The University of Sydney
AUSTRALIA

School of Physics

INTERMEDIATE PHYSICS
SECOND SEMESTER, 2009

PHYS 2213 PHYSICS 2EE HANDBOOK

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TABLE OF CONTENTS

1 GENERAL INFORMATION

1.1 UNIT DESCRIPTION

PHYS 2213 is a six credit point unit of study, designed as a course in Intermediate Physics for students in the Faculty of Engineering. The unit is split into four modules: (i) lectures in Optics; (ii) lectures in Electromagnetic Properties of Matter; (iii) lectures in Solid State and Device Physics; (iv) sessions on computational optics in the Computational Physics Laboratory.

1.2 ENTRY REQUIREMENTS

The Prerequisites are PHYS 1001 (or 1901) and PHYS 1003 (or 1902). The Assumed Knowledge is MATH 1001 (or 1901), 1002 (or 1902), 1003 (or 1903). MATH 1005 (or 1905) would also be useful.

1.3 SENIOR PHYSICS

Students taking PHYS 2213 and who may wish to take Senior Physics should see the Senior Physics Coordinator. The prerequisites for most Senior Physics units are PHYS 2911/2011 and PHYS 2912/2012, but any students intending to major in Physics are encouraged to take PHYS 2913/2013 as well. Senior Physics also assumes knowledge of Intermediate mathematics. See the Senior Physics web pages[1] for more details.

1.4 REGISTRATION

You will be registered at the first Computational Physics session (in the second week of the semester). If you have not been assigned a session or there is an unresolved conflict in your timetable, attend the earliest session you can.

1.5 LECTURE ARRANGEMENTS

All Intermediate Physics lectures and computational physics sessions are held in the School of Physics. Room assignments are shown in the timetable in section 4. Please check the notice boards (next section) for any last minute changes.

Physics Lecture theatres are located as follows:-

- Lecture Theatre 1 (LT1) Eastern end level 4
- Computational Physics Lab (Rm 359) Western ('downhill') end level 3, far end of corridor.

1.6 INFORMATION ABOUT INTERMEDIATE PHYSICS

The Intermediate Physics noticeboard is located outside the Physics Student Support Office (Rm 202, Eastern end of level 2 - street level). Please check this notice board regularly for important information.

The 'Information for Undergraduate Students' link on the School of Physics web page[2] provides resources to help you with your studies. Please spend time getting acquainted with this site, and the specific page relative to this unit of study. Unit webpages are provided

[1] http://www.physics.usyd.edu.au/current/spc.shtml

[2] http://www.physics.usyd.edu.au/current/undergrad_info.shtml

under the University's WebCT environment, which can be accessed from the Intermediate Physics webpages[3] or the USYDnet site[4]. Access requires a Unikey (Extro account) Username and Password that is issued with your confirmation of enrolment. The University provides computer facilities in the Access Centres[5]. A brief introduction to web access is available on the Intermediate Physics web page.

1.7 CONSULTATION

Students who have general questions about the unit should ask at the Student Support Office. If necessary, questions about organisation and administration may be referred to the Coordinator of Intermediate Physics.

Questions about specific lecture modules should be directed to the lecturer concerned. Questions about computational laboratory matters should be directed to your laboratory supervisor in the first instance.

1.8 PRINTED NOTES

It is highly recommended that each student of PHYS2213 purchase the current edition of 'PHYS 2213 Computational Physics Engineering Optics Notes'. Copies of these notes are available at the University Copy Centre.

Other materials (lecture handouts, assignment questions and solutions) may be handed out during lectures and will subsequently be available on WebCT and request from Undergraduate Physics Office (room 202). There is no charge for these materials.

Some more extensive lecture notes, in particular, the booklet 'PHYS 2213 Physical Optics Notes', will be sold through the University Copy Centre.

