groups – principles – Constructions -Construction with the Wulff net - Macroscopic Symmetry elements-Orthorhombic system- Tetragonal system- Cubic system - Hexagonal system- Trigonal system - Monoclinic system- Triclinic system - Laue groups -Space groups.

Module II

Optical Properties and Crystal Lasers (16 Hrs)

Lattice vacancies – diffusion – colour centres – F-centre and other centres inalkali halides – ionic conductivity – colour of crystals – excitons in molecular crystals – model of an ideal photoconductor – traps – space charge effects – experimental techniques – transit time excitation and emissionAicalf mechanism – model for thallium activated alkali halides -electroluminescence.

Lasers

Properties of laser beams - temporal coherence - spatial coherence –directionality – single mode operation - frequency stabilization – mode locking - Q-Switching - measurement of distance - Ruby laser - four-levelsolid state lasers - semiconductor lasers - Neodymium lasers (Nd:YAG, Nd:Glass)

Module III

Semiconductor crystals (18 Hrs)

Classification of materials as semiconductors - band Gap - band structure ofSilicon and germanium - equations of motion - intrinsic carrier concentration- impurity conductivity- Thermoelectric effects in semiconductors –semimetals - amorphous semiconductors - p-n junctions

Plasmons, Polaritons and Polarons

Dielectric function of the electron gas– plasmons - electrostatic screening- **p**olaritons and the LST relation –electron - electron interaction - Fermi liquid - electron-phonon interaction – Polarons- Peierls instability of linear metals.

Module IV

Imperfections and Dislocations (18 Hrs)

Types of imperfections in crystals - thermodynamic theory of atomic imperfections – experimental proof – diffusion mechanisms – atomicdiffusion theory – experimental determination of diffusion constant – ionic conduction – shear strength of single crystals - slip and plastic deformations. Dislocations - Burgers vectors – edge and screw dislocations – motion of dislocation – climb - stress and strain fields of dislocation – forces acting on

a dislocation –energy of dislocation – interaction – between dislocation densities – dislocation and crystal growth – Dislocation – Frank – Read mechanism - point defects - twinning.

Reference Books

1. Crystallography and crystal defects, A. Kelley, G.W. Groves & P. Kidd, Wiley
2. Crystallography applied to Solid State Physics, A.R. Verma, O.N. Srivastava, NAI
3. Solid State Physics, A.J.Dekker, Macmillan, (1967).
4. Lasers Theory and Applications, K.Thyagarajan, A.K. Ghatak, Plenum Press
5. Lasers and Non-Linear Optics, B B Laud, New Age International.
6. Solid State Physics, S.L. Gupta and V.Kumar, Pragati Prakashan.
7. Introduction to Theory of Solids, H.M. Rosenberg, Prentice Hall.
8. Solid State Physics,J.S. Blakemore, W.B.Saunders & Co. Philadelphia.
9. Solid State Physics, N.W. Ashcroft & N.D. Mermin, Brooks/ Cole
10. Crystal Defects and Crystal Interfaces, W. Bollmann, Springer Verlag.
11. A short course in Solid State Physics, Vol. I, F.C Auluck, Thomson Press Ltd.
12. Crystalline Solids, Duncan McKie, Christine McKie, Wiley

Competencies

C1. Discuss the anisotropy of the crystals using the different symmetry elements.

C2. Explain the restrictions on symmetry elements.

C3. Identify the possible combinations of rotational symmetries.

C4. Classify the crystal systems and discuss each one of them.

C5. Define Bravais lattices. How are they classified?

C6. Discuss the principle and construction of stereographic projection and point groups giving special emphasis to construction with the Wuff net.

C7. Compare the macroscopic symmetry elements of the seven crystal systems.

C8. Distinguish between Laue groups and space groups.

C9. Explain lattice vacancies and diffusion.

C10. Define colour centres and discuss about F centre and other centres in alkali halides.

C11. What is ionic conductivity?

C12. Discuss about excitons in molecular crystals.

C13. Explain the model of an ideal photoconductor.
C14. Discuss a model for thallium activated alkali halides.
C15. Explain electroluminescence.
C16. Discuss the properties of laser beams.
C17. Explain single mode operation.
C18. Explain mode locking and Q switching.
C19. Classify lasers into different categories and discuss an example for each.
C20. Classify materials in terms of their band gap.
C21. Explain the band structure of silicon and germanium.
C22. Derive the equation of motion.
C23. Derive expressions for carrier concentration and conductivity of semiconductors.
C24. Explain thermoelectric power in semiconductors and semimetals.
C25. Describe the properties of amorphous semiconductors.
C26. Differentiate between plasmons, polaritons and polarons.
C27. Derive the LST relation.
C28. Discuss Peierls instability of linear metals.
C29. Discuss about the different types of imperfections in crystals.
C30. Derive the thermodynamic theory of atomic imperfections and give experimental proof for the same.
C31. Discuss the atomic diffusion theory of diffusion mechanisms.
C32. Discuss how the diffusion constant can be determined experimentally.
C33. Distinguish between slip and plastic deformations.
C34. Classify dislocations in crystals.
C35. Discuss about the stress and strain fields, forces acting , energy and interaction between dislocations.
C36. Explain the Frank -Read mechanism.
C37. Define point defects and twinning.

Semester III

PH3EB2TM Crystal Growth Techniques

Credit-4

Total Lecture hours- 72

Aim

The course is expected to provide experimental and theoretical aspects of crystal growth. The significance of single crystals, the science of growing the crystals and the modern crystal growth techniques will be introduced to the student through this course.

Course Overview and context

The modern technological developments depend greatly on the availability of suitable single crystals. In spite of great technological advancements in the recent years, we are still in an early stage with respect to the growth of good quality single crystals. In this context, this course is introduced for the material science students. The course includes the science of crystal growth and a description of various crystal growth techniques. The last module discusses about materials for semiconductor devices.

