Department of Materials
Imperial College London

Materials Science and Engineering (MEng)
Biomaterials and Tissue Engineering (MEng)
Materials with Nuclear Engineering (MEng)
Materials Science and Engineering (BEng)
Materials with Management (BEng)
Introduction

This handbook contains specific information for the Year 2 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.

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1. Welcome for Year Co-ordinator

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Tel: +44 (0) 20 7594 8547
Email: f.bouville@imperial.ac.uk

Welcome back for your second year at the department!

An interesting year in your curriculum, as you will both reinforce the skills you have from your first year and discover new aspects of materials science. This year is also the one in which you will start working on group project more regularly to help you build your very own experiences and interests. The teaching team will be there to guide you along the way, so now only one thing left to say: happy learning and growth!

2. Programme Information

Key dates 2019 – 20

Please note that academic activities will take place from the beginning of each term and can run to the last day of term. Therefore, do not plan travel inside the term dates.

| Term Dates |  
|-------------|--------------------------------------------------|
| Autumn term: | 28 September 2019 - 13 December 2019 |
| Spring term: | 4 January 2020 - 20 March 2020 |
| Summer term: | 25 April 2020 - 26 June 2020 |

| Closure Dates |  
|---------------|----------------------------------|
| Christmas/New year: | 23 December 2020 – 1 January 2020 *(College reopens on 2 January 2020)* |
| Easter Holiday: | 9 April 2020 – 14 April 2020 *(College reopens on 15 April 2020)* |
| Early May Bank Holiday: | 8 May 2020 |
| Spring Bank Holiday: | 25 May 2020 |
| Summer Bank Holiday: | 31 August 2020 |
Year structure

Second year comprises 6 modules: 5 which are primarily lectures courses, 1 of which has a significant lab component and which is around engineering essential skills. These modules are listed below along with the relative module weighting in the year structure and the contribution of each component to the module.

<table>
<thead>
<tr>
<th>Module</th>
<th>Name</th>
<th>% Contribution</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATE95001</td>
<td>Mathematics and Computing</td>
<td>% Contribution</td>
<td>16.875</td>
</tr>
<tr>
<td>(MSE 201)</td>
<td>January Progress Test</td>
<td>8%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Computing Exercise</td>
<td>8.5%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Computing Assessment</td>
<td>8.5%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Exam</td>
<td>75%</td>
<td></td>
</tr>
<tr>
<td>MATE95002</td>
<td>Materials Chemistry and Polymer Science</td>
<td>% Contribution</td>
<td>14.375</td>
</tr>
<tr>
<td>(MSE 202)</td>
<td>25% of the Long Lab</td>
<td>13%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Exam</td>
<td>87%</td>
<td></td>
</tr>
<tr>
<td>MATE95003</td>
<td>Mechanical Behaviour</td>
<td>% Contribution</td>
<td>14.375</td>
</tr>
<tr>
<td>(MSE 203)</td>
<td>25% of the Long Lab</td>
<td>13%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Exam</td>
<td>87%</td>
<td></td>
</tr>
<tr>
<td>MATE95004</td>
<td>Microstructure</td>
<td>% Contribution</td>
<td>14.375</td>
</tr>
<tr>
<td>(MSE 204)</td>
<td>25% of the Long Lab</td>
<td>13%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Exam</td>
<td>87%</td>
<td></td>
</tr>
<tr>
<td>MATE95005</td>
<td>Electronic Properties of Materials</td>
<td>% Contribution</td>
<td>14.375</td>
</tr>
<tr>
<td>(MSE 205)</td>
<td>25% of the Long Lab</td>
<td>13%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Exam</td>
<td>87%</td>
<td></td>
</tr>
<tr>
<td>MATE95006</td>
<td>Materials Engineering</td>
<td>% Contribution</td>
<td>25.625</td>
</tr>
<tr>
<td>(MSE 206)</td>
<td>Characterisation Labs</td>
<td>14.65%</td>
<td></td>
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<tr>
<td></td>
<td>Characterisation Test</td>
<td>2.44%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Case Study Report</td>
<td>15.60%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Case Study Presentation</td>
<td>3.90%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heat flow coursework exercises (combined)</td>
<td>4.88%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Process principles poster</td>
<td>9.75%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BPES Project Management</td>
<td>48.78%</td>
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</table>

Progression

Progression criteria for Year 2 are:
- passing every module with a minimum of 40%
- passing the combined coursework from all modules with a minimum of 40%

Additional progression criteria for students on the MEng
- passing with a year total of at least 60%

The combined coursework mark is calculated by summing the module and coursework item weighting.
3. **Coursework Deadlines**

Please note that these dates are **preliminary and may change throughout the year**. You will be notified of changes by the Student Office by email.

<table>
<thead>
<tr>
<th>Term</th>
<th>Module</th>
<th>Assignment/Event</th>
<th>Due Date</th>
<th>Format</th>
<th>Feedback/Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autumn</td>
<td>MATE95001 (MSE 201)</td>
<td>Programming Challenge 1</td>
<td>09:00 05/12/2019</td>
<td>Group Submission electronically via Blackboard Learn</td>
<td>3 weeks*</td>
</tr>
<tr>
<td></td>
<td>MATE95006 (MSE 206)</td>
<td>Case Study Report Groups A&amp;B 09:00 10/12/2019 Groups C&amp;D 09:00 13/12/2019</td>
<td>Individual copy of the report compiled in your groups electronically via Blackboard Learn</td>
<td>2 weeks*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MATE95006 (MSE 206)</td>
<td>Case Study Presentation (upload) Groups A&amp;B 09:00 02/12/2019 Groups C&amp;D 09:00 05/12/2019</td>
<td>Electronically via Blackboard Learn</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Case Study Presentation (Oral Presentation) Groups A&amp;B 13:00 – 17:00 03/12/2019 Groups C&amp;D 13:00 – 17:00 06/12/2019</td>
<td>N/A</td>
<td>2 weeks*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MATE95006 (MSE 206)</td>
<td>Heat/Mass Flow short assignment 09:00 23/01/2020</td>
<td>Online test via Blackboard Learn</td>
<td>Immediate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MATE95006 (MSE 206)</td>
<td>Heat/Mass Flow long assignment 09:00 27/02/2020</td>
<td>Electronically via Blackboard Learn</td>
<td>2 weeks*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MATE95002 (MSE 202)</td>
<td>MATE95003 (MSE 203) MATE95004 (MSE 204) MATE95005 (MSE 205) Long Labs 09:00 05/03/2020</td>
<td>Electronically via Blackboard Learn</td>
<td>3 weeks*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MATE95006 (MSE 206)</td>
<td>Process Principles Poster Submission 09:00 10/03/2020</td>
<td>Electronically via Blackboard Learn</td>
<td>2 weeks*</td>
<td></td>
</tr>
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</table>

* The above dates do not include the Student Office processing time which can be up to **additional 5 working days** on top of the estimated feedback/marker timeframe.
### Exam and Tests Timetable

<table>
<thead>
<tr>
<th>Date</th>
<th>Test Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>07/11/2019</td>
<td>MATE95006 Characterisation Test</td>
</tr>
<tr>
<td>08/11/2019</td>
<td>MATE95001 Computing Test</td>
</tr>
<tr>
<td>10/01/2020</td>
<td>MATE95001 Maths Progress Test</td>
</tr>
</tbody>
</table>

#### Exams 2020

<table>
<thead>
<tr>
<th>Wk</th>
<th>27th Apr</th>
<th>4th May</th>
<th>11th May</th>
<th>18th May</th>
<th>25th May</th>
<th>1st June</th>
<th>8th June</th>
<th>15th June</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Monday

- **AM**
- **Lunch**
- **PM**
  - Bank Holiday

#### Tuesday

- **AM**
  - 201
- **PM**
  - 202

#### Wednesday

- **AM**
  - 205
- **PM**
- **Lunch**

#### Thursday

- **AM**
- **PM**
- **Lunch**

#### Friday

- **AM**
  - Bank Holiday
- **PM**
  - 204
- **Teaching Committee**
4. Module Information

MATE95001 (MSE 201) Mathematics and Computing

<table>
<thead>
<tr>
<th>Module Leader:</th>
<th>Paul Tangney</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaching Staff:</td>
<td>Johannes Lischner, Arash Mostofi, Peter Haynes, Stefano Angioletti-Uberti</td>
</tr>
</tbody>
</table>

Why study this module?
This course is a continuation of the first-year course MSE 101 and aims to give students a firm foundation in the aspects of Mathematics and Computing of most relevance to Materials Science and Engineering, especially the topics required in subsequent years of study. The missions of Mathematics and Computer Programming are to provide tools, and sufficient knowledge to use them safely, for the purpose of understanding and applying the quantitative methods of Materials Science and Engineering.