2 ASSESSMENT OF THE UNIT OF STUDY

2.1 ASSESSMENT

This unit is assessed through an examination, assignments throughout the semester, a poster, participation in computational physics sessions and a computational test at the end of the semester. Proof of identification is required at all examinations.

Except where otherwise noted, candidates will not be allowed to bring books or papers into the examination room. Examinations however are not meant to be tests of rote memorisation, and formula and data sheets will normally be included in the examination papers. Copies of these will be provided towards the end of the semester.

A preliminary examination timetable is released late in each semester and students are asked to report all clashes to the Student Centre (in the Carslaw Building). The final timetable may differ from the preliminary one and it is each student's responsibility to determine the date, time and location of their scheduled examinations.

The weighting of the assessments in the various components of the unit to the final mark is as follows:-

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[3] http://www.physics.usyd.edu.au/current/ipc.shtml
[4] http://myuni.usyd.edu.au
[5] http://www.usyd.edu.au/ict/switch/labs/index.shtml

Examination (3 hour paper):		
	Optics	40
	Electromagnetic Properties of Matter	40
	Solid State and Device Physics	40
Assignments:		15
Computational Physics:		50
Maximum Total:		**185**

The final marks and merit grades are determined, allowing scaling of marks from separate modules, to take into account the class average of Annual Average Mark (AAM). The minimum Pass mark is never more than 50% of the final scaled mark.

2.2 ASSIGNMENTS

There will be one assignment from each of the two lecture modules Optics, and Electromagnetic Properties of Matter and a poster from the third lecture module Solid State and Device Physics. Assignment questions and specifications for the poster will be handed out in lectures, and each assignment will normally contain four questions. Students will submit individual assignments. Even though students may work in groups on solving the problems, the individually submitted answers must include explanations of how each individual has understood the problem and its solution.

Each handed in assignment must have a cover page, which may be obtained from the Physics Student Support office (Room 202, Physics building). In signing the cover sheet, each student is confirming awareness of the University's policy on plagiarism and academic honesty[6], and agreement to comply with that policy.

Assignments will be handed in at the Student Support Office. The poster (MS PowerPoint file) has to be sent to the lecturer via e-mail. **Late assignments and poster will not be marked.** Attendance of the last lecture is mandatory, as the posters will be presented and assessed during that lecture.

Your answers must identify the key physical principles; marks will not be awarded for simply putting numbers into formulae without explanation. Model solutions to all the questions or problems will be posted on the unit WebCT pages when the marked assignments are returned.

Assignments will be handed back in computational laboratory sessions. The poster will be returned in the last lecture that is mandatory.

2.3 CONSIDERATION OF FACTORS AFFECTING YOUR STUDY

If your academic performance in a Science Faculty unit of study is adversely affected by illness or some other serious event, such as an accident, you should notify the Faculty of Science Student Information Office (level 2 of the Carslaw building) within 7 days after the period for which consideration is sought, by completing an Application for Special Consideration with accompanying documentation. This is especially important if you miss an examination.

If you have another reason for the Science Faculty to take account of your circumstances - religious commitments, legal commitments (e.g. Jury duty), elite sporting or cultural commitments (representing the University, state or country), or Australian Defence Force

[6] http://www.usyd.edu.au/senate/policies/Plagiarism.pdf

commitments (e.g. Army Reserve) - you should notify the Faculty of Science Student Information Office (level 2 of the Carslaw building) at least 7 days BEFORE the period for which consideration is sought, by completing an Application for Special Arrangements with accompanying documentation.

These two forms of Consideration should cover most allowable circumstances. However, if you have another reason for requiring the School of Physics to take account of your circumstances, you should notify the School of Physics Student Office (room 202 in the Physics building) beforehand (or at the latest within 7 days afterwards), by completing an Application for Consideration of Special Circumstances by Physics with accompanying documentation.

You should not submit an application of any type if

* there is no assessment associated with a missed class, or

* you have a reasonable opportunity to make up any work you missed.

