Module Description

The field of Nanoscience is concerned with the study of matter on the nanoscale (10^{-9}m).

At this scale the fundamental quantum mechanical interactions determine the properties of materials. The key and revolutionary aspect of nanoscience is that we are now able to manipulate matter on such a scale and that we can fabricate materials with unique properties by design at the nanoscale. This course introduces the physical principles that govern the electronic and optical properties of matter at the nanoscale. In addition, the fabrication methods and underlying operating principles of technologically important electronic and photonic structures are presented, together with techniques for making measurements and characterisation at the nanoscale.

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Module outcomes

Students who successfully complete the course will:

• Understand the physical basis for nanoscience and how it enables new technologies.
• Understand how the electronic and optical properties of materials are determined by its physical structure.
  - Understanding the electronic configuration on the atomic level
  - Calculate the confined energy levels and density of states in low dimensional semiconductors: namely the quantum well, quantum wire and quantum dot structures.
  - Appreciate how important optoelectronic devices such as lasers, photodetectors and optical modulators are derived from low dimensional semiconductors.
  - Understand qualitatively the electronic structure of other nanomaterials, such as fullerenes and nanotubes
  - Understand the fundamentals of Bragg reflection/scattering off periodic media.
  - Appreciate the role of photonic bandgap dispersion relations in one dimensional examples.
  - Understand how enhanced interactions arise in resonant photonic bandgap materials
  - Appreciate how slow-light arises in photonic bandgap materials
  - Derive the coupled mode theory for one-dimensional periodic structures (e.g. Bragg gratings) and apply it in different structures.
  - Grasp the technological significance of two and three dimensional photonic band-gap technology.
  - Understand the basic properties of 2D and 3D photonic band-gap structures, namely angular dependent Bragg scattering, presence of a complete band-gap and the associated dispersion relations using reciprocal space.
  - Understand how photonic band-gap structures enable light to be guided in air (photonic crystal fibres) control spontaneous emission and guide light using photonic nanowires.

• Appreciate the relative merits, applicability, and limitations of nanoassembly/nanofabrication approaches, specifically:
  - Atom-by-atom manipulation
  - Top-down nanofabrication approaches using lithography, patterning, etching, etc.
  - Self-assembly
• Understand how energy minimisation drives self-assembly by means of surface and interface energies and the control that can be achieved by applying system constraints and external guiding forces.
• Understand the physics relevant to top-down and atom-by-atom approaches and the limitations it imposes on these methods.
• Understand the physical basis and importance of materials characterization techniques relating to nanoscience:
  o Electron microscopy: specifically the electron-matter interaction, transmission and scanning electron microscopy and quantitative analysis, advantages and disadvantages.
  o Chemical analysis techniques such as X-ray photoelectron spectroscopy
• Understand the past, present and likely future directions of microelectronics

Assessment
Two assignments will be issued. The assignments will be issued during the lectures and made available on the web. The due dates will be available on the web.

Study resources
There is no one recommended textbook. Most of the lecture notes are compiled based on the texts listed below. Students are encouraged to consult these texts for additional information:

• Nanophysics and Nanotechnology - An Introduction to Modern Concept in Nanoscience 2nd ed., Wolf
• Optical Properties of Solids, Fox
• Nanoscale – Science and Technology, Kelsall, Hamley and Geoghrgan
• Physical Methods for Material Characterisation, Flewitt and Wild
• Solid States Electronics Devices 6th ed., Streetman and Banerjee
• Transmission Electron Microscopy – Vol. 1-4, Williams and Carter
• Electronic and Optoelectronic Properties of Semiconductor Structure, Singh
• Physics of Semiconductor devices, Sze

Where to go for help
If you need help, you can
• as a first step, always check your unit eLearning pages for information, documents and links
• go to the Physics Student Services Office, Room 210 in the Physics building, or phone 9351 3037
• ask your lecturer or tutor
• ask other students using the Discussion forum provided in the Discussions link on the unit eLearning page.
• consult one of the many services provided by the University, such as the Maths Learning Centre. These can be found at sydney.edu.au/current_students/student_services/index.shtml or through your MyUni pages sydney.edu.au/myuni.

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 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 Physics Student Services, Room 210 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.

**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 at [sydney.edu.au/science/cstudent/ug/forms.shtml](http://sydney.edu.au/science/cstudent/ug/forms.shtml), or Physics Student Services.
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 Physics Student Services. 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 [sydney.edu.au/policy](http://sydney.edu.au/policy).

**Consideration by Physics**

An application for *Consideration by Physics* requires you to:

2. Complete the form and obtain whatever original documentary evidence is appropriate.
3. Take the original copy of the form and supporting documents, plus a copy for yourself, to Physics Student Services, Room 210. 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 Physics Student Services.

It is important to realise that the policies on *Special Consideration* and *Special Arrangements* 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.