Syllabus for **Semesters - I to IV**

**Program - M. Sc**

**Course - Physics**

(Credit based Semester and Grading system
With effect from the academic year 2012-13)
Course Structure & Distribution of Credits.

M. Sc. in Physics Program consists of total 16 theory courses, total 6 practical lab courses and 2 projects spread over four semesters. Twelve theory courses and four practical lab course will be common and compulsory to all the students. Four theory courses can be chosen from the elective courses offered by the institute. Two Lab courses can be chosen from the elective lab courses offered by the institute. Each theory course will be of 4 (four) credits, a practical lab course will be of 4 (four) credits and a project will be of 4 (four) credits. A project can be on theoretical physics, experimental physics, applied physics, development physics, computational physics or industrial product development. A student earns 24 (twenty four) credits per semester and total 96 (ninety six) credits in four semesters. The course structure is as follows,

<table>
<thead>
<tr>
<th>Theory Courses</th>
<th>Paper-1</th>
<th>Paper-2</th>
<th>Paper-3</th>
<th>Paper-4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semester-II</td>
<td>Advanced Electronics</td>
<td>Electrodynamics</td>
<td>Quantum Mechanics-II</td>
<td>Solid State Physics</td>
</tr>
<tr>
<td>Semester-III</td>
<td>Statistical Mechanics</td>
<td>Nuclear Physics</td>
<td>Elective Course</td>
<td>Elective Course</td>
</tr>
<tr>
<td>Semester-IV</td>
<td>Experimental Physics</td>
<td>Atomic and Molecular Physics</td>
<td>Elective Course</td>
<td>Elective Course</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Practical Lab courses</th>
<th>Lab Course -1</th>
<th>Lab Course -2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semester-I</td>
<td>Lab Course -3</td>
<td>Lab Course -4</td>
</tr>
<tr>
<td>Semester-II</td>
<td>Project-1</td>
<td>Elective Lab Course-1</td>
</tr>
<tr>
<td>Semester-III</td>
<td>Project-2</td>
<td>Elective Lab Course-2</td>
</tr>
</tbody>
</table>

The elective theory courses offered by PG Centers will be from the following list: 1; Nuclear Structure 2; Experimental Techniques in Nuclear Physics 3; Electronic structure of solids 4; Surfaces and Thin Films 5; Microcontrollers and Interfacing 6; Embedded systems and RTOS 7; Signal Modulation and Transmission Techniques 8; Microwave Electronics, Radar and Optical Fiber Communication 9; Semiconductor Physics 10; Thin Film Physics and Techniques 11; Fundamentals of Materials Science 12; Nanoscience & Nanotechnology 13; Astronomy and Space Physics 14; Laser Physics 15; Group Theory 16; Applied Thermodynamics 17; Quantum Field Theory 18; Nuclear Reactions 19; Particle Physics 10; Properties of Solids 21; Crystalline &
Non-crystalline solids 22; Advanced Microprocessor and ARM-7 23; VHDL and communication Interface 24; Digital Communication Systems and Python Programming 25; Computer Networking 26; Physics of Semiconductor Devices 27; Semiconductor Technology 28; Materials and their applications 29; Energy Studies 30; Galactic & Extragalactic Astronomy 31; Plasma Physics 32; Liquid Crystals 33; Numerical Techniques 34; Polymer Physics. Only some electives will be offered by each PG centre. Every year different electives may be offered depending on the availability of experts in PG centers.

**Semester I**

M.Sc. in Physics Program for Semester-I consists of four theory courses and two practical courses. The details are as follows:

Theory Courses (4): 16 hours per week (One lecture of one hour duration)

<table>
<thead>
<tr>
<th>Theory Paper</th>
<th>Subject</th>
<th>Lectures (Hrs.)</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSPH101</td>
<td>Mathematical Methods</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td>PSPH102</td>
<td>Classical Mechanics</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td>PSPH103</td>
<td>Quantum Mechanics I</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td>PSPH104</td>
<td>Solid State Devices</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>240</strong></td>
<td><strong>16</strong></td>
</tr>
</tbody>
</table>

Practical lab courses (2): 16 hours per week

<table>
<thead>
<tr>
<th>Practical Lab Course</th>
<th>Practical Lab Sessions (Hrs)</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSPHP101</td>
<td>120</td>
<td>04</td>
</tr>
<tr>
<td>PSPHP102</td>
<td>120</td>
<td>04</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>240</strong></td>
<td><strong>08</strong></td>
</tr>
</tbody>
</table>

**Semester II**

M.Sc. in Physics Program for Semester-II consists of four theory courses and two practical courses. The details are as follows:

Theory Courses (4): 16 hours per week (One lecture of one week duration)

<table>
<thead>
<tr>
<th>Theory Paper</th>
<th>Subjects</th>
<th>Lectures (Hrs.)</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSPH201</td>
<td>Advanced Electronics</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td>PSPH202</td>
<td>Electrodynamics</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td>PSPH203</td>
<td>Quantum Mechanics II</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td>PSPH204</td>
<td>Solid State Physics</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>240</strong></td>
<td><strong>16</strong></td>
</tr>
</tbody>
</table>
Practical lab courses (2): 16 hours per week

<table>
<thead>
<tr>
<th>Practical Lab Course</th>
<th>Practical Lab Sessions (Hrs.)</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSPHP201</td>
<td>120</td>
<td>04</td>
</tr>
<tr>
<td>PSPHP202</td>
<td>120</td>
<td>04</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>240</strong></td>
<td><strong>08</strong></td>
</tr>
</tbody>
</table>

Semester III

M.Sc. in Physics Program for Semester-III consists of four theory courses, one practical course and one Project. The details are as follows:

Theory Courses (4): 16 hours per week (One lecture of one week duration)

<table>
<thead>
<tr>
<th>Theory Paper</th>
<th>Subjects</th>
<th>Lectures (Hrs)</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSPH301</td>
<td>Statistical Mechanics</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td>PSPH302</td>
<td>Nuclear Physics</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td>*</td>
<td>Elective Course</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td>*</td>
<td>Elective Course</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>240</strong></td>
<td></td>
<td><strong>16</strong></td>
</tr>
</tbody>
</table>

*: To be chosen from the list below with odd-even number combination. Odd numbered course will be paper-3 and even numbered course will be paper-4.

<table>
<thead>
<tr>
<th>Theory Paper</th>
<th>Subjects</th>
<th>Lectures (Hrs)</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSPHET301</td>
<td>Nuclear Structure</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td>PSPHET302</td>
<td>Nuclear Reactions</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td>PSPHET303</td>
<td>Electronic structure of solids</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td>PSPHET304</td>
<td>Surfaces and Thin Films</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td>PSPHET305</td>
<td>Microcontrollers and Interfacing</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td>PSPHET306</td>
<td>Embedded systems and RTOS</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td>PSPHET307</td>
<td>Signal Modulation and Transmission Techniques</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td>PSPHET308</td>
<td>Microwave Electronics, Radar and Optical Fiber Communication</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td>PSPHET309</td>
<td>Semiconductor Physics</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td>PSPHET310</td>
<td>Thin Film Physics and Techniques</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td>PSPHET311</td>
<td>Fundamentals of Materials Science</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td>PSPHET312</td>
<td>Nanoscience &amp; Nanotechnology</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td>PSPHET313</td>
<td>Galactic &amp; Extragalactic Astronomy</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td>PSPHET314</td>
<td>Plasma Physics</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td>Course Code</td>
<td>Course Title</td>
<td>Credits</td>
<td></td>
</tr>
<tr>
<td>-------------</td>
<td>----------------------------------</td>
<td>---------</td>
<td></td>
</tr>
<tr>
<td>PSPHET315</td>
<td>Group Theory</td>
<td>04</td>
<td></td>
</tr>
<tr>
<td>PSPHET316</td>
<td>Applied Thermodynamics</td>
<td>04</td>
<td></td>
</tr>
<tr>
<td>PSPHET317</td>
<td>Quantum Field Theory</td>
<td>04</td>
<td></td>
</tr>
</tbody>
</table>

Project (1): 8 hours per week

<table>
<thead>
<tr>
<th>Project</th>
<th>Course</th>
<th>Total Project period (Hrs.)</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSPHP301</td>
<td>Project-1</td>
<td>120</td>
<td>04</td>
</tr>
</tbody>
</table>

Practical lab courses (1): 8 hours per week

<table>
<thead>
<tr>
<th>Practical Lab Course</th>
<th>Course</th>
<th>Practical Lab Sessions (Hrs.)</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSPHPAP302</td>
<td>Advanced Physics Lab-1</td>
<td>120</td>
<td>04</td>
</tr>
</tbody>
</table>

Semester IV

M.Sc. in Physics Program for Semester-IV consists of four theory courses, one practical course and one Project. The details are as follows:

Theory Courses (4): 16 hours per week (One lecture of one week duration)

<table>
<thead>
<tr>
<th>Theory Paper</th>
<th>Subjects</th>
<th>Lectures (Hrs)</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSPH401</td>
<td>Experimental Physics</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td>PSPH402</td>
<td>Atomic and Molecular Physics</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td>*</td>
<td>Elective Course</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td>*</td>
<td>Elective Course</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>240</strong></td>
<td><strong>16</strong></td>
</tr>
</tbody>
</table>

*: To be chosen from the list below with odd-even number combination. Odd numbered course will be paper-3 and even numbered course will be paper-4.

<table>
<thead>
<tr>
<th>Theory Paper</th>
<th>Subjects</th>
<th>Lectures (Hrs)</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSPHET401</td>
<td>Experimental Techniques in Nuclear Physics</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td>PSPHET402</td>
<td>Particle Physics</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td>PSPHET403</td>
<td>Crystalline &amp; Non-crystalline solids</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td>PSPHET404</td>
<td>Properties of Solids</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td>PSPHET405</td>
<td>Advanced Microprocessor and ARM-7</td>
<td>60</td>
<td>04</td>
</tr>
<tr>
<td>Course Code</td>
<td>Course Title</td>
<td>Credits</td>
<td></td>
</tr>
<tr>
<td>-------------</td>
<td>--------------------------------------------------</td>
<td>---------</td>
<td></td>
</tr>
<tr>
<td>PSPHET406</td>
<td>VHDL and communication Interface</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>PSPHET407</td>
<td>Digital Communication Systems and Python Programming</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>PSPHET408</td>
<td>Computer Networking</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>PSPHET409</td>
<td>Physics of Semiconductor Devices</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>PSPHET410</td>
<td>Semiconductor Technology</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>PSPHET411</td>
<td>Materials and their applications</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>PSPHET412</td>
<td>Energy Studies</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>PSPHET413</td>
<td>Astronomy and Space Physics</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>PSPHET414</td>
<td>Laser Physics</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>PSPHET415</td>
<td>Liquid Crystals</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>PSPHET416</td>
<td>Numerical Techniques</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>PSPHET417</td>
<td>Polymer Physics</td>
<td>60</td>
<td></td>
</tr>
</tbody>
</table>

**Project (1):** 8 hours per week

<table>
<thead>
<tr>
<th>Project</th>
<th>Total Project period (Hrs)</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSPHP401</td>
<td>120</td>
<td>04</td>
</tr>
</tbody>
</table>

**Practical lab courses (1):** 8 hours per week

<table>
<thead>
<tr>
<th>Practical Lab Course</th>
<th>Subject</th>
<th>Practical Lab Sessions (Hrs)</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSPHPAP402</td>
<td>Advanced Physics Lab-2</td>
<td>120</td>
<td>04</td>
</tr>
</tbody>
</table>

The candidate shall be awarded the degree of Master of Science in Physics (**M. Sc. in Physics**) after completing the course and meeting all the evaluation criteria. The Elective Course Titles will appear in the statement of marks. When the elective courses are chosen from a particular specialization, the statement of marks shall also carry a name of the specializations as stated below. Courses selected at third semester for a particular specialization are pre-requisites for courses in fourth semester for that specialization.

<table>
<thead>
<tr>
<th>No.</th>
<th>Group of Elective Courses chosen</th>
<th>Name appearing in the Statement of Marks</th>
<th>Name appearing in the Degree Certificate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PSPHET301, PSPHET302, PSPHET401, PSPHET402</td>
<td>M. Sc. in Physics (Nuclear Physics)</td>
<td>M. Sc. in Physics</td>
</tr>
<tr>
<td>2</td>
<td>PSPHET303, PSPHET304, PSPHET403, PSPHET404</td>
<td>M. Sc. in Physics (Solid State Physics)</td>
<td>M. Sc. in Physics</td>
</tr>
<tr>
<td>3</td>
<td>PSPHET305, PSPHET306</td>
<td>M. Sc. in Physics</td>
<td>M. Sc. in Physics</td>
</tr>
<tr>
<td>Course Code</td>
<td>Course Title</td>
<td>M.Sc. in Physics</td>
<td>M.Sc. in Physics</td>
</tr>
<tr>
<td>------------------</td>
<td>--------------------------------------------------</td>
<td>-------------------------------------------------------</td>
<td>-------------------------------------------------------</td>
</tr>
<tr>
<td>PSPHET405, PSPHET406</td>
<td>(Electronics-I)</td>
<td>M. Sc. in Physics (Electronics-II)</td>
<td>M. Sc. in Physics</td>
</tr>
<tr>
<td>4</td>
<td>PSPHET307, PSPHET308</td>
<td>M. Sc. in Physics (Solid State Electronics)</td>
<td>M. Sc. in Physics</td>
</tr>
<tr>
<td></td>
<td>PSPHET407, PSPHET408</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>PSPHET309, PSPHET310</td>
<td>M. Sc. in Physics (Materials Science)</td>
<td>M. Sc. in Physics</td>
</tr>
<tr>
<td></td>
<td>PSPHET409, PSPHET410</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>PSPHET311, PSPHET312</td>
<td>M. Sc. in Physics (Materials for Energy Technology)</td>
<td>M. Sc. in Physics</td>
</tr>
<tr>
<td></td>
<td>PSPHET411, PSPHET404</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Any other combination of courses</td>
<td>M. Sc. in Physics</td>
<td>M. Sc. in Physics</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. **Scheme of Examination and Passing:**

1. This course will have 40% Term Work (TW) / Internal Assessment (IA) and 60% external (University written examination of 2.5 Hours duration for each course paper and practical examination of 4 Hours duration for each practical). All external examinations will be held at the end of each semester and will be conducted by the University as per the existing norms.

2. Term Work / Internal Assessment - IA (40%) and University examination (60%) shall have separate heads of passing. For Theory courses, internal assessment shall carry 40 marks and Semester-end examination shall carry 60 marks for each Theory Course.

3. To pass, a student has to obtain minimum grade point E, and above separately in the IA and external examination.

4. The University (external) examination for Theory and Practical shall be conducted at the end of each Semester and the evaluation of Project work i.e. Dissertation if any, at the end of the each Semester.

5. The candidates shall appear for external examination of 4 theory courses each carrying 60 marks of 2.5 hours duration and 2 practical courses each carrying 100 marks at the end of each semester.

6. The candidate shall prepare and submit for practical examination a certified Journal based on the practical course carried out under the guidance of a faculty member with minimum number of experiments as specified in the syllabus for each group.

3. **Standard of Passing for University Examinations:**

As per ordinances and regulations prescribed by the University for semester based credit and grading system.
4. Standard point scale for grading:

<table>
<thead>
<tr>
<th>Grade</th>
<th>Marks</th>
<th>Grade Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>70 &amp; above</td>
<td>7</td>
</tr>
<tr>
<td>A</td>
<td>60 to 69.99</td>
<td>6</td>
</tr>
<tr>
<td>B</td>
<td>55 to 59.99</td>
<td>5</td>
</tr>
<tr>
<td>C</td>
<td>50 to 54.99</td>
<td>4</td>
</tr>
<tr>
<td>D</td>
<td>45 to 49.99</td>
<td>3</td>
</tr>
<tr>
<td>E</td>
<td>40 to 44.99</td>
<td>2</td>
</tr>
<tr>
<td>F (Fail)</td>
<td>39.99 &amp; below</td>
<td>1</td>
</tr>
</tbody>
</table>

5. Grade Point Average (GPA) calculation:

1. GPA is calculated at the end of each semester after grades have been processed and after any grade have been updated or changed. Individual assignments / quizzes / surprise tests / unit tests / tutorials / practicals / project / seminars etc. as prescribed by University are all based on the same criteria as given above. The teacher should convert his marking into the Quality-Points and Letter-Grade.

2. Performance of a student in a semester is indicated by a number called Semester Grade Point Average (SGPA). It is the weighted average of the grade points obtained in all the subjects registered by the students during the semester

\[
\text{SGPA} = \frac{\sum C_i p_i}{\sum C_i} \quad \text{where} \quad C_i = \text{The number of credits earned in the } i^{\text{th}} \text{ course of a semester.}
\]

\[
\text{SGPA} = \frac{\sum C_i p_i}{\sum C_i} \quad \text{for } i = 1, 2, ..., n \text{ represents number of courses for which the student is registered.}
\]

3. The Final remark will be decided on the basis of Cumulative Grade Point Average (CGPA) which is weighted average of the grade point obtained in all the semesters registered by the learner.
\[ \sum_{j=1}^{C_j p_j} \quad \text{C}_j = \text{The number of credits earned in the } j^{\text{th}} \text{ course upto the semester for which the CGPA is calculated} \]

\[ \text{CGPA} = \sum_{j=1}^{\text{C}_j} \quad \text{p}_j = \text{Grade point earned in the } j^{\text{th}} \text{ course}^* \]

\[ \sum_{j=1}^{\text{C}_j} \quad \text{j} = 1, 2, ..., \text{n represents number of courses for which the student is registered upto the semester for which the CGPA is calculated.} \]

* : A letter Grade lower than E in a subject shall not be taken into consideration for the calculation of CGPA

The CGPA is rounded upto the two decimal places.

