Department of Materials Science and Engineering and
Department of Mechanical Engineering
University of Maryland
College Park, MD

ENMA 430: Quantum Size Effects in Nanomaterials

Instructor: **Dr. Oded Rabin**
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Class hours: MWF 10:00-10:50 (JMP 2022) **Office hours: MF 11:00-11:45**

Course announcements, documents, etc. will be posted to this website. Please check it often.

Description: This undergraduate course surveys materials systems whose properties are governed by quantum mechanical phenomena. The time-independent Schrodinger equation is employed to relate materials structure and size to their electrical, thermal and optical properties. Integrated throughout the course are (1) surveys of approaches for the synthesis of the nanoscale structures (nanoparticles, nanowires, nanotubes, etc.), (2) computer-based exercises, (3) review of influential articles from the scientific literature, and (4) in-depth analysis of devices and applications that utilize the quantum materials.

Prerequisites: Basic knowledge in quantum mechanics and solid state physics (e.g. ENMA460). Also recommended sophomore physical or organic chemistry (e.g. CHEM481 or CHEM231).

Course Objectives: The course objective is to familiarize the student with the scientific concepts behind nanoscience and quantum materials, and enable them to critically approach the scientific literature in the area and understand it. The focus will be on the relationship between structure, physical properties, and applications.

Course Goals to Meet ABET 2005 Criteria:

(a) Understand the size-dependence of properties of nanoscale structures.
(b) Understand the implications of the quantized nature of electrons and spins in materials.
(c) Learn to summarize and present information from current scientific papers.

Student Outcomes covered by the Course:

ABET Outcome (a): Ability to Apply Knowledge of Math, Engineering and Science.
ABET Outcome (c): Ability to Design a System, Component or Process to Meet Desired Needs.
ABET Outcome (g): Ability to Communicate Effectively
ABET Outcome (h): Broad Education to Understand the Impact of Engineering Solutions in a Global and Societal Context
ABET Outcome (j): Knowledge of Contemporary Issues

Tentative topics:

Introduction
Quantum Mechanics
    Electronic States and Band Structures in 0D, 1D, 2D, 3D
Nanoparticles: Quantum Dots
    Electronic Structure
    Synthetic Approaches, Stability
    Nucleation, Growth and Ripening
Nanoparticles: Plasmonics
Nanoparticle: Applications: Biomarkers, Imaging, Sensing, Hyperthermia
Carbon Nanotubes
    Nomenclature
    Electronic Structure
    CNT circuitry
Graphene
    Massless electrons?
    Graphene analogs, Artificial 2D stacks
N-V Diamond
    Spin states, Spin manipulation
    Applications: B-field sensors, Materials for quantum computers

Supplementary Text:

(a) **Introduction to Nanoscience and Nanotechnology: A Workbook** by Masaru Kuno (Univ. NotreDame) v.2004 [download from web]
(b) **Nanochemistry: A Chemical Approach to Nanomaterials** by Geoffrey Ozin and Andre Arsenault, RCS Publishing
(c) **Physical Properties of Carbon Nanotubes** by R Saito, G Dresselhaus & M S Dresselhaus, Imperial College Press
(d) Reviews from scientific journals

Grading:

2 Mid Term Exams (38%)
Homework (15%)
Term paper (35%)
Participation & Quizzes (10%)
Final Exam (2%)

- Mid Term Exams : EITHER during class time, 50min OR take home, >24hrs.
- Quizzes : during class time, 15min, maybe unannounced.
- Topic of term paper is chosen by student with approval of instructor.
- The Term Paper is due by the time of class on **Monday, May 1**.
- Final is scheduled for **Tuesday, May 16, 8:00-10:00am**.
- Homework is due 1 week from the date it was issued.
- Homework and Participation require completion of reading assignments.

Homeworks

Homework is an important component to accomplish the educational mission of the course. It is aimed to assist the student in identifying his/her strengths and weaknesses, as well as practicing math and computational skills that cannot otherwise be effectively incorporated in the curriculum.

Unless otherwise stated on the HW, students are expected to work on their homework individually and independently. Similar homeworks will be graded 0 – strictly enforced regardless of which is the original source and which is the follower!

Homework questions are, to large extent, original to the instructor. Sharing them or posting them online, as a whole or in part, without permission is a copyright violation. You should not need to look for homework solutions on the web. Internet use should be restricted to study material, journal articles, and reference data. Wikipedia should never be used for HW completion.

You will be given approximately 7 days to complete the HW. Early HW submissions are allowed, late submissions are not allowed.

Homework may be submitted electronically via CANVAS (if typed or as high-quality images) or on paper in class. Hand-written submissions have to be in single-column format, single sided and stapled. Plots and graphs must be made with a computer. Sketches and tables can be made by hand.

The instructor reserves the right to refuse hand-written and image submissions from specific students, if the clarity of the homework is below standard.

The instructor will use the UMD guide for course policies for undergraduate courses (http://www.ugst.umd.edu/courserelatedpolicies.html) to address requests for special accommodations and student grievances in a consistent manner.

Guidelines on how to "Study together – Complete homework individually"

- Separate group study sessions and doing homework, in time and in location. You may discuss the homework with follow students, but submissions must not include material written down while consulting with others. At the end of the study session, discard all written materials so you are not tempted to copy from your notes to the submission. If you understood your fellow student's strategy and explanation, you should be able to recreate them independently in private.
- Support your answers with motivation and explanations in your own words.
- You should not ask others to review your submissions. You should not show your submissions to others.

Attendance: Students are expected to attend at least 80% of the lectures and all the examinations.

Academic Accommodations: If you have a documented disability, you should contact Disability Support Services 0126 Shoemaker Hall. Each semester students with documented disabilities should apply to DSS for accommodation request forms, which you can provide to your professors as proof of your eligibility for accommodations. The rules for eligibility and the

types of accommodations a student may request can be reviewed on the DSS web site at http://www.counseling.umd.edu/DSS/receiving_serv.html.

Religious Observances: The University System of Maryland policy provides that students should not be penalized because of observances of their religious beliefs, students shall be given an opportunity, whenever feasible, to make up within a reasonable time any academic assignment that is missed due to individual participation in religious observances. It is the responsibility of the student to inform the instructor of any intended absences for religious observances in advance. Notice should be provided as soon as possible but no later than the end of the schedule adjustment period. Faculty should further remind students that prior notification is especially important in connection with final exams, since failure to reschedule a final exam before the conclusion of the final examination period may result in loss of credits during the semester. The problem is especially likely to arise when final exams are scheduled on Saturdays.

Academic integrity: The University of Maryland has a nationally recognized Code of Academic Integrity, administered by the Student Honor Council. This Code sets standards for academic integrity at Maryland for all undergraduate and graduate students. As a student you are responsible for upholding these standards for this course. It is very important for you to be aware of the consequences of cheating, fabrication, facilitation, and plagiarism. For more information on the Code of Academic Integrity or the Student Honor Council, please visit http://www.studenthonorcouncil.umd.edu/whatis.html. The University of Maryland is one of a small number of universities with a student-administered Honors Code and an Honors Pledge, available on the web at http://www.jpo.umd.edu/aca/honorpledge.html. The code prohibits students from cheating on exams, plagiarizing papers, submitting the same paper for credit in two courses without authorization, buying papers, submitting fraudulent documents, and forging signatures. The University Senate encourages instructors to ask students to write the following signed statement on each examination or assignment: "I pledge on my honor that I have not given or received any unauthorized assistance on this examination (or assignment)."