

Small steps towards incorporating nano concepts in the undergraduate physics curriculum

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Why nanoscience?

Over half of our graduates go on to graduate school: aim for exposure to current topics.

Carleton interdisciplinary science initiative.

Disclaimer: no research experience in nanoscience, but personal interest in the topic.

Overview of 05-06 efforts

Phys 260: Materials Science

Junior/senior elective. Interdisciplinary (chem, geo, phys, comp sci, econ).

Phys 235: Electricity and Magnetism

Requirement for sophomore physics majors.

Wanted to include some nano elements in intro physics (i.e. forces relevant at nanoscale, oscillators, etc), but schedule was too rigid.

Phys 260: Materials Science

Desired nano learning outcomes:

- Materials properties are size dependent
- Appreciation of size of nano scale and tools used to probe this scale
- Assess possibilities for technological applications of materials for nanotech
- Reflect on ethical and societal implications of nanoscience developments

Class schedule of Physics 260: Lecture, essays, problem sets

September	12 M	Introduction; atomic structure	
	14 W	Bonding	
	16 F	Bonding; crystal structure	
	19 M	Crystal structure; defects and disorder	PS 2: Relative length scales Surface energies
	21 W	Crystal structure; defects and disorder	
	23 F	Techniques for studying the structure of materials (x-ray, SEM, TEM, AFM, STM)	
	26 M	Techniques for studying the structure of materials	
	28 W	Mechanical properties, dislocations and strengthening mechanisms	
	30 F	Mechanical properties, dislocations and strengthening mechanisms	
	October	3 M	Electronic properties of metals, insulators, semiconductors
5 W		Semiconductors: doping and devices	
7 F		Scaling down devices, dielectric materials	PS 4: High K materials Shrinking devices
10 M		Ferroelectrics, piezoelectrics	
12 W		Superconductors: magnetic and electronic properties	
14 F		Magnetic properties of materials	PS 5: Data storage with magnetic materials
17 M		Midterm break!	
19 W		Magnetic properties of materials; magnetic data storage	
21 F		In-class activities	
24 M		Optical properties; color	R/E essay 6: Assessment of possible technologies
26 W		Optical properties of nanoparticles	
28 F	Optical devices: LEDs, lasers, optical data storage		
November	31 M	Polymers: structure and properties	
	2 W	Polymers: structure and properties	
	4 F	Polymers: applications	
	7 M	Ceramics and glasses	
	9 W	Ceramics and glasses	
	11 F	No formal class meeting—group interviews for final projects	
	14 M	Special topics	
	16 W	Special topics	

Tools for probing small scales

X-ray, SEM, TEM, AFM, STM

Method: Groups of 2-3, each assigned one tool.

- Explain the tool.
- Relevant materials properties to be studied?
- Sample images.
- Applications besides materials characterization?

Class presentations followed by guided discussion in groups that include 1 “expert” of each method.

Tools for probing small scales

How do we assess student learning?

Students are not graded specifically on presentations; this is considered class participation. One expert per group allows informal assessment of student ownership.

An essay question on the exam is based on these presentations/discussions.

Society and nanotechnology

Reflection/exploration essay; in-class discussion.

Find an article that discusses the societal implications of nanotechnology: possible dangers, potential for positive change, disparity between haves and have nots.

Explore the source of the article.

Can you identify fact, fiction, exaggeration?

How do social perceptions impact scientific progress?

Phys 235: Electricity & Magnetism

Desired nano learning outcomes:

- Understand that capacitance is a function of geometry and appreciate the effect of nanoscale geometries.
- Explain how field effect transistors work and explore the effects of scaling to smaller sizes.
- Awareness that conductance properties at nanoscale differ from responses in large samples.

Problem sets

Introduction of concept of capacitance as a geometrical quantity and how to calculate energy stored in a capacitor.

- Estimate the voltage change produced by adding a single electron to a “quantum dot” based on calculation of capacitance. How many electrons are on the dot?

Follow-up presentation: Coulomb blockade in quantum dots.

Problem sets

Introduction of FETs: Overview of MOSFET operation and shrinking size.

- Calculate the power dissipated, dopant concentration, carrier density induced, etc for various FETs.
- In a manner appropriate for 6th grader, compare the size of the first transistor with one in the typical computer today.

Follow-up: Carbon nanotube transistors, single molecule transistors, and other new directions.

A few thoughts

An entire nano course was not possible for me. By looking for connections, I found opportunities to insert concepts (briefly) into traditional curriculum.

Nano lessons generated positive responses from students although in end-of-term evaluations students rarely mentioned the nano content specifically.

Future endeavors.