Module I

Crystal Growth phenomena (18 Hrs)

The historical development of crystal growth – significance of single crystals- crystal growth techniques - the chemical physics of crystal growth - Theories of nucleation - Gibb's Thompson equation for vapour, melt and solution- energy of formation of spherical nucleus- heterogeneous nucleation- kinetics of crystal growth, singular and rough faces, KSV theory, BCFtheory - periodic bond chain theory- The Muller- Krumbhaar model

Module II

Crystal Growth from Melt and Solution Growth (18Hrs)

Growth from the melt - the Bridgmann technique – crystal pulling -Czochralski method- experimental set up - controlling parameters advantages and disadvantages - convection in melts – liquid solid interface shape -crystal growth by zone melting - Verneuil flame fusion technique - Low temperature solution growth - methods of crystallization – slow cooling,solvent evaporation, temperature gradient methods - crystal growth system -growth of KDP, ADP and KTP crystals - high temperature solution growth,gel growth.

Module III

Vapour Growth and Epitaxial Growth (18 Hrs)

Physical vapour deposition - chemical vapour transport – definition,fundamentals, criteria for transport - Specifications, STP, LTVTP & OTP -advantages and limitations of the technique, hydrothermal growth, designaspect of autoclave – growth of quartz, sapphire and garnet - Advantages of epitaxial growth, epitaxial techniques - liquid phase epitaxy,vapour phase epitaxy, molecular beam epitaxy, chemical beam epitaxy and atomic layer epitaxy

Module IV

Materials for Semiconductor Devices (18Hrs)

Semiconductor optoelectronic properties - band structure - absorption and recombination, semiconductor alloys - group III-V materials selection -binary compounds, ternary alloys, lattice mismatch - lattice mismatched ternary alloy structures - compositional grading, heteroepitaxial ternary alloy structure - Quaternary alloys -Semiconductor Devices - Laser diodes, light emitting diodes (LED),photocathodes, microwave Field-Effect Transistors (FET).

Reference Books

1. The Growth of Single Crystal, R.A. Laudise, Prentice Hall, NJ.

2. Crystal Growth: Principles and Progress , A.W. Vere, Plenum Press, NY.

3. Crystal Growth Processes and methods, P.S. Raghavan and P. Ramasamy, KRU Publications

4. A Short course in Solid State Physics, Vol. I, F.C. Auluck, Thomson Press India Ltd.

5. Crystal Growth, B.R. Pamplin, Pergamon, (1980)

6. Crystal Growth in Gel, Heinz K Henish, Dover Publication

Competencies

C1. Discuss the significance of single crystals and different crystal growth techniques.

C2. Explain the theories of nucleation.

C3. Derive the Gibb's Thompson equation for vapour, melt and solution.

C4. Explain heterogeneous nucleation and energy of formation of spherical nucleus.

C5. Discuss the various theories of kinetics of crystal growth.

C6. Discuss the crystal growth techniques - growth from melt, crystal pulling and zone melting.

C7. Discuss the different low temperature solution growth techniques.

C8. Explain the growth of KDP, ADP and KTP crystals.

C9. Discuss the high temperature solution growth.

C10. Discuss the physical and chemical vapour deposition techniques.

C11. Distinguish between STP, LTVTP and OTP.

C12. Explain hydrothermal growth.

C13. Discuss the design aspects of autoclave.

C14. Explain the growth of quartz, sapphire and garnet.

C15. Classify different epitaxial techniques and explain each one of them.

C16. Discuss the optoelectronic properties of semiconductors.

C17. Discuss about semiconductor alloys.

C18. Explain lattice mismatch. Discuss about various lattice mismatched alloy structures.

C19. Discuss about various semiconductor devices.

Semester IV

PH4EB3TM Nanostructures and Characterization

Credit-4

Total Lecture hours- 72

Aim

Nanoscience and nanotechnology is an example of a truly interdisciplinary field of research which has revolutionized human life. Because of the tremendous importance and funding that is given to nanoscience, it is slowly occupying the position of one of the core subjects in several divisions of science and technology. Therefore it is essential that we introduce a course on nanostructures and their characterization to the post graduate students.

Course overview and Context

The course starts with the concepts of low dimensional structures, size and dimensionality effects in Q-well wires and dots. MEMS and NEMS technology is also mentioned here. The course also includes Carbon nanostructures, various analysis methods for nanomaterials and also an outline of some of the spectrometry techniques.

Module I

Low Dimensional Structures (18hrs)

Preparation of quantum nanostructures - size and dimensionality effects –size effects potential wells - partial confinement - conduction electrons and dimensionality -Fermi gas and density of states - properties dependent on density of states - excitons - single-electron tunneling - applications -infrared detectors - quantum dot lasers - superconductivity.Microelectromechanical Systems (MEMS) Nanoelectromechanical Systems(NEMS) –Fabrication of nanodevices and nanomachines - Molecular andSupramolecular Switches.

ModuleII

Carbon Nanostructures (18hrs)

Carbon Molecules - Nature of the Carbon Bond - New Carbon Structures -Carbon Clusters -Small Carbon Clusters - Carbon Nano tubes - Fabrication -Structure – Electrical Properties - Vibrational Properties –Mechanical Properties - Applications of Carbon Nano Tubes - Computers - Fuel Cells -Chemical Sensors - Catalysis – Mechanical Reinforcement - Field Emission and Shielding. Solid Disordered Nanostructures - Methods of Synthesis -Failure Mechanisms of Conventional Grain sized Materials –Mechanical

Properties – Nano structured Multi layers -Electrical Properties –Porous Silicon - Metal Nano cluster - Composite Glasses.

ModuleIII

Thermal, Microscopic and Infrared Analysis (18 Hrs)

Thermal analysis – DTA, DSC and TGA – methodology of DTA, DSC and TGA andInstrumentation. Microscopy – Electron microscopy – Principles and instrumentation – resolution limit – scanning tunnelling microscopy – principles – scanning tunneling microscope - SEM & TEM. Atomic force microscope –Instrumentation. IR spectrophotometers – Theory and Instrumentation- Applications. Fouriertransform techniques – FTIR principles and instrumentation. Raman spectroscopy – Principles, Instrumentation and Applications. MicrowaveSpectroscopy -Instrumentation and Applications

ModuleIV

Mass Spectrometry, Resonance Spectroscopy (18 Hrs)

Mass Spectrometry - Principle – Instrumentation – Types of ions produced in a Mass spectrometer - Interpretation of Mass spectra – Applications. NMR – Principles andInstrumentation – Chemical shift - Spin-spin coupling- Applications of NMR – Electron spin resonance spectrometry – Theory ofESR –Instrumentation - Interpretation of ESR spectra - Applications.

