

**Scheme and Syllabi for Ph.D. Course work in Physics**  
**(Effective from the Session 2026-27)**  
**Program Specific Outcomes of the Ph.D. Course Work (Physics)**

PSO1: The grasp of research methodology enables the research scholars in designing, defining and formulation of research programs with the objectives stated therein.

PSO2: The contents in the program are designed in a manner to have a significant improvement in analytical skills of the research scholars engaged in experimental work.

PSO3: In depth understanding of structural properties of materials as important in designing about the applications in different domains.

PSO4: The curriculum has been designed in a manner for detailed exposure of advanced characterization techniques important from basic as well as applied point of view.

PSO5: Due to training in various software/s the students are enabled for proper analysis of the data and preparation of manuscripts / presentation.

**Duration:** One Semester (Six months)

**Total Credit requirement:** 12 Credits

| Course Code                                           | Nomenclature of Course             | Theory Marks(end semester Examination) | Internal Assessment marks | Maximum marks | Hours/ Week | Credits   |
|-------------------------------------------------------|------------------------------------|----------------------------------------|---------------------------|---------------|-------------|-----------|
| 23PHYPH11C1<br>(Compulsory for all Ph.D. Course work) | Research Methodology               | 70                                     | 30                        | 100           | 4           | 4         |
| 23CCPH11C1<br>(Compulsory for all Ph.D. Course work)  | Research and Publication Ethics    | 35                                     | 15                        | 50            | 2           | 2         |
| 23PHYPH11C3                                           | Electronic Properties of Materials | 70                                     | 30                        | 100           | 4           | 4         |
| 23PHYPH11C4                                           | Characterization Techniques        | 35                                     | 15                        | 50            | 2           | 2         |
| <b>Total marks/Credits</b>                            |                                    |                                        |                           | <b>300</b>    | <b>12</b>   | <b>12</b> |

**Note:**

- (i) The compulsory course on 'Research and Publication Ethics' of 2 credits shall be offered by Ch. Ranbir Singh Institute of Social and Economic Change for all UTDs/Centers/Institutes passed vide Resolution No. 27 of the 271st meeting of EC held on 29.7.2020. (As per template provided by Director, IQAC).
- (ii) Each course shall have an internal assessment of 30%. It shall comprise of two written assignments (7.5 % each) and two presentations (7.5 % each). The concerned teacher/Head of the Department shall maintain the record for at least six months after the declaration of results.

