PHYS201

Physics IIA

S1 Day 2014

Physics and Astronomy

Contents

General Information

Unit convenor and teaching staff Unit Convenor James Cresser james.cresser@mq.edu.au Contact via james.cresser@mq.edu.au E6B2.711 Tuesday 1-5 Co-lecturer & Numerical lab supervisor Alexei Gilchrist alexei.gilchrist@mq.edu.au Contact via alexei.gilchrist@mq.edu.au E6B 2.610 Senior Scientific Officer Adam Joyce adam.joyce@mq.edu.au Contact via adam.joyce@mq.edu.au E7B 214 Laboratory Supervisor Michael Steel michael.steel@mq.edu.au Contact via michael.steel@mq.edu.au E6B 2.708 By appointment
Credit points 3
Prerequisites [(PHYS140(P) and PHYS143(P)) or (PHYS106 and PHYS107)] and (MATH133 or corequisite MATH136)
Corequisites
Co-badged status

Unit description
Harmonic oscillation and wave motion are central to many areas of physics, ranging from the mechanical vibrations of machinery and nanoscale springs, to the propagation of sound and light waves, and the probability-amplitude waves encountered in quantum mechanics. This unit is concerned with describing the properties of harmonic oscillations and wave motion. The first half of the unit covers such topics as resonance, transients, coupled oscillators, transverse and longitudinal waves. The second half looks at interference and diffraction, firstly as important properties of waves in general, and then using the interference of matter waves as the starting point in studying the dual wave-particle nature of matter and the wave mechanics of Schrodinger, the basis of modern quantum mechanics. An introduction to data acquisition software combined with further development of experimental skills such as problem solving, data analysis and report writing is catered for by regular guided laboratory sessions.

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:

- To appreciate how oscillatory dynamics is ubiquitous in the physical world and to be able to formulate a basic description of the oscillatory behaviour regardless of system.
- To understand, apply and solve the mathematical description of oscillatory behaviour including damped and driven systems.
- To understand how complex dynamics can be built from multiple coupled oscillators, and be able to analyse such dynamics.
- To understand the continuum limit of discrete oscillators as the basis of wave motion.
- To develop laboratory skills, in undertaking experiments, presenting and analysing the results and drawing conclusions based on the results
- To develop programming-based numerical skills
- To understand the dynamics and mathematical description of waves.
- Acquisition of an understanding of the wave function formalism of quantum wave mechanics and the physical motivations behind this formalism.
- Experience in applying knowledge of wave functions to solve a range of basic problems in quantum mechanics.

Assessment Tasks

Name	Weighting	Due
Final exam	40%	University Examination Period
Mid-session exam	10%	See Unit Schedule
Assignments	15%	See Unit Schedule
Laboratory workbook	20%	See Unit Schedule
Numerical lab	10%	See Unit Schedule
Tutorial exercises	5%	See Unit Schedule

Final exam

Due: **University Examination Period**
Weighting: **40%**

You should have a scientific calculator for use during the final examination. Note that calculators with text retrieval are not permitted for the final examination.

You are expected to present yourself for the final examination at the time and place designated in the University examination timetable (http://www.timetables.mq.edu.au/exam/). The timetable will be available in draft form approximately eight weeks before the commencement of examinations and in final form approximately four weeks before the commencement of examinations.

On successful completion you will be able to:

- To appreciate how oscillatory dynamics is ubiquitous in the physical world and to be able to formulate a basic description of the oscillatory behaviour regardless of system.
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- To understand how complex dynamics can be built from multiple coupled oscillators, and be able to analyse such dynamics.
- To understand the continuum limit of discrete oscillators as the basis of wave motion.
- To understand the dynamics and mathematical description of waves.
- Acquisition of an understanding of the wave function formalism of quantum wave mechanics and the physical motivations behind this formalism.
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Mid-session exam

Due: **See Unit Schedule**
Weighting: **10%**

A one hour exam at the end of the first part of the unit on oscillations and waves

On successful completion you will be able to:

- To appreciate how oscillatory dynamics is ubiquitous in the physical world and to be able to formulate a basic description of the oscillatory behaviour regardless of system.
- To understand, apply and solve the mathematical description of oscillatory behaviour including damped and driven systems.
- To understand how complex dynamics can be built from multiple coupled oscillators, and be able to analyse such dynamics.
- To understand the continuum limit of discrete oscillators as the basis of wave motion.
- To understand the dynamics and mathematical description of waves.

