VCU
Virginia Commonwealth University

Martin Muñoz
Assistant Professor
Department of Physics

Oliver Hall North, Room 2011
1020 W. Main Street, P.O. Box 842000
Richmond, VA 23284
Phone: (804) 828 1950
Fax: (804) 828 7073
e-mail: mmunoz@vcu.edu

Students with Disabilities: The Americans with Disabilities Act of 1990 requires Virginia Commonwealth University to provide a "reasonable accommodation" to any individual who advises us of a physical or mental disability. If you have a physical or mental limitation that requires an accommodation or an academic adjustment, please arrange a meeting with me at your earliest convenience.

Honor Code: Please read the VCU Honor System Statement. Clear and convincing evidence of honor system violations in this class will result in the submission of formal written charges to the Honor System Coordinator. Under these circumstances I do not give warnings or ask students for explanations.

PHYS 440
Introduction to Condensed Matter Physics
Instructor: Dr. Martin Muñoz

General Information about the course: This course is intended to provide an introduction to the fundamentals of solid state physics. We will basically follow the sequence of topics as outlined in the text by Kittel until we have covered the core material (essentially the first 9 chapters). The rest of the semester will then target material from special topics areas such as magnetism, superconductivity, dielectrics and ferroelectrics, optical process, alloys and amorphous solids, and nanostructures. Some of these topics are described at the end.

Class schedule: Tuesday and Thursday: 14:00-15:15 (Room 2121)

Office hours: Tuesday and Thursday: 15:30-17:00 or by appointment.

Homework: The homework problems consist of numbered problems, taken from the textbook, and supplementary problems. The problems will be assigned after the completion of each chapter and the solutions are due a week later. **No late homework** will be accepted; however, your **lowest** homework grade will be **dropped**.

Class: Class sessions will focus on discussing concepts and on problem solving. There are no attendance requirements, however your are responsible for all the announcements, homework and material covered in class whether you are present in class or not. Participation in class sessions will be considered.

Exams: There will two midterm exams and one final exam; no makeup exams; no dropped exam scores. The exams will include some of the homework problems, but they will not be based exclusively on the homework problems.

Presentation: Each student will prepare a 20-30 min. presentation of one advanced topic during the course. The topic will be defined in agreement with the instructor.

Grades: The students will be graded based on the following components:

Martin Muñoz
Assistant Professor
Department of Physics

Oliver Hall North, Room 2011
1020 W. Main Street, P.O. Box 842000
Richmond, VA 23284
Phone: (804) 828 1950
Fax: (804) 828 7073
e-mail: mmunoz@vcu.edu

- Midterm exams (each) 20%
- Final exam 30%
- Homework assignments 20%
- Advanced topic presentation 10%
- Tentative letter grades will be assigned on the following scale: A: 90-100%, B: 80-89%, C: 70-79%, D: 60-69%, and F: <60%

Exam Schedule: 1st on September 23rd, 2nd on November 2nd, Final December 13-17.

Required Text:

- *Introduction to Solid State Physics, 7th Edition, C. Kitttel; John Wiley, 1996*

Additional Refereences:

- *Solid-state physics: an introduction to principles of materials science*, Harald Ibach, Hans Lüth, Berlin; New York, Springer, 2003.
- *Solid state physics*, Gerald Burns, Academic Press, 1985.
- *Solid state physics*, G. Grosso, and G. P. Parravicini. Academic Press, 2000.
- *Solid State Physics*, N. W. Aschcroft and N. D. Mermin; Saunders College/Harcourt-Brace College Publishers.
- *Fundamentals of Semiconductors*, P. Yu and M. Cardona; Springer, New York, 1999.

