School of Physics

Course Outline 2021

PHYS3118

Quantum Physics of Solids & Devices

School of Physics

Faculty of Science

T2, 2021

1. Staff

Position	Name	Email	Consultation times and locations	Contact Details
Course Convenor	Prof Sven Rogge	Sven.rogge@unsw.edu.au	Please email lecturers only for urgent matters and arranging a consultation time. Questions about course related matters should be posted on the appropriate Moodle discussion forum	
Lecturer	Prof Alexander Hamilton	Alex.hamilton@unsw.edu.au		
Laboratory Manager	Tamara Reztsova	t.reztsova@unsw.edu.au	Higher Year Lab OMB142	(02) 9385 4577
Teaching Support Officer	Zofia Krawczyk-Bernotas	z.krawczyk-bernotas@unsw.edu.au	School of Physics office G06, Old Main Building	(02) 9065 5719

2. Course information

Units of credit: 6
Pre-requisite(s): PHYS2111 or PHYS2110 and PHYS3113

Teaching times and locations:
http://timetable.unsw.edu.au/2021/PHYS3118.html

2.1 Course summary

Quantum mechanics plays a key role in the properties of solids, and already underpins the operation of devices such as laser diodes and superconducting quantum interference devices (SQUIDs). Quantum physics will play an even more significant role is new generations of electronic devices, such as quantum sensors and quantum computers. This course covers three main areas. The first is 'The Quantum Physics of Solids', which covers crystal structure, phonons as quantum oscillations, electrons as quantum particles in solids, band structure and unconventional materials. The second area is 'Interactions in Quantum Systems', with topics including the different forms of magnetism, electron-electron interactions and their role in screening and plasmonic effects, and superconductivity. The third is 'From Semiconductors to Quantum Devices', with topics including charge carriers in semiconductors, p-n junctions, quantum confinement, Coulomb blockade, and quantum bits. The course will appeal to those seeking a better contextual understanding of quantum mechanics and to learn about its real world applications: past, present and future.

2.2 Course aims

Graduate Attributes Developed in this Course

- Research, inquiry and analytical thinking abilities
- Capability and motivation for intellectual development
- Ethical, social and professional understanding
- Communication in a scientific/technical context
- Collaborative and management skills

- Information literacy

2.3 Course learning outcomes (CLO)

The coupling of Solid State Physics and Quantum Physics is the basis for virtually all technological aspects of modern life. This course aims to give an overview of the basic concepts of solid state physics, and introduce a number of essential physics concepts that underlie the operation of all electronic, magnetic and superconducting devices.

Learning outcomes:

1. Describe the essential concepts of basic solid state physics and methods for dealing with the structural, thermal and electronic properties of solids.

2. Explain the physics of particle-particle interactions in solids and the effects they produce, e.g., superconductivity, magnetism, etc.

3. Explain the physics of semiconductors and how this is translated into modern functional electronic and magnetic device structures.

2.4 Relationship between course and program learning outcomes and assessments

Course learning outcomes 1-3 are assessed in the 4 assessment tasks. These assessments are largely of a critical-thinking nature designed to determine students' ability to deploy acquired knowledge to new situations, which is a key graduate attribute for successful university graduates.

3. Strategies and approaches to learning

3.1 Learning and teaching activities

Assumed Knowledge

Pre-requisite(s): PHYS2111 or PHYS2110 nd PHYS3113

Timetable

Lectures: 1x 2hr plus 2x 1hr lectures per week (Weeks 1-5, 7-10)

Laboratory: 2 x 4hr per term

Lecture Timetable

Day	***Time***	***Location***	***Weeks***
Monday	1500-1700	Webster Theatre B	1-2, 4-5, 7-10
Wednesday	1600-1700	Webster Theatre B	1-5, 7-10
Thursday	0900-1000	Webster Theatre B	1-5, 7-10

Lecture Information

Lecturer: This course is taught by two lecturers teaching 18 hours each.

Monday 14th June (Week 3) is a public holiday. There will be no lecuture on this day but a make-up lecture will be scheduled at another time during the term. Please check Moodle announcements.

Laboratory Information

Two experiments need to be conducted during the term. The laboratory component of the course will be held in OMB142. For details about lab days, times and class codes, see http://timetable.unsw.edu.au/2021/PHYS3118.htm lor contact Laboratory Staff (Tamara Reztsova at t.reztsova@unsw.edu.au).

3.2 Expectations of students

We believe that effective learning is best supported by a climate of enquiry, in which students are actively engaged in the learning process. To ensure effective learning, students should participate in class. Effective learning is achieved when students attend all classes, have prepared effectively for classes by reading through previous lecture notes, in the case of lectures, and, in the case of tutorials or laboratories, have made a serious attempt at doing the problems or pre-work themselves prior to the class. Furthermore, lectures should be viewed by the student as an opportunity to learn, rather than just copy down lecture notes. Effective learning is achieved when students have a genuine interest in the subject and make a serious effort to master the basic material.

Academic misconduct will not be tolerated in any form in this course. Substantiated instances of cheating, plagiarism or copying answers may result in a failure grade or significant deduction of marks. Please see https://student.unsw.edu.au/plagiarism if you are in any way unsure of what constitutes plagiarism. Assignments in this class are to be done independently.

4. Course schedule and structure

Detailed Syllabus and indicative lecture content

Week 1: Intro, What solids are, why they form, what the types are (crystal, amorphous, etc), basic structures. Bravais lattices, introduce k-space and reciprocal lattices. Phonons – 1D chain model. Group and phase velocities. Phonons in 3D, x-rays and neutrons as analytical techniques.

