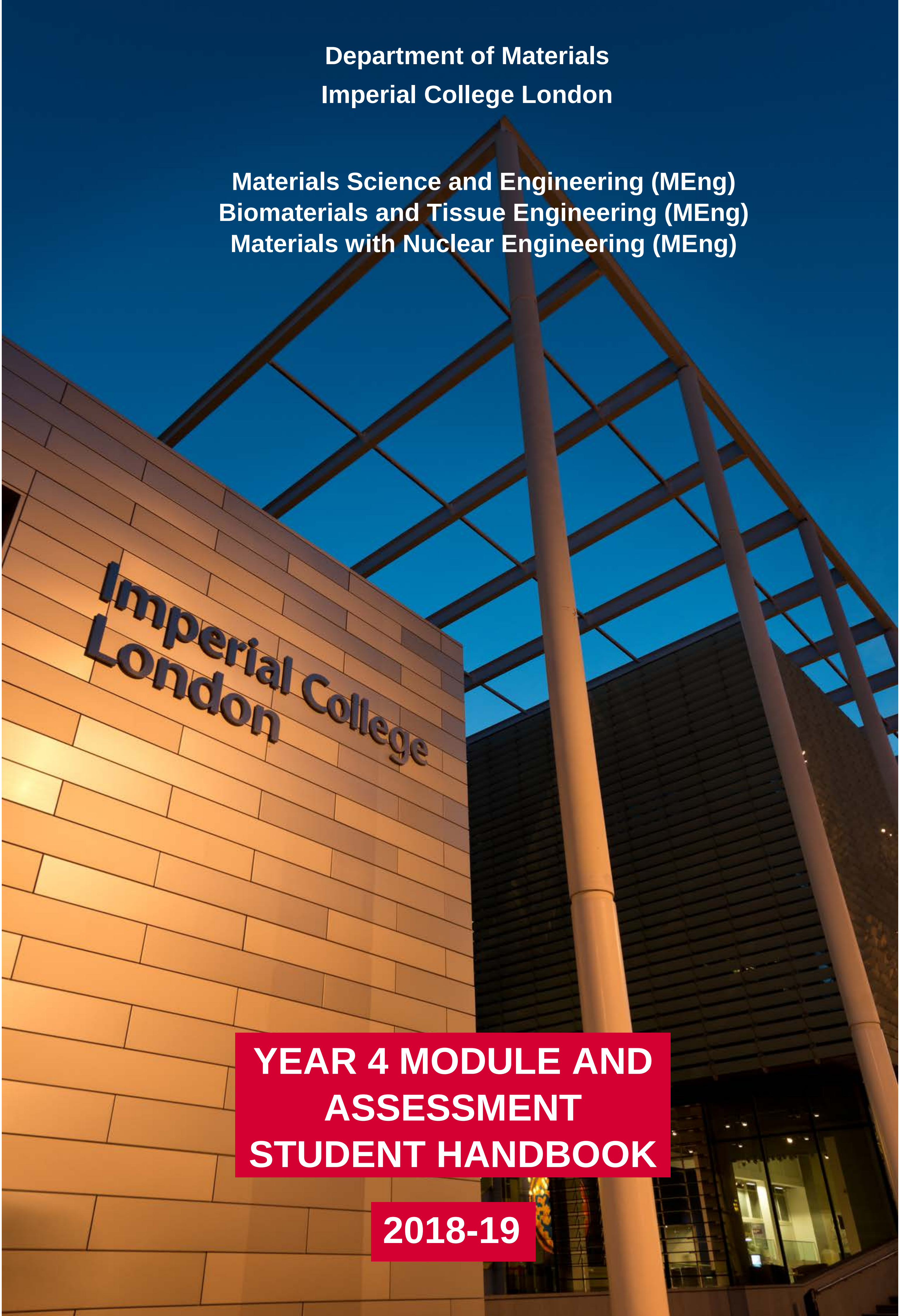
Department of Materials

Imperial College London

Materials Science and Engineering (MEng)
Biomaterials and Tissue Engineering (MEng)
Materials with Nuclear Engineering (MEng)



YEAR 4 MODULE AND ASSESSMENT STUDENT HANDBOOK

2018-19

Introduction

This handbook contains specific information for the Year 4 students in the 2018-2019 cohort, including the module details and assessment deadlines and year composition for this academic year. It is to be used in conjunction with the General Handbook for all students for full regulations and guidance on the undergraduate programmes in the Department of Materials.

Contents

1. **Programme information** **2**
    - Key dates 2018–19 2
    - Year structure 2
    - Progression 2
2. **Module Information** **3**
    - MSE 404 Modelling Materials with Density-Functional Theory 3
    - MSE 409 Advanced Engineering Alloys 4
    - MSE 410 Advanced Thin Films Manufacturing Technologies 5
    - MSE 411 Electroceramics 6
    - MSE 412 Nanomaterials II 8
    - MSE 413 Advanced Structural Ceramics 9
    - MSE 414 Nuclear Materials for Reactor Systems 11
    - MSE 417 Advanced Biomaterials 13
    - MSE 418 Advanced Tissue Engineering 15
3. **Assessments** **16**
    - Coursework elements 16
    - MEng Project Deadlines 16
4. **MEng Project Guidelines** **17**
    - Supervision 17
    - Initial Meeting 17
    - Assessors 17
    - End of Autumn Term Assessment 17
    - Spring Term 17
    - Research Project Presentation 18
    - Research Project Thesis 18
    - Viva 18
    - Guidance on the Thesis 18
5. **Assessment forms and rubrics** **19**

1. Programme information

Key dates 2018–19

Term dates

Autumn term:	29 September - 14 December 2018
Spring term:	5 January - 22 March 2019
Summer term:	27 April - 28 June 2019

Closure dates

Christmas/New year:	24 December 2018 – 1 January 2019 (College reopens on 2 January 2019)
Easter holiday:	18 April – 23 April 2019 (College reopens on 24 April 2019)
Early May bank holiday:	6 May 2019
Spring bank holiday:	27 May 2019
Summer bank holiday:	26 August 2019

Year structure

4th year comprises 3 core modules (marked with a ** below) and 4 elective modules All potential modules from within the department are listed below along with the relative module weighting in the year structure. Not all modules are always available and some modules are linked to specific degree structures and are not generally available. There are additional inter-departmental exchange (IDX) and Horizons/Business modules that can also be taken.

**MSE 420	Research Project	40%
++**MSE 421	Work placement	10%
**BS0845	Strategic management	10%
BE9-MSPHYS	Bioengineering : Systems Physiology	10%
MSE 407	Nuclear Thermal Hydraulics	10%
MSE 408	Nuclear Reactor Physics	10%
MSE 409	High Performance Alloys	10%
MSE 410	Advanced Thin Film Manufacturing	10%
MSE 411	Electroceramics	10%
MSE 412	Nanomaterials 2	10%
MSE 413	Advanced Structural Ceramics	10%
MSE 414	Nuclear Materials for reactor systems	10%
MSE 417	Advanced Biomaterials	10%
MSE 418	Tissue Engineering	10%

++If a placement does not happen, then this core module is removed from the year calculation and the year is rescaled out of the residual 90% comprising the 2 core modules and 4 option modules

Progression

Progression from year 4 requires passing every module with a minimum of 40%

2. Module Information

MSE 404 Modelling Materials with Density-Functional Theory	
Course Co-ordinator: Dr Johannes Lischner Status: Year 4 and MSc Advanced MSE option *Prerequisites: N/A*	
Aims This course will introduce students to the modelling of materials with density-functional theory. After a brief review of the quantum-mechanical foundations of density-functional theory, the course will focus on the application of this technique to the calculation of material properties, such as elastic constants, equilibrium structures, phase diagrams or band structures. The concepts introduced in the lectures will be put to practical use in the computer lab session, where students will learn to use a density-functional theory software package and compute the properties of real materials from first principles.	
Learning outcomes At the end of the course the student will be able to - Explain the basic principles and capabilities of materials modeling with density functional theory (DFT) - Explain the quantum-mechanical basis of DFT and its limitations - Use a standard DFT software package to compute material properties, including o The total energy of the electronic ground state o Atomic forces using the Hellmann-Feynman theorem o Equilibrium structures of molecules and crystals o Elastic constants o Energies of vibrations in molecules and solids o Phonon band structure and density of states o IR and Raman intensities o Cohesive energies o Phase diagrams o Electronic band structures of metals, insulators and semiconductors o The dielectric function of a solid and optical properties o The effect of approximations to exchange and correlation on calculated properties o The effect of pseudopotential approximations on calculated properties	
Recommended textbooks A = required, B = recommended but not essential, C = background reading.	
A	*Materials modelling using Density-Functional Theory: Properties and Predictions*, F. Giustino, Oxford University Press, 2014.
B	*Electronic Structure Calculations For Solids and Molecules: Theory and Computational Methods*, J. Kohanoff, Cambridge University Press, 2006.
C	*Introduction to Quantum Mechanics*, D. J. Griffith, Pearson Education International, 1995.
Structure, teaching and learning methods 12 lectures, 12 computer lab sessions	
Assessment *Assessment is through weekly problem sets and a written exam.* *The problem sets are worth 40 % and the exam 60 %.* **The pass mark for the module is 40% for MEng students and for MSc students the pass mark is 50%. The module contributes 100 marks of the fourth year.**	