You will study:
- Vector calculus
- Fourier methods
- Cartesian tensors
- Partial differential equations
- Mathematics of Electromagnetism
- Probability theory and Statistics
- Computer Programming

How will I be Taught?
Mathematics
48 lectures: Autumn and Spring terms
10 tutorials: Autumn and Spring terms

Computer Programming
7 practical classes: Autumn term

How will I be Assessed?
Mathematics
Examination
The course is examined in the Summer term. The examination paper, duration 3 hours, is in two sections. Section A is compulsory and consists of short answer questions on all parts of the course. Section B contains 4 questions of which students must answer 3.

Tutorials
There are 10 tutorials for which students need to prepare answers to problem sets.

Progress Test
There will be a test at the start of the Spring term on material that is covered during the autumn term.

Computer Programming
There is no examination for this. Students will complete an in-class assessment in week 5 of the course and will provide 50% of the contribution to the module. The other component will be a group coding exercise.
### Module Breakdown:

<table>
<thead>
<tr>
<th></th>
<th>% Contribution to module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Progress Test 1</td>
<td>8%</td>
</tr>
<tr>
<td>Computing Test &amp; Exercise</td>
<td>17%</td>
</tr>
<tr>
<td>Exam</td>
<td>75%</td>
</tr>
</tbody>
</table>

### Reading List:

**Required**
- *Getting Started with MATLAB*, Rudra Pratap, Oxford University Press 2009

**Recommended but not essential**

**Background reading**
- *Practical Physics*, G. Squires, CUP 2001

### Learning Outcomes of this Module:

#### Vector calculus
Preliminaries: cylindrical and spherical polars; double and triple integrals. Vector calculus: gradient, divergence, curl and Laplacian in cylindrical and spherical polars; line, surface and volume integrals, proof and application of divergence and Stokes’ theorems; Maxwell’s equations leading to Gauss’s Law and Ampère’s Law.

#### Fourier methods
Orthogonality of functions; periodic functions; orthogonality relations of sine and cosine; Fourier series; discontinuous functions; use of symmetry; Parseval’s theorem for Fourier series. Fourier transform: definition, relation to Fourier series, simple properties; bandwidth theorem; Parseval and convolution theorems for Fourier transforms; applications to diffraction and partial differential equations (e.g., heat diffusion).

#### Cartesian tensors
Basic properties and rules of tensor algebra; transformation laws; isotropic tensors; symmetric and anti-symmetric tensors; suffix notation and Einstein summation convention; Kronecker and Levi-Civita symbols; representation of grad, div and curl; principal axes and diagonalisation; matter tensors and Neumann’s Principle; applications to elasticity, anisotropic dielectrics, conductivity.

#### Partial differential equations
Skills to construct a PDE from a given problem in solid mechanics, diffusion or heat conduction in 1-3 dimensions. Separation of variables; Laplace, Poisson, diffusion and wave equations, equations from simple problems in linear elasticity; initial conditions and boundary conditions. Green functions.

#### Mathematics of Electromagnetism
**Probability theory and Statistics**
Venn diagrams and set theory notation; basic definitions and rules of probability; Bayes’ theorem; combinations and permutations; discrete random variables; probability distributions; Properties of distributions: mean, mode and median, variance, higher moments, probability generating functions; Poisson and binomial distributions; Continuous random variables; probability density functions, moment generating functions; Gaussian and exponential distributions; central limit theorem; parameter estimation, error estimation.

**Computer Programming**
Classes and building new objects in Python; Numpy and Scipy library for scientific computing & assemble code by using pre-written libraries; measuring the efficiency of a code / profiling; understanding how to write a properly structured program, "divide and conquer" strategies for solving computational problems.

### Programming challenge coursework information form

<table>
<thead>
<tr>
<th>Module code</th>
<th>MATE95001 (MSE 201) Maths and Computing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year of Study</td>
<td>2nd Year UG</td>
</tr>
<tr>
<td>Assignment Name</td>
<td>Programming Challenge</td>
</tr>
<tr>
<td>Academic in Charge</td>
<td>Dr Stefano Angioletti-Uberti</td>
</tr>
<tr>
<td>When the assignment is presented to the students</td>
<td>5th week of lectures</td>
</tr>
<tr>
<td>Method of submission</td>
<td>Group submission via Blackboard Learn</td>
</tr>
<tr>
<td>Student’s self-study hours</td>
<td>Its group work – 5 hrs of self-study</td>
</tr>
<tr>
<td>Deadline date</td>
<td>5th December 2019 9am</td>
</tr>
<tr>
<td>Percentage of the module total</td>
<td>50% of the Computing Grade (the other 50% is a test and the Computing is 17% of the whole Maths and Computing) module</td>
</tr>
<tr>
<td>Estimated marking/feedback time</td>
<td>3 weeks</td>
</tr>
<tr>
<td>Turn-it-in requirement</td>
<td>No</td>
</tr>
</tbody>
</table>

**Assignment details**
Group coding exercise – students will hand in the code from a group project (each group will be 4 or 5 students), which will give the other 50% of the mark for Computing. The submission must be within two weeks of the last lecture.

**Rubric:**
- Correct and efficient use of python language (50 %)
- Structure of the code (25 %) and best practices (commenting of functions, structuring in different subtasks, presence of redundant parts, ...)
- Code solves the required task (25 %)
**Why study this module?**

This course is designed to (i) give students a fundamental understanding of materials stability and the implications for corrosion and protection of engineering materials, (ii) develop students understanding of polymer synthesis, characterisation, structure and properties, and (iii) to develop an understanding of how macromolecules arrange themselves in polymer solids and how that arrangement affects the macroscopic properties. The module also covers how polymers are processed into useful products and how macroscopic properties can be controlled through processing. The course content follows on directly from the first year 102 and 104 courses and develops many of the concepts of thermodynamics, kinetics and polymers applied to materials systems.

You will study:

- Glasses and their degradation
- Degradation of Polymers
- Phase Stability Diagrams and High Temperature Oxidation
- Aqueous Corrosion and Protection
- Polymers

**How will I be Taught?**

40 lectures: Autumn and Spring terms
8 tutorials: Autumn and Spring terms

**How will I be Assessed?**

**Examination**

The course is examined in the Summer term. The examination paper, duration 3 hours, is in two sections. Section A is compulsory and consists of short answer questions on all parts of the course. Section B contains 4 questions of which students must answer 3.

**Tutorials**

There are 8 tutorials for which students need to prepare answers to problem sets.

