Reg No: FYAD07/20252

Faculty of Health, Science and Technology
Physics

Syllabus

Scanning Probe Microscopy

Course Code:	FYAD07
Course Title:	Scanning Probe Microscopy *Svepprobmikroskopi*
Credits:	7.5
Degree Level:	Master's level
Progressive Specialisation:	Second cycle, has only first-cycle course/s as entry requirements (A1N)

Major Field of Study:
FYA (Physics)

Course Approval
The syllabus was approved by the Faculty of Health, Science and Technology 2025-02-20, and is valid from the Autumn semester 2025 at Karlstad University.

Prerequisites
Mathematics, 45 ECTS credits, and Physics, 60 ECTS credits, including the courses Quantum Physics I, 7.5 ECTS credits, and Solid State Physics, 7.5 ECTS credits, and upper secondary level English 6, or equivalent

Learning Outcomes
Upon completion of the course, students should be able to:
- give an account of the basic technical conditions for scanning probe microscopy (SPM)
- give an account of the quantum mechanical theory for tunneling in scanning tunneling microscopy (STM)
- describe in depth different measurement methods in STM, including tunneling spectroscopy, as well as data analysis and artifacts in STM experiments
- give an account of the physical basis for scanning force microscopy (SFM, also commonly denoted AFM), including the different forces that are relevant in a SFM measurement.

- describe in depth different SFM measurement methods, and their relation to the different forces that affect the measurements, in particular the three most common methods: contact mode, so-called "tapping" mode, and non-contact mode, as well as advanced analysis and artifacts in SFM measurements
- give an account of different types of atom and nanostructure manipulation on surfaces with STM and SFM
- give a summary account of other SPM techniques and their use
- independently perform measurements with a SFM instrument

Content
The course treats modern scanning probe microscopy (SPM) techniques, primarily scanning tunneling microscopy (STM) and scanning force microscopy (SFM), regarding both theory and practice. The physical foundations and theory of STM and SFM are treated thoroughly, as well as basic measurement modes. The course also covers advanced measurement and analysis methods, artifacts, as well as manipulation with STM and SFM. Several examples of the use of SPM techniques in current research and industry are given. Finally, an overview of other SPM techniques is given. The course includes laboratory sessions with mandatory participation.

Course content:
Fundamental experimental and technical aspects of scanning probe microscopy.
STM: STM theory, Measurements modes, resolution limits, tunneling spectroscopy, low-temperature STM, inelastic tunneling, spin-polarised STM. Advanced analysis, electronic and atomic effects, artifacts, manipulation on atomic level.
SFM: Instrumental aspects, including cantilevers deflection sensors and tip preparation. Relevant forces for SFM. Measurement modes: static and dynamic methods, contact, "tapping" and non-contact methods. Magnetic force measurements. Spectroscopy, advanced analysis, artifacts in SFM. Overview of manipulation and lithography with SFM.
Overview of other SPM techniques, including scanning near-field optical microscopy (SNOM).

Reading List
See separate document.

Examination
Assessment is based on mandatory presentations in seminars, hand-in assignments, a written exam, and written and oral presentations of a specialisation project. A Pass degree is required for the mandatory laboratory component.

If students have a decision from Karlstad University entitling them to Targeted Study Support due to a documented disability, the examiner has the right to give such students an adapted examination or to examine them in a different manner.

Grades
One of the grades 5 (Pass with Distinction), 4 (Pass with Some Distinction), 3 (Pass), or U (Fail) is awarded in the examination of the course.

Quality Assurance
Follow-up relating to learning conditions and goal-fulfilment takes place both during and upon completion of the course in order to ensure continuous improvement. Course evaluation is partly based on student views and experiences obtained in accordance with current regulations and partly on other data and documentation. Students will be informed of the result of the evaluation and of any measures to be taken.

Course Certificate

A course certificate will be provided upon request.

Additional information
The local regulations for studies at the Bachelor and Master levels at Karlstad University stipulate the obligations and rights of students and staff.