MSE 409
Advanced Engineering Alloys

Course Co-ordinator: Professor F P E Dunne
Status: Fourth Year Optional/MSc
Prerequisites: MSE 203 States of Stress; MSE 203 Continuum Mechanics; MSE 204 Microstructure; MSE 307 Engineering Alloys

Aims

This course builds on knowledge acquired from MSE307 (Engineering Alloys) and addresses aspects of processing (particularly casting) through to resultant microstructure and properties, and then considers alloy structural behaviour and performance in service under mechanical and thermal loading. The links between processing, microstructure, properties and performance of engineering alloys in service are emphasised. Two case studies, one in each of processing and performance, are included to relate the course content to engineering practice and to reinforce the process-microstructure-properties-performance paradigm

Learning outcomes

At the end of each part of the course the student will be able to:

Microstructure formation during solidification (Dr C M Gourlay)

- use heat transfer approaches to calculate and estimate casting parameters
- understand interface undercooling and constitutional supercooling and their role in (i) the columnar-to-equiaxed transition and (ii) the control of grain size.
- understand the physical basis for the Jackson-Hunt equations for regular eutectic growth and use it to predict interphase spacings and eutectic morphologies
- understand competitive solidification criteria for single phase dendrites vs. fully-eutectic growth; stable vs. metastable eutectic growth; and nucleation controlled phase selection.
- calculate simple microstructure selection maps from solidification models and data, and use them to predict microstructures from processing parameters.
- Use all of the above to discuss microstructure selection in light alloy castings for aerospace applications

Microstructure and performance (Prof F P E Dunne)

- understand generalized crystal deformation – stretch, slip and rigid body rotation
- understand slip in fcc, bcc, and hcp crystal lattices and slip systems, Schmid rule, strain from slip, strain and rotation rates
- understand and use slip rules and slip by dislocation glide and thermally-activated climb; self and latent hardening
- understand EBSD, texture and its representation, pole figures and Kearns factors;
- cold dwell fatigue in the Ti alloys; mechanistic assessment, crystallography; role of rate sensitivity; load shedding; microstructure (morphology and micro-texture); thermal alleviation

Recommended textbooks A = required, B = recommended but not essential, C = background reading.

A Links to underpinning scientific journal papers are provided on WebCT

B Dantzig, J.A. & M. Rappaz. Solidification. EPFL press, 2016.
Roters, F, Eisenlohr, P, Bieler, TR, Raabe, D, Crystal Plasticity Finite Element Methods, Wiley-VCH, 2010.
Hertzberg RW, Deformation & Fracture Mechanics of Engineering Materials, John Wiley, 2012.

Structure, teaching and learning methods

24 lectures:

Assessment

Examination

The course is examined in the summer term. The examination is 2.5 hours and consists of 5 questions, of which the students have to answer 3. Questions could be from a single part of the course or be more general in nature and require the students to use elements from several parts of the course.

The pass mark for the module is 40% for MEng students and for MSc students the pass mark is 50%. The module contributes 100 marks of the fourth year.

MSE 410
Advanced Thin Films Manufacturing Technologies

Course Co-ordinator: Dr Peter Petrov

Status: MEng Fourth Year option and MSc Advanced MSE option

Aims

- To familiarise students with the basic vacuum concepts.
- To explain the essential concepts involved in using vapour deposition techniques to develop thin films.
- To provide a foundation required to successfully use lithographic and other microfabrication methods.
- To provide students with the basics for working in, and understanding the microfabrication in production environment.
- To provide hand-on experience in thin film deposition (magnetron sputtering, e-beam evaporation), photolithography and ion-milling.

Learning outcomes

At the end of each part of the course the student will be able to:

Introduction to vacuum technologies:

- Explain on the principles of vacuum production and its classification.
- Understand the working principles and limitations of the vacuum pumps and gauges.

Principles and equipment for thin film deposition processes:

- Understand essential concepts involved in using vapour deposition techniques to develop thin films.
- Describe the most common types of vapour deposition technologies (chemical vapour deposition (CVD), physical vapour deposition (PVD) and mixed deposition).
- Explain the three basic PVD techniques: vacuum evaporation (thermal/e-beam evaporation), sputter deposition (DC-, RF-, reactive- magnetron sputtering) and pulsed laser deposition.
- Discuss the connection between vapour deposition parameters and thin film properties.
- Identify the most appropriate method/equipment for a deposition process and discuss its advantages and disadvantages.

Principles and equipment for thin film patterning:

- Understand the characteristics and practical limitations of basic lithographic methods (e.g. photo-, e-beam-, and x-ray lithography) used today for integrated circuit manufacturing.
- Discuss and compare the etching methods used in a microfabrication process e.g. wet etching, ion milling, reactive ion etching and focused ion milling.
- Identify the most appropriate method and equipment for a patterning process (e.g. mask-aligner, spinner) and outline their principles of operation and limitations.

Thin film manufacturing environment:

- Understand the basics principles for working in hi-tech (e.g. semiconductor) production environment.

- Know the Clean room classification, Clean room design principles and Clean room control measures (gowning, equipment and consumables).

Lab sessions:

- Prepare samples for further processing.
- Assist in thin film deposition (magnetron sputtering, e-beam evaporation), photolithography and ion-milling processes.

Recommended textbooks A = required, B = recommended but not essential, C = background reading.

B R.W. Berry, P.M. Hall & M.T. Harris: 'Thin Film Technology', published by D. Van Nostrand Company, 1968
Krishna Seshan et al., 'Handbook of Thin Film Deposition Processes and Technologies', Second Edition, Noyes Publications, 2002
K.L. Saenger, in: D.B. Chrisey and G.K. Hubler (Eds.), 'Pulsed laser deposition of thin films', Wiley Interscience, New York, 1994
Fundamentals of Vacuum Technology (revised and compiled by W Umrath) Oerlikon Leybold Vacuum 00.200.02 Kat.-Nr. 199 90

Structure, teaching and learning methods
18 lecture hours and 3 lab sessions (2 hours each):

Assessment
Examination (70%)
The course is examined in the summer term. The exam is 2.5 hours and consists of 5 questions from which the students must answer 3.
Lab-work (30%)
Each Lab-work (three in total) is assessed on the base of the following criteria:

i) preparation for the Lab session (40%) – 15-20 min Q&A session before the experimental work starts
ii) engagement in the experimental work (20%),
iii) Lab report (40%) – It has to be submitted within one week after the Lab-session.

The pass mark for the module is 40% for MEng students and for MSc Advanced Materials Science and Engineering students it is 50%, formed from at least 35% Examination and at least 15% Lab works.

MSE 411
Electroceramics

Course Co-ordinator: Prof Stephen Skinner
Status: MEng Fourth year option and MSc Advanced MSE option
Prerequisites: MSE 205 Electronic Properties of Materials

Aims
The aim of the course is to gain an understanding of the fundamental science governing the electronic and ionic conductivity of metal oxides and to then use this knowledge to describe the operation of devices based on these properties, such as gas sensors, fuel cells, batteries and thermoelectric.