Reference Books

1. Introduction to Nanotechnology, Charles P. Poole, Jr. and Frank J.Owens, Wiley, 2003
2. MEMS/NEMS: micro electro mechanical systems/nano electro mechanical systems Volume 1, Design Methods, Cornelius T.Leondes, Springer, (2006).
3. Instrumental methods of Chemical Analysis, G. Chatwal & ShamAnand, Himalaya
4. Introduction to Infrared and Raman spectroscopy, Norman DColthup, Lawrence H Daly and Stephen E Wiberley, Academic press,NY.
5. Instrumental methods of analysis, H.H. Willard, L.L. Merrit, J.A.Dean & F.A. Settle, CBS Pub.
6. Principles of Instrumental analysis, Skoog and West – Hall – SandersInt.

7. Instrumental methods of chemical analysis, G W Ewing, MGH
8. Scanning Tunnelling Microscopy, R. Wiesendanger & H.J.Guntherodt, Springer
9. Thermal Analysis, Wesley W.M. Wendlandt , Wiley.

Competencies

C1. Describes various concepts mentioned in the syllabus.

C2. Identify the dimensionality effects in various quantum confined structures.

C3. Compare the electron transport properties in quantum confined and bulk structures.

C4. Compare the NEMS and MEMS technology.

C5. Identify various molecules that can work as components for molecular switches.

C6. Describe the applications of carbon nanotubes and various carbon nanostructures.

C7. Describe various synthesis techniques for CNTs.

C8. Compare various analysis techniques for nanostructures.

C9. Compare various spectrometry techniques.

C10. Describe the applications of various spectrometric methods.

PH4EB1PMMATERIAL SCIENCE PRACTICALS

1. Ultrasonic Interferometer – ultrasonic velocity in liquids
2. Ultrasonic Interferometer – Young's modulus and elastic constant of solids
3. Determination of dielectric constant
4. Determination of forbidden energy gap
5. Determination of Stephan's constant
6. Determination of Fermi energy of copper
7. Study of ionic conductivity in KCl / NaCl crystals
8. Thermo emf of bulk samples of metals (aluminium or copper)
9. Study of physical properties of crystals (specific heat, thermalexpansion, thermal conductivity,dielectric constant)
10. Study of variation of dielectric constant of a ferro electric material with temperature (barium titanate)
11. Study of variation of magnetic properties with composition of a ferritespecimen
12. Four probe method – energy gap
13. Energy gap of Ge or Si
14. Hall effect – Hall constant
15. Thin film coating by polymerization
16. Measurement of thickness of a thin film
17. Study of dielectric properties of a thin film
18. Study of electrical properties of a thin film (sheet resistance)
19. Growth of single crystal from solution and the determination of itsstructural,electrical and optical properties (NaCl,KBr,KCl,NHB4BCl etc.)
20. Determination of lattice constant of a cubic crystal with accuracy and indexing the Bragg reflections in a powder X-ray photograph of a crystal
21. Observation of dislocation – etch pit method
22. Michelson Interferometer – Thickness of transparent film
23. X-ray diffraction – lattice constant

24. Optical absorption coefficient of thin films by filterphotometry
25. Temperature measurement with sensor interfaced to a PC or amicroprocessor
26. ESR spectrometer – g factor
27. Beam profile of diode laser
28. Track width of a CD using laser beam
29. He – Ne laser- verification of Malus law, measurement of Brewsterangle,refractive index of a material

ELECTIVE BUNCH C: THEORETICAL PHYSICS

Semester III

PH3EC1TM Astrophysics

Credit – 4

Total Lecture Hours- 72

Aim

To impart the knowledge of origin of Universe, and Physics related to stars to students. This course provides a basis in Astrophysics which will be useful in inculcating interest towards research on this topic

Course Overview and Context

Module I gives brief outline of origin of the Universe and stars. Module II describes properties of stars and its radiations. Module III gives a description of energy production in stars and Module IV summarizes the possible later stages of stars. In the study of particle Physics the study of origin and development of Universe and formation of stars is important

Module I

Basic Concepts in Astrophysics (18 Hrs)

A brief history of the universe; big-bang hypothesis; the synthesis of Helium; Gravitational contraction, free fall, hydrostatic equilibrium; equilibrium of a gas of non-relativistic particles; equilibrium of a gas of ultra-relativistic particles, equilibrium and the adiabatic index; star formation, conditions for gravitational collapse, contraction of a protostar, conditions for stardom; The Hertzsprung – Russell diagram, luminosity and surface temperature

Module II

Properties of Matter and Radiation (18 Hrs)

Electrons in stars – degenerate electron gas, density-temperature diagram, electrons in massive stars; Photons in stars – The Photon gas, radiation pressure in stars, The Saha equation, ionization in stars, stellar interiors, stellar atmosphere.

Module III

Thermonuclear Fusion and Heat Transfer in Stars (18 hours)

The physics of nuclear fusion, barrier penetration, fusion cross-section, thermonuclear reaction rates. Hydrogen burning- proton-proton chain, Carbon Nitrogen cycle, solar neutrinos. Helium burning, carbon production Heat transfer by conduction by ions and electrons, radiation, convection.

Module IV

Stellar Structure and stellar evolution (18 hours)

Simple stellar models; pressure, density and temperature inside stars; modeling the Sun, solar luminosity; minimum and maximum mass of stars. White dwarfs- mass, central density and radius, collapse of a stellar core, the onset of collapse, nuclear photodisintegration, electron capture, the aftermath. Neutron stars- the size of neutron stars, gravitational binding energy of neutron stars, rotating neutron stars and pulsars, The maximum mass of neutron star; black holes.

