Dr. Babasaheb Ambedkar Marathwada University, Aurangabad – 431001 (MS)

Department of Physics

Structure and Curriculum

for

M. Sc. (Physics) Programme

(Choice Based Credit System)

(Effective from June 2016 onwards)

Structure and Curriculum for M.Sc. (Physics) Programme
(Choice Based Credit System)

The M.Sc. (Physics) programme is divided into four semesters having **106 credits (104 + 02).** There are **17 theory courses** of **65 credits** subdivided into **05 core courses of 17 credits**, **05 foundation courses of 20 credits** and **07 elective courses of 28 credits (Generic Elective : 24 credits and Open Elective : 04 Credits).** Besides there are **07 laboratory courses of 17 credits, research project of 22 credits** (distributed in three semesters; **2nd semester 04 credits, 3rd semester 09 credits and 4th semester 09 credits**) and one course on **constitution of India is of 02 credits**. Tutorial, assignments and seminar presentation are integral components of all theory courses. Approximately **16 % are core courses**, **19 % are foundation courses**, **26 % are elective courses**, **16 % are laboratory courses** and **21 % weightage is given for research project**. Approximately **26 % weightage is given for research components** (22 credits for research project at 2nd , 3rd and 4th semester , 01 credit for research methodology foundation course at 1st semester and 04 credits for research based electives at fourth semester). **There are 16 options in 3rd semester and 12 options in 4th semester for generic elective courses**. Students can opt any course of 04 credits (Open Elective) from any department in the university campus.

Eligibility:

Those who have completed B. Sc. with Physics as an optional subject from any recognized University/ Institution are eligible for registration subject to the rules and regulations laid down by Dr. Babasaheb Ambedkar Marathwada University, Aurangabad.

Admission / Promotion Process:

In response to the advertisement for registration, interested students will have to register themselves. Admission will be done on the basis of Common Entrance Test (CET) and performance of students at their qualifying graduate level examination (Marks obtained in the subject of Physics at B. Sc. 2nd year and 3rd year). Once the student is admitted he / she will be promoted to the 2nd year (3rd semester) with full carryon. Students will have to register themselves for every consecutive semester. Dropout students will be allowed to register for respective semester as and when the concerned courses are offered by the department, however he / she should not exceed more than twice the duration of the course from the date of first registration at parent department. The admission of the concern student will be automatically cancelled if he / she fails to complete the M. Sc. degree within a period of maximum four years / eight semesters.

Choice Based Credit System (CBCS) :

The choice based credit system has been adopted by this department. This provides flexibility to make the system more responsive to the changing needs of our students, the professionals and society. It gives greater freedom to students to determine their own pace of study. The credit based system also facilitates the transfer of credits.

- Students will have to earn 106 credits for the award of M.Sc. (Physics) degree.
- Out of 106 credits, students will have to earn 100 credits (Core courses worth 17 credits, foundation courses worth 20 credits, generic elective courses worth 24 credits, laboratory courses worth 17 credits and research project worth 22 credits) from physics

department, 04 credits of open elective from any other Department in the university campus and 02 credits from the course ‘Constitution of India’

Credit-to- contact hour Mapping:

One contact hour per week is assigned 1 credit for theory and 0.5 credits for laboratory courses/ research project. Thus a 4 - credit theory course corresponds to 4 contact hours per week and same analogy will be applicable for laboratory courses / research project.

Course Structure:

Semester I (Core and Foundation Courses)				
Course	**Course Title**	**Teaching time/week**	**Marks**	Credits
PHYC-111	Mathematical Methods in Physics	4 hours	100	4
PHYC-112	Classical Mechanics	4 hours	100	4
PHYC-113	Quantum Mechanics	4 hours	100	4
PHYC-114	Statistical Mechanics	4 hours	100	4
PHYF-115	Research Methodology	1 hours	30	1
COM-100	***Constitution of India***	***2 hours***	***50***	***2***
PHYL- 121	Lab course 1 (General Physics)	4 hours	50	2
PHYL- 122	Lab course 2 (Computational Physics based on PHYC -111, 112, 113 and114)	4 hours	50	2
Total Credits for Semester I : 23 (Theory : 19 ; Laboratory : 04)				
Semester II (Foundation Courses)				
PHYF-211	Foundation Course in Electronics (Linear and Digital Electronics)	4 hours	100	4
PHYF-212	Foundation Course in Spectroscopy (Atomic and Molecular Physics)	4 hours	100	4
PHYF-213	Foundation Course in Nuclear Physics (General Nuclear Physics)	4 hours	100	4
PHYF-214	Foundation Course in Condensed Matter Physics (General Condensed Matter Physics)	4 hours	100	4
PHYL-221	Lab course 3 (Condensed Matter Physics + Nuclear Physics+ Spectroscopy)	4 hours	50	2
PHYL-222	Lab course 4 (Electronics + Computational Physics)	4 hours	50	2
PHYR-231	Review of literature for Research Project	4 hours	50	2
PHYR-232	Formulation of Topic of Research Project	4 hours	50	2

Total Credits for Semester II : 24 (Theory : 16 ; Laboratory : 04 ; Research Project : 04)				
Semester III (Foundation and Generic Elective Courses)				
PHYF-311	Methods of Theoretical Physics	4 hours	100	4
PHYE-312	Generic Electives 1 (A1/ B1/ C1/ D1)	4 hours	100	4
PHYE-313	Generic Electives 2 (A2/ B2/ C2/ D2)	4 hours	100	4
PHYE-314	Generic Electives 3 (A3/ B3/ C3/ D3/ E3 / F3/G3/H3)	4 hours	100	4
PHYL-321	Lab course 5 (Based on Electives A1/ B1/ C1/ D1)	6 hours	50	3
PHYL-322	Lab course 6 (Based on Electives A2/ B2/ C2/ D2)	6 hours	50	3
PHYR-331	Research Project Part I (Experimental Work)	12 hours	100	6
PHYR-332	Research Project Part II (Organization of Results)	6 hours	50	3
Total Credits for Semester III : 31 (Theory : 16 ; Laboratory : 06 ; Research Project : 09)				
Semester IV (Generic and Open Elective Courses)				
PHYE-411	Generic Electives 4 (A4/ B4/ C4/ D4)	4 hours	100	4
PHYE-412	Generic Electives 5 (A5/ B5/ C5/ D5)	4 hours	100	4
PHYE-413	Generic Electives 6 (A6/ B6/ C6/ D6) (Research Oriented)	4 hours	100	4
OELE-101	Service Course of Department of Physics (from other Departments)	4 hours	100	4
PHYL-421	Lab course 7 (Based on Electives A4,A5/ B4,B5/ C4,C5/ D4,D5)	6 hours	50	3
PHYR-431	Research Project Part III (Interpretation of Results)	6 hours	50	3
PHYR-432	Research Project Part IV (Dissertation and Presentation)	12 hours	100	6
Total Credits for Semester IV : 28 (Theory : 16 ; Laboratory : 03 ; Research Project : 09)				
Total Credits : 106 (Sem I : 23 + Sem II : 24 : Sem III : 31 + Sem IV : 28)				

List of Generic Elective Courses for Semester III			
Sr. No.	Code	Name of Course	Semester
		A: Electronics ; B : Spectroscopy C : Nuclear Physics D : Condensed Matter Physics	
1	A1	8086 Microprocessor and Interfacing	III
2	B1	Atomic Spectroscopy	III
3	C1	Radioactivity and Nuclear Decay	III
4	D1	Crystallography	III
5	A2	Microwaves	III
6	B2	Molecular Spectroscopy	III
7	C2	Nuclear Reactions	III
8	D2	Electrical Properties of Solids and Superconductivity	III
9	A3	Industrial Electronics	III
10	B3	Modern Trends in Spectroscopy	III
11	C3	Reactor Physics	III
12	D3	Physics of Nanomaterials	III
13	E3	X-Ray Diffraction	III
14	F3	Thin Film and Vacuum Technology	III
15	G3	Nuclear Spectroscopy	III
16	H3	Micro Electro Mechanical System (MEMS)	III
List of Generic Elective Courses for Semester IV			
1	A4	Fundamentals of Sensors	IV
2	B4	Applied Spectroscopy	IV
3	C4	Particle Physics, Nuclear forces and Cosmic rays	IV
4	D4	Magnetic Materials and Superfluidity	IV
5	A5	8051- Microcontroller	IV
6	B5	Lasers, Nonlinear Optical mixing and Spectroscopic Phenomena	IV
7	C5	Radiation Measurements And Nuclear Dosimetry	IV
8	D5	Material Synthesis and Characterization	IV
9	A6	Advanced Sensor Technology	IV
10	B6	X-ray Spectroscopy	IV
11	C6	Accelerator Physics	IV
12	D6	Ferromagnetism	IV

Notes:

- Tutorial / assignments are integral components of all theory courses. Tutorials consists of conceptual as well as numerical problems / questions based the respective theory courses in the semester covering all four (04) units.

- Each course / paper should be taught for 60 contact hours (48 lectures and 12 tutorials).
- Teaching duration for LAB COURSES in first and second semesters should be of 04 hours and for those in third and fourth semesters should be 06 hours per week per batch.
- One batch of the students will be consisting 08 students for laboratory courses as well as project.
- Each of the course is divided into four units.
- The content of theory course / paper as well laboratory (practical) course may be modified time to time (with the approval DC) to keep pace with the recent developments and trends in the subject.

Course Contents:

Learning objectives and learning outcomes will be integral part of course contents. Learning objectives will describe why the course is necessary ? why it should be taught as Core / Foundation / Elective ? why it should be taught at Sem I / Sem II / Sem III / Sem IV and learning outcomes will describe how the course will be beneficial ? what are the job / research opportunities for the takers of the course? is the said course a pre-requisite for certain other courses? can one start an entrepreneurship after the said course or will the course help for such activity.
Each course will have 04 units and will have 60 contact hours (48 lectures and 12 tutorials).
Reference section consist of latest references of reputed authors and publishers by having all details of the books such as title, author(s), edition, publisher, year, ISBN or ISSN, etc. In case of e-reference, a web link is also included.

Attendance:

Students must have 75 % of attendance in each core, foundation, elective, laboratory and research project course for appearing examination otherwise he / she will be strictly not allowed for appearing the examination of each course. However, students having 65 % attendance with medical certificate may request Head of the Department for the condonation of attendance.

Departmental Committee:

The existing Departmental Committee (DC) will monitor the smooth functioning of M. Sc. programme.

Results Grievances / Redressal Committee

Grievances / redressal committee will be constituted in the department to resolve all grievances relating to the evaluation. The committee shall consist of Head of the department, the concerned teacher of a particular course and senior faculty member of the Departmental Committee. The decision of Grievances / redressal committee will have to be approved by the Department committee.

Evaluation Methods:

- The assessment will be based on 50:50 ratio of continuous internal assessment (CIA) and semester end examination (SEE).
- Separate and Independent passing in CIA and SEE will be mandatory. In case of failure in CIA of a particular course, student will have to appear for same CIA at his/her own responsibility in the next academic year, when the same course is offered during regular academic session.
- In case a student fails in certain courses in a particular semester and the same courses are modified / revised / removed from the curriculum in due course of time, the student will have to appear as per the newly framed curriculum and or pattern in subsequent semester at his / her responsibility.

Continuous Internal Assessment (CIA):

- There will be 50 marks for Continuous Internal Assessment. Distribution of 50 marks will be as follows- 05 marks for tutorials, 05 marks for assignment, 10 marks for seminar presentation and 30 marks for weekly tests. Weekly tests of 10 marks each based on subjective short questions will be conducted every week during the semester as a part of continuous assessment. At the end of the semester average of all weekly tests will be converted into 30 marks. The setting of the question papers and the assessment will be done by the concerned teacher.

Semester End Examination (SEE) :

- The semester end theory examination for each theory course will be of 50 marks. The total marks shall be 100 for 4 credit theory course (50 marks semester end exam + 50 marks CIA); 50 for 2 credit theory course (25 marks semester end exam + 25 marks CIA) 30 for 1 credit theory course (15 marks semester end exam + 15 marks CIA).

- Semester end examination (SEE) time table will be declared by the departmental committee (as per the university annual calendar). The paper setting and assessment of theory courses, laboratory courses and research project will done by external (50 %) and internal (50%) examiners. However, in case of non-availability of external examiner for either paper setting or assessment or both, department committee will be empowered to take appropriate decision.

- Pattern of semester end question paper will be as below:

    - The semester end examination of theory course will have two parts (10+40 = 50 Marks)
    - Part A will be consisting of 10 questions having 1 marks each (multiple choice questions / fill in the blanks/ answer in one sentence) as compulsory questions and it should cover entire course curriculum (10 Marks) having at least 2 questions from each unit of course curriculum.
    - Part B will carry 8 questions (02 questions from each of 04 units and students will have to attempt any one). Therefore, students will have to attempt 04 questions out of 08 (40 Marks).
    - 20 to 30% weightage can be given to problems/ numerical wherein use of non-programmable scientific calculator may be allowed.

- Number of sub questions (with allotment of marks) in a question may be decided by the examiner.

- Assessment of laboratory courses and research project will also have 50 % internal and 50 % semester end assessment. Semester end practical examination will be of 25 marks and 25 marks will be for internal examination. Student must perform at least eight experiments from each laboratory course. The semester end practical examination will be conducted at the end of each semester along with the theory examination.

- The Head of the Department shall send all results to the Controller of Examination for further processing.

- Every student will have privilege for revaluation of answer sheets or recounting of marks for each semester end examination. However, students will have to submit an application within 15 days from the date of declaration of results.

- Applications received for revaluation / recounting will be discussed in the Departmental committee and examiners will be appointed accordingly.

- The results of revaluation / recounting will be approved by Departmental committee and forwarded to the Controller of Examination for further processing.

Earning Credits:

At the end of every semester, a letter grade will be awarded in each course for which a student had registered. A student's performance will be measured by the number of credits that he/she earned by the weighted Grade Point Average (GPA). The SGPA (Semester Grade Point Average) will be awarded after completion of respective semester and the CGPA (Cumulative Grade Point Average) will be awarded at the end of the 4th semester.

Grading System:

- The grading reflects a student-own proficiency in the course. A ten point rating scale shall be used for the evaluation of the performance of the students to provide letter grade for each course and overall grade for the Master Programme. Grade points are based on the total number of marks obtained by him / her in all heads of the examination of the course. The grade points and their equivalent range of marks are shown in Table-I

Table – I : Ten point grade and grade description

Marks Obtained (%)	Grade Point	Letter Grade	Description
90-100	9.00- 10	O	Outstanding
80-89	8.00-8.90	A^{++}	Exceptional
70-79	7.00-7.90	A^{+}	Excellent
60-69	6.00-6.90	A	Very Good
55-59	5.50-5.90	B^{+}	Good
50-54	5.00-5.40	B	Fair
45-49	4.50-4.90	C^{++}	Average (Above)

41-44	4.1-4.49	C	Average
40	4.0	P	Pass
< 40	0.0	F	Fail (Unsatisfactory
	0.0	AB	Absent

- Non appearance in any examination / assessment shall be treated as the students have secured zero marks in that subject examination / assessment.

- Minimum P grade (4.00 grade points) shall be the limit to clear / pass the course / subject. A student with F grade will be considered as 'failed" in the concerned course and he / she has to clear the course by appearing in the next successive semester examinations.

- Every student shall be awarded grade points out of maximum 10 points in each subject (based on 10 point scale). Based on the grade points obtained in each subject, Semester Grade Point Average (SGPA) and then Cumulative Grade Point Average (CGPA) shall be computed. Results will be announced at the end of each semester and CGPA will be given on the completion of M. Sc. programme.

Computation of SGPA (Semester Grade Point Average) and CGPA (Cumulative Grade Point Average)

Grade in each subject / course will be calculated based on the summation of marks obtained in internal and semester end examination.

The computation of SGPA and CGPA will be as below

- Semester Grade Point Average (SGPA) is the weighted average points obtained by the students in a semester and will be computed as follows

$$\text{SGPA} = \frac{\text{Sum (Course Credit X Number of Grade Points in concern Course Gained by the Student)}}{\text{Sum (Course Credit)}}$$

The SGPA will be mentioned on the mark sheet at the end of every semester.

- The Cumulative Grade Point Average (CGPA) will be used to describe the overall performance of a student in all semester of the course and will be computed as under.

$$\text{CGPA} = \frac{\text{Sum (All four Semester SGPA)}}{\text{Total Number of Semester}}$$

The SGPA and CGPA shall be rounded off to the second place of decimal.

Grade Card

Results will be declared by the Departmental Committee and the grade card (containing the grades obtained by the student along with SGPA) will be issued by the university after completion of every semester. The grade card will be consisting of following details.

- Title of the courses along with code opted by the student.
- Credits associated with the course.
- Grades and grade points secured by the student.
- Total credits earned by the student in a particular semester.
- Total credits earned by the students till that semester.
- SGPA of the student.
- CGPA of the student (at the end of the 4^{th} semester).

Cumulative Grade Card

The grade card sheet showing details grades secured by the student in each subject in all semester along with overall CGPA will be issued by the University at the end of 4^{th} semester.

Semester - I

M. Sc. (Physics) Curriculum
Semester – I

PHYC-111 : Mathematical Methods in Physics

(Credits: 04; Contact Hours: 60)

Lectures: 48

Tutorials: 12

Learning Objectives:

1. To facilitate the students to understand -
   a) the basic elements of complex mathematical analysis, including the integral transform and Laplace transform.
   b) to expand a function in terms of a Fourier series, with knowledge of the conditions for the validity of the series expansion.
   c) to apply integral transform (Fourier and Laplace) to solve mathematical problems of interest in physics, use Fourier transforms as an aid for analyzing experimental data.
   d) to solve solve partial differential equations of second order by use of series expansion (Fourier series) and integral transforms.

Learning Outcomes:

1. After finishing the course the student should be able to:
   a) master the basic elements of complex mathematical analysis, including the integral theorems, obtain the residues of a complex function and to use the residue theorem to evaluate definite integrals
   b) solve ordinary differential equations of second order that are common in the physical sciences.
   c) expand a function in terms of a Fourier series, with knowledge of the conditions for the validity of the series expansion.
   d) apply integral transform (Fourier and Laplace) to solve mathematical problems of interest in physics, use Fourier transforms as an aid for analyzing experimental data.
   e) solve partial differential equations of second order by use of standard methods like separation of variables, series expansion (Fourier series) and integral transforms.
   f) Solve some simple classical variational problems.

Course Contents:

Unit I : Fourier series

Definition, Evaluation of coefficient, Fourier series representation of even and odd function General properties of Fourier series, simple applications, convergence, integration, differentiation, problems.

Unit II : Integrals Transforms

Fourier Transforms: Fourier Integral theorem. Fourier Transform. Examples. Fourier transform of trigonometric, Gaussian, finite wave train & other functions. Representation of Dirac delta function as a Fourier Integral. Fourier transform of derivatives, Inverse Fourier transform, Convolution theorem. Properties of Fourier transforms (translation, change of scale, complex conjugation, etc.). Three dimensional Fourier transforms with examples. Application of Fourier Transforms to differential equations: One dimensional
Wave and Diffusion/Heat Flow Equations.

Unit III : Laplace Transforms

Laplace Transform (LT) of Elementary functions. Properties of LTs: Change of Scale Theorem, Shifting Theorem. LTs of Derivatives and Integrals of Functions, Derivatives and Integrals of LTs. LT of Unit Step function, Dirac Delta function, Periodic Functions. Convolution Theorem. Inverse LT. Application of Laplace Transforms to Differential Equations: Damped Harmonic Oscillator, Simple Electrical Circuits.

Unit IV : Complex Analysis

Brief Revision of Complex Numbers and their Graphical Representation. Euler's formula, De Moivre's theorem, Roots of Complex Numbers. Functions of Complex Variables. Analyticity and Cauchy-Riemann Conditions. Examples of analytic functions. Singular functions: poles and branch points, order of singularity, branch cuts. Integration of a function of a complex variable. Cauchy's Inequality. Cauchy's Integral formula. Simply and multiply connected region. Laurent and Taylor's expansion. Residues and Residue Theorem. Application in solving Definite Integrals.

References:

1. Mathematical Methods for Physics and Engineers, K.F Riley, M.P. Hobson and S. J. Bence, 3rd ed., **2006,** Cambridge University Press /ISBN978052167918/2006
2. Mathematics for Physicists, P. Dennery and A. Krzywicki, 1967, Dover Publications/ ISBN-13: 978- 0486691930/1996
3. Complex Variables, A.S. Fokas & M.J. Ablowitz, Cambridge University Press, **ISBN**-13: 978- 0521534291/2003.
4. Complex Variables and Applications, J.W. Brown & R.V. Churchill, 8th Ed./ (**ISBN**: 978-0-07-333730-2/ 2004, Tata McGraw-Hill
5. First course in complex analysis with applications, D.G. Zill and P.D. Shanahan, Jones & Bartlett/ **ISBN**-13: 978-0763757724/2nd edition /1940.
6. Mathematical Physics- B.S. Rajput, Pragati Prakashan (Meerut). **ISBN** 10: 8175568712/23 edition/2005
7. Engineering Mathematics H. K. Dass/ S. Chand co. / 9788121914697/2012
8. Mathematical Physics- Kumar and Gupta/ **ISBN** 10: 8125930965/ Vikas Publishing House, New Delhi/2008

PHYC-112 : Classical Mechanics

(Credits: 04; Contact Hours: 60)

Lectures: 48

Tutorials: 12

Learning Objectives:

Classical mechanics is a course where it all started. Newton demonstrated that the same forces and laws of mechanics that apply to apples and everyday objects (the terrestrial) also govern the behavior of the moon and the planets (the celestial). He showed that nature had a high degree of structure and order, and that we could hope to uncover it and so physics was born. Newton's laws of motion, or mechanics, were not only universal, they proved to be useful. In a wide array of physical situations, classical mechanics is all you need to be able to predict the motion of apples, baseballs, bones, bridges, cars, cats, and so on. For these two reasons alone: the universality of the laws and their wide range of applicability, classical mechanics is an essential course for students of physics. But there's more: recent developments in classical mechanics have led to the theory of Chaos.