Learning outcomes
At the end of this part of the course the student will be able to:

Defect chemistry, electrical conductivity and secondary batteries (Dr Ainara Aguadero)

- Obtain a full set of algebraic expressions for the point defect concentrations in pure and doped oxide materials. They will be able to write out the intrinsic defect equilibria for a simple binary oxide and the appropriate redox equilibria. They will be able to apply the neutrality condition to obtain a set of linked defect equations

- Further develop the expressions obtained above to identify suitable approximations to the full neutrality condition, and hence solve the defect equations and construct a simple Brouwer diagram for a binary oxide. They will be able to use the diagram to predict the conductivity variation with P_{O2} for a simple binary oxide
- Construct expression for the incorporation of extrinsic defects and incorporate this in the Brouwer diagram: analyse constant and variable dopant concentrations
- Discuss type of conductivity and applicability of materials in electrochemical systems
- Describe the operation of secondary batteries. Identify main battery types, and processes involved. Define main battery characteristics.
- Identify different electrode reaction mechanism in secondary batteries
- Analyse electrochemical performance in terms of the band theory of solids
- Discuss electrode and electrolyte materials chemical and electrochemical stability properties
- Describe different types of solid electrolytes and ionic conduction mechanisms for alkaline ions.
- Discuss relationships between crystal structure, composition and morphology with transport properties.
- Identify novel materials for ceramic based devices. Explain further alternatives for high energy batteries development

Fuel cells, sensors and devices (Prof S Skinner)

- Explain the concept of anionic, cationic and mixed conductors. They will be able to derive an algebraic expression for the temperature dependence of the ionic conductivity of an oxide ion conductor and identify oxide materials with superior ionic conductivity
- Derive a simple relationship for the operation of a ceramic membrane device and use this expression to select appropriate materials for the fabrication devices such as a single SOFC cell
- Explain the operation of a fuel cell and give an account of the basic details of the four main types of cell. They will be able to describe the main features of the competing designs of Solid Oxide Fuel Cells (SOFC's)
- Define the excess air factor λ and describe the variation of the P_{O2}, and pollutant content, of the exhaust gasses of an internal combustion engine as a function of λ
- Describe the operation of two oxide based sensors which can be used to sense the changes in oxygen activity arising from the λ curve, the common zirconia based λ probe, and the semiconducting TiO_2 sensor
- Describe a further sensor based on the amperometric technique for determining the P_{O2} of the exhaust gasses in an internal combustion engine in the lean burn region of operation
- Describe two simple sensors for the detection of flammable gasses based on the surface absorption and acceptor activity of oxygen
- Brief introduction to thermoelectric materials.

Recommended textbooks A = required, B = recommended but not essential, C = background reading.

A *Electroceramics*, A.J.Moulson and J.M.Herbert
Chapman and Hall (1992). 2nd Edition John Wiley and Sons (2003)

B *Physical Ceramics*, Chiang, Birnie and Kingery, John Wiley and Sons (1997).
Ceramic Materials for Electronics, R.C.Buchanan, Marcel Dekker (1991), 3rd Edition CRC press 2004
Electronic Ceramics Properties Devices and Applications Lionel M. Levinson.Marcel Dekker (1988)
High-temperature solid oxide fuel cells: fundamentals, design and applications Edited by Subhash C. Singhal and Kevin Kendall, Elsevier, Oxford (2003)

Fuel Cell systems explained, James Larminie and Andrew Dicks, Wiley (2003)

Solid oxide fuel cell technology: Principles, performance and operations, Kevin Huang and John B. Goodenough, Woodhead Publishing Ltd (2009)

Structure, teaching and learning methods

24 lectures:

Assessment

Examination

The course is examined in the summer term. The examination paper, duration 2.5 hours, is in two sections. Section A (20 marks) is compulsory and consists of a single question on all parts of the course. Section B contains 3 questions of which students must answer 2 (20 marks per question).

The pass mark for the module is 40% for MEng students and for MSc students the pass mark is 50%. The module contributes 100 marks of the fourth year.

MSE 412
Nanomaterials II

Course Co-ordinator: Prof Sandrine Heutz

Status: MEng Year Four option and MSc Advanced MSE Option

Prerequisites: MSE 312 (Nanomaterials I)

Aims

This course is designed to provide the students with an insight into the emerging applications of nanotechnology through a series of topically relevant case studies. The underlying nanoscience as well as the engineering aspects of material and device operation is given. The broader societal impacts of nanotechnology and its impact on human health are explored.

Learning outcomes

Molecular Magnetism (Prof Sandrine Heutz)

At the end of the course students should be able to:

- Define characteristics of molecular nanomagnets and name some examples.
- Understand concepts of superparamagnetism, and important parameters defining this property.
- Describe mechanisms to store and manipulate information in molecular nanomagnets.
- Give some applications in which molecular magnets are used, describe their potential and limitation.

Nanophotonics (Prof M P Ryan)

At the end of the course students should:

- Understand 1, 2 and 3 dimensional dielectric periodicity and the resultant photonic band structures.
- Be able to describe quantitatively the propagation of light in solids.
- Be able to describe nanofabrication methods for the preparation of periodic 1, 2 and 3 dimensional structures with nano-scale periodicities.
- Have a detailed understanding of the structure of self-assembled colloidal crystals.
- Be able to describe the relationships between structure, materials, properties and preparation methods of 3D periodic porous solids and nanocomposites.

Plasmonic Nanoparticles *(Dr Fang Xie)*

At the end of the course students should be able to:

- Understand the general synthetic routes including top-down and bottom up methods
- Understand the factors to control nanoparticles size and shape

- Be able to describe the possible growth mechanism of metal nanoparticles including Au, Ag, and Pd
- Understand the optical properties of metal nanoparticles and their size/shape dependency
- Be able to describe metal nanoparticles' application in medical diagnosis, therapy, and solar energy conversion.

Two-dimensional materials for electronics and optoelectronics (Dr Cecilia Mattevi)

- Discuss the chemical characteristics of layered compounds and their elementary building blocks
- Describe the electronic band structure of graphene and group VI of transition metal disulphide and diselenide.
- Discuss the properties of graphene and group VI of transition metal disulphide and diselenide relevant for applications
- Discuss the chemical vapour deposition synthesis method for graphene.

Nanotoxicity (Prof Alex Porter)

At the end of the course students should be able to:

- Describe the routes of exposure of nanoparticles to the body.
- Understand and discuss the effect of shape, size and chemistry of nanostructures on the interaction of nanoparticles with the body.
- Assess critically the potential risk of nanoparticles to human health.

Structure, teaching and learning methods

21 lectures

3 hours poster presentation

Assessment

Examination

The course is examined in the summer term. The examination paper, duration 2.5 hours is in 2 sections. Section A contains 5 short calculation-type questions (6 marks each); section B contains 2 essay questions (20 marks each). All questions are compulsory.

Coursework

30 marks are associated with the poster exercise (preparation and presentation).

The pass mark for the MEng cohort is 40% and for the MSc Advanced Materials Science and Engineering course is 50%. The module contributes 100 marks of the MEng fourth year.

MSE 413
Advanced Structural Ceramics

Course Co-ordinator: Prof L Vandeperre

Status: MEng Fourth Year Aerospace Materials Core, MEng Fourth Year option and MSc Advanced MSE option

Prerequisites: MSE 203 Mechanical behaviour

Useful : MSE 308 Ceramics and Glasses, MSE 309 Polymers and Composites

Aims

- To review microstructural aspects of the behaviour of major ceramic families such as alumina, silicon carbide, silicon nitride, zirconia and glass and contrast microstructural control aimed at increases strength with microstructural approaches aiming to improve toughness to offer a reference frame in which to understand current research and development
- To clarify the need for composites and to contrast the mechanical response of ceramic composites with that of monoliths
- To re-examine the general theoretical concepts underpinning the structural performance of materials developed in MSE.203 Mechanical behaviour with an aim to strengthen the students ability to apply the general principles to ceramics

- To explore the transitions in mechanical behaviour and relate these to the different micro-mechanism of deformation that act in ceramics so that students can judge how microstructure, time, scale and deformation rate can alter the response
- To explain the concepts underpinning the state-of-the-art methodologies, which can be used to design monolithic ceramic components with confidence
- To train students in fractography of ceramics
- To discuss high temperature ceramics, the various forms in which these materials are used such as coatings, fibres and composites and how they are made.
- To examine the fundamental quantitative factors that control stability, mechanical performance and damage accumulation under service conditions.

Learning outcomes

At the end of each part of the course the student will be able to:

Design implications of reliability and fracture of ceramics (Prof L Vandeperre, 12 lectures)

- State a range of classical families of advanced structural ceramics including alumina, zirconia, silicon nitride, silicon carbide and ceramic matrix composites
- List and explain approaches to improve the strength of these materials
- List and explain approaches to improve the toughness of these materials
- List and explain a range of ceramic composite approaches and their failure modes
- Distinguish between inherent toughness, apparent toughness, and fracture energy
- Predict crack progression for stable cracking and for materials with R-curve behaviour
- Calculate the driving force for cracking under mixed mode loading and for published crack configurations
- Be aware of existing failure criterions for mixed mode loading and their limitations
- Have some understanding of possible fatigue effects in ceramics
- Inspect a ceramic fracture surface and determine failure origin, and failure type
- Describe the mechanism of slow crack growth (subcritical crack growth)
- Calculate expected life-time accounting for slow crack growth.
- Determine Weibull distributions including choice of probability estimator and fitting methodology and understand the link with defect distributions
- Calculate material Weibull parameters and test Weibull parameters and covert between both
- Estimate the probability of failure for simple loading cases
- Incorporate proof testing or non-destructive evaluation in a reliability strategy
- Outline a design methodology for complex ceramic components based on probability of failure

Deformation of ceramics (Dr F Giuliani, 6 lectures)

- Compare and contrast deformation behaviour of ceramics with other materials
- Identify the deformation mechanisms active in ceramics
- Draw out a schematic representation of the bounds on stress, temperature and strain rate where the different mechanisms can be expected to operate
- Sketch out microstructural influences on transitions in deformation mechanisms
- Predict the mechanical response from deformation mechanism maps
- Justify why scale affects the deformation response
- Produce an experimental strategy to investigate the different deformation mechanisms
- Discuss strengths and problems associated with different experimental approaches (both small scale measurements and microscopic measurements).

