SYLLABUS FOR THE BATCH FROM YEAR 2025 TO 2026

FOR

Certificate/Diploma in Analytical Instrumentation

(Credit Based Evaluation and Grading System)

Semester: I-II

EXAMINATIONS: 2025-2026

The Certificate/Diploma Programme Offered:

- **Certificate Course in Analytical Instrumentation (6 Months duration)**
- **Diploma in Analytical Instrumentation (6+6 = 12 Months duration)**

Program Outcomes:

- **Fundamental Knowledge of Analytical Instrumentation –** Students will gain an understanding of the core principles and concepts of analytical instrumentation, enabling them to work effectively in laboratory environments.
- **Enhanced Technical Skills** – The program focuses on improving students' technical abilities in spectroscopic, microscopic, and magnetic resonance techniques.
- **Practical Experience** – Through hands-on assignments and lab work, students will develop problem-solving skills by working with real-world instruments.
- **Career Readiness & Employability** – The program prepares students for careers in research, material science, nanotechnology, and biomedical applications.

Department of Physics

In collaboration with

Directorate of Open & Distance Learning and Online Studies

GURU NANAK DEV UNIVERSITY
AMRITSAR

Certificate/Diploma in Analytical Instrumentation (SEMESTER SYSTEM) under Directorate of Open & Distance Learning, Guru Nanak Dev University, Amritsar

Eligibility:

- +2 in any stream or Equivalent.
- Any student pursuing Bachelor Degree, Master Degree, M.Phil, Ph.D. from GNDU campus or constituent, affiliated colleges

SEMESTER-I

Code	Subject	Marks			Credits
		Internal Assessment	End Term	Total	
ODAI111T	Optical Spectroscopy	30	70	100	4
ODAI12T	Diffraction Techniques	30	70	100	4
ODAI113T	Magnetic Properties and Characterization	30	70	100	4
ODAI114P	Lab- I	30	70	100	4
	Total Marks & Credits	**120**	**280**	**400**	**16**

SEMESTER-II

Code	Subject	Marks			Credits
		Internal Assessment	End Term	Total	
ODAI211T	Magnetic Resonance Techniques	30	70	100	4
ODAI212T	Electron Microscopy	30	70	100	4
ODAI213T	Surface Analysis Technique	30	70	100	4
ODAI214P	Lab- II	30	70	100	4
	Total Marks & Credits	**120**	**280**	**400**	**16**

Certificate/Diploma in Analytical Instrumentation (SEMESTER SYSTEM) under Directorate of Open & Distance Learning, Guru Nanak Dev University, Amritsar

Optical Spectroscopy

ODAI111T

(Semester – I)

Credit: 4

Time: 03 Hours **Max. Marks: 100 Marks**

Internal Assessment: 30 Marks

End Term: 70 Marks

Instructions for the Paper-Setter/examiner:

1. Question paper shall consist of **Four sections**.
2. Paper setter shall set **Eight questions** in all by selecting **Two questions** of equal marks from each section. However, a question may have sub-parts (not exceeding four sub-parts) and appropriate allocation of marks should be done for each sub-part.
3. Candidates shall attempt **Five questions** in all, by at least selecting **One question** from each section and the **5th question** may be attempted from any of the **Four sections**.
4. The question paper should be strictly according to the instructions mentioned above. In no case a question should be asked outside the syllabus.

Section – A

Introduction to UV-Visible Spectroscopy: Basic Principles and Electronic Transitions, Instrumentation and Data Analysis in UV-Vis Spectroscopy, Applications of UV-Visible Spectroscopy in Materials and Biological Sciences.
(2 Lectures)

Section – B

Principles of Raman Spectroscopy, Instrumentation and Enhancement Techniques, Applications of Raman Spectroscopy . (2 Lectures)

Section – C

Fundamentals of Infrared (IR) and FTIR Spectroscopy: FTIR Instrumentation and Data Analysis, Applications of FTIR Spectroscopy in Environmental, Chemical, and Biological Studies (3 Lectures)

Section - D

Principles of Fluorescence and Phosphorescence: Jablonski Diagram, Instrumentation and Measurement Techniques in Fluorescence Spectroscopy, Applications of Fluorescence Spectroscopy in Imaging, Sensing, and Nanotechnology. (3 Lectures)