**Module Breakdown:**

<table>
<thead>
<tr>
<th>% Contribution to module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long Lab</td>
</tr>
<tr>
<td>Exam</td>
</tr>
</tbody>
</table>

**The mark from this exercise is split evenly between 4 modules, irrespective of which module it forms a part of. Therefore, it contributes 13% to each of the listed modules**

**Reading List:**

**Required**

- *Introduction to the High Temperature Oxidation of Metals*, Birks, Meier, Pettit, CUP 2006
- *Introduction to Polymer Science*, RJ Young and PA Lovell, Chapman And Hall 1991

**Recommended but not essential**

- *Basic Chemical Thermodynamics*, EB Smith, ICP 2004
- *Polymer Chemistry and Physics of Modern Materials* JMG Cowie, Billings and Son London.
- *Textbook of Polymer Science*, FW Billmeyer, Wiley Interscience
Background reading


Learning Outcomes of this Module:

**Glasses and their degradation**
- Define a glass
- Describe glass production by the melt-quench and sol-gel chemistry routes
- Describe the structure of glasses
- Describe and explain the evolution of atomic and nanostructure of glasses
- Explain the differences in synthesis, structure and properties of melt and sol-gel derived silicate glasses
- Describe the properties needed for window glass, nuclear waste glass and bioactive glass for medical implants
- Explain the corrosion/ degradation mechanisms of glasses for window glass, nuclear waste glass and bioactive glass for medical implants

**Degradation of Polymers**
- Describe the molecular structure of degradable polymers
- Explain the degradation of common degradable polymers such as polyesters
- Describe the advantages and disadvantages of degradation mechanisms with respect to applications such as medical implants and packaging

**Phase Stability Diagrams and High Temperature Oxidation**
- Describe how free energy concepts can be used to understand material and phase stability in a range of systems.
- Construct and use Ellingham Diagrams
- Construct and use Phase Predominance and Vapour Species Diagrams
- Give examples of the use of thermodynamic diagrams for industrial processes (e.g. metal extraction)
- Describes the main types of high temperature oxidation and understand the implications of each in terms of materials stability and selection
- Describe the role of defects in oxidation processes and give examples of defect formation in semi-conducting oxides
- Derive equations that relate defect concentration with oxygen partial pressure
- Describe Wagner’s theory of oxidation and use a simplified model to derive the parabolic rate law.

**Aqueous Corrosion and Protection**
- Construct thermodynamic diagrams (Pourbaix) for simple systems and use them in a predictive manner
- Understand the factors that affect corrosion rates and write down electrochemical equations that describe them.
- Calculate thickness loss from electrochemical data
- Explain the concept of passivity and its breakdown
- Describe the main types of corrosion
- Discuss the synergistic effects of dissolution and mechanical stress
- Describe the main physical, chemical and electrochemical methods of corrosion protection and give appropriate examples of their industrial use.
- Explain the concept of risk-based management of corrosion inspection and maintenance.
**Polymers**

- Understand relevant polymer structure-property-processing interrelationships,
- Know which factor influence polymer solidification/crystallization,
- Understand concepts that lead to higher order in macromolecular structures,
- Are familiar with the crystallization kinetics of polymer solidification, and why this is of importance when processing this class of materials into functional architectures,
- Understand what influences the melting of (semi-)crystalline polymers (including effects of diluents – i.e. Flory Huggins equation)
- Understand how processing and solidification conditions influence the properties of the final structures (mechanical, optical as well as electronic characteristics).
MATE95003 (MSE 203) Mechanical Behaviour

Module Leader: Finn Giuliani
Teaching Staff: Minh-Son Pham
David Dye
Trevor Lindley

Why study this module?
To understand mechanical behaviour of materials in terms of microstructure and continuum mechanics.
You will study:
- Dislocations and Hardening
  The aim of the course is to examine how defects, crystal structure and microstructure affects mechanical
  properties, particularly strength. A range of length scales are addressed, from the atomic (nm), such as the
effect of solute atoms, through dislocations (10's of nm), grain boundaries (mm) to second phases (nm to
mm). This develops an insight into the range of strengthening mechanisms and defects which give rise to
strength and lead to fracture.
- Fracture and yield
  This aspect of the course examines mechanical behaviour in terms of macro and micro-mechanisms. The aim
  is to develop understanding of the mechanics of fracture and the influence of microstructure on mechanical
  behaviour.
- States of Stress
  This aims to develop the ability to set up and manipulate descriptions of the state of stress in a material and
to understand and apply yield criteria.
- Continuum Aspects of Deformation
  Here students will develop an understanding of the macro-aspects of fracture, fatigue and creep behaviour
  leading to the ability to quantitatively assess the different types of failure including plastic collapse, brittle
  fracture, fatigue

How will I be Taught?
40 lectures: Autumn and Spring terms
8 tutorials: Autumn and Spring terms

How will I be Assessed?
Examination
The course is examined in the summer term in a single 3-hour examination paper composed of eight
questions, which will reflect the balance of lectures across the course. The exam is split into two sections; one
on mechanisms and one on stress states, with four questions in each section. Students answer 5 questions
from the 8 available, with a minimum of two from each section; each question is worth 20 marks giving a total
of 100 for the paper.

Module Breakdown:

<table>
<thead>
<tr>
<th></th>
<th>% Contribution to module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long Lab</td>
<td>13% **</td>
</tr>
<tr>
<td>Exam</td>
<td>87%</td>
</tr>
</tbody>
</table>

**The mark from this exercise is split evenly between 4 modules, irrespective of which module it forms a part of.
Therefore, it contributes 13% to each of the listed modules.

Reading List:
Required
n/a
Recommended but not essential
Learning Outcomes of this Module:

**Dislocations and Hardening**

- Micro-mechanisms of deformation: slip systems, Schmid law. Ideal Shear vs Dislocations; types, motion.
- Stress and strain fields, dislocation multiplication, forces between dislocations.
- Strengthening mechanisms: grain boundary hardening; solution hardening, ordering; second phase hardening; work hardening; thermal activation; athermal and thermal obstacles.
- Further plasticity phenomena; twinning, textures.

**Fracture and yield**

- Brittle and ductile fracture and its transition
- Extension of Griffith to small scale plasticity; the strain energy release rate
- The stress intensity approach to fracture in plane stress and plane strain
- Crack tip plasticity and plastic zone size and the effect of sample thickness
- Measurement of fracture toughness
- Weibull statistics for brittle materials
- Ductile failure: yield and plasticity
- The instability condition in uniaxial and multiaxial stress
- Mechanistic basis of ductile fracture
- The J-integral approach for ductile cracking
- Introduction to mechanistic basis of fatigue crack nucleation and growth

**States of Stress**

- To derive equations for the normal and shear stresses in multiaxial stress situations from the forces within a component.
- To be able to write these as a stress matrix.
- To introduce the concepts of principle stress and strain and maximum shear stress including Mohr’s circle.
- To recognize the principle stresses / strains as the eigenvalues of the stress / strain matrix.
- To be able to rotate a stress or strain matrix and find the orientation of the principal axes.
- To be able to analyse the stress and strain state for the cases of a rotating shaft, a pressure vessel.
- To be able to use Nye's convention for calculating stresses in anisotropic media from the stiffness constants and strain tensor, and vice-versa; to be able therefore to calculate directional moduli and applied shear stresses on slip systems.
- To be able to determine the stress tensor from diffraction data.
- To be able to use the Von Mises and Tresca Yield Criteria, and understand the pi-plane convention.
**Continuum Aspects of Deformation**

- Types of failure - plastic, fracture, fatigue and creep
- Plasticity - tensile instability (necking) and the effect of work hardening and strain rate dependence, bending beams including initiation of plasticity, plastic collapse, residual stresses, springback.
- Torsion of rotating shafts.
- Fracture - Gc from load/displacement diagrams, fracture toughness in plane strain and plane stress with effect of thickness, stress concentrations, principal stresses and fracture, leak before break.
- Fatigue - HCF, LCF and crack growth, stages of development of fatigue cracks including persistent slip band formation, striations, S-N curves-Basquin’s, Goodman’s and Miner’s laws, Low cycle fatigue-Coffin-Manson law, fatigue crack growth-Paris law.
- Creep - including creep and rupture data and design requirements, isothermal and isochronal displays, parametric representations-Larson-Miller, Sherby-Dorn, Manson-Haferd, creep curves and modern design procedures, empirical versus physical models of creep curves, Monkman-Grant and life fraction laws, strain hardening versus time hardening, combined creep and fatigue damage.
- Understand the statistical approach to failure (Weibull)