The Effect of High Temperature on Ceramics (Prof Luc Vandeperre, 6 lectures)

- Understand the importance of thermo-mechanical properties at temperature
- Understand the thermodynamics and kinetics behind degradation mechanisms of ceramic at high temperature due to stress including creep, fatigue and thermal shock, due to corrosion or due to radiation
- Understand mechanical damage mechanisms in ceramics including from wear and impact/erosion.
- Distinguish between local and global chemical equilibrium

- Describe applications of high temperature ceramics and why they are used thermal protection systems, thermal barrier coatings in jet engines, and processing equipment in glass making, steel making and other industrial high temperature processes.
- Choose appropriate refractory materials for specific applications
- Understand the limits of established material systems and recognize underpinning principles in new developments.

Recommended textbooks A = required, B = recommended but not essential, C = background reading.

A Links to research papers are provided on Blackboard

B Materials for High Temperature Engineering Applications, GW Meetham and MH Van de Voorde, (Springer 2000).
Ceramic Microstructures, Property Control by Processing, WE Lee and WM Rainforth, (Chapman & Hall 1994).
Hull, D. (1999). Fractography. Cambridge, Cambridge University Press.
Lawn, B. R. and T. R. Wilshaw (1975). Fracture of Brittle Solids. Cambridge, Cambridge University Press.

C See weblinks on WebCT

Structure, teaching and learning methods
24 lectures

Assessment
Examination
The course is examined in the summer term. The exam paper is 2.5 hours and consists of 5 questions, students should answer 3 questions.
The pass mark for the module is 40% for MEng students and for MSc students the pass mark is 50%. The module contributes 100 marks of the fourth year.

MSE 414
Nuclear Materials for Reactor Systems

Course Co-ordinator: Dr Mark R Wenman
Status: Fourth Year option/MSc Advanced Nuclear Engineering/MRes Core course
Prerequisites: None.
Introduction to Nuclear Energy 3rd year Mech Eng course very useful; knowledge of basic materials defects and the concept of microstructure very useful.

Aims
The course will assume students have at least a basic understanding of a reactor system. The aim is then to develop an appreciation of materials issues associated with nuclear reactor technology and how this information is used when designing reactor systems. A mechanistic description of materials selection for intense radiation fields and the associated degradation mechanisms will be covered for different classes of material with a focus on the specific advantages and disadvantages. The course will then cover specific cases where materials issues have been crucial to systems performance and a variety of degradation and failure mechanisms as well as the radiation damage processes that brought about these failures. NB: Although not solely focused on water reactor systems (especially PWR) the course will be aimed at this system

Learning outcomes
At the end of the course students should be able to:
Prof R W Grimes

- Review radiation types, radioactive decay and dose units.
- Discuss the mechanisms of radiation damage of nuclear materials, the units used to measure damage and the models behind them.
- Use the Kinchin-Pease Model to predict damage accumulation and its part in general chemical rate theory of radiation damage.
- Recall the types of fuel and components for the Nuclear Fuel Assembly.
- Discuss the fuel cycle and fuel fabrication

Dr M Wenman

- Explain the use of different materials (stainless steels, Ni alloys) used in a PWR primary circuit and the problems and mitigation strategies associated with them.
- Understand the microstructure and mechanical properties of ferritic steels used for reactor pressure vessels (including welded structures) and the degradation of the steels due to neutron irradiation.
- Define and explain the terms residual stress, primary stress and secondary stress and how they affect structural integrity assessments of nuclear plant.
- Use the FAD and Weibull analysis methods to predict failure in nuclear components.
- Describe the phenomenon of pellet-clad mechanical interactions (PCMI) in PWR and AGR systems, the pellet-clad gap, its closure, heat transfer mechanisms and their roles in PCMI.

Dr B Britton

- Outline the motivation for zirconium as a cladding in PWR environments
- Discuss alloying of zirconium for cladding materials, including the presence of microstructure in single phase and dual phase alloys and secondary phase particles (SPPs).
- Introduce deformation modes in zirconium systems and their impact on crystallographic texture evolution, including crystallographic slip and twinning.
- Discuss crystallographic texture and its importance in highly engineered systems, including how to measure texture and describe it using pole figures & Kearn's factors.
- Introduce ageing and corrosion of zirconium in power plant systems, with a focus on hydrides, oxidation, radiation creep and growth.
- Discuss engineering decisions for tube fabrication, as well as a simple overview of the benefits and disadvantages of different joining technologies.

Recommended textbooks A = required, B = recommended but not essential, C = background reading.

C J G Collier and G F Hewitt "Introduction to Nuclear Power", Hemisphere Publishing Corporation, New York, 2000.

C P D Wilson (Editor) "The Nuclear Fuel Cycle: From Ore to Waste" (0198565402W)

B G S Was "Fundamentals of Radiation Materials Science" Springer (978-3-540-49471-3)

Structure, teaching and learning methods
24 lectures:

Assessment
Examination
The course is examined in the summer term, and the students answer any 3 of 5 questions.

The pass mark for the MEng cohort is 40% and for the MSc/MRes courses is 50%. The module contributes 100 marks of the MEng fourth year, or a core module for MSc/MRes.

MSE 417
Advanced Biomaterials

Course Coordinator: Prof J R Jones

Status: MEng Fourth Year Biomaterials and Tissue Engineering core and MEng and MSc Advanced MSE option/IDX option

Prerequisites: MSE 315 Biomaterials

Aims

The course aims to introduce students to the latest developments in hard tissue biology.

Learning outcomes

At the end of this lecture series the students should be able to describe the main classes of natural polymers, their structure and their applications.

Synthetic scaffolds (Prof J Jones)

At the end of the module the student should be able to:

- Explain the shortfalls of bone replacement materials to the biomaterials industry and investors
- Have knowledge of commercially available bone graft replacement materials and be able to discuss their benefits and shortfalls.
- Present alternative means to repair skeletal tissues to both healthcare professionals and patients.
- Communicate the differences between melt and sol-gel derived bioactive glasses, their mechanisms of bioactivity and application
- Design an ideal bone replacement material
- Discuss processing methods for production of artificial bone grafts including advantages and disadvantages of each, including the various 3D printing methods
- Explain the challenges involved with transfer of laboratory inventions to a clinical product

Bioactive nanoparticles (Prof Alexandra Porter)

At the end of the course students should be able to describe:

- Production and application of HA and bioactive glass nanoparticles
- Cell uptake routes and nanotoxicity of both classes of nanoparticle
- Concepts of non-conventional pharmaceuticals

Nanotoxicology, Nanotherapeutics (Prof Alexandra Porter)

At the end of the course students should be able to discuss:

- Types of therapeutic nanomaterials and their applications
- Cancer treatment through the use of particles
- Cell uptake routes and nanotoxicity of both classes of nanoparticle
- Transformations and translocation of nanomaterials in the body: Physiological responses to biomaterials and how materials properties determine outcome.

Ion doped ceramics (Prof Alexandra Porter)

At the end of the course the students should be able to describe:

- To compare the composition of hydroxyapatite and bone apatite
- To understand the different routes for processing synthetic hydroxyapatite
- To describe the mechanism of bioactivity of hydroxyapatite and the dissolution-reprecipitation mechanism leading to bone formation around the implant surface.
- To understand the limitations of HA and the need for and advantages of using substituted hydroxyapatites: Si-HA, CHA
- To be able to describe the different applications and forms of HA used in bone grafting applications

Interactions in biomaterials (Dr Stefano Angioletti-Uberti)

At the end of the course students should be able to discuss:

- Describe qualitatively through simple models some of the major types of microscopic interactions in biomaterials: ionic interactions, polymer-mediated and water-mediated interactions, ligand-receptor interactions
- Understand the microscopic origins generating and controlling the aforementioned interactions.
- Understand their effect in the development of applications, e.g. in drug-delivery, controlled protein adsorption or biosensing.