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**M.Sc. (Physics) Theory Courses**

**Semester - I**

**Paper - I:**

**Course no.: PSPH101: Mathematical Methods (60 lectures, 4 credits)**

**Unit - I**


**Unit - II**

Matrices, Eigenvalues and Eigen vectors, Diagonalization of Matrices, Application to Physics problems, Applications to differential equations. Introduction to Tensor Analysis, Addition and Subtraction of Tensors, summation convention, Contraction, Direct Product, Levi-Civita Symbol

**Unit - III**

Complex Variables, Limits, Continuity, Derivatives, Cauchy-Riemann Equations, Analytic functions, Harmonic functions, Elementary functions: Exponential and Trigonometric, Taylor and Laurent series, Residues, Residue theorem, Principal part of the functions, Residues at poles, zeroes and poles of order m, Contour Integrals, Evaluation of improper real integrals, improper integral involving Sines and Cosines, Definite integrals involving sine and cosine functions.
Unit-IV

Main references:
S.D. Joglekar, Mathematical Physics: The Basics, Universities Press 2005
M.L. Boas, Mathematical methods in the Physical Sciences, Wiley India 2006

Additional references.
2. A.K. Ghatak, I.C. Goyal and S.J. Chua, Mathematical Physics, McMillan
4. E. Butkov, Mathematical Methods, Addison-Wesley
5. J. Mathews and R.L. Walker, Mathematical Methods of physics
6. P. Dennery and A. Krzywicki, Mathematics for physicists
7. T. Das and S.K. Sharma, Mathematical methods in Classical and Quantum Mechanics
9. A. W. Joshi, Matrices and Tensors in Physics, Wiley India

Semester-I: Paper-II:
Course no.: PSPH102: Classical Mechanics (60 lectures, 4 credits)

Unit-I

Unit-II

**Unit-III**
Small Oscillations: Formulation of the problem, The eigenvalue equation and the principal axis transformation, Frequencies of free vibration and normal coordinates, Forced and damped oscillations, Resonance and beats.

Legendre transformations and the Hamilton equations of motion, Cyclic coordinates and conservation theorems, Derivation of Hamilton’s equations from a variational principle.

**Unit-IV**
Canonical Transformations, Examples of canonical transformations, The symplectic approach to canonical transformations, Poisson brackets and other canonical invariants, Equations of motion, infinitesimal canonical transformations and conservation theorems in the Poisson bracket formulation, The angular momentum Poisson bracket relations.

**Main Text**: Classical Mechanics, H. Goldstein, Poole and Safco, 3rd Edition, Narosa Publication (2001)

**Additional References**:
Semester-I : Paper-III:
Course no.: PSPH103: Quantum Mechanics-I (60 lectures, 4 credits)

Unit-I: Theory:
Review of concepts: Analysis of the double-slit particle diffraction experiment; the de Broglie hypothesis; Heisenberg’s uncertainty principle; probability waves. Postulates of QM: Observables and operators; measurements; the state function and expectation values; the time-dependent Schrodinger equation; time development of state functions; solution to the initial value problem. Superposition and Commutation: The superposition principle; commutator relations; their connection to the uncertainty principle; degeneracy; complete sets of commuting observables. Time development of state functions and expectation values; conservation of energy, linear momentum and angular momentum; parity.

Unit-II: Formalism:
Dirac notation; Hilbert space; Hermitian operators and their properties. Matrix mechanics: Basis and representations; matrix properties; unitary and similarity transformations; the energy representation. Schrodinger, Heisenberg and Interaction pictures.

Unit-III: Schrodinger equation solutions: One-dimensional Problems:
General properties of one-dimensional Schrodinger equation. Particle in a box. Harmonic oscillator. Unbound states; one-dimensional barrier problems. Finite potential well.

Unit-IV: Schrodinger equation solutions: Three-dimensional Problems:
Orbital angular momentum operators in cartesian and spherical polar coordinates, commutation and uncertainty relations, spherical harmonics. Two-particle problem - coordinates relative to the centre of mass; radial equation for a spherically symmetric central potential. Hydrogen atom, eigenvalues and radial eigenfunctions, degeneracy, probability distribution.

Texts:
2. DJ Griffiths, Introduction to Quantum Mechanics, 1995. (DG)

Additional References:
Semester-I : Paper-IV:
Course no.: PSPH104: Solid State Devices (60 lectures, 4 credits)

Note: Problems form an integral part of the course.

Unit-I: Semiconductor Physics:
Classification of Semiconductors; Crystal structure with examples of Si, Ge & GaAs semiconductors; Energy band structure of Si, Ge & GaAs; Extrinsic and compensated Semiconductors; Temperature dependence of Fermi-energy and carrier concentration. Drift, diffusion and injection of carriers; Carrier generation and recombination processes- Direct recombination, Indirect recombination, Surface recombination, Auger recombination; Applications of continuity equation-Steady state injection from one side, Minority carriers at surface, Haynes Shockley experiment, High field effects. Hall effect; Four – point probe resistivity measurement; Carrier life time measurement by light pulse technique. Introduction to amorphous semiconductors, Growth of semiconductor crystals.

Unit-II: Semiconductor Devices I:
p-n junction : Fabrication of p-n junction by diffusion and ion-implantation; Abrupt and linearly graded junctions; Thermal equilibrium conditions; Depletion regions; Depletion capacitance, Capacitance – voltage (C-V) characteristics, Evaluation of impurity distribution, Varactor; Ideal and Practical Current-voltage (I-V) characteristics; Tunneling and avalanche reverse junction break down mechanisms; Minority carrier storage, diffusion capacitance, transient behavior; Ideality factor and carrier concentration measurements; Carrier life time measurement by reverse recovery of junction diode;; p-i-n diode; Tunnel diode, Introduction to p-n junction solar cell and semiconductor laser diode.

Unit-III: Semiconductor Devices II:

Unit-IV: Semiconductor Devices III:
Metal-semiconductor field effect transistor (MESFET)- Device structure, Principles of operation, Current voltage (I-V) characteristics, High frequency performance. Modulation doped field effect transistor (MODFET); Introduction to ideal MOS device; MOSFET
fundamentals, Measurement of mobility, channel conductance etc. from $I_{ds}$ vs $V_{ds}$ and $I_{ds}$ vs $V_g$ characteristics. Introduction to Integrated circuits.

**Main References:**


**Additional References:**

<table>
<thead>
<tr>
<th>Experiment</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Michelson Interferometer</td>
<td>Advanced Practical Physics - Worsnop and Flint</td>
</tr>
<tr>
<td></td>
<td>b). Experiments in modern physics - Mellissinos</td>
</tr>
<tr>
<td>3. h/e by vacuum photocell</td>
<td>a). Advance practical physics - Worsnop and Flint</td>
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<td>b). Experiments in modern physics - Mellissinos</td>
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<tr>
<td></td>
<td>b). Elementary experiments with Laser - G. white</td>
</tr>
<tr>
<td>5. Susceptibility measurement by Quincke's method / Guoy's balance method</td>
<td>Advance practical physics - Worsnop and Flint</td>
</tr>
<tr>
<td>6. Absorption spectrum of specific liquids</td>
<td>Advance practical physics - Worsnop and Flint</td>
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</table>
**Group B:**

<table>
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<tr>
<th>Experiment</th>
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</tr>
</thead>
<tbody>
<tr>
<td>1, Diac - Triac phase control circuit</td>
<td>a) Solid state devices- W.D. Cooper b) Electronic text lab manual - P.B. Zbar</td>
</tr>
<tr>
<td>2. Delayed linear sweep using 1C 555</td>
<td>a) Electronic Principles - A. P. Malvino</td>
</tr>
<tr>
<td>3. Regulated power supply using 1C LM 317 voltage regulator IC</td>
<td>a) Opeational amplifiers and linear Integrated circuits - Coughlin &amp; Driscoll b) Practical analysis of electronic circuits through experimentation - L.MacDonald</td>
</tr>
<tr>
<td>4. Regulated dual power supply using IC LM 317 &amp; 1C LM 337 voltage regulator ICs</td>
<td>a) Opeational amplifiers and linear Integrated circuits - Coughlin &amp; Driscoll b) Practical analysis of electronic circuits through experimentation - L.MacDonald</td>
</tr>
<tr>
<td>6. Active filter circuits (second order)</td>
<td>a) Op-amps and linear integrated circuit technology- R. Gayakwad b) Operational amplifiers and linear integrated circuits - Coughlin &amp; Driscoll</td>
</tr>
<tr>
<td>7. Study of 4 digit multiplex display system</td>
<td>Digital Electronics - Roger Tokheim</td>
</tr>
</tbody>
</table>

**Note:** Minimum number of experiments to be performed and reported in the journal = 06 with minimum 3 experiments from each Group. i.e. Group A: 03 and Group B: 03
**Group A**

<table>
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<tbody>
<tr>
<td>1. Carrier lifetime by pulsed reverse method</td>
<td>Semiconductor electronics by Gibson</td>
</tr>
<tr>
<td>2. Resistivity by four probe method</td>
<td>Semiconductor measurements by Runyan</td>
</tr>
<tr>
<td>3. Temperature dependence of avalanche and Zener breakdown diodes</td>
<td>a) Solid state devices - W.D. Cooper</td>
</tr>
<tr>
<td></td>
<td>b) Electronic text lab manual - PB Zbar</td>
</tr>
<tr>
<td></td>
<td>c) Electronic devices &amp; circuits - Millman and Halkias</td>
</tr>
<tr>
<td>4. DC Hall effect</td>
<td>a) Manual of experimental physics - E.V. Smith</td>
</tr>
<tr>
<td></td>
<td>b) Semiconductor Measurements - Runyan</td>
</tr>
<tr>
<td></td>
<td>c) Semiconductors and solid state physics - Mackelvy</td>
</tr>
<tr>
<td></td>
<td>d) Handbook of semiconductors – Hunter</td>
</tr>
<tr>
<td>5. Determination of particle size of lycopodium particles by laser diffraction method</td>
<td>a). A course of experiments with Laser - Sirohi</td>
</tr>
<tr>
<td></td>
<td>b). Elementary experiments with Laser - G. white</td>
</tr>
<tr>
<td>6. Magneto resistance of Bi specimen</td>
<td>Semiconductor measurements by Runyan</td>
</tr>
<tr>
<td>7. Microwave oscillator characteristics</td>
<td>a) Physics of Semiconductor Devices by S.M.Sze</td>
</tr>
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</table>
## Group B:

<table>
<thead>
<tr>
<th>Experiment</th>
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<tbody>
<tr>
<td>1. Temperature on-off controller using IC</td>
<td>a) Op-amps and linear integrated circuit technology by Gayakwad</td>
</tr>
</tbody>
</table>
| 2. Waveform Generator using ICs                      | a) Operational amplifiers and linear integrated circuits — Coughlin & Driscoll  
|                                                      | b) Op-amps and linear integrated circuit technology — R. Gayakwad          |
|                                                      | c) Operational amplifiers: experimental manual C.B. Clayton                 |
| 3. Instrumentation amplifier and its applications     | a) Operational amplifiers and linear integrated circuits - Coughlin & Driscoll  
|                                                      | b) Integrated Circuits - K. R. Botkar                                      |
| 4. Study of 8 bit DAC                                 | a) Op-amps and linear integrated circuit technology — R. Gayakwad          |
|                                                      | b) Digital principles and applications by Malvino and Leach                 |
| 5. 16 channel digital multiplexer                     | a) Digital principles and applications by Malvino and Leach                 |
|                                                      | b) Digital circuit practice by RP Jain                                      |

**Note:** Minimum number of experiments to be performed and reported in the journal = 06 with minimum 3 experiments from each Group. i.e. Group A: 03 and Group B: 03

### Additional references:

1. Digital theory and experimentation using integrated circuits - Morris E. Levine (Prentice Hall)
3. Logic design projects using standard integrated circuits - John F. Waker (John Wiley & sons)
5. Digital logic design, a text lab manual - Anala Pandit (Nandu printers and publishers Pvt. Ltd.)

**Note:**

1. Journal should be certified by the laboratory in-charge only if the student performs satisfactorily the minimum number of experiments as stipulated above. Such students, who do not have certified journals, will not be allowed to appear for the practical examinations.
2. Total marks for the practical examinations = 200
M.Sc. (Physics) Theory Courses
Semester –II

Semester-II : Paper-I:
Course no.: PSPH201: Advanced Electronics (60 lectures, 4 credits)

Unit-I Microprocessors and Microcontrollers:

Unit-II Analog and Data Acquisition Systems:
(a) Power Supplies: Linear Power supply, Switch Mode Power supply, Uninterrupted Power Supply, Step up and Step down Switching Voltage Regulators.
(b) Inverters: Principle of voltage driven inversion, Principle of current driven inversion, sine wave inverter, Square wave inverter.
(c) Signal Conditioning: Operational Amplifier, Instrumentation Amplifier using IC, Precision Rectifier, Voltage to Current Converter, Current to Voltage Converter, Op-Amp Based Butterworth Higher Order Active Filters and Multiple Feedback Filters, Voltage Controlled Oscillator, Analog Multiplexer, Sample and Hold circuits, Analog to Digital Converters, Digital to Analog Converters.

Unit-III Data Transmissions, Instrumentations Circuits& Designs:
(b) Optical Fiber: Introduction to optical fibers, wave propagation and total internal reflection in optical fiber, structure of optical fiber, Types of optical fiber, numerical aperture, acceptance angle, single and multimode optical fibers, optical fiber materials and fabrication,
attenuation, dispersion, splicing and fiber connectors, fiber optic communication system, fiber sensor, optical sources and optical detectors for optical fiber.

**Unit-IV Instrumentation Circuits and Designs :**

**Reference Books:**


**Semester-II : Paper-II:**
**Course no.: PSPH202: Electrodynamics (60 lectures, 4 credits)**

**Unit-I:**

**Unit-II:**
Electromagnetic waves in vacuum, Polarization of plane waves. Electromagnetic waves in matter, frequency dependence of conductivity, frequency dependence of polarizability,
frequency dependence of refractive index. Wave guides, boundary conditions, classification of fields in wave guides, phase velocity and group velocity, resonant cavities.

**Unit-III:**
Moving charges in vacuum, gauge transformation, The time dependent Green function, The Lienard- Wiechert potentials, Leinard- Wiechert fields, application to fields-radiation from a charged particle, Antennas, Radiation by multipole moments, Electric dipole radiation, Complete fields of a time dependent electric dipole, Magnetic dipole radiation

**Unit-IV:**
Relativistic covariant Lagrangian formalism: Covariant Lagrangian formalism for relativistic point charges, The energy-momentum tensor, Conservation laws.

**Main Texts:**

**Additional references:**

**Semester-II : Paper-III:**
**Course no.: PSPH203: Quantum Mechanics-II (60 lectures, 4 credits)**

**Unit-I: Angular Momentum:**
1. Ladder operators, eigen values and eigen functions of $L^2$ and $L_z$ using spherical harmonics, angular momentum and rotations.
2. Total angular momentum $J$; L.S coupling; eigen values of $J^2$ and $J_z$.
3. Addition of angular momentum, Clebsch Gordon coefficients for $j_1=j_2=1/2$ and $j_1= 1$, $j_2 =1/2$, coupled and uncoupled representation of eigen functions.
4. Angular momentum matrices; Pauli spin matrices; spin eigen functions; free particle wave functions including spin, addition of two spins.
5. Identical particles: symmetric / antisymmetric wavefunctions.
**Unit-II: Perturbation Theory:**
1. Time-independent perturbation theory: First-order and second-order corrections to non-degenerate perturbation theory. Degenerate perturbation theory - First order energies and secular equation.
   Time-dependent perturbation theory and applications.

**Unit-III: Approximation methods:**
2. Ritz variational method: basic principles, illustration by simple examples.
3. WKB Method.

**Unit-IV: Scattering theory:**
   Scattering cross section and scattering amplitude; partial wave phase shift -- optical theorem, S-wave scattering from a finite spherical attractive and repulsive potential wells; centre of mass frame; Born approximation.

**Texts:**

**Additional References:**
Semester-II : Paper-IV:
Course no.: PSPH204: Solid State Physics (60 lectures, 4 credits)

Unit-I: Crystal Diffraction and Reciprocal Lattice:
Crystal Diffraction Methods for X rays- Laue, Rotating Crystal, Powder Method. Reciprocal Lattice and Brillouin Zones. Reciprocal Lattice to sc, bcc, fcc., Scattered wave amplitude, Fourier analysis of the basis ; Structure Factor of lattices (sc, bcc, fcc) ; Atomic Form Factor; Temperature dependence of reflection lines. Elastic scattering from Surfaces; Elastic scattering from amorphous solids.

Unit-II: Lattice Vibrations and thermal properties:

Unit-III: Diamagnetism and Paramagnetism:
Langevin diamagnetic equation, diamagnetic response, Quantum mechanical formulation, core diamagnetism. Quantum Theory of Paramagnetism, Rare Earth Ions, Hund’s Rule, Iron Group ions, Crystal Field Splitting and Quenching of orbital angular momentum; Adiabatic Demagnetisation of a paramagnetic Salt, Paramagnetic susceptibility of conduction electrons;

Unit-IV: Magnetic Ordering:
Ferromagnetic order- Exchange Integral, Saturation magnetisation, Magnons, neutron magnetic scattering; Ferrimagnetic order, spinels, Yttrium Iron Garnets, Anti Ferromagnetic order. Ferromagnetic Domains – Anisotropy energy, origin of domains, transition region between domains, Bloch wall, Coercive force and hysteresis.

