# Course Syllabus for Engineering ENGN 2991: Characterizing Nanomaterial Structure

*Spring 2018, Brown University*


**Instructors:** Professor Vicki Colvin

Geochem 225

**Vicki_Colvin@brown.edu**


**Canvas site:** TBA

**Lecture:** MW 9-9:50 am, Friday discussion (typically the same times)

**Office Hours:** Vicki Colvin: by appointment on google calendar[1] - see link below or email.

**Course Description:** Characterizing nanomaterial structure is a challenge as it requires multiple methods drawn from disciplines ranging from materials engineering to colloidal chemistry. This class will describe these analysis tools and illustrate their application to nanostructures, specifically those prepared via solution-phase chemistry. Material will be structured into four modules on (a) dimensions and morphology (b) internal structure (c) surface chemistry and (d) molecular analysis. Case studies will be used to illustrate the best, and sometimes worst, practices for analyzing and reporting characterization data; students will in their final project explore tools for characterizing a property of nanomaterials (e.g. optical, magnetic, chemical, biological). The breadth of this course provides students an opportunity to compare different methodologies as well as select not just sufficient, but appropriate, tools for nanomaterial characterization.

After this class students will be able to:

(A) Describe a range of methods for nanomaterial characterization that draw from materials engineering, physical biology, molecular and colloidal chemistry.

(B) Grasp the underlying theory of common characterization methods and how these principles may impact application of the methods.

(C) Select an appropriate set of tools for addressing problems in nanomaterial characterization.

(D) Critically evaluate how analysis tools are applied to nanomaterials in the modern research literature and suggest methods for improving data analysis and presentation.

**ABET Student Outcomes:** This course addresses the following ABET Student Outcomes: (a) an ability to apply knowledge of mathematics, science, and engineering; (b) an ability to design and conduct experiments, as well as to analyze and interpret data; (f) an understanding of professional and ethical responsibility; (g) an ability to communicate effectively; (i) a recognition of the need for, and an ability to engage in life-long learning; (j) a knowledge of contemporary issues.

**Grading:** ENGN 2991 is a letter graded class. A total of 1000 points will be awarded:

| | |
|---|---|
| Six problem sets (lowest dropped, 50 points each): | 250 |
| Three Module exams (100 points each): | 300 |
| Eight discussion quizzes (25 points each): | 200 |
| Final project [may be oral or written depending on class size]: | 200 |
| Class participation (based on attendance/discussion/discretion of instructor): | 50 |
| **TOTAL:** | **1000** |

[1] https://calendar.google.com/calendar/selfsched?sstoken=UUdLRnpLb0VCNkRXfGRlZmF1bHR8MDNkOTdhMmM0ZmY3YTkyZjgxMTY5NzNiNDc4ZmVlYzU

Consistent with Brown University policy, only full letter grades will be offered:

| | |
|---|---|
| *To receive an "A" in this class you must have* | > 880 points |
| *To receive a "B" in this class you must have* | >760 points |
| *To receive a "C" in this class you must have* | >640 points |
| *To receive a "S" (e.g. a pass if declared a S/NC)* | >550 points* |

The professors reserve the right to lower the cut-offs for the letter grades listed above but will not raise them. *Any student declared S/NC must complete all modular exams and the final project even if their points scored exceeds 550 points.

**Course requirements:** This is a graduate level course for chemistry and engineering graduate students. Students should have completed a basic introductory course in nanotechnology or nanomaterials. Lectures will assume a working familiarity with common size-dependent properties in both 2D and 3D nanoscale materials. Engineering graduate students will have strong preparation for the microscopy and solid state structure elements of the class, but will need to refer to background materials for the colloidal and molecular modules. Conversely chemistry graduate students will be well prepared for the latter two modules, but may have to rely on provided background reading in materials engineering relevant to the first two modules. All students should have had organic chemistry or its equivalent.

**Course activities:**

*Problem sets (six):* These problem sets are designed to build student's understanding of the characterization methodologies and their application in the current research literature. Students may be asked to critique one or more research papers, work problems relevant to the method under evaluation, or analyze datasets using common analysis tools such as ImageJ.

*On-line quizzes and short answers (eight):* Fridays will be reserved for discussion and critique of papers from the nanoscience literature. On-line quizzes provided on Canvas on the relevant reading must be completed prior to attendance.

*In-class Exams (three):* Multiple choice and short answer exams will examine a student's familiarity with the vocabulary, theory and application of nanomaterial characterization tools.

*Final project:* While this class centers on material structure, the final project will allow students to explore a nanomaterial class and property – electronic, magnetic, optical, catalytic.

**Credit Hour Expectations:** 14 weeks * (2.5 hours class + 10 hours reading/writing or problem set) + 3 exams * (8 hours of study) + 40 hours final project **= 239 total hours**

**Policies regarding exams and assignments:** No late problem sets will be accepted. The lowest grade on these assignments will be dropped to allow for the inevitable illnesses and unexpected emergencies that can arise. <u>Please do not request an extension on a weekly homework for any reason.</u> In the case of exams, students who identify scheduling conflicts by the second week of class may be offered the chance to complete assignments and exams early. <u>No late exams are given under any circumstances.</u> Students are expected to check their point totals on the course website; if there is a data entry error students should ask for a correction within three weeks of the assignment due date.