**Long Lab coursework information form**

<table>
<thead>
<tr>
<th>Module code</th>
<th>MATE95002/3/4/5</th>
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<tbody>
<tr>
<td>Year of Study</td>
<td>2nd year</td>
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<tr>
<td>Assignment Name</td>
<td>Long lab</td>
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<td>Academic in Charge</td>
<td>Dr Finn Giuliani</td>
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<td>8th week of lectures</td>
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<td>Method of submission</td>
<td>via Blackboard Learn</td>
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<td>20-25 hours of self-study required</td>
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<td>Thurs 5 Mar 9am</td>
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<td>Percentage of the module total</td>
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<td>Estimated marking/feedback time</td>
<td>3 weeks marking time (administrative process time will be added on additionally)</td>
</tr>
<tr>
<td>Turn-it-in requirement</td>
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**Assignment details**

It is expected that this is a full lab report that covers the work done during the experimental sessions, as all the labs are a little different the exact requirements of the write up will be explained to you by the academic in charge. However, the standard rubric is attached below.

**Other requirements**

Not more than 3000 words, excluding references
Rubric (for experimental based long labs):
Sections to include and weighting in the marking.

**Abstract /10**
Summarize the aim of your work, what you did to achieve it and the findings relative to that aim.

**Introduction /20**
Start by explaining the problem, then describe the information you have found by reading in books or papers on this topic (if you haven’t found anything, you can always check [http://wok.mimas.ac.uk](http://wok.mimas.ac.uk) which is a database of the scientific literature and which allows you to look for papers using keywords; when a paper looks interesting, click on the “SFX” symbol to be connected to the journal where the paper was published. For many journals you can then download the pdf of the article) to set to context as to what could be expected. Then explain how you have organised your investigation, i.e. describe in general terms what you have done and how that addresses your stated aim.

Credit will be given to:
- The quality of your argument in outlining what could be expected to be the results
- In how far the experimental approach you have decided to take taking into account the constraints of the lab is likely to answer the question (If in writing the report you discover that you should have done things differently, you will have to address this in the discussion section).

**Experimental /10**
Describe the exact nature of the procedures you have followed to obtain your results. The information to include must be such that a member of staff would be able to reproduce the experiments you have done.

For example, do not write a manual for slip casting

“First a plaster board was made by mixing plaster of Paris with water, then stirring to remove the air and then casting this into a cake mould. .... “

but write something along the lines of (please avoid plagiarism):

“Samples measuring $$ mm by $$ mm by $$ mm were produced by slip casting small amounts (~ $$ g) of Porcelain slurry onto a Plaster of Paris board.”

So, do include make and models of the instruments you have used and record everything that was unique to your procedure. Where you are just following the instructions from the manufacturer, there is no need to include.

Credit will be given to
- Ability to describe the experimental work in a brief but complete manner

**Results /20**
Present your results in a logical way. This requires you to write text which explains how the data collected hangs together and which points out what the reader should pay particular attention to in plots of data or micrographs. Do not mix results and discussion. In the results section you should report the facts and findings. Hence, in the results section you report what someone, who repeats what you have done, would also obtain.

Make sure to make good quality figures, include a scale-bar on your micrographs and if needed include an arrow to point at a specific site. Aim to be as quantitative as you can and don’t be afraid to treat your data to achieve this.

For example don’t say

“The microstructure contains large and small pores”

Say

“The microstructure is a mixture of pores of 20±2 μm size and pores of 2±0.5 μm in size.”

But obviously this requires you to have measured the pore size and to have included your method for doing so in the experimental section.

Credit will be given to
- The organisation of the results in a logical manner
- The choices made to convey the maximum amount of information in the least number of figures and micrographs needed to convey that information.
• The quality of graphs and micrographs
• The level of treatment of the results from raw data to information

**Discussion /30**
In the discussion you need to compare your results against expectations based on your reading before you started doing the work, and against things you might have read after you achieved your results to see whether other people have observed similar things you weren’t expecting. Your aim is to determine what in your results is noteworthy and new, and also to validate your experimental approach as when your results are in line with what can be reasonably expected, this strengthens their credibility.

In a second phase of the discussion you should then explain in how far your results, combined with the information obtained from elsewhere, allow you to answer the research question you were aiming to answer. If you feel you have only confirmed things, then say so. If you found something different and interesting, say so too.

Credit will be given to
• Correct linking of results to existing theories and experiments relating to your research question
• Quality of the assessment of what can be learned from the experiments

**Conclusions /10**
Re-iterate any conclusions you have drawn from your work in your report. This section should not contain anything new: any conclusion you include should have been stated in some way in the report.

Please note that credit will be given in all sections for the clarity of presentation (does the lay-out make it easy for the reader), the correctness of spelling and grammar and the style in which you write.
MATE95004 (MSE 204) Microstructure

Module Leader: Chris Gourlay
Teaching Staff: Fang Xie, Katharina Marquardt

Why study this module?
This course is designed to allow students to progress in their understanding of thermodynamics and kinetics so as to allow them to investigate, explain and quantify the formation of microstructures by either solidification or by solid state phase transformations. It introduces them to a wide range of solid state phase transformations and through detailed analysis equips them with an insight into the scientific concepts underpinning the control of microstructures in primarily metals but also to some extent ceramics. This course also aims to: show how equilibrium phase diagrams can be used to predict the solidification process and the microstructure of materials that have been crystallised from a melt under equilibrium conditions; consider the effect of non-equilibrium solidification processes; and introduce examples from alloy, ceramic and glass-ceramic systems.

You will study:
- Solid state phase transformations
- Liquid-solid transformations
- Liquid-solid transformations

How will I be Taught?
40 lectures: Autumn and Spring terms
8 tutorials: Autumn and Spring terms

How will I be Assessed?
Examination
The course is examined in the summer term. The examination paper, duration 3 hours, is in three sections. Section A is compulsory and consists of a range of short answer and multiple choice questions on all parts of the course (20 marks) and a compulsory question on the use of ternary phase diagrams to predict solidification (20 marks). Section B is one question and is also compulsory. Section C contains 4 questions of which students must answer 3 (20 marks per question)

Module Breakdown:

<table>
<thead>
<tr>
<th></th>
<th>% Contribution to module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long Lab</td>
<td>13% **</td>
</tr>
<tr>
<td>Exam</td>
<td>87%</td>
</tr>
</tbody>
</table>

**The mark from this exercise is split evenly between 4 modules, irrespective of which module it forms a part of. Therefore, it contributes 13% to each of the listed modules.