Learning Outcomes:

Classical mechanics is a hot area of active research once more. Chaos has lead to significant advances in mathematics and physics (for example, it offers some explanation for the phenomenon of ergodicity in statistical mechanics) and fundamentally changes the way we look a predictability and solvability of dynamical systems. And there's even more: while classical mechanics, by definition, does not include the 21^{st} century advances of quantum mechanics and relativity, it is nevertheless an essential prerequisite for study of these topics. For example, the Hamiltonian in quantum mechanics originates from the classical mechanics Hamiltonian that we will encounter. We use concepts of forces and energy throughout physics, so a strong grounding in classical mechanics is essential. While students studied classical mechanics already in B.Sc, in this course we will encounter more advanced techniques and solve a wider variety of problems. For example, we will encounter a reformulation of classical mechanics by Lagrange (and Hamilton) which makes it easier to deal with complicated situations such as more general coordinates or constraints on the motion. We will study the phenomenon of chaos, fully solve two-body orbit problems and derive Kepler's Laws, and develop the theory of effective forces that arise in no inertial frames. We will close with the profound Liouville's theorem for Hamiltonian mechanics and its implications in chaotic and planetary systems.

Course Contents:

Unit I : Constrained Motion

Constraints, Classification of Constraints, Principal of Virtual Work, D'Alembert's principal and its applications (Problems only), (One or Two Problems should be discussed with D'Alembert's, Lagrangian, Hamiltons from same set of problems). **Lagrangian formulation:**Generalized coordinates, Langrange's equations of motion, properties of kinetic energy function, theorem on total energy, generalized momenta, cyclic-coordinates, integrals of motion, Jacobi integrals and energy conservation,

Unit II : Hamilton's formulation

Hamilton's function and Hamilton's equation of motion, configuration space, phase space and state space, Lagrangian and Hamiltonian of relativistic particles and light rays. **Variational Principle**: Variational principle, Euler's equation, applications of variational principle, shortest distance problem, brachistrochrone, Geodesics of a Sphere

Unit III : Canonical transformation and central force

Generating function, Conditions for canonical transformation and problem, theory of chaos,Two body central force problem, stability of orbits, condition for closure, integrable power laws, Kepler's problems, orbits of artificial satellites, Virial theorem.**Poisson Brackets**: Definition, Identities, Poisson theorem, Jacobi-Poisson theorem, Jacobi identity, (Statement only), invariance of PB under canonical transformation.

Unit IV : Rotational and oscillatory motion

Rotating frames of reference, inertial forces in rotating frames, Larmour precision, electromagnetic analogy of inertial forces, effects of Coriolis force, Focoult's pendulum, small oscillations, Normal co-ordinates and applications to vibrations of linear in triatomic molecules. Liouville's theorem for Hamiltonian mechanics and its implications in chaotic and planetary systems.

References:

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2. Classical Mechanics, by H. Goldstein, Charles Poole, John Safco, 3 rd Edition (Published by Pearson Education Asia (2014)) ISBN 10:8131758915 / ISBN 13:9788131758915
3. Classical Mechanics, by N.C. Rana and P.S. Joag (Tata McGraw-Hill, 1991) ISBN 10: 0074603159 ISBN 13: 9780074603154
4. Mechanics, by A. Sommerfeld (Academic Press, 1952) ISBN 10: 0126546703 ISBN 13: 9780126546705
5. Introduction to Dynamics, by I. Perceival and D Richards (Cambridge Univ. Press. 1982). ISBN-10: 0521281490 / ISBN-13: 978-0521174060
6. Classical Mechanics, P. V. Panat (Narosa Pub. House Pvt. Ltd.) 2008 ISBN: 9788173196317 / 8173196311
7. Classical Mechanics, by Gupta, Kumar and Sharma, Pragati Prakashan, Meerut (2012). ISBN number 9350063808 / 9789350063804
8. Classical Dynamics of Particles and Systems by Marion and Thomtron, Third Edition, Horoloma Book Jovanovich College Publisher (2003) ISBN-10: 0534408966 ISBN-13: 978-0534408961
9. Introduction to Classical Mechanics by R. G. Takawale and P. S. Puranik, Tata Mc-Graw Hill Publishing Company Limited, New Delhi. ISBN 10:0070966176 / ISBN 13: 9780070966178
10. Classical Mechanics by J. C. Upadhyaya, Himalaya Publishing House (2015) ISBN Number: 978-93-5142-798-8, Book Edition :2nd

PHYC-113 : Quantum Mechanics

(Credits: 04; Contact Hours: 60)

Lectures: 48

Tutorials: 12

Learning Objectives: Being a core course, this course is central in answering fundamental questions in physics as well as to further the ability to design and exploit physical phenomena for applications. With advances in material synthesis and device processing capabilities, this course will be beneficial in applied disciplines, such as material science, electrical engineering and of course applied physics. The dependence on simplistic phenomenological equations does no longer work with, understanding a more fundamental origin of the phenomena is a need of hour. Devices such as Josephson junctions, semiconductor lasers and transistors cannot be understood in terms of simple classical concepts. Applied scientist will be able to design and exploit such devices for the information age.

Learning Outcomes of the Course: In the course important quantum mechanical concepts will be developed. These concepts may be the electronic levels in the hydrogen atoms or the rate at which electrons scatter from a defect. The concepts developed will then be applied to typical problems encountered in technology-related applications. Numerical values are used to give the student a feel for numbers which are encountered in real applications.

Solving number / concept oriented problems will help the takers of this course in excelling the competitive exams such as GATE, NET, DRDO-SET, BARC Training School Entrance Exam, etc. Further the course can be a pre-requisite for elective courses in nuclear physics, spectroscopy, condensed matter physics, semiconductor physics, sensor physics, etc.

Course Contents:

Unit : I - Physical Symmetries and Conservation Laws:

Introduction; Symmetry and Conservation Laws; Spatial Translation an Momentum Conservation; Time Displacement Symmetry; Rotation Symmetry and Angular Momentum; Angular Momentum: Commutator algebra of L and p, L and r, L^2 and r^2, etc., Eigen values and Eigenfunctions; Spin Angular Momentum: Stern Gerlach experiment; General angular momentum: definition of J, commutator of J and components of J, ladder operators J_+ and J_-, commutators of ladder operators, ladder operator with J and J_z, eigen values of J_+, J_-, J^2, components of J; Combination of Angular Momentum States: Clebsch-Gordon or Wigner Coefficients, Application Example: Bandedge States in Optical Materials

Unit : II Approximation methods:

The WKB approximation. Application to bound states connecting formulae Bohr sommerfield Quantization rules, WKB application to transmission problem, Variational method: Particle in a box, harmonic oscillator, H_2^+ ion; Time independent Perturbation theory, non-degenerate and degenerate cases. Application to anharmonic potentials of the form x^3 ; Time dependent perturbation theory, Fermi's rule, Harmonic perturbation

Unit : III Collisions and Scattering:

Introduction, Two-Particle Collisions: Center of Mass and Laboratory Coordinate Description; Scattering Cross Section, Scattering Angles in Laboratory and Center-of-Mass Systems; Scattering as a Stationary State Problem: An integral equation for scattering, Microscopic Reversibility and Optical Theorem, The Born Approximation: Validity of the Born Approximation, Partial Wave Analysis: Calculation of the Phase Shifts, Application Example: Screened Coulomb Potential Scattering; Scattering Rate and Macroscopic Transport Properties; Ionized Impurity Limited Mobility, Application Example: Alloy scattering; Application example: Interface Roughness Scattering, Application Example: Carrier-Carrier Scattering; Electron-Hole Scattering; Electron-Electron Scattering; Auger Processes and Impact Ionization

Unit : IV : Magnetic Effects:

Introduction, Charged Particles in a Magnetic Field: General Hamiltonian, Free Electrons in a Magnetic Field, Landau levels, The Aharonov-Bohm effect, Applications: Superconducting devices, Quantum Hall Effect, Zeeman effect, Spin-Orbit Coupling: Diamagnetic and Paramagnetic Effects in atoms and solids, Paramagnetism in the Conduction Electrons in Metals, Application Example: Cooling by Demagnetization, Exchange Interaction: Ferromagnetism and Antiferromagnetism, Exchange Interaction and Ferromagnetism, Antifenomagnetic Ordering, Application Example: Magnetic Recording, Magnetic Resonance Effects - Nuclear Magnetic Resonance

References:

(1) Quantum Mechanics: Fundamentals and Applications to Technology, Jasprit Singh, (ISBN 0-471-15758-9, John Wiley 7 sons 1997) (*The course is based on this book*).
(2) Introduction to Quantum Mechanics David J Griffiths (2nd Edition, ISBN-13: 978-0131118928 ISBN-10: 0131118927; Prentice Hall, Upper Saddle River NJ 07458, 2004)
(3) Quantum Chemistry, Donald A McQuarrie (2nd Edition ISBN -13: 978-1891389504 ISBN-10: 1891389505; University Science Books, 2008)
(4) Quantum Mechanics : Concepts and Applications, Nouredine Zettili (ISBN 978-0-470-02678-6 **ISBN** 978-0-470-02679-3 John Wiley & Sons 2009)

PHYC-114 Statistical Mechanics

(Credits: 04; Contact Hours: 60)

Lectures: 48

Tutorials: 12

Learning Objectives: Various properties of matter in both equilibrium with environment and in non-equilibrium can be explained by the ultimate laws of physics, viz., statistical mechanics. This course deals with the laws of quantum statistical mechanics. Main objectives include how a collection of quantum particles would behave. Being a core course it should be taught in the first or second semester.

Learning Outcomes: The course is based on minimal mathematical derivations and maximum applications to various modern discoveries ranging from Ohm's law to quantum Hall effect to Bose Einstein condensates – optical molasses. The takers of this course will get an in depth knowledge of the fundamental idea behind various phenomena in condensed matter physics. Further the problems taken will help a student in various exams like JEST, GATE, etc.

Course Contents:

Unit I : Ideal Fermi-Dirac Gas:

Fermi-Dirac distribution, Degeneracy, Electrons in metals, Thermionic emission, Magnetic susceptibility of free electrons, Superconductivity

Unit II : Ideal Bose systems:

Photons, Phonons in solids, Bose-Einstein Condensation Liquid He, Tisza 2-fluid model, Landau theory, superfluidity

Unit III: Semiconductor Statistics:

Statistical equilibrium of free electrons in semiconductors, Non-degenerate case, Impurity semiconductors, Degenerate Semiconductors, Occupation of donor levels, Electrostatic property of P-N junction

Unit IV: Special Topics in Statistical Mechanics:Non-Equilibrium States:

Boltzmann transport equation, Particle diffusion, Electrical conductivity, Isothermal Hall effect, Electron-Hole recombination, The Ising model, Bragg-Williams approximation, The 1-D Ising model

References

(1) Statistical Mechanics, , Kerson Huang (ISBN 0-471-8158-7, John Wiley & Sons 1987)
(2) Statistical Mechanics, B K Agarwal and Melvin Eisner (ISBN 9788122433548, New Age International (p) Ltd 2013)
(3) Statistical Mechanics, B B Laud (ISBN-10: 8122432786 ISBN-13: 978- 8122432787 ASIN: B0075MAT4S, New Age International Publishers Ltd.-New Delhi 2012)

PHYF-115 : Research Methodology

(Credits : 01 ; Contact Hours : 15)

Lectures: 12

Tutorials: 03

Learning Objectives:

1. to define research and describe the research process and research methods
2. to understand qualitative research and methods used to execute and validate qualitative research
3. to know how to apply the basic aspects of the research process in order to plan and execute a research project.
4. to provide insight into the processes that lead to the publishing of research.
5. to be able to present, review and publish scientific articles

Learning Outcomes:

1. Students will be able to -

   a) do systematic literature survey, formulation of a research topic, study design, analysis and interpretation of data.
   b) to design a research approach for a specific research issue of their choice.
   c) select a suitable analytical method for a specific research approach.
   d) demonstrate a good understanding of how to write a research report.
   e) critically assess published quantitative research with regard to the statistical methods and approaches adopted

Course Contents:

Unit I : Research Fundamentals:

Introduction: Definition, objectives of the research, characteristics of the research, what makes people to do research, importance of research,

Unit II : Identification of Research Problem :

Defining the research problem: Identification of research problems, selection of research problem, facts one should know regarding selection of research problem, the process of research problem definition, some facts involved in defining research problem

Unit III : Formulation of Research Problem :

Formulation of the problems: steps involved in defining a problem, formulation of the problems, Formulation of hypothesis: Concept of hypothesis, hypothesis testing, Developing the research plan: implementation, interpreting and reporting the findings, Importance of hypothesis of in decision making.

Unit IV : Research Report and Proposal Writing :

Introduction, research proposal writing: costing, the research proposal, rationale for the study, research objectives, research methodology, target respondents, research Centres, sample size and sample composition, sampling procedures, research project execution, research units; An insight into research report and proposal, research project synopsis, research report writing : types of research reports, guidelines for writing reports; Steps in writing report, report presentation, typing the report, documentation and bibliography, formatting guidelines for writing a good research report / research paper.

References:

1. Research Methodology by Dr. S. L. Gupta, Hitesh Gupta; International Book House Pvt Ltd **(2013),** ISBN-10: 8191064278, ISBN-13: 978-8191064278
2. Basic Research Methods-Gerard Guthrie SAGE Publications, India, Pvt Ltd, New Delhi **(2010),** ISBN-10: 8132104579, ISBN-13: 978-8132104575
3. Research Methodology-methods and techniques By C. R. Kothari, New Age International Publishers **(2011)** ISBN 978-81-224-1522-3
4. Principles of Research Methodology- Phyllis G. Supino, Jeffrey S. Borer; Springer, Verlag New York **(2012),** ISBN-ebook: 1461433592, ISBN (Hardcover): 978-1461433590
5. Research Design Qualitative, Quantitative. and Mixed Methods Approaches- John W. Creswell; SAGE Publications Ltd, UK **(2011),** ISBN-9780857023452
6. Research Methodology -A Step-by-Step Guide for Beginners- Ranjit Kumar; Sage Publications Ltd **(2010)**, ISBN- 1849203016.
7. Scientific Writing and Communication- Angelika Hofmann; Oxford University Press, US **(2010),** ISBN-13-: 978-0 199947560, ISBN-10: 01 99947562
8. Writing Science: How to Write Papers That Get Cited and Proposals That Get Funded- Joshua Schimel, Oxford University Press, **(2011)**, ISBN: 9780199760237
9. Handbook of Scientific Proposal Writing- A.Yavuz Oruc; CRC Press, Taylor & Francis group **(2011)**, ISBN: 9781439869185

<u>COM-100 : Constitution India ((Credits : 02 ; Contact Hours : 30)</u>

This course will be taught at common level. University will arrange teaching classes for this course.

PHYL-121 Lab course 1 (General Physics) : Credits 2
and
PHYL-122 Lab course 2 (Computational Physics based on PHYC -111, 112 , 113 and 114) : Credits 2

Learning Objectives:

Physics is a science and art of measurements. "Measure the things that are measurable. Things which are not measurable, make them measurable". In these lab courses spanned over two semesters, a student will have hands on training on measurements of fundamental constants in physics as well as computational physics. Therefore this be taught at Sem I and II levels. Students will get knowledge about usage of units and dimensions. This course is based on concepts in quantum mechanics, statistical mechanics and electrodynamics. The solution of Schrodinger equation will bring excitements.

Learning Outcomes :

This course will help a student in designing an experiment for measurements of desirables. This being a core course the students will gain knowledge in understanding various concepts in physics.

A student is expected to perform at least 8 experiments in each of the courses.

PHYL-121 Lab Course 1 (General Physics) : Credits 2

(1) Determination of charge on an electron by Millikan's oil drop method
(2) Determination of specific charge (e/m) of an electron by Thomson method
(3) Study of black body radiation and determination of the Planck constant h
(4) Verification of Bohr's theory using Franck Hertz apparatus
(5) Study of Boltzmann statistics and determination of Boltzmann constant k_B
(6) Determination of thickness of a given thin wire using LASER
(7) Determination of wavelength of a given source using Michelson's interferometer
(8) Determination of compressibility of a given liquid using Raman Nath experiment
(9) Determination of spin on an electron using Stern Gerlach experiment
(10) Study of magnetic resonance in given samples using ESR/NMR kit
(11) Study of the x-ray telexometer

PHYL-122 Lab Course 2 (Computational Physics based on PHYC -111, 112, 113 and 114) : Credits 2

(This course is based on computation using MS-EXCEL)

(1) Determine the roots of given equation/expression
(2) Evaluation of given integrals using Simpson's 1/3 rule
(3) Solution of Schrodinger equation for square / harmonic oscillator potential
(4) Solution of Schrodinger equation for triangular potential
(5) Plotting the hydrogen atom ground state 1s and 2s wave functions
(6) Determination of normalization constant for 1s wave function of hydrogen atom
(7) Plotting the hydrogen atom ground state 2p wave function
(8) Study of Gaussian Type Orbitals (GTOs) and Slater Type Orbitals (STOs)
(9) Comparison of Gaussian Type Orbitals (GTOs) with Slater Type Orbitals (STOs)

Semester - II

Semester – II

PHYF-211 : Foundation Course in Electronics
(Linear and Digital Electronics)

(Credits: 04; Contact Hours: 60)

Lectures: 48

Tutorials: 12

Learning Objectives:

- To establishes the general method for analyzing and predicting the performance of operational amplifiers and related integrated circuits.
- To develop the students for designing realistic circuits to perform specified operations.
- To enable the students to select available devices for intended operations.

Learning Outcomes:

After going through this course students will get confidence about designing of linear and digital electronics circuit for various applications.

Course Contents:

Unit I : Operational amplifier:

Symbol and terminals, the ideal op-amp, the practical op-amp. Operational amplifier parameters**:** Input offset voltage, Input offset current, Input bias current, Input impedance, Output impedance, Open loop voltage gain, Common – Mode rejection ratio, Slew rate. Inverting, non - inverting amplifier.

Unit II: Applications of Operational Amplifier and Timing Circuits:

Adder, Subtractor, Integrator, differentiator, Comparator & Schmitt's trigger; Wave form generators: Astable Multivibrator, Monostable Multivibrator, and Wien Bridge Oscillator. Integrated circuit timer**:** Block diagram of IC – 555, Monostable, Astable Multivibrator using IC- 555.

Unit III : Numbers systems, Codes and Combinational Logic:

Decimal, Binary, & Hexadecimal numbers systems, and its arithmetic's. BCD and Gray code. AND, OR, NOT operations, NAND and NOR operations, NAND and NOR as building blocks, Exclusive – OR operation. Boolean algebra, Standard Representation for Logical Functions, Half & Full adder, Parallel 4-bit adder, encoder (decimal to binary), Decoder (BCD to decimal), BCD to seven segment decoder, Multiplexer: (4:1) and (8:1), Demultiplexer: (1:8) and (1:16) and their applications.

Unit IV : Sequential Logic:

Flip-Flops: S-R, D- type, T-type, J-K and J-K master-slave. Shift registers: Serial in Serial out, Serial in parallel out, Parallel in Parallel out, Parallel in Serial out. Ripple counters: Mod-16, Mod – 12 and Mod- 10. Synchronous counters: Mod-8 and Mod-16.

References:

1. Operational amplifier with Linear integrated circuits**,** by William D Staney Fourth Edition, LPE PEARSON Education, 2004, ISBN 81-297-0463-3.
2. Op-Amp and Linear Integrated Circuits, R. A. Gaikwad 4^{th}. Ed, Prentice Hall of India, 2002, ISBN 81 –203–2058–1.
3. Operational amplifier & Linear integrated circuits, 6/e Robert F. Coughlin, Frederick F. Driscoll Modern Digital Electronics , by R P Jain, 3'rd Edition, Tata McGraw – Hill Publishing Company Ltd. 2003, ISBN 0-07-049492-4.
4. Digital Electronics, Second Edition, Tokheim, 1985, ISBN 0-07-064980-4.
5. Principles of Electronics, V. K. Metha , Rohit Mehta, S. Chand and Company Ltd. 2012, ISBN: 81-219-2450-2.
6. Digital Fundamentals, by Thomas L Floyd, 2^{nd} Edition Charles E. Merrill Publishing Company.
7. Electronic Devices**,** by Thomas L Floyd, Charles E. Merrill Publishing company

PHYF-212 : Foundation Course in Spectroscopy
(Atomic and Molecular Physics)

(Credits: 04; Contact Hours: 60)

Lectures: 48

Tutorials: 12

Learning objectives:

The atom, the nucleus, the electron and the photon - four necessary steps for the development of quantum physics. The structure of the atom. Atoms in electric and magnetic fields. Fine and hyperfine structure. X-ray spectroscopy. Molecular structure. Rotation-, vibration- and electronic spectra. Chemical bonds. Optical spectroscopy. Applying laser spectroscopic methods as well as other modern tools in atomic and molecular physics, special efforts will be made in laboratory work.