**Academic Honesty:** Please review http://www.brown.edu/academics/college/degree/policies/academic---code. All work submitted for grading should reflect you own individual work. Discussions with other students or the instructors are allowed, but copying is not acceptable. Sharing, copying, or obtaining information from unauthorized sources during any of the assessment activities in this class are violations of the code. No electronics, books or notes are allowed during the in-class exams. Violations will result in NC in the course and notification to the Dean of the College. Misunderstanding of the Academic Code is not accepted as an excuse for dishonest work.

**Accommodations:** If you need an accommodation please submit documentation from student and employee accessibility services (SEAS) to Professor Colvin in the first few weeks of the semester. You may either do this through office hours or email her for an appointment.

**Classroom Participation and Expectations:** Students are expected to attend lecture and fully participate in class discussions. Friday discussions will be entirely graded on participation; brief on-line quizzes will precede these discussion times and are expected to be completed before the start of class.

**Required Textbook/Materials:** All students should have access to Microsoft office products, a laptop computer that is web connected, and MatLab. Data analysis programs, such as ImageJ, will be used in this class. Lecture notes will be distributed and reading material for every week will be provided on the course website. It is vital that students regularly check the course website for announcements, reading material and assignment information.

**ENGN 2991: Characterizing Nanomaterial Structure**

| *Lecture #* | *Day* | *Date* | *Module* | *Title* |
|---|---|---|---|---|
| 1 | Wednesday | 24-Jan | **Microscopy** | Introduction to class and to microscopy |
| 2 | Friday | 26-Jan | | Light microscopies and nanomaterials |
| 3 | Monday | 29-Jan | | Electron microscopy (theory) |
| 4 | Wednesday | 31-Jan | | Transmission electron microscopy |
| 5 | Friday | 2-Feb | | *Discussion: TEM and sample preparation* |
| 6 | Monday | 5-Feb | | Scanning electron microscopy |
| 7 | Wednesday | 7-Feb | | Force microscopies |
| 8 | Friday | 9-Feb | | *Discussion: Matching material to microscopy* |
| 9 | Monday | 12-Feb | | Reporting dimensions: Statistics and sampling |
| 10 | Wednesday | 14-Feb | | Discussion: Critique of sampling methods |
| 11 | Friday | 16-Feb | | *MODULE TEST (1)* |
| | Monday | 19-Feb | | |
| 12 | Wednesday | 21-Feb | **Solid state structure** | Introduction to diffraction |
| 13 | Friday | 23-Feb | | Miller indices and surface structure |
| 14 | Monday | 26-Feb | | Phase identification 1: a typical powder pattern |
| 15 | Wednesday | 28-Feb | | Solid state vibrational: Raman and IR |
| 16 | Friday | 2-Mar | | *Discussion: XRD peak widths and NM dimensions* |
| 17 | Monday | 5-Mar | | EXAFS and XANES: synchrotron methods |
| 18 | Wednesday | 7-Mar | | X-ray photoemission spectroscopy |
| 19 | Friday | 9-Mar | | *Discussion: Surface structure of NM* |
| 20 | Monday | 12-Mar | | Phase identification 2: Rietvald analysis |
| 21 | Wednesday | 14-Mar | | Defect identification |
| 22 | Friday | 16-Mar | | *MODULE TEST (2)* |
| 23 | Monday | 19-Mar | **Colloidal Methods** | Introduction to colloidal science |
| 24 | Wednesday | 21-Mar | | Light scattering, hydrodynamic diameter |
| 25 | Friday | 23-Mar | | *Discussion: DLS as a measure of NM dimension* |
| | Monday | 26-Mar | | |
| | Wednesday | 28-Mar | | |
| | Friday | 30-Mar | | |
| 26 | Monday | 2-Apr | | Zeta potential and surface charge |
| 27 | Wednesday | 4-Apr | | Sedimentation of nanoparticles |
| 28 | Friday | 6-Apr | | *Discussion: Detecting aggregation in NM samples* |
| 29 | Monday | 9-Apr | | Small-angle x-ray scattering |
| 30 | Wednesday | 11-Apr | | *Discussion: Hydrodynamic diameter - best method* |
| 31 | Friday | 13-Apr | | *MODULE TEST (3)* |
| 32 | Monday | 16-Apr | **Molecular Composition** | NMR - The Basics |
| 33 | Wednesday | 18-Apr | | Examples of NMR applied to NM |
| 34 | Friday | 20-Apr | | *Discussion: NMR for surface structure of coatings* |
| 35 | Monday | 23-Apr | | Vibrational spectroscopies |
| 36 | Wednesday | 25-Apr | | Mass spectrometry and NM |
| 37 | Friday | 27-Apr | | *Discussion: Detecting molecular impurities* |

Final Paper (1500 words) due 05/08