References:-
**M.Sc. (Physics) Practical Lab Course**  
**Semester –II**  

**Semester –II Lab-1**  
**Course number: PSPHP201** (120 hours, 4 credits)  

**Group A**

<table>
<thead>
<tr>
<th>Experiment</th>
<th>References</th>
</tr>
</thead>
</table>
b). Experiments in modern physics - Mellissinos |
c). Experimental physics for students - Whittle &. Yarwood |
| 3. Ultrasonic Interferometry - Velocity measurements in different Fluids | Medical Electronics- Khandpur |
| 5. I-V/ C-V measurement on semiconductor specimen | Semiconductor measurements - Runyan |
| 6. Double slit- Fraunhofer diffraction (missing order etc.) | Advance practical physics - Worsnop and Flint |
| 7. Determination of Young’s modulus of metal rod by interference method | Advance practical physics - Worsnop and Flint (page 338) |

**Group B**

<table>
<thead>
<tr>
<th>Experiment</th>
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</table>
| 1. Adder-subtractor circuits using ICs | a) Digital principles and applications -- Malvino and Leach  
b) Digital circuits practice - R.P. Jain |
b) Digital principles and applications --Malvino and Leach  
c) Experiments in digital practice -Jain & Anand |
| 3. TTL characteristics of totem pole, open collector and tristate devices | a) Digital circuits practice - Jain & Anand  
b) Digital principles and applications --Malvino |
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<tr>
<td>4. Pulse width modulation for speed control of dc toy motor</td>
<td>and Leach</td>
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<td>5. Study of sample and hold circuit</td>
<td>Electronic Instrumentation - H. S. Kalsi</td>
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### Group A

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<td>1. Carrier mobility by conductivity</td>
<td>Semiconductor electronics - Gibson</td>
</tr>
</tbody>
</table>
| 2. Measurement of dielectric constant, Curie temperature and verification of Curie— Weiss law for ferroelectric material | a) Electronic instrumentation & measurement - W. D. Cooper  
  b) Introduction to solid state physics - C. Kittel  
  c) Solid state physics — A. J. Dekkar |
| 3. Barrier capacitance of a junction diode                               | Electronic engineering - Millman Halkias                                                      |
| 4. Linear Voltage Differential Transformer                                | Electronic Instrumentation - W.D. Cooper                                                     |
  2. Experimental physics for students - Whittle & Yarwood                             |
| a) To Calibrate Electromagnet                                            |                                                                                              |
| b) To determine Verdet's constant for KCl & KI solutions.                |                                                                                              |
| 6. Energy Band gap by four probe method                                  | Semiconductor measurements — Runyan                                                           |
| 7. Measurement of dielectric constant (Capacitance)                      | a) Electronic instrumentation & measurement - W. D. Cooper  
  b) Introduction to solid state physics - C. Kittel |

### Group B

<table>
<thead>
<tr>
<th>Experiment</th>
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</tr>
</thead>
</table>
| 1. Shift registers                                                         | a) Experiments in digital principles-D.P. Leach  
  b) Digital principles and applications - Malvino and Leach |
| 2. Study of 8085 microprocessor Kit and execution of simple Programmes    | a) Microprocessor Architecture, Programming and Applications with the 8085 - R. S. Gaonkar  
  b) Microprocessor fundamentals. Schaum Series - Tokheim  
  c) 8085 Kit user manual |
| 3. Waveform generation using 8085                                         | a) Microprocessor Architecture, Programming and Applications with the 8085 - R. S. Gaonkar  
  b) Microprocessor fundamentals, Schaum Series —Tokheim. |
| 4. SID & SOD using 805 | a) Microprocessor Architecture, Programming and Applications with the 8085 - R. S. Gaonkar  
| | b) Microprocessor Fundamentals, Schaum Series — Tokheim  
| | c) 805 Kit user manual  
| 5. Ambient Light control power switch | a) Electronic Instrumentation H. S. Kalsi  
| | b) Helfrick & Cooper, PHI  
| 6. Interfacing TTL with buzzers, relays, motors and solenoids. | Digital Electronics by Roger Tokheim  

**Note:** Minimum number of experiments to be performed and reported in the journal = 06 with minimum 3 experiments from each Group. i.e. Group A: 03 and Group B: 03

Additional references:
1. Digital theory and experimentation using integrated circuits - Morris E. Levine (Prentice Hall)
3. Logic design projects using standard integrated circuits - John F. Waker (John Wiley & sons)
5. Digital logic design, a text lab manual - Anala Pandit (Nandu printers and publishers Pvt. Ltd.)

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2. Total marks for the practical examinations = 200
Unit I: Classical Statistical Mechanics
1. Phase space and number of accessible microstates \( \Omega \) given the macrostate; Statistical definition of entropy; Gibb’s paradox and correct counting of microstates \( \Omega \).
2. Ensemble Theory: Phase space density and ergodic hypothesis; Liouville theorem; Microcanonical ensemble; Entropy as an ensemble average; Examples of classical ideal gas, ultra-relativistic gas, harmonic oscillators.
3. Canonical ensemble: Equilibrium between a system and an energy reservoir, Canonical partition function and derivation of thermodynamics; Applications to classical ideal gas, system of classical and quantum-mechanical harmonic oscillators, ultra-relativistic ideal gas; Energy fluctuations, Virial and equipartition theorems. Quantum systems in Boltzmann statistics – system of quantum-mechanical harmonic oscillators, paramagnetic system.

Unit II: Quantum Statistical Mechanics
4. Grand canonical ensemble: Equilibrium between a system and a particle-energy reservoir; Grand partition function and derivation of thermodynamics; Fluctuations.
6. Ideal gas in q.m. microcanonical ensemble; Statistical weights and occupation number distribution for ideal Bose, Fermi and Maxwell-Boltzmann gases.

Unit III: Ideal Fermi and Bose Systems
7. Ideal gas in q.m. canonical and grand canonical ensembles; Statistics of occupation numbers.
9. Thermodynamic behavior of an ideal Fermi gas, concept of Fermi energy, behaviour of specific heat with temperature.

Unit IV: Non-Equilibrium Statistical Mechanics
10. Brownian motion: as a random walk (Einstein theory), as a diffusion process; Langevin theory of Brownian motion; Fluctuation-dissipation theorem.
11. Master equation and Fokker-Planck equation.
P : 15.2 - 15.6 ; see also H : 16 , 18.1 - 18.7.

Texts:
- *Thermodynamics and Statistical Mechanics*, Greiner, Neise and Stocker, Springer 1995. (G)
- *Introduction to Statistical Physics*, Kerson Huang (H), Taylor and Francis 2001. (H)

References:
- *Thermal and Statistical Physics*, F Reif.
- *Statistical Mechanics*, Kerson Huang.
- *Thermodynamics*, H.B. Callen

Semester-III : Paper-II:
Course no.: PSPH302: Nuclear Physics (60 lectures, 4 credits)

Unit I. (12 Lectures + 3 Tutorials)
Overview of Nuclear Physics (including Introduction to Regulatory framework and nuclear safety in India), Nuclear Properties, Measurement of Nuclear size and estimation of $R_0$, Deuteron system and its characteristic, Estimate the depth and size of (assume) square well potential, introduction to Tensor force, nucleon-nucleon scattering-qualitative discussion on results, Spin-orbit strong interaction between nucleon, double scattering experiment, The Shell Model (extreme single particle): Introduction, Assumptions, Evidences, Spin-orbit interactions, Predictions, limitation, introduction to Nilsson Model.
*Tutorials should include 3 problem solving session based on above mentioned topics

Unit II. (11 Lectures + 4 Tutorials)
*Tutorials should include 4 problem solving session based on above mentioned topics
Unit III. (11 Lectures + 4 Tutorials)
Conservation laws, Types of nuclear reaction, Q- value equation of nuclear reaction, Center of Mass frame, reaction cross sections (Classical and Quantum), Compound nuclear reaction, Introduction to fission reaction, Characteristics of Fission, Energy in Fission, Controlled fission reaction, Introduction to 3 stage- Nuclear programme of India, Introduction to Fusion Reaction, Characteristics of Fusion, Solar Fusion and CNO cycle, introduction to Controlled fission reaction.
*Tutorials should include 4 problem solving session based on above mentioned topics

Unit IV. (11 Lectures + 4 Tutorials)
Introduction to the elementary particle Physics, The Eight fold way, the Quark Model, the November revolution and aftermath, The standard Model, Revision of the four forces, cross sections, decays and resonances, Introduction to Quantum Eletrodynamics, Introduction to Quantum Chromodynamics. weak interactions and Unification Schemes (qualitative description), Revision of Lorentz transformations, Four-vectors, Energy and Momentum. Properties of Neutrino, helicity of Neutrino, Parity, Qualitative discussion on Parity violation in beta decay and Wu’s Experiment, Charge conjugation, Time reversal, Qualitative introduction to CP violation and TCP theorem.
*Tutorials should include 4 problem solving session based on above mentioned topics

Main References:
1. *Introduction to Nuclear Physics*, Kenneth Krane, Wiley India Pvt. Ltd.
4. [http://dae.nic.in](http://dae.nic.in) or [http://www.npcil.nic.in](http://www.npcil.nic.in) for 3 stage- Nuclear programme of India.

Other References:
1. *Introduction to Nuclear Physics*, H. A. Enge, Eddison Wesley
2. *Nuclei and Particle*, E. Segre, W. A Benjamin,
3. *Concepts of Nuclear Physics*, B. L. Cohen
5. *Nuclear Physics, Experimental and Theoretical*, H. S. Hans, New Age International
6. *Introduction to Nuclear and Particle Physics*, A. Das & T. Ferbel, World Scientific
7. *Introduction to high energy physics*, D. H. Perkins, Addison Wesley
8. *Nuclear and Particle Physics*, W. E. Burcham and M. Jobes, Addison Wesley
9. *Nuclear Physics*, S. N. Ghoshal
11. *Nuclear Physics* - D. C. Tayal

**Semester-III : Elective Paper-III**

**Course no.: PSPHET301: Nuclear Structure (60 lectures, 4 credits)**

**UNIT I: Microscopic Models I (12 lectures + 3 tutorials)**
Experimental evidence for shell effects, Concept of average potential, Spin-orbit coupling, Single-particle shell structure, Predictions of the independent particle shell model: spin-parity, magnetic dipole and electric quadrupole moments; Isospin, Two- and Multi- particle configurations, Residual interactions, Pairing interactions: BCS model.

**UNIT II: Microscopic Models II (11 lectures + 4 tutorials)**

**UNIT III: Collective models (11 lectures + 4 tutorials)**
Liquid drop model and mass formulas, Fission barriers and types of fission; Parameterization of nuclear surface deformations, Prolate and oblate shapes, Types of multipole deformations, Rotational states in axially symmetric deformed even-even and odd-A nuclei, Rotation of axially asymmetric nuclei, Octupole and higher-order deformations, Rotation-vibration coupling in deformed nuclei: beta and gamma vibrations; Giant resonances;

**UNIT IV: Related concepts and selected phenomena**
Cranking model and its semi-classical derivation, Cranking formula and applications, High-spin states and nucleon pair breaking at high angular momentum, Cranked Nilsson model, Yrast states in nuclei, Nuclear Isomerism and types of isomers, Superdeformed states in nuclei, Particle-plus-rotor model: weak-coupling limit and strong-coupling approximation

**Suggested Reading:**

1) *Nuclear Models*, by W. Greiner and J.A. Maruhn (Springer 1996)
2) *Nuclear Structure from a Simple Perspective*, by R. F. Casten (Oxford University Press 1990)
Semester-III : Elective Paper-IV  
Course no.: PSPHET302: Nuclear Reactions (60 lectures, 4 credits)

UNIT I: Basics: (12 lectures + 3 tutorials)  
1. Basic elements of nuclear reactions:  
   (i) cross section (σ), mean free path; definition/expression for σ : experimental and theoretical.  
   (ii) Use of σ to calculate: Stopping length, life time modification of unstable states in a medium, mean life of a moving particle in an interacting volume, etc.  
   (iii) Conservation laws: Energy, momentum, angular momentum, parity, isospin.  
   (iv) Frame of reference: Lab. and c.m.  
   (v) Q-values and threshold energies.  
3. Optical potential: Basic definition. Relation between the imaginary part, W of the OP and σ_{abs} , and between W and mean free path. Folding model and a high energy estimate of the OP.  

UNIT II: Categorization of Nuclear Reaction mechanisms (11 lectures + 4 tutorials)  
1. Low energies : Discrete region, Continuum Region  
   (a) Discrete Region:  
      (i) Resonance scattering. Derivation of the resonance cross section from phase shift description of cross section.  
      (ii) Transmission through a square well and resonances in continuum.  
      (iii) Coulomb barrier penetration for charged particles scattering and centrifugal barrier for l non-zero states.  
      (iv) Angular distributions of the particles in resonance scattering.  
      (v) Application to hydrogen burning in stars.  
   (b) Continuum Region:  
      (i) Bohr’s compound nucleus model, and its experimental verifications.  
      (ii) Statistical parameters and their estimates for the continuum region.  
      (iii) Energy distribution of evaporated particles from compound nucleus.  
2. Higher energies: Direct Reaction
(i) Cross section in terms of the T-matrix. Phase space, and its evaluation for simple cases. Lippmann Schwinger equation for the scattering wave function, and its formal solution. On-shell and off-shell scattering.
(ii) Plane wave and distorted wave approximation to the T-matrix (PWBA, DWBA). Application to various direct reactions like, stripping, pick-up, knock-out etc.
(iii) High energy scattering. Eikonal approximation to the scattering wave function. Evaluation of scattering cross section in eikonal approximation.

Suggested Reading:
(i) *Nuclear Reactions*, by Daphne F Jackson (Methen & Co. Ltd.)
(ii) *Theoretical Nuclear Physics*, by John M Blatt and Victor F Weisskopf (John Wiley)
(iii) *Direct Nuclear Reaction Theories*, by Norman Austern (John Wiley)
(iv) *Concepts of Nuclear Physics*, by B. L. Cohen (Tata McGrow-Hill)
(v) *Introduction to Nuclear and Particle Physics*, by A. Das & T. Ferbel (World Scientific)

UNIT III: Physics of ion (stable and unstable) scattering (11 lectures + 4 tutorials)

1. Stable ions
   (i) Basics of heavy ions: short wave length, large angular momentum transfer, kinematics and Coulomb potential.
   (ii) Classical scattering: rainbow, orbiting, glory, etc. Semi-classical scattering.
   (iii) Quantum mechanical description.

2. Radioactive ion beams (RIB)
   (i) From stable to exotic nuclei in nuclear chart. Production and acceleration of radioactive ion beams (RIB). Shell structure of exotic nuclei and magicity. Structural properties of unstable nuclei: radii, skins and halos, spins and electromagnetic moments. Coulomb excitation and knock-out in RIBs.

Suggested Reading:
(i) *Semi-classical methods for nucleus-nucleus scattering*, by D. M. Brink(Cambridge University press 1985)
(ii) *Nuclear heavy ion reactions*, by P. E. Hodgson (Clarendon press 1978)
(iii) *Introduction to nuclear reactions*, by G. R. Satchler (McMillan 1990)
UNIT IV: Intermediate Energy Physics and Non-nucleonic Degrees of Freedom (11 lectures + 4 tutorials)

1. Introduction: Classification of elementary particles, Isospin, Conservation rules for strong interaction, Threshold beam energies in pp collisions for the production of various mesons and baryons.
2. Proton-nucleus scattering at high energies: Eikonal approximation, Glauber model, etc.
4. Pion-nucleon scattering, \( ^{33} \) resonance. Pion-nucleon coupling, pseudoscalar and pseudovector. Pion capture in nuclei. One nucleon and two nucleon mechanisms.
5. Pion production and excitation of nucleonic resonances in p-p and p-nucleus collisions, experiments and theory.

Suggested Reading:

1. *Nuclear reactions*, by D. F. Jackson (Methuen & Co. 1970)
2. *Nuclear Interactions*, by Sergio DeBenedetti (John Wiley 1964)

Semester-III : Elective Paper-III

Course no.: PSPHET303: Electronic Structure of Solids (60 lectures, 4 credits)

Unit I. Prototype Electronic Structure

2. Electron energy levels in a periodic potential.
3. Nearly-free electron approximation.
4. The tight-binding method.
Unit II. Electronic Band Structure Methods
1. Cellular method; Augmented plane-wave (APW) method; Green’s function (KKR) method; Orthogonalized plane wave (OPW) method; Pseudopotentials.
2. Band structure / Fermi surface of selected metals – alkali and noble metals, simple multivalent metals, transition metals, rare-earths, semi-metals, semiconductors Si and Ge.

Unit III. Motion of Band Electrons
Semi-classical electron dynamics; Motion of band electrons and the effective mass; currents in bands and holes; scattering of band electrons; Boltzmann equation and relaxation time; band electrons in electric field; electrical conductivity of metals; thermoelectric effects; Wiedemann-Franz law; Electrical conductivity of localized electrons; Band electrons in cross E and B fields – magnetoresistance and Hall effect.

Unit IV. Many – Body Effects
1. The Hartree-Fock method; exchange and correlation.
3. Computations on simple atoms.

Texts:

References:
Semester-III : Elective Paper-IV
Course no.: PSPHET304: Surfaces and Thin Films (60 lectures, 4 credits)

Unit I: Physics of Surfaces, Interfaces and Thin films
Mechanism of thin film formation: Condensation and nucleation, growth and coalescence of islands, Crystallographic structure of films, factors affecting structure and properties of thin films; Properties of thin films: Transport and optical properties of metallic, semiconducting and dielectric films; Application of thin films.