TOPICS TO BE COVERED

1) Crystal Lattices
   - Crystal structure with basis
   - Primitive, conventional and Wigner-Seitz cells
   - Lattice planes and Miller indices
   - Cubic (simple, body-centered, face-centered), diamond-and zincblende, Sodium Chloride, Cesium Chloride, hexagonal close pack.
   - Classification of Bravais Lattices and Crystal Structures
     - Seven crystal systems and fourteen Bravais lattices
     - Point group symmetry; Schoenflies and International notation
2) Reciprocal Lattice and Determination of Crystal Structures by X-rays
   - Bragg law
   - The Reciprocal Lattice
   - Laue formulation
   - Ewald construction
   - Geometric structure factor
   - Atomic form factor
   - Debye-Waller factor
   - Experimental methods

Virginia Commonwealth University

Martin Muñoz
Assistant Professor
Department of Physics

Oliver Hall North, Room 2011
1020 W. Main Street, P.O. Box 842000
Richmond, VA 23284
Phone: (804) 828 1950
Fax: (804) 828 7073
e-mail: mmunoz@vcu.edu

- Brillouin zones

3) Crystal Binding and Elastic constants
   - Van der Waal's crystals, Lennard-Jones potential
   - Ionic crystals, Madelung constant
   - Covalent crystals-hydrogen molecule ion as an example
   - Hydrogen bonded crystals
   - Elastic strains
   - Elastic compliance and stiffness constants
4) Crystal Vibrations
   - One dimensional linear chain model with nearest neighbor interactions with one and two atoms per cell-acoustical and optical modes
   - Dispersion relations
   - Elastic Waves
   - Phonon Momentum
5) Thermal Properties
   - Planck Distribution
   - Phonon density of states, Debye model, calculation of specific heat
   - Anharmonic Effects in Crystals: Thermal expansion and Thermal conductivity
   - Van Hove singularities
6) Free Electron Fermi Gas
   - Energy levels in a square well potential
   - Fermi-Dirac Distribution
   - Free electron gas in three dimensions and Electronic density of states
   - Heat capacity of the electron gas
   - Electrical conductivity
   - Motion in electromagnetic fields; Hall effect and magnetoresitance
7) Energy Bands
   - Electronic Levels in a Periodic Potential: General Properties, Energy Gap
   - Periodic potential and Bloch's theorem
   - Kronig-Penney model
   - Wave equation of electron in a periodic potential
8) Semiconductor Crystals
   - Band Gap
   - Semiclassical Theory of Electron Dynamics
     - Equations of motion in electric and magnetic fields
     - Effective mass and its relation to the band width
     - Filled bands are inert; concept of the Hole
   - Intrinsic carrier concentration

VCU
Virginia Commonwealth University

Martin Muñoz
Assistant Professor
Department of Physics

Oliver Hall North, Room 2011
1020 W. Main Street, P.O. Box 842000
Richmond, VA 23284
Phone: (804) 828 1950
Fax: (804) 828 7073
e-mail: mmunoz@vcu.edu

- Impurity conductivity

9) Fermi surfaces
   - Reduced and periodic zone scheme
   - The Fermi surface
   - Calculation of Energy bands
   - The Tight-Binding Method
   - Empirical pseudopotential method
   - ***k·p*** method; relation of effective mass to band gap

Some of the following selected topics or others will be covered if time permits:

10) Homogeneous Semiconductors
    - Semiconductor band structure; direct and indirect gaps
    - Carrier statistics; intrinsic carrier concentration, Fermi level
    - Intrinsic and extrinsic semiconductors; impurity levels
    - Thermal equilibrium carrier densities of impure semiconductors
11) Inhomogeneous Semiconductors
    - The p-n junction in equilibrium; depletion and Debye lengths
    - Elementary picture of rectification by a p-n junction; n-p-n transistor
    - Non-equilibrium p-n junction
    - Schottky barrier
12) Optical properties of semiconductors
    - Relation of band structure to optical properties, van Hove singularities
    - Direct band gap materials; line shape of absorption coefficient
    - Indirect band gap materials; phonon assisted transitions, electron-phonon interaction; lineshape of absorption coefficient
    - Excitons
13) Semiconductor Superlattices and Quantum Wells
    - Band offsets
    - Envelope function approximation, Kronig-Penney model with effective masses; isolated states and formation of minibands
    - Optical properties; selection rules; two-dimensional excitons