



B.S. Abdur Rahman

Crescent

Institute of Science & Technology

Deemed to be University u/s 3 of the UGC Act, 1956

Regulations 2019
Curriculum and Syllabi

(Amendments updated upto June 2020)

M.Sc.
(Physics)



**REGULATIONS 2019
CURRICULUM AND SYLLABI
(Amendments updated upto June 2020)**

**M.Sc.
PHYSICS**

VISION AND MISSION OF THE INSTITUTION

VISION

B.S.Abdur Rahman Crescent Institute of Science and Technology aspires to be a leader in Education, Training and Research in multidisciplinary areas of importance and to play a vital role in the Socio-Economic progress of the Country in a sustainable manner.

MISSION

- To blossom into an internationally renowned Institute.
- To empower the youth through quality and value-based education.
- To promote professional leadership and entrepreneurship.
- To achieve excellence in all its endeavors to face global challenges.
- To provide excellent teaching and research ambience.
- To network with global Institutions of Excellence, Business, Industry and Research Organizations.
- To contribute to the knowledge base through Scientific enquiry, Applied Research and Innovation.

VISION AND MISSION OF DEPARTMENT OF PHYSICS

VISION

To be a leader in providing quality higher education through well designed programs and undertake research in Physical Sciences and related interdisciplinary areas.

MISSION

- To provide quality education in the field of Physical Sciences through well designed programs.
- To provide necessary knowledge in Physical Sciences required for all programs in science and engineering.
- To offer quality programs in advanced and applied physical sciences.
- To undertake fundamental, applied and interdisciplinary research in emerging areas.

PROGRAMME EDUCATIONAL OBJECTIVES AND OUTCOMES
M.Sc (Physics)

Programme Educational Objectives (PEOs)

- To identify, formulate, analyze and optimize variety of problems related to various fields of Physics through basic knowledge and to apply the skills and knowledge acquired during the UG studies.
- To acquire knowledge of fundamental laws and principles in wide areas of Physics along with their applications so as to develop strong student competencies in Physics and its applications in a technology-rich, interactive environment.
- To prepare for the successful pursuit of Post Graduate studies and shall have abilities to engage in life-long learning in various fields of Physics and General Science.
- To understand the challenges of a dynamically and globalised changing world adapting their skills through continuous learning and self-improvement.
- To work effectively in bringing interdisciplinary ideas related to diverse environmental skills to excel in technical careers and thrive in Post Graduate and research studies using scientific principles and applications of Physical Science.
- To become effective researcher who will be able to provide lucid summation of the scientific literature on a given topic of study.
- To develop their skills to plan, execute and report the results of extended computational techniques, experimental and theoretical Physics based projects in a research environment.
- To inculcate the sense of ethics, professionalism and effective communication skills amongst graduates improve their workplaces, communities and the society through professional and personal responsibilities and activities of their work.
- To prepare the students to successfully compete for employment and to offer a wide range of experience in research methods, data analysis to meet the industrial needs.

Programme Outcomes (POs)

After the completion of PG programme, graduates will be able to

- Design and conduct experiments, as well as to analyze and interpret data.
- Function on interdisciplinary teams with professional and ethical responsibility.
- Use the modern techniques, skills and sophisticated equipment necessary for research.
- Apply knowledge and skill in the design and development of Electronics circuits to cater to the needs of Electronic Industry.
- Become professionally trained in the area of optical communication, lasers, nonlinear circuits, materials development and characterization including nanomaterials.
- Demonstrate highest standards of actuarial ethical conduct and professional actuarial behavior, critical, interpersonal and communication skills as well as a commitment to life-long learning.
- Successfully compete for employment in the field of Teaching, Research and Industries.

**B.S. ABDUR RAHMAN CRESCENT INSTITUTE OF SCIENCE & TECHNOLOGY,
CHENNAI – 600 048.**

**REGULATIONS - 2019 FOR
M.Tech. / MCA / M.Sc. DEGREE PROGRAMMES
(Under Choice Based Credit System)**

1.0 PRELIMINARY DEFINITIONS AND NOMENCLATURE

In these Regulations, unless the context otherwise requires "**Programme**" means Post Graduate Degree Programme (M.Tech. / MCA / M.Sc.)

"**Course**" means a theory / practical / laboratory integrated theory / mini project / seminar / internship / Project and any other subject that is normally studied in a semester like Advanced Concrete Technology, Electro Optic Systems, Financial Reporting and Accounting, Analytical Chemistry, etc.,

"**Institution**" means B.S. Abdur Rahman Crescent Institute of Science & Technology.

"**Academic Council**" means the Academic Council, which is the apex body on all academic matters of B.S. Abdur Rahman Crescent Institute of Science & Technology.

"**Dean (Academic Affairs)**" means Dean (Academic Affairs) of B.S. Abdur Rahman Crescent Institute of Science & Technology who administers the academic matters.

"**Dean (Student Affairs)**" means Dean (Student Affairs) of B.S. Abdur Rahman Crescent Institute of Science & Technology, who looks after the welfare and discipline of the students.

"**Controller of Examinations**" means the Controller of Examinations of B.S. Abdur Rahman Crescent Institute of Science & Technology who is responsible for the conduct of examinations and declaration of results.

2.0 PROGRAMMES OFFERED AND ADMISSION REQUIREMENTS

2.1 Programmes Offered

The various programmes and their mode of study are as follows:

Degree	Mode of Study
M.Tech.	Full Time
MCA	
M.Sc.	

2.2 ADMISSION REQUIREMENTS

2.2.1 Students for admission to the first semester of the Master's Degree Programme shall be required to have passed the appropriate degree examination of this Institution as specified in the clause 3.2 [Eligible entry qualifications for admission to P.G. programmes] or any other degree examination of any University or authority accepted by this Institution as equivalent thereto.

2.2.2 Eligibility conditions for admission such as class obtained, number of attempts in the qualifying examination and physical fitness will be as prescribed by the Institution from time to time.

3.0 DURATION, ELIGIBILITY AND STRUCTURE OF THE PROGRAMME

3.1. The minimum and maximum period for completion of the Programmes are given below:

Programme	Min. No. of Semesters	Max. No. of Semesters
M.Tech.	4	8
MCA (3 years)	6	12
MCA (Lateral Entry)	4	8
MCA (2 years)	4	8
M.Sc.	4	8

3.1.1 Each academic semester shall normally comprise of 90 working days. Semester End Examinations shall follow within 10 days of the last Instructional day.

3.1.2 Medium of instruction, examinations and project report shall be in English.

3.2 ELIGIBLE ENTRY QUALIFICATIONS FOR ADMISSION TO PROGRAMMES

Sl. No.	Name of the Department	Programmes offered	Qualifications for admission
1.	Aeronautical Engineering	M. Tech. (Avionics)	B.E. / B. Tech. (Aeronautical Engineering)
2.	Civil Engineering	M. Tech. (Structural Engineering)	B.E. / B. Tech. (Civil Engineering) / (Structural Engineering)

		M. Tech. (Construction Engineering and Project Management)	B.E. / B. Tech. (Civil Engineering) / (Structural Engineering) / B. Arch.
3.	Mechanical Engineering	M.Tech. (Manufacturing Engineering)	B.E. / B.Tech. (Mechanical / Automobile / Manufacturing / Production / Industrial / Mechatronics / Metallurgy / Aerospace /Aeronautical / Material Science / Marine Engineering)
		M.Tech. (CAD/CAM)	
4.	Electrical and Electronics Engineering	M.Tech. (Power Systems Engg.)	B.E. / B. Tech. (EEE/ECE/E&I/I&C / Electronics / Instrumentation)
		M.Tech. (Power Electronics and Drives)	
5.	Electronics and Communication Engineering	M.Tech. (Communication Systems)	B.E. / B. Tech. (EEE/ ECE / E&I / CSE IT / I&C / Electronics / Instrumentation)
		M.Tech. (VLSI and Embedded Systems)	B.E. / B. Tech. (ECE / E&I / I&C / EEE / CSE / IT)
6.	Electronics and Instrumentation Engineering	M.Tech. (Electronics and Instrumentation Engineering)	B.E. / B. Tech. (EIE/ICE/Electronics/ECE/EEE)
7.	Computer Science and Engineering	M.Tech. (Computer Science and Engineering)	B.E. / B. Tech. (CSE/IT/ECE/EEE/EIE/ICE/ Electronics / MCA)
8.	Information Technology	M.Tech. (Information Technology)	B.E. / B. Tech. (IT/CSE/ECE/EEE/EIE/ICE/ Electronics / MCA)

9.	Computer Applications	MCA (3 years)	Bachelor Degree in any discipline with Mathematics as one of the subjects (or) Mathematics at +2 level
		MCA – (Lateral Entry)	B.Sc. Computer Science / B.Sc. Information Technology / BCA
		MCA (2 years)	Bachelor Degree in any discipline with Mathematics as one of the subjects (or) Mathematics at +2 level or B.Sc. Computer Science / B.Sc. Information Technology / BCA
10.	Mathematics	M.Sc. (Actuarial Science)	Any Degree with Mathematics / Statistics as one of the subjects of study
11.	Physics	M.Sc.(Physics)	B.Sc. (Physics / Applied Science / Electronics / Electronics Science / Electronics & Instrumentation)
12.	Chemistry	M.Sc.(Chemistry)	B.Sc. (Chemistry / Applied Science)
13.	Life Sciences	M.Sc. Molecular Biology & Biochemistry	B.Sc. in any branch of Life Sciences
		M.Sc. Biotechnology	B.Sc. in any branch of Life Sciences
		M.Sc. Microbiology	B.Sc. in any branch of Life Sciences
		M.Tech. Biotechnology	B.Tech. (Biotechnology / Chemical Engineering) / M.Sc. in any branch of Life Sciences

3.3. STRUCTURE OF THE PROGRAMME

3.3.1 The PG. programmes consist of the following components as prescribed in

the respective curriculum

- i. Core courses
- ii. Elective courses
- iii. Laboratory oriented core courses
- iv. Project work / thesis / dissertation
- v. Laboratory Courses
- vi. Seminars
- vii. Mini Project
- viii. Industrial Internship
- ix. Value Added Courses
- x. MOOC Courses (NPTEL, SWAYAM, etc.,)

3.3.2 The curriculum and syllabi of all programmes shall be approved by the Academic Council of this Institution.

3.3.3 For the award of the degree, the student has to earn a minimum total credits specified in the curriculum of the respective specialization of the programme.

3.3.4 The curriculum of programmes shall be so designed that the minimum prescribed credits required for the award of the degree shall be within the limits specified below:

Programme	Range of credits
M.Tech.	74 - 80
MCA (3 years)	118 - 126
MCA (Lateral Entry)	80 - 85
MCA (2 years)	85 - 90
M.Sc.	77- 82

3.3.5 Credits will be assigned to the courses for all programmes as given below:

- ❖ One credit for one lecture period per week or 15 periods of lecture per semester
- ❖ One credit for one tutorial period per week or 15 periods per semester
- ❖ One credit each for seminar/practical session/project of two or three periods per week or 30 periods per semester
- ❖ One credit for four weeks of industrial internship or 160 hours per semester.

3.3.6 The number of credits the student shall enroll in a non-project semester and

project semester is as specified below to facilitate implementation of Choice Based Credit System.

Programme	Non-project semester	Project semester
M.Tech.	9 to 28	18 to 26
MCA	12 to 33	12 to 26
M.Sc.	9 to 32	10 to 26

3.3.7 The student may choose a course prescribed in the curriculum from any department offering that course without affecting regular class schedule. The attendance will be maintained course wise only.

3.3.8 The students shall choose the electives from the curriculum with the approval of the Head of the Department / Dean of School.

3.3.9 Apart from the various elective courses listed in the curriculum for each specialization of programme, the student can choose a maximum of two electives from any other similar programmes across departments, during the entire period of study, with the approval of the Head of the department offering the course and parent department.

3.4. ONLINE COURSES

3.4.1 Students are permitted to undergo department approved online courses under SWAYAM up to 20% of credits of courses in a semester excluding project semester with the recommendation of the Head of the Department / Dean of School and with the prior approval of Dean Academic Affairs during his/ her period of study. The credits earned through online courses ratified by the respective Board of Studies shall be transferred following the due approval procedures. The online courses can be considered in lieu of core courses and elective courses.

3.4.2 Students shall undergo project related online course on their own with the mentoring of the faculty member.

3.5 PROJECT WORK / DISSERTATION

3.5.1 Project work / Dissertation shall be carried out by the student under the supervision of a Faculty member in the department with similar specialization.

3.5.2 A student may however, in certain cases, be permitted to work for the project in an Industry / Research Organization, with the approval of the Head of the Department/ Dean of School. In such cases, the project work shall be jointly

supervised by a faculty of the Department and an Engineer / Scientist from the organization and the student shall be instructed to meet the faculty periodically and to attend the review meetings for evaluating the progress.

3.5.3 The timeline for submission of final project report / dissertation is within 30 calendar days from the last Instructional day of the semester in which Project / Dissertation is done.

3.5.4 If a student does not comply with the submission of project report / dissertation on or before the specified timeline he / she is deemed to have not completed the project work / dissertation and shall re-register in the subsequent semester.

4.0 CLASS ADVISOR AND FACULTY ADVISOR

4.1 CLASS ADVISOR

A faculty member shall be nominated by the HOD / Dean of School as Class Advisor for the whole class. He/she is responsible for maintaining the academic, curricular and co-curricular records of all students throughout their period of study.

4.2 FACULTY ADVISOR

To help the students in planning their courses of study and for general counseling on the academic programme, the Head of the Department / Dean of School of the students shall attach a certain number of students to a faculty member of the department who shall function as Faculty Advisor for the students throughout their period of study. Such Faculty Advisor shall offer advice to the students on academic and personal matters, and guide the students in taking up courses for registration and enrolment in every semester.

5.0 CLASS COMMITTEE

5.1 A class committee comprising faculty members handling the classes, student representatives and a senior faculty member not handling the courses as chairman will be constituted in every semester:

5.2 The composition of the class committee will be as follows:

- i) One senior faculty member preferably not handling courses for the concerned semester, appointed as chairman by the Head of the Department
- ii) Faculty members of all courses of the semester

- iii) All the students of the class
- iv) Faculty advisor and class advisor
- v) Head of the Department – Ex officio member

5.3 The class committee shall meet at least three times during the semester. The first meeting shall be held within two weeks from the date of commencement of classes, in which the nature of continuous assessment for various courses and the weightages for each component of assessment shall be decided for the first and second assessment. The second meeting shall be held within a week after the date of first assessment report, to review the students' performance and for follow up action.

5.4 During these two meetings the student members, shall meaningfully interact and express opinions and suggestions to improve the effectiveness of the teaching-learning process, curriculum and syllabus.

5.5 The third meeting of the class committee, excluding the student members, shall meet within 5 days from the last day of the semester end examination to analyze the performance of the students in all the components of assessments and decide their grades in each course. The grades for a common course shall be decided by the concerned course committee and shall be presented to the class committee(s) by the concerned course coordinator.

6.0 COURSE COMMITTEE

6.1 Each common theory / laboratory course offered to more than one group of students shall have a "Course Committee" comprising all the teachers handling the common course with one of them nominated as course coordinator. The nomination of the course coordinator shall be made by the Head of the Department / Dean (Academic Affairs) depending upon whether all the teachers handling the common course belong to a single department or from several departments. The Course Committee shall meet as often as possible to prepare a common question paper, scheme of evaluation and ensure uniform evaluation of the assessment tests and semester end examination.

7.0 REGISTRATION AND ENROLLMENT

7.1 The students of first semester shall register and enroll at the time of admission by paying the prescribed fees.

- 7.2** For the subsequent semesters registration for the courses shall be done by the student one week before the last working day of the previous semester.
- 7.3** A student can withdraw from an enrolled course at any time before the first assessment test for genuine reasons, with the approval of the Dean (Academic Affairs), on the recommendation of the Head of the Department of the student.
- 7.4** A student can change an enrolled course within 10 working days from the commencement of the course, with the approval of the Dean (Academic Affairs), on the recommendation of the Head of the Department of the student.

8.0 TEMPORARY BREAK OF STUDY FROM THE PROGRAMME

- 8.1** A student may be permitted by the Dean (Academic Affairs) to avail temporary break of study from the programme up to a maximum of two semesters for reasons of ill health or other valid grounds. A student can avail the break of study before the start of first assessment test of the ongoing semester. However the total duration for completion of the programme shall not exceed the prescribed maximum number of semesters (vide clause 3.1). If any student is debarred for want of attendance or suspended due to any act of indiscipline, it will not be considered as break of study. A student who has availed break of study has to rejoin in the same semester only in the subsequent year. The student availing break of study is permitted to write arrear examinations by paying the prescribed fees.

9.0 MINIMUM REQUIREMENTS TO REGISTER FOR PROJECT / DISSERTATION

- 9.1** A student is permitted to register for project semester, if he/she has earned the minimum number of credits specified below:

Programme	Minimum no. of credits to be earned to enroll for project semester
M.Tech.	18
MCA (3 years)	45
MCA (Lateral Entry)	22
MCA (2 years)	22
M.Sc.	18

- 9.2** If the student has not earned minimum number of credits specified, he/she

has to earn the required credits, at least to the extent of minimum credits specified in clause 9.1 and then register for the project semester.

10.0 ATTENDANCE

- 10.1** A student shall earn 100% attendance in the contact periods of every course, subject to a maximum relaxation of 25% (for genuine reasons such as medical grounds, representing for the institution in approved events, etc.) to become eligible to appear for the semester end examination in that course, failing which the student shall be awarded “I” grade in that course. The courses in which the student is awarded “I” grade, shall register and redo the course when it is offered next.
- 10.2** The faculty member of each course shall cumulate the attendance details for the semester and furnish the names of the students who have not earned the required attendance in that course to the Class Advisor. The Class Advisor will consolidate and furnish the list of students who have earned less than 75% attendance, in various courses, to the Dean (Academic Affairs) through the Head of the Department / Dean of School. Thereupon, the Dean (Academic Affairs) shall announce the names of such students prevented from writing the semester end examination in each course.
- 10.3** A student who has obtained ‘I’ grade in all the courses in a semester is not permitted to move to next higher semester. Such student shall redo all the courses of the semester in the subsequent academic year. However he / she is permitted to redo the courses awarded with 'I' grade / arrear in previous semesters. They shall also be permitted to write arrear examinations by paying the prescribed fee.
- 10.4** A student shall register to redo a core course wherein “I” or “W” grade is awarded. If the student is awarded, “I” or “W” grade in an elective course either the same elective course may be repeated or a new elective course may be chosen with the approval of Head of the Department / Dean of School.

11.0 REDO COURSES

- 11.1** A student can register for a maximum of two redo courses per semester in the evening after regular working hours, if such courses are offered by the concerned department. Students may also opt to redo the courses offered during regular semesters, without affecting the regular academic schedule

and not exceeding prescribed maximum credits.