Unit II: Thin films: Formation & Measurement
Vacuum Techniques: Review: Production of low pressures; Measurement of pressure, Leak detections, Materials used
Preparation of Thin Films: Thermal evaporation, Cathode Sputtering, Chemical Deposition, Laser Ablation, Langmur Blochet Films;
Thickness Measurements: Stylus Method, Electrical Method, Quartz Crystal Method, Optical Methods, mass measurements (microbalance)

Unit III: Nano Science and Nano Technology
Band structure and Density of States at Nanoscale, Quantum mechanics for nanoscience- size effects, application of Schrodinger equation, quantum confinement. Growth techniques for nano materials- Top down, Bottom up technique. Nano technology applications- nano structures of Carbon, BN nanotubes, Nanoelectronics, nanobiometrics

Unit IV: Surface Analytical Techniques
X-ray Photoelectron spectroscopy (XPS), Auger Electron spectroscopy(AES), Depth profiling by Ar ions, Low Energy Electron Diffraction (LEED), Secondary Ion Mass spectroscopy (SIMS), Rutherford Backscattering spectroscopy (RBS), Transmission Electron Microscopy (TEM), Scanning Electron Microscopy (SEM) with EDAX, Scanning Probe Microscopy – a) Scanning Tunneling Microscopy (STM), and b) Atomic Force Microscopy (AFM)

References:-
Unit I:

Unit II:
1. A. Roth “Vacuum Technology” North Holland Amsterdam
Unit III: -

Unit IV: -

Semester-III : Elective Paper-III
Course no.: PSPHET305: Microcontrollers and Interfacing (60 lectures, 4 credits)

Unit-I:
8051 microcontroller: (Review of 8051), Timer/Counters, Interrupts, Serial communication
Programming 8051 Timers, Counter Programming

Basics of Serial Communication, 8051 Connection to RS232, 8051 Serial Port Programming in assembly.

8051 Interrupts, Programming Timer Interrupts, Programming External hardware Interrupts, Programming the Serial Communication Interrupt, Interrupt Priority in 8051/52.

Ref.AVD: - The 8051 Microcontroller

Unit-II

Ref. AVD: - Microcontrollers by Ajay V. Deshmukh, Tata-Mcgraw Hill Publication

Unit-III: PIC 16F8XX Flash Microcontrollers:
Introduction, Pin Diagram, STATUS Register, Power Control Register (PCON), OPTION_REG Register, Program memory, Data memory, I/O Ports
AVD – Ch 10: 10.1, 10.2, 10.3, 10.4, 10.5, 10.6, 10.7, 10.10

Capture/Compare/PWM (CCP) Modules in PIC 16F877, Analog-to-Digital Converter
AVD – Ch 11: 11.1, 11.2, 11.5

Ref. AVD: - Microcontrollers by Ajay V. Deshmukh, Tata-Mcgraw Hill Publication

Unit-IV: Interfacing microcontroller/PIC microcontroller and Industrial Applications of microcontrollers:
Light Emitting Diodes (LEDs); Push Buttons, Relays and Latch Connections; Keyboard Interfacing;
Interfacing 7-Segment Displays; LCD Interfacing; ADC and DAC Interfacing with 89C51 Microcontrollers.
Introduction and Measurement Applications (For DC motor interfacing and PWM refer Sec 17.3 of MMM)
AVD: Ch.12, Ch.13.
MMM: Sec 17.3

Ref: AVD: - Microcontrollers by Ajay V. Deshmukh, Tata-Mcgraw Hill Publication

Additional Reference books:
1. The 8051 Microcontroller & Embedded Systems-Dr. Rajiv Kapadia (Jaico Pub.House)
4. Programming & customizing the 8051 microcontroller By Myke Predko, TMH.

Semester-III : Elective Paper-IV
Course no.: PSPHET306: Embedded Systems and RTOS (60 lectures, 4 credits)

Unit-I:
Programming Using C++: Introduction to Computers and programming , Introduction to C++,
Expressions and interactivity , Making decisions, Looping , Functions , Arrays , Sorting arrays ,
Pointers
TG – Ch 1: 1.3 to 1.7 , Ch 2: 2.1 to 2.14, Ch 3: 3.1 to 3.11, Ch 4: 41 to 4.15, Ch 5: 5.1 to 5.13, Ch 6: 6.1 to 6.14, Ch 7: 7.1 to 7.9, Ch 8: 8.3, Ch 9: 9.1 to 9.7
Unit-II:
Introduction to classes: More about classes, Inheritance, polymorphism, virtual functions.
TG – Ch 13: 13.1 to 13.11, Ch 14: 14.1 to 14.5, Ch 15: 15.1 to 15.6

Introduction to VC++
YK – Ch 1, 2, 3

Unit-III: Embedded systems
SKV – Ch 1: 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7

A Typical Embedded system: Core of the embedded system
SKV – Ch 2: 2.1

Characteristics and quality Attributed of Embedded Systems: Characteristics of an Embedded System, Quality Attributes of Embedded Systems
SKV – Ch 3: 3.1, 3.2

Embedded Systems-Application and Domain–Specific: Washing Machine, Automatic-Domain
Specific examples of embedded system
SKV – Ch 4: 4.1, 4.2

Design Process and design Examples: Automatic Chocolate Vending machine (ACVM), Smart Card, Digital Camera, Mobile Phone, A Set of Robots
RK - Ch 1: 1.10.2, 1.10.3, 1.10.4, 1.10.5, 1.10.6, 1.10.7

Unit IV: - Real –Time Operating System based Embedded System Design:
Operating system Basics, Types of Operating Systems, Tasks, Process and Threads, Multi-processing and Multitasking, Task Scheduling, Threads, Processes and Scheduling: Putting them altogether, task Communication, task Synchronizations, Device Drivers, How to choose an RTOS.

SKV: Ch – 10: 10.1, 10.2, 10.3, 10.4, 10.5, 10.6, 10.7, 10.8, 10.9, 10.10

Ref: SKV : - Introduction to embedded systems, by Shibu K. V. ,Sixth Reprint 2012, Tata Mcgraw Hill

Additional references:
1. Object Oriented Programming with C++, By E. Balagurusamy, 2nd ed. TMH.
2. OOPS with C++ from the Foundation, By N. R. Parsa, Dream Tech Press India Ltd.

Semester-III : Elective Paper-III

Course no.: PSPHET307: Signal Modulation and Transmission Techniques, (60 lectures, 4 credits)

Unit I:

Unit II:
Transmission Line Theory: Fundamental of transmission lines, Different types of transmission lines; Telephone lines and cables, Radio frequency lines, Micro strip transmission lines. Definition of characteristics impedance, Losses in transmission lines, Standing waves, Quarter and Half wavelength lines, Reactance properties of transmission lines, Fundamental of the Smith charts and its applications.

Unit III:
Electromagnetic Radiation and Propagation of Waves: Fundamental of electromagnetic waves, Effects of the environment, Propagation of waves; Ground waves, Sky wave propagation, Space waves, Tropospheric scatter propagation, Extraterrestrial communication
Unit IV:

**Antennas:** Basic considerations, Wire radiators in space, Terms and definitions, Effects of ground on antennas, Antenna Coupling at medium frequencies, Directional high frequency antennas, UHF and Microwave antennas, Wideband and special purpose antennas

**Main References:**

**Additional References:**

**Semester-III : Elective Paper-IV**

**Course no.: PSPHET308: Microwave Electronics, Radar and Optical Fiber Communication, (60 lectures, 4 credits)**

**Unit I:**
Waveguides, Resonators and Components: Rectangular waveguides, Circular and other waveguides, Waveguide coupling, matching and attenuation, Cavity resonators, Auxiliary components.

**Unit II:**

**Microwave Tubes and Circuits:** Microwave triodes, Multicavity Klystron, Reflex Klystron, Magnetron, Traveling wave tube.

**Microwave Semiconductor Devices and Circuits:** Passive microwave circuits, Transistors and integrated circuits, parametric amplifiers, Tunnel Diodes and Negative Resistance Amplifier, Gunn effect and diodes, Avalanche effects and diodes. PIN Diode, Schottky barrier diode, backward diode.

**Microwave Measurements:** Slotted line VSWR measurement- Impedance measurement, insertion loss and attenuation measurements
Unit III:


Unit IV:

*Optical Fiber Communication Systems*: Introduction to optical fibers, signal degradation in optical fibers, Fiber optical sources and coupling, Fiber optical receivers, System parameters, Analog optical fiber communication links, Design procedure, Multichannel analog systems, FM/FDM video signal transmission, Digital optical fiber systems.

**Main References:**


**Additional References:**


**Semester-III : Elective Paper-III**

**Course no.: PSPHET309: Semiconductors Physics (60 lectures, 4 credits)**

(N.B.: Problems form an integral part of the course)

**Unit I: Transport Properties of Semiconductors:**

The Boltzmann transport equation and its solutions for (i) Electric field alone (ii) Electric and Magnetic fields together. Hall Effect and Magneto resistance (van der Ziel). Scattering mechanism and Relaxation time concept, Transport in high electric fields, hot electrons (Wang), transferred electron effects (Smith). Transport in 2-Dimentional
quantum well - (a) High field effects (i) Landau levels, (ii) Shubnikov de Hass effect, (iii) Quantum Hall effect (b) Perpendicular transport - Resonant Tunneling (JS- Art.17.3, 17.6, 17.7, 14.9).

**Unit II: Optical Properties of Semiconductors:**

**Unit III: Amorphous & Organic Semiconductors:**
Electronic density of states, localization, Transport properties, Optical properties, Hydrogenization of amorphous silicon, Si:H fields effect transistors-design, fabrication and characteristics. Organic semiconductors, Polymers.

**Unit IV: Advanced Electronic Materials:**
Photovoltaics Fundamentals & Materials, Spintronics materials, Dilute magnetic semiconductors, Magnetites, Giant-magneto resistance. Composites, Glasses, Ceramics, Liquid crystals, Quasicrystals.

**Main References:**
2. S.Y. Wang, Introduction to Solid State Electronics, North Holland, 1980,
5. M.H. Brodsky (ed), Topics in Applied Physics Vol.36, Amorphous Semiconductors,

**Additional References:**
1. J.I. Pankove, Optical processes in semiconductors,
2. J. Singh, Semiconductors, Optoelectronics, Mc-Graw Hill,
Semester-III : Elective Paper-IV
Course no.: PSPHET310: Thin Film Physics & Technology (60 lectures, 4 credits)

(N.B.: Problems form an integral part of the course)

Unit I: Thin films preparation & Thickness measurement
Methods of Preparation/synthesis of Thin films: Vacuum evaporation, Cathode sputtering, Anodic oxidation, Plasma anodization, Chemical vapour deposition(CVD), Ion-assisted deposition(IAD), Laser ablation, Longmuir Blochet film, Sol-gel film deposition. Thickness measurements: Resistance, capacitance, microbalance, Quartz crystal thickness monitor, Optical absorption, Multiple beam interference, Interference colour, Ellipsometry methods.

Unit II: Thin film Physics

Unit III: Thin films for Devices & other Applications:
Dielectric deposition- silicon dioxide, silicon nitride, silicon oxynitride, polysilicon deposition, metallization, electromigration, silicides. Thin film transistors, thin film multilayers, optical filters, mirrors, sensors and detectors.

Unit IV: Characterization/Analysis of materials and devices:
X-ray diffraction(XRD), Electron diffraction, Transmission electron microscopy (TEM), Scanning electron microscopy(SEM), Energy dispersive analysis of X-rays (EDAX), Low energy electron diffraction (LEED), UV-VIS spectroscopy, Fourier transform infrared (FTIR) spectroscopy, Raman spectroscopy, Electron spin resonance (ESR), X-ray fluorescence (XRF), Auger electron spectroscopy (AES), X-ray photoelectron spectroscopy (XPS), Scanning tunneling microscopy (STM), Atomic force microscopy (AFM). Ion beam analysis techniques: Rutherford backscattering (RBS), Channeling, Elastic recoil detection analysis (ERDA), Secondary ion mass spectroscopy (SIMS).

Main References:

Additional References:

Semester-III : Elective Paper-III
Course no.: PSPHET311: Fundamentals of Materials Science, (60 lectures, 4 credits)

Unit I:
Introduction to Materials Science and Engineering, Types of Materials, Competition among Materials, Future trends In Materials Usage, Atomic Structure and Bonding, Types of Atomic and Molecular Bonds, Ionic Bonding, Covalent Bonding, Metallic Bonding, Secondary Bonding, Mixed Bonding, Crystal Structures and Crystal Geometry, The Space Lattice and Unit Cells, Crystal Systems and Bravais Lattices, Principal Metallic Crystal Structures, Atom Positions in Cubic Unit Cells, Directions in Cubic Unit Cells, Miller Indices For Crystallographic Planes In Cubic Unit Cells, Crystallographic Planes and Directions In Hexagonal Unit Cells, Comparison of FCC, HCP, and BCC Crystal Structures, Volume, Planar, and Linear Density Unit Cell Calculations, Polymorphism or Allotropy, Crystal Structure Analysis

Unit II:
Solidification, Crystalline Imperfections, and Diffusion In Solids, Solidification of Metals, Solidification of Single Crystals, Metallic Solid Solutions, Crystalline Imperfections, Rate Processes In Solids, Atomic Diffusion In Solids, Industrial Applications of Diffusion Processes, Effect of Temperature on Diffusion In Solids.

Unit III:
Unit IV:

Reference:

Semester-III : Elective Paper-IV
Course no.: PSPHET312: Nanoscience and Nanotechnology (60 lectures, 4 credits)

Unit I:

Quantum wells, wires and dots: Fabricating Quantum Nanostructures: Solution fabrication, Lithography; Size and dimensionality effects: Size effects, Size effects on conduction electrons, Conduction electrons and dimensionality, Fermi gas and density of states, Potential wells, Partial confinement, Properties dependent on density of states; Excitons, Single electron Tunneling; Applications: Infrared detectors, Quantum dot lasers.

(Owns and Poole: Chapter 3, 6 and 9)

Unit II:
Vibrational Properties: The finite One-dimensional monoatomic lattice, Ionic solids, Experimental Observations: Optical and acoustical modes; Vibrational spectroscopy of surface layers of nanoparticles – Raman spectroscopy of surface layers, Infrared Spectroscopy of surface layers; Photon confinement, Effect of dimension on lattice vibrations, Effect of dimension on vibrational density of states, effect of size on Debye frequency, Melting
temperature, Specific heat, Plasmons, Surface-enhanced Raman Spectroscopy, Phase transitions.


**Carbon nanostructures**: Introduction; Carbon molecules: Nature of the carbon bond, New Carbon structures; Carbon clusters: Small Carbon clusters, Buckyball, The structure of molecular C\textsubscript{60}, Crystalline C\textsubscript{60}, Larger and smaller Buckyballs, Buckyballs of other atoms; Carbon nanotubes: Fabrication, Structure, Electronic properties, Vibrational properties, Functionalization, Doped Carbon Nanotubes, Mechanical properties; Nanotube Composites: Polymer-carbon nanotube composites, Metal-Carbon nanotube composites; Graphene nanostructures.

(Owens and Poole: Chapter 7, 8 and 10)

**Unit III:**

**Magnetism in Nanostructures**: Basics of Ferromagnetism; Behavior of Powders of Ferromagnetic Nanoparticles: Properties of a single Ferromagnetic Nanoparticles, Dynamic of Individual Magnetic Nanoparticles, Measurements of Superparamagnetism and the Blocking Temperature, Nanopore Containment of Magnetic Particles; Ferrofluids; Bulk nanostructured Magnetic Materials: Effect of nanosized grain structure on magnetic properties, Magnetoresisitive materials, Carbon nanostructured ferromagnets; Antiferromagnetic nanoparticles.

**Nanoelectronics**: N and P doping and PN junctions, MOSFET, Scaling of MOSFETs; Spintronics: Definition and examples of spintronic devices, Magnetic storage and spin valves, Dilute magnetic semiconductors; Molecular switches and electronics: Molecular switches, Molecular electronics, Mechanism of conduction through a molecule; Photonic crystals.

(Owens and Poole: Chapter 12, 13 and 14)
Unit IV:


Carbon: Introduction, Surface, Size, Shape, Self-assembly, Bio-nano, Conclusion, Carbon-Nanofood for thought. (Cademartiri and Ozin: Chapter 1, 3, 5, 6, and 7)

References:


Semester-III: Elective Paper-III
Course no.: PSPHET313: Galactic and Extra-Galactic Astronomy (60 lectures, 4 credits)

Unit I:
Unit II:


Unit III:

*Introduction to General Theory of Relativity*
Einstein's field eqns. (qualitative) FRW metric.