Week 2: Specific heat – Debye and Einstein models. Electron heat capacity, Fermi distribution (what happens when you have lots of electrons). Bloch's theorem and what electrons see inside a crystal (very large finite quantum well). Nearly free electron model and where band structure comes from.

Week 3: Bands in solids, metals, semiconductors & insulators, effective mass, etc. Non-conventional crystals: molecular crystals, amorphous materials, quasi-crystals, graphene, layered 2Ds.

Week 4: The failure of band theory in describing magnetism: Magnetism and magnetic materials – basic properties, classifications. Paramagnetism and diamagnetism.

Week 5: Spin interactions continued: Ising models, ferromagnetism and antiferromagnetism. Dielectrics. Interactions: electron-photon, electron-defect scattering. Interactions: electron-electron (heavy) and phonon-phonon (light).

Week 6: Superconductivity: Properties of material (e.g., Meissner), basics of BCS. Superconductivity: Josephson effect, SQUIDs, qubits and quantum sensors.

Week 7: Semiconductors: Start with direct/indirect, intrinsic, doping, drift and diffusion, Hall effect, p-n junctions, space charge, depletion.

Week 8: Applications of p-n junctions: diodes, bipolar transistor, light emission, photovoltaics. Hetero junctions: confinement, low-dimensional systems, excitons.

Week 9: From classical to quantum devices: MOSFETs. Coulomb Blockade, single-electron transistor, spin to charge conversion, control and readout of spin qubits.

5. Assessment

5.1 Assessment tasks

Course assessment comprises assignments, in-session test, laboratory and final examination.

Assessment task	Length	Weight	Mark	Due date *(normally midnight on due date)*
Assessment 1: Assignment 1	50 mins	20%		Monday 28th June (Week 5)
Assessment 2: Assignment 2		20%		Monday 2nd August (Week 10)
Assessment 3: Laboratory		10%		See above note regarding lab classes
Assessment 4: Final Exam	2 hours	50%		See Exam Schedule - TBA

Information about Special Consideration is available from https://student.unsw.edu.au/special-consideration

Further information
UNSW grading system: student.unsw.edu.au/grades
UNSW assessment policy: student.unsw.edu.au/assessment

5.2 Assessment criteria and standards

Please see Moodle for a marking rubric for each assessment task.

5.3 Submission of assessment tasks

Assignment Submissions

Unless otherwise specified, assignments should be submitted online by 5pm on the due date.

A downloadable assignment cover sheet is available from https://www.physics.unsw.edu.au/current-students/cover-sheet

Marks will be deducted for late assignments, at a rate of 5% of the maximum possible mark for the assignment per day. A weekend will count as two days. An assignment submitted after the solutions have been posted will automatically receive 0%.

5.4. Feedback on assessment

Please see Moodle for details on how feedback will be provided for each assessment task

6. Academic integrity, referencing and plagiarism

Referencing is a way of acknowledging the sources of information that you use to research your assignments. You need to provide a reference whenever you draw on someone else's words, ideas or research. Not referencing other people's work can constitute plagiarism.

Further information about referencing styles can be located at student.unsw.edu.au/referencing

Academic integrity is fundamental to success at university. Academic integrity can be defined as a commitment to six fundamental values in academic pursuits**:** honesty, trust, fairness, respect, responsibility and courage.[1] At UNSW, this means that your work must be your own, and others' ideas should be appropriately acknowledged. If you don't follow these rules, plagiarism may be detected in your work.

Further information about academic integrity and **plagiarism** can be located at:

- The *Current Students* site student.unsw.edu.au/plagiarism**,** and
- The *ELISE* training site subjectguides.library.unsw.edu.au/elise

The *Conduct and Integrity Unit* provides further resources to assist you to understand your conduct obligations as a student: student.unsw.edu.au/conduct.

7. Readings and resources

Textbooks

• Prescribed: Ibach & Lüth: "Solid-State Physics", 4th edition, Springer

• Reference: Kittel: "Introduction to Solid State Physics", 8th edition, Wiley Sze: "Physics of Semiconductor Devices, 3rd edition, Wiley

Other Resources

Lecture notes will be posted on Moodle.

Additional resources such as articles, papers, websites, other published material will be referred to during lectures and listed at the Moodle site.

8. Administrative matters

Communications
Students should check their UNSW email account regularly as all official university communication will be sent to that address. Students should use their university email account when writing to UNSW staff and should always include their name and student number.

Health and Safety
The School of Physics is actively committed to the health, safety and welfare of its staff and students. Information on relevant UNSW Occupational Health and Safety policies and expectations is available at: www.ohs.unsw.edu.au and https://www.physics.unsw.edu.au/about/safety

Recommended Internet Sites
The School of Physics website is www.physics.unsw.edu.au. Under the "Current Students" link students will find information about degrees, courses, and assessment.
The University website my.unsw.edu.au provides links to the UNSW Handbook, Timetables, Calendars and other student information.

[1] International Center for Academic Integrity, 'The Fundamental Values of Academic Integrity', T. Fishman (ed), Clemson University, 2013.

Student Complaint Procedures
UNSW has procedures for dealing with complaints. These aim to solve grievances as quickly and as close to the source as possible. Information is available here: student.unsw.edu.au/complaints. Staff who can assist include:

School Contacts:

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9. Additional support for students

- The *Current Students* Gateway: student.unsw.edu.au
- Academic Skills and Support: student.unsw.edu.au/skills
- Student Wellbeing, Health and Safety: student.unsw.edu.au/wellbeing
- Disability Support Services: student.unsw.edu.au/disability
- UNSW IT Service Centre: www.it.unsw.edu.au/students