If, for example, you miss an assignment, an application for appropriate Consideration is required to allow late submission, but we do expect the assignment to be submitted. Sometimes catching up may be impossible, in which case we will consider a pro-rata adjustment of your marks on the basis of an application for Consideration.

2.3.1 SPECIAL CONSIDERATION OR SPECIAL ARRANGEMENTS

To submit an application for Special Consideration or Special Arrangements you should:

1. Obtain the appropriate Application pack from the Student Information Office of the Faculty of Science, the Faculty website[7], or the Physics Student Office.

2. Complete the forms and obtain whatever original documentary evidence is appropriate. Note especially that the Professional Practitioner's Certificate is essential for Special Consideration on grounds of serious illness - Medical Certificates will NOT be accepted.

3. Take the original copy of all forms and documents, plus sufficient copies for each unit of study affected and yourself, to the Faculty of Science Student Information Office (NOT any other Faculty Office if you are seeking Consideration in a unit taught by Physics). They will sign/stamp both the original application form and the copies. In the case of Physics units, one copy of the documentation must then be submitted to the Physics Student Office. Keep one copy yourself. A formal decision on your application will be sent to your university email address within 14 days.

Further details on University policy regarding Considerations can be found in policy documents entitled Assessment and Examination at the University Policy web site[8].

2.3.2 CONSIDERATION BY PHYSICS

An application for Consideration by Physics requires you to:

1. Obtain an Application for Consideration of Special Circumstances by Physics from the School of Physics Student Office or the Physics web page[9].

2. Complete the form and obtain whatever original documentary evidence is appropriate.

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[7] http://www.science.usyd.edu.au/cstudent/ug/forms.shtml

[8] http://www.usyd.edu.au/policy/

[9] http://www.physics.usyd.edu.au/pdfs/local/consideration.pdf

3. Take the original copy of the form and supporting documents, plus a copy for yourself, to the Physics Student Office. They will sign/stamp both the original application form and the copy. A formal decision on your application will be sent to your university email address within 14 days.

Students unsure what type of Consideration is appropriate, or unhappy with a Consideration decision, should consult the Physics Student Office.

It is important to realise that the policies on Special Consideration apply throughout the University. Policies on other forms of Consideration are specific to Physics and may be different in Departments responsible for your other units of study.

3 GENERAL AIMS OF THE UNIT OF STUDY

This 6 credit point unit of study is made up of four modules:

- Optics lectures
- Electromagnetic properties of matter lectures
- Solid State and Device Physics lectures
- Computational Physics sessions on Optics

The aims and specific objectives of the modules are linked to the required generic attributes of graduates of the University in knowledge skills (in optics, electromagnetism and solid state and device physics), thinking skills (the analysis of problems in physics), personal skills and attributes (the ability to work independently and in groups), and practical skills (the use of computers).

By the end of the unit, students are expected to know:

- how to describe and apply the theory of light as electromagnetic radiation
- how to describe and apply the theory of electromagnetic properties of matter
- how to describe and apply the theory of solid state and device physics
- how to use computational software to model optical systems on a computer

Specific objectives of the modules making up this unit of study are given below.

4 TIMETABLE PHYS 2213 Physics 2EE Semester 2, 2009

Monday date	**Lecture** Lecture Theatre 1 (LT 1)			**Computational Physics**
	Tues 12 noon	Wed 12 noon	Fri 11am	Tues 1-3pm Thurs 11a-1p
27 Jul 2009	OPT-1	OPT-2	OPT-3	No class
03 Aug 2009	OPT-4	OPT-5	OPT-6	Set 1
10 Aug 2009	EMP-1	EMP-2	EMP-3	Set 1
17 Aug 2009	EMP-4	EMP-5	EMP-6	Set 2
24 Aug 2009	No class	No class	No class	Set 2
31 Aug 2009	EMP-7	EMP-8	EMP-9	Set 3
07 Sep 2009	EMP-10	EMP-11	EMP-12	Set 3
14 Sep 2009	OPT-7	OPT-8	OPT-9	Set 4
21 Sep 2009	OPT-10	OPT-11	OPT-12	Set 4
28 Sep 2009	MSB	MSB	MSB	MSB
05 Oct 2009	SSD-1	SSD-2	SSD-3	No class
12 Oct 2009	SSD-4	SSD-5	SSD-6	Review
19 Oct 2009	SSD-7	SSD-8	SSD-9	Exam
26 Oct 2009	SSD-10	SSD-11	SSD-12	