- 11.2** The Head of the Department with the approval of Dean (Academic Affairs) may arrange for the conduct of a few courses in the evening after regular working hours, depending on the availability of faculty members and subject to a specified minimum number of students registering for each of such courses.
- 11.3** The number of contact hours and the assessment procedure for any redo course will be the same as those during regular semesters except that there is no provision for any substitute examination and withdrawal from an evening redo course.

12.0 ASSESSMENTS AND EXAMINATIONS

- 12.1** Every theory course shall have a total of three assessments during a semester as given below:

Assessments	Weightage of Marks
Continuous Assessment 1	25%
Continuous Assessment 2	25%
Semester End Examination	50%

- 12.2** Appearing for semester end theory examination for each course is mandatory and a student should secure a minimum of 40% marks in each course in semester end examination for the successful completion of the course. Every practical course shall have 75% weightage for continuous assessments and 25% for semester end examination. However a student should have secured a minimum of 50% marks in the semester end practical examination for the award of pass grade.
- 12.3** For laboratory integrated theory courses, the theory and practical components shall be assessed separately for 100 marks each and consolidated by assigning a weightage of 75% for theory component and 25% for practical component. Grading shall be done for this consolidated mark. Assessment of theory component shall have a total of three assessments with two continuous assessments having 25% weightage each and semester end examination having 50% weightage. The student shall secure a separate minimum of 40% in the semester end theory examination for the award of pass grade. The evaluation of practical component shall be through continuous assessment.

- 12.4** The components of continuous assessment for theory/practical/laboratory integrated theory courses shall be finalized in the first class committee meeting.
- 12.5** In the case of Industrial training, the student shall submit a report, which shall be evaluated along with an oral examination by a committee of faculty members constituted by the Head of the Department. The student shall also submit an internship completion certificate issued by the industry / research organisation. The weightage for Industry internship report shall be 60% and 40% for viva voce examination.
- 12.6** In the case of project work, a committee of faculty members constituted by the Head of the Department will carry out three periodic reviews. Based on the project report submitted by the student, an oral examination (viva voce) shall be conducted as semester end examination by an external examiner approved by Controller of Examinations. The weightage for periodic reviews shall be 50%. Of the remaining 50%, 20% shall be for the project report and 30% for the Viva Voce examination.
- 12.7** For the first attempt of the arrear theory examination, the internal assessment marks scored for a course during first appearance shall be considered for grading along with the marks scored in the semester end arrear examination. From the subsequent appearance onwards, full weightage shall be assigned to the marks scored in the semester end examination to award grades and the internal assessment marks secured during the course of study shall not be considered.

In case of laboratory integrated theory courses, after one regular and one arrear appearance, the internal mark of theory component is invalid and full weightage shall be assigned to the marks scored in the semester end arrear examination for theory component. There shall be no arrear or improvement examination for lab component.

13.0 SUBSTITUTE EXAMINATIONS

- 13.1** A student who is absent, for genuine reasons, may be permitted to write a substitute examination for any one of the two continuous assessment tests of a course by paying the prescribed substitute examination fee. However, permission to take up a substitute examination will be given under exceptional circumstances, such as accidents, admission to a hospital due to illness, etc.

by a committee constituted by the Head of the Department / Dean of School for that purpose. However there is no substitute examination for semester end examination.

- 13.2** A student shall apply for substitute exam in the prescribed form to the Head of the Department / Dean of School within a week from the date of assessment test. However the substitute examination will be conducted only after the last working day of the semester and before the semester end examination.

14.0 SUPPLEMENTARY EXAMINATION

- 14.1** Final Year students can apply for supplementary examination for a maximum of three courses thus providing an opportunity to complete their degree programme. Likewise students with less credit can also apply for supplementary examination for a maximum of three courses to enable them to earn minimum credits to move to higher semester. The students can apply for supplementary examination within three weeks of the declaration of results in both odd and even semester.

15. PASSING, DECLARATION OF RESULTS AND GRADE SHEET

- 15.1** All assessments of a course shall be made on absolute marks basis. However, the Class Committee without the student members shall meet within 5 days after the semester end examination and analyze the performance of students in all assessments of a course and award letter grades. The letter grades and the corresponding grade points are as follows:

Letter Grade	Grade Points
S	10
A	9
B	8
C	7
D	6
E	5
U	0
W	0
I	0
AB	0

"W" denotes withdrawal from the course.

“**I**” denotes inadequate attendance and hence prevented from appearing for semester end examination

“**U**” denotes unsuccessful performance in the course.

“**AB**” denotes absence for the semester end examination.

15.2 A student who earns a minimum of five grade points (‘E’ grade) in a course is declared to have successfully completed the course. Such a course cannot be repeated by the student for improvement of grade.

15.3 The results, after awarding of grades, shall be signed by the Chairman of the Class Committee and Head of the Department / Dean of School and it shall be declared by the Controller of Examinations.

15.4 Within one week from the date of declaration of result, a student can apply for reevaluation of his / her semester end theory examination answer scripts of one or more courses, on payment of prescribed fee to the Controller of Examinations. Subsequently the Head of the Department/ Dean of School offered the course shall constitute a reevaluation committee consisting of Chairman of the Class Committee as convener, the faculty member of the course and a senior faculty member knowledgeable in that course as members. The committee shall meet within a week to re-evaluate the answer scripts and submit its report to the Controller of Examinations for consideration and decision.

15.5 After results are declared, grade sheets shall be issued to each student, which contains the following details: a) list of courses enrolled during the semester including redo courses / arrear courses, if any; b) grades scored; c) Grade Point Average (GPA) for the semester and d) Cumulative Grade Point Average (CGPA) of all courses enrolled from first semester onwards.

GPA is the ratio of the sum of the products of the number of credits of courses registered and the grade points corresponding to the grades scored in those courses, taken for all the courses, to the sum of the number of credits of all the courses in the semester.

If C_i is the number of credits assigned for the i^{th} course and GP_i is the Grade Point in the i^{th} course

$$GPA = \frac{\sum_{i=1}^n (C_i)(GP_i)}{\sum_{i=1}^n C_i}$$

Where n = number of courses

The Cumulative Grade Point Average (CGPA) is calculated in a similar manner, considering all the courses enrolled from first semester.

"I" and "W" grades are excluded for calculating GPA.

"U", "I", "AB" and "W" grades are excluded for calculating CGPA.

The formula for the conversion of CGPA to equivalent percentage of marks is as follows:

Percentage Equivalent of Marks = CGPA X 10

- 15.6** After successful completion of the programme, the Degree shall be awarded upon fulfillment of curriculum requirements and classification based on CGPA as follows:

Classification	CGPA
First Class with Distinction	8.50 and above and passing all the courses in first appearance and completing the programme within the minimum prescribed period.
First Class	6.50 and above and completing the programme within a minimum prescribed period plus two semesters.
Second Class	Others

However, to be eligible for First Class with Distinction, a student should not have obtained 'U' or 'I' grade in any course during his/her period of study and should have completed the P.G. programme within a minimum period (except break of study). To be eligible for First Class, a student should have passed the examination in all the courses within the specified minimum number of semesters reckoned from his/her commencement of study plus two semesters. For this purpose, the authorized break of study is not considered. The students who do not satisfy the above two conditions shall be classified as second class. For the purpose of classification, the CGPA shall be rounded to two decimal places. For the purpose of comparison of performance of students and ranking, CGPA will be considered up to three decimal places.

16.0 DISCIPLINE

- 16.1** Every student is expected to observe disciplined and decorous behaviour both inside and outside the campus and not to indulge in any activity which tends to affect the reputation of the Institution.

16.2 Any act of indiscipline of a student, reported to the Dean (Student Affairs), through the HOD / Dean shall be referred to a Discipline and Welfare Committee constituted by the Registrar for taking appropriate action.

17.0 ELIGIBILITY FOR THE AWARD OF THE MASTERS DEGREE

17.1 A student shall be declared to be eligible for the award of the Masters Degree, if he/she has:

- i. Successfully acquired the required credits as specified in the curriculum corresponding to his/her programme within the stipulated time.
- ii. No disciplinary action is pending against him/her.
- iii. Enrolled and completed at least one value added course.
- iv. Enrollment in at least one MOOC / SWAYAM course (non-credit) before the final semester.

17.2 The award of the degree must have been approved by the Institute.

18.0 POWER TO MODIFY

Notwithstanding all that have been stated above, the Academic Council has the right to modify any of the above regulations from time to time.

**B.S. ABDUR RAHMAN CRESCENT INSTITUTE OF SCIENCE
AND TECHNOLOGY**

**M.SC. (PHYSICS)
(Four Semesters/ Full Time)**

CURRICULUM

SEMESTER I

S. No.	Course Code	Course Title	L	T	P	C
1	PHD 6101	Classical Mechanics and Relativity	4	0	0	4
2	PHD 6102	Mathematical Physics	3	1	0	4
3	PHD 6103	Solid state Physics	3	0	0	3
4	PHD 6104	Physics of semiconductor devices	3	0	0	3
5		Elective – I	2/3	0	2/-	3
6		Elective – II	2/3	0	2/-	3
7	PHD 6105	Advanced Optics Laboratory	0	0	4	2
8	PHD 6106	Semiconductor devices and circuits Laboratory	0	0	4	2
Total						24

SEMESTER II

S. No.	Course Code	Course Title	L	T	P	C
1	PHD 6201	Quantum Mechanics	3	0	0	3
2	PHD 6202	Electromagnetic Theory & Electrodynamics	3	1	0	4
3	PHD 6203	Atomic Physics and Molecular Spectroscopy	4	0	0	4
4	GED 6202	Research Methodology	4	0	0	4
5		Elective – III	2/3	0	2/-	3
6		Elective – IV	2/3	0	2/-	3
7	PHD 6204	Thermal Physics Laboratory	0	0	4	2
8	PHD 6205	Seminar				1
Total						24

SEMESTER III

S. No.	Course Code	Course Title	L	T	P	C
1	PHD 7101	Digital Electronics and Microprocessors	4	0	0	4
2	PHD 7102	Thermodynamics and Statistical Physics	4	0	0	4
3	PHD 7103	Nuclear and Particle Physics	3	0	0	3
4		Elective –V	3	0	0	3
5		Elective –VI	3	0	0	3
6	PHD 7104	Advanced Electronics Laboratory	0	0	4	2
7	PHD 7105	Materials Science Laboratory	0	0	4	2
8	PHD 7106	Mini Project/Internship (during summer vacation after II Sem)			2	1
9	PHD 7201	Project phase – I				2
Total						24

SEMESTER IV

S. No.	Course Code	Course Title	L	T	P	C
1	PHD 7201	Project phase – II				10

Total credits = 82

LIST OF ELECTIVES**First year (Semester I)**

S. No.	Course Code	Course Name	L	T	P	C
1	PHDY 101	Crystal Growth Techniques	2	0	2	3
2	PHDY 102	Materials processing	3	0	0	3
3	PHDY 103	Materials Characterization	2	0	2	3
4	PHDY 104	Smart materials and structures	3	0	0	3
5	PHDY 105	Advanced Optics & Laser Technology	3	0	0	3
6	PHDY 106	Nonlinear optics	3	0	0	3
7	PHDY 107	Optical Fiber communication	2	0	2	3
8	PHDY 108	Optical computing	3	0	0	3
9	PHDY 109	Density Functional Theory	3	0	0	3

First year (Semester II)

S. No.	Course Code	Course Name	L	T	P	C
1	PHDY 201	Electro-Optic materials and devices	3	0	0	3
2	PHDY 202	Ferroelectric materials and devices	2	0	2	3
3	PHDY 203	Structure and properties of alloys	3	0	0	3
4	PHDY 204	Photonic materials and devices	3	0	0	3
5	PHDY 205	Numerical methods and programming	3	0	0	3
6	PHDY 206	Ultrasonics and Non-Destructive Testing	3	0	0	3
7	PHDY 207	Optoelectronic devices	2	0	2	3
8	PHDY 208	Biophotonics	3	0	0	3

Second year (Semester III)

S. No.	Course Code	Course Name	L	T	P	C
1	PHDY 301	Mathematical methods for nonlinear science	3	0	0	3
2	PHDY 302	Measurements and Instrumentation	3	0	0	3
3	PHDY 303	Biomedical Instrumentation	3	0	0	3
4	PHDY 304	Radiation Physics	3	0	0	3
5	PHDY 305	Laser spectroscopy and its applications	3	0	0	3
6	PHDY 306	Nanophotonics	3	0	0	3
7	PHDY 307	Nanoscience and Technology	3	0	0	3
8	PHDY 308	Thin film science and technology	3	0	0	3
9	PHDY 309	Corrosion science and technology	3	0	0	3
10	PHDY 310	Biomaterials	3	0	0	3

SEMESTER I

PHD 6101	CLASSICAL MECHANICS AND RELATIVITY	L	T	P	C
		4	0	0	4

OBJECTIVES:

- To provide the foundations of the advanced level mechanics
- To learn Lagrangian and Hamiltonian mechanics
- To understand rigid body dynamics and small oscillations
- To provide applications to relativistic mechanics
- To understand the nonlinear systems, chaos and solitons

MODULE I FUNDAMENTAL PRINCIPLES AND LAGRANGIAN FORMULATION 12

Mechanics of a particle and a system of particles – Conservation laws – Degrees of freedom – Constraints – Generalised coordinates – Principle of Virtual work – D'Alembert's Principle – Lagrange's equations of motion for conservative and Non-conservative systems – Applications: L-C circuit – Linear harmonic oscillator and Atwood's machine. Central force and motion in a plane – Equation of motion under central force and first integrals – Differential equation for an orbit – Inverse square law of force – Kepler's laws of planetary motion and their deduction –Virial theorem.

MODULE II HAMILTONIAN FORMULATION 12

Hamiltonian function – Physical significance – Hamilton's canonical equations of motion – Applications: Simple pendulum – Motion of a particle in a central force field – Charged particle in an electromagnetic field– Hamilton's variational principle – proof –Derivation of Lagrange's equations-Principle of Least Action – its deduction-Canonical Transformations-Generating function-Poisson bracket – properties – The Hamilton – Jacobi equation – Kepler's problem -solution by Hamilton – Jacobi method - Action and angle variables.

MODULE III RIGID BODY DYNAMICS AND SMALL OSCILLATIONS 12

Independent coordinates – Euler's angles – Components of Angular velocity in terms of Euler's angles –Angular momentum of a rigid body –Moments and products of inertia – Euler's equations of motion for a rigid body. Theory of small oscillations –

Frequencies of free vibration and normal coordinates – Two coupled harmonic oscillators – Vibrations of a linear triatomic molecule.

MODULE IV RELATIVISTIC MECHANICS 12

Reviews of basic ideas of special relativity – variation of mass with velocity– Relativistic energy – Mass- energy relation – Force in relativistic mechanics – Minkowski space and Lorentz transformations – four vectors – Elements of general theory of relativity.

MODULE V NONLINEAR DYNAMICS 12

Dynamical systems – Mathematical implications of nonlinearity – definition and effects of nonlinearity – Linear vs Nonlinear oscillators – Classification of equilibrium points – Logistic map – stability analysis – Period doubling phenomenon – definition of chaos – initial conditions – Linear and Nonlinear dispersive waves – KdV equation – solitary waves & solitons : Application in optical fibres.

Total Hours: 60

REFERENCES:

1. Golstein. H, Poole. C and Sofko. J, Classical Mecanics , Pearson Education, New Delhi, 2013.
2. Upadhyaya. J.C., Classical Mechanics, Himalaya Publishing House, 2010.
3. Marion and Thornton, Classical Dynamics of Particles and Systems, Fifth Edition, Holt Rinehart & Winston, 2012.
4. Panat. P.V, Classical Mechanics, Narosa Publishing Home, New Delhi, 2008.
5. Rana. N.C and Joag.P.S, Classical Mechanics, Tata Mc-Graw Hill Publishing Company Limited, New Delhi, 2004.
6. M.Lakshmanan and S.Rajasekar, Nonlinear dynamics: Integrability, Chaos and Spatio-temporal patterns, Springer-Verlag, 2003.
7. Steven H.Strogatz, Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering (Studies in Nonlinearity) 2nd Edition, 2015.

OUTCOMES:

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

- understand advanced level mechanics.

- learn the description of Lagrange's and Hamilton's equations for a system of particles.
 - comprehend the idea of Central force problems.
 - understand the dynamics of rigid body and small oscillations and apply them to real life examples.
 - correlate relativistic mechanics and non linear systems
- .

PHD 6102**MATHEMATICAL PHYSICS**

L	T	P	C
3	1	0	4

OBJECTIVES:

- To provide a strong mathematical foundation in vector calculus, matrices
- To discuss the properties of second order linear differential equations and special functions
- To understand the complex variables
- To learn about Fourier transform and Greens functions
- To provide the basics of Tensor analysis and Group theory

MODULE I VECTORS AND MATRICES**12**

Vector analysis: Gradient – Divergence – Curl – vector spaces – linear dependence and independence of vectors - second order derivatives

Gauss's theorem - Stoke's theorem - Green's theorem – Curvilinear coordinates-spherical polar-cylindrical coordinates. Matrices: Orthogonal and Unitary Matrices, Matrix diagonalization, Cayley-Hamilton theorem - eigen values and eigen vectors.

MODULE II SECOND ORDER LINEAR DIFFERENTIAL EQUATIONS AND SPECIAL FUNCTIONS**12**

Hermite, Legendre, Bessel and Laguerre differential equations –series solutions-generating functions-recurrence relations- Sturm Liouville theorem - Orthogonality of eigen function. Hyper geometric functions – generating functions.

MODULE III COMPLEX VARIABLES**12**

Functions of complex variables – single and many valued functions-analytic functions – Cauchy – Riemann equations –conjugate functions – complex line integrals-Cauchy's integral theorem-integral formula – Taylor and Laurent expansions –zeros and singularities – residues –Cauchy's Residue theorem and its applications for evaluation of integrals.

MODULE IV FOURIER TRANSFORM AND GREEN FUNCTIONS**12**

Fourier Transform: Fourier transform – sine and cosine transform – properties Faultung's theorem- application in heat conduction and spectroscopy. Laplace transforms – Inverse transforms – Linearity and Shifting theorems. Linear spaces – Basis-change of basis –

Inner product space – Schmidt's orthogonalisation procedure – Schwartz's inequality – Hilbert spaces - properties. Green's function: Definition and construction – symmetry properties - expression for Green's functions in terms of Eigen functions - Green's functions for simple and second order operator.