Text Book:*The Physics of Stars, A.C Phillips, 2ndEdn. John Wiley & Sons Ltd.*

Reference Books:

1. Stellar Interiors, Hansen and Kawler, Springer Verlag.
2. Astrophysics – Stars and Galaxies, K.D.Abyankar, Universities Press.
3. Stars: their structure and evolution, R.J. Taylor, CambridgeUniversity Press.
4. Introduction to Modern Astrophysics, B.W. Carroll &D.A.Ostie, Addison Wesley.
5. A Course on Theoretical Astro physics, Vol. II, T. Padmanabhan, Cambridge Uni. Press.
6. An Introduction to Astrophysics, BaidyanathBasu, Prentice Hall India.

Competencies

C1. Outline brief history of the universe in the context of big-bang hypothesis and synthesis of Helium,

C2. Discuss star formation.

C3. Draw the HertzprungRussel diagram and describe.

C4. Discuss Gravitational contraction, free fall, hydrostatic equilibrium

C5. Compare equilibrium of a gas of non-relativistic particles and equilibrium of a gas of ultra-relativistic particles

C6. Examine equilibrium and the adiabatic index with respect to the Universe after Big Bang.

C7. Examine the presence of electrons in stars and its degeneracy with the help of density temperature diagram.

C8. Describe the radiation pressure in stars.

C9. Recognize the relevance of the Saha equation with respect to Stars.

C10. Discuss the ionization in stars.

C11. Give description of stellar interiors and stellar atmosphere.

C12. Examine the physics of nuclear fusion and relate it to the barrier penetration, fusion cross-section and thermonuclear reaction rates.

C13. Recognize and explain Hydrogen burning mechanisms - proton-proton chain,

C14. Carbon Nitrogen cycle and the role of solar neutrinos in it.

C15. Outline the techniques of Helium burning and carbon production.

C16. Distinguish between heat transfer methods like conduction by ions and electrons, radiation and convection.

C17. Summarize Simple stellar models and examine pressure, density and temperature inside stars.

C18. Illustrate modelling the Sun with respect to solar luminosity.

C19. Investigate the minimum and maximum mass of stars.

C20. Describe White dwarfs with respect to mass, central density and radius

C21. Examine collapse of a stellar core to recognize the onset of collapse,nuclear photodisintegration, electron capture and the final state.

C22. Give the description of neutron stars in connection with size of neutron stars, gravitational binding energy of neutron stars, rotating neutron stars pulsars and the maximum mass of neutron star

C23. Summarize the properties of black holes

Semester III

PH3EC2TM Nonlinear Dynamics

Credit – 4

Total Lecture Hours- 72

Aim

Most of the Physical phenomena are governed by Nonlinear dynamics and so this course aim to provide a theoretical basis for the analysis of nonlinear systems.

Course Overview and Context

Module I defines nonlinearity and examines simple examples for nonlinear systems. The qualitative features of nonlinear systems like existence of different types of attractors are examined in module II. The onset of chaos in dissipative systems and the features of chaotic systems are described in module III. The conservative systems with respect to chaos and its features are summarized in module IV. The course is meant for a better understanding of the rich characteristics of nonlinear systems which will motivate the student for knowledge generation in the field

Module I

Basic Concepts

What is Nonlinearity? Dynamical Systems: Linear and Nonlinear Systems-Linear Superposition Principle - Working Definition of Nonlinearity. Linear and Nonlinear Oscillators - Linear Oscillators and Predictability - Damped and Driven Nonlinear Oscillators - Forced Oscillations – Primary Resonance and Jump Phenomenon (Hysteresis) Secondary Resonances (subharmonic and superharmonic) Nonlinear Oscillations and Bifurcations

Module II

Qualitative Features of non-linear systems (18 Hrs)

Autonomous and Nonautonomous Systems - Dynamical Systems as Coupled First-Order Differential Equations; Equilibrium Points; Phase Space/Phase Plane and Phase Trajectories: Stability, Attractors and Repellers, Classification of Equilibrium Points: Two-Dimensional Case - General Criteria for Stability; Limit Cycle Motion – Periodic Attractor- Poincarè–Bendixson Theorem. Higher Dimensional Systems - Lorenz Equations ; More Complicated Attractors - Torus - Quasiperiodic Attractor - Poincarè Map - Chaotic Attractor ; Dissipative and Conservative Systems -Hamiltonian Systems

Module III

Chaos in Dissipative Systems (18 Hrs)

Bifurcations and Onset of Chaos in Dissipative Systems: Some Simple Bifurcations-Saddle- Node Bifurcation -The Pitchfork Bifurcation - Transcritical Bifurcation - Hopf Bifurcation ; Discrete Dynamical Systems ; The Logistic Map - Equilibrium Points and Their Stability - Periodic Solutions or Cycles -Period Doubling Phenomenon - Onset of Chaos – Lyapunov Exponent - Bifurcation Diagram - exact Solution at $a = 4$ - Logistic Map: A Geometric Construction of the Dynamics – CobwebChaos in Dissipative Nonlinear Oscillators and Criteria for Chaos: Bifurcation Scenario in Duffing Oscillator - Period Doubling Route to Chaos - Intermittency Transition - Quasiperiodic Route to Chaos - Strange Nonchaotic Attractors (SNAs) ; Lorenz Equations - Period Doubling Bifurcations and Chaos ; Necessary Conditions for Occurrence of Chaos - Continuous Time Dynamical Systems -Discrete Time Systems

Module IV

Chaos in Conservative Systems (18 Hrs)

Poincarè Cross Section ; Possible Orbits in Conservative Systems - Regular Trajectories - Irregular Trajectories - Canonical Perturbation Theory: Overlapping Resonances and Chaos; Hènon–Heiles System - Equilibrium Points - Poincarè Surface of Section of the System - Numerical Results; Periodically Driven UndampedDuffing Oscillator ; The Standard Map - Linear Stability and Invariant Curves - Numerical Analysis: Regular and Chaotic Motions; Kolmogorov–Arnold–Moser Theorem (qualitative ideas only)

Text Book: ***Nonlinear dynamics: integrability, chaos, and patterns, M. Lakshmanan& S. Rajasekar, Springer Verlag***

Reference Books:

1. Deterministic Chaos, N. Kumar, Universities Press.
2. Chaos and Nonlinear Dynamics, RC. Hilborn, Oxford University Press.
3. Chaotic Dynamics: An Introduction, G.L. Baker, and J.P. Gollub, CUP, 1993.
4. Deterministic Chaos, H.G. Schuster, Wiley, N.Y., 1995.
5. Chaos in Dynamical System, E. Ott, Cambridge University Press.
6. Encounters with Chaos, D. Gullick, MGH, 1992.