Leaning Outcome:

The course is a continuation of the Atomic and Molecular Physics course. Introductory Atomic- and Molecular Physics will be discussed more in detail. A big part of the course will give a view of the modern experimental tools of Atomic- and Molecular Physics job prospects.

Course Contents :

Unit I : Introduction

Stern Gerlach experiment, Quantum states of an electron. Quantum numbers. Spectra of Hydrogen atom. Spin angular momentum, orbital angular momentum. Coupling of spin and orbit. Fine structure, spectroscopic terms, selection rules. Spectra of the alkali elements.

Interaction energy in L-S and j-j coupling, Hund's rule and term reversal. Zeeman effect in one valence electron atoms, interaction energy, selection rules, Zeeman patterns. Paschen-Back effect, Pauli principle. Hyper fine structure (Qualitative)

Unit II : Rotational spectroscopy:

Classification of molecules, Interaction of radiation with rotating molecule, IR spectra of diatomic molecules, Rigid rotator, energy levels, eigen functions and spectrum of rigid rotator, non-rigid rotator, isotopic substitution, effect of vibration on rotation, Intensities of rotational lines, information derived from rotational spectra..

Unit III : Vibrational spectroscopy:

Vibrational course structure, Deslandres table, Diatomic molecule as a harmonic oscillator, energy levels, eigen functions and spectrum of harmonic oscillator, Morse potential, anharmonic oscillator, vibrating rotator with & without Born Oppenheimer approximation.

Unit IV : Laser Fundamentals:

Masers and lasers, methods of obtaining population inversion, Ammonia maser, Spontaneous and induced emission, Einstein's A and B coefficients, Properties of lasers, Principle & working of He-Ne, Ruby, semiconductor and color center.

References

1. Introduction to Atomic Spectra H. E. White McGraw Hill, First Edition ISBN-10: 0070697205 / ISBN-13: 978-0070697201.
2. Atomic Physics by Christopher J. Foot, Oxford University Press 2005. ISBN 10: 0198506961 / ISBN 13: 9780198506966
3. Fundamentals of Molecular Spectroscopy C.N Banwell & Elaine M. McCash. Tata McGraw Hill. ISBN 10: 0077079760 ISBN 13: 9780077079765
4. Spectra of diatomic molecules G. Herzberg, Krieger Malbar Florida (2015). ISBN 10: 5458354060 ISBN 13: 9785458354066.
5. Molecular structure and spectroscopy by G Aruldhas Prentice Hall of India (2009) ISBN 10: 8120332156 ISBN 13: 9788120332157.
6. Spectroscopy volume 2, Edited by B.P. Straughan and S.Walker, London Chapman and Hall. ISBN 10: 0470150319 ISBN 13: 9780470150313.
7. Laser & Non linear Optics B. B. Laud. Wiley Eastern Limited (2011). ISBN 10: 8122430562 ISBN 13: 9788122430561
8. Laser Spectroscopy, Basic Concepts and Instrumentation by W. Demtroder, Springer. ISBN 10: 0387103430 ISBN 13: 9780387103433
9. Physics of atoms and molecules B. H. Bransden and C. J. Joachain Pearson Education. ISBN 10: 0306410494 ISBN 13: 9780306410499

PHYF-213: Foundation Course in Nuclear Physics (General Nuclear Physics)

(Credits: 04; Contact Hours: 60)

Lectures: 48

Tutorials: 12

Learning Objective:

This course will introduce students to the fundamentals of General Nuclear Physics. It aims to provide a coherent and concise coverage of traditional nuclear physics. Important topics of current research interest will be also discussed, such as radioactivity, radiation detector and accelerators which plays an important role in the realization of this course.
A General Nuclear Physics is a foundation course as it is a preparatory course for university-level art and design education.

Learning Outcomes:

On successful completion of the course, students should be able to:

1. Apply general considerations of Nuclear physics to atomic and nuclear system; make general orders of magnitude of estimation of physical effects.
2. Explain how interaction of gamma radiation with matter; the working principle of accelerators and radiation detector.

Pre-requisite - This general nuclear physics is a pre-requisite for certain other courses. One can starts an entrepreneurship after the completion of this general nuclear physics foundation course.

Course Contents:

Unit I : General Properties of Nucleus:

Nuclear size and its determination, nuclear radii by electron scattering and mirror nuclei methods. Binding energy, mass defect, Packing fraction. Semi-empirical mass formula and its applications. Quantum numbers of nuclei, nuclear angular momentum, nuclear magnetic dipole moment, electric quadrupole moment.

Unit II : Radioactivity (Natural and Artificial):

The basis of the theory of radioactive disintegration, the disintegration constant, half life and the mean life. Successive radioactive transformation, radioactive equilibrium, the natural radioactive series, units of radioactivity. The discovery of artificial radioactivity, the artificial radio nucleids, electron and positron emission, orbital electron capture, the artificial radio nucleids: alpha emitters.

Unit III : Nuclear Radiation detectors:

Types of detectors, ionization chamber, G.M. Counters, proportional counter, semiconductor detector, counting errors, counting efficiency, scintillation counter, energy decapitation in phosphor, photoemission from phosphor.

Unit IV : Nuclear Models and Acceleration of Charged particles:

Liquid drop model, single particle levels and magic numbers, evidence of shell effects, Bhor-wheeler theory of fission. Shell model, single particle shell model, deformed nuclei and collective model, nuclear wave function for even-even nuclei, energy spectrum and wave function for odd – A nuclei. Acceleration of Charged particles: Cascade generators, Cockroft and Walton voltage multiplier, Vande Graff machine, tandem accelerators, linear multipole accelerator, wave-guide accelerator, cyclotron.

Books:

1. Introduction to Nuclear Physics; H.A. Enge, Addison- Wesley, 1975.
2. Nuclear Physics; I. Kaplan, 2nd edition, Narosa, 1989.
3. The atomic Nucleus; R.D. Evans, Mc Graw- Hill, New York 1955.
4. Nuclear Physics; R.R. Roy and B.P. Nigam, Wiley – Eastern Ltd, 1983.
5. Basic Nuclear physics; B. N. Shrivastava, Pragati prakashan, Meerut.
6. Theory of Nuclear Structure; M. K. Pal, East – weast press Ltd. 1982.
7. Nuclear Physics; D.C. Tayal, Himalaya Publishing House, Bombay.
8. Experimental Nuclear Physics; E.Serge, John Wiley and sons, New York, 1959.
9. Encyclopaedia of nuclear Physics 3 : M.Chandrabhanu first edition : 2011.
10. Atomic and Nuclear Physics: N Subrahmanyam Brijlal. first edition : 1984.
11.. Atomic and Nuclear Physics : Shatendra Sharma 2008.
12. Nuclear Physics An Introduction: S B Patel 2011.
13. Nuclear Physics : Rajkumar First Edition 2010.
14. Fundamentals of Nuclear Physics : Prof Jahan Singh, Pragati Prakashan First Edition 2012.
15. Radiation Physics For Medical Physicists E.B Podgor Second,Enlarged Edition Springer 2009.
16. Physics and Engineering of Radiation Detection Syed Naeem Ahmed Queen's University, Kingston, Ontario Academic Press Inc. Published by Elsevier First edition 2007
17. Radiation, Ionization, and Detection in Nuclear Medicine: Tapan K.Gupta ISBN978-3-642-34076- 5(eBook) Springer-Verlag Berlin Heidelberg 2013.

PHYF-214: Foundation Course in Condensed Matter Physics
(General Condensed Matter Physics)

(Credits: 04; Contact Hours: 60)

Lectures: 48

Tutorials: 12

Learning Objectives: Bonding in solids, thermal and electrical properties of solids, energy bands, imperfections in solids, properties of semiconductors and insulators. This course deals with crystalline solids and is intended to provide students with the basic physical concept and mathematical tools used to describe solids. The course deals with groups of materials, as in the periodic table, in terms of their structure, electronic, optical, and thermal properties. Specific objectives are: To show how crystal symmetry leads to substantial mathematical simplifications when dealing with solids. To describe basic experimental measurements, to show typical data sets and to compare these with theory.

Learning Outcomes: The field of General Condensed Matter Physics investigates different classes of materials -metals, ceramics, electronic materials with an emphasis on the relationships between the underlying structure and the processing, properties, and performance of the materials. Research opportunities are offered as scientists and technologists, etc in national and international institutions.

Course Contents:

Unit I : Crystal Structure :
Lattice translation vectors and lattices, basis crystal structure, primitive and non-primitive cell, fundamental types of lattices, 2d & 3d Bravais lattices, characteristics of cubic lattices, miller indices, symmetry elements, point group and space groups, different crystal structures : hexagonal close packed structure, s.c., b.c.c., f.c.c, sodium chloride, liquid crystals.

Unit II : Lattice vibration and thermal properties :
Vibrations of one –dimensional monoatomic and diatomic lattice, properties of lattice waves, phonons, Einstein's theory of specific heat, Debye models of lattice heat capacity, anharmonicity, thermal expansion and thermal conductivity, inelastic scattering of neutron by phonons, lattice thermal conductivity.

Unit III : Free electron model of metals :
Free electron gas in three dimensions, Fermi – Dirac distribution, heat capacity of electron gas, hall effect, Matthiessen rule, fermi surface, de Hass von Alfen effect, magnetoresistance, tight binding method, pseudopotentials.

Unit IV : Energy bands in solids :
Origin of energy band gap, Bloch function, Kronig-Penny Model, number of states in a band, distinction between metals, insulators and semiconductors, concept of holes, equation of motion for electron and holes, effective mass of electron and holes.

References

1. Introduction to solid state physics – C. Kittel, Willey Eastern Pvt. Ltd. (2015) ISBN 10: 8126535180 ISBN 13: 9788126535187.
2. Elementary Solid State Physics – M. A. Omar, Addition Wesley Pvt. Ltd. ISBN 10: 0201607336 ISBN 13: 9780201607338
3. Solid State Physics – A. J. Dekker, Mcmillan India Ltd. (1958)
4. Solid State Physics - Aschroft and Mermen, New York, Holt, Rinehart and Winston (1976).
5. Introduction to Solids – L. V. Azaroff McGraw Hill, New York (1960)
6. Solid State Physics – S. O. Pillai, New age International Pvt. Ltd (2015). ISBN 10: 8122436978 ISBN 13: 9788122436976
7. Solid State Physics – M. A. Wahab (2011). ISBN 10: 8184870566 ISBN 13: 9788184870565
8. Concept in Solid State Physics – J. P. Shrivastava, Prentice Hall Ltd.
9. Solid State Physics – Saxena, Gupta, Saxena. ISBN 10: 9350068435 ISBN 13: 9789350068434

PHYL-221 Lab course 3 (Condensed Matter Physics + Nuclear Physics + Spectroscopy)

This course is based on **Foundation Courses: Condensed Matter Physics, Nuclear Physics and Spectroscopy**)

(1) Determination of characteristics of Geiger Muller counter/tube: Operating voltage and Dead time
(2) Determination of characteristics of Geiger Muller counter/tube: Counting statistics
(3) Study of Hall effect and determination of type and number of charge carriers, Hall coefficient and drift mobility
(4) Study of variation of resistivity of given specimen using 4-probe method and determination of its energy bandgap
(5) Determination of magnetic susceptibility of diamagnetic and paramagnetic samples using Guoy balance method
(6) Study of variation of dielectric constant as a function of temperature and verification of the Curie law and determination of the Curie temperature
(7) Study of variation of photoconductivity using polarized light
(8) Recording of spectra of given specimen using spectrophotometer

A student is expected to perform at least 8 experiments.

PHYL-222 Lab course 4 (Electronics + Computational Physics)

This course is based on **Foundation Course: Electronics**. It also contains some experiments based on **Computational Physics**. Students will choose any four experiments from list of experiments below based on Electronics and four experiments from list of experiments below based on computational physics)

(1) Determination of characteristics of OP-AMP 741 : CMRR and Slew rate
(2) Determination of characteristics of OP-AMP 741 : input offset voltage and input bias current
(3) Unity gain amplifier and adder using OP-AMP 741
(4) Monostable multivibrator using OP-AMP 741
(5) Astable multivibrator using OP-AMP 741
(6) Schmidt trigger using OP-AMP 741
(7) Inverting and non inverting amplifier using OP-AMP 741
(8) Determination of band structure of given specimen
(9) Study of given XRD data for cubic and diagonal type materials and determination of lattice parameters
(10) Study of given XRD data for tetragonal and hexagonal type materials and determination of lattice parameters

A student is expected to perform at least 8 experiments.

PHYR-231 : (Review of literature for Research Project)

Students are expected to undertake research project and complete review of literature

PHYR-232 : (Formulation of Topic of Research Project)

Students are expected to formulate the topic of research project

Semester - III

Semester – III

PHYF-311 : Methods in Theoretical Physics

(Credits: 04; Contact Hours: 60)

Lectures: 48

Tutorials: 12

PHYE-312 Generic Electives 1 (A1/ B1/ C1/ D1)
PHYE-312 – Elective 1 (A1): 8086 Microprocessor and Interfacing
(Credits: 04; Contact Hours: 60)

Lectures: 48

Tutorials: 12

Learning Objectives:

1. To facilitate the students to understand
   a) the concepts of microprocessor and assembly language programming.
   b) the concept of interfacing devices at laboratory as well industrial level
2. To provide an opportunity to the students to enter into entrepreneurship.

Learning Outcome:

1. Students will be able to learn
   a) Microprocessor architecture, physical configuration of memory, logical configuration of memory, microprocessor programming and interfacing.
2. Students will be capable to perform following job
   a) Industrial automation using 8086 interfacing and programming.
   b) Start his / her own small scale industry for manufacturing microprocessor based automated devices.
3. Students will have option to start his / her teaching career either in science or engineering colleges / institutes as this course is included in science as well engineering discipline.

Course Contents:

Unit I : Introduction :

Overview of Microcomputer structure and operation, memory, input / output, CPU, address bus, data bus, control bus, 8086 microprocessor family overview, **8086 internal architecture:** execution unit, (flag register, general purpose register, ALU), Bus interface unit, segment register, stack pointer register, pointer and index register [Refer Douglas and Hall book for above articles], **Pin out and pin functions of 8086 :** The pin out, power supply requirements, DC characteristics, input characteristics, output characteristics, pin connections (common pins, maximum mode pins and minimum mode pins) **Addressing Modes**: Data addressing modes: Register addressing, Immediate addressing, Direct addressing, register indirect addressing, base plus index addressing, register relative addressing, base relative plus index addressing, Programme memory addressing modes: Direct program memory addressing, relative program memory addressing, indirect program memory addressing; stack memory addressing modes.

Unit II : Data Movement, Arithmetic and Logical Instructions:

MOV revised: machine language, the opcode, MOD field, register assignments, R/M memory addressing, special addressing, **PUSH/POP :** PUSH, POP, initializing the stack**; Miscellaneous data transfer instructions:** XCHG, IN and OUT, **Arithmetic**

and Logic Instructions: Addition, subtraction and comparison: Addition: Register addition, immediate addition, memory to register addition, array addition, increment addition, addition with carry**; Subtraction:** Register subtraction, immediate subtraction, decrement subtraction, subtraction with barrow**; Comparison, Multiplication and division**: **Multiplication**: 8 bit multiplication, 16 bit multiplication; **Division:** 8 bit division, 16 bit division; **Basic Logic Instructions:** AND, OR, Ex-OR, TEST, NOT, NEG**; Shift and Rotate: Shift:** left shift, right shift; **Rotate:** Rotate left, rotate right

Unit III: Program Control Instructions and Assembly Language Programming:

The Jump Group: **Unconditional jump:** short jump, near jump, far jump, indirect jumps using an index; **Conditional Jumps:** LOOP, conditional LOOPs; **Procedures**: CALL, near CALL, far CALL, indirect memory address, RET; **Machine Control and Miscellaneous Instructions:** Controlling the carry flag bit, wait, HLT, NOP ; **Assembly Language Programming: Assembler directives:** ASSUME, DB, DD, DQ, DT, DW, END, ENDP, ENDS, EQU, EVEN, EXTRN, GLOBAL, GROUP, INCLUDE, LABEL, LENGTH, NAME, OFFSET, ORG, PROC, PTR, PUBLIC, SEGMENT, SHORT, TYPE [Refer Douglas and Hall book for above articles **Assembly Language Programming:** Sum of an array, factorial, largest / smallest from given array, sorting of numeric array, square root.

Unit IV : Input / Out Interfacing (with reference to 8086 Microprocessor):

Introduction to I/O interface, I/O instructions, isolated and memory mapped I/O, basic input and output interfaces, handshaking, **I**/O port address decoding: decoding of 8-bit I/O addresses, decoding of 16 – bit I/O address; The programmable peripheral interface: basic description of 8255, programming the 8255, mode 0 operation, an LCD display interfaced to 8255, a stepper motor interfaced to 8255, Mode 1 strobed input, mode1 strobed output , Mode 2 bisectional operation

References:

1. The Intel Microprocessors, Architecture Programming and interfacing, Barry B Brey ; Sixth Edition ; Prentice Hall International, Publications, **(2002),** ISBN-10: 0130607142, ISBN-13: 978-0130607140
2. The Intel Microprocessors, Architecture Programming and interfacing, Barry B Brey ;Eighth Edition ; Prentice Hall International, Publications **(2009),** ISBN 0-13-502645-8
3. Microprocessors and Interfacing : Programming and Hardware, Douglas V Hall : II Edition ; Tata McGraw-Hill **(1990),** ISBN-10: 0070257426, ISBN-13: 978-0070257429.
4. Microcomputer Systems : The 8086 / 8088 Family; Architecture, Programming and Design, Yu-Cheng Liu and Glenn A. Gibson, Prentice Hall International, Publications **(1986),** ISBN-10: 013580499X, ISBN-13: 9780135804995.
5. The 8086/8088 Family: Design, Programming and Interfacing, John, Uffenbeck, Prentice Hall International, Publications **(1986),** ISBN-10: 0132467526, ISBN-13: 978-0132467520

PHYE-312 – Elective 1 (B1) : Atomic Spectroscopy:

(Credits: 04; Contact Hours: 60)

Lectures: 48

Tutorials: 12

Learning Objectives:

a) The concept of the photon, however, emerged from experimentation with **thermal radiation**, electromagnetic radiation emitted as the result of a source's temperature, which produces a continuous spectrum of energies. More direct evidence was needed to verify the quantized nature of electromagnetic radiation. In this course, we describe how experimentation with visible light provided this evidence.
b) This course addresses various aspects of atomic spectroscopic analysis relevant to research and industry.
c) Seeing that spectroscopy is a set of tools that can be put together in different ways to understand systems and solve chemical problems
d) Understanding basic concepts of instrumentation, data acquisition and data processing.

Learning Outcomes:

After completing this course the student will be able to use spectroscopic methods for qualitative and quantitative analysis.

Course Contents

1. **Reletivistic effect on Atomic Spectra**: Sommerfeld relativity correction, fine structure and spinning electrin, observed hydrogen fine structure, fine structure of ionized helium line λ = 4686 Å, the Dirac electron in hydrogen atom, Sommerfeld formula from Dirac's theory, Lamb shift (qualitative).

2. **Atoms in magnetic field**: Vector model of a one electron system in weak magnetic field, magnetic moment of bound electron, magnetic interaction energy, selection rules, intensity rules, Paschen Back effect, Paschen Back effect of a Principal series doublet, selection rules for Paschen Back effect, The Zeeman and Paschen Back effects for hydrohen, Quantum mechanical model of an atom in a strong magnetic field.

3. **Complex Spectra & X-ray Spectra**: Displacement law, Law of alternation of multiplicities. Terms arising due to three or more valence electrons, Lande interval rule. Hund's rules, Pauli exclusion principle for p^2, p^3, p^4, p^5, d^2 electrons.
   Mosley's law, Absorption spectra, energy levels, selection and intensity rules (Burger - Dorgelo - Ornstein rules), regular and irregular doublet law, predicted structure in x-rays, x-ray satellites, explanation of x-ray absorption spectra.

4. **Widths and Profiles of Spectral Lines** : Natural Linewidth, Lorentzian Line Profile of the Emitted Radiation, Relation Between Linewidth and Lifetime, Natural Linewidth of Absorbing Transitions, Doppler Width, Collisional Broadening of Spectral Lines, Phenomenological Description, Relations Between Interaction Potential, Line Broadening, and Shifts, Collisional Narrowing of Lines, Transit-Time Broadening, Homogeneous and Inhomogeneous Line Broadening.