MODULE V TENSORS AND GROUP THEORY

12

Tensor analysis : Cartesian tensors – law of transformation of first and second order tensors- addition, subtraction and multiplication (inner and outer product) of tensors –rank ,covariant, contravariant and mixed tensors-symmetric and antisymmetric tensors-Quotient law. Group Theory: Basic definitions- subgroups- permutation groups-Cyclic groups - cosets - Normal Subgroups-Isomorphism - Homomorphsim-Rotation groups - Reducible – Irreducible representations – Applications.

Total Hours: 60

REFERENCES:

1. G.B. Arfken, H.J.Weber and F.E. Harris, Mathematical Methods for Physicists, Seventh Edition, Academic Press, 2012
2. S.Andrilli and D.Hecker, Elementary Linear Algebra,Academic Press, 2006
3. Chattopadhyay. P.K, Mathematical Physics, 3rd Edition, New Academic Science, 2014.
4. Joshi. A. W, Matrices and Tensors in Physics, 3rd edition, Wiley Eastern Ltd., New Delhi, 1995.
5. Gupta. B. D., Mathematical Physics, 4th edition, Vikas Publishing House Pvt Limited, 2007.
6. Murray Spiegel, Schaum's Outline of Advanced Mathematics for Engineers and Scientists, Schaum's Outline Series, McGraw-Hill, 2009.

OUTCOMES:

At the end of the course, the students will be able to,

- understand the vector, vector fields, matrices and their need in science
- apply knowledge in solving the second order linear differential equations and special functions
- solve the problems in complex variables
- analyse knowledge in Fourier Transforms and green's functions
- develop the essential mathematical skills to solve problems in tensors and group theory.

PHD 6103**SOLID STATE PHYSICS**

L	T	P	C
3	0	0	3

OBJECTIVES:

- To provide the knowledge of crystal structures and bonding in solids
- To know the transport properties and band theory of solids
- To understand the thermal vibrations in solids and thermal properties
- To provide the knowledge of magnetic and dielectric properties of materials
- To learn the superconducting and optical properties of materials

MODULE I CRYSTAL STRUCTURE AND BINDING**9**

General Description of Crystal Structures – Bravais lattices- Cubic Structures, NaCl, CsCl, Diamond, Zinc blende, HCP structures- Miller Indices- interplanar distance(derivation) - The Reciprocal Lattice - defects and dislocations-Quasi crystals -Force between atoms-cohesive energy –bonding in solids - binding energy of ionic crystals(derivation)-Madelung constant – Born Haber cycle.

MODULE II TRANSPORT PROPERTIES AND BAND THEORY OF SOLIDS**9**

Free electron theory (Sommerfeld theory) – electronic specific heat- electrical and thermal conductivity of metals – Wiedemann Franz law (derivation)- Hall effect and Thermoelectric power - Effective mass and concept of hole- electron motion in periodic potential – Bloch's theorem - band theory of solids -construction of Brillouin zone - Fermi surface in metals – characteristics of Fermi surface- De Haas van Alphen effect - Kronig Penney model (derivation).

MODULE III PHONONS : CRYSTAL VIBRATIONS AND THERMAL PROPERTIES**8**

Vibrations of crystals with monoatomic lattice(derivation) - Vibrations of crystals with diatomic lattice (derivation)– optical and acoustical modes – number of normal modes of vibrations in a band-Phonon momentum- inelastic scattering of photons by phonons – Debye's theory of lattice specific heat(derivation) - anharmonic effects.

MODULE IV MAGNETIC AND DIELECTRIC PROPERTIES**10**

Types of magnetic materials –Diamagnetism – Langevin's theory(derivation)-

Paramagnetism – Hund’s rules – rare earth ions-iron group ions-crystal field splitting-Pauli paramagnetism- Ferromagnetism – domain theory- Curie-Weiss law (derivation)- antiferromagnetism-ferrites. Polarization and polarizability- types of polarization (qualitative) and dependence on frequency and temperature-local electric field in an atom-Clausius Mossotti relation(derivation) -Piezo, pyro and ferroelectric properties of crystals.

MODULE V SUPERCONDUCTIVITY AND OPTICAL PROPERTIES 9

Properties of superconductor – critical magnetic field – Meissner effect (derivation) – Type I and Type II super conductors – superfluidity - entropy and heat capacity –energy gap- quantum tunneling - London equations (derivation) –coherence length-BCS theory –RVB - AC and DC Josephson effect – SQUID. Traps – Excitons – coloration of crystals - types of colour centers - Luminescence: fluorescence and phosphorescence– activators - Emission and absorption spectra – Efficiency of phosphor.

Total Hours: 45

REFERENCES:

1. Kittel. C, Introduction to Solid State Physics, 8th edition, Wiley Eastern, New Delhi, 2019.
2. Pillai. S.O, Solid State Physics, New Age International, New Delhi, 2009.
3. Blakemore. J. S, Solid State Physics, 2nd edition, Cambridge University Press, Cambridge, 1985.
4. Philip Hofmann, Solid State Physics, 1st edition, Wiley-VCH Publishers, 2011.
5. Wahab. A, Solid State Physics: Structure and Properties of Materials , Alpha Science International Ltd; 2nd Revised edition,2005

OUTCOMES:

At the end of the course, the students will be able

- to illustrate the concepts on crystal structures and bonding nature of solids
- to analyse the thermal properties on the basis of thermal vibrations
- to explain the thermal properties, electrical properties and electronic band structure of solids
- to elucidate the magnetic and dielectric properties and their applications
- to exemplify the superconducting and optical properties of materials and their applications

PHD 6104**PHYSICS OF SEMICONDUCTOR DEVICES****L T P C****3 0 0 3****OBJECTIVES:**

- To understand the fundamentals of physics of semiconducting materials
- To construct and study the operations of semiconductor devices in the family of diodes and transistors under different operating conditions.
- To expose to circuit design of different types of amplifiers and oscillators.
- To explore the knowledge on various types of oscillators and convertors
- To understand the design and fabrication of Integrated Circuits (ICs) and timer.

MODULE I SEMICONDUCTOR DIODES**9**

Semiconductors: N and P type, mass action law - continuity equation – PN junction diode under forward and reverse bias – Band structure – Einstein's diode equation – Zener diode - Varactor diode – Schottky diode – Tunnel diode – Gunn diode – Optoelectronic diodes – LED, LASER diode and photo diode.

MODULE II SPECIAL DEVICES**9**

BJT construction and characteristics – biasing circuits – current components - JFET-structure and working –V-I Characteristics – pinch off voltage –Depletion and Enhancement type MOSFET – UJT – SCR–DIAC, TRIAC - applications.

MODULE III AMPLIFIERS**9**

BJT single stage amplifier - FET single stage amplifier – small signal analysis - Operational amplifier - inverting and non-inverting amplifier – instrumentation amplifier – voltage follower –comparator - integrating and differential circuits – log & antilog amplifiers –active filters : lowpass, high pass, band pass & band rejection filters.

MODULE IV OSCILLATORS and CONVERTORS**9**

Colpitt's oscillator – Hartley oscillator - Wien bridge, phase shift oscillators - – triangular, sawtooth and square wave generators-Schmitt's trigger – sample and hold circuits –phase locked loops. Basic D to A conversion and A to D conversion.

MODULE V IC FABRICATION AND IC TIMER**9**

Basic monolithic ICs – epitaxial growth – masking – etching impurity diffusion fabricating monolithic resistors, diodes, transistors and capacitors – circuit layout – contacts and inter connections – 555 timer – description of the functional diagram – mono stable operation – applications of mono shots – astable operation and pulse generation.

Total Hours: 45**REFERENCES:**

1. Floyd L, Electronic Devices, Pearson Education, 10th edition, New York, 2018.
2. Milman.J and Halkias.C.C, Electronic devices and circuits, 4th edition, Tata McGraw Hill, 2015.
3. Roy Choudhary. D, Linear Integrated Circuits, 5th edition, New Academic Science Ltd, 2018.
4. Mottershead, A., Electronic Devices and Circuits - An Introduction, Prentice,1979
5. SM.Sze, Semiconductor devices – Physics and Technology, 2nd Ed, John Wiley 2008.
6. Donald A Neaman, Semiconductor physics and devices, 4th Ed, Tata McGraw Hill, 2017.
7. S. Salivahanan, N.Suresh Kumar and A.Vallavaraj, Electronic devices and circuits, Tata McGraw Hill, Third Edition, 2012.

OUTCOMES:

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

- understand the fundamentals and working of semiconductor diodes
- explore the working and application of various type of transistors
- comprehend the principles and working mechanism of various types of amplifiers and filters
- compare and correlate the characteristics of oscillators and converters
- analyse the various applications of electronic devices in fabrication of Integrated circuits (ICs) and timer circuits

PHD 6105**ADVANCED OPTICS LABORATORY****L T P C****0 0 4 2****OBJECTIVES**

- To gain in-depth knowledge in the field of optics
- To apply the concepts learnt through laboratory in various applications to meet the epithetical needs of the society.

LIST OF EXPERMENTS**(ANY TEN)**

1. Determination of wavelength of light using Michelson interferometer
2. Refractive index of a given liquid using Hollow prism method
3. Air – wedge experiment
4. Numerical aperture and acceptance angle of an optical fibre.
5. Particle size determination of different materials
6. Spectrometer experiment – determination of wavelength of prominent line of mercury spectrum.
7. Determination of Brewster angle using fibre optics
8. Fraunhofer diffraction experiment
9. Fresnel diffraction experiment
10. Beam divergence of He – Ne laser semiconductor diode laser
11. Single mode fibre characteristics
12. Nonlinear optical studies using Pulsed Nd: YAG Laser
13. Demonstrate the principle of Rayleigh Scattering
14. Polarization experiments using polarimeter

Total Hours: 60**OUTCOMES:**

At the end of the course, the student will be able to

- comprehend the different experimental techniques in Advanced optics and use it to analytical problems.
- apply the concepts of Physics principles and interpret them to carry out experiments using interference, diffraction, polarization phenomenon.

PHD 6106 SEMICONDUCTOR DEVICES AND CIRCUITS L T P C
LABORATORY

0 0 4 2

OBJECTIVES:

- To make the student understand the classification of transistor characteristics
- To enable the student to design amplifier, oscillator and other circuits using OP AMP

LIST OF EXPERMENTS

(ANY TEN)

1. Characteristics of PN Junction diode and Zener diode. Design of clipper and clamper circuits.
2. Input and Output characteristics of BJT in CB and CE configurations and comparison.
3. Characteristics of JFET and MOSFET
4. UJT and SCR characteristics
5. Characteristics of photodiode and photo transistor.
6. Design of single stage amplifier using BJT and JFET for small signal applications and comparison.
7. Design of Colpitt's and Hartley oscillators using BJT for a given frequency
8. Design of Wien bridge and Phase shift oscillators using OPAMP.
9. Schmitt's trigger: Triangular, sawtooth and square wave generators.
10. Design of Adder, Subtractor, Multiplier, Differentiator and Integrator circuits using OPAMP
11. Construction of Astable, Monostable and Bistable multivibrators using BJT / OPAMP.
12. Construction of Dual power supply.
13. Design of A / D and D / A convertors.
14. Design of modulation and demodulation circuits.

Total Hours: 60

OUTCOMES:

At the end of the course, the student will be able to

- classify the characteristics of semiconductor devices.
- design amplifier, oscillator and other circuits using OP AMP

SEMESTER II**PHD 6201****QUANTUM MECHANICS****L T P C****3 0 0 3****OBJECTIVES:**

- To understand the basic concepts of quantum mechanics.
- To know certain exactly solvable systems.
- To enable the students to explore the different approximation methods.
- To understand the scattering theory and angular momentum operators.
- To give the applications of relativistic quantum mechanics.

MODULE I BASIC FORMULATION**09**

Postulates of quantum mechanics - Schrodinger time independent and dependent equations— physical Interpretation of wave function Ψ - expectation values - Ehrenfest theorem-Basic postulates - Operators: Definition and properties- Eigen values and Eigen functions - self adjoint operators – Parity operator- uncertainty principle. (Statement and Proof) - Quantum pictures: Schroedinger, Heisenberg and Interaction.

MODULE II EXACTLY SOLVABLE SYSTEMS**09**

One dimensional linear harmonic oscillator – solutions to a square well potential – rigid rotator -Particle in a central potential – Particle in a periodic potential - Central forces and reduction of two body problem – Particle in a spherical well – Hydrogen atom.

MODULE III APPROXIMATION METHODS**09**

Time independent perturbation theory: Equations in various orders of time independent perturbation theory for non- degenerate case: first and second order– Stark effect – Zeeman effect- Application to ground state of Helium atom – Time dependent perturbation theory: harmonic perturbation (Fermi-Golden Rule) - Adiabatic, Sudden Approximation perturbation.

MODULE IV SCATTERING THEORY AND ANGULAR MOMENTUM**09**

Scattering theory: Scattering amplitude and cross-section – Green's function approach -- Born approximation and its application to square-well and screened Coulomb potentials. Angular momentum: Components of orbital angular momentum

– Properties of L and L^2 – Eigen pairs of L^2 and L_z – Eigen states and Eigen values of J^2 and J_z – addition of angular momentum – Clebsch Gordan coefficients - spin angular momentum – Pauli's spin matrices.

MODULE V RELATIVISTIC QUANTUM MECHANICS

09

Klein Gordon equation for a free particle and its solution – Dirac's equation for free particle – Dirac matrices - covariant form of Dirac's equation - Spin of Dirac's particle- Charge and current densities – Plane wave solution – Negative energy states – Zitterbewegung – Spin of a Dirac particle – Spin-orbit coupling.

Total Hours: 45

REFERENCES:

1. David J. Griffiths, Introduction to Quantum Mechanics, Pearson Publication, 2nd Edition, 2015.
2. L. Schiff, Quantum Mechanics, Tata McGraw Hill, New Delhi, 2014, 4th edition.
3. Satya Prakash, Quantum Mechanics, Sultan Chand Publishers, New Delhi, 2004.
4. S. Rajasekar, R. Velusamy, Quantum Mechanics I: The Fundamentals, CRC Press, 2014.
5. S L Gupta, V Kumar, H V Sharma, Quantum Mechanics, Jai Prakash Nath Publications, 2015
6. P M Mathews, K.Venkatesan ,Text Book of Quantum Mechanics, 2nd Ed, Tata McGraw-Hill Education, 2017
7. A.K. Ghatak and S. Lokanathan, Quantum Mechanics: Theory & Applications (Macmillan, Chennai, 2004) 5th edition.
8. R. Shankar, Principles of Quantum Mechanics (Springer, New Delhi, 2007).

OUTCOMES:

At the end of the course, the students will be able to

- Comprehend the basics of quantum mechanics and to apply it in different branches of Physics.
- Apply the knowledge gained in the solvable system in the field of harmonic oscillator and hydrogen atom
- Enable the students to explore the different approximation methods used in quantum mechanics.
- Familiarize with the concepts of scattering theory and angular momentum and its importance.
- Understand the applications of relativistic quantum mechanics.

PHD 6202	ELECTROMAGNETIC THEORY AND ELECTRODYNAMICS	L T P C 3 1 0 4
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OBJECTIVES:

- To know the principles of electrostatics and magnetostatics.
- To familiarize with the Maxwell's equation and boundary conditions.
- To understand the basic concepts in electromagnetic wave and radiation.
- To study the laws governing the propagation of electromagnetic waves.
- To enable the student to explore the field of electrodynamics

MODULE I ELECTROSTATICS 12

Coulomb's law, Gauss's law and applications, Electrostatic potential – Laplace and Poisson's equation – Laplace equation in three dimensions - Boundary value problems and uniqueness theorem, Polarization and displacement vectors - Boundary conditions - Dielectric sphere in a uniform field – Molecular polarisability and electrical susceptibility – Electrostatic energy in the presence of dielectric – Multipole expansion.

MODULE II MAGNETOSTATICS 12

Biot-Savart Law and its Applications, Ampere's circuital Law – Applications – Magnetic vector and scalar potential - Magnetic moment, force and torque on a current distribution in an external field - Magnetostatic energy - Magnetic induction and magnetic field in macroscopic media - Boundary conditions.

MODULE III MAXWELL'S EQUATION 12

Faraday's laws of Induction - Maxwell's displacement current - Maxwell's equations – free space and linear isotropic media – Boundary conditions on the fields at interfaces - Vector and scalar potentials - Gauge invariance - Wave equation in one dimension - Coulomb and Lorentz gauges - Energy and momentum of the field - Poynting's theorem - Lorentz force - Conservation laws for a system of charges and electromagnetic fields.

MODULE IV ELECTROMAGNETIC WAVES & INTERACTION WITH MATTER 12

Electromagnetic waves in free space – Plane waves in non-conducting media - Linear and circular polarization, reflection and refraction at a plane interface-

Fresnel's law, interference, coherence and diffraction – Dynamics of charged particles in static and uniform electromagnetic fields - Waves in a conducting medium - Propagation in linear media – Reflection and transmission at Normal incidence – Reflection and Transmission at Oblique incidence –Laws of incidence and reflectance, Snell's law, Brewster law – Fresnel's equations.

MODULE V RELATIVISTIC AND QUANTUM ELECTRODYNAMICS 12

Four vectors - Lorentz transformation – invariance of Maxwell's equations under Lorentz transformation - invariance of D'Alembertian operator – invariance of Maxwell's field equations in terms of four vector – Radiation from moving charges and dipoles and retarded potentials - Quantum Electrodynamics (QED) – Introduction - S-Matrix and its expansion. Ordering theorems, Feynman graph and Feynman rules - Application - Rutherford scattering and Compton scattering.

Total Hours: 60

REFERENCES:

1. David J.Griffith, Introduction to Electrodynamics, 4th Edition, Pearson New International Edition, New Delhi, 2014.
2. John David Jackson, Classical electrodynamics, 3rd edition, Wiley Eastern Ltd. (1999).
3. Zangwill A, Modern Electrodynamics, 1st edition, Cambridge (2013).
4. Reitz, John R.; Milford, Frederick J., Christy., Robert W., Foundations of Electromagnetic Theory 4th ed. Addison Wesley (2008).
5. Gupta, Kumar, Singh, Electrodynamics, Pragati Prakashan (2001).
6. Capri A.Z. and Panat P.V., Introduction to Electrodynamics, Narosa Publishing House, 2010.
7. Satya Prakash, Electromagnetic theory and Electrodynamics, 10th edition, Kedar Nath and co., Meerut, 1999.
8. Matthew N.O, Sadiku, Elements of Electromagnetics, 3rd Ed. 2006

OUTCOMES:

At the end of the program, the students will

- Familiarize with the concepts of electrostatics and magnetostatics.
- Apply Maxwell's equations to circuit theory.
- Acquaint with the boundary conditions.
- Gain knowledge on the propagation of electromagnetic waves.
- Disseminate the principles of Quantum Electrodynamics.