7. Introduction to Chaos and coherence, J. Froyland, IOP Publishing Ltd.
8. Nonlinear Dynamics and Chaos, J.M.T. Thomson& I. Stewart, John Wiley & Sons.

Competencies

C1 Distinguish between linear and non linear systems.

C2 Examine the working definition of nonlinearity.

C3 Compare linear and nonlinear oscillators.

C4 Differentiate between damped and driven nonlinear oscillators.

C5 Describe primary resonance and Jump phenomenon.

C6 Differentiate subharmonics from superharmonic

C7 Illustrate nonlinear Oscillations and Bifurcations

C8 Recognize autonomous and non autonomous systems

C9 Describe the dynamical systems as coupled First-Order Differential Equations

C10 State the features of Equilibrium Points

C11 Examine Phase Space/Phase Plane and Phase Trajectories

C12 Relate Stability to Attractors and Repellers

C13 Classify Equilibrium Points

C14 Outline General Criteria for Stability

C15 Describe Limit Cycle Motion in two dimensions

C16 Describe Periodic Attractor and Poincare–Bendixson Theorem.

C17 Illustrate Higher Dimensional Systems with the example of Lorenz Equations

C18 Illustrate more Complicated Attractors like Torus the Quasiperiodic Attractor

C19 Define Poincarè Map

C20 Describe the Chaotic Attractor

C21 Compare Dissipative and Conservative Systems

C22 Summarize the features of chaos in Hamiltonian Systems

C23 Outline Bifurcations and Onset of Chaos in Dissipative Systems

C24 Compare the Simple Bifurcations- Saddle- Node Bifurcation, the Pitchfork Bifurcation, Transcritical Bifurcation and Hopf Bifurcation

C25 Extend the features of Discrete Dynamical Systems to describe the Logistic Map with respect to equilibrium Points and their Stability,periodic Solutions or Cycles, period doubling Phenomenon, Onset of Chaos, Lyapunov Exponent

C26 Cobweb Chaos in Dissipative Nonlinear Oscillators and Criteria for Chaos

C27 Examine the Bifurcation in Duffing Oscillator

C28 Compare different routes to chaos like Period Doubling Route, Intermittency Transition and Quasiperiodic Route to Chaos

C29 Describe Strange Nonchaotic Attractors (SNAs)

C30 Summarize the features of system given by Lorenz Equations

C31 Relate Period Doubling Bifurcations and Chaos

C32 Give the Necessary Conditions for Occurrence of Chaos

C33 Distinguish between continuous time dynamical systems &discrete time systems

C34 Define Poincarè Cross Section

C35 Describe the possible Orbits in Conservative Systems and compare regular Trajectories and Irregular Trajectories

C37 Relate Overlapping Resonances and Chaos

C38 Describe Hènon–Heiles System with respect to Equilibrium Points, Poincarè Surface of Section of the System and Numerical Results

C39 Examine Periodically Driven UndampedDuffing Oscillator with respect to the Standard Map & relate Linear Stability & Invariant Curves with Numerical Analysis

C40 Describe Regular and Chaotic Motions in the context of Kolmogorov–Arnold–Moser Theorem

Semester IV

PH4EC3TM Quantum Field Theory

Credit-4

Total Lecture hours- 72

Aim

The quantum field theory is one of the emerging branch of Physics. Extensive studies are being conducted to develop new models in quantum filed theory and to explain the intricacy of quantum world. Therefore it is essential that a post graduate student in physics learn the basics and possibilities of this branch of physics.

Course overview and Context

Quantum field theory discusses the behavior of quantum particles in detail. It enables us to learn how sub atomic level particles interact, and what consequences are produced a result of these interactions. This course starts with the basics of path integrals and perturbation theory and an understanding of the quantization procedures of scalar and spinor fields. The student proceeds to learn the quantization of gauge fields.A discussion of Weinberg-Salam model is also provided.

Module I

Path Integrals and Quantum Mechanics (18 Hrs)

Review of single particle relativistic wave equations – Klein- Gordon equation, Dirac equation, Maxwell and Proca equations; Path integral formulation of quantum mechanics; perturbation theory and the S matrix; Coulomb scattering; Functional calculus: differentiation, generating functional for scalar fields. Functional integration

Module II

Path Integral Quantization of Scalar and Spinor Fields (18 Hrs)

Free particle Green's functions, Generating functional for interacting field; φ^4 theory – generating functional, 2-point function, 4-point function; generating functional for connected diagrams; fermions and functional methods, The S – matrix and reduction formula, pion-nucleon scattering amplitude, scattering cross-section

Module III

Path Integral Quantization of Gauge Field Fields (18 Hrs)

Propagators and gauge conditions in QED; Non-abelian gauge fields and Faddeev - Popov method; Self-energy operator and vertex functions; Ward – Takahashi identities in QED, Becchi – Rouet – Stora transformations; Slavnov – Taylor identities.

Module IV

The Weinberg – Salam Model (18 hours)

Field theory vacuum; the Goldstone theorem; Spontaneous symmetry breaking of gauge symmetries; superconductivity; Higgs boson; The Weinberg – Salam model; Experimental confirmation of the models

Text Book: ***Quantum Field Theory, Lewis H. Ryder, 2nd, Edn, Cambridge University Press, (1996).***

Reference Books : Introduction to Quantum Field Theory, S J Chang, World Scientific

Competencies

C1. Describe the Klein Gordon equation.