References :

1. Introduction to Atomic spectra by H E White McGraw Hill. McGraw-Hill Inc.,New York, US, **ISBN-10:** 0070697205, **ISBN-13:** 978-0070697201, (1934 & 1954)
2. Atomic Physics by Christopher J. Foot, ISBN: 9780198506959 Published by Oxford University Press, New York 2005-02-10 (2005) Oxford University Press.
3. Laser Spectroscopy, Volume 1: Basic Principles, Fourth Edition by Wolfgang Demtroder, Springer,
   ISBN 978-3-540-73415-4 e-ISBN 978-3-540-73418-5, DOI 10.1007/978-3-540-73418-5 Library of Congress Control Number: 2007939486, © 2008, 2003, 1996, 1981 Springer-Verlag Berlin Heidelberg.
4. Atom, laser and spectroscopy by S. N. Thakur and D. K. Rai, ISBN: 9788120339569 Published by A. K. Ghosh Prentice Hall India Learning Private Limited, New Delhi (2010) First Edition. Second Edition ISBN: 9788120348325, Published Prentice Hall India Learning Private Limited, New Delhi (2011).
5. Modern Spectroscopy by J. M. Hollas, ISBN: 9780470844167, Published by John Wiley & Sons Ltd. (2004) Fourth Edition.

PHYE-312 – Elective 1 (C1) : Radioactivity and Nuclear Decay:

(Credits: 04; Contact Hours: 60)

Lectures: 48

Tutorials: 12

Learning Objectives: Nuclear physics is one of the most important topic of physics. This course is necessary as it gives the idea of important phenomenon of Radioactivity and various nuclear decays, the course will help the student for preparation of NET/SET and other competitive examinations. It should be taught as an Elective.

Learning Outcomes: This course is beneficial to students because it can help to understand the uses of radioactivity in determining age of earth, mountains, etc. The understanding of various nuclear decay is beneficial in radio physics / Chemistry and in the field of medical (Treating the cancer patients). The students can get job in medical diagnostic centers as well as they can do research in BARC and other institutions.

Course Contents:

Unit I: Radioactivity

Introduction, Basic parameters of radioactivity, radioactive series, Induced radioactivity (Artificial radioactivity), radioactivity dating, The age of earth, Units of radioactivity, Radiation dosimetry.

Unit II: Alpha Decay

Introduction, Properties of alpha particle, Disintegration energy of alpha decay, Alpha Spectrum, Range of alpha-particles and Geiger–Nuttal law, Long range alpha-particles, Experimental methods for range of alpha-particles (Bragg and Kleeman method, Geiger-Nuttal method), Conservation laws in alpha decay, Gammows theory of alpha decay.

Unit III: Beta Decay

Introduction, Properties of beta-ray, Types of beta decay processes, Energetics of beta decay, Bucherer's method for e/m, Beta ray spectra, Pauli's Neutrino hypothesis, Fermi's theory of beta decay, Selection rules in beta decay, Energy levels and decay schemes.

Unit IV: Gamma Decay

Introduction, Properties of gamma-ray, Selection rule, Multipolarity in gamma transitions, Life time of gamma active nuclei, Gamma rays spectra, Conservation laws in gamma emission, Internal conversion, Nuclear isomerism, Mossbauer effect, Interaction of gamma rays with matter.

References:

1. **Nuclear Physics,** R. C. Sharma, 1st edition, K. Nath & Co. Meerut- (2007) (ISBN-EBK0036746).
2. **Fundamentals of Nuclear Physics,** Jahan Singh, 1st edition, Pragati Prakashan, Meerut- (2012) (ISBN-978-93-5006-593-8)
3. **Radioactive Materials,** Dr. B. M. Rao, 1st edition, Himalaya Publishing House, Mumbai- (2002).
4. **Nuclear Physics,** S. B. Patil, 1st edition, New Age International Publishers, New Delhi- (1991) (ISBN-978-81-224-0125-7).
5. **Nuclear Physics,** D. C. Tayal, 10th edition, Himalaya Publishing House, Mumbai- (2005) (ISBN-81-8318-281-x).
6. **Basic Nuclear Physics,** B. N. Srivastava, 14th edition, Pragati Prakashan, Meerut (2008) (ISBN-978-81-8398-474-4).
7. **Nuclear Physics,** Satya Prakash, 2nd edition, Pragati Prakashan, Meerut (2011) (ISBN-81-7556-915-8).
8. **Nuclear Physics,** K. P. Das, 1st edition, Cyber Tech Publications, New Delhi- (2009) (ISBN-978-81-7884-517-3).

PHYE-312 – Elective 1 (D1) : Crystallography :
(Credits: 04; Contact Hours: 60)

Lectures: 48

Tutorials: 12

Learning objectives: This activity introduces the fundamental principles of X-ray crystallography, and guides students through a series of activities for learning how structural information can be derived from X-ray diffraction patterns.

Students will be able to: 1) Describe what can be detected with X-ray crystallography. 2) explain the impact of temperature, atom size, and impurities on the tests.

Learning Outcomes: Acquisition of the following skills: i) Ability to explain basic/fundamental crystallographic concepts ii) Ability to extort the relevant information from a crystallographic paper.iii) Ability to find specific tools for solution of a given crystallographic problem.

Course Contents:

Unit I : Crystal Binding:

Crystal of inert gases, Van der Waals – London interaction, repulsive interaction, cohesive energy, ionic crystals, Madelung energy, Born-Mayer model, evaluation of Madelung constant for an infinite line of ions, binding in covalent, metal and Hydrogen bonded crystals, Atomic radii.

Unit II : Crystal Physics and X-ray Crystallography:

External symmetry elements of crystals, influence of symmetry on physical properties, derivation of equivalent point position, experimental determination of space groups; Principle of powder diffraction method, interpretation of powder photographs, indexing of powder patterns, accurate determination of lattice parameters, least square method, Synchrotron X-ray diffraction (SCXRD), applications of powder method, Diffraction by an ideal crystal, The Debye – Waller factor.

Unit III : Defects and Alloys:

Classification of defects, Point defects, lattice vacancies, alloys, diffusion, magnetic alloys and Kondo effect, Colour centers, Dislocation in Crystals: slip and plastic deformation, shear strength of single crystals, edge and screw dislocation, Burgers vectors, stress fields of dislocations, dislocation multiplication and slip, short and low range order in liquids and solids, liquid crystals, quasi crystals and glasses, low angle grain boundaries, dislocation densities, dislocation and crystal growth, whiskers.

Unit IV : Semiconductor Devices:

Intrinsic and extrinsic semiconductors, intrinsic and extrinsic carriers concentration, electrical conductivity and mobility and their temperature dependence, thermal electron power transport in semiconductors, Hall effect, Experimental determination of Hall coefficient, Semiconductor Devices: p-n junction, forward and reverse biasing, volt-ampere characteristic of p-n junction, Zener diodes, Tunnel Diode, Photodiode, Solar cells, Light emitting diode (LED), Thermistors and Batteries, Field effect Transistor(FET), Metal Oxide Semiconductor Field Effect Transistor (MOSFET), Quantum Dots (QDs), applications of semiconductors, Problems.

References:

1. Introduction to Solid State Physics- Charles Kittel, Willey Eastern Pvt. Ltd. Seventh Edition -2009.
2. Elementary Solid State Physics – M. A. Omar, Addition Wesley Publishing Company 1993, Digitized 21/11/2007, ISBN: 0201607336.
3. Solid State Physics – A. J. Dekker, Text Book Publishers, 2003, ISBN 0758158955.
4. Solid State Physics – N. W. Aschroft and N. D. Mermin, Publisher Cengage Learning, 2011, ISBN: 8131500527.
5. Introduction to Solids – L. V. Azaroff, McGraw Hill, New York, 2001, ISBN: 10:0070992193.
6. Solid State Physics – S. O. Pillai, Publisher Kent: New Age Science, 2010,
7. Solid State Physics – M. A. Wahab, Narosa Publishinng House, ISBN: 81-7319-266-9.
8. Concept in Solid State Physics – J. P. Shrivastava, Prentice Hall Ltd.
9. Solid State Physics – Saxena, Gupta, Saxena, Pragati Prakashan Eleventh Edition, 2007, ISBN: 81-8398-135-6.
10. Crystallography of Quasicrystals- Walter Steurer; Sofa Deloudi, Springer 2009, e-Book.
11. Crystallography- E.J.W. Whittaker, Elsevier Science 2013, e-Book.
12. Point Defects in Solids- James H.Crawford; Lawrence M. Slifkin, Springer US 2012, e-Book
13. Alloy Physics- Wolfgang Pfeiler, Wiley 2008, e-Book
14. The Physics of Dilute Magnetic Alloys- Jun Kondo; Shigeru Koikegami; Kosuke Odagiri; Kunihiko Yamaji; Takashi Yanagisawa, Cambridge University Press 2012, e-Book.
15. Dislocations in Solids-John P. Hirth, Elsevier Science 2011, e-Book.
16. Crystal Growth Technology: Semiconductors and Dielectrics (Kindle Edn.) –Hans J. Scheel (Editor), Peter Capper (Editor), Peter Rudolph (Editor) 2011, Amazon Inc. e-Book.
17. Dislocation Models of Crystal Grain Boundaries, W. T. Read and W. Shockley, APS Journals, Physical Review Letters, Phys. Rev. 78, 275 – Published 1 May 1950

PHYE-313 Generic Electives 2 (A2/ B2/ C2/ D2)

PHYE-313 – Elective 2 (A2) : Microwaves

(Credits: 04; Contact Hours: 60)

Lectures: 48

Tutorials: 12

Learning Objectives:

The course Microwaves is going to taught for third year Engineering students at Electronics and Telecommunication branch. Similar course has been introduced at M.Sc. Physics (Third semester) for Electronics specialization. The students of microwaves are going to study, its origin, features, applications and various bands. The transmission line circuits and theory, smith charts. Microwave generators, solid state devices, various components, antennas used at microwave frequency and its different measurement techniques. Microwave bands are introduced by means of laboratory exercises. Project work serves to develop student engineering design and report writing skills.

Learning Outcomes:

After the course the participants/students should be able to apply electromagnetic theory to calculations regarding waveguides and transmission lines- Describe, analyze and design of simple microwave circuits and devices e.g. matching circuits, couplers, antennas and amplifiers- Describe and coarsely design common systems such as radar and microwave transmission links- Describe common devices such as microwave vacuum tubes, high-speed transistors and ferrite devices- Handle microwave equipment and make measurements.

Course contents:

Unit I: Introduction of microwaves and Transmission Line Theory:

Microwave frequency, characteristic features, applications and bands. Distributed parameters, Basic transmission line equations and solution, Determination of alpha and beta for a transmission line. Distortion on a transmission line, conditions for distortion less line. Standing waves, standing waves ratio, quarter & half wavelength lines, Properties of lines of various lengths, Impedance matching by use of studs, matched lines, Smith chart.

Unit II: Microwaves Generators:

Tubes: Two cavity Klystron, velocity modulation, performance and applications. Multi cavity klystron. Reflex klystron, operation, transit time, Relation between repeller voltage and frequency, Modes, Applications. Magnetrons, crossed electric and magnetic fields, RF structure of magnetron, Oscillation mechanism in magnetron. Traveling wave tube amplifier. Backward wave oscillator. Microwave solid state devices: MESFET, principle of operation, Gunn diode, background. Gunn effect, Mode of operations, Gunn oscillator modes, Transit time mode, Quenched and delayed domain modes, LSA mode, Gunn oscillator circuits, coaxial cavity waveguide cavity circuits.

Unit III: Microwave Components and antennas:

Waveguide tees, E- plane tee and H-plane tee. Hybrid junction. Directional coupler, two hole directional coupler, loop directional coupler, Isolators, Faraday's rotational isolator, applications, Circulator, Microwave network representations, S- Matrix theory of E, H, Directional coupler and magic tee. Microwave antenna: Horn antenna, microwave dish antenna, lens antenna, slot antenna, broadband antenna.

Unit IV: Microwave Measurements:

Measurement of power by bolometer, calorimeter, VSWR Measurement (High & low), Detector diodes and detector mounts, Detector output indicator, Impedance measurement by slot line and probe, Network analyzer, Measurement of scattering parameters, Frequency measurement by wave meter, Electronics techniques for frequency measurement, transfer oscillator and direct reading microwave counters.

References:

1. Microwave Devices and Circuits, by Samuel, Liao, Fourteenth impression PHI. ISBN 81-978-81-7758 (2012)
2. Microwaves, by K.C. Gupta, Wiley Estern Ltd. ISBN 0 85226 346 5
3. Microwave Engineering, by Sanjeev Gupta, Khanna Publishers.
4. Electronics Communications, by Sanjeeva Gupta, Khanna Publishers Delhi- 6. (For Chap. 3 and 5)
5. Electronics Communication systems By George Kennedy third Edn
6. Networks Lines and Filters by John D. Ryder, PHI second Edn.
7. Microwave Engineering by Annapurna Das & Sisir K. Das (TMH Publication) 2000.
8. Introduction to Microwaves, by G. I Wheelers, PHI
9. Microwave and Radar Engineering, by M. Kulkarni, 3rd Edition , Umesh Publications Delhi 110006
10. Microwave Engineering, by Monojit Mitra, II Edition,

PHYE-313 – Elective 2 (B2) : Molecular Spectroscopy

(Credits: 04; Contact Hours: 60)

Lectures: 48

Tutorials: 12

Learning Objectives:

a) Study of fundamentals of uv-visible, IR and Raman spectra of diatomic/polyatomic molecules for determining their structure
b) To understand the electronic structure, coarse and fine structure of energies of electronic states, etc., of diatomic molecules
c) To understand the vibrational, rotational motions and coupling of these motions by evaluating the vibrational and rotational constants of the electronic states
d) To understand the basic physics, experimental techniques and analysis of Raman spectra for investigating the molecular structure

Learning Outcomes:

a) The student will be able to analyze the uv-visible spectra of diatomic molecules, and determine their structure
b) The student will be able to analyze the Raman spectra of molecules, and determine their structure
c) After learning these techniques, the student can join research activities in many branches of Physics, Chemistry and allied subjects

Course Contents:

Unit I : Electronic Spectra of Diatomic Molecules :

Electronic energy and total energy, electronic energy and potential curves; stable and unstable molecular states, resolution of total eigen functions, resolution of total energy, Vibrational structure of electronic transitions: general formulae, examples; graphical representation, Deslanders table, progressions and sequences, evaluation of vibrational constants, Rotational structure of electronic bands. Band head formation and shading of bands. Combination relation and evaluation of rotational constant for bands without and with Q branches. Band origin determination. Isotope effect in electronic spectra

Unit II :Coupling of rotation and electronic motion :

Classification of electronic states; multiplet structure, orbital angular momentum, spin, total angular momentum of the electrons; multiplets, symmetry properties of the electronic eigen functions, Hunds cases a, b and c, Uncoupling phenomena: Λ type doubling, Spin Uncoupling. Symmetry properties of rotational levels. Types of electronic transitions, selection rules, Study of $^1\Sigma$- $^1\Sigma$, $^2\Sigma$ – $^2\Sigma$ and $^1\Pi$- $^1\Sigma$ transitions.

Unit III: Determination of term manifold:

Separated atoms. (like and unlike atoms) Term manifold from electronic configuration. Pauli principle. Term of non-equivalent electrons. Molecular configurations of CO, C_2, N_2, AlO, BeO, BeH etc molecules. Types of binding. Homopolar, Heteropolar and Van der Waal.

Unit IV : Raman Spectroscopy:

Classical theory and quantum theory of Raman effect, Pure rotational Raman Spectra, Raman spectra of linear, symmetric top and asymmetric top molecules. Raman activity of vibrations, vibrational Raman Spectra. Rotational fine structure, polarization of light and Raman effect, degree of polarization, Vibration of spherical top molecules. Structure determination from Raman and IR spectra, Instrumentation: Raman spectrometer

References:

1. Spectra of Diatomic Molecules by G. Herzberg, Krieger Malbar Florida,1950, **ISBN-10:** 1406738530, **ISBN-13:** 978-1406738537
2. MOLECULAR STRUCTURE AND SPECTROSCOPY, by ARULDHAS, G. , Second Edition ,2004; ISBN: 978-81-203-3215-7, PHI Learning

PHYE-313 – Elective 2 (C2) : Nuclear Reactions and Nuclear Energy

(Credits: 04; Contact Hours: 60)

Lectures: 48

Tutorials: 12

Learning Objectives : This course gives basic foundation to specialization in nuclear physics and applications, including power production through fission and fusion reactors. The course is an advanced course and requires special efforts. So, it can be taught as an elective course only. The course will help the student for preparation of NET/SET and other competitive examinations. The course is most suitable in IIIrd semester, because this knowledge is essential for understanding the contents of the next following course "radiation measurements and Nuclear dosimetry" to be covered as elective course in IVth semester.

Learning Outcomes: After completing this course the student will be to prepared to understand the scope and possibilities of studies in nuclear physics for research career as well as in industry. This course is prerequisite to the second elective course as mentioned above for IVth semester.

Course Contents :

Unit I: General Features of Nuclear Reaction

Introduction, Conservation laws in nuclear reactions, Energetics and Q-Value of nuclear reaction, Nuclear transmutation, Nuclear reaction cross-section, Partial cross-section, Determination of cross-section, partial wave analysis for reaction cross-section, Breit-Wigner dispersion formula, Level width.

Unit II: Nuclear Reaction Mechanism

Types of nuclear reaction, Compound Nucleus, Theory of nuclear reaction, Characteristics of pre-equilibrium reaction, Direct reaction, Theory of Stripping and Pick-up reaction, Continuum theory of nuclear reaction, Statistical theory of nuclear reaction.

Unit III: Nuclear Fission

Introduction, Nuclear fission, Types of fission, Emission of nuclear fission, fission of fertile material, Distribution of mass of fission products, Energy released in fission, Distribution of energy of fragments, Neutrons released in fission, Prompt and delayed neutrons, Spontaneous fission, Theory of fission (Liquid drop model), Nuclear chain reaction, Four factor formula, Nuclear Reactor, Breeding of fuel, Classification of Nuclear Reactor.

Unit IV: Nuclear Fussion

Introduction, The plasma, Fussion reaction in the plasma, Conditions for maintain fussion reaction, Stellar energy, Sources of stellar energy, Carbon-Nitrogen cycle, Controlled thermal nuclear reactions, The eight synthesizing processes.

References :

1. **Nuclear Physics,** D. C. Tayal, 10th edition, Himalaya Publishing House, Mumbai- (2005) (ISBN-81-8318-281-x).
2. **Nuclear Physics,** R. C. Sharma, 1st edition, K. Nath & Co. Meerut- (2007) (ISBN-EBK0036746).
3. **Fundamentals of Nuclear Physics,** Jahan Singh, 1st edition, Pragati Prakashan, Meerut- (2012) (ISBN-978-93-5006-593-8)
4. **Nuclear Physics,** S. B. Patil, 1st edition, New Age International Publishers, New Delhi- (1991) (ISBN-978-81-224-0125-7).
5. **Nuclear Measurement Techniques,** K. Sri Ram, 1st edition, Affiliated East-West Press, Madras(1986) (ISBN-81-85095-56-6).
6. **Basic Nuclear Physics,** B. N. Srivastava, 14th edition, Pragati Prakashan, Meerut (2008) (ISBN-978-81-8398-474-4).
7. **Nuclear Physics,** Satya Prakash, 2nd edition, Pragati Prakashan, Meerut (2011) (ISBN-81-7556-915-8).
8. **Nuclear Physics,** K. P. Das, 1st edition, Cyber Tech Publications, New Delhi- (2009) (ISBN-978-81-7884-517-3).
9. **Radioactive Materials,** Dr. B. M. Rao, 1st edition, Himalaya Publishing House, Mumbai- (2002).
10. **Nuclear Energy,** R. K. Taneja, 1st edition, Cyber Tech Publications, New Delhi- (2009) (ISBN-978-81-7884-516-6).

PHYE-313 – Elective 2 (D2) : Electrical Properties of Solids and Superconductivity

(Credits: 04; Contact Hours: 60)

Lectures: 48

Tutorials: 12

Learning Objectives:

The course aims at giving the students,

- in depth knowledge and know-how within the theory of superconductivity in order to understand and describe the principles behind various superconducting applications.
- acquiring of knowledge concerning the electrical behaviour of dielectric and ferroelectric materials.
- acquiring of knowledge concerning the electrical behaviour of dielectric materials.
- Knowledge about the experimental investigation methods of dielectrics.

Learning Outcome:

After the course, the students should be able to:-

- describe different theories of superconductivity
- describe the basic properties of superconductors;
- explain type-I and type-II superconductivity based on thermodynamic calculations of the Gibbs free energy for a superconductor
- apply fundamental knowledge of superconductors to applications of superconductivity in technology and the research laboratory;
- Students will have option to start his / her teaching career either in science or engineering colleges / institutes as this course is included in science as well engineering discipline.

Course Contents:

Unit I: Dielectric Properties of Solids

Fundamental definitions, Local field, Clausius- Mossotti relation, Polarization mechanisms in dielectrics: induced, orientational, electronic, ionic, interfacial and lattice polarizations; combined mechanisms, frequency and temperature effects on polarization, Classical theory of electronic polarizability, dipolar polarizability. Langevin's theory of dipolar polarizability dielectric loss, dielectric breakdown, determination of dielectric constant, properties and different types of insulating materials, Debye theory, Onsager equation, Applications.