Characterisation of material: biomaterial-tissue and biomaterial-cell interfaces (Prof Alexandra Porter)

By the end of this lecture series, the students should understand how the following techniques can be used to characterise biomaterials:

- Methods for testing bio and nanomaterials including: Simulated body fluid, in vitro and in vivo testing methods
- Chemical characterisation: Appreciate the need for using a range of techniques to characterise the physicochemistry of nanomaterials.
- To understand SIMS, Raman spectroscopy and Zeta potential measurements
- Imaging interfaces between biomaterials-protein/cells/ tissues
- Scanning probe techniques (AFM), optical microscopy, confocal microscopy
- Imaging and analysis of biomaterials: SEM, TEM
- 3D imaging of nanomaterials inside cells

Commercialisation/ translation of medical devices (Prof J Jones)

Students will have an understanding of the mechanism and stages needed to take a new device from concept to clinic. This will be achieved through a practical Dragon's Den exercise in groups

- Patenting
- Regulatory procedures and claims
- Clinical trials
- Good manufacturing practice

Recommended textbooks A = required, B = recommended but not essential, C = background reading.

A Various printed publications

Structure, teaching and learning methods

24 lectures, 3 feedback sessions,: Spring term. 1 revision lecture : summer term

Assessment

Examination

The course is examined in the summer term. The exam is 2.5 hours in duration and consists of 5 questions, from which students must answer 3 questions (each marked out of 20).

The pass mark for the MEng cohort is 40% and for an MSc course is 50%. The module contributes 100 marks of the fourth year.

MSE 418 **Advanced Tissue Engineering**
Course Co-ordinator: Dr I E Dunlop Status: MEng Biomaterials and Tissue Engineering core course and MEng Fourth Year and MSc Advanced MSE option course *Prerequisites: None*
Aim Students will learn about modern developments in tissue engineering, and about the principles on which they are based.
Learning outcomes *Cellular responses to the local environment (Dr I Dunlop)* • Describe and explain the role of cellular responses to the local environment in tissue engineering. • Distinguish between empirical and rational design approaches to tissue engineering. • Describe and explain the principles and basic mechanisms of cellular signalling, in the abstract, and with reference to the examples given in the course. Apply this knowledge to newly encountered systems. • Describe and explain the principles and mechanisms of cellular mechanotransduction. • Describe and explain the aspects of surface chemistry and protein adsorption that are most relevant to tissue engineering. Explain the importance and relevance of this topic. *Materials synthesis for tissue engineering (Dr Theoni Georgiou)* • Describe and provide reasoning for the property requirements of scaffold materials for regenerative biological applications. • Describe, with aid of suitable recent examples, various strategies to fabricate porous materials. Suggest drawbacks and advantages of these approaches. • Describe different approaches to functionalisation of porous materials and apply this to newly encountered systems. • Demonstrate the ability to inter-link the above three learning outcomes to address new (i.e., potentially “unseen”) materials. *Clinical aspects of tissue engineering (Prof Molly Stevens)* • Describe and explain the role and importance of the extracellular matrix in tissue engineering • Understand the advantages and disadvantages of hydrogels and other scaffolds for tissue engineering. • Give examples of the applications of scaffolds for tissue engineering of tissues such as heart, bone, liver, kidney, nervous system. • Describe the application of polymers in drug delivery as a basis of polymer structure • Describe and explain the clinical case studies presented, and relate them to the concepts taught previously.
Structure, teaching and learning methods 24 lectures
Assessment *Examination* The course is examined in the summer term. The paper is 2.5 hours and students are required to answer 3 questions from the 5 set on the examination paper. **The pass mark for the MEng cohort is 40% and for an MSc course is 50%. The module contributes 100 marks of the fourth year of the MEng courses.**

3. Assessments

Coursework, tests and laboratory exercises make up the coursework mark that is used in the calculation of the year mark. The tables in this section will help you to be able to plan your study and revision timetable based on the due dates for the various elements. Each of the items here have a corresponding assessment description sheet that is included at the end of the handbook. This also includes a rough rubric for each assessment that can be used to guide the preparation of the item.

Coursework elements

Module	Due Date	% Contribution to Module
MSE 421 Placement report	Thurs 4 Oct	50%
MSE 421 Placement presentation	Mon/Tues 8/9 Oct	50%
MSE 410 Lab 1	1 week from lab (starting 19/11)	10%
MSE 410 Lab 2	1 week from lab (starting 19/11)	10%
MSE 410 Lab 3	1 week from lab (starting 19/11)	10%
MSE 404 Coursework	Thurs 7 Mar 19	40%
MSE 412 Poster exercise: abstract file	Friday 15 Feb 19	30%
MSE 412L Poster exercise: poster file	Monday 4 Mar 19	0% (But prerequisite for graduation/progression)

Exercises outside of the Department of Materials are not captured in this list.

MEng Project Deadlines

Assessment title	Group/Individual Deadline	Contribution
End of Autumn Term Assessment	6-14 Dec 2018	5% (S) + 5% (A)
Last day for experimental work	8 March 2019, 5pm	-
Research Project Presentation	14-22 March 2019	10%
Recommended draft report	29 March 2019	-
Research Project Thesis	29 April 2019, 4pm	20% (S) + 50% (A)
Viva	6-17 June 2019	10% (P)

(S) Supervisor
(A) Assessors
(P) Assessor panel

4. MEng Project Guidelines

The Research Project is the capstone of the Masters' degree programme where you get a taste of doing research. Since, even in industry, Materials Science and Engineering is mostly a research and development based discipline, this is of broad interest even if you do not intend to do a PhD or want to think about pursuing an academic career. Also, after *studying* science since school, it is very interesting to try *doing* science, where the outcome is not known in advance. Accordingly, it is worth 40% of the 4th year and therefore 40% x 45% = 18% of the degree. It should account for around 50% of your work over the year, with most of the work taking place over the autumn and spring terms.

Supervision

You will have one supervisor, and possibly co-supervisor(s). Their role is to provide scientific direction over the course of the project; they will be your *line manager* over the course of the year. For employment applications, they will most likely be one of your referees (the other being your personal tutor). You should meet with them regularly; the exact style of supervision will depend on the research group but the expectation is that you would meet with them at least 8 times over the two terms, in addition to any group meetings. Often, one or more PhD students or PDRAs will be involved in your supervision, especially in the practical, computational and analysis aspects.

Initial Meeting

To meet in the first week or so of the autumn term to (i) discuss the project and its overall aims, (ii) to set the stage for performing a critical literature review and planning the project, (iii) to organise the pace of regular meetings through the term, (iv) to introduce any assisting PhD students and PDRAs, and (v) to organise *e.g.* lab safety training and training in techniques.

You will then meet regularly and review results and progress (*e.g.* slides of results or notes) through the project. You should begin your thesis by making a critical review of the literature, so that you know what the key scientific questions are in the field and how your research will contribute to our understanding of the subject of study.

Assessors

You will also have two assigned assessors who will monitor your progress through the project and who assign most of the project marks. One will be from your approximate research area, and the other will be a generalist.

End of Autumn Term Assessment

Towards the end of the Autumn term you will meet with your supervisor to prepare a quad chard (1 slide) on your project using the template provided. A quad chart is a commonly used project management and presentation tool for compactly reviewing projects. It describes the project aims, scientific background, initial results and research plan going forward. You should also prepare additional slides (up to 5) detailing the results and plans. There will be a briefing on the preparation of this slide pack. You will then (in approx. the last week of term, 6-14 Dec 2018) meet with your assessors for 20 minutes to present this work and discuss your progress. The assessors will provide feedback and make suggestions for how you might proceed. The supervisor (5%) and assessors (5%) will allocate 10% of the project marks at this stage.

Spring Term

During the spring term you will continue to work on your project, meeting regularly with your supervisor. The last day for experimental work in the laboratory will be two weeks before the end of term (5pm, 8 March 2019). In order to leave room for revision, and so that your supervisor can comment on drafts, you should be continuing to add results and analysis to your thesis over this time, as well as presenting results informally, e.g. using slides.

Research Project Presentation

At the end of the spring term (14-22 March) you will present your results, analysis and findings-in-progress to your peers (10% of the marks). The Department is very approximately organised into research themes so this will be an open presentation to staff and students in your research theme. The format will be a 15 minute presentation followed by a 5 minute question-and-answer discussion session. There will be a briefing in the spring term on making scientific presentations and on writing theses. The academic staff present will submit a joint assessment and provide you with feedback to help you write up the project report. Your presentation should (i) introduce the aims of the project and situate it in the context of the research literature, (ii) show the main results and findings, (iii) discuss those results and present your conclusions so far.

