PHYS303

Atomic and Solid-State Physics

S1 Day 2016

Dept of Physics and Astronomy

Contents

General Information

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Credit points 3
Prerequisites PHYS201 and PHYS202
Corequisites
Co-badged status

Unit description

This unit gives an understanding of the fundamentals of atomic physics that lead to the unique energy-level diagram (and consequent unique spectrum of frequencies of electromagnetic radiation that can be emitted and/or absorbed) for each atom in the periodic table. Hydrogen is a particularly important atom in this context because its theoretical description is the most complete of any atom. When many atoms are very close together in a crystalline solid, discrete energy levels form into bands in the solid. This band structure determines many properties of the resulting solid, depending on the atomic arrangement, and is at the heart of how solids can be exploited, for example in semiconductor devices. Specific topics covered include: revision of wave mechanics; solution of the 1D and 3D Schrodinger equations; the physics of the hydrogen atom; magnetic dipole moments; spin and transition rates; properties of multi-electron atoms: modern methods of atom manipulation: revision of Fourier transforms; crystalline structure; bonding; lattice vibrations; lattice thermal energy; electrons in metals; band theory of solids; free-electron model; tight-binding model; semiconductors; and semiconductor device physics.

Important Academic Dates

Information about important academic dates including deadlines for withdrawing from units are available at https://www.mq.edu.au/study/calendar-of-dates

Learning Outcomes

On successful completion of this unit, you will be able to:

- Know the basic premises of quantum mechanics. Idenetify and use standard solutions of Schrodinger equation [free, infinite well, step, Coulomb potential]
- Know the experimental basis of the orbital angular momentum and spin; being able to implement their basic math and physics in calculations
- Know the basic rules of the atomic transitions; be able to apply them in the spectral analysis. Understand the elements involved in the many-body physics. Ability to qualitatively predict structure of atoms and ions and periodic table and their spectra in external magnetic and electric fields
- Be aware of the current developments [optical lattices, condensates] and techniques. Know and be able to clacluate some of the relevant processes
- Understand the applications of Fourier theory to condensed matter physics and be able to perform the standard Fourier analysis manipulations.
- Have an understanding of how the quantization of crystal lattice vibrations leads to the concept of phonons and estimate their basic properties
- Have an understanding of how the periodic potential of the crystal lattice leads to the formation of delocalised electronic states. Have an understanding of the concept of

crystal momentum and how this applies to the quantization of electronic states in crystals.
Have an understanding of the electronic structure and properties of intrinsic semiconductors. Have an understanding of the changes produced by semiconductor doping and the application of this to electronic device operation.

Assessment Tasks

Name	Weighting	Due
exam	60%	set by the University
assignment	20%	continuous
tests	20%	TBA

exam

Due: **set by the University**
Weighting: **60%**

A three hour final exam will be set from approx 75% of the unit content. Specifically named topics covered in the class summary tests as specified below are excluded from the final examination. All other topics may be covered in the final exam. The exam will consist of two parts, dealing with the atomic and condensed matter physics, respectively. All the necessary physical and mathematical formulas will be provided.

On successful completion you will be able to:

- Know the basic premises of quantum mechanics. Idenetify and use standard solutions of Schrodinger equation [free, infinite well, step, Coulomb potential]
- Know the experimental basis of the orbital angular momentum and spin; being able to implement their basic math and physics in calculations
- Be aware of the current developments [optical lattices, condensates] and techniques. Know and be able to clacluate some of the relevant processes
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crystal momentum and how this applies to the quantization of electronic states in crystals.
- Have an understanding of the electronic structure and properties of intrinsic semiconductors. Have an understanding of the changes produced by semiconductor doping and the application of this to electronic device operation.

assignment

Due: **continuous**
Weighting: **20%**

Assignments will be set and marked for assessment purposes and issued approximately once a week. Solutions will not be issued, but the submitted assignments will be individually corrected.

The best four assignments [unless agreed otherwise] in each half of the course (i.e. 4+4) will be selected to contribute to the assignment grade.