PHD 6203**ATOMIC PHYSICS AND MOLECULAR
SPECTROSCOPY****L T P C
4 0 0 4****OBJECTIVES:**

- To provide basic knowledge of modern atomic and molecular physics
- To understand different spectroscopic studies on matter on the basis of quantum mechanics
- To master the experimental and theoretical methods in atomic and molecular spectroscopy
- To gain knowledge about NMR and ESR spectroscopy
- To obtain understanding on NQR and Mossbauer spectroscopy

MODULE I ATOMIC AND MOLECULAR STRUCTURE**12**

Atomic models: Vector atom model – Pauli's exclusion principle – Heisenberg's uncertainty principle – Types of spectra - Equation of motion of matters waves – operators - momentum and energy operators - eigen functions and eigen values — Many electron atoms – coupling schemes – Spin orbit interaction -energy levels – Spin functions of two and three electrons - Central field approximation: Thomas Fermi statistical model — Paschen back effect – Covalent bond - Hybridization: sp, sp², sp³ - molecular orbital theory –Heitler London theory of Hydrogen ion and Helium molecule.

MODULE II INFRARED AND MICROWAVE SPECTROSCOPY**12**

Characteristic features of pure rotation – vibration – rotation and vibration of a diatomic molecule – theory – evaluation of molecular constants – IR spectra of polyatomic molecules – experimental techniques of IR – Dipole moment studies – molecular structure determination. Microwave spectra of polyatomic molecules – experimental techniques of microwave spectroscopy – inversion spectrum of ammonia – Maser principles – Ammonia Maser– applications of Masers.

MODULE III RAMAN SPECTROSCOPY**12**

Semi classical treatment of emission and absorption of radiation – emission and absorption coefficients – spontaneous and induced emission of radiation – polarisability – Rayleigh scattering – Raman effect – basic principles of Raman scattering – vibrational and rotational Raman spectra – Experimental techniques of Raman Spectroscopy- – molecular structure studies – Laser as a Raman source.

MODULE IV NMR AND ESR SPECTROSCOPY**12**

NMR spectroscopy Basic principles- classical and quantum mechanical techniques - Bloch equations- spin- spin and spin- lattice relaxation times-experimental technique - single coil and double coil methods- pulse ESR spectroscopy- basic principles- ESR spectrometer- Nuclear interaction and hyperfine structure- Relaxation effects- 'g' factor- biological applications.

MODULE V NQR AND MOSSBAUER SPECTROSCOPY**12**

NQR spectroscopy- basic principles- quadrupole Hamiltonian- Nuclear quadrupole energy levels- for axial and non axial symmetry- NQR spectrometer-chemical bonding- molecular structure and molecular symmetry studies. Mossbauer spectroscopy-principle experimental arrangement - chemical shift-quadrupole splitting-applications.

Total Hours: 60**REFERENCES:**

1. Sune Svanberg, Atomic and Molecular spectroscopy, 3rd Edition, Springer Publishers, 2012.
2. Jain V. K., Introduction to Atomic And Molecular Spectroscopy, Alpha Science Intl Publishers, 2007.
3. Colin N. Banwell and Elaine M. McCash, Fundamentals of Molecular spectroscopy, McGraw-Hill College, 1994.
4. G.Aruldas, Molecular structure and Spectroscopy, 2nd Ed., PHI learning Pvt.Ltd. 2014.
5. R.Gopalan, P.S.Subramanian and K.Rengarajan, Elements of Analytical Chemistry, Sultan Chand & sons, 2011
6. Jeanne L. McHale, Molecular spectroscopy, Prentice Hall, 1994.

OUTCOMES:

At the end of the course, the students will be able to

- explain the basic ideas about the various energy levels in matter
- understand the concepts of different spectroscopic studies
- carry out theoretical and experimental studies on molecular spectroscopy
- focus on structure and dynamics of atoms and molecules
- gain knowledge in Mossbauer and NQR spectroscopy towards chemical shift and quadrupole splitting applications

GEC 6202	RESEARCH METHODOLOGY	L	T	P	C
		4	0	0	4

OBJECTIVES:

The students will be trained to

- Select and Define a research problem
- Describe the Methodology of Research
- Acquire good laboratory practices
- Operate the software for Programming techniques
- Demonstrate the Plagiarism check by turtin

MODULE I RESEARCH METHODOLOGY- AN INTRODUCTION 12

Research: Objectives, Motivation and types - Approaches, Significance of Research, Research Methods versus Methodology, Research and Scientific Method, Research Process, Criteria of Good Research, Problems Encountered by Researchers - Introduction to ethics, scientific conduct and misconduct, Misconduct and why it occurs, Fabrication, Authorship issues, The investigation and punishment of scientific misconduct.

MODULE II GOOD LABORATORY PRACTICES AND SAFETY 12

Introduction: History, definition, Principles, Good Laboratory Practices (GLP) and its application GLP training: Resources, Rules, Characterization, Documentation, quality assurance, Resources, Facilities: building and equipment, Personnel, GLP and FDA, Stepwise implementation of GLP and compliance monitoring. Safety Symbols, Science Safety Rules- Dress Code, First Aid, Heating and Fire Safety

MODULE III PROGRAMMING TECHNIQUES 12

Data analysis using Excel, Origin and Sigma plot Analyzing the chemical data and drawing chemical structures using Chemdraw and Chems sketch. Basics of C and C++ programme – MATLAB – Numerical Methods – Ordinary Differential Equation – Partial Differential Equation – Runge Kutta Method.

MODULE IV INTERPRETATION OF RESULTS AND ANALYSIS 12

Importance and scientific methodology in recording results, importance of negative results, different ways of recording, industrial requirement, artifacts versus true results, types of analysis (analytical, objective, subjective) and cross verification, correlation with published results, discussion, outcome as new idea, hypothesis,

concept, theory, model etc.

Conceptions of error of measurement, true score theory and generalisability theory. Measures of central tendency or averages – mean median and mode. Measures of dispersion – range, variance, and standard deviation: The normal distribution and the normal probability curve.

MODULE V SCIENTIFIC WRITING, TECHNICAL PUBLICATION AND 12 **RESEARCH PROPOSAL**

Different types of scientific and technical publications in the area of research, and their specifications, Ways to protect intellectual property – Patents, technical writing skills, definition and importance of impact factor and citation index - assignment in technical writing, The research problem, finding related literature, computer generated references sources and the research project, model research proposal. Plagiarism checking by Turtin –demonstration

Total Hours –60

REFERENCES:

1. Essentials of Research Design and Methodology Geoffrey R. Marczyk, David DeMatteo, David Festinger, 2005 John Wiley & Sons Publishers, Inc
2. Biochemical Calculations: How to Solve Mathematical Problems in General Biochemistry, 2nd Edition, Irwin H. Segel, 1976 John Wiley & Sons Publishers, Inc
3. Guide to Publishing a Scientific paper, Ann M. Korner, 2004, Bioscript Press.
4. P Laake, H B Benestad, B R Olsen. Research Methodology in the medical and biological sciences. Academic Press, 2007.
5. R Arora. Encyclopaedia of Research Methodology in Biological Sciences. Anmol Publishing, 2004.
6. Kothari C.R., Research Methodology, Methods and Techniques, Wiley Eastern Ltd., NewDelhi, 1991.
7. Coghill M. and Gardson L.R., The ACS Style Guide Effective Communication of Scientific Information, 3rd Edn., Oxford University Press, 2006.
8. Willa Y. Garner, Maureen S. Barge, James, P, Good Laboratory Practice Standards: Applications for Field and Laboratory Studies (ACS Professional References Book).

OUTCOMES:

At the end of this course, the students should be able to:

- recognize the basic concepts of research and its methodologies
- Identify appropriate research topics
- Select and define appropriate research problem and parameters
- Organize and conduct research (advanced project) in a more appropriate manner
- Write a research report and thesis

PHD 6204**THERMAL PHYSICS LABORATORY****L T P C****0 0 4 2****OBJECTIVES:**

- To make the student familiarize with the basics of experimental physics
- To enable the student to explore the concepts involved in the thermodynamics and heat
- To allow the student to apply the fundamentals of instruments involved in thermal process.

LIST OF EXPERMENTS**(ANY TEN)**

1. Radiation from a black body: Stefan-Boltzmann Law
2. Thermal conductivity of good conductors by Forbe's method.
3. To determine the Coefficient of Thermal Conductivity of Copper by Searle's and Angstrom's method.
4. To determine the Coefficient of Thermal Conductivity of a bad conductor by Lee disc method.
5. To study the variation of Thermo-Emf of a Thermocouple with Difference of Temperature of its Two Junctions.
6. Measurement of Planck's constant using black body radiation.
7. Determination of Stefan's constant.
8. Specific heat of liquid – Newtons law of cooling
9. EMF of a thermocouple – Mirror galvanometer – Direct deflection method.
10. Verification of Newton's Law of cooling.
11. Thermal conductivity of a good conductor by Searle's method.
12. Temperature characteristics of thermistor.
13. Specific heat of liquid – Joule's Calorimeter
14. Thermal expansion by Fizeau's method (Coefficient of linear expansion of brass).
15. Determination of co-efficient of thermal conductivity of a single crystal.

Total Hours: 60**OUTCOMES:**

At the end of the course, the student will be able to

- apply the knowledge gained about the experimental techniques in different thermal applications.
- comprehend the ideas and principles involved in thermal experiments
- analyse various experimental techniques involving thermal procedures.

SEMESTER III

PHD 7101 DIGITAL ELECTRONIC AND MICROPROCESSORS L T P C
4 0 0 4

OBJECTIVES:

- To understand the concepts of microprocessors and microcontrollers.
- To comprehend the ideas about the digital electronics
- To get knowledge on 8085 microprocessors
- To perform arithmetic operations using 8085 microprocessor programming
- To study the interfacing technique using 8085 microprocessor

MODULE I LOGIC GATES 12

Logic gates - block diagram - truth table - XOR gate - equivalent functions - combinational logic - half adder / subtractor - full adder / subtractor – De Morgan's laws-Boolean algebra - Karnaugh maps - max and min terms -encoders and decoders - multiplexers and demultiplexers.

MODULE II COUNTERS 12

Sequential logic – flip flops – sequential circuit analysis – state diagram – state equation – registers – counters – up down counters – timing sequences – the memory MODULE – Random Access Memory (RAM) – Magnetic core memory.

MODULE III INTRODUCTION TO MICROPROCESSOR 12

Common microprocessor characteristics - pin diagram and functions for generic microprocessor - microprocessor architecture - the intel 8085 microprocessor - the 8085 pin diagram and functions - 8085 architecture - different addressing modes - 8085 instruction set - arithmetic, logical and branch instructions - the 8085 stack, I/O and control instructions.

MODULE IV 8085 MICROPROCESSOR 12

Programming the 8085 microprocessor - 8 bit addition, subtraction, multiplication and division - looping programs - sum of data - maximum, minimum values of the given array - ascending / descending - data transfer- 16 bit addition – relay generation – multiple precision arithmetic

decimal arithmetic - subroutine programs - ASCII to decimal multiple precision addition subroutine.

MODULE V MICROPROCESSOR INTERFACING

12

Timing diagram - instruction cycle, machine cycle, R/W cycle – interfacing the microprocessor - interfacing with ROM - interfacing with RAM - I/O interfacing basics.

Total Hours: 60

REFERENCES:

1. Jain R. P, Digital Electronics and Microprocessors, First Edition, Tata – McGraw Hill, 1987.
2. Anokh Singh, A.k.Chhabra, Fundamental of Digital Electronics and Microprocessors, 2nd Edition, S. Chand Limited, 2005.
3. Anokh Singh, Chhabra A.k, Fundamental of Digital Electronics and its application, S. Chand Limited, 2005.
4. Sumit Kumar Singh, Fundamental of Digital Electronics and Microprocessors, Coronet Books Incorporated, 2008.
5. Jain, Modern Digital Electronics, 3rd Edition, Tata McGraw Hill, 2003.

OUTCOMES:

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

- handle the working of digital electronic devices
- develop circuits using working model of microprocessors and microcontrollers
- work in the programming of addition and subtraction using microprocessors.
- execute the interfacing of 8085 microprocessors

MODULE V APPLICATIONS OF QUANTUM STATISTICAL MECHANICS 12

Ideal Bose System: Photons – Black body and Planck radiation – Specific heat of solids – Liquid helium. Ideal Fermi System: Properties – Degeneracy – Electron gas – Pauli paramagnetism. Ferromagnetism: Ising and Heisenberg models.

Total Hours: 60**REFERENCES:**

1. Frederick Reif, Fundamentals of statistical and thermal physics, McGraw- Hill, 2008.
2. Agarwal B.K. and Eisner M, Statistical Mechanics, 2nd Edition, New Age International, New Delhi, 1998.
3. Sears F.W and Salinger G.L, Thermodynamics, kinetic theory and statistical thermodynamics, Narosa publishing House, 1998.
4. Huang. K, Statistical Mechanics, Wiley Eastern Ltd., 2nd Edition, New Delhi, 1987.
5. Bhattacharjee J.K, Statistical Mechanics: An Introductory Text, Allied Publication, New Delhi, 1996.

OUTCOMES:

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

- understand the fundamentals of thermodynamical systems.
- apply the principles of kinetic theory of gases to various thermodynamic systems.
- approach the theory of ensembles and solve classical/quantum thermodynamic systems
- obtain theoretically the partition function by solving and applying to thermodynamic quantities.
- comprehend principles of classical/quantum mechanics

PHD7103**NUCLEAR AND PARTICLE PHYSICS****L T P C****3 0 0 3****OBJECTIVES:**

- To acquire the knowledge of basic properties of nucleus.
- To have an idea on the nature of nuclear forces.
- To gain the knowledge on elementary particles.
- To introduce the concepts of radioactivity
- To get an insight into nuclear reactions

MODULE I NUCLEAR STRUCTURE**9**

Basic properties: nuclear size-nuclear radius-estimation of nuclear size - nuclear structure, Rutherford's formula for alpha particle scattering - magnetic moments - systematics of stable nuclei - semi empirical mass formula of Weizsacker - nuclear stability - mass parabolas- liquid drop model- shell model.

MODULE II NUCLEAR FORCES**9**

Ground state of deuteron – Orbitals in deuteron – Non central forces of deuteron - magnetic dipole moment of deuteron-square well potential of deuteron- Neutron-neutron, proton-proton forces - Scattering Processes: The scattering problem-formulation- scattering amplitude- Low energy neutron-proton scattering - phase shifts- scattering length and effective range.

MODULE III RADIOACTIVITY**9**

Alpha particle emission- Geiger Nuttal law- Gamow's theory of alpha decay- fine structure of alpha spectra-beta decay- Neutrino hypothesis- Fermi's theory of beta decay-Fermi and G.T.Selection rules- pair production- annihilation - Gamma emission-selections rules- transition probability-internal conversion- nuclear isomerism.

MODULE IV NUCLEAR REACTIONS**9**

Energies of Nuclear reaction- level widths - cross sections- compound nucleus model- resonance scattering- Breit- Wigner one level formula- optical model- direct reactions- Stripping and pick- up reactions- Fission and fusion reactions- elementary ideas of fission reaction- theory of fission- elementary ideas of fusion- controlled thermonuclear reactions- ideas of nuclear reactors.

MODULE V ELEMENTARY PARTICLES**9**

Classification of fundamental elementary particles- isospin strangeness- Gell Mann Nishijima's formula- symmetry of elementary particles-weight diagrams- quark model- CPT theorem - elementary ideas of gauge theory of strong and weak interactions – Higg's boson particle.

Total Hrs : 45**REFERENCES:**

1. Tayal D.C., Nuclear Physics, Himalaya Publishing House, 1997.
2. Khanna M.P., Introduction to Particle Physics, Prentice Hall of India, 2004.
3. Williams W. S. C., Nuclear and Particle Physics, Oxford University Press, 1991.
4. Brian Martin, Nuclear and Particle Physics: An Introduction, Wiley Publishers, 2011.
5. I. S. Hughes, Elementary Particles, Cambridge University Press.
6. Roy and Nigam, Nuclear Physics, Wiley.

OUTCOMES:

At the end of the course, the students will be able to

- explore the basic concepts of nucleus and its properties
- explore the basic ideas and comprehend concepts of Nuclear forces
- get an exposure of radioactivity concepts
- apply the concepts of quantum forces in nuclear reactions
- gain knowledge on elementary particles.

PHD7104**ADVANCED ELECTRONICS LABORATORY****L T P C****0 0 4 2****OBJECTIVES:**

- To understand basic analog circuit designs
- To know the working of amplifiers
- To study transistor biasing

LIST OF EXPERMENTS**(ANY TEN)**

1. Combinational circuit (Half Adder, Half - Subtractor, Full Adder and Full-Subtractor)
2. Design a BCD to Excess 3 code converter using combinational circuits.
3. Design a combinational circuit whose output is the 2's complement of the input number.
4. To design and construct of a 4-bit parallel Binary Adder
5. To design and construct multiplexer and demultiplexer
6. To design and verify encoder and decoder
7. To Verification of Flip-Flop (JK, RS,T& D)
8. To verify the operation of a 4 bit shift register using IC 7495
9. To design and construct Synchronous Counter
10. To verify the operation of a ring counter
11. To verify the operation of a decade counter
12. Addition and subtraction of two numbers using 8085 Microprocessor.
13. Multiplication of 2 - 8 numbers using 8085 Microprocessor

Total Hours: 60**OUTCOMES:**

- Students can simulate building and test basic analog circuit
- Students can simulate building and test amplifier circuits
- Students can simulate building and test Transistor biasing

PHD7105**MATERIALS SCIENCE LABORATORY****L T P C****0 0 4 2****OBJECTIVES:**

- To make the student understand the basics of materials science.
- To enable the student to explore the concepts involved in various instrumentation techniques
- To make the student understand the basic concepts of electronic band structures and some applications
- To allow the student to understand the fundamentals of nonlinear optics.