Unit IV:

*Cosmology*

**Main Texts / References:**

**Semester-III : Elective Paper-IV**

**Course no.: PSPHET314: Plasma Physics, (60 lectures, 4 credits)**

**Unit I:**
Definition of Plasma, occurrence of plasma, Debye shielding, plasma parameters, criterion for plasma, (FC, JB, KT)
Single particle motion in uniform E and B fields, time varying E field, time varying B field, magnetic mirrors, Adiabatic invariants (FC, JB)
Transport phenomenon, Binary Coulomb collision, multiple Coulomb collisions, Lorentz model of weakly ionized plasma, Diffusion and mobility in weakly ionized gases, collision and diffusion parameters, ambipolar diffusion, diffusion in slab, steady state solutions, recombination, plasma resistivity. Bohm diffusion. (FC, KT)

**Unit II:**
Plasma Kinetic Theory and Vlasov equation: Introduction to plasma kinetic theory, zeroth order

Unit III:

Unit IV:
Plasma production and diagnostics: Various plasma production techniques, Electrical breakdown in gases using dc. rf, microwave and high frequency fields Glow and arc discharge. (IH, JR) Plasma diagnostics, electrostatic probe, Magnetic probes, spectroscopic diagnostics, active and passive techniques, interferometry techniques. (IH) Low temperature plasma applications: plasma processing of materials: Physics of high and low pressure plasma sours and applications to materials processing. Brief review of plasma etching, PECVD, display, radiation sources, plasma source ion implantation. Plasma cutting, melting, spraying and waste processing. Applications to nuclear, space and semiconductor industries. (IH) High temperature plasma applications, controlled thermonuclear fusion, Introduction to thermonuclear fusion, fusion reactions, cross sections, radiative processes in plasmas, energy loss, Lawson criterion, break even and ignition, magnetic and inertial confinement scheme and devices, emission of X rays and neutrons, fusion plasma diagnostics. (DM, ST)

Main References:
1. Francis F. Chen, Introduction to Plasma Physics and Controlled Fusion Volume 1 Springer (FC)
Additional References:
1. An introduction to plasma Physics. R. R. Goldston & P. H Rutherford
2. Plasma Physics - An introduction. R. Dendy,
3. The physics of lasers plasma & interactions. W. L. Kruer, Addison-Wesley, 1988

Semester-III : Elective Paper-III
Course no.: PSPHET315: Group Theory (60 lectures, 4 credits)

UNIT I: Finite Groups and their Representations (12 lectures + 3 tutorials)

1. Finite Groups
   Group axioms, Finite groups of low order, Cyclic Groups, Permutation Groups ,
   Basic Concepts- Conjugation, Normal Subgroups, Quotient Group, Simple Groups, Semi-
   direct product, Young Tableaux

2. Group Representations
   Introduction, Reducible and Irreducible Representations, Schur’s Lemmas, Great
   Orthogonality Theorem, Character Tables, Examples.

UNIT II: Lie Groups (11 lectures + 4 tutorials)

1. Lie Groups and Lie Algebras
   Introduction to Lie groups and Lie algebras- Roots and Weights, Lie Algebras of matrix
   Lie groups

2. Representation Theory for Lie Groups/Algebras
   Representations of Lie groups and Lie Algebras, Adjoint representation, Representations
   of disconnected Lie groups, Direct product of representations of a Lie Group, The groups
   O(3) and SO(3) as examples.

UNIT III: Group Theory Applications in Non-relativistic Quantum Mechanics (11 lectures + 4 tutorials)

1. Rotation Group and Angular Momentum
   Angular Momentum algebra, Addition of angular momenta uncoupled and coupled
   representation. Clebsch – Gordon coefficients and their simple properties(For revision
purpose only). Spin ½, Matrix Representations, The rotation operators and rotation matrices, spin angular momentum and its wavefunction, Representations of the rotation group, irreducible tensor operators, The Wigner – Eckart theorem,

2. Applications in Solid State Physics
Point and Space Groups, Stereographic projections of simple crystallographic point groups, Crystal field splittings of atomic energy levels.

UNIT IV: GROUP THEORY APPLICATIONS IN RELATIVISTIC QUANTUM MECHANICS (11 LECTURES + 4 TUTORIALS)

1. Lorentz Group and its Representations
   Space –time symmetries, Lorentz and Poincare group, Conformal group.
2. Unitary Groups and Unitary Symmetries
   SU(2) and Isospin, SU(3), GellMann matrices, Weights and roots of SU(3), Fundamental representations of SU(3).

Suggested reading:
2. Lie Algebras in Particle Physics, by Howard Georgi (Westview, 1995)

Semester-III : Elective Paper-IV
Course no.: PSPHET316: Applied Thermodynamics (60 lectures, 4 credits)

Unit I
First Law of Thermodynamics: Energy, enthalpy, specific heats, first law applied to systems and control volumes, steady and unsteady flow analysis.
Second Law of Thermodynamics: Kelvin-Planck and Clausius statements, reversible and irreversible processes, Carnot theorems, thermodynamic temperature scale, Clausius inequality and concept of entropy, principle of increase of entropy; availability and irreversibility.
Zeroth Law of Thermodynamics: concept of temperature, Overview of techniques in low temperature production
Unit II

Unit III

Unit IV
Thermodynamics of Phase transformation and Heterogeneous Systems: Melting and solidification, precipitation, eutectoid, massive, spinodal, martensitic, order disorder transformations and glass transition. First and second order transitions. Equilibrium Constants and Ellingham diagrams

References:
4. Physical Chemistry of Metals: L.S. Darken and R.W. Gurry
5. Thermodynamics of Solids: R.A. Swalin

Semester-III : Elective Paper-IV
Course no.: PSPHET317: Quantum Field Theory, (60 lectures, 4 credits)

UNIT I: RELATIVISTIC WAVE EQUATIONS AND CLASSICAL FIELDS (12 lectures + 3 tutorials)
1. Klein Gordon equation
Relativistic energy-momentum relation, Klein-Gordon equation, solutions of the equation, probability conservation problem, relation with negative energy states.

2. Dirac equation
Dirac equation, algebra of matrices, conservation of probability, solutions of Dirac equation, helicity and chirality, Lorentz covariance, bilinear covariants, trace relations and similar identities.

3. Dynamics of a solid
The linear atomic chain as a system of coupled oscillators, periodic boundary conditions, normal modes, continuum limit, Lagrangian and Hamiltonian density, Euler-Lagrange equations for fields, extension to two and three dimensions, velocity of sound.

4. Free fields
Lagrangian formulation for the Schrödinger, Dirac and Klein-Gordon fields, Nöther’s theorem, global gauge symmetries and associated Nöther currents.

UNIT II: CANONICAL QUANTISATION OF FREE FIELDS (11 LECTURES + 4 TUTORIALS)

5. Quantisation of solids
Quantisation of the linear chain, creation and annihilation operators, phonons, occupation number representation, extension to two and three dimensions, polarisation vectors.

6. Quantisation of the Schrödinger field
Expansion of the Schrödinger field in terms of eigenstates of the single particle wave equation, creation and annihilation operators, number operator, occupation number representation, Slater determinant.

7. Quantisation of Relativistic fields
Quantisation of the scalar field, positive and negative energy solutions, expansion in terms of creation and annihilation operators, antiparticles, eigenvalues of energy and charge.
Quantisation of the Dirac field along same lines as quantisation of the scalar field.
Quantisation of the electromagnetic field using Hamiltonian method, gauge invariance, modification of the commutation relation.

UNIT III: INTERACTING FIELDS AND FADYMAN DIAGRAMS (11 LECTURES + 4 TUTORIALS)

8. Dyson formulation for scattering: S matrix
Interaction picture, time evolution operator, Dyson expansion and S matrix, transition matrix, relation to Fermi’s golden rule.

9. Wick expansion and contractions
Normal-ordered product, time-ordered product and contractions, Wick’s theorem for the Schrödinger, Dirac and Klein-Gordon fields,
10. Feynman diagrams and Feynman rules
diagrammatic representation, tree and loop diagrams, Feynman rules from the Wick expansion.

UNIT IV: QUANTUM ELECTRODYNAMICS (11 LECTURES + 4 TUTORIALS)
11. The QED Lagrangian
Structure of the QED Lagrangian, gauge invariance and conserved current, Feynman rules for QED, scalar electrodynamics.
12. Basic Processes in QED
Feynman diagram calculation for \( e^+e^- \rightarrow \mu^+\mu^- \), phase space integration, Møller and Bhabha scattering, polarisation vectors, Compton scattering and pair creation/annihilation, Klein-Nishina formula.
13. Loops and Renormalisation in QED
Loop diagrams: bubble, triangle and box, Ward identity for QED, UV and IR divergences, cutoff regularisation, on-shell renormalisation of mass, wavefunction and charge, BPH renormalisation, counterterms, renormalisation group, running coupling constant.

Suggested reading:

M.Sc. (Physics) Practical Lab Course
Semester –III

Semester III Elective Lab Course-1
Course no.: PSPHAP302: Advanced Physics Lab-1 (120 hours, 4 credits)
A) For Students offering electives other than PSPH305, 306, 307, 308 (i.e. Electronics I or Electronics II), have to perform at least 10 experiments from the following
I. X-ray Powder Diffraction – (4-5 experiments/ analysis of given data)
   1. Structure determination of powder polycrystalline sample
   2. Intensity analysis of XRD peaks
   3. Strain analysis and Particle size determination by XRD
   4. XRD Studies of Thin Films: Phase determination by JCPDS
II. Hall Effect
   1. AC & DC effect in given semiconducting specimen
   2. AC & DC effect at different temperatures and determination of carrier mobility
3. Calibration of unknown magnetic field using a Hall probe

III. Thermometry –
1. Measurement of thermo-emf of Iron-Copper (Fe-Cu) or chromel-alumel thermocouple as a function of temperature.
2. Voltage-Temperature characteristics of a Silicon diode sensor

IV. Dielectric Constant using LCR bridge
1. Determination of Transition Temperature of a Ferroelectric Material
2. Determination of Dielectric constant and studying its frequency dependence

V. LASER
2. Laser interferometer to find the wavelength.

VI. Plasma
1. Measurement of critical spark voltage at different separation at a constant pressure.

VII. Nuclear Physics
1. Mass absorption Coefficient of Beta rays and energy range calculation.
2. Understanding of Poisson distribution and Gaussian distribution.
3. Calculation of rest mass of electron using Compton scattering experiment.
4. Understanding of Surface barrier detector
5. Relative efficiency of beta and gamma rays using GM counter and feather comparison method to find range of unknown beta source.

VIII. Semiconductors and devices
1. Resistivity of Ge sample by van der Pauw method at different temp and determination of band gap
2. Optical transmission and absorption studies of elemental/ compound semiconductors
3. Band gap of semiconductors by photoconductivity
4. I-V measurements of Ge, Si, GaAs diodes at room temp, identification of different regions, determination of ideality factor
5. Carrier lifetime by light pulse method

IX. Vacuum techniques and thin films
1. Pump-down characteristics: pumping speed of rotary and diffusion pump at constant volume
2. Pumping speed of rotary and diffusion pump at constant volume
4. Measurement of thickness of vacuum evaporated thin films by gravimetric method and by interferometry (Tolansky)

X. Computation
1. Least squares fit / curve-fitting
2. Interpolation

XI. Microscopy
1. Texture determination by polarizing microscopy

XII. Astronomy and Space Physics
1. Image processing in Astronomy: Use of one of the standard software packages like IRAF / MIDAS. Aperture photometry using the given observational data. Seeing profile of a star.
2. CCD: Characteristics of a CCD camera. Differential photometry of a star w.r.t. a standard star.

B) The Students offering electives PSPH305, PSPH306. (i.e. Electronics I ) have to perform at least 10 experiments from the following:

I Interfacing 8031/8051 based experiments:
1. Interfacing 8 bit DAC with 8031/51 to generate waveforms: square, sawtooth, triangular.
2. Interfacing stepper motor with 8031/51: to control direction, speed and number of steps.
3. Interface 8-bit ADC (0804) with 8031/51: to convert an analog signal into its binary equivalent.

II Microcontroller 8031/8051 based experiments:
1. 8031/51 assembly language programming:
   Simple data manipulation programs.(8/16-bit addition, subtraction, multiplication, division, 8/16 bit data transfer, cubes of nos., to rotate a 32- bit number, finding greatest/smallest number from a block of data, decimal / hexadecimal counter)

2. Study of IN and OUT port of 8031/51 by Interfacing switches, LEDs and Relays: to display bit pattern on LED’s, to count the number of “ON” switches and display on LED’s, to trip a relay depending on the logic condition of switches, event counter(using LDR and light source)

3. Study of external interrupts (INT0/INT1) of 8031/51.
4. Study of internal timer and counter in 8031/51.
III  (16F84 or 16FXXX) PIC Micro-controller based experiments (Using assembly language only):

1. Interfacing LED’s: flashing LED’s, to display bit pattern, 8-bit counter.

2. Interfacing Push Buttons: to increment and decrement the count value at the output by recognizing of push buttons, etc

3. Interfacing Relay: to drive an ac bulb through a relay; the relay should be tripped on recognizing of a push button.

4. Interfacing buzzer: the buzzer should be activated for two different frequencies, depending on recognizing of corresponding push buttons.

IV  C++ and Visual C++ experiments:

1. C++ Program (Conversion from decimal system to binary, octal, hexadecimal system).

2. C++ Program (Program on mean, variance, standard deviation for a set of numbers.

3. C++ Program (Sorting of data in ascending or descending order).

4. C++ experiment (Programs on class, traffic lights)

5. C++ experiment (Programs on inheritance, over loading)

6. Visual C++ experiment

V  Computation

1. Least squares fit / curve-fitting

2. Interpolation

C) The Students offering electives PSPH307, PSPH308 (i.e. Electronics II), have to perform at least 10 experiments from the following:

I  Electronics Communication:

1. Generation of AM signal using OTA IC CA3080/op-amp and demodulation using diode demodulator.

2. Balanced modulator and demodulator - study of suppressed carrier AM generation using IC 1496/1596.

3. Generation of FM signal using IC 566/XR 2206


5. Frequency multiplication using PLL IC 565/4046.

6. FM modulator and demodulator using PLL IC 565/4046.
7. Loss measurements and numerical aperture in optical fiber.
8. Linear control system using fiber optical communication method.
9. Telemetry using optical fiber system.
11. Study of propagation characteristics in a waveguide.
12. Simulation of radiation patterns of various antennas.

II Computation
   1. Least squares fit / curve-fitting
   2. Interpolation

References:
(vii) Microwaves by K. C. Gupta (New Age International Ltd.).
(ix) Basic microwave techniques and laboratory manual by M. L. Sisodia and G. S. Raghuvanshi (Wiley Eastern Ltd. 1987.).
(xi) Digital communication systems by Harold Kolimbiris (Pearson Education Asia).
(xv) Parallel port complete by Jan Axelson, (Penram International Publications, India).
(xvi) Serial port complete by Jan Axelson, (Penram International Publications, India).
(xvii) 8031/8051 Manuel Provided by the manufacturers
(xviii) AVD: - Microcontrollers by Ajay V. Deshmukh, Tata-Mcgraw Hill Publication
(xx) Starting out with C++ from Control structures through objects, by Tony Gaddis, Sixth edition, Penram International Publications, India
(xxi) Object Oriented Programming with C++, By E. Balagurusamy, 2nd ed. TMH.

Note:
1. Journal should be certified by the laboratory in-charge only if the student performs satisfactorily the minimum number of experiments as stipulated above. Such students, who do not have certified journals, will not be allowed to appear for the practical examinations.
M.Sc. (Physics) Theory Courses
Semester –IV

Semester-IV : Paper-I:
Course no: PSPH401 Experimental Physics (60 hours 4 Credits)

Unit-I

Data Analysis for Physical Sciences: Population and Sample, Data distributions Probability, Probability Distribution, Distribution of Real Data, The normal distribution, The normal distribution, From area under a normal curve to an interval, Distribution of sample means, The central limit theorem, The t distribution, The log-normal distribution, Assessing the normality of data, Population mean and continuous distributions, Population mean and expectation value, The binomial distribution The Poisson distribution, Experimental Error, Measurement, error and uncertainty, The process of measurement, True value and error, Precision and accuracy, Random and systematic errors, Random errors, Uncertainty in measurement, Combining uncertainties, Expanded uncertainty, Relative standard uncertainty, Coping with outliers, Weighted mean , Least squares, The equation of a straight line, Excel's LINESTQ function, Using the line of best fit, Fitting a straight line to data when random errors are confined to the x quantity, Linear correlation coefficient, Residuals, Data rejection, Transforming data for least squares analysis, Weighted least squares, Tests of significance, Hypothesis testing, Comparing x with 0 when sample sizes are small Significance testing for least squares parameters Comparison of the means of two samples Comparing variances using the F test Comparing expected and observed frequencies using the %2 test Analysis of variance


Internal tests will be of solving problems using Excel.