On successful completion you will be able to:

- Know the basic premises of quantum mechanics. Idenetify and use standard solutions of Schrodinger equation [free, infinite well, step, Coulomb potential]
- Know the experimental basis of the orbital angular momentum and spin; being able to implement their basic math and physics in calculations
- Know the basic rules of the atomic transitions; be able to apply them in the spectral analysis. Understand the elements involved in the many-body physics. Ability to qualitatively predict structure of atoms and ions and periodic table and their spectra in external magnetic and electric fields
- Be aware of the current developments [optical lattices, condensates] and techniques. Know and be able to clacluate some of the relevant processes
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- Have an understanding of the electronic structure and properties of intrinsic semiconductors. Have an understanding of the changes produced by semiconductor

doping and the application of this to electronic device operation.

tests

Due: **TBA**
Weighting: **20%**

Some topics have been chosen for assessment via two class tests This represents approximately one quarter of the unit content that will not be examined in the final exam. The topics are:

1. Energy Levels of Multi-Electron Atoms

2. Bonding & Crystal Structure

There is some flexibility in setting the test times and the selected material. Please use the dedicated iLearn discussion forum to make suggestions for the alternative times.

Decision deadline: Mar 18

The form of these test tasks is the following. Students can prepare their own hand written summary notes on the topic(s) of the summary test to take into the test. Students can use these notes freely to complete the test question(s) which will have been broadly defined prior to the test.

The summary notes and the test script will be collected and assessed to ensure the notes were independently prepared and for the quality/ correctness of the test answer(s). *Summary notes are limited to only one A4 page (double side) .*

Weight of each test: 10%.

On successful completion you will be able to:

- Know the basic premises of quantum mechanics. Idenetify and use standard solutions of Schrodinger equation [free, infinite well, step, Coulomb potential]
- Know the experimental basis of the orbital angular momentum and spin; being able to implement their basic math and physics in calculations
- Know the basic rules of the atomic transitions; be able to apply them in the spectral analysis. Understand the elements involved in the many-body physics. Ability to

qualitatively predict structure of atoms and ions and periodic table and their spectra in external magnetic and electric fields

- Have an understanding of how the quantization of crystal lattice vibrations leads to the concept of phonons and estimate their basic properties
- Have an understanding of how the periodic potential of the crystal lattice leads to the formation of delocalised electronic states. Have an understanding of the concept of crystal momentum and how this applies to the quantization of electronic states in crystals.

Delivery and Resources

Lecture materials, additional reading and assignments will be posted to iLearn

Policies and Procedures

Macquarie University policies and procedures are accessible from Policy Central. Students should be aware of the following policies in particular with regard to Learning and Teaching:

Academic Honesty Policy http://mq.edu.au/policy/docs/academic_honesty/policy.html

New Assessment Policy in effect from Session 2 2016 http://mq.edu.au/policy/docs/assessment/policy_2016.html. For more information visit http://students.mq.edu.au/events/2016/07/19/new_assessment_policy_in_place_from_session_2/

Assessment Policy prior to Session 2 2016 http://mq.edu.au/policy/docs/assessment/policy.html

Grading Policy prior to Session 2 2016 http://mq.edu.au/policy/docs/grading/policy.html

Grade Appeal Policy http://mq.edu.au/policy/docs/gradeappeal/policy.html

Complaint Management Procedure for Students and Members of the Public http://www.mq.edu.au/policy/docs/complaint_management/procedure.html

Disruption to Studies Policy http://www.mq.edu.au/policy/docs/disruption_studies/policy.html *The Disruption to Studies Policy is effective from March 3 2014 and replaces the Special Consideration Policy.*

In addition, a number of other policies can be found in the Learning and Teaching Category of Policy Central.

Student Code of Conduct

Macquarie University students have a responsibility to be familiar with the Student Code of Conduct: https://students.mq.edu.au/support/student_conduct/

Results

Results shown in *iLearn*, or released directly by your Unit Convenor, are not confirmed as they are subject to final approval by the University. Once approved, final results will be sent to your student email address and will be made available in eStudent. For more information visit ask.mq.edu.au.