Unit II: Ferroelectric properties of Solids

Fundamentals, Curie-Weiss law, Classification of ferroelectric materials, Theory of spontaneous polarization of $BaTiO_3$, antiferroelectricity and ferrielectricity, Ferroelectric domains, Piezoelectricity, Pyroelectricity, Applications

Unit III: Superconductivity I

Some fundamental Phenomena associated with Superconductivity (Zero resistance, persistent currents, superconducting transition temperature T_c, isotope effect, perfect diamagnetism and Meissner effect, penetration depth and critical field.). Phenomenological description by Means of the London Equations. Constructing Bosons from Fermions. Electron -Electron Interaction via Lattice Cooper Pairs, BCS Wave function. Supercurrents and Critical Currents. Coherence of the BCS Ground State and the Meissner-Ochsenfeld Effect, Quantization of Magnetic Flux.

Unit IV: Superconductivity II

Type-I and Type-II Superconductors, Characteristics Length, Intermediate states, mixed states, Tunneling phenomenon, energy level diagram, Josephson Effects, quantum interference. Thermodynamics of superconducting transition: First order and second order transition, specific heat above and below T_c, thermal conductivity; Novel High Temperature superconductors, Applications.

References:

1. Introduction to Solid State Physics, C.kittl;7th Edition; Wiley Eastern Pvt. Ltd.(2011); ISBN-978-81-265-1045-0.
2. Solid State Physics, A.J.Dekker; Macmillan Publishers India Ltd.; (2012); ISBN-10: 0333-91833-9; ISBN-13: 978-0333-91833-3.
3. Introduction to Solids, L.V.Azaroff; TMH Edition; 33rd reprint (2009); TATA McGraw Hill; ISBN-13: 978-0-07-099-219-1; ISBN-10: 0-07-099-219-3
4. Solid State Physics, M.A.Wahab; 2nd Edition; 3rd reprint (2008); Narosa Publishing House Pvt. Ltd; ISBN: 978-81-7319-603-4.
5. Solid state physics, S.O.Pillai; 6th Edition; New Age international Pvt. Ltd.; (2005); ISBN:81-224-1682-9.
6. Solid State Physics, Vimal Kumar Jain; Ane Books Pvt. Ltc; (2013); ISBN:978-93-8116-297-2.
7. Modern Physics and Solid State Physics (Problems and Solutions), S.O.Pillai; Revised 3rd Edition; New Age International Publishers; ISBN:81-224-1704-3.
8. Elementary Solid State Physics, M. Ali Omar; 5th Impression (2009); Pearson Education.inc; ISBN:978-81-7758-377-9.
9. Fundamentals of Solid State Physics, Saxena, Gupta, Saxena,; 50th Edition; Pragati Prakashan; (2012); ISBN:978-93-5006-539-6.
10. Solid State Physics, Neil W. Ashcroft, N. Devid Mermin; 9th Indian Reprint (2010); CENGAGE Learning India Pvt. Ltd. (India Edition); ISBN-13: 978-81-315-0052-1.

PHYE-314 – Electives 3 (A3/ B3/ C3/ D3/E3/F3/G3/H3)

PHYE-314 – Electives 3 (A3) : Industrial Electronics:

(Credits: 04; Contact Hours: 60)

Lectures: 48

Tutorials: 12

Learning Objectives:

- To get an overview of different types power semiconductor devices and their switching characteristics.
- To learn about types of operations.
- To learn about types of power converters.
- To learn about dc converters.

Learning Outcomes :

After going through this course students will get ideas about working of power electronics devices and supporting devises. Students can use this knowledge for designing of power electronics circuit for controlling and saving electrical power in many applications.

Course contents:

Unit I: Thyristor: Principles and Characteristics:

Thyristor family, Principle of operation of SCR, Two transistor model of SCR, Thyristor Construction, Turn on methods of Thyristor, Dynamic turn on switching characteristics, Turn off mechanism.
Gate Triggering Circuits**:** Resistance firing circuit, Resistance and capacitance firing circuit, Resistance capacitance full wave trigger circuit, Unijunction transistor, Basic operation, UJT relaxation oscillator, UJT as an SCR trigger, Synchronized UJT triggering. Programmable Unijunction transistor, PUT as an SCR trigger.

Unit II: Series and Parallel operation of Thyristors

Series operation of Thyristors**,** Need for equalizing Network, equalizing network design, Triggering of series connected Thyristors, Parallel operation of Thyristors, Methods of ensuring proper current sharing, triggering of Thyristors in parallel .

Unit III: Phase Controlled Rectifiers

Phase angle control, Single-phase half-wave controlled rectifier: with restive load, with inductive load, effect of freewheeling diode, Single-phase full-wave controlled rectifier: Mid point converter (M-2 connection): with restive load, with inductive load, effect of freewheeling diode.

Unit IV: Choppers:

Introduction, Principle of chopper operation, Control strategies: Time-Ratio Control, constant frequency system, variable frequency system, Current-limit Control; Step-Up Choppers, Step-Up/down chopper, Jones chopper (design not expected).

References:

1. Power Electronics, M D Singh and K B Khanchandani (TMH), 2004, ISBN0-07-463369-4.
2. Power Electronics, M.S.Jamil Asghar, PHI, 2006, ISBN :81-203-2396-3.
3. Principles of Electronics, V.K.Metha , Rohit Mehta, S. Chand and Company Ltd. 2012, ISBN: 81-219-2450-2.
4. Power Electronics P S Bimbhra Khanna Publishers 1998, ISBN 81-7409-020-7.
5. Electrical circuits and Basic Semiconductor Electroics, Pragati Prakashan Meerut, 2010, ISBN 978-93-5006-302-6.
6. Industrial Electronics, G.K.mithal, Khanna Publishers, Delhi, 1987.
7. Industrial Electronics, S.N.Biswas, Dhanpat rai and Sons, 1996.

PHYE- 314 – Electives 3 (B3) : Modern Trends in Spectroscopy

(Credits: 04; Contact Hours: 60)

Lectures: 48

Tutorials: 12

Learning Objectives:

a) Acquiring of knowledge concerning the electrical behavior of dielectric materials.
b) The students become accustomed with the nuclear magnetic resonance (NMR) methods.
c) The student will develop their abilities to investigate polyatomic molecules by NMR spectroscopy.
d) Imparting knowledge based on fundamentals of physical principles and measurement methods used for characterization.

Learning Outcomes:

a) The student will be able to analyze the molecular spectra.
b) The student will be able to analyze the FTIR spectra of thin film and molecules and determine their structure.
c) The student will be able to analyze the NMR spectra of molecules, and determine their structure

Course Contents

1. **ELECTRONS SPIN RESONANCE SPECTROSCOPY:**
Principle of ESR, ESR Spectrometer, Total Hamiltonian, Hyperfine Structure. ESR Spectrum of Hydrogen Atom, ESR Spectra of Free Radicals in Solution- Energies of Radicals with One Unpaired Electron, CH_3 Radical, Benzene Anion ($C_6H_6^-$), etc.

2. **FOURIER TRANSFORM INFRARED SPECTROSCOPY:**
Introduction, Historical Background, FT-IR Spectroscopy, Basic Integral Equation, Attenuated Total Reflectance, Experimental Setup, Advantages, Other Aspects, Applications, Surface Studies, Characterization of Optical Fibers, Vibrational Analysis of Molecules, Study of Biological Molecules, Study of Polymers.

3. **NUCLEAR MAGNETIC RESONANCE SPECTROSCOPY**
Introduction, Magnetic Properties of Nuclei, Resonance Condition, NMR Spectrometer, Relaxation Processes and their Mechanism. Bloch Equation, Fourier Transformation, Dipolar Interaction, Chemical Shift. Indirect Spin Interaction. Spectrum of Spin $^1/_2$ AB System. Interpretation of Few NMR Spectra.

4. DIELECTRIC SPECTROSCOPY:

Classification of the experimental methods. Frequency methods: Bridges, Resonance methods, Coaxial lines, Waveguides, Transient methods, Strip lines, etc. Broad Band Dielectric Spectroscopy: A frequency response analyzer (10^4Hz 10^6 Hz), automatic radio frequency bridge (10 Hz -10^7 Hz) coaxial line reflectometer (10^6 Hz 10^9 Hz) and coaxial vector network analyzer (10^7 Hz 10^{10} Hz). Time Domain Dielectric Spectroscopy: The single reflection and transition methods. Multiple reflection, transition, lumped capacitance methods. Non-uniform sampling, Fourier transform and the time domain treatment, Applications of dielectric spectroscopy.

References :

1. Dielectric Properties and Molecular Behaviour, by Nora E. Hill, A. H. Price and Mansel Davies, ISBN 10: 0442034113 ISBN 13: 9780442034115 Published by Van Nostrand Reinhold Company (1969) London.
2. Handbook of Applied Solid State Spectroscopy, by D. R. Vij, ISBN: 978-0-387-32497-5 (Print) 978-0-387-37590-8 (Online) **DOI** 10.1007/0-387-37590-2, 2006 Springer.
3. MOLECULAR STRUCTURE AND SPECTROSCOPY, by ARULDHAS, G. , Second Edition ,2004. ISBN: 978-81-203-3215-7, PHI Learning.

<u>PHYE-314 – Electives 3 (C3) : Reactor Physics</u>

<u>(Credits: 04; Contact Hours: 60)</u>

Lectures: 48

Tutorials: 12

Learning Objectives:

To enable the students to study the basic and advance concepts of Reactor Physics

Learning Outcomes:

Students will be able to study the basic and advance concepts of Reactor Physics will be able have job opportunities in BARC.

Course contents:

Unit I: The Neutron

Discovery of neutron, neutron sources, basic properties of neutrons, wavelength of neutrons, high energy neutrons, measurements of energy of neutrons, time of flight method.

Unit II: Neutron Detections

Detection of neutrons, detection of slow neutrons- foil- activation method, ionization chambers and counter tubes for the detection of slow neutrons, Scintillatiors for the detection of slow neutrons, fission chambers for detection of thermal neutrons, detection of fast neutrons.

Unit III: Neutron Diffraction

Neutron diffraction from crystal, reflection for slow neutrons from mirrors, mechanical velocity selectors, measurement of neutron cross-section as a function of energy, cold neutrons and their isolations, neuton electron interaction, decay of neutrons.

Unit IV: Physics of Nuclear Reactors

Thermalization of neutrons, dynamics of elastic scattering of neutrons, angular distribution of neutons, diffusion of thermal neutron ,Fermi age equation, condition of criticality of a reactor, critical equation of a reactor, rectangular parallelepiped reactor.

Types of Nuclear reactors **:** Spherical reactor, reactor in the shape of a cylinder, Physical processes in a reactor, control of reactors, nuclear fuel conversion, nuclear materials employed in reactors, moderators, some important reactors, Swimming pool (Apsara) type reactor, Zerlina type reactor.

References:

1.**Nuclear Physics,** R. C. Sharma.
2. **Nuclear Physics**, I. Kaplan, 2nd edition, Narosa, 1989.
3. **Basic Nuclear physics**, B. N. Shrivastava, Pragati prakashan, Meerut.
4. **Nuclear Physics**, D.C. Tayal, Himalaya Publishing House, Bombay.
5. **The elements of nuclear reactor theory,** Glastone and Edund.
6. **Introduction to Nuclear Engineering,** Murry.

PHYE-314 – Electives 3 (D3) : Physics of Nanomaterials

(Credits: 04; Contact Hours: 60)

Lectures: 48

Tutorials: 12

Learning objectives:

Students should be able to,

- describe the physical properties of nanomaterials resulting from constraints on their nanoscale organization.
- analyze structure-function relationships at the nanoscale.
- discuss how to analyze and understand nanoscale features of materials
- gain basic knowledge in the synthesis of nanomaterials, their properties and characterization.
- be able to apply basic knowledge of physics and materials science to develop proficient understanding of how nanoscale properties affect macroscale performance and enable new technologies.

Learning outcomes:

Student will,

- acquire knowledge about the techniques of how to synthesize nanomaterials and will understand their nanoscale properties;
- acquire insight into how macroscopic properties can be changed via molecular level engineering and nanoscale manipulation;
- acquire fundamental knowledge of nanotechnology principles and applications.

Course Contents:

Unit I: Fundamentals of nanosized particles:

Concepts of nanomaterials, Size and Dimensionality Effects, idea of quantum well structure, quantum dots, Energy levels of quantum dots. Quantum Mechanical background;(electron confinement in: square well of finite depth & infinitely deep square well, confinement in two dimensional well).

Unit II: Synthesis of nanomaterials:

Top down and Bottom up concepts, Growth techniques of nanomaterials: Plasma Arc discharge, Sputtering, Evaporation, physical vapor deposition, Chemical vapor deposition, Pulsed Laser deposition, Molecular beam epitaxy, Sol-gel process, Co-precipitation process.

Unit III: Characterization techniques:

XRD,Scanning Probe Microscopy (SPM), Scanning Tunneling Microscopy (STM), Atomic Force Microscopy (AFM), Electron Microscopy: Scanning Electron Microscopy (SEM & FESEM), Transmission Electron Microscopy (TEM).

Unit IV: Properties and applications of nanomaterials:

Physical Properties of nanomaterials ; i) Photocatalytic. ii) Dielectric. iii) Magnetic.
iv) Optical. v) Mechanical.

Carbon clusters & Fullerenes; Carbon Nanotubes: Structures & Electronic Properties, Application of carbon Nanotubes.

References:

1. Nanotechnology: Principles and Practices, Sulbha K. kulkarni; (2009), Revised Reprint; Capital Publishing Company; ISBN:81-85589-29-1.
2. Introduction to Nanoscience, Charles P. Poole, Jr., Frank J. Owens; Reprint (2011); Wiley India Edition; ISBN: 978-81-265-1099-3.
3. The physics and Chemistry of Nanotechnology, Frank j. Owens, Charles P. Poole Jr.; John Wiley & Sons. Inc. Hoboken, New Jersey; (2008); ISBN: 978-0-470-06740-6 (cloth).
4. Nano Materials, Nanotechnologies and Design, Michael F. Ashby. Paulo J. Ferreira, Daniel L. Shodek; © 2009 First Printed in India (2011); Butterworth-Heinemann, An imprint of Elsevier; ISBN: 978-93-80931-77-7.
5. Introduction to Nanoscience, S.M.Lindsay; Indian Edition; Oxford University Press; (2010); ISBN-13: 978-0-19-959129-9
6. Nanostructures and Nanomaterials: synthesis, properties and applications, Guozhong Cao, zying Wang; 2nd Edition; World Scientific Publishing; (2011); ISBN-13:978-981-4322-50-8; ISBN-10:9814-4322-50-4; ISBN-13:978-981-4324-55-7(pbk) ; ISBN-10:981-4324-55-8(pbk)
7. Introduction to Nanoscience, Gabor L. Hornyak, Joydeep Dutta, Harry F. Tibbals, Anil Rao; CRC Press, Taylor & Francis Group; © (2008); ISBN-978-1-4200-4805-6.

<u>PHYE-314 – Electives 3 (E3) : X ray Diffraction</u>

<u>(Credits: 04; Contact Hours: 60)</u>

Lectures: 48

Tutorials: 12

Learning Objectives: With the establishment of national synchrotron source in Indore (a few hundred km from Aurangabad) this course will help a student in understanding the most powerful source of plane and circularly polarized x rays. Further such a course is not taught at present anywhere in India. Being an Elective Course this course be taught during Sem IV. This course is based on the various research activities carried out on the India's indigenously built synchrotron source INDUS 2. The students will have a prior training before they pursue their research activities on INDUS 2 or any SR in the world.

Learning Outcomes:

1. The takers can fetch a job or research fellowship at SR INDUS
2. The practice of data analyses will help a student in getting a job in pharma industries.

Course Contents:

Unit I : **X ray Diffraction-1**:

Limitations of x rays from tubes as regards x ray diffraction studies, synchrotron radiation as source of x rays: Production and properties of radiation from storage rings, wigglers and undulators, Insertion devices. types of polarized x rays using SR, INDUS I and INDUS II, Diffraction using SR: using plane polarized x rays and using circularly and elliptically polarized x rays (X ray Circular Magnetic Dichroism XCMD): methods of obtaining monochromatic x rays, polarized x rays; Detectors: high flux (> 10^8photons/sr/sec), very low time structure (~ 10^{-9} sec or less)

Unit II: X ray Diffraction-2:

X ray diffraction data analysis of various types of samples : cubic, tetragonal, hexagonal, etc, determination of various parameters like lattice parameters, near neighbor distances, strain, etc. Pair distribution Function (PDF) analysis

Unit III: Emission Spectroscopy:

Continuous and characteristic X-ray spectra, Energy level diagram. Dipole, forbidden and satellite lines. Regular and irregular doublets. Relative intensity of X-ray lines. Chemical effects in X-ray spectra; Experimental techniques of wavelength and energy dispersive Xray spectroscopy: Bragg and double crystal spectrometers. Focussing spectrographs: Cauchois, Johann and Johanson types. Tangential incidence grating spectrographs.

Unit IV: Absorption Spectroscopy:

Absorption of X-rays. Physical process of X ray absorption. Measurement of X-ray absorption coefficients. Units of dose and intensity, X-ray fluorescence. Auger effect. Fluorescence yield. Auger electron spectroscopy, Photoelectron spectroscopy, Chemical effects in X-ray absorption spectra. White line, Chemical shifts of absorption edges, Fine structures (XANES and EXAFS) associated with the absorption edges and their applications. Soft X-ray spectroscopy of metals and alloys, Applications to semiconductors and insulators

References:

(1) X-rays in Theory and Experiment , A.H. Compton and S.K. Allison, 1935,(New York: D. Van Nostrand Company, Inc. 1935) This is a classic book written by a Nobel Laureate.
(2) Elements of Modern X-ray Physics, Jens Als-Nielsen and Des McMorrow (ISBN 0471498580, 9780471498582, Wiley 2001)
(3) X-Ray Science and Technology, A. G. Michette and C. J. Buckley (ISBN-13: 978-0750302333 ISBN-10: 075030233X CRC Press 1993)
(4) Principles and Practice of X-ray Spectrometric Analysis, E.P. Bertin (ISBN 1461344166, 9781461344162 Springer Science & Business Media 2012)

PHYE-314 – Electives 3 (F3) : Thin film and Vacuum Technology

(Credits: 04; Contact Hours: 60)

Lectures: 48

Tutorials: 12

Learning Objectives: This program will help prepare students to work as technicians in industries which rely on vacuum-based processes to create and manufacture products. Individuals studying vacuum technology will learn skills in building, validating, operating, maintaining, and troubleshooting vacuum-based equipment as well as providing advice on the use of this equipment and the processes supported by this technology. Positions may include responsibilities associated with research and design, operations, quality control, technical writing, and technical sales.

Learning Outcome : Employment opportunities span a variety of industries such as semiconductor, microelectromechanical systems (MEMS), glass, optics, light-emitting diodes (LEDS), solar cells, vacuum-based equipment and other industries which used thin film coating processes. The duties of a technician include building, validating, operating, maintaining, and troubleshooting vacuum-based equipment as well as providing advice on the use of this equipment and processes supported by this technology. The Vacuum and Thin Film Technology program prepares a student to work as a technician in industries which rely on vacuum-based processes to create and manufacture products. Employment opportunities span a variety of industries such as:Semiconductor, Microelectromechanical systems (MEMS), Glass, Optics, Light-emitting diodes (LEDS), Solar cells, Vacuum-based equipment, Other industries which use thin film coating processes

Course contents:

Unit I: .

Thermodynamics and Thin Film growth, Vacuum Technology: Gas Laws, Kinetic Theory of Gases, Conductance and Throughput, Gas Sources in a Vacuum Chamber, Vacuum Pumps.

Unit II: .

Physical Vapor Deposition: Sputtering (Plasma Physics (DC Diode), rf Plasmas, Magnetic Fields in Plasmas, Sputtering Mechanisms) and Evaporation.

Unit III: .

Chemical Vapor Deposition: Mechanisms, Materials, Chemistries, Systems. Module-V Etching: Wet Chemical Etching (Mechanisms, Materials and Chemistries), Dry Plasma Etching/Reactive Ion Etching (Mechanisms, Materials and Chemistries).

Unit IV: .

FILM Formation and Structure: Capillarity Theory, Atomistic Nucleation processes, Cluster Coalescence, Grain Structure of Films. Thin Film Characterization: Structural, optical, electrical and magnetic

References

1. R. K. Waits, Thin Film Deposition and Patterning, American Vacuum Society, 1998. M. Ohring, ISBN 10: 156396872X ISBN 13: 9781563968723
2. The Materials Science of Thin Films, Academic Press, Boston, 1991. Ludmila Eckertova, Physics of Thin Films, 2nd Plenum Press New York, 1986 (QC 176.83.E2613 1986) ISBN 10: 0123418240 ISBN 13: 9780123418241
3. Kasturi L. Chopra, Thin Film Phenomena (McGraw-Hill, 1969). ISBN 10: 0070107998 ISBN 13: 9780070107991
4. Handbook of Thin Film : Maissel and Glang (1970). ISBN 10: 0070397422 ISBN 13: 9780070397422

PHYE-314 – Electives 3 (G3) : Nuclear Spectroscopy

(Credits: 04; Contact Hours: 60)

Lectures: 48

Tutorials: 12

PHYE-314 – Electives 3 (H3) : Micro Electro Mechanical System

(Credits: 04; Contact Hours: 60)

Lectures: 48

Tutorials: 12

PHYL-321 : Lab course 5 (Based on Electives A1/ B1/ C1/ D1)

PHYL-321 – Lab course 5 (A1) : 8086 Microprocessor and interfacing : Credits 3

Learning Objectives:

1. To facilitate the students to understand
   a) the concepts of microprocessor and assembly language programming.
   b) the concept of interfacing devices at laboratory as well industrial level

2. To provide an opportunity to the students to enter into entrepreneurship.

Learning Outcome:

1. Students will be able to learn

   a) Microprocessor architecture, physical configuration of memory, logical configuration of memory, microprocessor programming and interfacing.