References

1. Hollas, J. M. *Modern Spectroscopy*, Wiley, 2004.
2. Banwell, C. N., & McCash, E. M. *Fundamentals of Molecular Spectroscopy*, McGraw-Hill, 1994.
3. Long, D. A. *The Raman Effect: A Unified Treatment of the Theory of Raman Scattering by Molecules*, Wiley, 2002.
4. Smith, E., & Dent, G. *Modern Raman Spectroscopy: A Practical Approach*, Wiley, 2005.
5. Stuart, B. *Infrared Spectroscopy: Fundamentals and Applications*, Wiley, 2004.
6. Griffiths, P. R., & de Haseth, J. A. *Fourier Transform Infrared Spectrometry*, Wiley, 2007.
7. Lakowicz, J. R. *Principles of Fluorescence Spectroscopy*, Springer, 2006.
8. Valeur, B. *Molecular Fluorescence: Principles and Applications*, Wiley, 2001.

Certificate/Diploma in Analytical Instrumentation (SEMESTER SYSTEM) under Directorate of Open & Distance Learning, Guru Nanak Dev University, Amritsar

Diffraction Techniques

ODAI112T

(Semester – I)

Credit: 4

Time: 03 Hours | **Max. Marks: 100 Marks**

Internal Assessment: 30 Marks

End Term: 70 Marks

Instructions for the Paper-Setter/examiner:

1. Question paper shall consist of **Four sections**.
2. Paper setter shall set **Eight questions** in all by selecting **Two questions** of equal marks from each section. However, a question may have sub-parts (not exceeding four sub- parts) and appropriate allocation of marks should be done for each sub-part.
3. Candidates shall attempt **Five questions** in all, by at least selecting **One question** from each section and the **5th question** may be attempted from any of the **Four sections**.
4. The question paper should be strictly according to the instructions mentioned above. In no case a question should be asked outside the syllabus.

Section – A

Crystal structures and symmetry, Bravais lattices and unit cells, Miller indices and lattice planes.

(2 Lectures)

Section – B

X-ray generation, Bragg's law and diffraction, Powder X-ray Diffraction (PXRD) and its applications

(2 Lectures)

Section – C

Neutron Diffraction: Fundamentals, Methods, and Instrumentation, Applications of Neutron Diffraction

(3 Lectures)

Section – D

Pair Distribution Function (PDF) Analysis, Experimental Techniques for PDF Analysis, Applications of PDF in Materials Science (3 Lectures)

References

1. Cullity, B. D., & Stock, S. R. *Elements of X-ray Diffraction*, 3rd Edition, Pearson, 2001.
2. Azaroff, L. V. *Elements of X-ray Crystallography*, McGraw-Hill, 1968.
3. Hammond, C. *The Basics of Crystallography and Diffraction*, Oxford University Press, 2009.
4. Guinebretière, R. *X-ray Diffraction by Polycrystalline Materials*, ISTE-Wiley, 2007.
5. Young, R. A. *The Rietveld Method*, Oxford University Press, 1995.
6. Skoeld, K., & Price, D. L. *Neutron Scattering: Fundamentals*, Academic Press, 1986.
7. Egami, T., & Billinge, S. J. L. *Underneath the Bragg Peaks: Structural Analysis of Complex Materials*, Elsevier, 2012.
8. Keen, D. A., & Goodwin, A. L. *The Pair Distribution Function in Crystallography*, IUCrJ, 2015.

Certificate/Diploma in Analytical Instrumentation (SEMESTER SYSTEM) under Directorate of Open & Distance Learning, Guru Nanak Dev University, Amritsar

Magnetic Properties and Characterization

ODAI113T

(Semester – I)

Credit: 4

Time: 03 Hours **Max. Marks: 100 Marks**

Internal Assessment: 30 Marks

End Term: 70 Marks

Instructions for the Paper-Setter/examiner:

Question paper shall consist of **Four sections**.

Paper setter shall set **Eight questions** in all by selecting **Two questions** of equal marks from each section. However, a question may have sub-parts (not exceeding four sub- parts) and appropriate allocation of marks should be done for each sub-part.

Candidates shall attempt **Five questions** in all, by at least selecting **One question** from each section and the **5th question** may be attempted from any of the **Four sections**.

The question paper should be strictly according to the instructions mentioned above. In no case a question should be asked outside the syllabus.