Research Project Thesis

The project report is due by **4pm on Monday 29th April 2019, as a PDF via Blackboard**. The difficulty in setting this deadline is scheduling exams, which run over four weeks of the summer term. There isn't then time to give you (say) two weeks to finalise the thesis, time for marking during the exam marking period and then to hold vivas before degree results need to start being finalised on 18th June. Ideally therefore you would finish before starting revision for the 4th year exams, but if the deadline were the end of the spring term that would result in a limited experiment period, rushed analysis and inadequate time for the revision of drafts, etc. Therefore the deadline is a compromise. The recommendation is that you (i) complete the literature review and introduction in the autumn term, (ii) agree a structure for the report mid-way through the spring term, (iii) write up the results concurrently with performing your final experiments during the second half of the spring term and (iv) then hand in a draft to your supervisor at the end of the spring term (29 March), which is summarised in the presentation. Your supervisor can then comment on your draft whilst you revise before Easter (reasonable duration: 10 days) and you then can (iv) finalise your thesis (time estimate: 3 days) in-between revision before the end of the Easter revision period. Early submissions are welcome – there is no need to push right up to the deadline. Therefore in terms of managing your own schedule and receiving feedback it is critical to complete a good thesis draft by **29 March**.

Your supervisor will make an assessment at this point (20% of the marks) of your demonstration of professional skills throughout the project and a commentary for the assessors who mark your project. The two assessors will independently mark your report (50% of the marks).

Viva

Your two assessors and another pair of staff will form a viva panel, taking place 6-17 June. The viva will be 20 minutes long and will be led by your assessor that is in your field (10% of the marks). They will aim to discuss your results and conclusions with you, such that they are satisfied that you can discuss your work in a scientific fashion and that your conclusions are robust. You can expect that they will seek to explore the limits of your understanding and see how you reason when you are unsure of the answer. This will be the climax of the project process, and provides a taster of the process in PhD exams. The viva panel will then provide an overall moderated mark for your project.

Guidance on the Thesis

Writing science concisely is a skill that you should be developing throughout the degree programme. It is also easier to write a high quality short document than a long one, and this is easier to mark in a robust fashion. Therefore the project report is limited to **40 pages in length** (excluding any appendices for the supervisor, etc) – a total of 20 sides of A4, including cover sheet and references. A template (in LaTeX and MSWord) is provided and should be respected – 11pt Arial/Calibri for the main text, with 1.5cm margins, single spaced. It should include:

1pp Title Page and Abstract. To include project title, your name, supervisors incl PhDs and PDRAs and an abstract of up to 150 words.
1pp Contents. Do not go beyond the first subheading level. If appropriate, here include a paragraph providing commentary, on industrial involvement in the project and its relationship to any prior work, e.g. in a UROP or summer placement. A paragraph of acknowledgements and thanks should also be included here.
1pp Aims and Context. 1 paragraph on the aims of the project, and then a brief outline of the application context of the work and the relevance of the topic of study to society and industry.
12-18pp Literature Review.
14-18pp Results.
3-5pp Discussion.
0.5pp Conclusions.
1-2.5pp References. Around 60 references would be normal.
Further guidance will be provided in the templates provided and the marking rubrics.

5. Assessment forms and rubrics

Individual Coursework Information form

Module code	Research Project
Year of Study	MEng Y4
Assignment Name	Research Project Autumn term check-up
Academic in Charge	Prof David Dye
Marker	5% Research Project Supervisor 5% Research Project Assessors (pair)
When the assignment is presented to the students	During week 1 of Term 1
Method of submission	Blackboard Learn
Student's self-study hours	200 hours of self-study required (50% for 1 term)
Deadline date	End of the autumn term
Percentage of the module total	5% - supervisor assessment 5% - assessors feedback

Assignment details

Towards the end of the autumn term you will meet with your supervisor to prepare a quad chard (1 slide) on your project using the template provided. A quad chart is a commonly used project management and presentation tool for compactly reviewing projects. It describes the project aims, scientific background, initial results and research plan going forward. You should also prepare additional slides (up to 5) detailing the results and plans. There will be a briefing on the preparation of this slide pack. You will then (in approx. the last week of term, 6-14 Dec 2018) meet with your assessors for 20 minutes to present this work and discuss your progress. The assessors will provide feedback and make suggestions for how you might proceed. The supervisor (5%) and assessors (5%) will allocate 10% of the project marks at this stage.

Marking forms associated

Department of Materials, Imperial College

MEng Research Project
End-of-Autumn Term Feedback (Supervisor)

Student:

Project:

Supervisor:

Brief: Provide written feedback on performance over the term. The primary deliverables for the term were: (i) a complete literature review draft, (ii) a project concept and plan delivered as a quad chart, and (iii) approx. 5 weeks' practical/computational/theoretical work, and some preliminary results. The student is also expected to have met with you regularly and demonstrated professional and technical skills in the areas of practical/ computational/ theoretical work, time management etc. Your written comments (which need not be typed) should be discussed with the student in a 1-1 meeting before the end of term. Highlight the aspects that the student did well and provide constructive criticism and guidance on how to improve. This assessment comprises 5% of the overall project mark and is intended to be primarily formative in nature.

Student effort and effectiveness of that effort in moving towards objectives: has the student devoted sufficient time and energy to the project? Has the student worked efficiently? Have they demonstrated and developed appropriate professional skills, e.g. timeliness and organisation?
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Scientific quality and comprehension: does the student have a good level of understanding of the science? Have they made a realistic appraisal of the achievable objectives?
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Demonstration of effective use of skills: has there been effective demonstration / development of the student's computing/experimental/theoretical skills to the research? Have they worked sufficiently independently?
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Supervisor Signature:	**Total (/60):**
Student Signature:	**Date:**

Department of Materials, Imperial College

MEng Research Project
End-of-Autumn Term Feedback (Assessors)

Student:

Project:

Supervisor:

Brief: Meet with the student for 25 min to discuss their project progress independently from the supervisor to check that the project is set up and verify that the supervision arrangements are working well. The student will have a quad chart outlining the project and up to 5 slides of results to show in the meeting. You are to discuss the project and their progress with them and provide advice and comments here. This assessment in primarily formative in nature and is worth 5% of the overall project mark.

Quad Chart: Could the student communicate the project aims, scientific background and plan clearly to you? Does the student understand the aims and literature and have a clear and realistic plan for achieving those aims?

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Initial Results (up to 5 slides): Are the initial results of an appropriate quality and quantity? Could the student discuss these and the next steps with you in a scientific fashion?

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Assessor 1 Signature:

Assessor 2 Signature: **Total (/40):**

Student Signature: **Date:**

Individual Coursework Information form

Module code	Research Project
Year of Study	MEng Y4
Assignment Name	Research Project Presentation
Academic in Charge	Prof David Dye
Marker	Research theme academic staff
When the assignment is presented to the students	During week 1 of Term 1
Method of submission	Oral presentation
Student's self-study hours	6h preparation, half day attending presentations and presenting
Deadline date	End of the spring term (14-22 Mar 2019)
Percentage of the module total	10%

Assignment details

At the end of the spring term (14-22 March) you will present your results, analysis and findings-in-progress to your peers (10% of the marks). The Department is very approximately organised into research themes so this will be an open presentation to staff and students in your research theme. The format will be a 15 minute presentation followed by a 5 minute question-and-answer discussion session. There will be a briefing in the spring term on making scientific presentations and on writing theses. The academic staff present will submit a joint assessment and provide you with feedback to help you write up the project report. Your presentation should (i) introduce the aims of the project and situate it in the context of the research literature, (ii) show the main results and findings, (iii) discuss those results and present your conclusions so far.

Other requirements

AV equipment and a PC will be available for the use of Powerpoint of other visual aids software.

Marking forms associated

Brief: All projects in the research theme will be presented together over the course of a half-day or day. Academic staff from the theme present should provide a collective mark list and feedback to each student. This element comprises 10% of the overall mark for the research project. Give approximately equal weight to each of the elements below and provide feedback under each heading.

Background: Was the scientific and technological context and motivation for the work clearly exposited?

Methods and Results: Was it clear *what* was done, *how* it was done, and were errors/uncertainties handled properly?

Discussion and Conclusions: Were the results discussed in the context of the literature and appropriate conclusions drawn?

Oral Presentation: Was the oral presentation, including questions, handled well? Was the talk well organised and stayed within the time restriction?

Visual Aids: slides, figures and graphs: Rate the quality (including logical structure) of the visual aids used.

(Academic) Staff Members Present:

Mark (/20):

Date:

Important: *All results prior to the examination board meeting at the end of each academic year are provisional; they may change before final ratification by Registry. For the MEng research project, the overall project mark will also be moderated by the viva panel.*

At the end of the presentations, hand a copy of this form to the student and send the original to the student office.