MSB Mid Semester Break
OPT Optics lectures
EMP Electromagnetic properties of matter lectures
SSD Solid State and Device Physics lectures
Note: Public holiday on Monday 5 October

Computational Physics (Optics). You will be assigned one 2-hour session per week, in the Computational Physics Laboratory (Physics room 359)

5 PHYS 2213 2EE MODULE DESCRIPTIONS

5.1 INTRODUCTION

For each module we have defined broadly what we expect you to learn and understand. Understanding implies that you should be able to discuss and explain fundamental concepts and principles including examples of their application.

Understanding in the lecture modules on Optics, Electromagnetic Properties of Matter, and Solid State and Device Physics will be tested in the end of semester examination by asking you to write descriptive answers to qualitative questions and by evaluating your explanations of physical principles and reasoning in answers to quantitative questions. Ability to memorise formulae and manipulate them without understanding the associated physics will not be rewarded.

Specific objectives define what you should learn and understand about the detailed content of each part of the module. Understanding a term or concept means that you should be able to:

- explain its meaning in writing and give examples,
- interpret it correctly when you read or hear it,
- use it correctly in your own writing,
- apply it correctly to examples and problems.

The lecture modules and the computational physics modules are now described.

5.2 MODULE 1: OPTICS

The **12 lectures** will be given by Dr David Moss.

This module is linked in subject matter to the Computational Physics module.

5.2.1 TEXT

The module is defined by a set of comprehensive lecture notes ('PHYS 2213: Physics 2EE Physical Optics Notes') available from the Copy Centre. The notes are constructed around technological devices but a useful reference for the optical principles discussed is "Optics" by Hecht and Zajac, published by Addison Wesley. The lecture notes contain formulas as will be required in the examination paper. A sheet of formulas will be provided in the exam but you only use this to jog your memory as no explanation of the formulas will be provided. The notes contain 32 problems which will augment the understanding gained through reading the notes. A thorough understanding of notes, assignment and solutions to the problems will provide a good basis for tackling the exam questions. Everything in the notes or said in class is examinable.

5.2.2 ASSIGNMENTS

There will be one assignment for the module, as described above in Section 2.2.

5.2.3 ASSESSMENT

Assessment is by examination of material presented in class and by assignment (see section 2.1).

5.2.4 SPECIFIC OBJECTIVES

The Laser
Lecture Notes Section: 1.2
Specific Objectives – after studying this part you will be able to:

- Discuss the advantages of a laser light source over an incoherent source
- Understand the characteristic of stimulated and spontaneous light emission
- Understand the conditions necessary for light amplification
- Discuss the role of a resonator in lasing
- Discuss laser threshold and the laser output characteristic
- Describe the essential elements of a semiconductor laser

Superposition of Light
Lecture Notes Section: 1.3
Specific Objectives – after studying this part you will be able to:
- Outline how the bumps on a CD encode information
- Write down the equation of a simple harmonic light wave and define the parameters appearing in it
- Understand the relationship between the speed, wavelength and frequency of a light wave and the concept of refractive index
- Convert wavelength to frequency differences using a linear approximation
- Understand and apply Optical Path Length (OPL)
- Understand and discuss the Principle of Superposition – Constructive and Destructive Interference
- Discuss single layer reflection and anti-reflection coatings and be able to relate the thickness of such a film to the refractive indices of the coating and coated material and to the wavelength of incident light
- Discuss how the wavelike nature of light allows extraction of the information encoded on the CD surface

