Course ID MASC501 Solid State
Units: 4
Term—Day—Time:
Spring 2021 Tu & Th 2PM to 3:50PM

IMPORTANT:
The general formula for contact hours is as follows:
Courses must meet for a minimum of one 50 minute session per unit per week over a fifteen-week semester. Standard fall and spring sessions require a final summative experience during the University scheduled final exam day and time.

(Please refer to the *Contact Hours Reference,* located at arr.usc.edu/services/curriculum/resources.html.)

Location: TBD.

Instructor: Anupam Madhukar
Office: VHE 502
Office Hours: Thursday, 4PM-6PM or by appointment.
Contact Info: madhukar@usc.edu

Teaching Assistant: TBD
Office:
Office Hours:
Contact Info: Email, phone number (office, cell), Skype, etc.

IT Help: Not Applicable.
Hours of Service:
Contact Info: Email, phone number (office, cell), Skype, etc.

Course Description

An expanded version of the description published in the University catalogue. Describe the student audience for whom the course is appropriate. Aspirational statements are not learning objectives, but are valuable and belong in this section.

This course, enhanced to four units, is designed as an introductory graduate-level course on the basics of the physics and chemistry of solids. The content represents new material added (beyond the 3 unit course syllabus) guided by the recognition over three decades of teaching this course that the background material preparation of the incoming students has increasingly become inadequate while many new categories of solid materials made of tailored building blocks have emerged that increasingly form the basis for expanding classes of applications in high technology (such as information processing, communication, computing, etc.). The topics added over the three-unit syllabus are highlighted in red.

The basic content and logical structure of the course continues to emphasize: the quantum mechanical nature of atoms and their bonding; crystal structure; quantum mechanical description of the motion of electrons and ion lattice in crystals; and thermodynamic properties (e.g. specific heat, thermal and electrical conductivity, etc.) of crystalline solids related to the motion of electrons and ions. The course is thus particularly well-suited for PhD students in materials science, physics, chemistry, electrical engineering, biomedical engineering, environmental engineering, and mechanical engineering. Students pursuing master's degree in any of these disciplines can also benefit provided they satisfy the prerequisite.

Learning Objectives

Identify what specific, measurable skills a student will demonstrate by the end of the course. Learning objectives should be both taught and assessed in your course. They are aligned with your assignments, assessments and learning materials.

The hydrogen atom electron states and nomenclature; many electron atoms and concept of valency; molecular bonding; one- electron-at-a-time description; the tight-binding model; crystal structure; reciprocal lattice; diffraction and crystal structure determination; crystal binding and cohesive energy of solids; harmonic approximation and lattice vibrations; phonons; thermal expansion and thermal conductivity; energy bands; the free electron model for simple metals; specific heat; electrical conductivity; semiconductor versus metal; electron behavior in reduced dimensional (2D and 1D) solids.

Prerequisite(s): EE/MASC 471 or EE/MASC 539, or Equivalent (Instructor's permission needed)
Co-Requisite(s): None
Concurrent Enrollment: None
Recommended Preparation: Graduate level mathematical methods (such as Vector analysis, Linear algebra, Complex variables, Transforms, Ordinary and Partial second order differential equations, etc.) for engineers

Course Notes

Grading Type, if other than the assumed letter grade (i.e., Credit No-Credit or Numeric and/or In Progress). Note any unique characteristics of the course of operating procedure. Is the course Web-Enhanced (i.e. Blackboard), Blended or Online? If copies of lecture slides and other class information will be posted on Blackboard, note that here. If multimedia or technology-enhanced learning strategies will be used, please describe them here.

Letter grade.

Technological Proficiency and Hardware/Software Required

Matlab

Required Readings and Supplementary Materials

Assigned weekly; Materials supplied as needed.

Description and Assessment of Assignments

What kind of work is to be done and how should it be completed, i.e. how the learning outcome will be assessed. Include any assessment and grading rubrics to be used.