Student Support

Macquarie University provides a range of support services for students. For details, visit http://students.mq.edu.au/support/

Learning Skills

Learning Skills (mq.edu.au/learningskills) provides academic writing resources and study strategies to improve your marks and take control of your study.

- Workshops
- StudyWise
- Academic Integrity Module for Students
- Ask a Learning Adviser

Student Services and Support

Students with a disability are encouraged to contact the Disability Service who can provide appropriate help with any issues that arise during their studies.

Student Enquiries

For all student enquiries, visit Student Connect at ask.mq.edu.au

IT Help

For help with University computer systems and technology, visit http://www.mq.edu.au/about_us/offices_and_units/information_technology/help/.

When using the University's IT, you must adhere to the Acceptable Use of IT Resources Policy. The policy applies to all who connect to the MQ network including students.

Graduate Capabilities

Creative and Innovative

Our graduates will also be capable of creative thinking and of creating knowledge. They will be imaginative and open to experience and capable of innovation at work and in the community. We want them to be engaged in applying their critical, creative thinking.

This graduate capability is supported by:

Learning outcomes

- Be aware of the current developments [optical lattices, condensates] and techniques. Know and be able to claculate some of the relevant processes
- Have an understanding of how the quantization of crystal lattice vibrations leads to the concept of phonons and estimate their basic properties
- Have an understanding of the electronic structure and properties of intrinsic

semiconductors. Have an understanding of the changes produced by semiconductor doping and the application of this to electronic device operation.

Assessment task

- exam

Capable of Professional and Personal Judgement and Initiative

We want our graduates to have emotional intelligence and sound interpersonal skills and to demonstrate discernment and common sense in their professional and personal judgement. They will exercise initiative as needed. They will be capable of risk assessment, and be able to handle ambiguity and complexity, enabling them to be adaptable in diverse and changing environments.

This graduate capability is supported by:

Learning outcomes

- Know the basic rules of the atomic transitions; be able to apply them in the spectral analysis. Understand the elements involved in the many-body physics. Ability to qualitatively predict structure of atoms and ions and periodic table and their spectra in external magnetic and electric fields
- Have an understanding of the electronic structure and properties of intrinsic semiconductors. Have an understanding of the changes produced by semiconductor doping and the application of this to electronic device operation.

Commitment to Continuous Learning

Our graduates will have enquiring minds and a literate curiosity which will lead them to pursue knowledge for its own sake. They will continue to pursue learning in their careers and as they participate in the world. They will be capable of reflecting on their experiences and relationships with others and the environment, learning from them, and growing - personally, professionally and socially.

This graduate capability is supported by:

Learning outcomes

- Know the basic premises of quantum mechanics. Idenetify and use standard solutions of Schrodinger equation [free, infinite well, step, Coulomb potential]
- Know the basic rules of the atomic transitions; be able to apply them in the spectral analysis. Understand the elements involved in the many-body physics. Ability to qualitatively predict structure of atoms and ions and periodic table and their spectra in external magnetic and electric fields
- Have an understanding of the electronic structure and properties of intrinsic

semiconductors. Have an understanding of the changes produced by semiconductor doping and the application of this to electronic device operation.

Assessment tasks

- assignment
- tests

Discipline Specific Knowledge and Skills

Our graduates will take with them the intellectual development, depth and breadth of knowledge, scholarly understanding, and specific subject content in their chosen fields to make them competent and confident in their subject or profession. They will be able to demonstrate, where relevant, professional technical competence and meet professional standards. They will be able to articulate the structure of knowledge of their discipline, be able to adapt discipline-specific knowledge to novel situations, and be able to contribute from their discipline to inter-disciplinary solutions to problems.