C2. Discuss Dirac equation and Maxwell and Proca equations.

C3. Analyze the path integral formulation of quantum mechanics

C4. Explain Coulomb scattering

C5. Discuss the perturbation theory in quantum mechanics

C6. Derive the S-matrix using perturbation theory

C7. List the features of scalar fields.

C8. Discuss functional integration.

C9. Analyze free particle Green's functions.

C10. Discuss the generating functional for the interacting field.

C11. Explain 2-point and 4-point functions.

C12. Derive the reduction formula

C13. Calculate the pion-nucleon scattering amplitude

C14. Derive the expression for scattering cross section.

C15. Discuss the propagators and gauge conditions in QED.

C16. Explain non abelian gauge fields.

C17. Discuss Becchi – Rouet – Stora transformations.

C18. Discuss Slavnov – Taylor identities.

C19. Identify Ward – Takahashi identities in QED

C20. Analyze the field theory in vacuum.

C21. Derive the Goldstone theorem.

C22. Explain the spontaneous symmetry breaking of gauge symmetries

C23. List the features of superconductivity

C24. Discuss the properties of Higg's Boson

C25. Explain Weinberg-Salam model.

PH4EC1PMSpecial Computational Practicals

(The experiments are to be done on the PC by developing the required algorithm and program including graphical displays. Students may use C++ or Python.)

1. Trajectory of motion of (a) projectile without air resistance (b) projectile with air resistance
2. Phase space trajectories of a pendulum- with and without damping.
3. Phase space trajectories of a pendulum – with non-linear term.
4. Trajectory of a particle moving in a Coulomb field (Rutherford scattering) and to determine the deflection angle as a function of the impact parameter
5. Trajectory of a ion in the combined Coulomb and nuclear potential and determine the angle of scattering for different impact parameters
6. Simulation of the wave function for a particle in a box - To plot the wave function and probability density; Schrödinger equation to be solved and eigen value calculated numerically.
7. Iterates of the logistic map.
8. Bifurcation diagram for the logistic map.
9. Calculation and plotting of the Lyapunov exponents.
10. Plotting of Julia set.
11. Plotting of Mandelbrot set.
12. Creating a fractal by Iteration Function Scheme

Reference Books:

1. Computational Physics- RC Verma, P.K. Ahluwalia & K.C. Sharma-New Age.
2. Chaos & Fractals- Peitgen, Jurgens&Saupe – Springer.

SYLLABI OF COURSES – OPEN ELECTIVE

Semester IV

PH4OE1TMOptoelectronics&Optical Fiber Communication.

Credits- 4

No- of lecture hours- 72

Aim

Optoelectronics is based on the quantum mechanical effects of light on electronic materials, especially semiconductors, sometimes in the presence of electric fields. This field is a growth area, and is strongly dependent on the science underpinning the topics. It's for this reason that a course in Optoelectronics is essential part of physics education at postgraduate level. This course is designed to provide a sound foundation in Optoelectronics.

Course overview and context.

This course envisages covering semiconductor physics, LED principle and structure, fiber optics, different types of lasers, generation of high power laser pulse through Q switching, non linear optics, photodetectors and modulators

Module I

Semiconductor Science and Light Emitting Diodes (10 hrs)

Semiconductor energy bands - semiconductor statistics – extrinsic semiconductors – compensation doping – degenerate and non degenerate semiconductors – energy band diagrams in applied field - direct and indirect bandgap semiconductors, - p-n junction principles - open circuit- forward and reverse bias – depletion layer capacitance – recombination life time – p-n junction band diagram - open circuit - forward and reverse bias – light emitting diodes – principles - device structures - LED materials, heterojunction high intensity LEDs – double heterostructure - LED characteristics and LEDs for optical fiber communications - surface and edge emitting LEDs.

Text Book: ***Optoelectronics and Photonics: Principles and Practices, S.O. Kasap, Pearson 2009,***

Fiber Optics (10 Hrs)

Symmetric planar dielectric slab waveguide – waveguide condition – single and multimode waveguides – TE and TM modes – modal and waveguide dispersion in the planar waveguide – dispersion diagram – intermodal dispersion – intramodal dispersion – dispersion in single mode fibers – material dispersion – waveguide dispersion – chromatic dispersion – profile and polarization dispersion – dispersion flattened fibers - bit rate and dispersion – optical and electrical bandwidth – graded index optical fiber - light absorption and scattering – attenuation in optical fibers.

Text Book:*Optoelectronics and Photonics: Principles and Practices*, *S.O. Kasap, Pearson 2009*

Module II

Laser Principles (10 hrs)

Laser oscillation conditions - diode laser principles - heterostructure laser diode – double heterostructure – stripe geometry – buried heterostructure – gain and index guiding - laser diode characteristics – laser diode equation - single frequency solid state lasers – distributed feedback –quantum well lasers - vertical cavity surface emitting laser - optical laser amplifiers.

Text Book:*Optoelectronics and Photonics: Principles and Practices*, *S.O. Kasap, Pearson 2009*

Laser Output Control (6 hrs)

Generation of high power pulses- Q-factor- Q-switching for giant pulses- methods of Q-switching- mode locking and techniques for mode locking.

Text Book: *Laser fundamentals- William T.Silfvast- CUP 2nd Edn.(2009).*

Module III

Photodetectors and Photovoltaics (18 hrs)

Principle of p-n junction photodiode - Ramo's theorem and external photocurrent - absorption coefficient and photodiode materials - quantum efficiency and responsivity - PIN-photodiode – avalanche photodiode – phototransistor - photoconductive detectors and photoconductive gain - noise in photo-detectors – noise in avalanche photodiode - solar energy spectrum - photovoltaic device principles – I-V characteristics - series resistance and equivalent circuit - temperature effects - solar cell materials- device and efficiencies

Text Book:*Optoelectronics and Photonics: Principles and Practices- S.O. Kasap-Pearson (2009)*

Module IV

Optoelectronic Modulators (10 Hrs)

Optical polarization - birefringence - retardation plates - electro-optic modulators – Pockels effect - longitudinal and transverse electro-optic modulators- Kerr effect - Magneto-optic effect- acousto-optic effect – Raman Nath and Bragg-types.