Section – A

Fundamentals of Magnetism : Classification of Magnetic Materials: Paramagnetic, Diamagnetic, and Ferromagnetic Materials, Magnetic Domains and Hysteresis (2 Lectures)

Section – B

Magnetic Characterization Techniques : Vibrating Sample Magnetometry (VSM), Working Principle, Detection of Magnetic Moment, Calibration, and Measurement Sensitivity, Superconducting Quantum Interference Device (SQUID) Magnetometry (3 Lectures)

Section – C

Magnetic Properties and Dynamics: Magnetic Hysteresis Analysis, Hysteresis Loops: Coercivity, Remanence, and Saturation Magnetization, Soft vs. Hard Magnetic Materials, Temperature-Dependent Magnetic Properties, Curie and Néel temperature (3 lectures)

Section – D

Magnetization Relaxation and Damping Mechanisms: Time-Resolved Magnetization Dynamics and Applications in Data Storage, Ferromagnetic Resonance (FMR). (2 Lectures)

References

1. O'Handley, R. C. *Modern Magnetic Materials: Principles and Applications*, Wiley, 1999.
2. Cullity, B. D., & Graham, C. D. *Introduction to Magnetic Materials*, Wiley-IEEE Press, 2009.
3. Coey, J. M. D. *Magnetism and Magnetic Materials*, Cambridge University Press, 2010.
4. Blundell, S. *Magnetism in Condensed Matter*, Oxford University Press, 2001.
5. Chikazumi, S., & Graham, C. D. *Physics of Ferromagnetism*, Oxford University Press, 2009.
6. Aharoni, A. *Introduction to the Theory of Ferromagnetism*, Oxford University Press, 2000.
7. Stöhr, J., & Siegmann, H. C. *Magnetism: From Fundamentals to Nanoscale Dynamics*, Springer, 2006.
8. Maekawa, S. *Concepts in Spin Electronics*, Oxford University Press, 2006.

Certificate/Diploma in Analytical Instrumentation (SEMESTER SYSTEM) under Directorate of Open & Distance Learning, Guru Nanak Dev University, Amritsar

ODAI114P

Lab- 1

Credit: 4

(Semester – I)

Photoluminescence (PL) Studies

1. **Study of PL of a semiconductor material** – Measure the photoluminescence spectra of a direct and indirect bandgap semiconductor and analyze emission properties.
2. **PL characterization of rare-earth-doped materials** – Investigate emission spectra from phosphors and rare-earth-doped compounds.
3. **Effect of excitation wavelength on PL emission** – Study how different excitation wavelengths affect the PL response of a material.

Raman Spectroscopy Experiments

1. **Raman spectra of a bulk material** – Obtain the Raman spectrum of a standard material such as silicon or graphite and analyze vibrational modes.
2. **Comparative Raman analysis of bulk and nanomaterials** – Study the shift in Raman peaks for nanomaterials such as grapheme or carbon nanotubes.
3. **Polarization-dependent Raman spectroscopy** – Measure Raman spectra using different laser polarization directions and analyze anisotropy.

FTIR Spectroscopy Experiments

1 **FTIR spectra of a polymer material** – Measure the FTIR spectrum of a polymer and identify characteristic functional groups.

2 **Comparative FTIR analysis of organic compounds** – Study the spectral differences between alcohols, ketones, and carboxylic acids.

3 **FTIR spectroscopy of thin films and coatings** – Analyze chemical bonding in deposited thin films such as ZnO or TiO_2 .

Certificate/Diploma in Analytical Instrumentation (SEMESTER SYSTEM) under Directorate of Open & Distance Learning, Guru Nanak Dev University, Amritsar

ODAI211T

Magnetic Resonance Techniques

(Semester – II)

Credit: 4

Time: 03 Hours **Max. Marks: 100 Marks**

Internal Assessment: 30 Marks

End Term: 70 Marks

Instructions for the Paper-Setter/examiner:

1. Question paper shall consist of **Four sections**.
2. Paper setter shall set **Eight questions** in all by selecting **Two questions** of equal marks from each section. However, a question may have sub-parts (not exceeding four sub- parts) and appropriate allocation of marks should be done for each sub-part.
3. Candidates shall attempt **Five questions** in all, by at least selecting **One question** from each section and the **5th question** may be attempted from any of the **Four sections**.
4. The question paper should be strictly according to the instructions mentioned above. In no case a question should be asked outside the syllabus.