2. Students will be capable to perform following job

   a) Industrial automation using 8086 interfacing and programming.
   b) Start his / her own small scale industry for manufacturing microprocessor based automated devices.

3. Students will have option to start his / her teaching career either in science or engineering colleges / institutes as this course is included in science as well engineering discipline.

Experiments using 8086 Kit

1. Data transfer, addition, subtraction, multiplication, division and sum of series
2. Factorial and square of the number
3. Sorting of data (ascending / descending), square root of a number
4. Arithmetic mean of N- numbers and sum of square of Numbers
5. Interfacing of SPDT switches and 7 segment display as a position encoder / decoder
6. Interfacing of stepper motor
7. Interfacing of DC motor
8. Interfacing of DAC to generate ramp wave, triangular wave and square wave.
9. Interfacing of 8-bit ADC
10. Interfacing of LCD display

Experiments Using 8086 Assembler

11. Data transfer, addition, subtraction, multiplication, division and sum of series
12. Factorial and square of the number
13. Sorting of data (ascending / descending), square root of a Number
14. Arithmetic mean of N- numbers and sum of square of Numbers

Note: Students should perform any eight experiments.

<u>**PHYL-321 – Lab course 5 (B1) : Atomic Spectroscopy : Credits 3**</u>

Learning Objectives:

a) Recording the atomic spectra using latest computer interfaced instruments
b) Analysis of recorded atomic spectra
c) Study of various types of excitation mechanisms and excitation sources
d) Study the effect of external electromagnetic fields on the atomic spectra
e) Analysis of the recorded atomic spectra

Learning Outcomes:

a) The student will get a training for using state of the art data acquisition system in spectroscopy laboratory
b) The student will get a training for analysis of recorded atomic spectra
c) The student will be able to design various kinds of spectroscopic emission sources and their power supplies
d) The student will be able to design the electromagnets and their power supplies
e) Hence the Entrepreneurship.

Course Contents:

1. Record the spectrum of Hydrogen using HR 4000 spectrometer and determine Rydberg constant
2. Record the spectra of (arc sources) copper, iron, zinc and brass using HR 4000 spectrometer
3. Record the spectra of (gas discharge sources) Hg, Cd using HR 4000 spectrometer
4. Record the spectra of (inert gases) Ne, He using HR 4000 spectrometer
5. Study of NMR spectra of various samples using NMR spectrometer
6. To verify the line spectra of calcium and to verify the Lande interval rule
7. To verify the Lande interval rule for the sharp series lines of Zinc
8. Record the absorption spectrum of the Sun using HR 4000 spectrometer and identify the elements in the spectrum
9. Study of hyperfine structure using Zeeman effect
10. Study of normal Zeeman effect and calculation of *e/m*
11. Determining earth's magnetic field with ESR

References:

1. ATOM, LASER AND SPECTROSCOPY by THAKUR, S. N. , RAI, D. K. , SECOND EDITION , 2010 ; ISBN: 978-81-203-4832-5

Note: Students should perform any eight experiments.

PHYL-321 – Lab course 5 (C1) Nuclear Physics Credits 3

1. To study characteristics of Geiger-Muller (G-M) counter.
2. Determination of dead time of Geiger-Muller G-M) counter (Two source method).
3. Determination of dead time of Geiger-Muller (G-M) counter (Absorber method).
4. To study absorption of beta particles in matter.
5. Verification of the Inverse Square Law.
6. Window thickness of a Geiger-Muller (G-M) counter.
7. Window thickness of a Geiger-Muller (G-M) counter (Inverse Square Law).
8. Shelf ratios of a sample holder.
9. Determination of Efficiency of a Geiger-Muller (G-M) counter.
10. Energy dependence of Geiger-Muller (G-M) counter efficiency.
11. Determination of beta decay energy.
12. Relationship between thickness of absorber and backscattering
13. Shielding effect of radiation penetrability
14. Strength of a beta-source
15. Determination of Half-Life of unknown sample
16. Half-life of ^{40}K.
17. Statistics of radioactive measurements.
18. Poisson distribution of radioactive measurements.
19. Gaussian distribution of radioactive measurements.
20. Chi-Square test of Geiger-Muller (G-M) counter.
21. Study of Mossbauer spectra of magnetic materials.
22. Statistical aspects of radioactivity measurements.
23. Beta backscattering as a function of atomic number.
24. Determination of the air borne activity.
25. Secular equilibrium.
26. Transient equilibrium.

Note: Students should perform any eight experiments.

PHYL-321 – Lab course 5 (D1) : CRYSTALLOGRAPHY : Credits 3

Experiments on Crystallography:

1. Determination of energy band gap of semiconducting material (Thermister) by Bridge method.
2. Measurement of Hall coefficient of a given sample..
3. Energy band gap of a P-N junction
4. To measure the ionic conductivity of ionic solids and to determine activation energy
5. Variation of specific heat of solid with temperature
6. To determine the coefficient of thermal conductivity
7. Determination of velocity and wavelength of ultrasonic waves.
8. Study of crystal structure by Powder method front reflection, back reflection (measurement of lattice parameter and indexing of powder photograph / X ray powder diffractometer data cubic, tetragonal, orthorhombic)
9. Interpretation of transmission Buare photograph
10. Determination of orientation of crystal by back reflection Laue method
11. Rotation / Oscillation photograph and their interpretation
12. Determination of particle size using X-ray powder method
13. Porosity determination of semiconducting material.
14. Structural analysis of thin film by XRD

Note: 1) Other experiments may be added as per the availability of instruments. 2) Students should perform any eight experiments.

PHYL-322 : Lab course 6 (Based on Electives A2/ B2/ C2/ D2)

PHYL-322 – Lab course 6 (A2) : Microwave and communication Electronics: Credits 3

Experiments based on Microwave and communication Electronics:

1. Demonstrate the relationship between frequency (f), wavelength (λ_0) in free space and wavelength in waveguide (λ_g)
2. Reflex Klystron Characteristics – Mode diagrams, ETR and ETS
3. Gunn Diode Characteristics; I-V Characteristics, Power versus bias characteristics and Power-frequency characteristics
4. Microwave Horn Antenna E-H Plane pattern and Beam width
5. Study of square law behavior of microwave crystal detector and hence to determine Operating range and detection frequency
6. Study of high and low VSWR and impedance measurements using Smith chart.
7. Measurement of S- parameters of a) E-Tee b) Magic Tee c) Directional coupler.
8. Determination of dielectric constant of solids – Two point method
9. Determination of dielectric constant of liquids – Robert-Von Hipple method
10. Study of Faraday's rotational principle
10. Study of PAM and its detection
11. Study of Balance modulator using IC 1596
12. Study of FSK modulation and detection
13. Study of PPM and detection
14. Study of PLL
15. Study of PWM and detection

Note: Students must perform at least **eight** experiments from above list.

PHYL-322 – Lab course 6 (B2) : Molecular Spectroscopy: Credits 3

Learning Objectives:

a) Recording the molecular spectra using latest computer interfaced instruments
b) Vibrational and rotational analysis of the recorded molecular spectra and estimation of molecular parameters
c) Study of various types of excitation mechanisms and excitation sources
d) Theoretical knowledge of potential energy curves, wavefunctions, molecular orbitals, basis sets, functions

Learning Outcomes:

a) The student will get a training for using state of the art data acquisition system in spectroscopy laboratory
b) The student will get a training for analysis of recorded molecular spectra
c) The student will be able to design various kinds of spectroscopic emission sources and their power supplies
d) The student will be able to design the electromagnets and their power supplies
e) Hence the Entrepreneurship.

Experiments based on Molecular Spectroscopy

1. Vibrational analysis AlO : Record the spectrum of Al arc in air using HR4000 spectrometer. Construct the Deslandre's table by using known wavelengths and calculate the vibrational constants of upper and lower electronic states
2. Vibrational analysis C_2 Swan system: Record the spectrum of gas flame (C_2 Swan system) in air using high resolution monochromator. Construct the Deslandre's table by using known wavelengths and calculate vibrational constants of upper and lower electronic states
3. Recording the high resolution spectra of BeO using high resolution spectrometer with CCD camera and calculate vibrational constants of upper and lower electronic states
4. Rotational analysis of spectra of diatomic molecules (High resolution spectroscopy)
5. Studies of IR spectra of organic molecules containing various functional groups using IR/FTIR spectrometers.
6. Spectroscopic investigations of molecules using Raman Spectrometer.
7. Record the spectrum of Iodine and determine dissociation energy of I_2 molecule by Brige-Spooner method
8. Calculation of Morse potential energy curves for molecular X and B states of AlO, and to plot wavefunctions and probability amplitudes for first three vibrational levels of the two states

9. Calculation of Morse potential energy curves for molecular states of Swan system of C_2, and to plot wavefunctions and probability amplitudes for first three vibrational levels of the two states.
10. Calculation of Morse potential energy curves for molecular states of visible system of BeO, and to plot wavefunctions and probability amplitudes for first three vibrational levels of the two states
11. "Comparing STO's and GTO's " Lab procedure
12. Basis sets, Functions , and CPU time Lab Procedure
13. Study of ESR spectra of various samples using ESR spectrometer

Note: Students should perform any eight experiments.

PHYL-322 – Lab course 6 (C2) : Nuclear Physics: Credits 3

Experiments based on Nuclear Physics

1. Study of gamma ray spectrum using scintillation counter using single channel analyzer.
2. Absorption of gamma rays in lead.
3. Absorption of gamma rays in aluminium.
4. Alpha spectroscopy with surface barrier detector- energy analysis of an unknown gamma source.
5. Determination of range of beta particles in aluminium.
6. X-ray fluorescence with proportional counter.
7. Determination of range of beta particles from unknown source by feather analysis.
8. Design, fabrication and study of Linear pulse amplifier.
9. Excitation of K-X-rays in different material by beta radiation (verification of Mosley's law).
10. Kinematics of Compton scattering. Compton scattering process.

Note: Students should perform any eight experiments.

PHYL-322 – Lab course 6 (D2) : Electrical Properties and Superconductivity: Credits 3

Experiments based on Electrical Properties and Superconductivity

1. Resistivity Measurement of a given sample by four probe method.
2. Characteristics of solar cell.
3. Measurement of dielectric constant and its variation with temperature.
4. Determination of bulk density of different materials using immersion technique.
5. Measurement of dielectric constant of liquids.
6. Measurement of electrical conductivity of Graphite at room temperature.
7. Determination of specific heat of Graphite at different temperatures.
8. Wind energy.
9. Measurement of dielectric constant of solids.
10. Porosity determination of Superconducting materials.
11. Determination of Bulk density of ferroelectric materials.
12. To measure ferroelectric hysteresis curves
13. Determination of Curie Temperature of Ferroelectrics.

Note: 1) Other experiments may be added as per the availability of instruments.2) **Students should perform any eight experiments.**

PHYR-331 : Research Project Part I (Experimental Work) : Credits 6

Students are expected to do experimental work as per the formulation of topic of research project selected during 2nd semester

PHYR-332 : Research Project Part V (Organization of Results) : Credits 3

Students are expected to organize the results of experiments carried out

_Semester - IV

Semester – IV
(Elective Courses)

PHYE-411: Generic Electives - 4 (A4/ B4/ C4/ D4): Credits 4

PHYE-411 – Generic Electives 4 (A4): Fundamentals of Sensors: Credits 4

(Credits: 04; Contact Hours: 60)

Lectures: 48

Tutorials: 12

Learning Objectives:

1. To facilitate the students to understand
   a) the concepts of sensor
   b) the concept of different principles of sensors
2. To provide an opportunity to the students to enter into sensor research
3. To create enthusiasm among the students to undertake research in sensors

Learning Outcome:

1. Students will be able to -
   a) learn Sensors, characteristics of sensors, optical fiber and optical sensors.
   b) develop sensor devices.

2. Students will be capable to undertake research in Sensors.

Course Contents:

Unit I : Introduction

Sensors and Sensor Science, Sensors–Eyes and Ears of Machines, The Term 'Sensor', Optical Sensors, Physical Sensors, Chemical Sensors, elements of chemical sensors, **Sensor Physics**, Solids, Energy Band Model, Lattice Defects, Ionic Conductance, Hopping, Junctions and Potential Barriers, **Primary electronics for sensors :** Amplification by Operational Amplifier, Instruments for electric measurements.

Unit II : Sensors and Sensor Characteristics

Sensors, Signals, and Systems; Ideal sensor curve, ideal sensor requisite, Sensor Classifications ; **Sensor Characteristics**: Transfer Function; Span (Full-Scale Input) ; Full-Scale Output ; Accuracy ; Calibration ; Calibration Error ; Hysteresis; Nonlinearity ; Saturation ; Repeatability ; Dead Band ; Resolution ; **Parameters of sensors** : Sensitivity, detection limit, response and recovery time, selectivity, dynamic range, linearity, stability

Unit III : Optical Sensors

Introduction of light detectors: Photodiodes, Phototransistor , Photoresistors ; photovoltaic cell, Optical waveguides and fibres, types of optical fibers : single mode, multimode and graded index optical fiber, concept of TIR and ATR, Optical fibre sensors: Introduction and classification of sensors with optical fibres, Optical fibre sensors with amplitude modulation, Sensor with wavelength modulation; Optical chemical sensors: Introduction, Optical sensors: Methods of detection, Evanescent wave sensors.

Unit IV : Physical Sensors

Potentiometric Sensors; Gravitational Sensors; LVDT and RVDT , Eddy Current Sensors , Piezoelectric sensors, **Resistive Sensors:** Potentiometers, Strain gages**;** Inductive sensors, Capacitive sensors, Bridge circuits, Displacement Measurements, **Blood Pressure Measurements:** Extravascular sensors, Intravascular sensors, Disposable pressure sensors

References:

1. Chemical Sensors: An Introduction for Scientists and Engineers : Grundler, Peter; Springer Berlin Heidelberg New York **(2007),** ISBN 978-3-540-45742-8
2. Modern Sensors Handbook, Edited by Pavel Ripka and Alois Tipek; ISTE Ltd, USA **(2007)**, ISBN 978-1-905209-66-8.
3. Handbook of Chemical and Biological Sensors; Edited by Richard F Taylor, Arthur D Little Inc., Jerome S Schultz, University of Pittsburgh ; Institute of Physics Publishing Bristol and Philadelphia; **(1996)** ISBN 0 7503 0323 9
4. Hand Book of Modern Sensors : Physics, Designs and Applications By Jacob Fraden Third Edition (Springer-Verlag New York, Inc.) **(2004)**, ISBN 0-387-00750-4.
5. Understanding Smart Sensors By Randy Frank; Second Edition; Artech House Boston . London **(2000),** ISBN 1-58053-398-1.
6. Sensors and Transducers, Third Edition By Ian R. Sinclair; Butterworth-Heinemann publication, Woburn **(2001),** ISBN 0 7506 4932 1
7. Principles of Chemical Sensors : Janata, Jiri 2nd Edition ; Springer Dordrecht Heidelberg London, New York **(2009),** ISBN 978-0-387-69930-1 e-ISBN 978-0-387-69931-8
8. Optoelectronics Devices and System SECOND EDITION by S. C. Gupta; Prentice Hall International **(2011)** ISBN: 978-81-203-5065-6
9. Optical Fibers and fiber optic communication Systems by Subir Kumar Sarkar; S Chand & Company Ltd **(2000),** ISBN: 9788121914598
10. Lasers and Optical Fiber Communications by P Sarah; I.K. International Publishing House Pvt Ltd, New Delhi **(2008),** ISBN : 9788189866587 / 8189866583
11. Optoelectronics by R. A. Barapate (Tech-Max Publication) **(2003)**

PHYE-411 – Generic Electives 4 (B4) : Applied Spectroscopy

(Credits: 04; Contact Hours: 60)

Lectures: 48

Tutorials: 12

Learning Objectives:

a) Describe the basic principles of physics as related to the field of photonics.
b) Integrate the concepts of light, geometric and wave optics and their practical applications in photonics.
c) Theory and practice of instrumental methods for the separation, identification and quantitative analysis of chemical substances.
d) To understand how structure and bonding influence the physical properties and reactivity of molecules.
e) To be able to use crystal field theory to understand the electronic and magnetic properties of transition metal complexes.
f) To be able to use symmetry to predict molecular orbital diagrams and explain electronic spectra

Learning Outcomes:

a) After completing this course the student will be able to use spectroscopic methods for qualitative and quantitative analysis.

Course Contents

1. **SPECTROSCOPIC INSTRUMENTATION:** Spectrographs and Monochromators, Speed of Spectrometer, Spectral Transmission Range, Spectral Resolving Power, Free Spectral Range, Prism Spectrometer, Basic Considerations and Spectral Resolving Power of Grating Spectrometers, Multiple Beam Interferometry: Basic Concepts, Comparison between Spectrometer and Interferometer: Spectral Resolving Power, Light Gathering Power, Accurate Wavelength Measurement.

2. **DETECTION OF LIGHT**: Thermal Detectors, Photodiodes, Photoconductive Diodes, Photovoltaic Detectors, Fast Photodiodes, Photodiode Arrays, Photoemissive Detectors, Photocathodes, Photomultipliers, Detection Techniques and Electronic Equipment, photon counting, Charge Couple Devices.

3. **FLUORESCENCE & PHOSPHORESCENCE SPECTROSCOPY**: Fluorescence. Joblanski Diagram, Resonance Fluorescence and Normal Fluorescence. Intensity of Transitions. Non Radiative Decay of Fluorescent Molecules, Effects of Medium on Fluorescence Spectra. Population of Triplet States, Phosphorescence Intensity, Solvent

Effect, Delayed Fluorescence. Excitation Spectra. Experimental Methods, Emission Life Time Measurement. Application of Fluorescence and Phosphorescence.

4. **MOLECULAR SYMMETRY AND GROUP THEORY:** The Defining Properties of a Group, Some Examples of Groups, Subgroups, Classes, Symmetry Operations, Symmetry Elements, Algebra of Symmetry Operations, Multiplication Table. Molecular Point Groups, Matrix Representation of Symmetry Operations, Reducible and Irreducible Representations, Character Table for C_{2v} and C_{3v} Point Groups, Symmetry Species of Point Groups, Complete Character Table for Point Group, Distribution of Fundamentals among the Symmetry Species, Infrared Activity, Raman Activity.

References :

1. Laser Spectroscopy, Volume 1: Basic Principles, Fourth Edition by Wolfgang Demtroder, Springer,
   ISBN: 978-3-540-73415-4 e-ISBN 978-3-540-73418-5, DOI 10.1007/978-3-540-73418-5 Library of Congress Control Number: 2007939486, © 2008, 2003, 1996, 1981 Springer-Verlag Berlin Heidelberg.
2. Modern Spectroscopy by J. M. Hollas, ISBN: 9780470844167, Published by John Wiley & Sons Ltd. (2004) Fourth Edition.
3. Spectroscopy by B. P. Straughan & S. Walker, ISBN: 0470150319 (v.1, Halsted Press), ISBN: 0470150327 (v.2), ISBN: 0412133806 (v.3, Cased Ed.) London: Chapman & Hall, New York, Vol. 1,2 & 3 (1976)
4. MOLECULAR STRUCTURE AND SPECTROSCOPY, by ARULDHAS, G. , Second Edition ,2004. ISBN: 978-81-203-3215-7, PHI Learning
5. Chemical Applications of Group Theory by F. Albert Cotton, ISBN: 9780471510949, John wiley & Sons (Wiley - Interscience) (1990) Third Edition.
6. Elements of Group Theory for Physicists by A. W. Joshi, ISBN: 812240975X, New Age International Private Limited publishers, New Delhi, (1997) Revised Fourth Edition.
7. Group Theory and Quantum Mechanics by M. Tinkham, ISBN: 9780486432472, Mc-Graw Hill Book Company, New Delhi (1964).

PHYE-411 – Generic Electives 4 (C4) : Particle Physics, Nuclear forces and Cosmic rays:

(Credits: 04; Contact Hours: 60)

Lectures: 48

Tutorials: 12

Learning Objectives:

This course is necessary for the students to make aware to various elementary particles apart from proton, neutron and electron. The knowledge of elementary particles is helpful in understanding the nuclear structure, their interactions, the course should be taught as an elective and it should be taught at Semester-IV as it requires understanding of interactions of those particles with other particles (elementary particles) which is a very involved topic and requires knowledge of other aspects of nuclear physics covered in IIIrd semester. The course will help the student for preparation of NET/SET and other competitive examinations.

Learning Outcomes:

The course is useful to students as it provides knowledge of various elementary particles, their properties etc and the nature of strongest force i.e. Nuclear force. The students can get job and opportunity of research in nuclear energy sector and accelerator center. The course is extremely important for carrying out theoretical research leading to more and more elementary particles and ultimately vision of universe. The origin of universe is a hot topic these days, for which studies in cosmic rays in also necessary in short, the course for the basis for front-line research in physics in present times.

