STATE UNIVERSITY OF NEW YORK !
COLLEGE OF TECHNOLOGY !
CANTON, NEW YORK !

MASTER SYLLABUS

COURSE NUMBER – COURSE NAME
PHYS 410 – SOLID STATE SCIENCE

Created by: Dr. Lawretta Ononye

Updated by: Dr. Lawretta Ononye

Canino School of Engineering Technology !

Department: Physics !

Semester/Year: Fall 2018 !

A. **TITLE**: Solid State Science

B. **COURSE NUMBER:** PHYS 410

C. **CREDIT HOURS: (Hours of Lecture, Laboratory, Recitation, Tutorial, Activity)**

 # Credit Hours: 3
 # Lecture Hours: 3 **per week**
 # Lab Hours: **per week**
Other: **per week**

Course Length: 15 **Weeks**

D. **WRITING INTENSIVE COURSE**: Yes ☐ No ☒

E. **GER CATEGORY: None:** ☒ **Yes:** GER !
***If course satisfies more than one*:** GER !

F. **SEMESTER(S) OFFERED: Fall** ☐ **Spring** ☐ **Fall & Spring** ☒

G. **COURSE DESCRIPTION:**

This course explores how the diverse properties (mechanical, electronic, optical and magnetic) of solid materials can be related to the structure of the material or interactions at the atomistic level. Topics include crystal structures; bonding in solids; x-ray, neutron, and electron diffraction in crystals; lattice vibrations; energy bands in solids; the free-electron model; semiconductor and semiconductor devices.

H. **PRE-REQUISITES: None** ☐ **Yes** ☒ **If yes, list below:**

PHYS 132 (University Physics II) or PHYS 122 (College Physics II)
or permission of instructor

CO-REQUISITES: None ☒ **Yes** ☐ **If yes, list below:**

I. STUDENT LEARNING OUTCOMES: (*see key below*)

By the end of this course, the student will be able to:

Course Student Learning Outcome [SLO]	***Program Student Learning Outcome [PSLO]***	***GER*** *[If Applicable]*	***ISLO & SUBSETS***	
a. Integrate the structure of solids with their thermal, mechanical, electrical, optical and magnetic properties.			2-Crit Think ISLO ISLO	CA Subsets Subsets Subsets
b. Explain the generation and absorption of x-rays; Bragg's Law, and the diffraction methods for determining crystal structure.			1-Comm Skills 2-Crit Think ISLO	W CA PS Subsets
c. Appraise the free electron model and show how this can provide an explanation for many features of metallic behavior. Explain energy band in solid.			2-Crit Think ISLO ISLO	CA PS Subsets Subsets
d. Explain the band structure in solid and the basic features of semiconductor and relate this to simple semiconductor device.			1-Comm Skills 2-Crit Think ISLO	W CA Subsets Subsets
e. Demonstrate an understanding of physics application of concepts and models.			2-Crit Think ISLO ISLO	CA PS Subsets Subsets

KEY	**Institutional Student Learning Outcomes [ISLO 1 – 5]**
ISLO #	**ISLO & Subsets**
1	**Communication Skills** Oral [O], Written [W]
2	**Critical Thinking** *Critical Analysis [CA] , Inquiry & Analysis [IA] , Problem Solving [PS]*
3	**Foundational Skills** *Information Management [IM], Quantitative Lit,/Reasoning [QTR]*
4	**Social Responsibility** *Ethical Reasoning [ER], Global Learning [GL], Intercultural Knowledge [IK], Teamwork [T]*
5	**Industry, Professional, Discipline Specific Knowledge and Skills**

*Include program objectives if applicable. Please consult with Program Coordinator !

J. ! APPLIED LEARNING COMPONENT: Yes ☒ No ☐

If YES, select one or more of the following categories:

☒ Classroom/Lab
☐ Internship
☐ Clinical Placement
☐ Practicum
☐ Service Learning !
☐ Community Service
☐ Civic Engagement
☐ Creative Works/Senior Project
☐ Research
☐ Entrepreneurship (program, class, project)

K. ! TEXTS:

Omar, Ali (1993) Elementary Solid State Physics. Boston, MA: AddisonWesley Publication.

L. ! REFERENCES:

Kittle, Charles (2008). Introduction to Solid State Physics. Hoboken, NJ: John Wiley and Sons, Inc.

M. ! EQUIPMENT: None ☐ Needed: Technology enhanced classroom

N. ! GRADING METHOD: A-F

O. ! SUGGESTED MEASUREMENT CRITERIA/METHODS:

• Exams • Quizzes • Homework • Participation • Project/Presentation

P. DETAILED COURSE OUTLINE:

I. ! What is Solid State Science?

II. ! Material Structure and Interatomic Bonding
A. ! Crystal structure.
B. ! The seven crystal systems.
C. ! Introduce the idea of a primitive unit cell and contrast it with a conventional cell.
D. ! Elements of symmetry.
E. ! Crystal directions and planes; Miller indices.
G. ! Bonding in solids.
H. ! Interatomic forces.