Lens Equation
Lecture Notes Section: 1.4
Specific Objectives – after studying this part you will be able to:
- Understand the use of the simple lens equation and magnification formula
- Be familiar with the key results obtained from the lens formula – focusing parallel rays, 1:1 imaging, magnification and demagnification.
- Understand the most significant lens aberrations and astigmatism

Propagation of Light - Interference and Diffraction
Lecture Notes Sections: 1.5
Specific Objectives – after studying this part you will be able to:
- Describe the phenomenon of diffraction and discuss its relationship to interference
- State Huygens's Principle and understand how it may be applied to the propagation of light
- Understand how Huygens's Principle may be applied and describe the phenomena associated with the double slit experiment
- Apply the formula determining the position of light and dark fringes on a screen for the double slit experiment
- Recognise the diffraction pattern for a circular aperture and be able to draw the intensity distribution pattern illustrating the relative scales of the central and secondary maxima
- Understand the dependence of the diffraction pattern on the wavelength of light
- Understand how diffraction at an aperture affects the resolving power of instruments and the diameter of the focal spot of a coherent light beam
- Understand how a diffraction grating generates an array of light beams
- Apply the formula to describe the angular separation of the diffraction orders

Polarisation

Lecture Notes Section: 1.6

Specific Objectives – after studying this part you will be able to:

- Define what is meant by unpolarised, plane polarized and circularly polarised light
- Describe how plane polarised light can be produced from unpolarised light by reflection and scattering
- Define and calculate the Brewster angle given the refractive indices either side of a boundary between two media
- Describe how circularly polarised light may be produced
- Describe both a quarter wave and half wave plate and compute the required thickness given the refractive indices for the fast and slow axes

Optical Fibres

Lecture Notes Sections: 2.1

Specific Objectives – after studying this part you will be able to:

- Understand the motivation for the use of optical fibres for communications
- Understand the concept of Bandwidth and Attenuation
- Apply the formula for signal attenuation
- Understand Total Internal Reflection (TIR), critical angle and apply the formula to calculate critical angle
- Understand the concept of an evanescent light field
- Apply total internal reflection to the guiding of light in fibres
- Be able to describe and explain the construction of a modern index guiding optical fibre
- Understand the concept of and calculate Numerical Aperture
- Describe how optical fibres are made
- Understand the various loss mechanisms in optical fibres
- Understand the concept Dispersion and the various types thereof
- Be able to calculate the dispersion of a pulse
- Understand the basic concept of a mode and be able to calculate both cutoff for an optical fibre as well as the number of supported modes

Optical Fibre Bragg Gratings

Lecture Notes Sections: 2.2

Specific Objectives – after studying this part you will be able to:

- Understand how a standing wave of light can modulate in the refractive index of a fibre
- Describe how the periodic modulation causes a resonant reflection of light
- Apply the formula relating the Bragg wavelength to the period of the modulation
- Describe Sidelobes and the effect of Apodisation
- Apply the formula to give the strength of a uniform grating
- Be able to express reflection and absorption on a dB scale
- Understand the relationship between grating strength, length and bandwidth
- Be able to calculate the bandwidth of a grating
- Describe the use of a fibre Bragg grating as a sensor and dispersion compensator
- Be able to calculate the dispersive properties of a grating

Mach Zehnder Modulator – Interferometers and Electro-optic Effect

Lecture Notes Sections: 2.3

Specific Objectives – after studying this part you will be able to:

- Draw the topology of the Mach Zehnder interferometer
- Understand the conditions for bright and dark fringes
- Be able to apply the formula for fringe brightness as a function of path length difference
- Understand the impact of the environment on the stability of interferometers and how that may be minimized through the application of common mode rejection (CMR)

- Understand the concept of temporal coherence
- Be able to calculate the coherence length and time of a source
- Understand the relationship between linewidth and coherence
- Understand the electro-optic effect and Pockels effect
- Outline other ways of affecting light through application of fields to crystals
- Understand the concept of phase matching

5.3 MODULE 2: ELECTROMAGNETIC PROPERTIES OF MATTER

The **12 lectures** will be given by Prof. Marcela Bilek.