Text Books:

1. Fiber optics and Optoelectronics- R.P. Khare- Oxford University Press- (2004)-

2. Optoelectronics: an Introduction- J. Wilson and J.F.B. Hawkes- PHI- (2000)-

Non-linear optics(8 Hrs)

Wave propagation in an anisotropic crystal - polarization response of materials to light - second order non-linear optical processes - second harmonic generation - sum and frequency generation- optical parametric oscillation - third order non-linear optical processes - third harmonic generation - intensity dependent refractive index - self-focusing - non-linear optical materials- phase matching - angle tuning - saturable absorption - optical bistability - two photon absorption.

Text Book:*Laser fundamentals- William T. Silfvast- CUP 2nd Edn. 2009*

Reference Books:

1. Semiconductor optoelectronic devices: Pallab Bhattacharya-Pearson(2008)
2. Optoelectronics: An introduction to materials and devices- Jasprit Singh- Mc Graw Hill International Edn.- (1996).
3. Optical waves in crystals: Propagation and Control of Laser Radiation- A. Yariv and P. Yeh- John Wiley and Sons Pub. (2003)

Competencies

C1 Discuss semiconductor physics and illustrate the working of pn junction under the influence of electric field.
C2 Discuss the principle- working and structure of LED.
C3 Describe the application of LED in optical fiber communication.
C4 Discuss TE and TM mode of transmission.
C5 Discuss dispersion in single mode fiber.
C6 Discuss light absorption ,scattering and attenuation in optical fibers.
C7 Discuss diode laser principle,characteristics and structure.
C8 Discuss quantum well laser and vertical cavity surface emitting laser.

C9 Discuss generation of high power laser pulses through Q switching.
C10 Discuss the principle, working, efficiency and advantages of photodiode, PIN diode and avalanche photo diode.
C11 Discuss the principle and working of phototransistor.
C12 Discuss the principle and working of photoconductive detectors and determine photoconductive gain.
C13 Discuss the principle working- characteristics and equivalent circuit of solar cell.
C14 Discuss Optical polarization- birefringence and retardation plates.
C15 Discuss longitudinal and transverse electro-optic modulators.
C16 Describe Kerr effect.
C17 Discuss Magneto-optic effect and acousto-optic effects
C18 Discuss wave propagation in anisotropic medium.
C19 Discuss second order non-linear optical processes and second harmonic generation.
C20 Discuss third order non-linear optical processes and third harmonic generation.
C21 Describe intensity dependent refractive index, self-focusing, non-linear optical materials, phase matching .angle tuning , saturable absorption and optical bistability.
C22 Explaintwo photon absorption.

Semester IV

PH4OE2TM Software Engineering and Web design

Credit-4

Total Lecture hours- 72

Aim

This course is intended to provide the learner the fundamentals of web design and software engineering. It is a basic course in designing of web pages and development of software modules.

Course Overview and Context

Module I deals with fundamentals of software engineering. The development phases of software modules are discussed in detail. The basics of HTML and HTML tags are dealt in detail in module II and module III. Object based programming using Javascript and fundamentals of dreamweaver and Microsoft publisher are included in module IV. The course is meant for a better understanding of the creation and styling web pages.

Module I

Software Engineering (18 Hrs)

Introduction to Software Engineering – Software development and Life cycle– Project Size and its categories – Planning a Software Project – Project Control – Project team standards-Design of solution strategies-Software cost estimation and evaluation techniques-Software design-design concepts and notations-Modern design techniques-Verification and validation methods-Documentation and implementation procedures-Performance of software systems.

Module II

The HTML (18 Hrs)

What is HTML? – Basic Tags of HTML – HTML – TITLE – BODY

Starting an HTML document – The <!DOCTYPE>declaration – setting boundaries with <HTML>– the HEAD element – the BODY element – the STYLE element and the SCRIPT element.

Formatting of text – Headers-Formatting Tags – PRE tag – FONT tag – Special Characters. Working with Images – META tag – Links – Anchor Tag.

Lists – Unordered Lists–Ordered Lists–Definition Lists

Tables – TABLE, TR and TD Tags–Cell Spacing and Cell Padding– Colspan and Rowspan
Frames – Frameset–FRAME Tag–NOFRAMES Tag

Module III

The HTML (18 Hrs)

Forms – FORM and INPUT Tag – Text Box – Radio Button–Checkbox – SELECT Tag and Pull Down Lists – Hidden–Submit and Reset.
Some Special Tags – COLGROUP-THREAD, TBODY – TFOOT – blank – self, parent – top –IRFRAME – LABEL – Attribute for <SELECT>– TEXTAREA.
Style sheets.
Introduction to scripting and HTML – purpose of scripting – JavaScript – VB Script – including scripts in an HTML document.

Module III

JAVASCRIPT (18Hrs)

JavaScript Variables and Data Types – Declaring Variables-Data Types Statements and Operators.
Control Structures – Conditional Statements–Loop Statements.
Object Based Programming – Functions–Executing Deferred Scripts–Objects Message Box in JavaScript – Dialog Boxes–Alert Boxes–Confirm Boxes–Prompt Boxes.
JavaScript with HTML – Events–Event Handlers.
Forms – Forms Array – form validation.
Ideas about Dreamweaver or Microsoft Publisher Text

Text Books :

1. ***Software Engineering, R.S. Pressman, McGraw Hill***
2. ***Software Engineering Concepts, R.E. Fairley, McGraw Hill***
3. ***HTML4, 2nd Edn. Rick Darnell, Techmedia***
4. ***HTML, The Complete Reference, Tata Mc Graw Hill***
5. ***JavaScript Programmers Reference, Cliff Wootton, Wrox Press Inc.***
6. ***Beginning JavaScrpit, Paul Wilton, Wrox Press Inc. 1st Edn.***