Assignments

Due: **See Unit Schedule**
Weighting: **15%**

As for all physics units, problem solving is an essential aid to understanding the physical concepts involved. Students will be given extended problem lists so that they can work through a full range of problems. Regular assignments will be set from these lists and the problems marked and returned. These assignment marks count as 15% of the final assessment. The assignment record will be used when considering requests for special consideration. Informal group discussion regarding the assignment problems is encouraged, but students should present their own solutions and should explicitly acknowledge those they have worked with on the assignment. You should also note that the examination in general contains material related to the assignment work.

On successful completion you will be able to:

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- To understand how complex dynamics can be built from multiple coupled oscillators, and be able to analyse such dynamics.
- To understand the continuum limit of discrete oscillators as the basis of wave motion.
- To understand the dynamics and mathematical description of waves.

- Acquisition of an understanding of the wave function formalism of quantum wave mechanics and the physical motivations behind this formalism.
- Experience in applying knowledge of wave functions to solve a range of basic problems in quantum mechanics.

Laboratory workbook

Due: **See Unit Schedule**
Weighting: **20%**

Second Year Physics Laboratories

These are found in E7B217. You should enter from the northern verandah on the second level of E7B. Lab classes will be held on Wednesday from 10 am to 1 pm, and 2 pm to 5 pm.

Laboratory Timetable and Procedures

The laboratory component of this unit consists of four one-week experiments illustrating oscillations in mechanical and electrical systems, and a three week introduction to using LabVIEW, a commercial software package used for computer control and data logging in experimental contexts, followed by a LabVIEW project utilising the knowledge gained in the final week.

The first group of four will be completed in weeks 3, 4, 5 & 6. The second group of experiments will be completed in weeks 9, 10, 11 & 12 of the semester. Note the two week break during semester one occurs between weeks 6 & 7.

Completing all laboratory classes is a compulsory component of the unit. You are not required to attend the laboratory in weeks when no lab is scheduled. If you miss a laboratory experiment session due to illness or misadventure, and can substantiate this with a medical certificate or other formal documentation, it should be possible to arrange a make-up session for the laboratory. For the four weeks of LabVIEW exercises this is best done in the same week, as the whole class is working through the exercises in parallel, with an instructor.

First group of experiments

Week 3 & 4 Exp 1 & Exp 2 Coupled oscillators (2 weeks) Week 5 Exp 3 The mechanical oscillator
Week 6

Exp 4 Resonance and Q in electric circuits
Second group of experiments LabVIEW

The LabVIEW software suite will be taught over a four week period. The first three weeks will introduce most the commonly used objects in LabVIEW with examples to help the students grasp the functionality of the software. The last week will be spent completing exercises on their own with help from the demonstrator.

Week 9
Introduction and Data Acquisition

Week 10
Using Loops and Analysing/Logging Data

Week 11
Waveforms, Error Clusters and Simple State Machine

Week 12 Exercises
Laboratory Notebook

Each **experiment** will be recorded in a **laboratory notebook which you must provide for the first laboratory session** and which will be left with the laboratory supervisor at the end of each session. This should have alternate pages for writing and graphical representations. The record of each experiment in this book will be marked each week and the marks from the first 4 week cycle will make up half of the grade for the laboratory section of the unit (each lab report contributes ~2% of the unit's total grade). The record in your laboratory notebook may be brief, but must include:

- Title of the experiment,
- Date performed and name of partner,
- Aims and Methods of the Experiment Results,
- Calculations, graphs, error estimates etc.,
- Comparison with theory, as necessary.
- The answers to any questions found in the notes and any comments that you think may help yourreport and clarify matters for the marker.

We ask you to write your reports with proper sentences and paragraphs. You should also pay special attention to details such as measurement uncertainties, labelling axes of graphs, using appropriate headings and tabulating results.

For the **LabVIEW Exercises** assessment will be based on:

- Activity (you work through the exercises as defined),
- Your written work to demonstrate understanding and knowledge of concepts and terms and
- Your LabVIEW program from the last week. You will be given one overall mark for LabVIEW which will make up the other half of assessing the laboratory section of the unit (10% of the total grade for the unit).

The Laboratory demonstrators will also meet briefly, during the lab period, with each student every two weeks for a short period (~5-minutes), to discuss their progress, and in particular, to discuss their development in executing laboratory experiments and in their notebook writeups. This will help the student understand better any assessment comments made in their notebooks or advice on their performance of the experiments.