Approximately eight home assignments requiring solution of problems based upon the topics covered until the time of the assignment; some assignments may be specified as group efforts and the solutions to these will be presented by the specified groups during specified hour for discussion by the whole class; A midterm and a final written exam comprising solving problems based upon all material covered.

Grading Breakdown

Including the above detailed assignments, how will students be graded overall? Participation should be no more than 15%, unless justified for a higher amount. All must total 100%.

Assignment	Points	% of Grade
Homework	20	20
Midterm	30	30
Final	50	50
TOTAL	100	100

Grading Scale (Example)

Course final grades will be determined using the following scale

A	80-100
A-	75-79
B+	70-74
B	65-69
B-	60-64
C+	55-59
C	50-54
C-	45-49
D+	40-44
D	35-39
D-	31-34
F	30 and below

Assignment Rubrics

Include assignment rubrics to be used, if any.

Assignment Submission Policy

Hardcopy of solutions to assigned problems are to be turned in at the specified class (typically one week from the date of assignment)

Grading Timeline

Graded homework will be returned typically within a week of the submission date.

Additional Policies

Add any additional policies that students should be aware of: late assignments, missed classes, attendance expectations, use of technology in the classroom, etc.

No late assignments accepted.
Expect 100% attendance.
If a class is to be missed, inform the instructor a week in advance so arrangement can be made (such as providing reading instructions and / or lecture handout, if any).
No electronic gadgets are allowed to be used in the class without the explicit permission of the instructor.

Course Schedule: A Weekly Breakdown

Provide a detailed course calendar that provides a thorough list of deliverables—readings, assignments, examinations, etc., broken down on at least a weekly basis. The format may vary, but the content must include:

- **Subject matter (topic) or activity**
- **Required preparatory reading, or other assignments (i.e., viewing videos) for each class session, including page numbers.**
- **Assignments or deliverables.**

IMPORTANT:
In addition to in-class contact hours, all courses must also meet a minimum standard for out-of-class time, which accounts for time students spend on homework, readings, writing, and other academic activities. **For each unit of in-class contact time, the university expects two hours of out of class student work per week over a semester.**

(Please refer to the *Contact Hours Reference* at arr.usc.edu/services/curriculum/resources.html.)

	Topics/Daily Activities	Readings and Homework	Deliverable/ Due Dates
Week 1	Review: Wave-Matter Duality Solution of hydrogen atom Schrodinger equation: electron level structure and atomic orbital nomenclature. Many electron atoms; Core & Valence electrons; Pseudopotential; Electronic configuration; Valency; Spin and Hund's rule.	Lecture notes	
Week 2	Diatomic molecule and bonding; Born-Oppenheimer approximation; The hydrogen molecule; mutually-induced dipole and van der Waals attraction; Molecular stability; Ignoring electron-electron repulsion-the one-electron-at-time approximation; Molecular orbital and Valence bond descriptions; Pauli principle & wavefunction anti-	Lecture notes HW 1	Problem solutions. In one week.

	symmetry; Singlet & Triplet states.		
Week 3	Heteropolar diatomic molecule; covalency & ionicity; Probing bonding: Photoemission & electron spectroscopy for chemical analysis (ESCA). Tri-atomic molecules: Orbital hybridization and Molecular structure.	Lecture notes	
Week 4	Monoatomic linear chain molecule/solid: Linear combination of atomic orbitals-molecular orbital method & the tight binding approximation; Born-von Karman boundary condition; unit cell; electron states and energy bands; band filling & Fermi energy; metal versus insulator; effective mass; Density of states.	Lecture notes. HW 2	Problem solutions. In one week.
Week 5	Crystal structure: space lattice & basis; primitive cell & translation vectors; Bravais lattices; types of crystal structures; Miller indices; directions & planes; Structure	C. KIttel, Ch.1 & Ch.2 HW 3: Problems from the text.	Problem solutions. In one week