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| <b>Name of the Program</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | <b>Ph.D. course work</b> | <b>Program Code</b> | PHYPH       |
| <b>Name of the Course</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Research Methodology     | <b>Course Code</b>  | 23PHYPH11C1 |
| <b>Hours/Week</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 4                        | <b>Credits</b>      | 4           |
| <b>Max. Marks.</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 70                       | <b>Time</b>         | 3 Hours     |
| <b>Note:</b> Examiner will set nine questions of fourteen marks each and the candidates will be required to attempt five questions in all. Question number one will be compulsory containing short answer type questions from all units. Further, examiner will set two questions from each unit and the candidates will be required to attempt one question from each Unit. All questions will carry equal marks.                                                                                                                                                                                                                                                                                                                                                                                                                                         |                          |                     |             |
| <b>Course Objectives:</b> <ol style="list-style-type: none"> <li>1. To apprise the students regarding selection of research problem and its objectives</li> <li>2. To acquaint the students with various aspects of preparation of research proposal and writing of research articles</li> <li>3. To enable the students in data handling, analysis, presentation and selection of suitable journal for publication.</li> <li>4. Familiarize the students with probe microscopic techniques such as AFM and STM</li> <li>5. To handle applications of MS office such as MS word, Power Point, Equation editor etc.</li> <li>6. To enable students, understand the crystal structure determination using x-ray diffraction and transmission electron microscopy.</li> </ol>                                                                                 |                          |                     |             |
| <b>Course Outcomes:</b> <ol style="list-style-type: none"> <li>1. The research students were enabled to appreciate the complexities of research proposals and implications.</li> <li>2. The students got well versed with skills of writing research papers and conclusion of the research problem</li> <li>3. Exposure to MS Office and other scientific softwares enabled the scholars in analyzing the data as well as in preparing manuscript and presentation</li> <li>4. Students acquired the skills of plotting multi-functional graph</li> <li>5. Students understood applications of Characterization techniques / setups including DSC, AFM, STM etc. in basic as well as applied research.</li> <li>6. Students acquired the skill of crystal structure determination using x-ray diffraction and transmission electron microscopy.</li> </ol> |                          |                     |             |
| <b>Unit - I</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                          |                     |             |
| Introduction of research methodology: meaning of research, objectives of research, types of research, significance of research, research and scientific method, research process; research problem: definition, necessity and techniques of defining research problem, formulation of research problem, objectives of research problem.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                          |                     |             |
| <b>Unit - II</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                          |                     |             |
| Scientific communications: publishing research papers, selection of a journal, writing of research papers: abstract, introduction/ formulation of problem, experimental details, results & discussion, references, submission of manuscript and handling of reviewer's comment; writing of thesis: format of a thesis, review of literature, writing methods, preparation of tables and figures, writing discussion; conclusions, summary and synopsis, research metrics.                                                                                                                                                                                                                                                                                                                                                                                  |                          |                     |             |
| <b>Unit - III</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                          |                     |             |
| Brief review of crystal structure, X-ray diffraction methods, modern X-ray diffractometer, indexing of X-ray diffraction peaks, data analysis and interpretation, crystallite size and strain measurement in nanomaterials, basic principle of scanning electron microscopy, energy dispersive X-ray analysis, basic principle of transmission electron microscopy, brief idea of set up, sample preparation, imaging modes: bright field imaging, dark field imaging, selected area electron diffraction etc. (case study of each technique)                                                                                                                                                                                                                                                                                                              |                          |                     |             |
| <b>Unit - IV</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                          |                     |             |
| Basic principle of atomic force microscopy, brief idea of set up, different modes of AFM (contact & tapping mode) and their importance, basic principle of scanning tunneling microscopy, brief idea of set up/components, different modes of STM and its importance, TGA and DSC/DTA: principle, practical aspects, experimental variables, data analysis and interpretation (case study of each technique)                                                                                                                                                                                                                                                                                                                                                                                                                                               |                          |                     |             |

**References:**

1. Gurumani, N. (2010). Scientific Thesis Writing and Paper Presentation. MJP Publishers.
2. Kothari, C.R. (2004). Research Methodology: Methods and Techniques. New Age International.
3. Evans, C., Brundle, R., & Wilson. S. (1992). Encyclopedia of Materials Characterization: Surfaces, Interfaces, Thin Films. Butterworth-Heinemann.
4. Leng, Y. (2013). Materials Characterization: Introduction to Microscopic and Spectroscopic Methods. Wiley-VCH.
5. Hummel, R.E. (2011). Electronic Properties of Materials. Springer.
6. Goldstein, J., Newbury, D.E., Joy, D.C., Lyman, C.E., Echlin, P., Lifshin, E., Sawyer, L., Michael, J.R. (2003). Scanning Electron Microscopy and X-Ray Microanalysis. Springer.
7. Cullity, B.D., & Stock, S.R. (2013). Elements of X-Ray Diffraction. Pearson.
8. Kaufmann, E.N. (2003). Characterization of Materials (Vol 1 & 2). John Wiley and Sons.
9. Carter, C.B., & Williams, D.B. (2016). Transmission Electron Microscopy Diffraction, Imaging, and Spectrometry (Carter, Barry, Williams, David B. Eds.)

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| <b>Name of the Program</b> | <b>Ph.D. course work</b>        | <b>Program Code</b> | PHYPH      |
| <b>Name of the Course</b>  | Research and Publication Ethics | <b>Course Code</b>  | 23CCPH11C1 |
| <b>Hours/Week</b>          | 2                               | <b>Credits</b>      | 2          |
| <b>Max. Marks.</b>         | 35                              | <b>Time</b>         | 3 Hours    |

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| <b>Name of the Program</b> | <b>Ph.D. course work</b>           | <b>Program Code</b> | PHYPH       |
| <b>Name of the Course</b>  | Electronic Properties of Materials | <b>Course Code</b>  | 23PHYPH11C3 |
| <b>Hours/Week</b>          | 4                                  | <b>Credits</b>      | 4           |
| <b>Max. Marks.</b>         | 70                                 | <b>Time</b>         | 3 Hours     |

**Note:** Examiner will set nine questions of fourteen marks each and the candidates will be required to attempt five questions in all. Question number one will be compulsory containing short answer type questions from all units. Further, examiner will set two questions from each unit and the candidates will be required to attempt one question from each Unit. All questions will carry equal marks.