5.3.1 TEXT

There is no single readily available text which treats this subject at the appropriate level for this course. Reference sections refer to Young and Freedman, "University Physics (with Modern Physics)", 11th edition, published by Addison-Wesley. The course notes referred to will consist of copies of the lecture slides plus additional notes provided by the lecturer. The text "Fundamentals of Electricity and Magnetism" (2nd Ed) by A. Kip is a useful reference, and several copies are available in the Madsen library.

5.3.2 ASSIGNMENTS

There will be one assignment for the module, as described above in Section 2.2.

5.3.3 SPECIFIC OBJECTIVES

The following specific objectives of this module will be tested by qualitative and quantitative questions in the written examination and the assignment.

Electrostatics, Gauss's Law, Electric Potential
Reference sections: 23-5, plus some revision of content in chapters 21, 22 and 23-1 to 23-4.
Specific Objectives - after studying this part you will be able to:
- interpret electric fields and field lines; use Gauss' law to find the electric field; discuss and apply the electric potential (revision)
- derive the electric field from the electric potential
- derive the field of electric dipoles and describe electric dipole moments
- calculate the electric potential of an electric dipole
- calculate the torque on an electric dipole and potential energy of an electric dipole (revision)

Capacitance and Dielectrics
Reference sections: 24-4 to 24-6, course notes
Some revision of content in 24-1 to 24-3
Specific Objectives - after studying this part you will be able to:
- define and use the concept of capacitance (revision)
- use dielectric constants and relative permittivity
- discuss the concept of polarization
- discuss the physical basis of dielectric materials in terms of electric dipoles
- apply Gauss' law to dielectric materials
- discuss the use of dielectrics in capacitors
- define and use the electric displacement vector and potential energy of a capacitor with dielectric
- discuss the concept of polarizability and its relationship to dielectric constant
- discuss the physical mechanism of piezoelectricity

- do calculations concerning capacitance and dielectrics

Magnetism and Magnetic Materials: Ferromagnetism, Paramagnetism, Diamagnetism
Reference sections: 27-7 to 27-9, 28-8.
Some revision of content in 27-1 to 27-4, 27-6, 28-1 to 28-6
Specific Objectives - after studying this part you will be able to:
- discuss and apply the concepts of magnetic field and magnetic forces (revision)
- discuss the magnetic force on a current (revision)
- explain and use the Hall effect
- calculate the magnetic field from the Biot-Savart law and Ampere's law
- discuss the magnetic dipole moment
- derive the torque on, and the potential energy of, a magnetic dipole
- discuss the physical mechanism of magnetism in terms of magnetic dipoles
- discuss and apply the concepts of the H field, magnetization and permeability
- discuss the basis of ferromagnetism
- discuss hysteresis
- discuss the processes of magnetic recording
- discuss the physical mechanism of paramagnetism and diamagnetism

Electromagnetic Waves
Reference sections: 32-1 to 32-6, course notes
Some revision of content in 29-7, 32-1.
Specific Objectives - after studying this part you will be able to:
- discuss the meaning of Maxwell's equations in vacuum and in matter, written in integral form
- discuss the relationship between oscillating charges and the emission of electromagnetic radiation
- derive the existence of electromagnetic waves
- understand the concepts of plane and sinusoidally varying electromagnetic waves
- discuss the propagation of electromagnetic waves in matter and the meaning of refractive index
- discuss and apply energy and momentum flow in electromagnetic waves, and the concept of radiation pressure
- describe standing electromagnetic waves and the propagation of electromagnetic waves in a wave guide
- describe the electromagnetic spectrum
- recognise Maxwell's equations written in differential form and compare them with the integral form

5.4 MODULE 3: SOLID STATE AND DEVICE PHYSICS

The **12 lectures** will be given by Dr Christelle Monat.