Laboratory Safety

A condition of entry to the laboratory is thorough knowledge of the safety requirements in the laboratory. Students should revise these and they should be observed during all laboratory sessions. The safety aspects of the laboratory can be found in the front of the PHYS 201 **Laboratory Notes 2010** and also on posters in the laboratory.

On successful completion you will be able to:

- To appreciate how oscillatory dynamics is ubiquitous in the physical world and to be able to formulate a basic description of the oscillatory behaviour regardless of system.
- To develop laboratory skills, in undertaking experiments, presenting and analysing the results and drawing conclusions based on the results

Numerical lab

Due: **See Unit Schedule**
Weighting: **10%**

The numerical lab will introduce students to the modern programming language Python and to scientific numerical modelling. In each laboratory session the students will work through an interactive worksheet which will introduce them to various techniques and pose some exercises to complete. The completed worksheets are to be handed in for assessment at the end of each lab.

On successful completion you will be able to:

- To understand, apply and solve the mathematical description of oscillatory behaviour including damped and driven systems.
- To develop laboratory skills, in undertaking experiments, presenting and analysing the results and drawing conclusions based on the results
- To develop programming-based numerical skills

Tutorial exercises

Due: **See Unit Schedule**
Weighting: **5%**

As part of the weekly tutorials, students will be required to write out, and hand in, the solution of a randomly chosen problem drawn from a weekly collection of solved problems. The balance of the tutorial will be used to discuss other problems and answer student questions about lecture material.

On successful completion you will be able to:

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- To understand, apply and solve the mathematical description of oscillatory behaviour including damped and driven systems.

- To understand how complex dynamics can be built from multiple coupled oscillators, and be able to analyse such dynamics.
- To understand the continuum limit of discrete oscillators as the basis of wave motion.
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- Experience in applying knowledge of wave functions to solve a range of basic problems in quantum mechanics.

Delivery and Resources

Technology used and required

Unit web page

The web page for this unit can be found at http://ilearn.mq.edu.au

Please check this web page regularly for announcements and material available for downloading. Some learning resources for the unit will be provided in hardcopy rather on-line.

Required and Recommended Texts and/or Materials

Text: There is no one textbook that sufficiently covers the material in this course.

Recommended Reading:

1. The Physics of Vibrations and Waves, Sixth Edition; H.J. Pain, Wiley (2005)

2. The Feynman Lectures on Physics, Vol. 1, R.P. Feynman, R.B. Leighton and M. Sands (QC23.F47)

3. Vibrations and Waves in Physics, Second Edition, I.G. Main, Cambridge University Press (QC136.M34)

4. Oscillations and Waves, R. Buckley, Adam Hilger (1985) (QC157.B82).

5. Vibrations and Waves, A.P. French, Norton (1971) (QC235.F74).

6. Wave Physics, R.E.I. Newton, Edward Arnold (QC157.N48).

7. The Physics of Vibrations and Waves, Fourth Edition, H.J. Pain, Wiley (1993) QC231.P3/1993.

8. The Physics of Vibrations and Waves, Fifth Edition, H.J. Pain, Wiley (1999)QC231.P3/1999.

9. Fundamentals of Optics, F.A. Jenkins and H.E. White, McGraw-Hill (QC355.2.J46).

10. Optics, E. Hecht, Addison-Wesley (QC355.H42).

Teaching and Learning Strategy

This unit is taught through lectures and tutorials. We strongly encourage students to attend lectures because they provide a much more interactive and effective learning experience than studying a textbook. Questions during and outside lectures are strongly encouraged in this unit - please do not be afraid to ask, as it is likely that your classmates will also want to know the answer. You should aim to read the relevant sections of the textbook before and after lectures and discuss the content with classmates and lecturers.

You should aim to spend 3 hours per week working on the assignments. You may wish to discuss your assignment problems with other students and the lecturers, but you are required to hand in your own work (see the note on plagiarism below). Assignments are provided as one of the key learning activities for this unit, they are not there just for assessment. It is by applying knowledge learned from lectures and textbooks to solve problems that you are best able to test and develop your skills and understanding of the material.

The experimental aspects of the unit require students to attend laboratories where they will be expected to set up experiments, take data, analyse the data within the context of the physical phenomena that are being studied, maintain a laboratory log-book, and report on their findings in clearly written laboratory reports.