Reading List:
Required
- DRF West and N Saunders, Ternary phase diagrams in materials science, 3rd edition, Maney Publications, 2002

Recommended but not essential
- Steels : microstructure and properties, Honeycombe, R. W. K., Edward Arnold
- Recrystallization and releated annealing phenomena, F.J. Humphreys, M. Hatherly, Pergamon

Background reading
Learning Outcomes of this Module:

**Solid state phase transformations**

- develop simple models for free energy of ideal and regular solutions
- define the chemical potential and derive the phase diagram from information about the free energy versus composition
- discuss diffusion and the relation between activation energy, temperature and diffusion rate
- derive Fick’s first law, be aware of Fick’s second law and realise that diffusion is driven by chemical potential gradients
- discuss a range of interfaces in solids (solid vapour, various types of grain boundaries, coherent, semi-coherent and incoherent interfaces)
- develop a simple model to explain the energy of solid-vapour surfaces, and use it to predict the shape of crystals (Wulff plot), and argue why solid-solid boundaries have a lower energy than solid-vapour interfaces
- explain how boundaries move through a material (diffusion and glissile dislocations)
- describe how surface energy drives the densification during sintering of powder compacts
- discuss homogeneous and heterogeneous nucleation of precipitates and derive the equations controlling the free energy changes upon nucleation and a model for the nucleation rate variations with temperature.
- explain what precipitate free zones are and how they can be avoided.
- discuss growth of precipitates under interface or diffusion control and show that thermodynamically microstructures with precipitates are unstable and evolve towards larger precipitates
- use their theoretical knowledge to discuss precipitate hardening in Al-Cu alloys
- discuss spinodal decomposition and argue why ordering in materials occurs
- outline the difference between first order and second order transformations.
- understand the different processes and energy changes involved in recovery and recrystallisation of deformed microstructures and be able to derive a kinetic model for recrystallisation (JMAK).
- explain why grains grow and derive an expression for Zener drag
- recognize and explain carbon steel microstructures and cast-iron microstructures with reference to the iron-carbon phase diagram
- be aware of the different forms of ferrite and by extension of precipitates (Widmanstatten, massive, grain boundary allotriomorphs)
- explain the formation of pearlite and by extension of eutectoid decomposition
- explain the differences between reconstructive and displacive phase transformations
- list macroscopic observations about martensite formation
- discuss the crystallography of the austenite to martensite transformation
- describe the sequence of events during tempering of martensite and how it influences the properties
distinguish conceptually between upper and lower bainite formation
- discuss and use TTT and CCT diagrams
- explain the mechanisms underpinning shape memory alloys (SMA)
- quantify the contribution of the martensitic transformation to toughening in zirconia

**Liquid-solid transformations**

- explain the physical basis of the barrier to nucleating a crystal in a liquid and compare this with nucleating a solid in a solid sample.
- derive the size of a critical nucleus as a function of melt supercooling and heterogeneous nucleating substrate size / type.
• predict the effect of nucleation difficulties of phase $\alpha$ on: (i) the growth of existing phase $\alpha$, and (ii) the subsequent growth of $\alpha$.

• list the differences between atomically smooth and atomically rough S-L interfaces.

• understand why the dimensionless entropy of fusion can be used to predict whether phases will have rough or smooth S-L interfaces.

• sketch the mechanisms of faceted crystal growth with the aid of a Kossel crystal, and explain why crystal defects are important in faceted crystal growth.

• sketch the mechanisms of nonfaceted (nf) crystal growth, explain why non-faceted growth requires lower growth undercooling, and why non faceted interfaces are more likely to develop curvature than faceted interfaces.

• derive the solidification path of a binary alloy assuming zero diffusion in the solid: the Scheil equation.

• derive the condition for constitutional supercooling during unidirectional solidification of a binary alloy. understand how interface velocity alters the diffusion profile in the liquid.

• discuss the interplay between the curvature of a S-L interface and the diffusion of heat and solute from the interface in determining the shape of growing non-faceted crystals. Qualitatively apply this to nucleation, interface stability, dendrite growth and eutectic growth.

• understand why the liquid becomes supersaturated in dissolved gas during solidification. Predict the hydrogen concentration in the liquid as a function of solid fraction in Al alloys.

• derive the shape of the shrinkage pipe formed in a pure metal solidifying in a cylindrical mould.

• explain the influence of the solidification mode of an alloy on the distribution of porosity.

• describe the origin of common types of macrosegregation.

**Liquid-liquid transformations**

• interpret all the features of a ternary liquidus projection and isothermal sections for systems containing solid phases that exhibit partial or complete solid solubility, three phase reactions, and binary and ternary compounds.

• use ternary phase diagrams to describe and quantify each stage of the solidification process for a three-component system that may contain binary and ternary invariant reactions.

• appreciate and understand that full equilibrium may not be achieved in the actual processing of molten material, and that phenomena such as segregation and constitutional supercooling can play important roles in determining the microstructure of solidified materials.
Why study this module?
This course is designed to:

- Give students an understanding of the quantum free electron theory of metals and the transport and optical properties, discuss the occurrence of band gaps within the nearly free electron model by Bragg reflection and describe the electrical properties of n and p type doped semiconductors.
- Describe the physics of some important semiconductor devices used in very large scale integration, in optoelectronics and in photovoltaic cells.
- Introduce the concepts of functional dielectric materials and to explore their use in selected devices
- Provide the theoretical background to the experiments performed in the second year electrical materials laboratory
- Strengthen the student’s preliminary knowledge of magnetism through a quantum mechanical analysis of the origins of magnetism, introduce techniques for measuring magnetic properties, give examples of magnetic materials and applications and explain the magnetic properties of superconductors.

You will study:
- Quantum theory of metals and semiconductors
- Electronic devices
- Magnetism and superconductivity
- Dielectric Materials

How will I be Taught?
40 lectures: Autumn and Spring terms
8 tutorials: Autumn and Spring terms

How will I be Assessed?
Examination
The course is examined in the summer term in a single 3-hour examination paper composed of eight questions, which will reflect the balance of lectures across the course. The exam is split into two sections; one on mechanisms and one on stress states, with four questions in each section. Students answer 5 questions from the 8 available, with a minimum of two from each section; each question is worth 20 marks giving a total of 100 for the paper.

Module Breakdown:

<table>
<thead>
<tr>
<th></th>
<th>% Contribution to module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long Lab</td>
<td>13% **</td>
</tr>
<tr>
<td>Exam</td>
<td>87%</td>
</tr>
</tbody>
</table>

**The mark from this exercise is split evenly between 4 modules, irrespective of which module it forms a part of. Therefore, it contributes 13% to each of the listed modules.

Reading List:
Required
- R. Waser (editor), “Nanoelectronic and Information Technology”, Chapter 2
- C. Kittel, “Introduction to solid state physics”, John Wiley and sons
Recommended but not essential

- S. M. Sze, K.K. Ng, “Physics of Semiconductor Devices”, John Wiley and Sons
- S. Dimitrijev, “Principles of Semiconductor Devices”, OUP
- R.G. Chambers, Electrons in metals and semiconductors, Chapman and Hall
- E. M. Purcell, Electricity and Magnetism, McGraw Hill
- S.M. Sze, “VLSI Technology” McGraw Hill
- Braithwaite and Weaver, Electronic Materials, OUP press, (1990)

Background reading

- Any standard textbook on Physics, for example Tipler
- C. Kittel, “Introduction to solid state physics”, John Wiley and sons
- Tilley & Tilley, “ Superfluidity and Superconductivity”, Chapter 1 and 6
- R. Waser (editor), “Nanoelectronic and Information Technology”, Chapter 4

Learning Outcomes of this Module:

**Quantum theory of metals and semiconductors**

- set out the working assumptions involved in the quantum theory of the free electron gas.
- solve the 3-dimensional Schroedinger equation for zero potential (free electron gas approximation) under consideration of Pauli’s exclusion principle.
- explain the concept of reciprocal space or k space, and explain the meaning of the Fermi wave vector, the Fermi energy, and the Fermi velocity.
- familiar with the Fermi Dirac distribution and the density of states.
- explain the specific heat of a free electron gas and its deviation from the classical expectation.
- discuss the electrical and thermal conductivity of a metal in the free electron approximation, its relation to the electron mean free path and the Fermi velocity and its temperature dependence.
- explain the optical response of a metal in the free electron gas approximation and explain the role of the plasma frequency.
- explain the meaning of Bloch waves and illustrate the one dimensional dispersion relation within the nearly free electron model and the effect of Bragg reflection.
- explain the origin of bandgaps within the nearly free electron model and illustrate the difference between insulators, semiconductors and metals based on the value of the Fermi energy.
- explain the effects of doping by the existence of acceptor and donor levels.
- explain the concept of effective mass and hole conductivity by the 1D dispersion relation of the free electron gas.
- explain the concept of reciprocal space and construct the Brillouin zone.
- explain the difference between direct and indirect semiconductors based on their band structure.
- discuss the properties of the most important semiconductors.