This graduate capability is supported by:

Learning outcomes

- Know the basic premises of quantum mechanics. Idenetify and use standard solutions of Schrodinger equation [free, infinite well, step, Coulomb potential]
- Know the experimental basis of the orbital angular momentum and spin; being able to implement their basic math and physics in calculations
- Know the basic rules of the atomic transitions; be able to apply them in the spectral analysis. Understand the elements involved in the many-body physics. Ability to qualitatively predict structure of atoms and ions and periodic table and their spectra in external magnetic and electric fields
- Be aware of the current developments [optical lattices, condensates] and techniques. Know and be able to clacluate some of the relevant processes
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doping and the application of this to electronic device operation.

Assessment tasks

- exam
- assignment
- tests

Critical, Analytical and Integrative Thinking

We want our graduates to be capable of reasoning, questioning and analysing, and to integrate and synthesise learning and knowledge from a range of sources and environments; to be able to critique constraints, assumptions and limitations; to be able to think independently and systemically in relation to scholarly activity, in the workplace, and in the world. We want them to have a level of scientific and information technology literacy.

This graduate capability is supported by:

Learning outcomes

- Know the basic premises of quantum mechanics. Idenetify and use standard solutions of Schrodinger equation [free, infinite well, step, Coulomb potential]
- Know the basic rules of the atomic transitions; be able to apply them in the spectral analysis. Understand the elements involved in the many-body physics. Ability to qualitatively predict structure of atoms and ions and periodic table and their spectra in external magnetic and electric fields
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Assessment tasks

- exam
- assignment

Problem Solving and Research Capability

Our graduates should be capable of researching; of analysing, and interpreting and assessing data and information in various forms; of drawing connections across fields of knowledge; and they should be able to relate their knowledge to complex situations at work or in the world, in order to diagnose and solve problems. We want them to have the confidence to take the initiative in doing so, within an awareness of their own limitations.

This graduate capability is supported by:

Learning outcomes

- Know the basic premises of quantum mechanics. Idenetify and use standard solutions of Schrodinger equation [free, infinite well, step, Coulomb potential]
- Know the experimental basis of the orbital angular momentum and spin; being able to implement their basic math and physics in calculations
- Know the basic rules of the atomic transitions; be able to apply them in the spectral analysis. Understand the elements involved in the many-body physics. Ability to qualitatively predict structure of atoms and ions and periodic table and their spectra in external magnetic and electric fields
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Assessment tasks

- exam
- assignment
- tests

Effective Communication

We want to develop in our students the ability to communicate and convey their views in forms effective with different audiences. We want our graduates to take with them the capability to read, listen, question, gather and evaluate information resources in a variety of formats, assess, write clearly, speak effectively, and to use visual communication and communication technologies as appropriate.

This graduate capability is supported by:

Assessment tasks

- exam
- assignment

Engaged and Ethical Local and Global citizens

As local citizens our graduates will be aware of indigenous perspectives and of the nation's historical context. They will be engaged with the challenges of contemporary society and with knowledge and ideas. We want our graduates to have respect for diversity, to be open-minded, sensitive to others and inclusive, and to be open to other cultures and perspectives: they should have a level of cultural literacy. Our graduates should be aware of disadvantage and social justice, and be willing to participate to help create a wiser and better society.

This graduate capability is supported by:

Learning outcome

- Have an understanding of the electronic structure and properties of intrinsic semiconductors. Have an understanding of the changes produced by semiconductor doping and the application of this to electronic device operation.

Socially and Environmentally Active and Responsible

We want our graduates to be aware of and have respect for self and others; to be able to work with others as a leader and a team player; to have a sense of connectedness with others and country; and to have a sense of mutual obligation. Our graduates should be informed and active participants in moving society towards sustainability.

This graduate capability is supported by:

Learning outcomes

- Know the basic premises of quantum mechanics. Idenetify and use standard solutions of Schrodinger equation [free, infinite well, step, Coulomb potential]
- Know the basic rules of the atomic transitions; be able to apply them in the spectral analysis. Understand the elements involved in the many-body physics. Ability to qualitatively predict structure of atoms and ions and periodic table and their spectra in external magnetic and electric fields