Changes since the last offering of this unit

- Inclusion of numerical lab work
- Removal of special laboratory report
- Introduction of a mid-session exam on first half of unit

Unit Schedule

Schedule of assessable tasks and related materials

Assignments

The assignments will be handed out according to the following approximate timetable

Assignment No.	Date available on iLearn	Date due
1	Monday 3 Mar Week 1	Monday 17 Mar Week 3
2	Monday 24 Mar Week 4	Monday 7 Apr Week 6
3	Monday 28 Apr Week 7	Monday 12 May Week 9
4	Monday 12 May Week 9	Monday 26 May Week 11
5	Monday 26 May Week 11	Monday 9 June Week 13

Students who have entered this unit with a waiver of prerequisites must hand in their assignments as required. No further concessions or assistance can be offered to these students if they fail to work as expected.

Lecture schedule

Schedule..	Lecturer	Topic
Weeks 1-2	Alexei Gilchrist	Examples of the use of the physics covered in this unit in modern contexts, including nanoscience. General overview of weeks 1-4. Simple harmonic motion, energy of oscillations, superposition.
Weeks 2-3	Alexei Gilchrist	Damped harmonic motion
Weeks 3-4	Alexei Gilchrist	Forced oscillation, resonance.
Week 5	Alexei Gilchrist	Coupled oscillations.
Weeks 6-7	Alexei Gilchrist	Transverse wave motion, wave equations and solutions, reflection and transmission at boundaries. Standing waves, wavegroups, group velocity, bandwidth theorem.
Weeks 7-8	James Cresser	Interference from 2 sources, Polar plots, 2 slit interference (Young's interference), interference from a linear array of N equal sources.
Week 9	James Cresser	Huygens wavelets and Huygens-Fresnel Principle, Fraunhofer diffraction through a slit.
Week 10	James Cresser	Einstein-de Broglie equations, the wave function, Uncertainty principle, size of H atom
Week 11	James Cresser	2 slit interference and wave-particle duality, the Born probability interpretation of the wave function, probability theory interlude.
Week 12	James Cresser	Infinite 1-D potential well, Schrödinger's wave equation.
Week 13	James Cresser	Harmonic oscillator, potential step.

Laboratories

The laboratory sessions are held in E7B217 on Wednesday 10 am to 1 pm and 2pm to 5pm in weeks 3 to 6 and weeks 9 to 12. The experiments are separated into two kinds, as described below.

First group of experiments

Week 3 & 4	Exp 1 & Exp 2	Coupled oscillators (2 weeks)
Week 5	Exp 3	The mechanical oscillator
Week 6	Exp 4	Resonance and Q in electric circuits

Second group of experiments LabVIEW

The LabVIEW software suite will be taught over a four week period. The first three weeks will introduce most the commonly used objects in LabVIEW with examples to help the students grasp the functionality of the software. The last week will be spent completing exercises on their own with help from the demonstrator.

Week 9	Introduction and Data Acquisition
Week 10	Using Loops and Analysing/Logging Data
Week 11	Waveforms, Error Clusters and Simple State Machine
Week 12	Exercises

Numerical laboratory

The classes are held in E7B217 at the same time as the laboratory classes are scheduled. They will be held in weeks 2, 7, 8 and 13.

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

Assessment Policy http://mq.edu.au/policy/docs/assessment/policy.html

Grading Policy http://mq.edu.au/policy/docs/grading/policy.html

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

Grievance Management Policy http://mq.edu.au/policy/docs/grievance_management/policy.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/

Student Support

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

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

Graduate Capabilities

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 outcome

- To develop laboratory skills, in undertaking experiments, presenting and analysing the results and drawing conclusions based on the results

Assessment task

- Mid-session exam

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

- To appreciate how oscillatory dynamics is ubiquitous in the physical world and to be able to formulate a basic description of the oscillatory behaviour regardless of system.
- To understand, apply and solve the mathematical description of oscillatory behaviour including damped and driven systems.
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- Experience in applying knowledge of wave functions to solve a range of basic problems in quantum mechanics.

Assessment tasks

- Final exam
- Mid-session exam
- Assignments
- Laboratory workbook
- Numerical lab
- Tutorial exercises

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

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Assessment tasks

- Final exam
- Mid-session exam
- Assignments
- Laboratory workbook
- Numerical lab
- Tutorial exercises

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

- To appreciate how oscillatory dynamics is ubiquitous in the physical world and to be able

to formulate a basic description of the oscillatory behaviour regardless of system.
- To understand, apply and solve the mathematical description of oscillatory behaviour including damped and driven systems.
- To understand how complex dynamics can be built from multiple coupled oscillators, and be able to analyse such dynamics.
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Assessment tasks

- Final exam
- Mid-session exam
- Assignments
- Laboratory workbook
- Numerical lab
- Tutorial exercises