**Electronic devices**

- understand key electronic concepts in semiconducting materials including band diagrams, Fermi distribution, and carrier types, and relate these to their application and behavior in fundamental semiconductor devices.
• understand fundamental semiconductor devices including p-n junctions, bipolar junction transistors and MOS capacitors. They will be able to explain the basic physical concepts of these devices, illustrate them using band structure diagrams, and give relevant examples of their application.

• describe and calculate fundamental device parameters of p-n junctions, bipolar junction transistors and MOS capacitors, as well as describe their operation modes.

• explain very large scale integration, and explain its relationship to integrated circuits, miniaturization, and MOSFET/CMOS technology.

• explain the structure, the basic device parameters, and the operational regions of a MOSFET. They will be able to calculate the threshold voltage and give details on optimization strategies for the threshold voltage.

• describe a static CMOS inverter and its operation. They will be able to outline a general CMOS process flow and describe all major fabrication steps involved. They will be able to draw a simple CMOS structure.

• understand the fundamentals of optoelectronics, including radiative transitions and optical absorption in semiconductors.

• describe the structure, function, and operation principles of LEDs, OLEDs, infrared LEDs, and fiber optics.

• explain the fundamentals of semiconductor lasers and give examples of laser materials and device structures.

• explain the fundamentals of photodetectors, including photoconductors, photodiodes, and p-i-n photodiodes.

• understand the function, structure, and device layout of photovoltaic cells.

**Magnetism and superconductivity**

• explain the meaning of the physical quantities related to magnetism, magnetic field, magnetic induction, magnetic moment, magnetization, magnetic susceptibility, and discuss their interrelations.

• explain the fundamentals of electromagnetism: Lorentz force, induction law, Ampere’s law.

• explain the Hall effect and derive an expression for the Hall voltage.

• explain the quantum mechanical properties of an atom in a magnetic field, in particular the roles of the quantum numbers for spin and angular momentum.

• the origin of diamagnetism by induced magnetic moments and calculate the diamagnetic susceptibility of atoms based on the classical Langevin result.

• discuss the interaction of a quantum mechanical angular momentum with a magnetic field and describe the Bohr magneton, the Landee factor and the Zeeman energy level splitting.

• explain the temperature dependence of the magnetic susceptibility of a paramagnetic material by the thermal occupation of the Zeeman energy levels.

• explain and illustrate the magnetic properties of a superconductor, in particular the Meissner effect and the London penetration depth.

• draw and explain the magnetization curves for type I and type 2 superconductors and explain the magnetic microstructure in the Shubnikov phase.

• explain how pinning by impurities can result in an increase of the critical current density.

• name and describe the properties of the important superconducting materials for high power and magnet applications.

• draw and explain the hysteresis curve of a ferromagnetic material and explain the relevant quantities.

• explain the difference between hard and soft magnetic materials, and to give and illustrate examples for materials and applications.

• derive the Curie – Weiss law by employing mean-field theory and the Curie law for the paramagnetic susceptibility.
- explain the most common methods for imaging of ferromagnetic domains.
- discuss the two competing energy terms at a Bloch wall (exchange and anisotropy energy) and their implications for the magnetic properties.
- explain the (giant) magnetoresistance and its application in information technology.

**Dielectric Materials**
- define the terms piezo-, pyro- and ferro- and anti-ferroelectric and explain the interrelationships between these properties.
- describe the polarisation behaviour of a ferroelectric material as a function of temperature and of applied stress. This will include an understanding of the Curie temperature which will link to the experiment performed as part of the second year electrical materials laboratory.
- sketch a P-E loop for a ferroelectric materials, label the important features, discuss poling and the origins of this hysteresis effect in terms of the domain structure of the material.
- describe the phenomenological theory of ferroelectricity in BaTiO3.
- sketch the phase diagram for PbZrO3-PbTiO3 (PZT’s) and use it as guide to materials selection for practical applications.
- describe the construction and operation of some simple devices based on ferroelectric ceramics, such as the spark igniter, intruder alarm, and FRAM devices.
- understand the role that phonons play in determining the optical properties of materials
- understand the concept of a solid ionic conductor and relate this to considerations of the defect structure of the materials.
- derive an expression for the ac impedance of a parallel R-C circuit and plot the frequency response of this circuit on an ac- impedance plot.
- use this plot to interpret the ac response of ceramic ionic conductor and relate this to the experiment performed in the second year electrical materials laboratory.
Why study this module?
The aim of the module is to provide the students with a fundamental understanding of mass and fluid flow, and of plasma physics and how it can be applied in nanofabrication processes.
You will study:
- Mass and Heat Flow
- Plasma in nanofabrication

How will I be Taught?
Characterisation
10 lectures and 5 Characterisation Labs: Autumn
Case Study
6 Lectures and 5 Labs as well as a Presentation afternoon: Autumn
Process Principles
6 Lecturers; 3 tutorials (2 compulsory and an optional) and Poster Exercise: Spring term
BS0821 Project Management
Lectures provided by the Business School: Spring

How will I be Assessed?
For Characterisation, there will be an in-class assessment during the last lecture along with associated submissions for the 5 characterisation laboratories. Students will work in groups on a case study in the 2nd half of the Autumn term which will be assessed via a report and presentation in the spring.
Process principles will be assessed through a course work and digital poster during the Spring term. The Project Management course is delivered by the Business School and further details can be found at: https://imperialcollege london.app.box.com/s/5mj1vcl5mnr9siguapic89e03q5ffana

How will I be Taught?
40 lectures: Autumn and Spring terms
8 tutorials: Autumn and Spring terms

Module Breakdown:

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**Reading List:**

Recommended but not essential

- Introduction to plasma physics, Goldston, Robert J. Rutherford, Paul H., Bristol : Institute of Physics Publishing 1995

**Learning Outcomes of this Module:**

**Mass and heat flow**

- By the end of the course, students should know and understand the following concepts and methods and be able to apply them to practical materials problems:
  - To understand and apply the fundamental heat transfer and mass transfer equations to the processing and production of materials
  - To quantitatively and qualitatively predict materials processing and materials behaviour for simplified classical examples
  - To apply the knowledge to process optimization
  - The specific objectives are:
    - Understand Fourier’s laws, Fick’s laws and Diffusion-Convection equations
    - Solve the heat and mass transfer governing equations in simplified boundary conditions
    - Derive the heat and mass transfer equation from the irreversible thermodynamic law
    - Familiar with the available numerical methods in solving the heat-mass transfer equations
    - Understand the physical basis of the fluid mechanics
    - Explain how flow develops in a pipe, and discuss the effect of the Reynolds number (laminar, transition and turbulent flow)
    - Derive and apply the Hagen Poiseuille equation for fluid flow down a pipe
    - Define Bernoulli’s equation as an energy balance and then expand it to account for pressure and minor losses, using friction factors
    - Apply the Mechanical Energy Balance to steady state and non-steady state pipe flow problems, including non-circular pipes and ducts
    - For flow over solid object (e.g. aircraft wings), calculate Friction and Pressure Drag and the effect of Reynolds number, define and apply Drag Coefficients, deriving Terminal Velocity
    - Understand the Carman Kozeny equation and how it is amended to produce the Ergun Equation
    - Understand the Navier-Stokes Equations

**Plasma in nanofabrication**

- Explain what plasma is and how it is generated.
- Describe plasma’s basic parameters and classification.
- Understand plasma behaviour (incl. plasma-matter interactions).
- Discuss the application of plasma in industrial processes.
Heat/Mass Flow long assignment coursework information form