Individual Coursework Information form

Module code	Research Project
Year of Study	MEng Y4
Assignment Name	Research Project Supervisor Assessment
Academic in Charge	Prof David Dye
Marker	Research Project Supervisor
When the assignment is presented to the students	During week 1 of Term 1
Method of submission	Performance over the project
Student's self-study hours	Autumn term: 200h (50%). Spring term: 200h (50%). Easter vacation: 40h (1 week).
Deadline date	12 April (Easter)
Percentage of the module total	20%

Assignment details

The research project supervisor is not involved in marking the thesis, so this element provides their assessment of the student's engagement; work rate; development and demonstration of interpersonal, professional and technical skills; performance in supervisions and collaboration with the research group. The supervisor will also provide a commentary for the assessors at this point on difficulties encountered, extent of PhD and PDRA involvement in supervision, etc.

Marking forms associated (following page)

Department of Materials, Imperial College
MEng Research Project
Supervisor Commentary

Student:
Project:
Supervisor:
Purpose. For the benefit of the assessors marking the project and external examiners, it is helpful to understand the background of the student and the extent and character of the assistance they have received throughout the course of the research; this form aims to capture this information. Please comment on the following aspects:

(i) Background of the student in the research field (previous degree and experience)

(ii) Relationship of the work to prior work by the student or ongoing research in the research group (UROPs, industrial placements, PhD/PDRA projects); what is new work by the student done in the project assessed here.

(iii) Extent of assistance received from collaborators / supervisors (e.g. PhD students, PDRAs, other groups), especially in advanced techniques, analysis tools and interpretation.

(iv) Extent of assistance with drafts by the supervisor and assistants, e.g. PhD students and PDRAs; e.g. in structuring the thesis, in editing for style and English, and in the interpretation and presentation of the science.

(v) Please also take this opportunity to recognise the contribution to supervision made by PhD students, PD RAs and fellows, and by internal and external collaborators, including industrial supervisors.

It is entirely normal and encouraged for others in the research group to supervise Masters-level research students in the lab, and to provide additional assistance, e.g. with advanced characterisation techniques and computational analysis. It is also encouraged for supervisors to help with outlining and structuring of the thesis, and for PhD students and PDRAs to comment on the style and English of drafts. Most theses will also have been commented upon by the supervisor, with a draft handed in around at the end of the spring term and returned for revision by Easter. If students do not prepare drafts for supervisor comment in good time, then they should expect to find that this reduces the quality of their thesis and therefore its overall mark. However, it is still useful to capture the extent of any input given.

Department of Materials, Imperial College
MEng Research Project
Supervisor Commentary

Student:
Project:
Supervisor:
Purpose. The two markers have no insight into the student's demonstration of professional skills over the course of the project, which is of course an important aspect. Therefore 20% of the overall mark or the project is reserved for your assessment of these aspects.

Skills and behaviours: demonstration of appropriate (laboratory) skills and behaviours. Examples: safe working practices, appropriate interpersonal behaviours with other group members and collaborators, (experimental / computational) aptitude and innovation.

Organisation and Dilligence: Proactiveness e.g. in organising meetings, preparation for supervision meetings (e.g. slides and notes on results and work in progress), timeliness, self-organisation of working schedules and timelines.

Intermediate Research Products: Examples: preparation of drafts, notes on literature, ability to discuss results and determine next steps, 'thinking scientifically.'

Supervisor Signature:
Total (/50):
Date:

Individual Coursework Information form

Module code	Research Project
Year of Study	MEng Y4
Assignment Name	Research Project Thesis
Academic in Charge	Prof David Dye
Marker	Research Project Assessors (blind double marking)
When the assignment is presented to the students	During week 1 of Term 1
Method of submission	PDF via Blackboard
Student's self-study hours	Autumn term: 200h (50%). Spring term: 200h (50%). Easter vacation: 40h (1 week). (for the entire project including all elements)
Deadline date	4PM, 29 April 2019, preferably sooner. First draft should be given to supervisor by the end of spring term; this will give space for final editing after Easter without interfering with revision.
Percentage of the module total	50%

Assignment details

Writing science concisely is a skill that you should be developing throughout the degree programme. It is also easier to write a high quality short document than a long one, and this is easier to mark in a robust fashion. Therefore the project report is limited to **40 pages in length** (excluding any appendices for the supervisor, etc) – a total of 20 sides of A4, including cover sheet and references. A template (in LaTeX and MSWord) is provided and should be respected – 11pt Arial/Calibri for the main text, with 1.5cm margins, single spaced. It should include

1pp	Title Page and Abstract. To include project title, your name, supervisors incl PhDs and PDRAs and an abstract of up to 150 words.
1pp	Contents. Do not go beyond the first subheading level. If appropriate, here include a paragraph providing commentary, on industrial involvement in the project and its relationship to any prior work, e.g. in a UROP or summer placement. A paragraph of acknowledgements and thanks should also be included here.
1pp	Aims and Context. 1 paragraph on the aims of the project, and then a brief outline of the application context and the relevance of the topic of study to society and industry.
15pp	Literature Review.
15-17pp	Results.
3-5pp	Discussion.
0.5pp	Conclusions.
1-2.5pp	References. Around 60 references would be normal.

Marking forms associated

Department of Materials, Imperial College

MEng Research Project
Thesis Assessment

Student:

Project:

Supervisor:

Brief: Two Assessors independently mark the thesis. Reconciliation will be performed when the viva panel meets to award a moderated mark for the project overall, including all the other elements. The thesis is 50% of the marks, the remainder comprising the autumn assessment (2x 5%), presentation & viva (2x10%), and supervisor assessment (20%). For each part of the rubric, guidance is provided overleaf; you should provide a rationale for your mark in each section for the purposes of reconciliation in the viva panel and for the external examiners.

1. Aim and Motivation (0-5):

2: Literature Review (0-25):

3. Result and Analysis (0-30):

4: Discussion, Conclusions and Abstract (0-20):

5: Written Presentation, presentation of (original) figures and handing of data (0-20):

Assessor:

Total (/100):

Date:

All results prior to the examination board meeting at the end of each academic year are provisional; they may change before final ratification by Registry. The original of this form should be taken to the viva panel and then provided to the student office.

Individual Coursework Information form

Module code	Research Project
Year of Study	MEng Y4
Assignment Name	Research Project Viva
Academic in Charge	Prof David Dye
Marker	Research Project viva panel (4 staff)
When the assignment is presented to the students	During week 1 of Term 1
Method of submission	PDF via Blackboard
Student's self-study hours	5h
Deadline date	6-17 June (date TBD).
Percentage of the module total	10%

Assignment details

Discuss the research project report with an assessor in front of the viva panel (4 staff including the assessor). Topics may include any relevant areas of the research project, including the background and motivation, aims, research methods, handling of data and uncertainties, results, challenges and difficulties encountered over the course of the project, discussion and the conclusions that may be drawn. Duration will be 20-25 mins.

Other requirements

The students need to express themselves confidently when discussing the work and answering questions.

The viva panel (4 staff) will also provide a moderated mark list for the 10-12 projects that they have assessed, based on all of the input marks (research plan, art of research, supervisor assessment, thesis and viva).

Marking forms associated

Department of Materials, Imperial College

MEng Research Project
Viva Assessment

Student:
Project:
Supervisor:

Brief: One of the two Assessors should lead the viva (20 mins) for the panel (four staff). The panel should award a mark for the viva performance (10% of the project total) and, at the end of the session, moderate all the overall project marks for their pool of candidates. In the viva, typically settle the student by asking them what their project aimed to achieve and what they found out (3 mins, no slides, thesis figures may be used). Then, explore the student's understanding of the subject, the robustness of their data and its analysis, and discuss the implications of their work to explore whether the conclusions are robust. Have all the implications which can be drawn, been explored? This should be a testing but enjoyable final element of the degree. Give approximately equal weight to each of the following aspects, and provide feedback.