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

- To appreciate how oscillatory dynamics is ubiquitous in the physical world and to be able to formulate a basic description of the oscillatory behaviour regardless of system.
- To understand, apply and solve the mathematical description of oscillatory behaviour including damped and driven systems.
- To understand how complex dynamics can be built from multiple coupled oscillators, and be able to analyse such dynamics.
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Assessment tasks

- Final exam
- Mid-session exam
- Assignments
- Laboratory workbook
- Numerical lab
- Tutorial exercises

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

- To appreciate how oscillatory dynamics is ubiquitous in the physical world and to be able to formulate a basic description of the oscillatory behaviour regardless of system.
- To understand, apply and solve the mathematical description of oscillatory behaviour including damped and driven systems.
- To develop laboratory skills, in undertaking experiments, presenting and analysing the results and drawing conclusions based on the results
- To understand the dynamics and mathematical description of waves.
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- Experience in applying knowledge of wave functions to solve a range of basic problems in quantum mechanics.

Assessment tasks

- Final exam
- Mid-session exam

- Assignments
- Laboratory workbook

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:

Learning outcome

- To develop laboratory skills, in undertaking experiments, presenting and analysing the results and drawing conclusions based on the results

Assessment tasks

- Final exam
- Mid-session exam
- Assignments
- Laboratory workbook
- Tutorial exercises

Feedback

Student Liaison Committee

The Physics Department values quality teaching and engages in periodic student evaluations of its units, external reviews of its programs and course units, and seeks formal feedback from students via focus groups and the Student Liaison Committee. Please consider being a member of this committee, which meets once during the semester (lunch provided), with the purpose of improving teaching via student feedback. The class will be asked to nominate two students as representatives for the PHYS201 unit on the student liaison committee. This nomination process will be conducted during lectures and the lecturer will forward the names to the Head of Department. The SLC meetings are minuted and student representatives receive copies of the minutes from the two preceding SLC meetings prior to the meeting. An update on the responses that have been made by the department to the feedback obtained at the two preceding SLC meetings are reported by the Head of Department at the beginning of each SLC meeting. These responses are also minuted. The feedback is acted upon in a number of ways mostly initiated via Department of Physics and Astronomy meetings, where decisions on actions are taken.

Prizes

The Dick Makinson prize is awarded for proficiency in 200-level units in physics (including certain 200-level electronics units) totalling no less than 9 credit points. All students (day, part time or evening) are eligible for the prize. The Makinson prize takes the form of a certificate and cheque for

$150.

Requirements in order to complete the unit satisfactorily

To pass the course unit you must:

- achieve a satisfactory standard overall
- achieve a satisfactory standard in each component of the unit, i.e. in waves & oscillations, in interference and diffraction and wave mecahnics, and in the laboratory work.

Standards Expectation

Grading

An aggregate standard number grade (SNG) corresponding to a pass (P) is required to pass this unit.

High Distinction (HD, 85-100%): provides consistent evidence of deep and critical understanding in relation to the learning outcomes. There is substantial originality and insight in identifying, generating and communicating competing arguments, perspectives or problem solving approaches; critical evaluation of problems, their solutions and their implications; creativity in application.

Distinction (D, 75-84%): provides evidence of integration and evaluation of critical ideas, principles and theories, distinctive insight and ability in applying relevant skills and concepts in relation to learning outcomes. There is demonstration of frequent originality in defining and analysing issues or problems and providing solutions; and the use of means of communication appropriate to the discipline and the audience.

Credit (Cr, 66-74%): provides evidence of learning that goes beyond replication of content knowledge or skills relevant to the learning outcomes. There is demonstration of substantial understanding of fundamental concepts in the field of study and the ability to apply these concepts in a variety of contexts; plus communication of ideas fluently and clearly in terms of the conventions of the discipline.

Pass (P, 50-65%): provides sufficient evidence of the achievement of learning outcomes. There is demonstration of understanding and application of fundamental concepts of the field of study; and communication of information and ideas adequately in terms of the conventions of the discipline. The learning attainment is considered satisfactory or adequate or competent or capable in relation to the specified outcomes.

Fail (F, 0-49%): does not provide evidence of attainment of all learning outcomes. There is missing or partial or superficial or faulty understanding and application of the fundamental concepts in the field of study; and incomplete, confusing or lacking communication of ideas in ways that give little attention to the conventions of the discipline.

Changes since First Published

Date	Description
13/04/2014	Michael Withford as laboratory supervisor has been replaced by Michael Steel