<table>
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<tr>
<th>Module code</th>
<th>MATE95006 (MSE 206)</th>
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<tbody>
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<td>Year 2</td>
</tr>
<tr>
<td>Assignment Name</td>
<td>Heat/Mass Flow long assignment</td>
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<tr>
<td>Academic in Charge</td>
<td>Dr Paul Franklyn and Dr Jonathan Rackham</td>
</tr>
<tr>
<td>When the assignment is presented to the students</td>
<td>Introduced at beginning of year. Email reminder in last week of Autumn term. Reminder in first workshop 7th Jan.</td>
</tr>
<tr>
<td>Method of submission</td>
<td>Blackboard submission</td>
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<tr>
<td>Student’s self-study hours</td>
<td>10 hours</td>
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<tr>
<td>Deadline date</td>
<td>9am, Thursday 27th Feb, Wk 20</td>
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<tr>
<td>Percentage of the module total</td>
<td>80% of the Heat/Mass flow coursework</td>
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<tr>
<td>Estimated marking/feedback time</td>
<td>2 weeks</td>
</tr>
<tr>
<td>Turn-it-in requirement</td>
<td>No</td>
</tr>
</tbody>
</table>

Assignment details

Students will tackle three heat/mass flow problems, two short and one long. The shorter problems will address analytical solutions and the interpretation of solutions provided. The longer problem will require the student to interpret a scenario, set up the problem mathematically, and solve this numerically using Python with the final solution being submitted in a combination of a table and an annotated 2-D plot.

Other requirements

Any source code submitted should be adequately commented so the operation and purpose of functions is clear to the reader.

Rubric:

1 - analytic solution of a scenario with boundary conditions
   - 20% of Heat/Mass Flow coursework mark
2 - description and interpretation of a numerical solution provided
   - 20% of Heat/Mass Flow coursework mark
3 - setup numerical solution of a scenario using Python, output to be returned in tabular and graphical form
   - 20% of Heat/Mass Flow coursework mark for the interpretation, conversion to a analytical problem, setup in numerical form
   - 20% of Heat/Mass Flow coursework mark for the code and plot and final output from the code.

Heat/Mass Flow short assignment coursework information form

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<tbody>
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<tr>
<td>Assignment Name</td>
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<tr>
<td>Academic in Charge</td>
<td>Dr Paul Franklyn and Dr Jonathan Rackham</td>
</tr>
<tr>
<td>When the assignment is presented to the students</td>
<td>Introduced at beginning of year. Email reminder in last week of Autumn term. Reminder in first workshop 7th Jan.</td>
</tr>
<tr>
<td>Method of submission</td>
<td>Blackboard test</td>
</tr>
<tr>
<td>Student’s self-study hours</td>
<td>2 hours</td>
</tr>
<tr>
<td>Deadline date</td>
<td>9:00 Thursday 23rd Jan, Wk 16</td>
</tr>
<tr>
<td>Percentage of the module total</td>
<td>20% of the heat/mass flow coursework</td>
</tr>
</tbody>
</table>
Assignment details

A short open-book assessment to demonstrate understanding of the course material in advance of the longer assignment. This will involve answering a combination of short questions and multiple choice questions in Blackboard.

Rubric:
12 questions total; 8 multiple choice and 4 short-answer (numeric or text).

Case study report coursework information form

<table>
<thead>
<tr>
<th>Module code</th>
<th>MATE95006 (MSE 206)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year of Study</td>
<td>2nd Year</td>
</tr>
<tr>
<td>Assignment Name</td>
<td>Case study Report</td>
</tr>
<tr>
<td>Academic in Charge</td>
<td>Dr Martyn McLachlan</td>
</tr>
<tr>
<td>When the assignment is presented to the students</td>
<td>Week commencing 4th November 2019</td>
</tr>
<tr>
<td>Method of submission</td>
<td>Blackboard Learn</td>
</tr>
<tr>
<td>Student’s self-study hours</td>
<td>10 hours for report preparation</td>
</tr>
</tbody>
</table>
| Deadline date       | Groups A&B, 9am, 10th December 2019  
Groups C&D, 9am, 13th December 2019 |
| Percentage of the module total | 80% of total case study mark |
| Estimated marking/feedback time | 2 weeks |
| Turn-it-in requirement | No |

Assignment details

The report details the findings of the group and should include the following elements:

- Include details of all laboratory investigations, giving a description of the preparation and analytical techniques used and the reason for your choice of each one.
- Identify the component's function and then deduce the required property characteristics which should be ranked according to their importance.
- Discussion of why the determined particular materials and processing route were selected for each component that is analysed.
- Any additional findings that you may consider relevant.
- Characteristics should be expressed in **quantitative** terms where possible – this may involve simple stress analysis, heat transfer calculations, analysis of electrical properties etc.

The report has a joint component and a mark for individual contribution. The joint mark reflects the combined input from all team members, while the individual reflects the contribution you have made to the overall report as well as your participation in the group exercise.

Each student will receive one grade for the report, based on individual performance this may differ from other members of your group. The mark given is generated based on the following breakdown:

**20% for the report as a joint effort:** Can your contribution to the written report be seen, what role did you have in preparing the final report, did you work as part of a team (lab sessions, project meetings), how did you assist in preparing the report (typesetting, preparing figures, formatting)?
**30% for the individual section of the report:** Is your section well written, is it concise, is your data well formatted, are figures clear, have you used references appropriately, does it fit logically into the report with the work of your group?

**35% for the data analysis, quality of characterisation, interpretation of data:** Have appropriate analytical techniques been used, is the analytical data well interpreted, is the analysis convincing, is the analysis correct, have you presented the data in a way it can be checked by the marker, have you been able to combine data from complimentary techniques?

**15% for effort, initiative, log book, etc. on an individual basis (supervisor):** How did you work within your team, was the log book well maintained and easy to interpret, did you support others in the group, did you attend project meetings, did you generate ideas?

**Other requirements**

The report should be written as a single, joint submission. As a guide, common elements e.g. introduction, conclusions should be shared between group members, similarly if common techniques are used multiple descriptions are not required and should be prepared jointly. The document should read as a single piece rather than a series of short reports stitched together. It is encouraged to submit, wither in the table or contents or as an appendix a breakdown of the individual contributions to the project, the report and any other aspects you may consider relevant.

This should be agreed and signed by all group members prior to submission. **Each student will need to submit an individual copy of the report complied in their groups.**

The upper limit is **8000** words regardless of group size, but shorter, **concise** reports are encouraged. This refers to the main body of text and excludes references, figures and their captions. Appendices may be included and should include raw data only with limited captioning and limited text.

**Rubric:**

**20% for the report as a joint effort:** Can your contribution to the written report be seen, what role did you have in preparing the final report, did you work as part of a team (lab sessions, project meetings), how did you assist in preparing the report (typesetting, preparing figures, formatting)?

**30% for the individual section of the report:** Is your section well written, is it concise, is your data well formatted, are figures clear, have you used references appropriately, does it fit logically into the report with the work of your group?

**35% for the data analysis, quality of characterisation, interpretation of data:** Have appropriate analytical techniques been used, is the analytical data well interpreted, is the analysis convincing, is the analysis correct, have you presented the data in a way it can be checked by the marker, have you been able to combine data from complimentary techniques?