**Course Objectives:**

1. To develop understanding about magnetic materials and related applications
2. To develop in-depth understanding of optical materials and related applications
3. To impart detailed knowledge of dielectric and ferroelectric properties of materials
4. To learn theoretical aspects of dielectric and optical properties of materials
5. Application of Quantum mechanics in understanding electronic properties.

**Course Outcomes:**

1. Capability of understanding the magnetic materials.
2. Understanding of various concepts of optical materials.
3. Application of electron theory of solids
4. Appreciation of dielectric properties of materials
5. Ability to realize possible applications of magnetic materials

**Unit - I**

Drude model: basic assumptions, collision or relaxation times, Hall-effect and magneto-resistance, electrical conductivity, dielectric function and plasma resonance, Sommerfeld model: density of allowed wave vectors, thermal properties of a free electron gas, theory of conduction, Wiedemann–Franz law, effect of periodic lattice potential: Bloch's theorem, crystal momentum, band index and velocity, density of levels and van Hove singularities.

**Unit - II**

Magnetic behavior: ferromagnetism and anti-ferromagnetism, exchange interaction and magnetic domains, anisotropy energy, transition between domains, solitons, origin of domains, coercivity and hysteresis, ferrimagnetic order, ferrites and garnets, hard and soft magnets, single domain magnets,

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| geomagnetism and bio-magnetism, magnetic force microscopy, spin waves, surface magnetism.                                                                                                                                                                                                                                         |
| <b>Unit - III</b>                                                                                                                                                                                                                                                                                                                 |
| Dielectric constants of solids and liquids, dipole theory of ferroelectricity, thermodynamics of ferroelectric transitions, ferroelectric domains, Clausius-Mossotti relation, dielectric dispersion and losses, classification of ferroelectric materials, piezo-, Ferro- and pyro- electricity, electrostriction                |
| <b>Unit - IV</b>                                                                                                                                                                                                                                                                                                                  |
| Optical constants: index of refraction, reflectivity, transmittance, damping constant, penetration depth and absorbance, atomistic theory of optical properties, free electrons with and without damping, bound electrons, Hagen-Rubens relation, quantum mechanical treatment, band transitions, dispersion, plasma oscillations |
| <b>References:</b>                                                                                                                                                                                                                                                                                                                |
| 1. Kasap, S.O. (2017). Principles of Electronic Materials and Devices. McGraw Hill.                                                                                                                                                                                                                                               |
| 2. Hummel, R.E. (2011). Electronic Properties of Materials. Springer.                                                                                                                                                                                                                                                             |
| 3. Ashcroft, N. W., & Mermin, N.D. (2003). Solid State Physics. CENGAGE Learning.                                                                                                                                                                                                                                                 |
| 4. Kittel, C. (2019). Introduction to Solid State Physics. Wiley India Edition.                                                                                                                                                                                                                                                   |
| 5. Dekker, A.J. (2008). Solid State Physics. Macmillan.                                                                                                                                                                                                                                                                           |
| 6. Solymar, L., Walsh, D., & Syms, R.R.A. (2018). Electrical Properties of Materials. Oxford University Press.                                                                                                                                                                                                                    |