LIST OF EXPERMENTS**(ANY TEN)**

1. Crystal growth – Constant temperature bath
 - i. Solubility Test
 - ii. Metastable zone width
 - iii. Slow evaporation technique
2. Determination of susceptibility of liquid using Quincke's method.
3. Determination of type of semiconductor by Hall Effect method.
4. Determination of Conductivity of a material using four probe method.
5. Determination of dielectric constant of material using LCR meter.
6. Determination of Young's Modulus using Flexural vibration
7. Determination of Band structure and Density of States (DOS)
8. Determination of magnetic properties using density functional theory (DFT).
9. Study of Nonlinear behaviors – Numerical simulation
10. Determination of Velocity and Compressibility of ultrasonic waves in liquid
11. Characteristics of solar cell
12. Comparative study of Compound pendulum and Torsion pendulum
13. Determination of Magnetic moment using materials modelling.
14. Measurement of Line intensities in Iron Arc Spectrum by spectrograph

Total Hours: 60**OUTCOMES:**

At the end of the course, the students will be able to

- demonstrate experiments related to Materials Science
- obtain electronic band structure through computational methods and investigate materials properties

**ELECTIVES
(I SEMESTER)**

PHDY 101	CRYSTAL GROWTH TECHNIQUES	L T P C
		2 0 2 3

OBJECTIVES:

- To get the basic understanding on Crystal-Symmetry operations and various defects in crystals
- To understand and compare the various solution-based Crystal Growth techniques.
- To know the principle in the methods involved in the growth of crystal using melt growth process.
- To study the applications of single crystals in non-linear optics

MODULE I CRYSTALLOGRAPHY 7

Symmetry elements, operations - translational symmetries - point groups - space groups - equivalent positions –close packed structures - voids - important crystal structures – defects in crystals, – polymorphism and twinning - polarizing microscope and uses-

MODULE II GROWTH FROM SOLUTIONS 9

Introduction to crystal growth – nucleation - Measurement of super saturation - solution growth methods – low and high temperature solution growth methods – vapour growth – Crystal growth in gel – Growth of biological crystals – Hydrothermal technique – Sol-gel growth – unidirectional growth of crystals from solution. Accelerated crucible rotation technique (ACRT)

MODULE III MELT GROWTH 7

Temperature measurement and control – Starting materials and purification – conservative and non-conservative process – Bridgman method – Czochralski method – Verneuil method – Zone melting – Zone refining- Skull melting

**MODULE IV APPLICATIONS OF LINEAR AND NON-LINEAR
CRYSTALS 7**

Nonlinear Optics in Linear Photonic Crystals - Phase Matching - Nonlinear Photonic Crystal Analysis – Nonlinear photonic crystals – photonic crystal fibers – photonic

crystal sensor - Materials: LiNbO₃, Chalcogenide Glasses, etc., Wavelength Converters, etc.

Total Hours: L – 30, P-15

LIST OF EXPERIMENTS:

1. Growth of crystal by slow evaporation technique
2. Growth of crystals from temperature reduction method.
3. Determination of melting point of given crystal.
4. Solubility test for different materials.
5. Determination of Meta-stable zone width.
6. Hydrothermal method of crystal growth
7. Sol-gel method of growing crystals
8. Characterization of second harmonic crystals
9. Simulation of crystal structures using DFT

REFERENCES:

1. Brice J.C., Crystal Growth Processes, John Wiley and Sons, New York, 1987.
2. Santhana Ragavan P. and Ramasamy P., Crystal Growth Processes and Methods, KRU Publications, Kumbakonam, 2001.
3. Scheel, Hans J. and Fukuda, Crystal Growth Technology, Wiley publishers, 2004.
4. Hans J. Scheel and Peter Capper, Crystal Growth Technology: From Fundamentals and Simulation to Large-scale Production, Wiley publishers, 2008.

OUTCOME:

At the end of the course, the students will be able to

- compare and analyze the various techniques of crystal growth
- Apply the principles of crystal growth techniques in laboratory practices.
- Understand the nuances of melt-growth technique.
- Approach crystal growth techniques holistically and extend it to study of non-linear crystals

PHDY 102**MATERIALS PROCESSING****L T P C****3 0 0 3****OBJECTIVES:**

- To introduce the basic concepts of physics of materials processing
- To provide knowledge of surface treatment processes
- To study about different welding processes
- To discuss various types of mechanical working of metals
- To give the basics of powder metallurgical process

MODULE I BASIC MANUFACTURING PROCESSES**9**

Fundamental analysis of Manufacturing processes, casting, casting processes, forging, methods of forging, extrusion, rolling, spinning, turning, planning and shaping, milling, grinding.

MODULE II SURFACE TREATMENT PROCESSES**9**

Necessity for surface modification, surface cladding, surface alloying, hard facing, shock hardening, conventional methods, carburizing, nitriding, cyaniding, advantages of laser surface treatment over conventional methods, typical laser variables used in surface alloying, laser cladding, experimental set up.

MODULE III WELDING PROCESSES**9**

Various processes of welding, fusion welding, pressure welding, oxyacetylene welding, resistance welding, spot welding, thermite welding, projection welding, seam welding, butt welding, thermal effects of welding, effects on grain size and microstructure, internal stresses effect, corrosion effect, high energy beam welding, laser beam and electron beam welding, key hole effect.

MODULE IV MECHANICAL WORKING OF METALS**9**

Hot working, cold working, normalizing, full annealing, tempering, theory of tempering, effect of tempering temperature on mechanical properties of carbon steels, different tempering process, deformation of metals, elastic deformation, plastic deformation, slip, twinning.

MODULE V POWDER METALLURGICAL PROCESS**9**

Production of powders, powder mixing, compacting, types of presses, sintering, soaking, finishing process, limitations and advantages of powder metallurgy, applications, production of cemented carbide cutting tools, self-lubricating bearings, magnets, cermets, ultrasonic ceramic transducers.

Total Hours: 45**REFERENCES:**

1. Rajan T.V, Sharma C.P and Ashok Sharma Heat treatment - Principles and Techniques, Prentice Hall of India Pvt. Ltd. New Delhi, 1995.
2. Muralidhara, M.K., Materials Science and Processes, Dhanpat Rai Publishing Co., New Delhi, 1998.
3. Rykalin, Uglov A, Kokona, A Laser and Electron beam material processing hand book, MIR Publishers, 1987.
4. Gupta, R.B. Materials Science and Processes, Satya Prakashan, New Delhi, 1995.

OUTCOMES:

At the end of the course the students will be able to understand

- basic manufacturing process such as casting, rolling, turning, shaping
- various surface treatment process such as hardening, nitriding etc
- a various welding process in materials processing
- Mechanical working processes such as hot working, cold working, twinning
- powder metallurgical process such as mixing, compacting, sintering and applications

PHDY 103	MATERIALS CHARACTERIZATION	L	T	P	C
		2	0	2	3

OBJECTIVES:

- To get knowledge on thermal analysis of materials using TGA, DTA and DSC
- To study on microscopic analysis
- To study on electrical analysis of various materials
- To obtain knowledge on spectroscopic analysis

MODULE I THERMAL ANALYSIS 7

Introduction – thermogravimetric analysis (TGA) –instrumentation – determination of weight loss and decomposition products – differential thermal analysis (DTA)-cooling curves - differential scanning calorimetry (DSC) – instrumentation – specific heat capacity measurements.

MODULE II OPTICAL AND ELECTRON MICROSCOPIC METHODS 10

Optical Microscopy: optical microscopy techniques – Bright field optical microscopy – Dark field optical microscopy – phase contrast microscopy - fluorescence microscopy - scanning probe microscopy (STM, AFM) - SEM, EDAX, ESCA, EPMA, TEM: working principle and Instrumentation - Photoluminescence – light–matter interaction – instrumentation – Applications.

MODULE III ELECTRICAL METHODS 7

Two probe and four probe methods- van der Pauw method – Hall probe and measurement – scattering mechanism – C-V characteristics – Schottky barrier capacitance – impurity concentration – electrochemical C-V profiling – limitations.

MODULE IV SPECTROSCOPY 6

Principles and instrumentation for UV-Vis-IR, FTIR spectroscopy, Raman spectroscopy, SIMS-proton induced X-ray Emission spectroscopy (PIXE).

Total Hours: L-30, P – 15.

LIST OF EXPERMENTS

1. Determination of the excitation and emission spectra using photoluminescence spectrophotometer.

2. Determination of Conductivity of a material using four probe method.
3. Determination of the absorbance and reflectance using UV-Vis analysis.
4. Determination of inorganic and organic mixtures of compounds using FTIR Spectrophotometer.
5. Surface analysis of grown crystals using optical microscope
6. Determination of spectral resolution of sodium d1 and d2 lines.

REFERENCES:

1. Stradling, R.A; Klipstain, P.C; Growth and Characterization of semiconductors, Adam Hilger, Bristol, 1990.
2. Belk, J.A; Electron microscopy and microanalysis of crystalline materials, Applied Science Publishers, London, 1979.
3. Lawrence E.Murr, Electron and Ion microscopy and Microanalysis principles and Applications, Marcel Dekker Inc., New York, 1991
4. D.Kealey&P.J.Haines, Analytical Chemistry, Viva Books Private Limited, New Delhi 2002.
5. Hobart Hurd Willard, Lynne Lionel Merritt, Instrumental Methods of Analysis, 6th ed, CBS Publishers & Distributors, 1986.

OUTCOMES:

At the end of the course, the students will be able to

- interpret data obtained through the characterization techniques
- explain various thermal analysis
- illustrate microscopic analysis using FESEM, TEM and STM
- interpret the electrical analysis of various materials

PHDY 104 FUNCTIONAL MATERIALS AND STRUCTURES L T P C
3 0 0 3

OBJECTIVES:

- To enable the students understand importance and structure of smart materials
- To gain knowledge on application of function materials for sensor applications
- To understand the electro rheological functional materials
- To understand the theory behind piezoelectric materials
- To make the students understand the applications of smart materials towards shape memory alloys

MODULE I INTRODUCTION AND HISTORICAL PERSPECTIVE 9

Classes of materials and their usage – Intelligent /Smart materials – Evaluation of materials Science – Structural material – Functional materials – Poly functional materials – Generation of smart materials – Diverse areas of intelligent materials – Primitive functions of intelligent materials – Intelligent inherent in materials – Examples of intelligent materials, structural materials, Electrical materials, bio-compatible materials etc. – Intelligent biological materials – Biomimetics – Wolff's law – Technological applications of Intelligent materials.

MODULE II FUNCTIONAL MATERIALS AND STRUCTURAL SYSTEMS 9

The principal ingredients of smart materials – Thermal materials – Sensing technologies – Micro sensors – Intelligent systems – Hybrid smart materials – An algorithm for synthesizing a smart material – Passive sensory smart structures – Reactive actuator based smart structures – Active sensing and reactive smart structures – Smart skins – Aero elastic tailoring of airfoils – Synthesis of future smart systems.

MODULE III ELECTRO-RHEOLOGICAL (FLUIDS) FUNCTIONAL MATERIALS 9

Suspensions and electro-rheological fluids – Bingham-body model – Newtonian viscosity and non-Newtonian viscosity – Principal characteristics of electro rheological fluids – The electro-rheological phenomenon – Charge migration mechanism for the dispersed phase – Electro-rheological fluid domain – Electrorheological fluid actuators – Electro-rheological fluid design parameter – Applications of Electrorheological fluids.

Traps, Evaporative Cooling and Bose Condensation. Medical applications - laser and tissue interaction – laser instrument of surgery.

Total Hours: 45

REFERENCES:

1. Born and Wolf, Principles of Optics, Cambridge University press, 1999.
2. Saleh and Tiech, Fundamentals of photonics, Wiley-Interscience Publishers, 2007.
3. Guenther. R.D., Modern Optics, John Wiley Publishers, 1990.
4. William T. Silfvast, Laser Fundamentals, Cambridge University press, 1996.
5. Robert Boyd. W, Non Linear Optics, 3rd edition, Academic Press, 2008.

OUTCOMES:

At the end of the course, the students will be able to

- illustrate the characteristics of the laser systems
- explain the imaging techniques using lasers
- elaborate the pumping mechanism of lasers
- explore Q-switching process in lasers and method of detection
- study various applications of laser systems.

PHDY 106**NONLINEAR OPTICS****L T P C****3 0 0 3****OBJECTIVES:**

- To teach the principles of nonlinear optics and origin of optical nonlinearities.
- To analyze various types of nonlinearities in optics and its applications.
- To study about third order nonlinearities and Kerr effect
- To provide the basics of photorefractive materials and multiphoton processes
- To give the details of different kinds of scattering processes

MODULE I INTRODUCTION TO NONLINEAR OPTICS**9**

Wave propagation in an anisotropic crystal – Polarization response of materials to light – Harmonic generation – Second harmonic generation – Sum and difference frequency generation – Phase matching – Third harmonic generation – bistability – self focusing.

MODULE II NONLINEAR PROCESSES**9**

Propagation of Electromagnetic Waves in Nonlinear medium, Self Focusing, Phase matching condition, Fiber Lasers, Stimulated Raman Scattering and Raman Lasers, CARS, Saturation and Two photon Absorptions.

MODULE III THIRD ORDER NONLINEARITIES**9**

Two photon process – Theory and experiment – Three photon process Parametric generation of light – Oscillator – Amplifier – Stimulated Raman scattering – Intensity dependent refractive index optical Kerr effect – photorefractive, electron optic effects.

MODULE IV MULTIPHOTON PROCESSES**9**

Electro-optic effects – Electro-optic modulators - Photorefractive effect - Two beam coupling in Photorefractive materials – Four wave mixing in Photorefractive materials.

MODULE V STIMULATED SCATTERING PROCESSES**9**

Stimulated scattering processes – Stimulated Brillouin scattering – Phase conjugation – Spontaneous Raman effect – Stimulated Raman Scattering – Stokes – Anti-Stokes Coupling in SRS – Stimulated Rayleigh - Wing Scattering.

Total Hours: 45**REFERENCES:**

1. Robert W. Boyd, "Non-linear Optics", Academic Press, London, 5th Edition, 2008.
2. A.Yariv, Opto Electronics, Third Edition, John Wiley and Sons, New York, 1990.
3. P.N.Butcher and D.Cotter, "The Elements of Nonlinear Optics", Cambridge Univ. Press, New York, 1990.
4. YVGS Murthi and C. Vijayan, Essentials of Nonlinear Optics, Ane/Athena Books 1st Edition (2014)

OUTCOMES:

At the end of the course the students will be able to

- explain the principles of nonlinear optics,
- explore detailed study on different nonlinear phenomena and its applications
- apply the knowledge for third harmonic conversion and evaluate nonlinear susceptibility of materials
- illustrate about multiphonon process and kerr effect
- explore about raman scattering process and its applications

PHDY 107**OPTICAL FIBER COMMUNICATION****L T P C****2 0 2 3****OBJECTIVES:**

- To introduce the principles and classifications of fiber optic communication.
- To introduce the various optical fiber modes, configurations and various signal degradation factors associated with optical fiber.
- To analyze the different types of optical fiber cables and connectors.
- To study about various optical sources and optical detectors and their use in the optical communication system.

MODULE I FIBER OPTICS**6**

Introduction to optical fiber – structure of an optical fiber - Total internal reflection - Phase shift & attenuation during total internal reflection - Hybrid modes - cutoff frequencies - meridinal rays & skew rays – Classifications of optical fiber.

MODULE II TRANSMISSION CHARACTERISTICS OF OPTICAL FIBERS**7**

Dispersion - Fiber attenuation, absorption loss & scattering loss measurement - Optical Time Domain Reflectometer (OTDR) and its uses - Interferometric method to measure fiber refractive index profile.

MODULE III OPTICAL FIBERS CABLES & CONNECTORS**7**

Fiber materials - Fiber fabrication- fiber optic cables design - fiber connectors - fiber splices - Lensing schemes for coupling improvements.

MODULE IV MODULATION, OPTICAL SOURCES, DETECTION AND COMMUNICATION NETWORKS**10**

Electrooptic and Acoustooptic modulation - Injection laser - Homojunction and Heterojunction lasers - Injection laser to fiber coupling - Fiber lasers - Surface Emitting, edge emitting and superluminescent LEDs - Optical Detectors - Pin photodiodes - Avalanche photodiodes - Multiplexers - wavelength division multiplexing - Elements of an optical fiber communication system - Coherent optical fiber communication system - Local Area Networks - Bus, ring and star topologies - optical fiber regenerative repeater - optical amplifiers - basic applications - Low speed industrial optical fiber networks

Total Hours – L - 15, P - 15

LIST OF EXPERIMENTS:

1. To measure the numerical aperture (NA) of the different optical fiber.
2. Measuring optical power attenuation in plastic optical fiber.
3. Measuring optical power bending loss and coupling loss in plastic optical fiber.
4. To check the VI characteristic of LED.
5. Characteristics of LASER Diode.
6. Characteristics of APD
7. Describe the operational characteristics and parameters of Photodiode used as photo detector in fiber optic system.

REFERENCES:

1. Gerd Keiser, "Optical fiber Communications", McGraw Hill Inc. Company, Tokyo, 5th Edition, 2017.
2. John M. Senior, "Optical Fiber Communications", Prentice Hall International Ltd., London, 3rd Edition, 2010.
3. Govind P. Agrawal, "Fiber Optic Communication Systems", John Wiley & Sons Inc., New York, 3rd Edition, 2007.
4. Allen H. Cherin, "An Introduction to Optical Fibers", Mc Graw Hill Inc., Tokyo, 1995.

OUTCOME:

On completion of this course the student will be able to

- Design optimization of single mode fibers, refractive index profile and cut-off wavelength.
- Know the various optical fiber modes, configurations and various signal degradation factors associated with optical fiber.
- Analyze the different types of optical fiber cables and connectors.
- Understand various optical sources and optical detectors and their use in the optical communication system.

PHDY 108**OPTICAL COMPUTING****L T P C****3 0 0 3****OBJECTIVES:**

- To introduce the concepts of digital images and optical computation
- To understand the analog based optical computing
- To provide knowledge of advanced digital communications areas.
- To introduce the students to neural networks and
- To gain knowledge on advanced memory techniques such as associative memory and artificial intelligence.

MODULE I DIGITAL IMAGE PROCESSING FUNDAMENTALS 5

Digital Image fundamentals - sampling and Quantization - Image Enhancement – Image Restoration – image filtering

MODULE II ANALOG OPTICAL COMPUTING 7

Optical Computing 4f - fourier system - Spatial filtering - Inverse filtering - Deblurring - Analog Optical Arithmetic - Halftone processing - Non-linear Optical processing - Matched filter - Joint transform correlation - Phase only filter - Amplitude-modulated recognition filters - Generalized correlation filter.

MODULE III DIGITAL LOGIC 14

Number Systems - Number representations - Codes - Arithmetic Operations - Logic elements and Operations - Basic Logic Operations - Logic function formulations - Boolean Algebra - Minimization of function using K-map - Universal Logic gates - Logic functions using Multiplexers - Threshold Logic - Combinational Logic- Binary Adders - Carry-Look Ahead adder - Arithmetic Logic Unit- Decoders and encoders - Sequential Logic -Flip-flops- Synchronous sequential circuits - Counters.

MODULE IV DIGITAL OPTICAL COMPUTING 14

Non-linear devices - Integrated Optics - Threshold Devices - Spatial Light Modulators - Theta Modulation Devices - Shadow casting and Symbolic substitution - Design Algorithm - POSC Logic operations - POSC Multiprocessor Parallel and Sequential ALU using POSC - POSC Image Processing - Symbolic Substitution- Optical Implementation- Limitations and Challenges - Optical Matrix Processing -

Multiplication using Convolution - Matrix Operations - Cellular Logic Architecture - Programmable Logic Array.