	determination; Diffraction & Bragg law; Reciprocal lattice; Brillouin zones; Scattering & Fourier analysis; Structure factor & Atomic form factor; Examples.		
Week 6	Structure determination: X-ray diffraction instrumentation and methods. Surface structure: nomenclature; surface reconstruction; reflection high-energy electron diffraction;	Lecture notes.	
Week 7	Review **Mid-Term Exam**		
Week 8	Band structure of three-dimensional crystalline solids: Cubic system with one and two atomic orbitals per atom; sp2 & sp3 hybridization & the planar 2D & 3D tetrahedrally- bonded semiconductors; Density of states.	Lecture notes. HW 4	Problem solutions In one week
Week 9	Crystal binding: Cohesive energy; van der Walls crystals, covalent, ionic, metallic; 2D solids.	C. Kittel, Ch.3 HW 5	Problem solutions In one week
Week 10	The ion system: harmonic oscillator model for ion motion; monoatomic chain & lattice vibrations; Quantization & phonons; diatomic chain and acoustic &	C. Kittel, Ch.4 HW 6	Problem solutions In one week

	optical phonon branches; Normal and Umklapp processes.		
Week 11	Phonon density of states; Specific heat. Anharmonic effects: thermal expansion and conductivity.	C. Kittel, Ch.5 HW 7	Problem solutions In one week
Week 12	The Free Electron model for metals; density of states and chemical potential; specific heat; electrical conductivity. Two-Dimensional free electron system. Nearly Free Electron model: energy gaps; extended and reduced zone pictures;	C. Kittel, Ch.6 HW 8	Problem solutions In one week
Week 13	Electron motion in periodic ion potential : Solution of one electron Schrodinger equation ; Bloch's theorem ; crystal momentum versus physical momentum.		
Week 14	Solid structures in reduced dimensions: Superlattices; Interfaces & Heterojunctions; Quantum wells, wires, & Dots; 2D materials.		
Week 15	The need for including electron-electron interaction. Review of the course.		

FINAL			May, 2020 2PM to : 4PM TBD For the date and time of the final for this class, consult the USC *Schedule of Classes* at www.usc.edu/soc.

Statement on Academic Conduct and Support Systems

Academic Conduct:
Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in *SCampus* in Part B, Section 11, "Behavior Violating University Standards" https://policy.usc.edu/scampus-part-b/. Other forms of academic dishonesty are equally unacceptable. See additional information in *SCampus* and university policies on scientific misconduct, http://policy.usc.edu/scientific-misconduct.

Support Systems:
Student Counseling Services (SCS) - (213) 740-7711 – 24/7 on call
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention. https://engemannshc.usc.edu/counseling/

National Suicide Prevention Lifeline - 1-800-273-8255
Provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week. http://www.suicidepreventionlifeline.org

Relationship and Sexual Violence Prevention Services (RSVP) - (213) 740-4900 - 24/7 on call
Free and confidential therapy services, workshops, and training for situations related to gender-based harm. https://engemannshc.usc.edu/rsvp/

Sexual Assault Resource Center
For more information about how to get help or help a survivor, rights, reporting options, and additional resources, visit the website: http://sarc.usc.edu/

Office of Equity and Diversity (OED)/Title IX Compliance – (213) 740-5086
Works with faculty, staff, visitors, applicants, and students around issues of protected class. https://equity.usc.edu/

Bias Assessment Response and Support
Incidents of bias, hate crimes and microaggressions need to be reported allowing for appropriate investigation and response. https://studentaffairs.usc.edu/bias-assessment-response-support/

The Office of Disability Services and Programs
Provides certification for students with disabilities and helps arrange relevant accommodations. http://dsp.usc.edu

Student Support and Advocacy – (213) 821-4710
Assists students and families in resolving complex issues adversely affecting their success as a student EX: personal, financial, and academic. https://studentaffairs.usc.edu/ssa/

Diversity at USC
Information on events, programs and training, the Diversity Task Force (including representatives for each school), chronology, participation, and various resources for students. https://diversity.usc.edu/

USC Emergency Information
Provides safety and other updates, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible, http://emergency.usc.edu

USC Department of Public Safety – 213-740-4321 (UPC) and 323-442-1000 (HSC) for 24-hour emergency assistance or to report a crime.
Provides overall safety to USC community. http://dps.usc.edu