Course Contents:

Unit I: Elementary Particles physics-I

Concept of elementary particle, Fundamental properties of elementary particles, Classification of elementary particles, Particle Interactions, Coupling constant, Quantum numbers of elementary particles, Conservation laws of elementary particles, Relationship between particle and antiparticle.

Unit II: Elementary Particle Physics-II

Properties of massless and Lepton Particles, Properties of mesons (Pions, Neutral π-meson, K-mesons, η-meson), Properties of Baryons (Nucleons, Hyperons, resonant particle), Description of strange particles (K-mesons and Hyperons, Violation of parity, Strangeness and hypercharge, Properties of strange particles), Quarks and Gluons, Inversions in elementary particles (Time-reversal, Parity, Charge conjugation), Elementary particle symmetries (SU (3)-symmetry, Gell-Mann-Okubo mass formula).

Unit III: Nuclear Forces

Introduction, Characteristics of nuclear forces, The deuteron, The ground state of deuteron, Radius of deuteron, n-n and n-p scattering, p-p scattering below 10MeV, Distinction between p-p and n-p scattering, Similarity between n-n and p-p forces, Meson theory of nuclear forces.

Unit IV: Cosmic rays

Introduction, Types of cosmic rays, Properties of primary cosmic rays, Geomagnetic effect, Interpretation of geomagnetic effect, Properties of secondary cosmic rays, Absorption of cosmic rays, cosmic ray showers, Extensive air showers, origin of cosmic rays.

References:

1. **Fundamentals of Nuclear Physics,** Jahan Singh, 1st edition, Pragati Prakashan, Meerut- (2012) (ISBN-978-93-5006-593-8)
2. **Nuclear Physics,** D. C. Tayal, 10th edition, Himalaya Publishing House, Mumbai- (2005) (ISBN-81-8318-281-x).
3. **Nuclear Physics,** Satya Prakash, 2nd edition, Pragati Prakashan, Meerut (2011) (ISBN-81-7556-915-8).
4. **Nuclear Physics,** S. B. Patil, 1st edition, New Age International Publishers, New Delhi- (1991) (ISBN-978-81-224-0125-7).
5. **Nuclear Measurement Techniques,** K. Sri Ram, 1st edition, Affiliated East-West Press, Madras(1986) (ISBN-81-85095-56-6).
6. **Basic Nuclear Physics,** B. N. Srivastava, 14th edition, Pragati Prakashan, Meerut (2008) (ISBN-978-81-8398-474-4).
7. **Nuclear Physics,** R. C. Sharma, 1st edition, K. Nath & Co. Meerut- (2007) (ISBN-EBK0036746).
8. **Nuclear Physics,** K. P. Das, 1st edition, Cyber Tech Publications, New Delhi- (2009) (ISBN-978-81-7884-517-3).
9. **Radioactive Materials,** Dr. B. M. Rao, 1st edition, Himalaya Publishing House, Mumbai- (2002).
10. **Nuclear Energy,** R. K. Taneja, 1st edition, Cyber Tech Publications, New Delhi- (2009) (ISBN-978-81-7884-516-6).

PHYE-411 – Generic Electives 4 (D4) : Magnetic Materials and Superfluidity

(Credits: 04; Contact Hours: 60)

Lectures: 48

Tutorials: 12

Learning Objectives:

The objective of the course is to teach types and origins of magnetism in solids. In addition, we will discuss physical reasons that is directly or indirectly related to magnetism. The theories of dia, para, ferro, antiferro, ferri-magnetism and superfluidity will be understood in detail.

Learning Outcomes:

Upon successful completion of the course, students will be able to:

1. Discover the physical origin of diamagnetism in solids.
2. Discover the physical origin of paramagnetism in solids.
3. Group the materials according to their magnetic susceptibilities
4. Analyze the strong magnetization in ferromagnetic materials
5. Determine the differences between ferro and ferrimagnetic substances
6. Compute the experimental results by theoretical calculations.
7. Argue the magnetic dipole, spin and superfluidity concepts in detail

Course Contents:

Unit I: Diamagnetism and Paramagnetism:

Classification of Magnetic Materials, Langevin's theory of diamagnetism, Quantum theory of Diamagnetism of Mononuclear system, Paramagnetism: Origin, Langevin's classical theory of Paramagnetism, Weiss theory, quantum theory of paramagnetism, magnetism of rare earth ions, iron group ions, crystal field splitting, quenching of orbital angular momentum, Hund rules, paramagnetic susceptibility of conduction electrons, Van Vleck Temperature – Independent Paramagnetism, Problems.

Unit II: Ferromagnetism:

Ferromagnetic ordering, Weiss theory, Curie – Weiss law, Heisenberg exchange interaction, magnon and dispersion relation for magnons, Quantization of spin waves, Thermal excitation of Magnons, origin of domains, domain walls, coercive force, hysteresis, motion of domain walls, experimental methods to determine the magnetic susceptibility, thickness and energy of Bloch wall, anisotropy energy, Problems.

Unit III: Antiferromagnetism and Ferrimagnetism:

Antiferromagnetc order, the two sublattice model, susceptibility below the Neel temperature, the dispersion relation for magnons in an antiferromagnet, super exchange interaction, Ferrimagnetic order, Curie temperature and susceptibility of ferrimagnets, Spinel, Garnets, ferrimagnetic compounds, properties of ferromagnetic substances: High Temperature Susceptibilities, Specific Heat, Thermal Conductivity, the structure of ferrites, the saturation magnetization, Neel's theory.

Unit IV: Superfluidity:

Phenomenology, two fluid model, Bose-Einstein Condensation, Landau theory, super fluid viscocity, super fluid flow, excited state, Ginzberg- Landau equations, second order critical fields, Abrikosov vortex lattices.

References:

1. Introduction to Solid State Physics, Charles Kittel, Willey Eastern Pvt. Ltd. Seventh Edition -2009.
2. Concepts of Solid State Physics- J. N. Mandal, Pragati Second Revised Edition 2011, ISBN: 978-93-5006-456-9.
3. Solid State Physics-Vimal Kumar Jain, Ane Books Pvt. Ltd., 2013, ISBN: 978-93-8116-297-2, Website: www.anebooks.com.
4. Superfluidity and Superconductivity, D. R. Tilley, J. Tilley,CRC Press, 01-Jan-1990 – Science.
5. Structure and Properties of Solids- B. A. Mattoo, A Pragati Edition, First Edition 2008, ISBN: 978-81-8398-495-9.
6. Materials Science- S. L. Kakani and Amit Kakani, A New Age International Publishers, 2004, ISBN: 81-224-1528-8.
7. Solid State Physics, S. O. Pillai, New Age International Pvt. Ltd.
8. Solid State Physics – M. A. Wahab, Narosa Publishing House, ISBN: 81-7319-266-9.
9. Solid State Physics, A. J. Dekker
10. Introduction to Solids – L. V. Azaroff, McGraw Hill, New York, 2001, ISBN: 10:0070992193.
11. Introduction to Magnetic Materials- B. D. Cullity and C. D. Graham, Second Edition, Willey Online Library, Published Online: 29 FEB 2008 DOI: 10.1002/9780470386323, e-Book.
12. The Physics of Ferromagnetism- Terunobu Miyazaki, Jin Hanmin, Springer 2012, ISBN: 9783642255830 e-Book 489 pages.
13. Hanbook of Magnetic Materials- K. H. J. Buschow(ed.), Elsevier Science 2013, ISBN: 9780444595959, e-Book 394 pages.
14. Physics of Ferromagnetism- Soshin Chilazumi, Oxford University Press 2009, ISBN: 9780191569852, e-Book 668 papges.
15. The Faraday effect in diamagnetic glasses, Jianrong Qiu[a1] and Kazuyuki Hirao[a2], □ Journal of Materials Research / Volume 13 / Issue 05 / 1998, pp 1358-1362, Copyright © Materials Research Society 1998, Published online: 31 January 2011.
16. Ferromagnetic ordering in $NpAl_2$: Magnetic susceptibility and ^{27}Al nuclear magnetic resonance, L. Martel, , J.-C. Griveau, R. Eloirdi, C. Selfslag, E. Colineau, R. Caciuffo, Journal of Magnetism and Magnetic Materials, Volume 387, 1 August 2015, Pages 72–76.
17. Carbon-Induced Ferromagnetism in the Antiferromagnetic Metallic Host Material Mn_3ZnN

Ying Sun *†, Yanfeng Guo ‡, Yoshihiro Tsujimoto †, Jiajia Yang §, Bin Shen §, Wei Yi Yoshitaka Matsushita ∥, Cong Wang ⊥, Xia Wang ‡, Jun Li ‡, Clastin I. Sathish ‡⊗, and Kazunari Yamaura *‡*Inorg. Chem.*, 2013, 52 (2), pp 800–806, **DOI:** 10.1021/ic3019265 Publication Date (Web): January 7, 2013.

18. Antiferromagnetic behavior in Y–Ba–($Cu_{1-x}Sc_x$)–O, A. Chakraborty[a1], X. D. Chen[a1], F. Zuo[a1], B. R. Patton[a1], J. R. Gaines[a1] and A. J. Epstein[a2], Journal of Materials Research Journal of Materials Research / Volume 4 / Issue 03 / 1989, pp 467-469, Copyright © Materials Research Society 1989, Published online: 31 January 2011, DOI: http://dx.doi.org/10.1557/JMR.1989.0467 (About DOI)
19. High-Temperature Ferrimagnetism Driven by Lattice Distortion in Double Perovskite Ca_2FeOsO_6, Hai L. Feng *†‡, Masao Arai §, Yoshitaka Matsushita ∥, Yoshihiro Tsujimoto ⊥, Yanfeng Guo †, Clastin I. Sathish †‡, Xia Wang †, Ya-Hua Yuan †‡, Masahiko Tanaka #, and Kazunari Yamaura, *J. Am. Chem. Soc.*, 2014, 136 (9), pp 3326–3329, **DOI:** 10.1021/ja411713q, Publication Date (Web): February 17, 2014, Copyright © 2014 American Chemical Society.
20. Calculation of losses in ferro- and ferrimagnetic materials based on the modified Steinmetz equation, J. Reinert A. Brockmeyer, A. Brockmeyer, Rik W. De Doncker, Rik W. De Doncker, Emotron AB, Helsingborg, IEEE Transactions on Industry Applications (Impact Factor: 2.05). 08/2001; DOI: 10.1109/28.936396, Source: IEEE Xplore.
21. Synthesis and characterization of coprecipitation-derived ferrimagnetic glass-ceramic, O. Bretcanu, S. Spriano, C. Brovarone Vitale, E. Verné, Journal of Materials Science, February 2006, Volume 41, Issue 4, pp 1029-1037, Date: 04 Feb 2006.

PHYE-412 – Electives 5 (A5/ B5/ C5/ D5)

PHYE-412 – Electives 5 (A5) : 8051- Microcontroller

(Credits: 04; Contact Hours: 60)

Lectures: 48

Tutorials: 12

Learning objectives:

- Give an understanding about the concepts and basic architecture of 8051
- Provide an overview of difference between microprocessor and micro controller
- Provide background knowledge and core expertise in 8 bit microcontroller 8051.
- Study the architecture, various blocks from 8051 , ports, memory organization and various addressing modes of 8051 and various moving op-code.
- Give knowledge about arithmetic operations and jump ranges and instructions.
- Impart knowledge about assembly language programs of 8051
- Help understand the importance of different peripheral devices & their interfacing to 8051
- Impart knowledge of different types of external interfaces including LEDS, LCD, Keypad Matrix, Stepper motor & seven segment displays.

Learning Outcomes :

- The students would learn the basic difference between the microprocessors and microcontroller with the family information.
- The students will learn the architecture and basic function of the microcontroller.
- The students will learn the programming tools which is used for the programming of the microcontroller.
- The students will learn the 8051 microcontroller assembly language program logic. The students will learn hardware interface of the microcontroller with the actual devices like stepper motor, LCD etc.

Course contents:

Unit I: 8051 Microcontroller:

An Introduction: Microprocessors and Microcontrollers, comparing microprocessors and Microcontrollers, a Microcontrollers survey, development system for Microcontrollers, 8051 Microcontroller hardware: Block diagram, Programming model, pin diagram, the 8051 oscillator and clock, program counter and data pointer, A and B CPU registers, flags and program status word, internal memory, internal RAM, the stack and the stack pointer, special function registers, internal ROM; Input / output pins, ports and circuits: port pin circuits, port 0, port 1, port 2, port 3; external memory, counters and timers, serial data input / outputs, interrupts.

Unit II: Moving data and logical operations:

Move Operations**:** Introduction, addressing modes, external data moves, code memory read only data moves, push and pop op-codes, data exchange, simple programs, Logical operations: Introduction, byte level logical operations, bit level logical operation, rotate and swap operations, examples programs.

Unit III: Arithmetic Operations:

Introduction, flags, instructions affecting flags, incrementing and decrementing, addition: unsigned and signed , multiple byte signed arithmetic, subtraction : Unsigned and signed subtraction, multiplication and division, decimal arithmetic, examples programs;

Unit IV: Jump and call Instructions and applications:

Introduction, the jump and call program range, relative range, Short absolute range, long absolute range. Jumps, bit jumps, byte jumps, unconditional jumps, Calls and subroutine, subroutines, Calls and the stacks, Calls and returns. Interrupts and returns, examples problems. Application of 8051 Microcontroller: Simple programmes using 8051 Microcontroller, Display, generation of waves, Pulse measurements, D/A and A/D conversion, Stepper motor.

References:

1. The 8051 Micorcontroller, Architecture, Programming and applications by Kenneth J Ayala ; Second Edition, ISBN 0-314—20188-2 (hard Copy) 1991; ISBN 0-314-77278-2(Soft) 2014.
2. Microprocessors and Interfacing : Programming and Hardware by Douglas V Hall : II Edition ; Tata McGraw-Hill Edition
3. The 8051 Microcontroller and embedded Systems by Muhammad Ali Mazidi and Janice Gillspie Mazidi; Pearson Education.

PHYE-412 – Electives 5 (B5) : Lasers, Nonlinear Optical mixing and Spectroscopic Phenomena

(Credits: 04; Contact Hours: 60)

Lectures: 48

Tutorials: 12

Learning Objectives:

To enable the students to study the basic and advance concepts of Lasers, non-linear optical mixing and spectroscopic phenomena.

Learning Outcomes:

Students will be able to study the basic and advance concepts of Lasers, non-linear optical mixing and spectroscopic phenomena.

Course Contents:

Unit I: Basic Concepts:

Absorption, induced and spontaneous emission, Polarization of light, absorption and emission spectra, transition probabilities, life times, spontaneous and radiationless transitions, Semiclassical description, Basic equations. Dipole approximation, Coherence properties of radiation fields, temporal, spatial coherence, coherence volume, the coherence function and the degree of coherence

Unit II: Lasers:

Fundamentals, basic elements, threshold condition, rate equations, laser resonators, open optical resonator, stability of resonators. Spectral characteristics of laser emission, active resonators and laser modes, gain saturation, spatial hole burning. Multimode lasers and gain competition, mode pulling

Unit III: Tunable lasers:

Basic concepts, semiconductor-diode laser, Tunable solid state lasers, color center lasers, Dye lasers: flash lamp pumped dye lasers, Pulsed-laser pumped dye laser, continuous wave dye laser

Unit IV: Non liner optical mixing:

Physical Background , Phase Matching, Second harmonic generation, Quasi Phase Matching Sum frequency & higher harmonic generation. X ray laser. Optical parametric oscillator, Difference-Frequency Spectrometer [Scope: Reference 1, chapter 5:5.8]

References:

1. Laser Spectroscopy, Volume 1: Basic Principles, Fourth Edition by Wolfgang Demtroder, Springer, ISBN 978-3-540-73415-4 e-ISBN 978-3-540-73418-5 , DOI 10.1007/978-3-540-73418-5, Library of Congress Control Number: 2007939486, © 2008, 2003, 1996, 1981 Springer-Verlag Berlin Heidelberg
2. MOLECULAR STRUCTURE AND SPECTROSCOPY, by ARULDHAS, G. , Second Edition ,2004. ISBN: 978-81-203-3215-7, PHI Learning
3. ATOM, LASER AND SPECTROSCOPY by THAKUR, S. N. , RAI, D. K. , SECOND EDITION , 2010; ISBN: 978-81-203-4832-5

PHYE-412 – Electives 5 (C5) : Radiation Measurements And Nuclear Dosimetry

(Credits: 04; Contact Hours: 60)

Lectures: 48

Tutorials: 12

Learning Objectives:

This course gives awareness and understanding of the applications of nuclear techniques in industry, Agriculture and Medical safety standards required. The course is very advanced course utilizing the concepts learnt in IIIrd semester in the elective course "Nuclear reactions and Nuclear energy" So this can also be only an elective course in IVth Semester. The course will help the student for preparation of NET/SET and other competitive examinations. After completion of this course the student will be able to understand the possibilities of starting one's own business, using nuclear radiations including agriculture like food preservations, improvement of seed qualities etc.

Learning Outcomes:

The student after completing M.Sc. degree with their specialization as nuclear physics will be able to do advanced diploma in using nuclear radiations for medical disorders and diseases on human-beings, animals etc. These students after completing their M.Sc. degree, will be having very good opportunities in industry like Polymers, Fault finding in metal, Polymer, equipments and components, high quality welding etc. The student will be highly beneficial to the society in his/her later life by performing many essential duties to help people to lead improved and prosperous lives.

Course Contents:

Unit I: Interaction of Nuclear Radiations with matter

Stopping power of charged nuclear particles, Range and straggling, Stopping power and range of electrons, Absorption of gamma rays, Photoelectric effect, Compton effect, Pair production.

Unit II: Nuclear radiation measurements

Crystal conduction counters, Energy resolution of the counter, Surface barrier counters, Cloud chamber, Diffusion cloud chamber, Bubble chamber, Spark chamber.

Unit III: Radiation Protections

Harms of radiation to body, Radiation safety standards, Radiation dosimetry measuring instruments, Film dosimetry principles, Experimental techniques, Applications, solid state nuclear track dosimetry, Track processing methods, Counting procedure and applications, Safe working methods of nuclear radiation.

Unit IV: Applications of Nuclear irradiations

Introduction, The technique of NMR, Seed oil mass screening by NMR technique, Mossbauer effect, Some experiments using Mossbauer effects, Activation analysis for element detection, Solid state nuclear track dosimetry (SSNTD), Radiation effects, Mutation by irradiation.

Books:

1. **Basic Nuclear Physics,** B. N. Srivastava, 14th edition, Pragati Prakashan, Meerut (2008) (ISBN-978-81-8398-474-4).
2. **Nuclear Physics,** D. C. Tayal, 10th edition, Himalaya Publishing House, Mumbai- (2005) (ISBN-81-8318-281-x).
3. **Nuclear Measurement Techniques,** K. Sri Ram, 1st edition, Affiliated East-West Press, Madras(1986) (ISBN-81-85095-56-6).
4. **Basic Nuclear Physics,** B. N. Srivastava, 14th edition, Pragati Prakashan, Meerut (2008) (ISBN-978-81-8398-474-4).
5. **Nuclear Physics,** R. C. Sharma, 1st edition, K. Nath & Co. Meerut- (2007) (ISBN-EBK0036746).
6. **Fundamentals of Nuclear Science;** P.N. Tiwari, Wiley eastern Pvt. Ltd. New Delhi, 1974.
7. **Fundamentals of Nuclear Physics,** Jahan Singh, 1st edition, Pragati Prakashan, Meerut- (2012) (ISBN-978-93-5006-593-8)

PHYE-412 – Electives 5 (D5) : Material Synthesis and Characterization

(Credits: 04; Contact Hours: 60)

Lectures: 48

Tutorials: 12

Learning objectives: Advances in technology depends more and more on the discovery and development of new materials having particular desired properties. In addition to mechanical strength, various structural, optical, electrical, magnetic and thermal properties are demanded from materials depending on the application.

Learning Outcomes: The field of Materials Science investigates different classes of materials - metals, ceramics, polymers, electronic materials, biomaterials- with an emphasis on the relationships between the underlying structure and the processing, properties, and performance of the materials. Research opportunities are offered as scientists and technologists, etc in national and international institutions

Course contents:

Unit I: Independent Electron Approximation

The Hartree equations, Thomas- Fermi and Lindhard Theory, the Hartree Fock approximation, the tight binding approximation, the Wigner and Seitz method, energy band calculations Fermi-Liquid theory, Lindhard theory.

Unit II: Synthesis and Characterization of Ferrites:

Synthesis: successive ionic layer adsorption and reaction (SILAR), solid state reaction route (SSRR), co-precipitation route (CR), properties: Electrical, Mechanical & magnetic, characterization: X-ray diffraction (XRD), Thermal electron microscopy (TEM).

Unit III: Thin Film Deposition Techniques:

Vacuum pumps: Mechanical pumps-oil sealed Rotary pumps, roots pumps, molecular-drag pumps, cryogenic pumps, vacuum seals, vacuum measurement- thin film nucleation- the capillarity model, the critical Nucleus physical vacuum deposition,

Unit IV: Synthesis and characterization of HTSC Materials:

Synthesis : solid state reaction route (SSRR), Chemical Route, Melt Grown Route, Melt Grown and Infiltration route, Co-precipitation Route, Sol-Gel Route. Properties: mechanical, electrical and magnetic, characterization: X-ray diffraction (XRD), determination of lattice parameters from XRD data, estimation of volume, density, scanning electron microscopy (SEM), Scanning tunneling microscopy (STM). Superconducting quantum interference devices system (SQUIDs).