MODULE V OPTICAL NEURAL NETWORKS

5

Neural Networks - Associative Memory - Optical Implementations - Interconnections - Artificial Intelligence.

Total Hours – 45

REFERENCES:

1. Mohammad A. Karim and Abdul A.S. Awwal, "Optical Computing - An Introduction", John Wiley & Sons, 2003.
2. Alistair D. McAulay, "Optical Computer Architectures", John Wiley & Sons, 1991.
3. Dror G. Fritelson, "Optical Computing", The MIT Press, 1988.
4. B.S. Wherrett and F.A.P. Tooley, "Optical Computing", Heriot-Watt University, Edinburgh, 1988. Henri H. Arsenault et al., "Optical Processing and Computing", Academic Press, London, 1989.
5. Morris Mano, "Fundamentals of Digital Logic Circuits", Prentice Hall, 2002.

OUTCOMES:

At the end of the course, the student will be able to

- explain digital image fundamentals and various imaging techniques
- explore the analog computing process
- gain required exposure to principle & working of digital logic operations
- understand the concept of neural networks
- explain concept related to advanced memory techniques

PHDY 109**DENSITY FUNCTIONAL THEORY****L T P C****3 0 0 3****OBJECTIVES:**

- To understand the Density Functional Theory in Functional and derivatives
- To solve the Many body problems using DFT.
- To understand the Local & semi Local Approximations.
- To solve Kohn-Sham equation
- To understand the applications of DFT

MODULE I INTRODUCTION TO MANY ELECTRON PROBLEMS 9

Hartree Fock (HF) theory- Configuration Interaction (CI) - Practical difficulties in solving many electron problems - The Thomas Fermi model: precursor to modern DFT - Functional and functional derivatives, Euler Lagrange equation - Hohenberg Kohn Theorem - N and v represent ability of densities, and non uniqueness of potentials.

MODULE II KOHN SHAM (KS) EQUATION 9

Effective exact single particle method to the many body problems - Exchange and correlation energies - Interpretation of KS Eigen values: Koopman's theorem, Ionization energy, Fermi surface, band gap KS equation for spin polarized systems

MODULE III APPROXIMATION TO FUNCTIONALS 9

Local approximation: local density approximation (LDA) – Semi local approximation: generalized gradient approximation (GGA) – Hubbard Model-applying GGA+U methods- Non local approximation: hybrid functional - Self interaction correction.

MODULE IV DENSITY FUNCTIONAL THEORIES 9

Introduction - Green's Function and Self-energy Operator - many-Body Perturbation Theory and the GW Approximation - Pathologies of the Kohn–Sham xc Functional - The Band Gap Problem - Widely Separated Open Shell Atoms - The Exchange-Correlation Electric Field - Total Energies from Many-Body Theory – Applications - Generalised KS Schemes and Self-energy Models

MODULE V PRACTICAL IMPLEMENTATION OF DFT METHODS 9

General scheme for solving Kohn Sham equation - Full potential and pseudo potential methods - Basis functions: Gaussian, LAPW, Numerical – Application of DFT methods for molecules and solids- vibrational frequencies, enthalpy, and Gibbs free energy of molecules.

Total Hours: 45

REFERENCES:

1. DensityFunctional Theory of Atoms and Molecules by Robert G. Parr and Yang Weitao, Publisher: Oxford University Press (1994).
2. Density Functional Theory: An Advanced Course by Eberhard Engel and Reiner M. Dreizle, Publisher: Springer, 2011 edition.
3. Electronic Structure: Basic Theory and Practical Methods by Richard M.Martin, Publisher: Cambridge University Press; 1 edition (2008).
4. Density Functional Theory: A Practical Introduction by David Sholl and Janice A Steckle, Publisher: WileyInterscience; 1 edition (2009)

OUTCOMES:

At the end of the course, the students will be able to

- Identify the difference between Hartree and Hartree Fock theorems.
- explain the basic concepts in many body problems.
- understand the basics of Kohn-Sham equations.
- interpret the various exchange-correlation schemes.
- apply theorems relating to the DFT to real problems.

Total Hours: 45**REFERENCES:**

1. Munn R W and Ironsid C N, "Non - Linear Optical Materials", Blackie Academic & Professional, Glassgow, 1993.
2. Kochner W, "Solid State Laser Engineering", Springer-Verlag, New York, 1976.
3. Yariv A, "Quantum Electronics", John Wiley & Sons, 1975.
4. Ivan P Kaminov, " Introduction to Electro-Optic Devices", Academic press, New York, 1974.

OUTCOMES:

At the end of the course the students will be able to understand

- basics concepts in Laser
- optical activity of crystals such as anisotropic media, index ellipsoid, wave plates
- the concept of the electro-optic effect
- the basic of acoustic optic and elasto-optic effects
- non-linear optics and photorefractive effect

PHDY 202 FERROELECTRIC MATERIALS AND DEVICES**L T P C****2 0 2 3****OBJECTIVES:**

- To enable the students understand the principles behind ferroelectric materials.
- To make the students understand materials, devices and applications.
- To understand the concept of dielectric materials
- To get knowledge on application of ferroelectric materials towards fabrication of piezoelectric devices

MODULE I INTRODUCTION**8**

Maxwell equations – Polarization – Macroscopic electric field – Local electric field at an atom – Dielectric constant and polarizability – Structural phase transitions – Displacive transitions – Soft optical phonons – Landau theory of the phase transition – Second order transition – First order transition – Antiferroelectricity – Ferroelectric domains – Optical ceramics.

MODULE II THEORY OF FERROELECTRICS**8**

Ferroelectricity, piezoelectricity and pyroelectricity – definitions – classification of ferroelectrics – oxygen octahedral and order – disorder ferroelectrics. Characteristics of typical ferroelectrics, barium titanate, potassium dihydrogen phosphate and triglycine sulphate – applications of ferroelectrics. Theories of ferroelectrics – dipole theory of ferroelectrics– first order and second order transitions – ferroelectric domains.

MODULE III HIGH PERMITTIVITY DIELECTRICS**7**

Ceramic capacitors. Chip capacitors. Hybrid substrate– High permittivity – Diffuse phase transition – Dielectric relaxation -IK dielectric materials. Ferroelectric memory devices: DRAM – Ferroelectric DRAM Pyroelectric devices: Pyroelectric materials – pyroelectric effect – responsivity – figures of merit. Temperature / infrared light sensors.

MODULE IV PIEZOELECTRIC DEVICES**7**

Piezoelectric materials and properties – Figures of Merit. – Single crystal – polycrystalline materials - relaxer ferroelectrics polymers – composites thin films.

Pressure sensors, accelerometers, gyroscopes. Piezoelectric vibrators – ultrasonic transducers – Resonators/filters. Piezoelectric transformers, Piezoelectric actuators.

Total Hours: L-30, P-15 hrs

LIST OF EXPERMENTS

1. Determination of transition temperature of a ferroelectric material by hysteresis.
2. Determination of dielectric constant of ferroelectric material..
3. Modelling of Crystal structure of a ferroelectric material using DFT.
4. Determination of Band structure and Density of States of ferroelectric material
5. Determination of Curie constant of a ferroelectric material.

REFERENCES:

1. Kenji Uchino, "Ferroelectric Devices", Marcel Dekker, INC, 2000.
2. Gerhard R, "Electrets", Vol 2, Laplacian Press, 2000.
3. Moulson A L and Herberh J M, "Electroceramics – Materials properties and Applications", Chapman & Hall, 2000.
4. Lines M E and Glass A M, "Principles and Applications of Ferroelectrics and Related Materials", Clarendon Press, 1977.
5. Jack C Burfoot, "Ferroelectrics – Introduction to the Physical Principles", D Van Nostrand Co., 1967.

OUTCOMES:

At the end of the course the students will be able to understand

- Understand the principles of ferroelectric materials.
- Comprehend and analyze the basic theory behind the concept of ferroelectricity
- Assimilate the concept of dielectric materials and apply its applications.
- Comprehensively grasp ideas related to ferroelectric materials, devices and applications

PHDY 203**STRUCTURE AND PROPERTIES OF ALLOYS****L T P C**
3 0 0 3**OBJECTIVES:**

- To enable the students understand importance of phase diagrams and their relationship with properties of alloys
- To make the students understand the basic structure and property relationship of the alloy
- To make students to learn the application of the alloys with respect to their phase diagram and properties
- To study the characteristics of copper-zinc alloy
- To study the characteristics of iron –carbon alloy

MODULE I SOLID SOLUTIONS**9**

Concept of solid solution - Solid solutions of Copper and Iron - Cu-Ni phase diagram - cast cupro nickel microstructures - Properties of annealed copper solid solution alloys - Soft magnetic alloys - Stainless steels.

MODULE II EUTECTIC ALLOYS**9**

Pb-Sb phase diagram and microstructure - Pb-Sn phase diagram - Cu:O system - Ternary Pb-Sn-Sb phase diagram - Characteristic properties of eutectic system alloys - Applications of Pb-Sn and Pb-Sn-Sb alloys.

MODULE III CAST AND WROUGHT ALLOYS**9**

Al-Si phase diagram - Al-Cu phase diagram -coherency theory of age hardneing - Microstructures – Cast aluminium alloy -properties-residual stresses and relaxation.

MODULE IV TWO PHASE ALLOYS**9**

Cu-Zn phase diagram – Cu-Zn alloy structure - Cu-Sn and Cu-Al alloy systems and their microstructures - Properties of brasses, tin brasses and aluminium bronzes.

MODULE V IRON-CARBON ALLOYS**9**

Fe-Fe₃C phase diagram - Solubility of carbon in austenite and ferrite-terminology- Equilibrium and non equilibrium - Microstructures-properties of normalized steels - Grain size of steels - Engineering applications of low carbon steels and low alloy high strength steels.

Total Hours: 45

REFERENCES:

1. Structure and Properties of Alloys, R.M.Brick and Arthur Philips, MCGraw Hill Book Co. inc, New york, 1985.
2. Solid State Physics - Structure and properties of materials, M.A.Wahab, Narosa publishing house, New Delhi, 2015
3. Heat Treatment - Principle and Techniques, T.V.Rajan, C.P.Sharma and Ashok Sharma, Prentice Hall of India pvt. Ltd., New Delhi, 1995.
4. Mateials Science and Processes, M.K.Muralidhara, Dhanpat Rai publishing company, New Delhi, 1998.
5. Charlie Brooks, R,Heat Treatment, Structure and properties of non ferrous alloys, American Society for Metals, U.S.A, 1984.
6. William F Smith, "Structure and Properties of Engineering Alloys", McGraw– Hill, 2nd Edition,1993
7. William D. Callister, David G. Rethwisch,"Materials Science and Engineering : AN Introduction" Wiley Publishing, 9th Edition, 2013.

OUTCOMES:

At the end of the course the students will be able to explain

- understand the importance of phase diagrams and their relationship with properties of alloys
- get insights into the basic structure and property relationship of the alloys
- analyze the applications of phase diagram and their importance
- create ideas about the application and characteristics of Cu-Zn alloy
- holistically map the characteristics of iron-carbon alloy

PHDY 204**PHOTONIC MATERIALS AND DEVICES****L T P C****3 0 0 3****OBJECTIVE:**

- To impart knowledge on photonic devices by going over the fundamentals of semiconductor physics and optical processes in semiconductors.
- To study about various optical process in semiconductors
- To explore device fabrication techniques using semiconductor materials
- To gain knowledge on characteristics of photonic devices
- To gain knowledge on photonic devices instruments

MODULE I SEMICONDUCTING MATERIALS**7**

Band gaps - density of states – materials - optical and electronic properties carrier generation and recombination - mobility and diffusion - low dimensional structures - quantum wells - wires and dots - heterostructures.

MODULE II OPTICAL PROCESSES IN SEMICONDUCTORS**10**

Electron-Hole formation and recombination – absorption in semiconductors – effect of electric field on absorption – absorption in quantum wells and the quantum-confined Stark effect – Kramer-Kronig relations – radiation in semiconductors – deep level transitions – auger recombination – Luminescence from quantum wells – measurement of absorption and luminescence spectra – time resolved photoluminescence.

MODULE III SEMICONDUCTOR DEVICE FABRICATION**10**

Types of photonic materials –III-V compound-II-VI compounds-Wafer preparation-interface quality- interdiffusion and doping. Quantum wells and bandgap engineering (examples of structures).Post-growth processing-Photolithography-different methodologies – patterning - fabrication of semiconductor devices.

MODULE IV PHOTONIC DEVICES**10**

Photodiodes: current-voltage equation – operation-spectral response of Ge and Si – quantum efficiency – response time – diffusion time – drift – capacitance of diodes, measurement - device configuration and efficiency – device performance.

MODULE V INSTRUMENTATION OF PHOTONIC MATERIALS 8

Measurements using lenses, monochromators, spectrometers, grating, mirrors, lock-in amplifiers – characterization of photodiodes, LEDs and laser diodes – modulation of lasers – rate equations.

Total Hours: 45

REFERENCES:

1. P. Bhattacharya, "Semiconductor optoelectronic devices", Prentice-Hall India, New Delhi, 2003.
2. B.E.A. Saleh and M.C. Teich., "Fundamentals of photonics", John Wiley., New York, 1991.
3. J. Singh, "Optoelectronics: An introduction to materials and devices", McGraw-Hill Co., New York, 1996.
4. S.O. Kasap, "Optoelectronics and photonics: Principles and practices", Prentice-Hall, New York, 2001.
5. T.P. Pearsall, "Photonics essentials: An introduction to experiments", McGraw-Hill Professional, New York, 2002.
6. Ajoy Ghatak and K Thyagarajan, "An Introduction on Fibre Optics", Cambridge University Press, 2012.

OUTCOMES:

At the end of the course, the students would be able to,

- analyze the optical processes in semiconductors
- understand the properties of a photonic materials.
- get deeper insights into the photonic devices and its characterization techniques.
- explore about the characteristics of photonic devices
- explain the instruments fabricated using photonic materials

PHDY 205 NUMERICAL METHODS AND PROGRAMMING**L T P C****3 0 0 3****OBJECTIVES:**

- To understand the basic errors occurring in numerical methods.
- To have an idea about Algebraic and Transcendental Equations.
- To know about the interpolation concepts.
- To familiarize the numerical differentiation and integration equations.
- To learn about the C programming and its applications in the research areas.

MODULE I ERRORS AND THE MEASUREMENTS**9**

Errors and their computations – General formula for errors – Errors of observation and measurement – Round off errors and Computer Arithmetic – Empirical formula – Graphical method – method of averages – Least square fitting – curve fitting – parabola, exponential – Algorithms and convergence.

**MODULE II NUMERICAL SOLUTION OF ALGEBRAIC AND
TRANSCENDENTAL EQUATIONS****9**

The iteration method – the bisection method – the method of false position – Newton – Raphson method. Simultaneous Linear algebraic equations: Direct methods – Gauss elimination method – Gauss – Jordan method – Iterative method – Jacobi's method – Gauss Seidel iterative method.

MODULE III INTERPOLATION**9**

Finite differences – Interpolation – Gregory – Newton forward interpolation of Newton's formula – Backward differences – Newton's Backward interpolation formula – central differences – Gauss's forward and backward formula – Stirling's formula – Divided differences – Newton's divided difference formula – Lagrange's interpolation formula.

**MODULE IV NUMERICAL DIFFERENTIATION AND
INTEGRATION****9**

Introduction – Numerical differentiation – Errors in numerical differentiation – The cubic spline method – Maximum and Minimum values of a tabulated function – Numerical integration – Trapezoidal rule – Simpson's rule – Extended Simpson's rule – Use of cubic splines – Romberg integration – Newton – Cotes Integration formulae – Euler – Maclaurin formula – Adaptive quadrature method – Gaussian integration.

MODULE V PROGRAMMING WITH C**9**

Introduction to C programming-program control-logical compares-functions, variables and prototypes-C preprocessor- strings, arrays-pointers- standard input & output-structures, Unions-bitwise operators.

Total Hours: 45**REFERENCES:**

1. Sastry, S.S., Introduction of Numerical Analysis, Fifth Edition, Prentice Hall of India, New Delhi, 2012.
2. Gerald C.F., Wheatley P.O., Applied Numerical Analysis, Seventh Edition, Addison – Wesley, Singapore, 2003.
3. Kandasamy, P., Thilakavthy, K and Gunavathy K., Numerical Methods, S.Chand and Co., New Delhi, 2006.
4. Grewal B.S., Grewal J.S., Numerical Methods in Engineering and Science, Khanna Publishers, New Delhi, 2015.
5. Balagurusamy. E, Programming in Ansi C, 7th Edition, Tata McGraw Hill, 2017.

OUTCOME:

At the end of the course, the students will be able to,

- familiarize towards the approach in solving errors in numerical methods.
- get deeper insights towards various numerical methods to solve the algebraic and transcendental equations.
- explore towards Newton's Gregory forward interpolation
- to solve differentiation and integration equations using numerical methods
- approach the numerical problems using C programming

PHDY 206 ULTRASONIC AND NON-DESTRUCTIVE TESTING**L T P C****3 0 0 3****OBJECTIVES:**

- To introduce students with the recent advances in the field of ultrasonics
- To equip them with the knowledge of different inspection methods.
- To introduce the other NDT techniques like LPI to equip the students to understand the evaluation method
- To understand the theory of wave guides and applications
- To study the detection mechanism of ultrasonic sounds

MODULE I FUNDAMENTALS OF ULTRASONIC WAVES**9**

Nature of sound waves, wave propagation in metals– modes of sound wave generation – longitudinal waves, transverse waves, surface waves, lamb waves – Velocity, frequency and wavelength of ultrasonic waves – Ultrasonic pressure, intensity and impedance – Attenuation of ultrasonic waves – reflection, refraction and mode convection – Snell’s law and critical angles – Fresnel and Fraunhofer effects – ultrasonic beam split – wave propagation in other engineering materials

MODULE II ULTRASONIC INSPECTION METHODS AND EQUIPMENT**9**

Principle of pulse echo method, through transmission method, resonance method – Advantages, limitations – contact testing, immersion testing, couplants – Data presentation A, B and C scan displays, comparison of contact and immersion method. Pulse Echo instrumentation, controls and circuits, pulse generation, signal detection, display and recording methods, gates, alarms and attenuators, detectability of defects

MODULE III ULTRASONIC GUIDED WAVES**9**

Types of guided waves – Generation of guided waves – Plate theory – Rayleigh-Lamb Equation, Guided waves in Plates, Pipes and rods – Wave structure analysis – Dispersion curves – Modes in guided waves – Air coupled ultrasonic guided waves – advantages and limitations – Applications, few case studies. Electro Magnetic Acoustic Transducer (EMAT)-Basic principles – types of coil and design – Generation and defect detection of guided waves using EMATS- - advantages and limitations – Applications- case studies

MODULE IV OPTICAL METHODS IN ULTRASONICS**9**

Laser Ultrasonics – Laser fundamentals – types of lasers – bulk wave and lamb wave generation mechanisms – optical detection of ultrasound – measurement of in

plane displacement and velocity – holographic NDT – recording and reconstruction of a hologram – Two wave mixing interferometry – Laser shearography – Applications (Laser ultrasonics for flaw detection and material characterization) – Case studies.