1. Ability to give a review of their work and place it into context

2: Understanding of the work undertaken

3. Ability to defend conclusions

4: Understanding of the relevance and limitations of the research study

Assessor:
Total (/20):
Date:

Individual Coursework Information form

Module code	MSE 404
Year of Study	4^{th} year and MSc Adv
Assignment Name	Homework problem 1
Academic in Charge	Dr Johannes Lischner
Marker	Dr Johannes Lischner and Dr Eamonn Murray
When the assignment is presented to the students	1^{st} week of lectures
Method of submission	Blackboard learn
Student's self-study hours	5 hours
Deadline date	7 days after receiving the assignment
Percentage of the module total	All assignments make up 40 percent of the total grade and are weighted equally

Assignment details

Calculate properties of electrons in square well and helium atom

Individual Coursework Information form

Module code	MSE 404
Year of Study	4^{th} year and MSc Adv
Assignment Name	Homework problem 2
Academic in Charge	Dr Johannes Lischner
Marker	Dr Johannes Lischner and Dr Eamonn Murray
When the assignment is presented to the students	2^{st} week of lectures
Method of submission	Blackboard learn
Student's self-study hours	5 hours
Deadline date	7 days after receiving the assignment
Percentage of the module total	All assignments make up 40 percent of the total grade and are weighted equally

Assignment details

Calculate properties of interacting electrons in He atom and diatomic molecules

Individual Coursework Information form

Module code	MSE 404
Year of Study	4^{th} year and MSc Adv
Assignment Name	Homework problem 3
Academic in Charge	Dr Johannes Lischner
Marker	Dr Johannes Lischner and Dr Eamonn Murray
When the assignment is presented to the students	3^{rd} week of lectures
Method of submission	Blackboard learn
Student's self-study hours	5 hours
Deadline date	7 days after receiving the assignment
Percentage of the module total	All assignments make up 40 percent of the total grade and are weighted equally

Assignment details

Explore plane wave representation of wavefunction and study convergence for diatomic molecules using computer code

Individual Coursework Information form

Module code	MSE 404
Year of Study	4^{th} year and MSc Adv
Assignment Name	Homework problem 4
Academic in Charge	Dr Johannes Lischner
Marker	Dr Johannes Lischner and Dr Eamonn Murray
When the assignment is presented to the students	4^{th} week of lectures
Method of submission	Blackboard learn
Student's self-study hours	5 hours
Deadline date	7 days after receiving the assignment
Percentage of the module total	All assignments make up 40 percent of the total grade and are weighted equally

Assignment details

Calculate the bandstructure of two-dimensional boron nitride using Quantum Espresso

Individual Coursework Information form

Module code	MSE 404
Year of Study	4th year and MSc Adv
Assignment Name	Homework problem 5
Academic in Charge	Dr Johannes Lischner
Marker	Dr Johannes Lischner and Dr Eamonn Murray
When the assignment is presented to the students	5th week of lectures
Method of submission	Blackboard learn
Student's self-study hours	5 hours
Deadline date	7 days after receiving the assignment
Percentage of the module total	All assignments make up 40 percent of the total grade and are weighted equally

Assignment details

Calculate properties of a vacancy defect in a silicon crystal using Quantum Espresso

Individual Coursework Information form

.Module code	MSE 404
Year of Study	4th year and MSc Adv
Assignment Name	Homework problem 6
Academic in Charge	Dr Johannes Lischner
Marker	Dr Johannes Lischner and Dr Eamonn Murray
When the assignment is presented to the students	6th week of lectures
Method of submission	Blackboard learn
Student's self-study hours	5 hours
Deadline date	7 days after receiving the assignment
Percentage of the module total	All assignments make up 40 percent of the total grade and are weighted equally

Assignment details

Calculate properties of atomic vibrations in a one-dimensional cumulene crystal using Quantum Espresso

Individual Coursework Information form

Module code	MSE 404
Year of Study	4th year and MSc Adv
Assignment Name	Homework problem 7
Academic in Charge	Dr Johannes Lischner
Marker	Dr Johannes Lischner and Dr Eamonn Murray
When the assignment is presented to the students	7th week of lectures
Method of submission	Blackboard learn
Student's self-study hours	5 hours
Deadline date	7 days after receiving the assignment
Percentage of the module total	All assignments make up 40 percent of the total grade and are weighted equally

Assignment details

Calculate the specific heat of a diamond crystal using Quantum Espresso

Individual Coursework Information form

Module code	MSE 404
Year of Study	4th year and MSc Adv
Assignment Name	Homework problem 8
Academic in Charge	Dr Johannes Lischner
Marker	Dr Johannes Lischner and Dr Eamonn Murray
When the assignment is presented to the students	8th week of lectures
Method of submission	Blackboard learn
Student's self-study hours	5 hours
Deadline date	7 days after receiving the assignment
Percentage of the module total	All assignments make up 40 percent of the total grade and are weighted equally

Assignment details

Study anti-ferromagnetism of nickel oxide using Quantum Espresso.

Individual Coursework Information form

Module code	MSE 410
Year of Study	4thyear and MSc Adv
Assignment Name	MSE 410 Lab 1
Academic in Charge	Dr Peter Petrov
Marker	GTAs
When the assignment is presented to the students	1st week of lectures
Method of submission	Blackboard Learn
Student's self-study hours	e.g. 5-10 hours of self-study required
Deadline date	Deadline depends on what group they are assigned (i.e. 7 days from the completing the lab)
Percentage of the module total	10%

Assignment details

A group of students needs to grow metal thin films with various growth conditions and compare difference in growth rates. Each student is required to clean a substrate, successfully deposit a metal thin film, measure thickness of the thin film and calculate growth rate.

1. Q&A (revise the lecture).
2. Substrate cleaning: each student is required to clean a substrate.
3. Substrate mounting: firmly stick the substrate on the sample holder.
4. Thin film sputtering: deposit ~50nm metal thin films on the substrate.
5. Sample removal: remove sample from the sample holder.
6. Thickness measurement: record results of measurements.
7. Report writing.

Other requirements

1. The report is due 1 week after the laboratory session.
2. The report should include the principle and schematic diagram of the DC magnetron sputtering system.
3. The report should include description of process.
4. Calculate growth rates of the material deposited and discuss the parameters which may affect the deposition and growth rates.

Individual Coursework Information form

Module code	MSE 410
Year of Study	4thyear and MSc Adv
Assignment Name	MSE 410 Lab 2
Academic in Charge	Dr Peter Petrov
Marker	GTAs
When the assignment is presented to the students	1st week of lectures
Method of submission	Blackboard Learn
Student's self-study hours	e.g. 5-10 hours of self-study required
Deadline date	Deadline depends on what group they are assigned (i.e. 7 days from the completing the lab)
Percentage of the module total	10%

Assignment details

Each student is required to select a pattern and successfully print the pattern on a sample. Measure dimensions of the selected patterns and compare them with the patterns on the mask.

1. Q&A (revise the lecture).
2. Sample cleaning and preparation: each student is required to clean a sample.
3. Photoresist application: apply photoresist on the sample surface.
4. Spin coating and soft baking the sample.
5. Exposure and developing.
6. Hard baking the sample.
7. Measuring dimensions of patterns.
8. Report writing.

Other requirements

1. The report is due 1 week after the laboratory session
2. The report should include the principle and schematic diagram of the mask aligner.
3. The report should focus mainly on depiction of process and interpretation of differential patterns between mask and sample.

Individual Coursework Information form

Module code	MSE 410
Year of Study	4thyear and MSc Adv
Assignment Name	MSE 410 Lab 3
Academic in Charge	Dr Peter Petrov
Marker	GTAs
When the assignment is presented to the students	1st week of lectures
Method of submission	Blackboard Learn
Student's self-study hours	e.g. 5-10 hours of self-study required
Deadline date	Deadline depends on what group they are assigned (i.e. 7 days from the completing the lab)
Percentage of the module total	10%

Assignment details

A group of students is required to etch two samples patterned previously by photolithography, measure the etched thicknesses of samples and calculate their etching rates. One sample needs to be etched using Ar gas. The other sample needs to be etched using CF_4 gas. 1. Q&A (revise the lecture). 2. Sample etching. 3. Photoresist stripping. 4. Thickness measurement. 5. Measuring dimensions of patterns. 6. Report writing.

Other requirements

1. The report is due 1 week after the laboratory session. 2. The report should include the principle and schematic diagram of the RIE system. 3. The report should include description of process. 4. The report should mainly focus on elucidation of the difference between samples etched by using different injected gases.

Individual Coursework Information form

Module code	MSE 412
Year of Study	4th year and MSc Adv
Assignment Name	Poster presentation
Academic in Charge	Dr Cecilia Mattevi
Marker	Dr Cecilia Mattevi and academics in related research themes
When the assignment is presented to the students	Week 1 of lectures
Method of submission	Via e-mail to Dr Cecilia Mattevi
Student's self-study hours	15 hours
Deadline date	Abstracts are required in week 6 (Friday 15th February 2019) and are used to provide feedback on choice of topic. Deadline for providing the file is Monday 4th March 2019 4pm. Posters are presented in week 9 (8th March 2019).
Percentage of the module total	30%

Assignment details

Students are required to present a poster on a general theme related to "Nano". Themes are deliberately broad and change every year. Students are required to focus on a topic not directly related to their research project and lectures, but use some of the knowledge acquired on the course. This work is presented as a group of 2-4 students, depending on numbers of students enrolled on the course and students are free to organise their groups as they wish. An abstract should be submitted by week 4, so that feedback can be provided on the suitability of the topic students have chosen to focus on. Posters should be fully referenced and of a standard expected in a research symposium. Posters will be presented at the annual Nano II symposium, which is attended by other academics in the department, as well as senior researchers. Students are marked on both the oral and written (design, clarity, remit of the poster) presentation.

Other requirements

A template is provided for the abstract so that it can be copied into the abstract booklet. The poster format is A0 portrait.