**15% for effort, initiative, log book, etc. on an individual basis (supervisor):** How did you work within your team, was the log book well maintained and easy to interpret, did you support others in the group, did you attend project meetings, did you generate ideas?
Case study presentation coursework information form

<table>
<thead>
<tr>
<th>Module code</th>
<th>MATE95006 (MSE 206)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year of Study</td>
<td>2nd Year</td>
</tr>
<tr>
<td>Assignment Name</td>
<td>Case Study Presentation</td>
</tr>
<tr>
<td>Academic in Charge</td>
<td>Dr Martyn McLachlan</td>
</tr>
<tr>
<td>When the assignment is presented to the students</td>
<td>Week commencing 4th November 2019</td>
</tr>
<tr>
<td>Method of submission</td>
<td>Oral Presentation: Presentation slides to be uploaded on Blackboard learn Groups A&amp;B 9am, 2nd December 2019 Groups C&amp;D 9am, 5th December 2019</td>
</tr>
<tr>
<td>Student’s self-study hours</td>
<td>6 hours maximum preparing presentation 8 hours attending ALL presentations</td>
</tr>
<tr>
<td>Presentation date</td>
<td>Groups A&amp;B, 13:00-17:00, 3rd December 2019 Groups C&amp;D, 13:00-17:00, 6th December 2019</td>
</tr>
<tr>
<td>Percentage of the module total</td>
<td>20% of case study</td>
</tr>
<tr>
<td>Estimated marking/feedback time</td>
<td>2 weeks</td>
</tr>
<tr>
<td>Turn-it-in requirement</td>
<td>No</td>
</tr>
</tbody>
</table>

Assignment details

The presentation is a 12 minute (plus 3 minutes for questions) talk. All students from the group are expected to be present and participate in the presentation, and all students should remain to hear their cohort present and participate in questions. The talk should include a brief introduction to the artefact and discussion of some of the key components. **You will not have time to describe everything so you need to be selective but detailed.** Scientific content, detail, understanding, presentation skills and personal contribution are all assessed for each person in the group. Questions will probe deeper understanding of the analytical techniques used, particularly focussing on your understanding of limitations of the techniques or unusual determinations made from the technique.

The presentation will be assessed as a whole, the mark given consists of the following elements.

- **Quality of slides/layout/presentation 15%**
- **Data presentation/clarity 15%**
- **Quality and clarity of explanations 20%**
- **Demonstration and understanding of technical content 30%**
- **Time 10%**
- **Questions 10%**

Other requirements

A Powerpoint presentation is suggested, but not prescriptive.

Rubric:

- Quality of slides/layout/presentation 15%
- Data presentation/clarity 15%
- Quality and clarity of explanations 20%
- Demonstration and understanding of technical content 30%
- Time 10%
- Questions 10%
Process principles poster coursework information form

<table>
<thead>
<tr>
<th>Module code</th>
<th>MATE95006 (MSE 206)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year of Study</td>
<td>2nd Year</td>
</tr>
<tr>
<td>Assignment Name</td>
<td>MATE95006 (MSE 206) : Process Principles Poster</td>
</tr>
<tr>
<td>Academic in Charge</td>
<td>Dr Peter Petrov</td>
</tr>
<tr>
<td>When the assignment is presented to the students</td>
<td>1st week of lectures (spring term)</td>
</tr>
<tr>
<td>Method of submission</td>
<td>Blackboard Learn</td>
</tr>
<tr>
<td>Student’s self-study hours</td>
<td>15-20 hours of self-study required</td>
</tr>
<tr>
<td>Deadline date</td>
<td>Tuesday, 10th March 9am</td>
</tr>
<tr>
<td>Percentage of the module total</td>
<td>100% of Process principles component</td>
</tr>
<tr>
<td>Estimated marking/feedback time</td>
<td>2 weeks</td>
</tr>
<tr>
<td>Turn-it-in requirement</td>
<td>No</td>
</tr>
</tbody>
</table>

Assignment details
Students are required individually, to prepare and submit via Blackboard a poster describing an application, discussed during the lecture course.

Other requirements
The poster should be size A1, and should be submitted in .pdf format.

Rubric:

I. Content:
   i. Describe an application 15%
   ii. Analyse the process(es), which it uses, in terms of what has been learned 15%
   iii. Discuss the compromises made to achieve a practical solution 15%
   iv. Summarise with thoughts on the future of the technology 15%

II. Presentation:
   i. Poster layout (balance between text and figures) 20%
   ii. Poster font size and colour scheme 20%
## 5. Laboratory Information

### Autumn Term: Year 2 (Labs: 1-4pm)

#### Autumn Laboratory Timetable

<table>
<thead>
<tr>
<th>Monday</th>
<th>Tuesday</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mate Folder (BL)</strong></td>
<td><strong>Experiment</strong></td>
</tr>
<tr>
<td>MATE95006</td>
<td>AC impedance</td>
</tr>
<tr>
<td>MATE95006</td>
<td>Infra-Red (IR) Spectroscopy (Big report)</td>
</tr>
<tr>
<td>MATE95006</td>
<td>Scanning Electron Microscopy (SEM)</td>
</tr>
<tr>
<td>MATE95006</td>
<td>XRD</td>
</tr>
<tr>
<td>MATE95006</td>
<td>DSC</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Thursday</th>
<th>Friday</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mate Folder (BL)</strong></td>
<td><strong>Experiment</strong></td>
</tr>
<tr>
<td>MATE95006</td>
<td>AC impedance</td>
</tr>
<tr>
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<td>MATE95006</td>
<td>XRD</td>
</tr>
<tr>
<td>MATE95006</td>
<td>DSC</td>
</tr>
</tbody>
</table>

Case Study: A separate timetable will be issued for the Case Study nearer the time.

### Key

- **Group A**
- **Group B**
- **Group C**
- **Group D**
# Autumn Laboratory Deadlines

<table>
<thead>
<tr>
<th>Mate Folder (BL)</th>
<th>Experiment</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Thursday</th>
<th>Friday</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lab</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>11-Nov</td>
<td>15-Oct</td>
<td>22-Oct</td>
<td>29-Oct</td>
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<td>05-Nov</td>
<td>12-Nov</td>
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</tr>
<tr>
<td>MATE95006</td>
<td>Infra-Red (IR) Spectroscopy (Big report)</td>
<td>A1</td>
<td>A5</td>
<td>A4</td>
<td>A3</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MATE95006</td>
<td>Scanning Electron Microscopy (SEM)</td>
<td>A2</td>
<td>A1</td>
<td>A5</td>
<td>A4</td>
</tr>
<tr>
<td></td>
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<td></td>
</tr>
<tr>
<td>MATE95006</td>
<td>XRD</td>
<td>A4</td>
<td>A3</td>
<td>A2</td>
<td>A1</td>
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<tr>
<td>MATE95006</td>
<td>DSC</td>
<td>A5</td>
<td>A4</td>
<td>A3</td>
<td>A2</td>
</tr>
</tbody>
</table>

**Key**
- Group A
- Group B
- Group C
- Group D

**Deadline Time:**
- 9am
- 7 days after the lab

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**Note:**
- Lab 7 days after the lab
Spring Term: Year 2 (Labs: 1-4pm)

Spring Laboratory Timetable

Long lab selection will take place through Blackboard. You will have the opportunity to rank your three preferences. Groups A&B will complete their long labs on a Tuesday afternoon and Groups C&D will complete their long lab sessions on a Friday. The selection will be opened towards the end of Autumn term and you will be informed within a week of the closing of your long lab group. Each lab has limited spaces and so, while every effort will be made to give all students their first choice, if the labs are full, reallocation will be done on a random basis – not on a first to submit basis. Any reallocation to a 2nd or 3rd choice will be done to try and maximise overall satisfaction, i.e. giving as many students as possible their 1st or 2nd choice.

The long labs will take place over 7 weeks in the spring. All of you will be advised to meet your supervisor on Friday of the 1st week (10th January 2020). Lab sessions are scheduled for week beginning the 13th, 20th, 27th January, 3rd, 10th, 24th of February and 2nd of March – they will be on Tuesday and Friday afternoons.

Note: In week 5 of your long lab, each group needs to provide their supervisors with their data. You should also schedule regular update meetings with your supervisor over the course of the lab period.

Spring Laboratory Deadline
Long Lab report is due on the 5th March 2020 at 09:00