MODULE V LIQUID PENETRANT TESTING

9

Principles – types and properties of liquid penetrants – developers – advantages and limitations of various methods - Preparation of test materials – Application of penetrants to parts, removal of excess penetrants, post cleaning – Control and measurement of penetrant process variables – selection of penetrant method – solvent removable, water washable, post emulsifiable – Units and lighting for penetrant testing – Interpretation and evaluation of test results - dye penetrant process, applicable codes and standards.

Total Hours: 45

Reference Books:

1. J. Krautkramer and H. Krautkramer, Ultrasonic Testing of Materials, Springer, 4 th edition (1990).
2. B. Raj, C.V. Subramanian and T. Jayakumar, Non Destructive Testing of Welds, Woodhead Publishing, 1st edition (2000).
3. L. Schmerr and J. Song, Fundamentals of Ultrasonic Nondestructive Evaluation, Springer, 1998.
4. P. J. Shull, Nondestructive Evaluation: Theory, Techniques, and Applications, CRC Press, 1st edition (2002).
5. C.V.Subramanian, Practical Ultrasonics, Alpha Science International, (2006).
6. A.S. Birks and R.E. Green, Ultrasonic Testing, Nondestructive Handbook, Vol. 7, American Society for Nondestructive Testing, 2nd edition (1991).

OUTCOMES:

After successful completion of this course the student will be able to

- have a thorough understanding of basics of ultrasonic.
- Learn testing and NDT methods to enable them to perform inspection of samples.
- Understand ultrasonic guided waves in instrumentation.
- Differentiate various defect types and select the appropriate NDT methods for the specimen
- Compare different processes involved in the LPT.

PHDY 207**OPTOELECTRONIC DEVICES**

L	T	P	C
2	0	2	3

OBJECTIVES:

- To make the students learn about the fundamentals of Photo-luminous-semiconductors, Optoelectronic devices, Optical modulators/detectors
- To make them understand the technology behind latest Display devices like LCD, Plasma and LED Panels.
- To make students understand the various types of optical modulators and detectors
- To get knowledge on photonic devices such as solar cells and photoconductors

MODULE I INTRODUCTION TO OPTOELECTRONIC MATERIALS 8

Energy bands in solids, Electrical conductivity, Semiconductors, carrier concentrations, Work function, Excess carrier in semiconductors, Junctions, , Metal-semiconductor junctions - semiconductor junctions: energy-band relation, surface states and depletion layer, Schottky-effect current transport process – thermo ionic emission, tunneling, device structures.

MODULE II OPTOELECTRONIC DEVICES 7

Light-Emitting Diodes, Semiconductor Lasers, Optical processes in semiconductor lasers - power and efficiency - double hetero LED - LED structure - LED characteristics - White LED – Applications.

MODULE III OPTICAL MODULATORS & DETECTORS 8

Modulation of light – birefringence - electro optic effect - EO materials - Kerr modulators - scanning and switching - self electro optic devices - MO devices, AO devices - AO modulators-Photo detectors - thermal detectors – photoconductors – detectors - photon devices - PMT- photodiodes - photo transistors - noise characteristics - PIN diode- APD characteristics - APD design of detector arrays – CCD

MODULE IV PHOTONIC DEVICES**7**

Photoconductors – Solar cells – basic principles, spectral response, efficiency, materials and cascaded solar cells, thin film solar cells, manufacturing and design characteristics.

LIST OF EXPERMENTS

1. Characteristics of LEDs
2. Characteristics of LASER diode
3. Characteristics of Photodiodes
4. Characteristics of Solar cells
5. Determination of electro-optic coefficient using KERR modulator.
6. Characteristics of Diodes

Total Hours – L-30, P-15**REFERENCES:**

1. Wilson & J.F.B. Hawkes, "Optoelectronics – An Introduction", Prentice Hall, India, 1998.
2. Bhattacharya, "Semiconductor optoelectronic devices", Second Edn Pearson Education, Singapore, 2002.
3. J. M. Senior, "Optical fiber communication", Prentice-Hall India, 2009.
4. J. Gowar, "Optical fiber communication systems", Prentice–Hall, 1995.
5. J .Palais, "Introduction to optical electronics", Prentice–Hall, 1988.
6. Jasprit Singh, "Semiconductor optoelectronics", McGraw–Hill, Inc, 1995.R. P.
7. Khare, "Fiber optics and Optoelectronics", Oxford University Press, 2004.

OUTCOME:

On completion of this course the student will explore

- Understand the concept and theory on semiconductor devices
- Analyse the concepts of light emitting diodes (LEDs) and Laser drive circuits.
- Comprehend thoroughly the principles of modulation of light, birefringence, MO devices, the working of optical detectors and various optical devices.
- Compare working mechanism of solar cells, efficiency calculation and large scale solar cells manufacturing technology

PHDY 208**BIOPHOTONICS****L T P C****3 0 0 3****OBJECTIVES:**

- To know the role of light and its interaction in the cells and tissues.
- To understand the different imaging techniques for the biological systems.
- To know the concepts of spectroscopy in biological applications.
- To understand the optical force spectroscopy.
- To understand the role of Biophotonic materials in applications.

MODULE I INTERACTION OF LIGHT WITH BIOLOGICAL SYSTEMS**9**

Interaction of light with cells, tissues, nonlinear optical processes with intense laser beams, photo-induced effects in biological systems.

MODULE II IMAGING TECHNIQUES**9**

Imaging techniques: Light microscopy, wide-field, laser scanning - confocal, multiphoton, fluorescence lifetime imaging, FRET imaging - Frequency-Domain lifetime imaging. Cellular Imaging - Imaging of soft and hard tissues and other biological structures.

MODULE III SINGLE MOLECULE SPECTROSCOPY**9**

Single molecule spectroscopy: UV-VIS spectroscopy of biological systems, single molecule spectra and characteristics – IR and Raman spectroscopy and Surface Enhanced Raman Spectroscopy for single molecule applications.

MODULE IV OPTICAL FORCE SPECTROSCOPY**9**

Optical Force Spectroscopy: Generation optical forces – Optical trapping and manipulation of single molecules and cells in optical confinement - Laser trapping and dissection for biological systems - single molecule biophysics, DNA protein interactions.

MODULE V BIOSENSORS**9**

Biosensors, Principles- DNA based biosensors – Protein based biosensors– materials for biosensor applications- fabrication of biosensors.

Total Hours: 45

REFERENCES:

1. Prasad. P.N., Introduction to Biophotonics, John Wiley & Sons, 2003
2. Michael P. Sheetz, Laser Tweezers in Cell Biology (Methods in Cell Biology), Vol.55, Academic Press Publishers, 1997.
3. Ranier .W, Nanoelectronics and Information Technology, Wiley Publishers, 2012.
4. Drexler. K.E., Nanosystems: Molecular Machinery, Manufacturing, and Computation, Wiley Publishers, 1992.

OUTCOMES:

At the end of the course, the students will be able to illustrate

- Make clear insights into the applications of light interaction with biological systems.
- Compare different imaging techniques.
- Understand and analyse the various spectroscopic techniques used in biological system.
- Effectively grasp the usage of the optical force spectroscopy.
- Get clear ideas and communicate about the importance of use of spectroscopy in design of bio-photonic devices.

ELECTIVES
III SEMESTER

PHDY 301

MATHEMATICAL METHODS
FOR NONLINEAR SCIENCE

L T P C
3 0 0 3

OBJECTIVES:

- To understand the basic concepts of different mathematical methods useful for nonlinear sciences.
- To provide the basics of nonlinear ordinary and partial differential equations
- To study discrete Fourier transform method to solve nonlinear systems
- To have a comprehensive idea on KdV and NLS soliton equations.
- To understand the Inverse scattering, Backlund transformations and Hirota's method to solve the integrable systems.

MODULE I FOURIER ANALYSIS AND OPTICS**8**

Fourier series – Harmonic analysis – Fourier Transform and applications – Convolution Theorem – Sampling Theorem and applications – Fourier Optics – Holographic filters.

MODULE II DISCRETE FOURIER TRANSFORM**7**

Discrete time signals – Discrete Fourier Transform – Butterfly algorithm – Fast Fourier Transform.

MODULE III DIFFERENTIAL EQUATIONS**10**

Ordinary differential equations (ODEs) – Partial differential equations (PDEs)– Nonlinear ordinary differential equations – Nonlinear partial differential equations.

MODULE IV SOLITON EQUATIONS**10**

Korteweg de Vries (K-dV) type equations – modified K-dV equation (MK-dV) – sine-Gordon m-Nonlinear Schrodinger type equations – Burger's equations.

MODULE V COHERENT STRUCTURES**10**

Solitons – Generating soliton equations (AKNS method) – Inverse scattering method – Backlund transformation – Hirota bilinearization method – Painleve Analysis – Lax pair.

Total Hours: 45**REFERENCES:**

1. L.A.Pipes, Applied mathematics for Engineers and Physicists, McGraw Hill book Co., 1980.
2. A.V.Oppenheim and R.W.Schafer, Digital Signal Processing, Printice Hall of India, 1995.
3. M.J.Ablowitz and H.Segur, Solitons and Inverse scattering Transform, Philadelphia, 1981.
4. J.M.T. Thomson and H.B.Stewart, Nonlinear Dynamics and Chaos, John Wiley and Sons, 1986.
5. M.Lakshmanan and S.Rajasekar, Nonlinear dynamics: Integrability, Chaos and Spatio-temporal patterns, Springer-Verlag, 2003.
6. Steven H.Strogatz, Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering (Studies in Nonlinearity) 2nd Edition, 2015.

OUTCOMES:

At the end of the course, the students will be able to

- Execute various mathematical problems using Fourier Transform.
- Use discrete Fourier transform method to solve nonlinear systems
- Apply various methods to solve ordinary differential equations and partial differential equations
- Understand the concepts and applications of solitons.
- Solve the integrable systems and study about solitons.

PHDY 302**MEASUREMENT AND INSTRUMENTATION****L T P C****3 0 0 3****OBJECTIVES:**

- To enable the students understand the importance of measurements.
- To make the students understand the principle behind the transducers
- To understand different types of bridges and recorders used in instrumentation techniques.
- To understand different types of electronic devices used in instrumentation techniques.
- To learn about the different advanced measuring instruments.

MODULE I PHYSICAL MEASUREMENT**7**

Measurement – result of a measurement – uncertainty and experimental error – systematic error – random error – repeated measurements – data distribution functions; mathematical description, derivation and properties

– propagation error – analysis of data – multi parameter experiments.

MODULE II TRANSDUCERS**10**

Classification of Transducers - Principle, construction and working of Thermistor - LVDT, Electrical strain gauges and capacitive transducers, Photoelectric transducer, Piezoelectric transducer - Measurement of non-electrical quantities - Strain, Displacement, temperature, Pressure, Magnetic fields, vibration, optical and particle detectors.

MODULE III BRIDGES AND RECORDERS**10**

DC bridges - Wheatstone's bridge – Kelvin's bridge – double bridge – AC bridges – bridges for capacitance and inductance comparison – Wien bridge – Schering bridge – Maxwell's inductance bridge – Maxwell – Wein bridge - Hay bridge – Anderson bridge – De sauty bridge – Owen bridge - resonance bridge – types of detectors – strip chart recorders – X-Y recorders – digital data recording – recorder specifications.

MODULE IV INSTRUMENTATION ELECTRONICS**8**

Op-amps – instrumentation amplifier – signal conditioning – filters – analog signal processing – high speed A/D conversion – D/A conversion – digital logic levels –

digital instrumentation – frequency measurements – FFT –sampling time and analyzing – IEEE 488 interface bus – LabView (basics).

MODULE V ADVANCED MEASUREMENTS

10

Spectroscopic instrumentation –UV – Vis spectrometer IR spectroscopy – spectrometer design – refraction and diffraction — dispersive elements – lasers – fiber optics – X-ray fluorescence: line spectra and fine structure – absorption and emission processes – X-ray production – X-ray crystallography –neutron diffraction – TEM – SEM – atomic force and tunneling scanning microscope.

Total Hours: 45

REFERENCES:

1. M. Sayer and A. Mansingh, “Measurement, instrumentation and experiment design in physics and engineering”, Prentice-Hall India Pvt. Ltd., New Delhi,2000.
2. H.S. Kalsi, ‘Electronic instrumentation’, (2nd Edition), Tata McGraw Hill Publication Co.Ltd., New Delhi, 2004.
3. R.F. Coughlin and F.F. Driscoll, “Operational amplifiers and linear integrated circuits”, Pearson Education, New Delhi, 2001.
4. E.O. Doebelin, “Measurement systems: Applications and design”, McGraw-Hill, New York, 2002.
5. Rangan Sharma and Mani, “Instrumentation devices and systems”, Tata McGraw-Hill, New Delhi, 2000.

OUTCOMES:

At the end of the course, the students will be able to,

- acquire the knowledge about the different errors and principle behind the instrumentation for measurement.
- Identify the various transducers involved in measurement.
- gain knowledge about bridges and recorders used in instrumentation techniques.
- Apply the knowledge gained in electronic devices for instrumentation techniques.
- Identify the different advanced measuring instruments for practical applications.

PHDY 303**BIOMEDICAL INSTRUMENTATION****L T P C****3 0 0 3****OBJECTIVES:**

- To understand the human physiological systems.
- To know the different aspects of biosignal acquisition.
- To understand the basics in biopotential recorders.
- To know the importance methods, instruments available for biomedical field.
- To analyze the special biomedical instrumentation systems.

MODULE I HUMAN PHYSIOLOGICAL SYSTEMS**9**

Cells and their structure – Nature of Cancer cells – Transport of ions through the cell membrane – Resting and action potentials – Bio-electric potentials – Nerve tissues and organs – Different systems of human body. Biopotential Electrodes and Transducers Design of Medical instruments – components of the biomedical instrument system – Electrodes – Transducers.

MODULE II BIOSIGNAL ACQUISITION**9**

Physiological signal amplifiers – Isolation amplifiers – Medical preamplifier design – Bridge amplifiers – Line driving amplifier – Current amplifier – Chopper amplifier – Biosignal analysis – Signal recovery and data acquisition – Drift Compensation in operational amplifier – Pattern recognition – Physiological Assist Devices. Pacemakers – Pacemakers batteries – Artificial heart valves – Defibrillators – nerve and muscle stimulators Heart – Lung machine – Kidney machine.

MODULE III BIOPOTENTIAL RECORDERS**9**

Characteristics of the recording system – Electrocardiography (ECG) – Electroencephalography (EEG) – Electromyography (EMG) – Electroethinography (ERG) and Electroculography (EOG) – Recorders with high accuracy – recorders for OFF line analysis.

MODULE IV OPERATION THEATRE EQUIPMENT**9**

Surgical diathermy- shortwave diathermy – Microwave diathermy – Ultrasonic diathermy – Therapeutic effect of heat – Range and area of irritation of different techniques – Ventilators – Anesthesia machine – Blood flowmeter – Cardiac Output

measurements – Pulmonary function analyzers – Gas analyzers – Blood gas analyzers – Oximeters – Elements of intensive care monitoring.

MODULE V SPECIALISED MEDICAL EQUIPMENTS

9

Blood Cell counter – Electron microscope – Radiation detectors – Photometers and colorimeters – digital thermometer – audiometers – X-rays tube – X-ray machine – image intensifiers – Angiography – Application of X-ray examination. Safety instrumentation: Radiation safety instrumentation – Physiological effects due to 50Hz current passage – Microshock and macroshock – electrical accident Hospitals – Devices to protect against electrical hazards – Hospitals architecture.

Total Hours: 45

REFERENCES:

1. Arumugam M., Biomedical Instrumentation, Anurada Agencies Publishers, 1992.
2. Khandpur R.S., Handbook of Biomedical Instrumentation, Third Edition, Tata McGraw-Hill Education, 2014.
3. Shakti Chatterjee and Aubert Miller, Biomedical Instrumentation Systems, Cengage Learning Publisher, 2010.
4. Gromwell L., Fred J. Weibell, Erich A. Pfeiffer, Biomedical Instrumentation and Measurements, Second Edition, Prentice Hall, 1980.

OUTCOMES:

At the end of the course, the students will be able to understand

- the human physiological systems.
- the different aspects of biosignal acquisition.
- different biopotential recorders such as EEG, ECG, EMG, EOG
- biomedical instruments involved in advanced operation theatres
- the application of biomaterials towards specialized medical equipment such as electron microscope and radiation detectors

PHDY 304**RADIATION PHYSICS****L T P C****3 0 0 3****OBJECTIVES:**

- To understand the theory of electromagnetic radiation.
- To know the difference between natural and artificial radioactivity
- To understand the effect of radiation factors.
- To study the interaction of radiation with matter and its effects.
- To understand the interaction of charged particles with matter.

MODULE I ELECTROMAGNETIC RADIATION**9**

Wave model – Quantum Model– visible light and fluorescence particulate radiation – inverse square law

MODULE II NATURAL AND ARTIFICIAL RADIOACTIVITY**9**

Radioactivity – General properties of alpha, beta and gamma rays – Laws Of radioactive disintegration – Radioactive decay constant – Half-life period – average life – Isotopes, Isobars, Isomers – Isotones and Isodiapheres – Natural radioactive series – Radioactive equilibrium –Radioactive decay - α particle decay – β particle decay – Theory of beta decay – Gamma emission – Electron capture – Internal conversion – Nuclear isomerism – Artificial radioactivity - Nuclear reactions – α , p reaction - α , n reaction-Proton bombardment – deuteron bombardment- neutron bombardment – photo disintegration – Activation of nuclides - Elementary ideas of fission, fusion and nuclear reactors.

MODULE III RADIATION FACTORS**9**

Quantities to describe a radiation beam - particle flux and fluence- Photon flux and fluence- cross section- linear and mass absorption coefficient-stopping power and LET Activity – Curie – Becquerel. Exposure and its measurements – Roentgen, Radiation absorbed Dose- Gray - kerma- kerma rate constant - Electronic equilibrium - relationship between kerma, exposure and absorbed dose – Relative biological effectiveness (RBE)- radiation weighting factors.

MODULE IV INTERACTION OF RADIATION WITH MATTER**9**

Interaction of electromagnetic radiation with matter: Ionization – Photon beam exponential attenuation – Rayleigh scattering – Photoelectric effect – Compton effect

- energy absorption – Pair production – Attenuation, energy transfer and mass energy absorption coefficients – Relative importance of various types of interactions.