5.4.1 TEXT

The module is based around the book "Semiconductor Devices: Physics & Technology", 2nd Edition by S M Sze, published by John Wiley & Sons (2002). Lecture notes and supplementary material will be posted on WebCT as the course proceeds.

5.4.2 ASSIGNMENTS & ASSESSMENT

- One assignment in form of a poster will be given. The poster (MS PowerPoint file) has to be sent to Dr Monat via e-mail (monat@physics.usyd.edu.au) before Monday, 26 October 2008, 2 pm. Attendance of the last lecture on Friday, 30 October 2008 is mandatory, as the posters will be presented and assessed during that lecture.
- Assessment: by examination of material introduced through the lectures, problem sheets and the poster.

5.4.3 SPECIFIC OBJECTIVES

Aim: To appreciate the origin, theoretical foundations and applications of semiconductor physics and common optoelectronic devices.

By the end of the module, students should be able to:

Introduction

- Describe general trends in the semiconductor road-map
- Understand how rapidly semiconductor technology has evolved over the last 50 years

Atoms & Electrons

- Discuss how atomic energy levels arise and describe their general properties
- Understand how bonding occurs in covalent crystals
- Understand how energy bands form in the presence of a periodic crystal
- Understand simple energy-momentum band-diagrams and identify direct and indirect band alignment
- Understand the concept of an energy dependent density of states

Crystal Properties & Growth of Semiconductors

- Identify three common cubic crystal structures; recognise the diamond and zincblende structure
- Understand the use of Miller indices for identifying crystal planes and apply them in cubic crystals
- Discuss different techniques for growing bulk crystals

Metals, Insulators & Semiconductors

- Understand the concept of electrons and holes
- Describe the difference in band-occupancy for a metal, insulator and semiconductor
- Discuss how the band properties and alignment affect the optical transparency of a material
- Understand the effect of doping on the carrier concentration in each band and describe common approaches for doping semiconductors
- Understand how the concept of a Fermi-energy describes the carrier concentration in a band

Carrier Transport

- Discuss the physical differences between drift and diffusive transport
- Understand how the resistivity of a material is linked to the Fermi-level, band structure and carrier mobility
- Describe how diffusive transport is related to carrier concentration and mobility
- Understand the concept of generation and recombination in a semiconductor; identify two general types of recombination: radiative and non-radiative
- Understand how drift and diffusive transport are combined in the continuity equation

Metal Semiconductor Contacts

- Describe common fabrication processes of metal contacts on semiconductors
- Understand the alignment of Fermi-energies and its effect on the band at the metal-semiconductor interface

- Discuss the basic properties of a Metal-Semiconductor Schottky diode and how it is distinct from an ohmic metal-semiconductor contact

p/n Junctions

- Describe fabrication processes for p/n junctions
- Understand how the alignment of the Fermi-energies affects the position of the bands in thermal equilibrium
- Understand the concept of a quasi-Fermi level in non-equilibrium situations, and how it and energy bands change under forward and reverse bias
- Describe the current voltage characteristics of a p/n junction using the Shockley diode equation

Optoelectronic Devices

- Describe epitaxial methods for forming light emitting diodes, laser diodes and photodetectors and how these differ from those required for solar cells
- Understand how electrical injection into a p/n junction gives rise to spontaneous light emission and describe the basic properties of a light emitting diode
- Describe the conditions and fabrication steps required to achieve stimulated (laser) emission in a semiconductor diode
- Describe the key differences between a photodetector and a solar cell

Transistors and Integrated Circuits

- Describe the fabrication techniques for transistors and integrated circuits
- Describe the basic operation and origin of current gain in a bipolar transistor and MOSFET
- Discuss how MOSFET technology is applied in CMOS devices and integrated circuits

Frontiers in Device Technology

- Describe why silicon-on-insulator, strained-silicon, SiGe, and high-k and low-k dielectric technologies allow smaller and faster integrated circuits to be made
- Understand the possibilities offered by novel technologies, such as quantum confined structures, for realising more efficient optoelectronic devices

5.5 MODULE 4: COMPUTATIONAL PHYSICS

The module is an introduction to the use of computers for investigating problems of physical interest. MatLab programming will be used, but *no prior knowledge of computing is required*.