Unit II

Vacuum Techniques: Fundamental processes at low pressures, Mean Free Path, Time to form monolayer, Number density, Materials used at low pressures, vapour pressure Impingement rate, Flow of gases, Laminar and turbulent flow, Production of low pressures; High Vacuum
Pumps and systems, Ultra High Vacuum Pumps and System, Measurement of pressure, Leak detections (9 Lectures)

References:

I. Vacuum Technology, A. Roth, North Holland Amsterdam

Instruments and Techniques: Instrumentation for UV-visible spectrophotometer, Fourier Transform IR technique, (3 Lectures)

Unit III

Nuclear Detectors: Gas Detector with emphasis on GM counter, Nal Scintillation Detector, Gamma ray spectrometer using Nal scintillation detector

Accelerators: Cockroft Walten Generator, Van de Graaf Generator, Sloan and Lawrence type Linear Accelerator, Proton Linear Accelerator, Cyclotron, Synchrotron

References

II. Techniques for Nuclear and Particle Physics Experiments, W.R. Leo, Springer- Verlag
IV. Particle Accelerators, Livingston, M. S.; Blewett, J.
V. Introduction to Nuclear Physics, HA Enge, pp 345-353
VI. Electricity & Magnetism and Atomic Physics Vol. II, J. Yarwood
VII. Principles of Particle Accelerators, E. Persico, E. Ferrari, S.E. Segre

Unit IV

Characterization techniques for materials analysis: UV Visible spectroscopy, FTIR spectroscopy, Raman Spectroscopy, Mossbauer Spectroscopy, RBS, XRD, XRF, SEM, EDAX, TEM, XPS

References:

i. An Introduction to Materials Characterization, Khangaonkar P. R., Penram International Publishing


vi. Fundamentals of Surface and Thin Film Analysis, L.C. Feldman and J.W. Mayer North Holland amsterdam


Semester-IV : Paper-II:
Course no: PSPH402 Atomic and Molecular Physics (60 hours 4 Credits)

Unit I:
Review* of one-electron eigenfunctions and energy levels of bound states, Probability density, Virial theorem. (1 lecture)

Fine structure of hydrogenic atoms, Lamb shift. Hyperfine structure and isotope shift. (ER 8-6) (2 lecture)

Linear and quadratic Stark effect in spherical polar coordinates. Zeeman effect in strong and weak fields, Paschen-Back effect. (BJ, GW) (5 lectures)

Schroedinger equation for two electron atoms: Identical particles, The Exclusion Principle. Exchange forces and the helium atom (ER), independent particle model, ground and excited states of two electron atoms. (BJ) (4 lectures)

Unit II
The central field, Thomas-Fermi potential, the gross structure of alkalis (GW). The Hartree theory, ground state of multi-electron atoms and the periodic table (ER), The L-S coupling approximation, allowed terms in LS coupling, fine structure in LS coupling, relative intensities in LS coupling, j-j coupling approximation and other types of coupling (GW) (12 lectures)

Unit III:
Interaction of one electron atoms with electromagnetic radiation: Electromagnetic radiation and its interaction with charged particles, absorption and emission transition rates,
dipole approximation. Einstein coefficients, selection rules. Line intensities and life times of excited state, line shapes and line widths. X-ray spectra. (BJ) (12 lectures)

**Unit IV:**

Born-Oppenheimer approximation - rotational, vibrational and electronic energy levels of diatomic molecules, Linear combination of atomic orbitals (LCAO) and Valence bond (VB) approximations, comparison of valence bond and molecular orbital theories (4 lectures) (GA, IL)

**A)** Rotation of molecules: rotational energy levels of rigid and non-rigid diatomic molecules, classification of molecules, linear, spherical, symmetric and asymmetric tops. **B)** Vibration of molecules: vibrational energy levels of diatomic molecules, simple harmonic and anharmonic oscillators, diatomic vibrating rotator and vibrational-rotational spectra. **c)** Electronic spectra of diatomic molecules: vibrational and rotational structure of electronic spectra.(4 lectures) (GA, IL)

Quantum theory of Raman effect, Pure rotational Raman spectra, Vibrational Raman spectra, Polarization of light and the Raman effect, Applications (2 lectures)

General theory of Nuclear Magnetic Resonance (NMR). NMR spectrometer, Principle of Electron spin resonance ESR. ESR spectrometer(2 lectures). (GA, IL)

(*Mathematical details can be found in BJ. The students are expected to be acquainted with them but not examined in these.)

**Reference:**

4. G. Aruldhas, Molecular structure and spectroscopy, Prentice Hall of India 2nd ed, 2002 (GA)

**Additional reference:**

1. Leighton, Principals of Modern Physics, McGraw hill
6. C.J. Foot, Atomic Physics, Oxford University Press, 2005 (CF)
**Semester-IV : Elective Paper-III**

**Course no.: PSPHET401: Experimental Techniques In Nuclear Physics (60 lectures, 4 credits)**

**UNIT I: (12 lectures + 3 Tutorials)**
Radiation sources: electrons, heavy charged particles, neutrons, neutrinos, and electromagnetic radiation. Charge particle interaction: Stopping power, energy loss and range straggling, scaling laws, bremsstrahlung, Cherenkov radiation. Interaction of photons: photoelectric effect, Compton scattering, pair production. Slow and fast neutron cross-sections, neutrino interactions, Radiation exposure and dose, Biological effects, Radiation safety in Nuclear Physics Laboratory.

**UNIT II: (11 lectures + 4 tutorials)**

**UNIT III: (11 lectures + 4 tutorials)**
Gas-filled ionization detectors: ionization chamber, proportional counters including Multi-Wire Proportional Counters, Geiger-Muller counter. Scintillation detectors: organic (crystals, liquids and plastics) and inorganic (alkali halide and activated). Light collection, Photomultiplier tubes. Semiconductor detectors: silicon diode detectors (surface barrier, ion-implanted, lithium-drifted), position-sensitive detectors, intrinsic germanium detectors, Introduction to Large Detector Arrays.

**UNIT IV: (11 lectures + 4 tutorials)**
Electronics for pulse Signal Processing: Pre-amplifiers, Main Amplifiers, Pulse shaping networks in Amplifiers, Biased Amplifiers, Discriminators, Constant fraction Discriminator, Single channel Analyser, Analog to Digital converter, Multi-channel Analyser, Time to Amplitude Converter. Delayed Coincidence Techniques, slow and fast Coincidence Techniques, Electrostatic and Magnetic Spectrometers, Overview of Instrumentation Standards.

**Note:** tutorials may include demonstration of the various instruments

**References:**
1. Techniques for Nuclear and Particle Physics Experiments, W.R. Leo, Springer-Verlag
3. Techniques for Nuclear and Particle Physics Experiments, Stefaan Tavernier, Springer

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Semester-IV : Elective Paper-IV
Course no.: PSPHET402: Particle Physics (60 lectures, 4 credits)

UNIT I: General Concepts (12 lectures + 3 tutorials)
1. Survey of Particle Physics
   The four fundamental interactions, classification by interaction strength and decay lifetimes, numerical estimates, use of natural units.
   Classification of elementary particles by masses, interactions and conserved quantum numbers, selection rules for particle decays and scattering.

2. Experimental Techniques:
   Particle detectors and accelerators: cloud and bubble chambers, emulsion techniques, electronic detectors, proportional counters, fixed target and collider machines, basic idea of cyclotron, synchrotron and linac.

3. Klein Gordon equation
   Relativistic energy-momentum relation, Klein-Gordon equation, solutions of the equation, probability conservation problem, relation with negative energy states.

4. Dirac equation
   Dirac equation, algebra of matrices, conservation of probability, solutions of Dirac equation, helicity and chirality, Lorentz covariance, bilinear covariants, trace relations and similar identities, C, P and T invariance of the Dirac equation.

UNIT II: Quantum Electrodynamics (11 lectures + 4 tutorials)
5. The QED Lagrangian
   Structure of the QED Lagrangian, gauge invariance and conserved current, scalar electrodynamics, Feynman rules for QED (no derivation).

6. Basic Processes in QED
   Feynman diagram calculation for $e^+e^- \rightarrow \mu^+\mu^-$, phase space integration, Møller and Bhabha scattering, polarisation vectors, Compton scattering and pair creation/annihilation, Klein-Nishina formula.

7. Higher Orders in QED
   Concept of multi-loop diagrams (no computation), momentum integral, UV and IR singularities, idea of regularisation, running coupling constant.
UNIT III: QUARK PARTON MODEL (11 LECTURES + 4 TUTORIALS)

8. The Eightfold Way
   Isospin and strangeness, introduction to unitary groups, generators, Casimir invariants, fundamental and adjoint representations, root and weight diagrams, meson and baryon octets, baryon decuplet and the prediction of the $\Omega^-$, Gell-Mann-Nishijima formula.

9. Quark Model
   Product representations and irreps, symmetry group, Young tableaux, quark model, meson and baryon wavefunctions.

10. Deep Inelastic Scattering
    Elastic scattering off a point particle, form factors, Rosenbluth formula, Breit frame, inelastic scattering, structure functions, dimensionless variables.

11. Parton Model
    Bjorken scaling, parton model, structure functions in terms of PDFs, Callan-Gross relation, kinematic regions, valence and sea quarks, gluons.

UNIT IV: WEAK INTERACTIONS (11 LECTURES + 4 TUTORIALS)

12. Fermi theory
    Beta decay, Fermi and Gamow-Teller transitions, current-current form of weak interactions, Fermi constant, universality, unitarity violation at high energies.

13. Intermediate vector bosons
    $W^\pm$ bosons, unitarity, requirement of conserved currents, muon decay, pion decay, form factor.

14. Parity violation
    Intrinsic parity, parity conservation in strong and electromagnetic interactions, parity violation in weak interactions, experiments of Wu et al and of Goldhaber et al, maximal parity violation.

15. Flavour Mixing and CP Violation
    FCNC suppression, Cabibbo hypothesis, kaon decays, theta-tau puzzle, $K^0 - \bar{K}^0$ mixing, regeneration experiment, GIM mechanism, CKM matrix and quark mixing.

Suggested reading:
1. Introduction to Elementary Particles, by D. Griffiths (Wiley 1987).
Semester-IV : Elective Paper-III  
Course no.: PSPHET403: Properties of Solids (60 lectures, 4 credits)

Unit I Optical and Dielectric properties  
Maxwell’s equations and the dielectric function, Lorentz oscillator, the Local field and the frequency dependence of the dielectric constant, Polarization catastrophe, Ferroelectrics Absorption and Dispersion, Kraemers’ Kronig relations and sum rules, single electron excitations and plasmons in simple metals, Reflectivity and photoemission in metals and semiconductors Interband transitions and introduction to excitons, Infrared spectroscopy

Unit II Transport Properties  
Motion of electrons and effective mass, The Boltzmann equation and relaxation time, Electrical conductivity of metals and alloys, Mathiessen’s rule, Thermo-electric effects, Wiedmann-Franz Law, Lorentz number, ac conductivity, Galvanomagnetic effects

Unit III Magnetism and Magnetic materials  
Review: Basic concepts and units, basic types of magnetic order Origin of atomic moments, Heisenberg exchange interaction, Localized and itinerant electron magnetism, Stoner criterion for ferromagnetism, Indirect exchange mechanism: superexchange and RKKY

Magnetic phase transition: Introduction to Ising Model and results based on Mean field theory  
Other types of magnetic order: superparamagnetism, helimagnetism, metamagnetism, spin-glasses

Magnetic phenomena: Hysteresis, Magnetostriction, Magnetoresistance, Magnetocaloric and magneto-optic effect

Magnetic Materials: Soft and hard magnets, permanent magnets, media for magnetic recording

Unit IV: Superconductivity  
The phenomenon of superconductivity: Perfect conductivity and Meissner effect, Electrodynamics of superconductivity: London’s equations, Thermodynamics of the superconducting phase transition: Free energy, entropy and specific heat jump

Ginzburg-Landau theory of superconductivity: GL equations, GL parameter and classification into Type I and Type II superconductors, The mixed state of superconductors
Microscopic theory: The Cooper problem, The BCS Hamiltonian, BCS ground state
Josephson effect: dc and ac effects, Quantum interference

Superconducting materials and applications: Conventional and High Tc superconductors, superconducting magnets and transmission lines, SQUIDs

References
2. Solid State Physics, Neil Ashcroft and David Mermin (AM)
3. Introduction to Solid State Physics (7th/ 8th ed) Charles Kittel (K)
4. Principles of Condensed Matter Physics, Chaikin and Lubensky (CL)
5. Intermediate theory of Solids, Alexander Animalu (AA)
7. Electrons and Phonons, J M Ziman
8. Electron transport in metals, J.L. Olsen
10. Introduction to Magnetism and Magnetic Materials, D. Jiles
11. Magnetism and Magnetic Materials, B. D. Cullity
12. Solid State Magnetism, J. Crangle
15. Superconductivity, Ketterson and Song
16. Introduction to Superconductivity, Tinkham

Semester-IV : Elective Paper-IV
Course no.: PSPHET404: Crystalline & Non crystalline solids, (60 lectures, 4 credits)

Unit I: Crystal Growth and Crystal Defects
Crystal growth: Phase equilibria and Crystallization Techniques, phase diagrams and solubility curves, Kinetics of Nucleation, Rate equation, Heterogeneous and secondary nucleation, Crystal surfaces, growth mechanisms, mass transport, crystal morphology, influence of supersaturation, temperature, solvents, impurities; Polymorphism – phase transition and kinetics.

Crystal Defects: Point Defects, equilibrium concentration of point defects, Activation Energy, Colour Centres, Screw and Edge Dislocations, Burger Vector and Burger circuit, Frank Read source, Stacking Faults, Grain boundaries, partial dislocations. Role of Crystal Defects in Crystal Growth
**Unit II: Crystal Growth Technology**

Silicon, Compound semiconductors, CdTe, CdZnTe - ,Czochralski technique, Bridgman technique, Float zone Process, Liquid Phase expitaxy, Molecular Beam epitaxy. Growth of Oxide & Halide crystals- Techniques and applications,

**Unit III: Non Crystalline Solids:**


*Liquid Crystals:* Classification-isotropic-nematic, smectic-cholesteric phases, Phase transition of liquid phases, Properties:* optical, electric and magnetic fields, Application of liquid crystals

*Polymers:* Major Polymer Transitions, Polymer Synthesis and Structures, Chain Polymer and Step Polymer, Cross Linking, fillers, Macromolecule Hypothesis, Phases: amorphous & Crystalline States

**Unit IV: Bulk Characterization Techniques**

Bulk Characterization Techniques and their applications: Normal and small angle XRD, FTIR, UV Spectroscopy, X-ray Fluorescence, Mossbauer, NMR, ESR, neutron diffraction

**References:**

Unit 1.

Unit 2

Unit 3:
(a) Liquid crystals
1. Peter J. Collins and Michael Hind (Taylor and Francis) Chap 1 and 9
(b) Amorphous semiconductors
(c) Polymers
5. L.H. Sperling “Introduction to Physical Polymer Science” Wiley interScience (2001) Chap 1 and Chap 5 and 6 (relevant portions only)

Unit 4:

Semester-IV : Elective Paper-III
Course no.: PSPHET405: Microprocessors and ARM 7 (60 lectures, 4 credits)

Unit-I:
**8085 Interrupts:** The 8085 Interrupt, 8085 Vectored Interrupts, Restart as Software Instructions, Additional I/O Concepts and Processes.
RSG - Ch 12: 12.1, 12.2, 12.3, 12.4

**Programmable Peripheral and Interface Devices:** The 8255A Programmable Peripheral Interface, Interfacing Keyboard and Seven Segment Display, the 8259A Programmable Interrupt Controller, Direct Memory Access (DMA) and 8237 DMA Controller, the 8279 Programmable Keyboard/Display Interface
RSG - Ch 15: 15.1, 15.2, 15.5, 15.6 & Ch 14: only 14.3

**Serial I/O and Data Communication:** Basic Concepts in Serial I/O, Software Controlled Asynchronous Serial I/O, The 8085 Serial I/O lines: SOD and SID
RSG - Ch 16: 16.1, 16.2, 16.3,

Ref. RSG: - Microprocessor Architecture, Programming and Applications with the 8085 by Ramesh S. Gaonkar, Fifth Edition Penram International Publication (India) Pvt Ltd
Unit-II

8086 microprocessor:
Register organization of 8086, Architecture, Signal Descriptions of 8086, Physical Memory Organization, General Bus operation, I/O Addressing Capability, Special Processor Activities, Minimum mode 8086 system and timings, Maximum mode of 8086 system and timings.
AB - Ch 1: 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9.

8086 Instruction set and assembler directives:
Machine Language Instructions Formats, Addressing modes of 8086, Instruction set of 8086.
AB - Ch 2: 2.1, 2.2, 2.3.

The Art of Assembly Language Programming with 8086:
A few machine level programs, Machine coding the programs, Programming with an assembler (only using Debug), Assembly language example programs.
AB - Ch 3: 3.1, 3.2, 3.3.4 & 3.4

Special architectural features and related programming:
Introduction to Stack, Stack structure of 8086, Interrupts and Interrupt Service Routines, Interrupt cycle of 8086, Non-maskable interrupt, Maskable interrupt (INTR).
AB - Ch 4: 4.1, 4.2, 4.3, 4.4, 4.5, 4.6
(Note: Also refer Intel’s 8086 Data Sheet)

Unit-III: ARM 7:
SF - Ch 2: 2.1, 2.2, 2.3, 2.4

ARM Organization and Implementation: 3 – stage Pipeline ARM organization, ARM instruction execution, ARM implementation.
SF - Ch 4: 4.1, 4.3, 4.4

ARM Processor Cores: ARM7TDMI
SF – Ch 9: 9.1 only

Unit-IV: ARM 7

**ARM Assembly language Programming:** Data processing instructions, Data transfer instructions, Control flow instructions, Writing simple assembly language programs.

SF – Ch 3: 3.1, 3.2, 3.3, 3.4

The **ARM Instruction Set:** Introduction, Exceptions, Condition execution, Branch and Branch with Link (B, BL), Branch, Branch with Link and eXchange (BX,BLX), Software Interrupt (SWI), Data processing instructions, Multiply instructions, Count leading zeros (CLZ), Single word and unsigned byte data transfer instructions, Half-word and signed byte data transfer instructions, Multiple register transfer instructions, Swap memory and register instructions (SWP), Status register to general register transfer instructions, General register to Status register transfer instructions

SF – Ch 5: 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 5.10, 5.11, 5.12, 5.13, 5.14, 5.15

The **Thumb Instruction Set:** the Thumb bit in the CPSR, The Thumb programmer’s model, Thumb branch instructions, Thumb software interrupt instruction, Thumb data processing instructions, Thumb single register data transfer instructions, Thumb multiple register data transfer instructions, Thumb breakpoint instruction, Thumb implementation, Thumb applications, Example and exercises.

