Section 1

Syllabus

Course Information

Description

Physics 586 is an introductory course to Transmission Electron Microscopy. Students are expected to learn to use the Transmission Electron Microscope (TEM) and several associated analytical tools for the characterization of material samples. The students are exposed to basic theoretical aspects of the TEM, such as bright field imaging (BF), Selected Area Electron Diffraction (SAED), Dark Field Imaging (DF). Scanning Transmission Electron Microscopy (STEM) and various Analytical Electron Microscopy (AEM) techniques will also be reviewed (e.g. X-ray energy dispersive spectrometry (XEDS), Converged Beam Electron Diffraction (CBED), Electron Energy-Loss Spectroscopy (EELS), or others).

Prerequisites

Permission-to-add code can be obtained in person by contacting Dr. Felipe Rivera.

- Due to the limited space in the course, a small interview will be requested to discuss the purpose and scope of the class, as well as the student's motivation for taking the course.

Recommended (but **not** required) courses:

- Electricity and Magnetism (PHSCS220 or higher)
- Modern Physics (PHSCS222 or higher)
- Solid State Physics (PHSCS281 or 581)
- Experimental Methods in Physics (PHSCS145 or similar)
- Scanning Electron Microscopy (PHSCS588)

There is a basic TEM training course available throughout the year. This basic training for the TEM consists of several "hands-on" sessions on our transmission electron microscope with Paul Minson in the underground lab facility of the Eyring Science center (ESC). This training will be covered as part of the course.

Instructors' Contact Information

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Hrs:	By appointment	By appointment

Materials

Required Text:Transmission Electron Microscopy (2009)by Williams,

There is a companion book, with advanced TEM techniques, published in 2016. While this is a nice reference book, its contents are beyond the scope of this course. Nonetheless, this book is also available as a download through the Harold B. Lee Library.

Learning Outcomes

Purpose of the Course

The purpose of this course is to teach students basic imaging and analytical techniques of the transmission electron microscopy (TEM) in both parallel beam imaging and in probe scanning mode (S/TEM).

Proficiency in basic S/TEM operation

Lab-based: The student will show proficiency in S/TEM operation. Some essential and advanced skills comprise:

1. Practical knowledge of the instrument and the purpose of its different components
2. Instrument alignments for various techniques
3. Sample loading and unloading
4. Proper selection of imaging conditions and alignments for the specimen
5. Adequate image acquisition for various imaging modes
   (a) Bright field imaging
   (b) Dark field imaging
   (c) Selected Area Electron Diffraction
   (d) Scanning Transmission Electron Microscopy
6. Verification of tool calibrations
7. X-ray Energy-Dispersive Spectroscopy (XEDS)

Overall knowledge on S/TEM analytical techniques

Class-based: The student will be aware of additional imaging and analytical techniques, for example:

- Convergent Beam Electron Diffraction (CBED)
- X-ray Energy-Dispersive Spectroscopy (XEDS)
- Electron Energy-Loss Spectroscopy (EELS)
- Energy Filtered Transmission Electron Microscopy (EFTEM)
- others

Grading Policy

In addition to the coursework and assignments given during the course lectures, there will be a significant portion of time dedicated to hands-on equipment utilization during the lab sections. The lab sections will be conducted in the transmission electron microscope located in the underground lab facility of the Eyring Science Center. It is expected that the students will learn to perform basic and more advanced imaging and analytical techniques on this instrument.

Students will be required to attend lectures and labs, participate in classroom discussion and complete lab work, lab write-ups, reading questions, midterms, and final exams.

- Reading Assignments = 14%
- Lab Reports = 14%
- Hands-On Lab Midterms = 24% (Cumulative)
  - Midterm 1, TEM Imaging
  - Midterm 2, STEM Imaging and Analysis
- Midterm Written Exam(s) = 24% (Cumulative)
  - Midterm 1, TEM Imaging
  - Midterm 2, STEM Imaging and Analysis
- Final Written Exam (Cumulative) = 20%
- Participation/Attendance = 4%

Attendance Policy

Full attendance is expected for lectures in order to motivate in-class discussion.

Equipment time will be blocked off for the duration of the semester for each section of the course. When needed, additional time may be scheduled by sending a request to Paul so that the microscope time can be billed to the course.

Microscope availability will be allocated in a first-come-first-served basis.

Grading Scale

Grades	Percent
A	93%
A-	90%
B+	87%
B	83%
B-	80%
C+	77%
C	73%
C-	70%
D+	67%
D	63%
D-	60%
E	0%

Teaching Philosophy

I consider myself, this lab, and this course as resources in your pursuit of education. As such:

- I'd place the onus on me to:
  - not compromise the content this course covers such that you may attain the skills you will need to succeed outside of academia
  - be well-prepared to provide the information you need or at least point you in the right direction to find the answer
  - ensure the lab resources are adequate to meet your needs
  - add enough flexibility to the course to build on your interests
  - share of my experiences that you may benefit from them
- I'd place the onus on you to:
  - be proactive in seeking the time to utilize the tool
  - take ownership of the material for this course
  - seek out help when needed

In my opinion, transmission electron microscopy is a powerful a scientific tool with high reproducibility of results. Nonetheless, the skills required are refined from consistent practice at the tool, thus I recommend additional practice as needed.