Section – A

Fundamentals of Magnetic Resonance: Introduction to Magnetic Resonance, Basic Principles and Spin Dynamics, Quantum Mechanical and Classical Description of Magnetic Resonance, Magnetic Resonance Instrumentation and Experimental Techniques (2 Lectures)

Section – B

Nuclear Magnetic Resonance (NMR) Spectroscopy: Principles of NMR: Chemical Shift, J-Coupling, and Relaxation Mechanisms, NMR Techniques: Pulse Sequences, Multi-Dimensional NMR, and Solid-State NMR, Applications of NMR in Chemistry, Biology, and Material Science (*2* Lectures)

Section – C

Electron Spin Resonance (ESR) & Electron Paramagnetic Resonance (EPR): Fundamentals of ESR/EPR: Principles, Zeeman Effect, and Hyperfine Interactions, Instrumentation and Advanced ESR/EPR Techniques. (3 Lectures)

Section – D

Ferromagnetic Resonance (FMR) and Magnetic Resonance Applications: Principles of Ferromagnetic Resonance (FMR) and Spin Dynamics in Magnetic Materials, Magnetic Resonance Imaging (MRI) and Functional MRI (fMRI) Techniques.

(3 Lectures)

References:

1. Principles of Nuclear Magnetic Resonance in One and Two Dimensions – Richard R. Ernst, G. Bodenhausen, and Alexander Wokaun
2. Understanding NMR Spectroscopy – James Keeler
3. Spin Dynamics: Basics of Nuclear Magnetic Resonance – Malcolm H. Levitt
4. High Resolution NMR Spectroscopy – Eberhard Breitmaier
5. Electron Paramagnetic Resonance: Elementary Theory and Practical Applications – John A. Weil, James R. Bolton
6. Principles of Electron Spin Resonance – Charles P. Poole, Horacio A. Farach
7. Magnetic Resonance of Carbonaceous Solids – R. Botto, Y. Sanada

Certificate/Diploma in Analytical Instrumentation (SEMESTER SYSTEM) under Directorate of Open & Distance Learning, Guru Nanak Dev University, Amritsar

ODAI212T

Electron Microscopy
(Semester – II)

Credit: 4

Time: 03 Hours **Max. Marks: 100 Marks**

Internal Assessment: 30 Marks

End Term: 70 Marks

Instructions for the Paper-Setter/examiner:

1. Question paper shall consist of **Four sections**.
2. Paper setter shall set **Eight questions** in all by selecting **Two questions** of equal marks from each section. However, a question may have sub-parts (not exceeding four sub- parts) and appropriate allocation of marks should be done for each sub-part.
3. Candidates shall attempt **Five questions** in all, by at least selecting **One question** from each section and the **5th question** may be attempted from any of the **Four sections**.
4. The question paper should be strictly according to the instructions mentioned above. In no case a question should be asked outside the syllabus.

Section – A

Fundamentals of Electron Microscopy & Surface Analysis Introduction to Electron Microscopy and Surface Analysis: Principles & Applications Electron-Sample Interactions: Elastic and Inelastic Scattering, Instrumentation & Detectors in Electron Microscopy and Spectroscopy. (2 Lectures)

Section – B

Scanning Electron Microscopy (SEM) & Energy-Dispersive X-ray Spectroscopy (EDS): Principles of Scanning Electron Microscopy (SEM): Electron Optics & Imaging, SEM Sample Preparation, Imaging Modes, and Resolution Limits, Energy-Dispersive X-ray Spectroscopy (EDS): Elemental Analysis in SEM. (2 Lectures)

Section – C

Transmission Electron Microscopy (TEM) & Electron Diffraction: Principles of Transmission Electron Microscopy (TEM): Electron Wave Propagation, High-Resolution TEM (HRTEM), Selected Area Electron Diffraction (SAED), and Imaging Modes, Sample Preparation for TEM. (3 Lectures)

Section – D

Surface Analysis Techniques : Low-Energy Electron Diffraction (LEED) and Reflection High-Energy Electron Diffraction (RHEED): Surface Structure Analysis, (3 Lectures)

References:

1. "Scanning Electron Microscopy and X-ray Microanalysis" – Joseph Goldstein, Dale E. Newbury, David C. Joy
2. "Transmission Electron Microscopy: A Textbook for Materials Science" – David B. Williams, C. Barry Carter
3. "Electron Microscopy: Principles and Fundamentals" – Peter W. Hawkes, John C.H. Spence
4. "X-ray Photoelectron Spectroscopy: An Introduction" – Paul van der Heide
5. "Low Energy Electron Diffraction: Experiment, Theory and Surface Structure Determination" – Michel A. Van Hove, Wolfgang H. Weinberg
6. "Reflection High-Energy Electron Diffraction and Reflection Electron Imaging of Surfaces" – Akihiko Ichimiya, Philip I. Cohen
7. "Surface Analysis – The Principal Techniques" – John C. Vickerman, Ian S. Gilmore

Certificate/Diploma in Analytical Instrumentation (SEMESTER SYSTEM) under Directorate of Open & Distance Learning, Guru Nanak Dev University, Amritsar

ODAI213T

Surface Analysis Technique

(Semester – II)

Credit: 4

Time: 03 Hours **Max. Marks: 100 Marks**

Internal Assessment: 30 Marks

End Term: 70 Marks

Instructions for the Paper-Setter/examiner:

1. Question paper shall consist of **Four sections**.
2. Paper setter shall set **Eight questions** in all by selecting **Two questions** of equal marks from each section. However, a question may have sub-parts (not exceeding four sub- parts) and appropriate allocation of marks should be done for each sub-part.
3. Candidates shall attempt **Five questions** in all, by at least selecting **One question** from each section and the **5th question** may be attempted from any of the **Four sections**.
4. The question paper should be strictly according to the instructions mentioned above. In no case a question should be asked outside the syllabus.

Section – A

• Principles of Quantum Tunneling and STM Working Mechanism: Construction and Components of an STM (Piezoelectric Positioning, Feedback Loop). (2 Lectures)

Section – B

Atomic and Molecular Manipulation with STM: Probing Electronic and Quantum States in 2D Materials and Superconductors. (3 Lectures)

Section – C

Principles of AFM: van der Waals Forces, Contact, and Non-Contact Modes: AFM Probe and Cantilever Mechanics: Tip-Sample Interaction Forces, Scanning and Imaging Modes: Tapping, Contact, and Force Modulation Modes. (3 Lectures)

Section – D

AFM for Mechanical and Electrical Property Characterization, X-ray photoelectron spectroscopy (XPS): Principle and Applications. (2 lectures)

References

1. Binnig, G., & Rohrer, H. *Scanning Tunneling Microscopy*, Springer, 1992.
2. Chen, C. J. *Introduction to Scanning Tunneling Microscopy*, Oxford University Press, 2008.
3. Wiesendanger, R. *Scanning Probe Microscopy and Spectroscopy: Methods and Applications*, Cambridge University Press, 1994.
4. Giessibl, F. J. *Atomic Force Microscopy: From Basic Principles to Advanced Applications*, Review of Modern Physics, 2003.
5. Meyer, E., Hug, H. J., & Bennewitz, R. *Scanning Probe Microscopy: The Lab on a Tip*, Springer, 2004.
6. Garcia, R. *Amplitude Modulation Atomic Force Microscopy*, Wiley-VCH, 2010.

Certificate/Diploma in Analytical Instrumentation (SEMESTER SYSTEM) under Directorate of Open & Distance Learning, Guru Nanak Dev University, Amritsar

ODAI214P

Lab-2

(Semester – II) **Credit: 4**

Time: 03 Hours **Max. Marks: 100 Marks**

PRACTICAL 1: Measurement of XRD Pattern and Analysis: To record the X-ray diffraction (XRD) pattern of a material and analyze its crystal structure, phase composition, and crystallite size.

PRACTICAL 2: Analysis of Topography and Elemental Composition Using FESEM**:** To study the surface morphology and elemental composition of a material using Field Emission Scanning Electron Microscopy (FESEM) coupled with Energy Dispersive X-ray Spectroscopy (EDX).

PRACTICAL 3: Analysis of Particle Size and SAED Pattern of a Sample: To determine the particle size and study the Selected Area Electron Diffraction (SAED) pattern using High-Resolution Transmission Electron Microscopy (HR-TEM).

PRACTICAL 4: Analysis of Magnetic Properties of Materials Using VSM: To measure the magnetic properties of a material, including hysteresis loop, coercivity, and saturation magnetization, using a Vibrating Sample Magnetometer (VSM).

PRACTICAL 5: Study of UV-VIS DRS of a Material: To measure the UV-VIS Diffuse Reflectance Spectroscopy (DRS) of a material and determine its bandgap using the Tauc plot method.