References :

1. Hand book of Thin Film Technology (McGraw-Hill Handbooks)Leon I. Maissel, Reinhard Glang Published by Mcgraw-Hill (Tx) (1970) ISBN 10: 0070397422 ISBN 13: 9780070397422
2. Super fluidity and Superconductivity – D. R. Tilley and J. Tilley Published by INST OF PHYSICS (2015) ISBN 10: 0750300337 ISBN 13: 9780750300339
3. Superconductivity – T. V. Ramakrishan and C. N. R. Rao
4. Physical and magnetic properties of High Temperature Superconductors – S. K. Malik and S. S. Shah (Nova Science publishers. Inc.)

PHYE-413: Generic Electives - 6 (A6/ B6/ C6/ D6): Credits 4
(Research Oriented)

PHYE-413 – Generic Electives 6 (A6): Advanced Sensor Technology
(Research Oriented)

(Credits: 04 ; Contact Hours : 60)

Lectures: 48

Tutorials: 12

Learning Objectives:

1. To facilitate the students to understand
   c) the concepts of sensor science and technology
   d) the concept of Sensor materials and different principles of sensing technology which are used at laboratory as well industrial level
2. To provide an opportunity to the students to enter into sensor research and develop smart sensor devices.
3. To create enthusiasm among the students to undertake research in sensors

Learning Outcome:

1. Students will be able to -
   c) learn sensor materials and technologies,
   d) develop sensor devices and sensor networks.

2. Students will be capable to undertake the job in sensor industries.
3. Students will have option to start his / her teaching career either in science or engineering colleges / institutes as this course is included in science as well engineering discipline OR do research in sensor science.

Course Contents:

Unit I : Sensor Materials and Sensor Matrix

Materials : Material selection criteria, fulfilment of ideal sensor requisite, importance of 1-D materials in sensors, importance of surface area enhancement and enhancement in surface activity, Importance of size dependent Properties for sensing applications; Promising sensing materials: Carbon Nanotubes, Organic Conducting Polymers, Porphyrins and metal nanoparticles, Sensor Fabrication Technologies : AC Dielectrophoretic alignment of SWNTs and surface modification of SWNTs by OCP by charge controlled potentiostatic deposition and porphyrins by solid casting, for SWNTs, confirmation of coating by I-V measurements and electrochemical measurements;

Unit II : Chemical Sensors

Chemical Sensor Characteristics ; Specific Difficulties ; Classification of Chemical-Sensing Mechanisms ; Direct Sensors : Metal-Oxide Chemical Sensors, Chemiresistive and ChemFET sensors, Electrochemical Sensors, Potentiometric Sensors, Conductometric Sensors, Amperometric Sensors, Complex Sensors: Optical Chemical Sensors Biosensor, Multisensor Arrays, Electronic Noses (Olfactory Sensors),

Unit III : Integrated circuit manufacturing techniques for Sensors

Introduction, **Photolithography:** Masks, Mask alignment, Spinning resist**; Exposure and development***: Exposure, Development,* Resist tone, Critical dimension (CD) and resolution *(R)* **,** **Resist stripping***: Wet stripping, Dry stripping***; Subtractive techniques**: Overview, **Dry etching:** *Physical etching: sputtering or ion etching, Etching profiles for physical etching, Dry chemical etching, Physical-chemical etching;* **Wet etching:** *Anisotropic and isotropic etching, Etch stop techniques*, Comparison of dry- and wet-etch techniques**;**

Unit IV : Sensors Technology (Techniques for Sensor Fabrication)

Chemical Methods for preparation of sensor matrix: Chemical bath deposition, SILAR, **Physical vapor deposition** ***:*** *Evaporation, Sputtering, Molecular beam epitaxy, Laser ablation deposition;* **Chemical vapor deposition:** ***AP*** *CVD and LP CVD, PE CVD, Spray pyrolysis;* **Electrodeposition and electroless deposition***: Electroless deposition , Electrodeposition, Potentiostatic, Galvanostatic, Cyclic voltammetry* : **Chemical sensor fabrication technology** : screen printing, spin coating, dip coating, casting

References:

1. Modern Sensors Handbook, Edited by Pavel Ripka and Alois Tipek; ISTE Ltd, USA **(2007),** ISBN 978-1-905209-66-8.
2. Handbook of Chemical and Biological Sensors; Edited by Richard F Taylor, Arthur D Little Inc., Jerome S Schultz, University of Pittsburgh ; Institute of Physics Publishing Bristol and Philadelphia; **(1996)** ISBN 0 7503 0323 9
3. Hand Book of Modern Sensors : Physics, Designs and Applications By Jacob Fraden Third Edition (Springer-Verlag New York, Inc.) **(2004)**, ISBN 0-387-00750-4.
4. Understanding Smart Sensors By Randy Frank; Second Edition; Artech House Boston . London **(2000),** ISBN 1-58053-398-1.
5. Sensors and Transducers, Third Edition By Ian R. Sinclair; Butterworth-Heinemann publication, Woburn **(2001),** ISBN 0 7506 4932 1
6. Chemical Sensors: An Introduction for Scientists and Engineers : Grundler, Peter; Springer Berlin Heidelberg New York **(2007),** ISBN 978-3-540-45742-8
7. Principles of Chemical Sensors : Janata, Jiri 2nd Edition ; Springer Dordrecht Heidelberg London, New York **(2009),** ISBN 978-0-387-69930-1 e-ISBN 978-0-387-69931-8
8. Optoelectronics Devices and System SECOND EDITION by S. C. Gupta; Prentice Hall International **(2011)** ISBN: 978-81-203-5065-6
9. Optical Fibers and fiber optic communication Systems by Subir Kumar Sarkar; S Chand & Company Ltd **(2000),** ISBN: 9788121914598
10. Lasers and Optical Fiber Communications by P Sarah; I.K. International Publishing House Pvt Ltd, New Delhi **(2008),** ISBN : 9788189866587 / 8189866583
11. Optoelectronics by R. A. Barapate (Tech-Max Publication) **(2003)**

PHYE-413 – Generic Electives 6 (B6): X-Ray Spectroscopy (Research Oriented)

(Credits: 04 ; Contact Hours : 60)

Lectures: 48

Tutorials: 12

PHYE-413 – Generic Electives 6 (C6): Accelerator Physics (Research Oriented)

(Credits: 04 ; Contact Hours : 60)

Lectures: 48

Tutorials: 12

PHYE-413 – Generic Electives 6 (D6): Ferromagnetism
(Research Oriented)

(Credits: 04 ; Contact Hours : 60)

Lectures: 48

Tutorials: 12

OELE-101 : Service Course of Department of Physics (Laser in its Application) From other Departments

(Credits: 04; Contact Hours: 60)

Course Contents:

Unit I: Basic Concepts:

Absorption, induced and spontaneous emission, Polarization of light, absorption and emission spectra, transition probabilities, life times, spontaneous and radiationless transitions, Semiclassical description, Basic equations. Dipole approximation, Coherence properties of radiation fields, temporal, spatial coherence, coherence volume, the coherence function and the degree of coherence

Unit II: Lasers:

Fundamentals, basic elements, threshold condition, rate equations, laser resonators, open optical resonator, stability of resonators. Spectral characteristics of laser emission, active resonators and laser modes, gain saturation, spatial hole burning. Multimode lasers and gain competition, mode pulling

Unit III: Types of the Laser

Basic characteristic of laser, Solid Laser, Gas Laser

Unit IV: Application of Laser

1. Electronics
2.Space Communication
3.Medical
4.Optoelectronics Devices
5. Agriculture

References:

1. **Laser Spectroscopy, Volume 1: Basic Principles, Fourth Edition by Wolfgang Demtroder, Springer, ISBN 978-3-540-73415-4 e-ISBN 978-3-540-73418-5 , DOI 10.1007/978-3-540-73418-5, Library of Congress Control Number: 2007939486, © 2008, 2003, 1996, 1981 Springer-Verlag Berlin Heidelberg**
2. **MOLECULAR STRUCTURE AND SPECTROSCOPY, by ARULDHAS, G. , Second Edition ,2004. ISBN: 978-81-203-3215-7, PHI Learning**
3. **ATOM, LASER AND SPECTROSCOPY by THAKUR, S. N. , RAI, D. K. , SECOND EDITION , 2010; ISBN: 978-81-203-4832-5**

PHYL-421 – Lab course 7 (Based on Electives A4,A5/ B4,B5/ C4,C5/ D4,D5)

PHYL-421 – Lab course 7 (A4, A5) :
Fundamentals of Sensors and 8051- Microcontroller: Credits 3

A4 : Fundamentals of Sensors

Learning Objectives:

1. To facilitate the students to understand
   a) the concepts of sensor science and technology from different principles of sensing viz. Optical fiber based chemical, displacement, pressure sensors, Potentiometric sensor and gas sensors based on conducting polymers and single walled carbon nanotubes.
   b) properties of optical fiber (viz. Numerical aperture, losses in optical fiber and optical to electrical and electrical – optical characteristics of fiber optic converter)
   c) the concept of Sensor materials and different principles of sensing technology which are used at laboratory as well industrial level

2. To provide an opportunity to the students to enter into sensor research and develop smart sensor devices.
3. To create enthusiasm among the students to undertake research in sensors.

Learning Outcome:

1. Students will be able to -
   a) learn Sensors, characteristics of sensors, sensor materials and technologies, optical fiber and optical sensors, various methods of detection.
   b) develop sensor devices and sensor networks based on optical, thermal, optical fiber and chemical sensors.

2. Students will be capable to undertake job in optical fiber industries and sensor industries.
3. Students will have option to start his / her teaching career either in science or engineering colleges / institutes as this course is included in science as well engineering discipline OR do research in sensor science.

Course Contents:

1. Determination of Numerical Aperture of PMMA optical fiber
2. Losses in Optical fiber.
3. Study of Optical to Electrical (O-E) characteristics of fiber optic Phototransistor converter.
4. Study of Electrical to Optical (E-O) characteristics of fiber optic 660nm an 850nm converter.
5. Optical fiber chemical sensor.
6. Study of Displacement sensor
7. Study of Potentiometric sensor.
8. Gas sensor based on OCP (organic Conducting Polymers)

9. Gas Sensor based on Single Walled carbon nanotubes (SWNTs)
10. Study of characteristics of photovoltaic cell
11. Study of characteristics of Phototransistor.
12. Study of characteristics of Photoconductive cell
13. Study of characteristics of PIN Photodiode
14. Study of characteristics of IC temperature sensor (LM 335)
15. Study of K (chromel – alumel) type Thermocouple
16. Characteristics of Platinum RTD (Resistance – Temperature Detector)
17. Characteristics of NTC (negative Temperature Coefficient) Thermistor
18. Study of Optical fiber Pressure sensor

Note: Students should perform at least four experiments

(A5) : 8051- Microcontroller:

1. Programs for addition using 8051 microcontroller.
2. Programs for subtraction using 8051 microcontroller.
3. Programs for multiplication using 8051 microcontroller.
4. Programs for division using 8051 microcontroller.
5. Programs for data transfer.
6. Programs for ones, twos complements.
7. Programs for counters.
8. Program for Ascending and descending numbers using 8051 microcontroller.
9. Program to find Square root of given number using 8051 microcontroller.
10. Program to find Maximum and minimum numbers using 8051 microcontroller.
11. Program for temperature control interface using 8051 Microcontroller.
12. Program for analog to digital converter using 8051 microcontroller.
13. Program to generate ramp, triangular and square waves using DAC through 8255 of 8051 microcontroller.
14. Program for stepper motor interface using 8051 microcontroller.

Note: Students must perform at least four experiments from above list.

PHYL-421 – Lab course 7 (B4, B5)

Applied Spectroscopy and Lasers, Nonlinear optical mixing and spectroscopic phenomena : Credits 3

B4 : Applied Spectroscopy

Learning Objectives:

a) Knowledge about the experimental investigation methods of dielectrics.
b) Understanding the theoretical knowledge by experiments.
c) Capacities development for establishing measurement methods.

Learning Outcomes:

a) After completing this course the student will be able to determine the vibrations for a polyatomic molecule and identify whether they are infrared-active.
b) On the basis of NMR, FTIR and ESR spectra student will able to identify the material.

List of Experiment

1. Study of dielectric relaxation phenomena using TDR.
2. Study of the temperature dependence of permittivity in water using TDR .
3. Study of the permittivity in aqueous solutions using TDR.
4. Study of the temperature dependence of permittivity in alcohol using TDR.
5. Study of FTIR spectra of alcohol using FTIR spectrometer
6. Study of FTIR spectra of dimethylacetamide using FTIR spectrometer
7. Study of FTIR spectra of water using FTIR spectrometer
8. Analysis of FTIR spectra of water using prerecorded sample spectrum
9. Analysis of FTIR spectra of dimethylacetamide using prerecorded sample spectrum
10. Analysis of FTIR spectra of alcohol using prerecorded sample spectrum
11. Study of NMR spectra of acrylic using NMR spectrometer
12. Study of NMR spectra of delrin using NMR spectrometer
13. Study of NMR spectra of HBF_4 using NMR spectrometer
14. Study of NMR spectra of $H_2O + CuSO_4$ using NMR spectrometer
15. Study of NMR spectra of rubber using NMR spectrometer
16. Study of FTIR spectra of dimethylacetamide using NMR spectrometer
17. Study of ESR spectra of acrylic using ESR spectrometer
18. Study of ESR spectra of delrin using ESR spectrometer
19. Study of ESR spectra of HBF_4 using ESR spectrometer
20. Study of ESR spectra of $H_2O + CuSO_4$ using ESR spectrometer
21. Study of ESR spectra of rubber using ESR spectrometer
22. Analysis of ESR spectra of water using prerecorded sample spectrum

23. Analysis of ESR spectra of alcohol using prerecorded sample spectrum

Note: Students should perform at least four experiments

B5 : Nonlinear optical mixing and spectroscopic phenomena

Learning Objectives:

a) Basic knowledge of optical phenomena such as interference, interference between parallel plates, polarization, birefringence, absorption in optical media, total internal reflection, etc.
b) Applications of these phenomena in determining splitting of spectral lines (high resolution spectroscopy)
c) Behavior of optical media in external electric and magnetic fields
d) Estimation of parameters of optical media
e) Applications of lasers in investigating these phenomena
f) Computer interfacing of these experiments and analysis of observations

Learning Outcomes:

a) Basic training in optics
b) Analysis of high resolution spectra
c) Analysis of Optical patterns and other observations
d) Training of spectrophotometric techniques
e) The student will get a training for using state of the art data acquisition system in spectroscopy laboratory
f) Hence the student can get a job as “Analyst” in Research labs

Advanced Optics experiments using lasers

1. Study of polarization of triplet components in transverse configuration using Zeeman effect
2. Study of polarization of doublet components in longitudinal configuration using Zeeman effect
3. Determine the thickness of Fabry-Perot interferometer by exact fraction using CCD camera setup
4. Measure the divergence of a LASER beam
5. To determine the unknown concentration of solute using spectrophotometer
6. Measure the refractive index of a liquid (Water) using hollow prism.
7. Measure the attenuation in an optical fiber
8. Verify the Malu’s law
9. Setup and study the electro-optic Kerr effect
10. Setup and study the Faraday effect in solids and liquids
11. Measure the grating element of transmission grating
12. Measure the numerical aperture of an optical fiber
13. Measure the Brewster angle and hence the refractive index of a glass
14. To verify Beer and Lamberts law using spectrophotometer
15. Michelson interferometer
16. Fabry-Perot Interferometer
17. Twyman-Green Interferometer

References:

1. MEASUREMENT, INSTRUMENTATION AND EXPERIMENT DESIGN IN PHYSICS AND ENGINEERING by SAYER, MICHAEL, MANSINGH, ABHAI , ISBN: 978-81-203-1269-2 , PHI Learning, 1999.

Note: Students should perform at least four experiments

PHYL-421 – Lab course 7 (C4, C5)

Particle Physics, Nuclear forces, Cosmic rays and Radiation Measurements, Nuclear Dosimetry : Credits 3

C4 : Particle Physics, Nuclear forces, Cosmic rays

1. Pulse height gamma-ray spectrum of ^{137}Cs.
2. Pulse height gamma-ray spectrum with multichannel analyzer.
3. Energy calibration of scintillation spectrometer with SCA.
4. Energy calibration of scintillation spectrometer with MCA.
5. Least square fitting of a straight line.
6. Inverse Square law.
7. Absorption of Gamma-rays in an absorber.
8. Compton scattering from a lead target.
9. Scattering cross section measurements from plastic targets.
10. Backscattering from different targets.
11. Relative efficiency calibration of a scintillation detector.
12. Absolute efficiency calibration of a NaI(Tl) detector.
13. Activity of Gamma-ray source (Area ratio method).
14. Absolute activity of Gamma-ray source.
15. Absolute activity of a Gamma source by sum peak method.
16. Gamma-Gamma angular correlation.
17. Pair production and annihilation phenomenon.
18. Escape peaks in ^{24}Na.
19. Verification of Moseley's Law.
20. Study of X-ray proportional counter.
21. Determination of absolute activity by high resolution gamma ray spectrometer with high purity germanium (HPGe) detector.
22. Estimation of alpha activity using SSNTD.
23. Determination of radioactivity in surface soil, cement and fly ash.
24. Half-Life determination of ^{137m}Ba.
25. Fission yield determination of ^{91}Sr/^{89}Sr.
26. Fission yield determination of iodine isotopes.
27. Determination of the solubility of a sparingly soluble salt.
28. Determination of manganese in steel by neutron activation analysis.
29. Multielement determination in soil by single comparator NAA.

Note: Students should perform at least four experiments

C5: Radiation Measurements, Nuclear Dosimetry

1. Plateau of a GM Counter.
2. Determination of Dead time of a GM Counter.
3. Statistical Aspects of Radioactivity Measurements.
4. Determination of Resolution of a NaI(Tl) Detector.
5. Determining the Activity of a Gamma Source.
6. The Absorption Coefficient as a Function of Gamma Ray Energy.
7. Beta Backscattering As a Function of Atomic Number.
8. Beta Energy Determination By Feather's Analysis.
9. Study of Scintillation Counter.
10. Study of Gamma Ray Coincidence Spectrometer.
11. Study of Beta Decay.
12. Study of G-M Counter.
13. Excitation of K-X-Ray by Beta Radiation.
14. A Micro Controller Based Machine for Lissajous Figures.

Note: Students should perform at least four experiments

PHYL-421 – Lab course 7 (D4, D5)

Magnetism, Superfluidity and Material Synthesis, Characterization : Credits 3

D4 : Magnetism, Superfluidity

1. Thin film deposition by Chemical Bath Deposition (CBD) and measure its thickness.
2. Variation of conductivity with temperature and frequency
3. Thin film deposition by chemical route (Electro deposition)
4. To study the vacuum system (production and measurement)
5. Synthesis of semiconductor nanoparticles by SILAR
6. Determination of size and position of nanoparticles using nano kit
7. Estimation of core loss and coercive force for a ferromagnetic core material of a transformer
8. Paramagnetic susceptibility temperature variation.
9. To determine the magneto resistance of Bismuth crystal / Bismuth compound thin film as a function of magnetic field.
10. Determination of Curie temperature of a ferromagnetic material.
11. Magnetic susceptibility of solids by Guoy's method.
12. Study of magnetic susceptibility in liquids
13. Variation of residual magnetization of carbon steel rod as a function of temperature.

Note: 1) **Other experiments may be added as per the availability of instruments.** 2) **Students should perform at least four experiments**

D5 : Material Synthesis, Characterization

Learning objectives of the course: Advances in technology depends more and more on the discovery and development of new materials having particular desired properties. In addition to mechanical strength, various structural, optical, electrical, magnetic and thermal properties are demanded from materials depending on the application.

Learning Outcome of the course: The field of Materials Science investigates different classes of materials -metals, ceramics, polymers, electronic materials, biomaterials- with an emphasis on the relationships between the underlying structure and the processing, properties, and performance of the materials. Research opportunities are offered as scientists and technologists, etc in national and international institutions

1. Thin film deposition by Chemical Bath Deposition (CBD) and measure its thickness.
2. Thin film deposition by thermal evaporation and measure its thickness
3. Characteristics of oil rotary pump
4. Characteristics of oil diffusion pump
5. Measurements of low and high vacuum techniques
6. Structural analysis of thin film by XRD

7. Variation of conductivity with temperature and frequency
8. To study the vacuum system (production and measurement)
9. Synthesis of semiconductor nanoparticles by SILAR
10. Determination of size and position of nanoparticles using nano kit
11. Porosity determination of semiconducting material.
12. Estimation of core loss and coercive force for a ferromagnetic core material of a transformer.
13. Characteristics of Superconducting quantum interference devices system (SQUIDs).

Note: Students should perform at least four experiments

<u>PHYR-431 – Research Project Part III (Interpretation of Results) : Credit 3</u>

Students are expected to do comprehensive interpretation of results

<u>PHYR-432 – Research Project Part VII (Dissertation and Presentation) : Credit 6</u>

Students are expected to write primary Dissertation and make presentation of the same.