Course Requisites (if applicable)

Pre-requisites	
Co-requisites	
Pre-requisite to	
Mutually exclusive to	
Replacement course to	
Remarks (if any)	

Course Aims

This course aims to acquaint you with many of the tools and techniques currently used by experimental condensed-matter physicists. Upon completion of the course, you should understand and feel comfortable with the experimental procedures presented in many condensed-matter publications, even if you may not be familiar with the materials or systems under investigation. You will also have produced a substantial literature review on a technique of your choice. Through this course, you will learn how the development of materials, measurement techniques, and theoretical insights are employed to explore the impact of quantum architecture of materials on new device responses. This builds an understanding of how experimental methods work and apply to real-world problems. It also improves your comprehension of how the data obtained can be analyzed to yield scientific discoveries. It builds a path towards the development of customized tools for the characterization of samples and devices in parameter spaces inaccessible by commercial instruments.

Course's Intended Learning Outcomes (ILOs)

Upon the successful completion of this course, you (student) would be able to:

ILO 1	Explain the experimental procedures presented in the majority of condensed-matter publications.
ILO 2	Develop a substantial literature review on a technique of their choice.
ILO 3	Interact with experts in the fields covered by the course.
ILO 4	Bridge theory and experiments.

Course Content

Following an introduction to the necessary theory, you will be introduced to a wide range of cutting-edge experimental techniques:

- Cryogenic and high magnetic field environments
- Electrical transport: resistivity, Hall effect, de Haas van Alphen oscillations,
- Thermal transport: including Nernst effect, thermopower, conductivity
- Magnetic characterization: AC susceptibility, DC and vibrating sample magnetometry, SQUID detectors, torque magnetometry
- Bulk thermodynamic techniques: heat capacity, magnetocaloric effect
- Synchrotron radiation: X-ray diffraction, X-ray magnetic circular dichroism, (resonant) inelastic X-ray scattering
- Neutron scattering, muon spin relaxation
- Nuclear magnetic/quadrupole resonance, Knight shift
- X-ray and angle-resolved photo-emission spectroscopy
- Tunnelling techniques: planar junctions, break-junctions, point contact/Andreev spectroscopy
- Local probes: scanning tunnelling spectroscopy, atomic and magnetic force microscopy, scanning SQUIDs.

Reading and References (if applicable)

Planned Schedule

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
1	Introduction to Condensed Matter	1		In-person	Lecture and Class discussion
2	Cooling Methods, Liquefiers, Cryostats and Materials for Cryogenic Engineering	1, 2		In-person	Lecture and Class discussion
3	High Field Magnets and Measurements in High Magnetic Fields	1		In-person	Lecture and Class discussion
4	Materials for Extreme Environments, Noise Sources and cancellation	1, 2		In-person	Lecture and Class discussion
5	Basic Electronic properties	1, 2, 3, 4		In-person	Lecture and Class discussion
6	Basic Magnetic Properties	1, 2, 3, 4		In-person	Lecture and Class discussion
7	Electrical Transport Measurements	1, 2, 3, 4		In-person	Lecture and Class discussion
8	Thermal Transport Measurements	1, 2, 3, 4		In-person	Lecture and Class discussion
9	Heat Capacity Measurements	1, 2, 3, 4		In-person	Lecture and Class discussion

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
10	Magnetometry Measurements	1, 2, 3, 4		In-person	Lecture and Class discussion
11	Neutron Scattering and Muon Spin Spectroscopy Measurements	1, 2, 3, 4		In-person	Lecture and Class discussion
12	Local Probe Microscopy Techniques and Measurements	1, 2, 3, 4		In-person	Lecture and Class discussion
13	Local Probe Microscopy Techniques and Measurements	1, 2, 3, 4		In-person	Lecture and Class discussion

Learning and Teaching Approach

Approach	How does this approach support you in achieving the learning outcomes?
Lecture	This course seeks to illustrate and explain the experimental methods available to contemporary solid-state physicists. Further to the lecture, group projects, student presentations, and in-class discussions are examples of ways this course promotes active learning.
Student-teacher Debates	This course offers a path for dialogue between theorists and experimentalists engaging several experimental methods.
Project Work	You will analyse an experimental setup for in-class discussion.
Lab Visits	For some of the methods, you will visit onsite labs to study home-built apparatus, often viewed only in literature.
Group Discussions	You will benefit from a dynamic classroom setting.
Presentations	You and your classmates will present as a team a topic of the lecture course.
Technology-Enhanced Learning (TEL)	Videos and graphics will be used for this course.

Assessment Structure

Assessment Components (includes both continuous and summative assessment)

No.	Component	ILO	Related PLO or Accreditation	Weightage	Team/Individual	Rubrics	Level of Understanding
1	Continuous Assessment (CA): Report/Case study(Report)	1, 2, 3, 4		60	Individual	Analytic	Relational
2	Continuous Assessment (CA): Oral Test(Oral Presentation)	1, 2, 3, 4		20	Individual	Analytic	Multistructural
3	Continuous Assessment (CA): Class Participation(Class participation)	1, 2, 3, 4		20	Individual	Holistic	Multistructural

Description of Assessment Components (if applicable)

CA1: You will write a report on existing literature to discuss a specific technique of your preference that was covered in the course.

CA2: You will do an oral presentation in front of class on the written report and there will be a Q&A session.

CA3: You will be encouraged to be an active participant in the lectures. This includes analyzing a topic that was covered in the course. The topic will be assigned to you by the lecturer, and you will be given one week to do the analysis.

Formative Feedback

You will receive feedback through verbal and/or written responses to your level of engagement in the class, presentation, collaboration with other members of the class, and your final report.

NTU Graduate Attributes/Competency Mapping

This course intends to develop the following graduate attributes and competencies (maximum 5 most relevant)

Attributes/Competency	Level
Creative Thinking	Advanced
Curiosity	Advanced
Problem Solving	Advanced
Project Management	Advanced
Critical Thinking	Advanced

Course Policy

Policy (Academic Integrity)

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values. As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the academic integrity website for more information. On the use of technological tools (such as Generative AI tools), different courses / assignments have different intended learning outcomes. Students should refer to the specific assignment instructions on their use and requirements and/or consult your instructors on how you can use these tools to help your learning. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Policy (General)

You are expected to complete all assigned readings, activities, assignments, attend all classes punctually and complete all scheduled assignments by due dates. You are expected to take responsibility to follow up with assignments and course related announcements. You are expected to participate in all project critiques, class discussions and activities.

Policy (Absenteeism)

In-class activities make up a significant portion of your course grade. Absence from class without a valid reason will affect your participation grade. Valid reasons include falling sick supported by a medical certificate and participation in NTU's approved activities supported by an excuse letter from the relevant bodies. There will be no make-up opportunities for in-class activities.

Policy (Others, if applicable)

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