The material covered in the computational physics course is coordinated with that in the Optics lecture module.

5.5.1 TEXT

The module is defined in terms of chapters of the ‘PHYS 2213 Physics 2EE Computational Physics Engineering Optics Notes’, available from the University Copy Centre. It is highly recommended that each student purchase the current edition of these notes.

5.5.2 SESSION ARRANGEMENTS

Students attend one 2-hour session per week in the Computational Physics Laboratory for 10 weeks, beginning in week 2 of the semester. Students are arranged in groups of 2 or 3 for each computer.

The sessions are run by a supervisor from the academic staff, and there are a number of tutors at each session. The module coordinator is Assoc. Prof. M. Sharma.

Sessions are held in the Computational Physics Laboratory, Physics Room 359. Details of the location are given in section 1.5 and the session times in the Timetable (section 4).

5.5.3 ASSESSMENT

The total mark for this module is 50 marks. Of these, 16 marks are awarded on the basis of participation at the eight weekly sessions during which Exercise Sets 1-4 are done. The remainder of the assessment (worth 36 marks) will be an in-lab exam, undertaken by each student individually, in week 12. The final mark will be returned out of 50 (not 52).

5.5.4 SPECIFIC OBJECTIVES

AIMS

- to teach optics, particularly those parts of the subject which benefit from a computational approach;
- to support the lecture course by allowing you to explore some topics in detail;
- to allow you to become comfortable with using computers in solving physics problems;
- to allow you to become familiar with the use of MatLab.

In greater detail:

(1) Optics is a subject well suited to the use of computer simulation. Simulations will be used to illustrate a number of topics, mainly in physical optics (interference, diffraction). The computer enables you to quickly and easily carry out ‘virtual experiments’, which will illustrate the effects caused by changes in vital parameters such as wavelength, slit width and separation, screen position, etc. In this way you will gain familiarity with the physics underlying the phenomena investigated, without the extra time (and expense) required to set up and operate actual apparatus to perform the same experiments. By seeing for yourself how the resulting image patterns depend on the relevant parameters, you will have the corresponding lecture content reinforced.

Through using software with a standardized user-interface, you will be able to concentrate the majority of your time and effort on understanding the optics content.

(2) Modern-day graduates in any branch of science or technology will, on many occasions, be required to learn and effectively use sophisticated mathematical computer packages. Learning to correctly and fully exploit the capacities of such packages is an important skill, and this computer laboratory optics component makes a start in such education.

The mathematical package that is used is MatLab. You will gain the experience of seeing MatLab scripts in operation, and towards the end of this module instructions will be briefer and activities more open-ended and you will be asked to write small, straightforward scripts of your own. It is not the object of this component to teach MatLab. However it is important that you learn how generic computer mathematical packages can facilitate some of the mathematical aspects of physics problems.

(3) Related to the above goals, but separate from them, is the idea that you will learn how to use computers in solving physics problems. The experience gained in the computer laboratory optics will bring home to you the role of computers in conveniently and rapidly illustrating what would happen in a wide variety of different experimental setups. At the same time you will become aware that the result of a simulation only reflects reality to the extent that the physical/mathematical model used as the basis for the code also corresponds to reality. Valuable lessons can be learned by showing where a model calculation breaks

down and a more sophisticated treatment must be used. The ability to see what level of approximation or exactness is needed for a particular problem is an important skill.

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