SF – Ch 7: 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11


Additional Ref:
1. Microprocessors and interfacing, programming and hardware, By Douglas V. Hall (TMH)
2. 8086 Microprocessor: Programming and Interfacing K.J.Ayala, Penram International

Semester-IV : Elective Paper-IV

**Course no.: PSPHET406: VHDL and Communication Interface (60 lectures, 4 credits)**

Unit – I: VHDL-I:

DLP - Ch 1
DLP - Ch 2

DLP - Ch 3

Ref. DLP: - VHDL programming by example by Douglas L. Perry, Fourth edition, Tata McGraw-Hill

Unit-II: VHDL-II:
Data Types: Object Types, Signal, Variables, Constants, Data Types, Scalar Types, Composite Types, Incomplete Types, File Types, File Type Caveats, Subtypes.
DLP - Ch 4

DLP - Ch 5

Predefined Attributes: Value Kind Attributes, Value Type Attributes, Value Array Attributes, Value Block Attributes, Function Kind Attributes, Function Type Attributes, Function Array Attributes, Function Signal Attributes, Attributes ‘EVENT and ’LAST-VALUE Attribute ‘LAST-EVENT Attribute, ‘ACTIVE and ‘LAST-ACTIVE Signal Kind Attributes, Attribute ‘DELAYED, Attribute ‘STABLE, Attribute ‘QUIET, Attribute TRANSACTION, Type Kind Attributes, Range Kind Attributes.
DLP - Ch 6

Configurations: Default Configurations, Component Configurations, Lower-Level Configurations, Entity-Architecture Pair Configuration, Port Maps, Mapping Library Entities, Generics in
Configurations, Generic Value Specification in Architecture, Generic Specifications in Configurations, Board-Socket-Chip Analogy, Block Configurations, Architecture configurations.

DLP - Ch 7

Ref. DLP: - VHDL programming by example by Douglas L. Perry, Fourth edition, Tata McGraw-Hill

Unit-III: Understanding USB and USB Protocols
USB Basics: Uses and limits, Evolution of an interface, Bus components, Division of Labor, Developing a Device.
JA – Ch 1

Inside USB Transfers: Transfer Basics, Elements of a Transfer, USB 2.0 Transactions, Ensuring Successful Transfers, SuperSpeed Transactions.
JA – Ch 2

A Transfer Type for Every Purpose: Control transfers, Bulk Transfers, Interrupt Transfers, Isochronous Transfers, More about time-critical transfers.
JA – Ch 3
JA – Ch 4

Control Transfers: Structured Requests for Critical Data: Elements of a Control Transfer, Standard Requests, Other Requests.
JA – Ch 5

Chip Choices: Components of USB device.
JA – Ch 6: Pages 137 - 141

How the Host Communicates: Device Drivers, Inside the Layers, Writing Drivers, Using GUIDs.
JA – Ch 8


Unit-IV: Communication Interface
On board Communication Interface: Inter Integrated Circuit (I2C), Serial Peripheral Interface (SPI), Universal Asynchronous Receiver Transmitter (UART), Wire Interface, Parallel Interface
External Communication Interfaces: RS-232 & RS-485, USB, IEEE 1394 (Firewire), Infrared (IrDA), Bluetooth, Wi-Fi, ZigBee, GPRS.
SKV: Ch – 2: 2.4

Detailed studies of I2C Bus refer:
I2C Bus Specification Version 2.1 by Philips (Pages 4-18 and 27-30)
(Download from www.nxp.com)
  • The I2C-Bus Benefits designers and manufacturers (Art 2: 2.1, 2.2)
  • Introduction to the I2C-Bus Specification (Art 3)
  • The I2C-Bus Concept (Art 4)
  • General Characteristics (Art 5)
  • Bit Transfer (Art 6)
Data validity (6.1), START and STOP conditions (6.2)
  • Transferring Data (Art 7)
Byte format 7.1, Acknowledge 7.2
  • Arbitration and Clock Generation (Art 8)
    Synchronization (8.1), Arbitration (8.2), Use of the clock synchronizing mechanism as a handshake (8.3)
  • Formats with 7-Bit Addresses (Art 9)
  • 7-Bit Addressing (Art 10)
Definition of bits in the first byte (10.1)
  • 10-Bit Addressing (Art 14)
Definition of bits in the first two bytes (14.1), Formats with 10-bit addresses (14.2)

Detailed study of Bluetooth: Overview, Radio Specifications, FHSS
WS: Ch- 15: 15.1, 15.2 upto Page 512

Ref: SKV :- Introduction to embedded systems, by Shibu K. V. ,Sixth Reprint 2012, Tata Mcgraw Hill

Semester-IV : Elective Paper-III
Course no.: PSPHET407: Digital Communication Systems and Python Programming language (60 lectures, 4 credits)

Unit I:
**Digital Modulation:** Introduction, information capacity, bits, bit rate, Baud and M-Ary encoding, ASK, FSK, PSK, QAM, Bandwidth efficiency, carrier recovery, clock recovery.

**Digital Transmission:** Introduction, Pulse modulation, PCM sampling, Signal to quantization noise ratio, Commanding, PCM line speed, Delta modulation PCM, Adaptive delta modulation.

Unit II:

**Telephone Instruments and Signals:** Introduction, The subscriber loop, Standard telephone set, Basic telephone call procedures, Call progress tones and signals, Cordless telephones, Caller ID, Electronic telephones, paging system.

**Telephone Circuits:** Introduction, Local subscriber loop, Transmission parameters and private line circuits (concepts only), Voice frequency circuit arrangement.

Unit III:

**Study of PC Serial Port:** Options and choices, Formats and protocols, The PCs serial port from the connector in, PC programming.

**Cellular Phone Concepts:** Introduction, Mobile phone service, evolution of cellular phone, frequency reuse, interference, cell Splitting, sectoring, segmentation and dualization, cellular system topology, roaming and handoffs

**Cellular Phone Systems:** Digital cellular phone, Interim standard 95, CDMA, GSM communication.

Unit IV:

**Python Programming language:** Introduction, Installing Python, First steps, The basics, operators and expressions, control flow, Functions.

**Main References:**

[1] Advanced Electronic Communications Systems (Sixth edition) by Wayne Tomasi (PHI EE Ed)
[2] Serial Port Complete by Jan Axelsson; Penram International Publications.

**Additional References:**


**Semester-IV : Elective Paper-IV**

**Course no.: PSPHET408: Computer Networking (60 lectures, 4 credits)**

Unit I:
Data Link layer: Error detection and correction, Types of errors, Detection, Error correction, Data link control and protocols, Flow and error control, Stop and wait ARQ, Go-back-N ARQ, Selective repeat ARQ, HDLC, Point to point access, Pont to point protocol, PPP stack, Multiple access, Random access, Controlled access, Channelization.

Unit II:
Local Area Networks: Ethernet: Traditional ethernet, Fast ethernet, Gigabit Ethernet, Wireless LANs, IEEE 802.11, Bluetooth. Connecting LANs, Connecting devices (Repeaters, Hubs, Bridges, Two layer switch, Router and three layer switches), Backbone networks, Virtual LANs, Virtual circuit switching, Frame relay, ATM, ATM LANs.

Unit III:
Transport Layer: Process to process delivery, User datagram protocol (UDP), Transmission control protocol (TCP).
Application Layer: Domain name system, Name space, Domain name space, Distribution of name space, DNS in the internet, Resolution, DNS messages, DDNS, Encapsulation, Electronic mail, File transfer (FTP), HTTP, World wide web (WWW).

Unit IV:

References:
2. Advanced Electronic communications systems (Sixth edition) by Wayne Tomasi (PHI – EE Ed)
3. Data Communications and Computer Networks by Prakash Gupta

**Semester-IV : Elective Paper-III**

**Course no.: PSPHET409: Physics of Semiconductor Devices (60 lectures, 4 credits)**

(N.B.: Problems form an integral part of the course)

**Unit I: Metal-Insulator-Semiconductor (MIS) Devices:**
Review of ideal MIS device, Si-SiO₂ Practical MOS diode, Oxide charges, defects, Surface and interface states, C-V and G-V measurement techniques and characterization of MOS devices. Review of MOSFET Basic device characteristics, Types of MOSFETs, Non-uniform doping and buried-channel devices, Short-channel effects, MOS transistor scaling. MOSFET structures- HMOS, DMOS, SOI, VMOS, and HEXFET. Charge coupled devices (CCDs), Non-volatile memory devices, Simulation.

**Unit II: Microwave, Power & Hot electron devices:**
Microwave devices-Different types of Tunnel diodes, Tunnel transistor, IMPATT diode, BARITT diode, DOVITT diode, Transferred electron device, Gunn diode, Microwave transistor, Thyristors, Bipolar power transistor, Hot electron transistor; MOS Power transistor, HEMT.

**Unit III: Optoelectronic Devices:**
Light-Emitting Diodes, Liquid crystal displays, Photo detectors, Photodiode materials, Phototransistor, Solar cells, Materials and design considerations, Thin film solar cells, amorphous silicon solar cells, Semiconductor Lasers, Optical processes in semiconductor lasers (JS-Art.15.8), Heterojunction lasers. Exciton (JS-Art16.1), Quantum confined Stark effect (JS.Art16.6), Quantum well IR photodetector, Application of laser in materials processing, Fiber optical waveguides, Losses and dispersion in fibers, Measurement of fiber characteristics, Fiber materials and fabrication, Fiber optics simulation.

**Unit IV: Quantum well & Nano structures:**
Quantum wells: Band structure modifications by heterostructures; Band structure in quantum wells, quantum wires, quantum dots; Modulation doping; Mobility in a MODFET quantum well (JS-6.2, 6.3, 8.6, 14.2) Nanotechnology: Nanomaterials, nanostructures, Synthesis of nanoparticles, Semiconductor nanocrystals, Metallic
nanoclusters, Carbon nanostructures, Bulk nanostructured materials, Microelectromechanical systems (MEMS).

Main References:

Additional References:

Semester-IV : Elective Paper-IV
Course no.: PSPHET410: Semiconductor Technology (60 lectures, 4 credits)

(N.B.: Problems form an integral part of the course)

Unit I: Crystal growth and Epitaxy
   (a) Crystal growth: Czochralski technique, Bridgman technique, Float zone process, Zone refining, Zone levelling.

   (b) Epitaxy Vapour phase epitaxy (VPE), Liquid phase epitaxy (LPE), Molecular beam epitaxy (MBE), MOCVD, Heteroepitaxy, Growth of III-V compound semiconductors, Growth of silicon on insulator (SOI) structures.

   (c) Oxidation and film deposition: Oxide formation, kinetics of oxide growth, thin oxide growth, oxidation systems.

Unit II: Diffusion and Ion-implantation
(a) Diffusion: Nature of diffusion, basic diffusion theory, extrinsic Diffusion, diffusion related physical processes, Boron diffusion system, Phosphorus diffusion system.

(b) Ion-implantation: Range of implanted ions, ion distribution, ion stopping, ion channeling, Radiation damage and annealing, implantation related processes, evaluation techniques for epitaxial layer, diffused layer implanted layer and oxide layer.

Unit III: Lithography and Etching
(a) Lithography: Clean room, Masking, Photoresist, Passivation, Optical, Electron-beam, X-ray & Ion-beam lithography.

(b) Etching: Wet chemical etching, Dry etching, Plasma etching.

Unit IV: Integrated Devices
Device and circuit design and fabrication: Passive components-Integrated circuit resistor, capacitor and inductor. Bipolar technology: Discrete bipolar circuit fabrication, Bipolar technology, MOSFET technology, MESFET Technology, Fundamental limits of integrated devices, ULSI Technology; Simulation.

Main References:
2. Integrated circuits (Design principles & fabrication) – R.M.Warner, Motorola series in Solid State Electronics,
3. K. Martin, Digital Integrated Circuit Design Oxford University Press,
   YMCA, New Delhi, 2004

Additional References:
1. E.L. Wolf, Nanophysics and Nanotechnology, Wiley-VCH Verlag, Weinheim, 2004
2. S.K. Ghandhi, The theory and practice of Microelectronics, John Wiley and Sons,

Semester-IV : Elective Paper-III
Course no.: PSPHET411: Materials and their applications (60 lectures, 4 credits)

Unit I:
Engineering Alloys, Production of Iron and Steel, The Iron-Iron Carbide Phase Diagram, Heat Treatment of Plain-Carbon Steels, Low-Alloy Steels, Aluminum Alloys, Copper Alloys, Stainless Steels, Cast Irons, Magnesium, Titanium, and Nickel Alloys,
Unit II:
Corrosion, Electrochemical Corrosion of Metals, Galvanic Cells, Corrosion Rates (Kinetics), Types of Corrosion, Oxidation of Metals, Corrosion Control

Unit III:

Unit IV:

Reference:

**Semester-IV : Elective Paper-IV**

**Course no.: PSPHET412: Elective 12 Energy Studies (60 lectures, 4 credits)**

**Unit I:**
A brief history of energy technology, Global energy trends, Global warming and the greenhouse effect, Units and dimensional analysis, Heat and temperature, Heat transfer, First law of thermodynamics and the efficiency of a thermal power plant, Closed cycle for a steam power plant, Useful thermodynamic quantities, Thermal properties of water and steam, Disadvantages of a Carnot cycle for a steam power plant,

Rankine cycle for steam power plants, Gas turbines and the Brayton (or Joule) cycle, Combined cycle gas turbine, Fossil fuels and combustion, Fluidized beds, Carbon sequestration, Geothermal energy, Basic physical properties of fluids, Streamlines and stream-tubes, Mass
continuity, Energy conservation in an ideal fluid: Bernoulli’s equation, Dynamics of a viscous fluid, Lift and circulation, Euler’s turbine equation.
(Andrews and Jelly: Chapter 1, 2, and 3)

**Unit II:**
Hydropower, power output from a dam, measurement of volume flow rate using a weir, Water turbines; Impact, economics and prospects of hydropower; Tides, Tidal power, Power from a tidal barrage, Tidal resonance, Kinetic energy of tidal currents, Ecological and environmental impact of tidal barrages, Economics and prospects for tidal power, Wave energy, Wave power devices; Environmental impact, economics and prospects of wavepower; Binding energy and stability of nuclei, Fission, Thermal reactors, Thermal reactor designs, Fast reactors, Present-day nuclear reactors, Safety of nuclear power, Economics of nuclear power, Environmental impact of nuclear power, Public opinion on nuclear power, Outlook for nuclear power, Magnetic confinement, D-T fusion reactor, Performance of tokamaks, Plasmas, Charged particle motion in E and B fields, Tokamaks, Plasma confinement, Divertor tokamaks, Outlook for controlled fusion.
(Andrews and Jelly: Chapter 4, 8, and 9)

**Unit III:**
(Andrews and Jelly: Chapter 5, 6, and 7)

**Unit IV:**
Generation of electricity, High voltage power transmission, Transformers, High voltage direct current transmission, Electricity grids, Energy storage, Pumped storage, Compressed air energy storage, Flywheels, Superconducting magnetic energy storage, Batteries, Fuel cells, Storage and production of hydrogen, Outlook for fuel cells, Environmental impact of energy production, Economics of energy production, Cost-benefit analysis and risk assessment, Designing safe
systems, carbon abatement policies, Stabilization wedges for limiting CO₂ emissions,
Conclusions.
(Andrews and Jelly: Chapter 10 and 11)

Reference:
ENERGY SCIENCE: principles, technologies, and impacts, John Andrews and Nick Jelley, Oxford
University Press

Semester-IV : Elective Paper-III
Course no.: PSPHET413: Astronomy and Space Physics (60 lectures, 4 credits)

Unit I:
The Sky, Instruments and Observational tools: (a) Inventory of the Universe
Wavelength bands of observation: radio, infrared, optical, UV, X-ray and Gamma-ray
windows. Ground-based, balloon-borne and satellite-borne telescopes, Celestial co-
ordinate system: Right Ascension, Declination Time keeping. Sidereal and Solar
(b) Resolution of Instruments and Limitations Optical telescopes, Photometers,
Spectrographs, CCDs, Polarimeters. Radio telescopes – interferometry X-ray and
Gamma-ray detectors Neutrino and Cosmic Ray astronomy - origin, composition and
spectrum.

Unit II:
Stellar Structure and Evolution: Stellar parameters: Mass, Radius, Luminosity, Chemical
Composition Spectral types colour, magnitude: H-R diagram. Stellar physics: Equation of
state, Opacity. Nuclear energy generation, Saha Ionization Equilibrium Planck Blackbody
Radiation. Radiative and convective transport of energy. Internal structure of stars and
Virial Theorem. Stellar atmosphere. Absorption and Emission of lines. Stellar Evolution:
Hayashi phase. Main sequence, Horizontal Branch, Red Giant and Asymptotic Giant
Branches. Planetary Nebulae and Supernova remnants. Stellar rotation. Stellar

Unit III:
Condensed Objects And High Energy Astrophysics: Compact objects: White dwarfs and
Chandrasekhar Limit. Neutron stars and Black holes: Pulsars, X-ray and Gamma-ray
sources. Binary systems: Accretion process and associated phenomena: Bursts and
Quasi-periodic oscillations. Radiation Processes: Blackbody, Bremstrahlung, Cyclotron,
Synchrotron and Inverse Compton emission. Interaction of high energy particles and

Unit IV:

*Solar Physics*: Description of solar internal and external layers, Magnetohydrodynamic equations, Hall effect and generalized Ohm’s law, Magnetostatic equilibrium and sunspots, Solar activity cycle, Force-free magnetic fields, Magnetic reconnections and solar flares, Waves: sound waves, Alfvén waves, Internal gravity waves, inertial waves, magnetosonic waves; Heating of the solar chromosphere and corona, Coronal mass ejections, Solar wind and Parker’s solution.