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| <b>Name of the Program</b>                                                                                                                                                                                                                                                                                                                                                                                                         | <b>Ph.D. course work</b>    | <b>Program Code</b> | PHYPH       |
| <b>Name of the Course</b>                                                                                                                                                                                                                                                                                                                                                                                                          | Characterization Techniques | <b>Course Code</b>  | 23PHYPH11C4 |
| <b>Hours/Week</b>                                                                                                                                                                                                                                                                                                                                                                                                                  | 2                           | <b>Credits</b>      | 2           |
| <b>Max. Marks.</b>                                                                                                                                                                                                                                                                                                                                                                                                                 | 35                          | <b>Time</b>         | 3 Hours     |
| <b>Note:</b> Examiner will set nine questions of seven marks each and the candidates will be required to attempt five questions in all. Question number one will be compulsory containing short answer type questions from all units. Further, examiner will set two questions from each unit and the candidates will be required to attempt one question from each Unit. All questions will carry equal marks.                    |                             |                     |             |
| <b>Course Objectives:</b>                                                                                                                                                                                                                                                                                                                                                                                                          |                             |                     |             |
| 1. To give a detailed flavor of various spectroscopic techniques and their use in material characterization                                                                                                                                                                                                                                                                                                                        |                             |                     |             |
| 2. To impart working knowledge of different techniques for electrical and magnetic properties.                                                                                                                                                                                                                                                                                                                                     |                             |                     |             |
| 3. Train the students regarding use of various equipments of material characterization and data analysis.                                                                                                                                                                                                                                                                                                                          |                             |                     |             |
| <b>Course Outcomes:</b>                                                                                                                                                                                                                                                                                                                                                                                                            |                             |                     |             |
| 1. Exposure to spectroscopic techniques enabled the scholars understand the complexities in Materials Science.                                                                                                                                                                                                                                                                                                                     |                             |                     |             |
| 2. Enabled handling of VSM, Hysteresis loop tracer, impedance analyzer.                                                                                                                                                                                                                                                                                                                                                            |                             |                     |             |
| 3. Students empowered in classification of material in crystalline and amorphous forms.                                                                                                                                                                                                                                                                                                                                            |                             |                     |             |
| 4. Enabled the students in data recording, handling and analysis.                                                                                                                                                                                                                                                                                                                                                                  |                             |                     |             |
| <b>Unit - I</b>                                                                                                                                                                                                                                                                                                                                                                                                                    |                             |                     |             |
| UV-Vis. Spectroscopy: basic principle, instrumentation, determination of optical band gap, and type of optical transition; Photoluminescence spectroscopy: basic principal and instrumentation, factors affecting decay time, peak width and peak intensity, Ellipsometry: basic principle and instrumentation, measurement of optical constant (n & k) and measurement of thickness of thin films. (case study of each technique) |                             |                     |             |
| <b>Unit – II</b>                                                                                                                                                                                                                                                                                                                                                                                                                   |                             |                     |             |
| Basic principle of FTIR and Raman spectroscopy, brief idea of set up (includes source, detector, operating conditions and excitation wavelength choice), deconvolution of the peaks, analysis of the spectra based on peak position, FWHM of the vibrational modes. (case study of each technique)                                                                                                                                 |                             |                     |             |
| <b>Unit - III</b>                                                                                                                                                                                                                                                                                                                                                                                                                  |                             |                     |             |
| Review of magnetic materials, basic principle and brief idea about set-up of vibrating sample                                                                                                                                                                                                                                                                                                                                      |                             |                     |             |

magnetometer (VSM) and SQUID magnetometer, magnetization vs. temperature profiling for zero field cooling (ZFC) and field cooling (FC), M-H hysteresis loops, AC magnetic susceptibility (case study of each technique)

#### **Unit - IV**

Electrical characterization: two probe, four-probe and van-der pauw method for resistivity measurements, Hall effect experiment, dielectric spectroscopy: measurement of dielectric constant, AC conductivity, impedance and inter conversion of various dielectric parameters; electrochemical techniques: cyclic voltammetry (case study of each technique) (case study of each technique)

#### **References:**

1. Evans, C., Brundle, R., & Wilson. S. (1992). Encyclopedia of Materials Characterization: Surfaces, Interfaces, Thin Films. Butterworth-Heinemann.
2. Leng, Y. (2013). Materials Characterization: Introduction to Microscopic and Spectroscopic Methods. Wiley-VCH.
3. Hummel, R.E. (2011). Electronic Properties of Materials. Springer.
4. Kaufmann, E.N. (2003). Characterization of Materials (Vol. 1 & 2). John Wiley and Sons.
5. Carter, C.B., & Williams, D.B. (2016). Transmission Electron Microscopy Diffraction, Imaging, and Spectrometry (Carter, Barry, Williams, David B. Eds.)