Reference

1. Software Engineering – A Practitioner's Approach, R.S. Pressman, MGH
2. Software Engineering, Ian Sommerville, 6^{th} Edn. Pearson (2001)

3. Mastering HTML4 – Ray D.S. and Ray E.J. – BPB
4. The JavaScript Bible, Danny Goodman, John Wiley & Sons Inc.

Competencies

C1. Discuss need of software design
C2. Identify different phases in software development
C3. Explain the life cycle of software development
C4. Describe the planning of software development
C5. Design solution strategies of software development
C6. Analyze modern software design methods
C7. Discuss the basic tags used in HTML.
C8. Apply the formatting techniques to a given web page
C9. Identify the tags used in creating and formatting tables in a web page
C10. Analyze the variables and data types in java script
C11. Discuss the special tags used in java script
C12. Explain style sheets in java
C13. Distinguish between java script and VB script

Semester IV

PH4OE3TM Nanophotonics

Credit-4

Total Lecture hours- 72

Aim

Nanoscience and nanotechnology is an example of a truly interdisciplinary field of research which has revolutionized human life. One of the most beautiful manifestations of nanostructures is their optical behavior that imparts size dependent optical reflection and transmission to nanostructures. This comes under Nanophotonics. Because of the tremendous importance and funding that is given to nanoscience, it is slowly occupying the position of one of the core subjects in several divisions of science and technology. A post graduate physics student should definitely be aware of the scope and significance of nanophotonics.

Course overview and Context

The course is designed in such a way that it complements the nanoscience and nanotechnology course offered to the B.Sc. students. It starts with the concepts in nanophotonics, proceeds to the understanding of photonic crystals and outlines some of the important fabrication and characterization methods. After this course, the students will have the required basics to proceed to a research program in nanoscience.

Module I

Nanophotonics (18 hrs)

Photons and electrons: similarities and differences-free space propagation-Confinement of photons and electrons-propagation through a classically forbidden zone : Tunneling-Localization under periodic potential : Band gap-Cooperative effects for photons and electrons-nanoscale optical interactionsaxial and lateral nanoscopic localization -quantum confined materials; quantum wells, quantum wires, quantum dots, quantum rings – quantum confined stark effect-dielectric confinement effect-super lattices – industrialnanophotonics-nanolithography (basic idea)-two photon lithography sunscreennanoparticles-self-cleaning glasses – fluorescent quantum dots nanobarcodes-introduction to nanotoxicology.

Module II

Photonic crystals (18 hrs)

Photonic crystals, 1D, 2D and 3D photonic crystals, origin of the photonic band gap, multilayer film, size of the photonic band gap, evanescent modes in photonic band gap, point defect, lone defect and surface defect, localized modes at defects, surface states, photonic crystal fibers, mechanism of confinement, index and band gap guidance, endless single mode fibers, enhancement of nonlinear effects, origin of band gap in holey fibers, guided modes in a hollow core, Bragg fibers, photonic crystals as a mirror, wave guide and cavity, waveguide bend, waveguide splitter.

Module III

Synthesis of Nano materials (18hrs)

Photolithography, other optical lithography (EUV, XRay, LIL), particle-beam lithographies (e-beam, focused ion beam, shadow mask evaporation), probe lithographies,

Non lithographic techniques: plasma arc discharge, sputtering, evaporation, chemical vapour deposition, pulsed laser deposition, molecular beam epitaxy, sol-gel technique, electrodepositionPattern replication techniques: soft lithography, nano imprint lithography.Pattern transfer and enhancement techniques: dry etching, wet etching,pattern growth techniques (polymerization, directed assembly).

Module IV

Thermal, Microscopic and Infrared Analysis (18 Hrs)

Thermal analysis:– DTA, DSC and TGA – methodology of DTA, DSC andTGA and Instrumentation.Microscopy – Electron microscopy – Principles and instrumentation – resolution limit – scanning tunneling microscopy – principles – scanningtunneling microscope - SEM & TEM. Atomic force microscope –Instrumentation.IR spectrophotometers – Theory and Instrumentation- Applications. Fouriertransform techniques – FTIR principles and instrumentation. Ramanspectroscopy – Principles, Instrumentation and Applications. MicrowaveSpectroscopy -Instrumentation and Applications

Reference books

1. Nano Photonics, P. N. Prasad, Wiley Interscience (2003)
2. Photonic crystals, moulding the flow of light, 2ed, John D Joannopoulos, Princeton University Press
3. Nano: the essentials, T. Pradeep, TMH, 2007

4. Introduction to Nanotechnology, Charles P. Poole, Jr. and Frank J.Owens, Wiley, (2003)
5. Instrumental methods of Chemical Analysis, G. Chatwal & ShamAnand, Himalaya
6. Scanning Tunnelling Microscopy, R. Wiesendanger & H.J.Guntherodt, Springer
7. Thermal Analysis, Wesley W.M. Wendlandt , Wiley.
8. Nanoscience, Nanotechnologies and Nanophysics, C. Dupas, P.Houdy & M. Lahmani, Springer-Verlag , (2007).
9. Introduction to Nanoscience and Nanotchnology, K K Chathopadhyay, A N Banerjee, PHI
10. Nanotechnology Fundamentals and applications, Manasi Karkare, I K International.

Competencies

C1. Describe each concept and idea mentioned in the syllabus.

C2. Illustrate the ideas using figures and diagrams wherever relevant.

C3. Apply equations to evaluate various physical parameters relevant to nanoparticles.

C4. Describe the working of various synthesis and characterization instruments used for nanoparticle study.

C5. Compare the relative merits of various characterization tools.

C6. Compare the similarities and differences in photonic and electronic crystals using the features of photons and electrons.

C7. Identify naturally occurring photonic crystals and appreciate the differences in the origin of colour in them compared to pigments.

C8. Acquire essential basic knowledge in nanoscience to equip them to proceed to a research career in nanoscience.