MODULE V INTERACTION OF CHARGED PARTICLES WITH MATTER 9

Classical theory of inelastic collisions with atomic electrons – Energy loss per ion pair by primary and secondary ionization – Dependence of collision energy losses on the physical and chemical state of the absorber – Cerenkov radiation – Electron absorption process – scattering excitation and ionization – Radiative collision – Bremsstrahlung – Range energy relation – Continuous slowing down approximation (CSDA) – straight ahead approximation and detour factors – transmission and depth dependence methods for determination of particle penetration - empirical relations between range and energy – Back scattering.

Total Hours: 45

REFERENCES:

1. Segre E., Experimental Nuclear Physics, Vol 3, John Wiley, 1959.
2. Theraja B.L., Modern Physics, S.Chand Company, 1995.
3. Faiz M Khan , The Physics of Radiation Therapy, Lippincott Williams & Wilkins Publishers, 2010.
4. Oliver R., Radiation Physics in Radiology, Blackwell Scientific Publication, 1974.
5. Frank Herbert Attix, Introduction to Radiological Physics and Radiation Dosimetry, Wiley-VCH Publishers, 1991.

OUTCOMES:

At the end of course, students will be able to understand

- concepts of electromagnetic radiation.
- theory of artificial and natural radioactivity
- interaction of radiation with matter.
- the interaction of radiation with matter and its effects.
- charged particles interaction with matter.

PHDY 305 LASER SPECTROSCOPY AND ITS APPLICATIONS L T P C
3 0 0 3

OBJECTIVES:

- To endow the students with the knowledge of the fundamentals of spectroscopy.
- To learn the basics in high resolution spectroscopy.
- To understand the applications of laser spectroscopy in various fields.
- To learn about the photobiology and medical lasers.
- To understand the thermal and non-thermal applications of lasers.

MODULE I TIME-RESOLVED SPECTROSCOPY 10

Generation of short optical pulses - generation of ultra short optical pulses - Measurement techniques for Optical Transients: Transient - Digitizer - Boxcar - Delayed coincidence- Streak-camera & Pump-probe techniques. Basics of lifetime measurements - Methods of measuring radiative properties - linewidth measurements - ODR and LC - Beam foil techniques - Beam laser techniques - Time resolved spectroscopy with pulsed lasers - Phase- shift method and emission method - The hook method - Quantum-Beat spectroscopy.

MODULE II HIGH RESOLUTION SPECTROSCOPY 8

Spectroscopy on collimated atomic beams: Detection through fluorescence - detection by photoionization - detection by the recoil effect detection by magnetic deflection. Saturation spectroscopy and related techniques - Doppler-free two-photon absorption - spectroscopy of trapped ions and atoms.

MODULE III APPLICATIONS OF LASER-SPECTROSCOPY 10

Diagnostics of combustion processes: Background - Laser-induced fluorescence and related techniques - Raman spectroscopy - coherent anti- Stokes Raman scattering - Velocity measurements. Laser remote sensing of the atmosphere: Optical heterodyne detection – long path absorption techniques - LIDAR techniques. Laser-induced fluorescence and Raman spectroscopy in liquids and solids: Hydrospheric remote sensing - monitoring of surface layers. Laser-induced chemical processes: Laser-induced chemistry - laser isotope separation - spectroscopic aspects of lasers in medicine.

MODULE IV PHOTOBIOLOGY AND MEDICAL LASERS**9**

Study of biological functions - Microradiation of cells - optical properties of tissues (normal and diseased state) - Experimental methods to determine the reflectance, absorption, transmittance and emission properties of tissues - Laser systems in medicine and biology - Nd: YAG, Ar ion, CO₂, Excimer, N₂, Gold Vapour laser - Beam delivery and measuring systems

MODULE V THERMAL APPLICATIONS**9**

Surgical applications of lasers - Sterilization - hermostasis - Cancer Liver stomach gynecological surgeries - Performance evaluation - Lasers in Ophthalmology - Dermatology and Dentistry - Cosmetic Surgery.

Total hours: 45**REFERENCES:**

1. S. Svanberg, "Atomic and Molecular Spectroscopy", Springer Verlag, Germany, 1992.
2. J. R. Lakowicz, "Principles of Fluorescence Spectroscopy", Kluwer Academic/ Plenum Publishers, New York, 1999.
3. Z. Wang and H. Xia, "Molecular and Laser Spectroscopy", Springer Series in Chemical Physics, Vol.50, 1991.
4. S.S. Martellucci and A.N. Chester, "Laser Photobiology and Photomedicine", Plenum Press, New York, 1985.
5. R. Pratesi and C.A. Sacchi, "Lasers in Photomedicine and Photobiology", Springer verlag, West Germany, 1980.
6. Carruth JAS & AL Mckenzie, "Medical Lasers Science and Clinical Practice", Adam Hilger Ltd., Bristol, 1991.
7. T. Kaluylu and M. Tsukakoshi, "Laser Microradiation of cells", Harward Academic publishers, New York, 1990.

OUTCOMES:

At the end of the course the student will be able to get knowledge in,

- different types spectroscopy and applications of laser spectroscopy in various fields.
- high resolution spectroscopy.
- laser tissue interaction.
- photobiology and medical lasers.
- Thermal and non-thermal applications of lasers and safety of lasers.

PHDY 306**NANO PHOTONICS**

L	T	P	C
3	0	0	3

OBJECTIVES:

- To understand basic concepts of Nano Photonics.
- To know the importance of nanophotonics materials.
- To understand concept of Plasmonics.
- To know electronics and photonic molecular materials and its applications
- To understand the application of plasmonics

MODULE I BASIC OF PHOTONICS 9

Similarities and differences between photon and electron- Free- Space propagation. Co-operative effects and confinement of Photons and Electrons. Maxwell equation for Photonic systems. Concept of near-field phenomena in photonics crystals. Band structures of photonics crystal. Optical properties of photonics materials. Confinement in 1-D, 2-D and 3-D structure.

MODULE II NEW APPROACHES IN NANOPHOTONICS 9

Near-Field Optics- Aperture near-field optics- Apertureless near-field optics-Near-field scanning optical microscopy (NSOM or SNOM)- SNOM based detection of plasmonic energy transport- SNOM based visualization of waveguide structures- SNOM in nanolithography- SNOM based optical data storage and recovery.

MODULE III PLASMONICS 9

Internal reflection and evanescent waves- plasmons and surface plasmon resonance (SPR)- Attenuated total reflection- Grating SPR coupling- Optical waveguide SPR coupling- SPR dependencies and materials- plasmonics and nanoparticles.

MODULE IV ELECTRONIC& PHOTONIC MOLECULAR MATERIALS 9

Preparation – Electroluminescent Organic materials - Laser Diodes - Quantum well lasers: Quantum cascade lasers - Cascade surface-emitting photonic crystal laser - Quantum dot lasers - Quantum wire lasers:- White LEDs - LEDs based on nanowires - LEDs based on nanotubes - LEDs based on nanorods - High Efficiency Materials for OLEDs - Quantum well infrared photo detectors.

MODULE V ELEMENTS OF PLASMONICS AND APPLICATIONS 9

Introduction to Plasmonics, merging photonics and electronics at nanoscale dimensions, single photon transistor using surface plasmon, nanowire surface plasmons-interaction with matter, single emitter as saturable mirror, photon correlation, and integrated systems. All optical modulation by plasmonic excitation of quantum dots, Channel plasmon-polariton guiding by subwavelength metal grooves, Near-field photonics: surface plasmon polaritons and localized surface plasmons, Slow guided surface plasmons at telecom frequencies.

Total Hours: 30**REFERENCES:**

1. Masuhara. H, Kawata. S and Tokunaga. F, Nano Biophotonics, Elsevier Science, 2014.
2. Saleh. B.E.A and Teich. A.C, Fundamentals of Photonics, John-Wiley & Sons, New York, 2014.
3. Ohtsu.M, Kobayashi.K, Kawazoe.T and Yatsui.T, Principles of Nanophotonics (Optics and Optoelectronics), University of Tokyo, Japan, 2013.
4. Joannopoulos.J.D, Meade. R.D and Winn. J.N, Photonic Crystals, Princeton University Press, Princeton, 2010.
5. Ranier. W, Nano Electronics and Information Technology, Wiley, 2013.

OUTCOMES:

At the end of the course, the students will be able to understand

- the Maxwell equation for Photonic systems and other basics of nanophotonics
- the mechanism of scanning optical microscopy and advanced lithography techniques
- the surface plasmon resonance (SPR) effect and its applications towards optical waveguides
- the working mechanism of optoelectronics devices Quantum wire lasers and hite LEDs
- the applications of Plamonics

PHDY 307**NANOSCIENCE AND TECHNOLOGY****L T P C****3 0 0 3****OBJECTIVES:**

- To enable students understand the general principles of nanomaterials.
- To learn the different tools for characterization.
- To get into Insight of the materials, fabrication and other experimental techniques that can be used on the nanoscale, as well as their limitations.
- To get in-depth knowledge of at least one specialisation area within the field of nanoscience and nanotechnology.
- To gain Sufficient scientific background to undertake research.

MODULE I NANOMATERIALS AND STRUCTURES**9**

Nanomaterials and types: nanowires, nanotubes, fullerenes, quantum dots, nanocomposites – properties – Methods of preparation: top-down, bottom-up.

MODULE II CHARACTERIZATION TOOLS**9**

Electron Microscopy Techniques – SEM, TEM, X ray methods – optical methods
Fluorescence Microscopy – Atomic Force Microscopy, STM and SPM.

MODULE III NANOMAGNETISM**9**

Mesoscopic magnetism – Magnetic measurements: miniature Hall detectors, integrated DC SQUID Microsusceptometry – magnetic recording technology, biological magnets.

MODULE IV NANO ELECTRONICS AND INTEGRATED SYSTEMS**9**

Basics of nanoelectronics – Single Electron Transistor – quantum computation – tools of micro-nanofabrication – nanolithography – quantum electronic devices – MEMS and NEMS – dynamics of NEMS – limits of integrated electronics.

MODULE V BIOMEDICAL APPLICATIONS OF NANOTECHNOLOGY**9**

Biological structures and functions – drug delivery systems – organic-inorganic nanohybrids – inorganic carriers – nanofluidics.

Total Hours: 45

REFERENCES:

1. Jan Korvink and Andreas Greiner, Semiconductors for Micro and Nanotechnology – an Introduction for Engineers, Weinheim Cambridge: Wiley-VCH, 2001.
2. Murty B.S., Shankar P. & et al., Textbook of Nanoscience and Nanotechnology, Universities Press (India) Private Ltd., 2012.
3. Richard Booker and Earl Boysen, Nanotechnology, Wiley Publishing, 2005.
4. Timp G (ed), Nanotechnology, AIP press, Springer, 1999.
5. Wilson M., Kannangara K., Smith G., Simmons M. and Raguse B., Nanotechnology: Basic Sciences and Energy Technologies, Overseas Press, 2005.

OUTCOMES:

At the end of the course, the students will be able to understand

- the basic concepts of nanomaterials
- working mechanism of various advanced characterization techniques
- applications of nanomagnetism in advanced instruments
- nanoelectronics towards MEMS applications.
- the application of nanomaterials in biomedical field.

PHDY 308**THIN FILM SCIENCE AND TECHNOLOGY****L T P C****3 0 0 3****OBJECTIVES:**

- To familiarize with preparation and properties of thin films.
- To understand the different kinetics of thin film nucleation.
- To understand the characterization tools for thin films.
- To study the different properties of thin films.
- To apply the knowledge of thin film technology into applications.

MODULE I PREPARATION OF THIN FILMS**9**

Kinetic aspects of gases in a vacuum chamber – classifications of vacuum ranges – production of vacuum - pressure measurement in vacuum systems– thin film (epitaxy) – definition – types of epitaxy. Different Growth Techniques: Liquid phase epitaxy – vapour phase epitaxy – molecular beam epitaxy – metal organic vapour phase epitaxy – sputtering (RF & DC) – pulsed laser deposition. Thickness Measurement: Microbalance technique – photometry-ellipsometry– interferometry.

MODULE II KINETICS OF THIN FILMS**9**

Nucleation Kinetics: types of nucleation – kinetic theory of nucleation – energy formation of a nucleus – critical nucleation parameters; spherical and non spherical (cap, disc and cubic shaped) Growth Kinetics: Kinetics of binary (GaAs, InP, etc.), ternary ($\text{Al}_{1-x}\text{Ga}_x\text{As}$, $\text{Ga}_{1-x}\text{In}_x\text{P}$, $\text{InAs}_{1-x}\text{Px}$, etc.) and quaternary ($\text{Ga}_{1-x}\text{In}_x\text{As}_{1-y}\text{Py}$, etc.) semiconductors – derivation of growth rate and composition expressions.

MODULE III CHARACTERIZATION**9**

X-ray diffraction – photoluminescence – UV-Vis-IR spectrophotometer – Atomic Force Microscope – Scanning Electron Microscope – Hall effect – Vibrational Sample Magnetometer – Secondary Ion Mass Spectrometry – X-ray Photoemission Spectroscopy.

MODULE IV PROPERTIES OF THIN FILMS**9**

Dielectric properties – experimental technique for the determination of dielectric properties – optical properties – experimental technique for the determination of optical constants – mechanical properties – experimental technique for the determination of mechanical properties of thin films – magnetic and superconducting properties.

MODULE V APPLICATIONS**9**

Optoelectronic devices: LED and Solar cell – Micro Electromechanical Systems (MEMS) – Fabrication of thin film capacitor – application of ferromagnetic thin films; data storage, Giant Magnetoresistance (GMR) – sensors – fabrication and characterization of thin film transistor and FET – quantum dot - Cryptography.

Total Hours: 45**REFERENCES:**

1. Goswami. A, Thin Film Fundamentals, New Age International (P) Limited, New Delhi, 1996.
2. AichaEishabini-Riad, Fred D. Barlow and ISHN, Thin film Technology Handbook, McGraw-Hill Professional Publishers, 1997.
3. Krishna Seshan, Handbook of Thin Film Deposition, William Andrew Publishers, 2012.
4. Donald Smith, Thin-Film Deposition: Principles and Practice, McGraw-Hill Professional Publishers, 1995.
5. K.L.Chopra, "Thin Film Phenomena", Malabar: Robert E. Krieger Publishing Company, 1979.

OUTCOMES:

At the end of the course, the students will be able to understand

- the basic concepts about the thin film technology.
- the different kinetics of thin film nucleation.
- the characterization tools for thin films.
- Structural, optical, dielectric and mechanical properties of thin films
- applications of thin films in optoelectronics

MODULE V COATING APPLICATIONS**8**

Abrasive, erosive and sliding wear. The interaction between wear and corrosion. Coating systems for corrosion and wear protection; new coating concepts including multi-layer structures, functionally gradient materials, intermetallic barrier coatings and thermal barrier coatings.

Total Hours: 45**REFERENCES:**

1. D.A. Jones, Principles and Prevention of Corrosion, 2nd Edition, Macmillan Publishing Co., 1995.
2. J.O.M. Bockris, B.E. Conway, E. Yeager and White, Electrochemical Materials Science in Comprehensive Treatise of Electrochemistry, Volume 4, Plenum press, 2001.
3. M.G. Fontanna and N.D. Greene, Corrosion Engineering, McGraw-Hill publishing, 1978
4. I.M. Hutchings, Tribology: Friction and Wear of Engineering Materials, CRC press, Boca Raton, 1992 D.O. Sprowds, Corrosion Testing and Evaluation, Corrosion Metals Hand book, vol. 13, 1986.

OUTCOMES:

At the end of the course the students will be able to understand

- various corrosion process involved in electrochemistry
- working mechanism of various instrumentation techniques
- various coating process,
- applications of coatings towards environmental safety
- industrial applications of coatings

PHDY 310**BIOMATERIALS****L T P C****3 0 0 3****OBJECTIVES:**

- To enable the students understand importance of and properties of Biomaterials
- To familiarize the students with different orthopaedic materials.
- To understand different cardiovascular materials.
- To help students study about materials in ophthalmology
- To make the students understand applications of various biomaterials

MODULE I BIOLOGICAL PERFORMANCE OF MATERIALS**9**

Biocompatibility- Introduction to the biological environment – Material response: swelling and leaching, corrosion and dissolution, deformation and failure, friction and wear – Host response: the inflammatory process - coagulation and hemolysis- approaches to thrombo- resistant materials development.

MODULE II ORTHOPAEDIC MATERIALS**9**

Bone composition and properties - temporary fixation devices - joint replacement – Biomaterials used in bone and joint replacement: metals and alloys – Stainless steel, cobalt based alloys, titanium based materials – Ceramics: carbon, alumina, zirconia, bioactive calcium phosphates, bioglass and glass ceramics – polymers: PMMA, UHMWPE/HDPE, PTFE – Bone cement – Composites.

MODULE III CARDIOVASCULAR MATERIALS**9**

Blood clotting – Blood rheology – Blood vessels – The heart – Aorta and valves – Geometry of blood circulation – The lungs - Vascular implants: vascular graft, cardiac valve prostheses, cardiac pacemakers – Blood substitutes – Extracorporeal blood circulation devices.

MODULE IV DENTAL MATERIALS**9**

Teeth composition and mechanical properties – Impression materials – Bases, liners and varnishes for cavities – Fillings and restoration materials – Materials for oral and maxillofacial surgery – Dental cements and dental amalgams – Dental adhesives.

MODULE V MATERIALS IN OPHTHALMOLOGY**9**

Biomaterials in ophthalmology – Viscoelastic solutions, contact lenses, intraocular lens materials – Tissue grafts – Skin grafts – Connective tissue grafts – Suture materials – Tissue adhesives – Drug delivery: methods and materials – Selection, performance and adhesion of polymeric encapsulants for implantable sensors-biomehtic materials-Technology from nature.

Total Hours: 45**REFERENCES:**

1. Sujata V. Bhat. Biomaterials, Narosa Publication House, New Delhi, 2002.
2. Jonathn Black. Biological Performance of Materials: Fundamentals of biocompatibility, Marcel Dekker Inc, New York, 1992.
3. D.F.Williams (editor). Materials Science and Technology: A comprehensive treatment, Volume 14. Medical and Dental Materials, VCH Publishers Inc, New York, 1992.
4. F.Silver and C.Doillon. Biocompatibility: Interactions of Biological and implantable materials. Volume I Polymers, VCH Publishers Inc, New York, 1989.
5. L.L.Hench and E.C.Ethridge. Biomaterials: An Interfacial Approach, Academic Press, 1982.
6. Joon Park, R. S. Lakes, Biomaterials. An Introduction, Springer, third edition, 2010. Springer

OUTCOMES:

At the end of the course the students will be able to understand the

- importance and properties of biomaterial.
- different classes of orthopaedic materials.
- different types of cardiovascular materials.
- various types of materials used in ophthalmology.
- applications of various biomaterials.