III. ! Diffraction Methods and Structural Determination
A. ! Discuss diffraction methods for determining crystal structure; x-ray, neutron, and electron diffraction in crystals.
B. ! N Generation and absorption of x-rays.
C. ! Bragg's law
D. ! Scattering from an atom and from a crystal.
E. ! Reciprocal lattice and x-ray diffraction.

F. ! The main techniques (diffractometers, powder photographs and Laue photographs) will be studied.

G. ! Discuss the advantages and disadvantages of using neutrons, electrons and Xrays to determine structures.

IV. ! Crystal Lattice Vibrations and Phonons

A. ! The coupled modes of oscillation of atoms in a crystal lattice, using a one dimensional chain of identical atoms.

B. ! The harmonic approximation will be introduced.

C. ! The effect of the boundary conditions on the solution.

D. ! Introduce the idea of a Brillouin zone.

E. ! The density of states of oscillatory modes.

F. ! The idea of a band gap in the density of states.

V. Thermal Properties of Solids

A. ! The Debye and Einstein models for the specific heat of solids.

B. ! Discuss thermal conductivity by phonon transport using a kinetic theory analogous to the kinetic theory of gases.

C. ! A phonon mean free path will be discussed and a qualitative account of phonon scattering mechanisms given

VI. Mechanical Properties of Solids

A. ! Show that the theoretical yield stress is far greater than the observed yield stress for any material.

B. ! Introduce the idea of a dislocation and show how it can lower the yield stress using the 'carpet ruck' analogy.

C. ! Discuss the two pure types of dislocation (edge and screw).

D. ! Introduce the concept of a Burgers vector.

E. ! Derive the strain field, and hence the elastic energy, for a screw dislocation.

F. ! The Frank-Read mechanism for dislocation multiplication will be briefly discussed and related to the phenomenon of work hardening.

VII. Electronic and Optical Properties of Solids

A. ! The electronic and optical properties of solids will be discussed using simple ideas of valence and conduction band structure for the electronic energy spectrum in materials, with examples.

B. ! Discuss materials ranging from electrical insulators to semiconductors and conductors. Transparency and opacity of solids will be considered, together with field emission and contact potentials.

C. ! Analogies between electron and phonon spectra, particularly with regard to band gaps will be made.

VIII. Models of Electrons in Solids, and Energy Bands in solids

A. ! Models will be used to show how electronic structure emerges from the fundamental interactions of electrons in materials, as described by quantum mechanics.

B. ! Conduction electrons.

C. ! The free-electron gas.

D. ! Electrical conductivity and resistivity.

E. ! Show how electrons bind atoms together in metals and covalent solids.

F. ! Calculate the electronic specific heat and, using the idea of a relaxation time, calculate the thermal conductivity due to free electrons, and discuss electrical

current, resistivity, the Wiedemann-Franz law and the Hall effect.

G. ! The Fermi surface.

H. ! Density of state.

I. ! Thermionic emission.

J. ! Discuss the drift of electrons in bands, introducing the idea of the effective mass.

K. ! Using perturbation theory and Bloch's theorem, the nearly-free electron model will be introduced to show how band gaps in the electron energy spectrum arise.

L. ! The tight binding model will be introduced and used to demonstrate, from a different point of view, how band gaps emerge.

M. Failure of the free-electron model.

IX. ! Semiconductors and Devices

A. ! Crystal structure and bonding.

B. ! Band structure.

C. ! Discuss the electronic structure of intrinsic and n- and p-type doped semiconductors.

D. ! Donor and acceptor states and the electronic structure of each type of semiconductor will be described.

E. ! Holes and electrons will be discussed.

F. ! Consider processes taking place at pn junctions, including carrier generation, and recombination.

G. ! Magnetic field effects: cyclotron resonance and Hall effect.

H. ! The Gunn effect.

I. ! Optical properties.

J. ! Discuss the operation of field effect transistors, light emitting diodes, semiconductor lasers and solar panels.

X. ! Superconductivity and the Magnetic Properties of Solids Superconductivity and the Magnetic Properties of Solids

A. ! Discuss para-, dia-, ferro- and antiferromagnetism using ideas of electron spins.

B. ! Using the free electron model calculate the paramagnetic susceptibility of simple metals.

C. ! Some of the features of superconductivity will be discussed and explained

XI. ! Dielectric and Optical Properties of Solids

A. ! The dielectric constant and polarizability.

Q. <u>LABORATORY OUTLINE</u>: None ☒ Yes ☐

N/A