Main References:

Unit 1:
   ii. R.C. Smith, Observational Astrophysics; CUP, 1995,

Unit 2:

Unit 3:
   i. H. Harwit, Astrophysical Concepts; Springer Verlag 1988,

Unit 4:

Additional Books:
   i. Astronomy, Fred Hoyle, 1975. Astronomy, 8th ed., Robert H Baker,

**Semester-IV : Elective Paper-IV**

**Course no.: PSPHET414: Laser Physics (60 lectures, 4 credits)**
Unit I: Laser characteristics and Resonators: Principles, Properties of laser radiation, Einstein Coefficients, Light amplification, Threshold condition for laser oscillations, Homogeneous and inhomogeneous broadening, Laser rate equations for 2,3 and 4 level, variation of laser power around threshold, optimum output coupling, Open planar resonator, Quality Factor, ultimate line width of the laser, Transverse and Longitudinal mode selection.

Unit II: Non linear optics- Techniques for Q-switching, Mode Locking, Hole burning and Lamb dip in Doppler broadened Gas laser, Non linear oscillator model, Non linear polarization and wave equation, perturbative solution of the Nonlinear oscillator equation, Harmonic generation, Second harmonic generation, Phase matching third harmonic generation. Optical wave mixing, parametric generation of light, parametric oscillation, tuning of parametric oscillators. Non-Linear susceptibilities, non-linear susceptibility tensor, non-linear materials


Unit IV: Spectroscopic Instrumentation and applications: Raman scattering, photo-acoustic Raman Spectroscopy. Raman Amplification and Raman laser, special techniques in non linear spectroscopy, polarization spectroscopy, multi-photon spectroscopy, photofluoroscence excitation spectroscopy.

Holographic Optical Element: HOE, Design aspects, resolution, vibration and motion analysis by Holographic techniques, holography, Spatial Frequency filtering, optical Communication, optical computers. Laser ablation, Laser in Biomedicine.

Main References:
5. Yariv, Optical Electronics in Modern Communications, Oxford University Press (1997),

Additional Reference books:
1. Laser: Svelto.
3. Laser spectroscopy: Demtroder.
Semester-IV : Elective Paper-III  
Course no.: PSPHET415: Liquid Crystals (60 lectures, 4 credits)  

Unit-I : Introduction to the Science and technology of Liquid Crystal.  
Types and Classification of liquid crystals, Nature’s of Anisotropic Liquid Crystals. Calamtic liquid crystal, Discotic Liquid crystal, Polymer liquid crystals, Chiral liquid crystal, membranescolloidal system. Display Technologies Overview.  
Ref: CP: Ch 1 ; PDG: Ch 1; PJC: Ch 1, 2, 3,4,5,6.  

Unit-II : Theoretical Insights  
Nature of phase transitions and critical phenomenon in liquid crystals, Maier-Saupe, Landau de gennes theory, Van der Walls theories. Continuum theory: Curvature elasticity in nematic smectic A phases, Distortions due to magnetic and electric fields, Magnetic coherence length, Freedeicksz transitions. Onsager's mean field theory  
Ref: PJC: Ch12, 10. PDG: Ch 7  

Unit-III: Merits of LCs  
Dynamical properties of Nematic, equations of nemato-dynamics, laminar flow, Fluid vs. solid membranes, energy and elasticity, surface tension, viscoelasticity, Molecular motions. LC in electric and magnetic fields, light and liquid crystals, Mechanical, Optical Properties: Cholesteric, Ferroelectric, Antiferroelectric, Polymer dispersed liquid crystals, Elastomer.  
Ref: PDG: Ch 5,6; SERS: Ch 9; CP: Ch 5  

Unit IV: Characterization Techniques and Applications  
Techniques used for Identification and characterizations of Liquid crystal phases, Lyotropic liquid crystals and biological membrane,: Survey over flat panel technologies. Liquid crystal displays, plasma displays .Applications of liquid crystals.  
Ref: Ref: CP: Ch 2, 9; PJC: Ch 9, 7, 13; DDLR.  

Text Book and References  
2. Liquid crystal: The fourth state of matter.Frankin D saeva. Wiely publication.  
4. The physics of liquid crystals: P G de Gennes and J Prost, Oxford University  
8. The Optic of Thermotropic Liquid Crystals. Steve Elston and Roy Sambles.
13. Handbook of Liquid Crystals, High Molecular Weight Liquid Crystal Dietrich Demus, John W. Goodby, George W. Gray, Hans W. Spiess, Volkmar Vills –
16. Properties and Structure of Liquid Crystals
Semester-IV : Elective Paper-IV  
Course no.: PSPHET416: Numerical Methods and Programming (60 lectures, 4 credits)

Unit I : Programming using C++  
Elementary information about digital computer, hardware, software, machine language program, assembly language program, assembler, disadvantages of machine and assembly language programming, High level language programs, interpreter and compilers, flow charts-symbols and simple flowcharts, Structure of a C program, header files, constant and variables, data types and their declarations, operators – arithmetic operators, relational operators, logical operators, assignment operators, conditional operator. Built in functions in C, Input/output functions for integer, floating points, characters and strings. Control statements-if, if-else, do-while. For loop, nested if and nested for loops, goto statement. Library functions- mathematical and trigonometric. Arrays- one dimensional and two-dimensional. User defined functions-definition and declaration of a function, passing arguments, return values. File handling-operation with files, opening and closing a file. (structures and unions and pointers are not expected)

Unit II : Curve fitting, interpolation, Roots of Equation  
Review of Intermediate Value theorem, Rolle's Theorem, Lagrange Mean Value theorem and Taylor's Theorem, Errors in computation and Numerical stability, Least squares method Principle, fitting a straight line, fitting a parabola, fitting an exponential curve, fitting curve of the form \( y=ax^b \), fitting through a polynomial, Linear interpolation, difference schemes, Newton’s forward and backward interpolation formula, Lagrange’s interpolation formula. Polynomial and transcendental equations, limits for the roots of polynomial equation. Bisecional method, false position method, Newton-Raphson method, direct substitution method

Unit III : Numerical integration and solution of differential equation:  
Newton cotes formula, Trapezoidal rule, Simpson’s one third rule, Simpson’s three eight rule, Gauss quadratics method, Monte Carlo method.

Solution of Ordinary differential equation using Taylor series method, Euler’s method, Runge-Kutta method, Milne’s and Adams Bashforth predictor-corrector methods

Classification of second order partial differential equation, Solution of partial differential equation-Difference equation method over a rectangular domain for solving elliptic, parabolic and hyperbolic partial differential equation
Unit IV: Solution of simultaneous equation and Random numbers
Gaussian elimination method, Gaussian elimination with pivotal condensation method, Gauss-Jordan elimination method, Gauss-Seidal iteration method, Gauss-Jordan matrix inversion method.
Random numbers - Random number generation, Monte Carlo simulation using Random walk on a square lattice.

Text and Reference books:

ii. S. S. Sastry: Introductory method of numerical analysis, PHI India 2005
iii. Rajaraman : Computer oriented Numerical methods, PHI 2004
ix. Numerical recipes in C

Semester-IV: Elective Paper-III
Course no.: PSPHET417: Polymer Physics (60 lectures, 4 credits)

Unit I:

Unit II:

Unit III:
Unit IV:
Preparation of thin films of organic materials (solution casting, electro-chemical, CVD, interfacial method, LB technique), their structure, props, & Application. Fundamentals of electrochemistry, electrochemical methods for preparation characterization of thin films-CV & impedance measurement. Sensors, types of sensors, electrochemical & optical sensors-Construction & functioning of these sensors, advantages & disadvantages of these sensors (study of at-least two types of sensors).

Main References:
1. Physics of Plastics, P.O. Ruchie. Illiffe Books Co. Ltd, (Chapters I to 4 and 6 to 8),

M.Sc. (Physics) Practical Lab Course
Semester – IV

Semester IV Elective Lab Course-2
Course no.: PSPHAP402: Advanced Physics Lab-2 (120 hours, 4 credits)
A) Students offering electives other than PSPH405, 406, 407, 408, (i.e. Electronics I or Electronics II), have to perform at least 10 experiments out of following:

I. Neutron Diffraction: Data analysis for structure and dynamic Q-factor
II. Mössbauer Spectroscopy
1. Fe$^{57}$ Mossbauer spectra: Calibration and determination of isomer shift and hyperfine field
2. Determination of isomer shift in stainless steel
3. Determination of isomer shift and quadrupole splitting in Sodium Nitroprusside
4. Fe-based specimen: Determination of isomer shift, hyperfine field, estimation of oxidation state in ferrite samples

III. Hartree –Fock Calculations

IV. Magnetization and Hysteresis
   1. B-H loop in low magnetic fields (dc and ac methods)
   2. Hysteresis of ring-shaped ferrite
   3. Determination of Curie/ Neel temperature
   4. Susceptibility of paramagnetic salt by Guoy’s method

V. Resistivity and Magnetoresistance
   1. Resistivity of metallic alloy specimens with varying temperatures
   2. Study of percolation limit by resistivity measurement on ceramic specimens
   3. Tracking of first and second order transition by resistivity measurement in shape memory (NiTi) alloy
   4. MR of Semiconductor, Bismuth and LSMO (Manganate) specimen
   5. Calibration of magnetic field using MR probe

VI. LASER
   1. Refractive index of the given materials
   2. Refractive index of the Air at different pressure.

VII. Plasma
   1. Measurement of plasma parameters. - Single probe

VIII. Nuclear Physics
   1. Energy resolution of NaI detector and understanding of its Pulse processing electronics
   2. Peak to total ratio and efficiency of NaI detector.
   3. Sum peak analysis and detector size effect on peak to total ratio using NaI detector.
   5. Coincidence Technique

IX. Semiconductors and devices
   1. Si, Ge and LED:
      a. I-V at different temperatures,
      b. C-V at room temperature and determination of barrier height.
   2. Schottky diode and MOS diode Fabrication
   3. Determination of carrier concentration and barrier height from C-V measurements
4. I-V characteristics and identification of the current conduction mechanisms
5. Determination oxide charge, carrier concentration and interface states of from C-V measurements.
7. Semiconductor lasers- Study of output characteristics and determination of threshold current, differential quantum efficiency and divergence.
8. Infrared detector characteristics and spectral response.
10. Gunn diode characteristics.
11. Determination of surface concentration and junction depth of diffused silicon wafers by four point probe method.

X. Experiments using Phoenix kit
XI. Astronomy and Space Physics
   1. The temperature of an artificial star by photometry.
   2. Study of the solar limb darkening effect.
   3. Polar aligning an astronomical telescope.
   4. Study of the atmospheric extinction for different colors.
   5. Study the effective temperature of stars by B-V photometry.
   6. Estimate of the night sky brightness with a photometer.

XII. Computation
      1. Computer program for file handling

XIII. Any one classical Experiment (available in department or affiliated institutions) e.g.
      1. Millikan’s oil-drop method,
      2. Raman effect in liquids,
      3. e/m by Thomson’s method
      4. Rydberg’s constant using constant deviation prism.

B) Students offering electives PSPH405, 406, (i.e. Electronics I), have to perform at least 10 experiments out of following:

I.: 8085/8086 Microprocessor based experiments:

   1. Study of 8085 interrupts (Vector Interrupt 7.5).
   2. Study of PPI 8255 as Handshake I/O (mode 1): interfacing switches and LED’s.
   3. 8086 assembly language programming:
   4. Simple data manipulation programs.(8/16-bit addition, subtraction, multiplication, division, 8/16 bit data transfer, finding greatest/smallest number, finding
positive/negative numbers, finding odd/even numbers, ascending/descending of numbers, converting BCD nos. into Binary using INT 20, displaying a string of characters using INT 20)

Please note: Assembly language programming of 8086 may be done by operating PC in real mode by using 'Debug' program. Separate 8086 study kit not needed.

II: ARM7 based experiments:
1. Simple data manipulation programs (addition, subtraction, multiplication, division etc).
2. Study of IN and OUT port of ARM7 by Interfacing switches, LEDs etc.
3. Study of Timer.

III: Basic VHDL experiments:
1. Write VHDL programs to realize: logic gates, half adder and full adder
2. Write VHDL programs to realize the following combinational designs: 2 to 4 decoder, 8 to 3 encoder without priority, 4 to 1 multiplexer, 1 to 4 de-multiplexer
3. Write VHDL programs to realize the following: SR – Flip Flop, JK – Flip Flop, T – Flip Flop
4. Write a VHDL program to realize a 2/3/4 - bit ALU (2- arithmetic,2-logical operations)

IV: VHDL Interfacing based experiments:
1. Interfacing stepper motor: write VHDL code to control direction, speed and number of steps.
2. Interfacing dc motor: write VHDL code to control direction and speed using PWM.
3. Interfacing relays: write VHDL code to control ac bulbs (at least two) using relays.

V: Computation
1. Computer program for file handling.

VI. Any one classical Experiment (available in department or affiliated institutions) e.g.
1. Millikan’s oil-drop method,
2. Raman effect in liquids,
3. e/m by Thomson’s method
4. Rydberg’s constant using constant deviation prism.
References:

1. Advanced Microprocessors and Peripherals by a K Ray and K M Bhurchandi  
3. VHDL programming by example by Douglas L. Perry, Fourth edition, Tata McGraw-Hill

B) Students offering electives PSPH407, 408, (i.e. Electronics II), have to perform at least 10 experiments out of following:

Experiments in Electronics Communication

1. Sample and hold circuit using FETs or CMOS switch IC CA 4016/4066 or IC LF398.
2. Study of ADC-DAC system using ADC 0804/0808 and DAC 0800/0808.
3. Flat top pulse amp. Modulation (PAM) using CMOS switch IC CA 4016/4066 FET.
4. Pulse width modulation (PWM) & pulse position modulation (PPM) using IC565/555.
5. Time division multiplexing (TDM) using IC CA 4016/4066 or FET.
6. FSK modulator using IC 555 or PLL IC 565 and demodulation using PLL IC 4046.
7. Study of PCM – Transmission and reception using CODEC IC.
8. Two channel analog multiplexer using CMOS switch CA4016/CA4066/LF398.
9. PC to PC communication through serial port.
10. PC to PC communication through parallel port.
11. Study of Manchester coding and decoding using CODEC IC.
12. Experiments using Phoenix kit
13. Computation : Computer program for file handling
14. Any one classical Experiment (available in department or affiliated institutions)  
   e.g.
   1. Millikan’s oil-drop method,
   2. Raman effect in liquids,
   3. e/m by Thomson’s method
   4. Rydberg’s constant using constant deviation prism.

References:

7. Microwaves by K. C. Gupta (New Age International Ltd.).
11. Digital communication systems by Harold Kolimbiris (Pearson Education Asia).
15. Parallel port complete by Jan Axelson, (Penram International Publications, India).
17. Innovative experiments using Phoenix by Ajit kumarm IUACm New Delhi, India.

Note:
1. Journal should be certified by the laboratory in-charge only if the student performs satisfactorily the minimum number of experiments as stipulated above. Such students, who do not have certified journals, will not be allowed to appear for the practical examinations.
M.Sc. (Physics) Projects

Semesters III and IV

Project evaluation guidelines

Every student will have to complete one project each in Semester III and Semester IV with four credits (100 marks) each. Students can take one long project (especially for SSP/SSE/Material Sc/Nanotechnology/Nuclear etc) or two short project (especially for EI/EII). However for one long project students have to submit two separate project reports / dissertation consisting of the problem definition, literature survey and current status, objectives, methodology and some preliminary experimental work in Semester III and actual experimental work, results and analysis in semester IV with four credits each. Those who have opted for two separate projects will also have to submit two separate project reports at each examination. The project can be a theoretical or experimental project, related to advanced topic, electronic circuits, models, industrial project, training in a research institute, training of handling a sophisticated equipments etc.

Maximum three students can do a joint project. Each one of them will submit a separate project report with details/part only he/she has done. However he/she can in brief (in a page one or two) mention in Introduction section what other group members have done. In case of electronic projects, use of readymade electronic kits available in the market should be avoided. The electronics project / models should be demonstrated during presentation of the project. In case a student takes training in a research institute/training of handling sophisticate equipment, he/she should mention in a report what training he/she has got, which instruments he/she handled and their principle and operation etc.

Each project will be of 100 marks with 50% by internal and 50% by external evaluation.
There project report should be file bound/spiral bound/hard bound and should have following format

Title Page/Cover page
Certificate endorsed by Project Supervisor and Head of Department
Declaration
Abstract of the project
Table of Contents
List of Figures
List of Tables
Chapters of Content –
Introduction and Objectives of the project
Experimental/Theoretical Methodology/Circuit/Model etc. details
Results and Discussion if any
Conclusions
References

Evaluation by External/Internal examiner will be based on following criteria: (each semester)

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<tr>
<th>criteria</th>
<th>Maximum Marks</th>
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<tbody>
<tr>
<td>Literature Survey</td>
<td>05</td>
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<tr>
<td>Objectives/Plan of the project</td>
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<tr>
<td>Experimental/Theoretical methodology/Working condition of project or model</td>
<td>10</td>
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<tr>
<td>Significance and originality of the study/Society application and Inclusion of recent References</td>
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<td>Depth of knowledge in the subject / Results and Discussions</td>
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<td>Presentation</td>
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<tr>
<td><strong>Maximum marks by External examiner</strong></td>
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<tr>
<td><strong>Maximum marks by internal examiner/guide</strong></td>
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<td><strong>Total marks</strong></td>
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