# School of Metallurgy & Materials

# Study Abroad Module Handbook 2024/25

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# **Materials: Semester 1 Modules:**

## LC Fundamentals of Materials Science

**Module Title:**LC Fundamentals of Materials Science

**Module Code:**31173

**Semester:**1

**Credits:**20

**Level:**LC

**Module Description:**The aim of this course is to develop the students' knowledge in the basic description of crystalline materials in terms of their bonding, crystal structure, phase, grain size, defects and composition. The thermodynamics of solutions will be covered as a basis for phase diagrams with nucleation and growth being exemplified using solidification, whilst thermally activated processes are illustrated through diffusion mechanisms and calculations.These link to the requirements in the QAA Materials benchmark statement of 2017, in particular:

3.4.i Atomic bonding, crystalline lattices, defects and disorder, amorphous materials

3.4.ii Phase equilibria and phase transformations multiphase materials, thermodynamic and kinetic aspects

3.4.iii Structure on the nano, micro, meso and macro scales

## LC Design for Functional Applications 1

**Module Title:**LC Design for Functional Applications 1

**Module Code:**31175

**Semester:**1

**Credits:**20

**Level:**LC

**Module Description:** This course is an introduction to functional materials including coverage of electronic structures of materials and how these give rise to basic thermal, electrical and magnetic behaviour. Measurement of magnetic, electrical and thermal properties will be covered. Functional materials, their processing and properties concentrating on magnetism (soft magnets for storage), semiconductors and batteries will be covered. This links to the 2017 QAA Subject Benchmark Statement for Materials:

3.4 i Atomic bonding, crystalline lattices, defects and disorder, amorphous materials

iii Structure on the nano, micro, meso and macro scales;

v Functional behaviour - the control through composition and structure of electrical, optical and magnetic properties as well as biocompatibility;

ix Techniques for determining electrical, optical and magnetic properties.

## LI Polymers, Composites and Ceramics

**Module Title:**LI Polymers, Composites and Ceramics

**Module Code:**31188

**Semester:**1

**Credits:**20

**Level:**LI

**Module Description:**This module will build on the basics covered at level C, in properties and processing of partially and non-crystalline materials. In particular it will emphasise time-dependent effects. The module will cover thermoplastics and thermosets, fibre-reinforced composites as well as aspects of ceramics and inorganic glasses. These link to the requirements in the QAA Materials benchmark statement of 2017, in particular:

3.4 iii Structure on the nano, micro, meso and macro scales,

3.4 iv Mechanical behaviour,

3.4 viii Bulk processing, heat and mass transfer, and fluid mechanics,

x Layered and additive manufacturing techniques, for example 3D printing,

xi Materials design - compositional variation and processing to achieve required microstructures, and hence properties,

xii Materials selection - consideration of material types, materials processing methods, and product costs.

## LH Advanced failure analysis and Characterisation

**Module Title:**LH Advanced failure analysis and Characterisation

**Module Code:**31195

**Semester:**1

**Credits:**20

**Level:**LH

**Module Description:**The aim of this module is to discuss in detail the main modes of failure in materials including creep, fatigue and fracture. Strategies to improve materials resistance to these failure types and methods to predict material failure will be evaluated. This includes understanding the advanced characterisation and non-destructive evaluation techniques required to evaluate materials failures. These link to the following topics in the 2017 QAA Materials Subject Benchmark Statement: iv mechanical behaviour - elastic and plastic deformation, creep and fatigue, fracture, strengthening, toughening and stiffening mechanisms vi structural characterisation - optical and electron microscopy techniques, electron and X-ray diffraction, scanning probe techniques, thermal analysis vii compositional analysis - spectroscopic methods (electron/X-ray probe/ infra-red/ultra-violet techniques), chemical analysis viii mechanical test methods, xiii degradation/durability of materials - effect of environment upon performance, corrosion, wear, and biodegradation.

## LH High Toughness Ceramics

**Module Title:**LH High Toughness Ceramics

**Module Code:**17190

**Semester:**1

**Credits:**10

**Level:**LH

**Module Description:** The module covers glass formation and controlled crystallisation of parent glass by thermal processing to form glass-ceramics, properties and applications of glass ceramics. Ceramic production/processing stages from powder to component will be covered, including ways of ensuring minimal particle agglomeration. SiAlON ceramics will be discussed with reference to their phase diagram. Factors affecting the strength of ceramics will be described. Toughening of zirconia and zirconia toughened ceramics will be described with application to bioceramics. Advanced ceramic matrix composites will be discussed. This links to QAA benchmark statements:

3.4 Structure: ii Phase equilibria and phase transformations, multiphase materials, thermodynamic and kinetic aspects

Properties: iv Mechanical behaviour - elastic and plastic deformation, creep and fatigue, fracture, strengthening, toughening and stiffening mechanisms

Processing: vii Materials synthesis - vapour, liquid, colloidal, powder and solid-state deposition techniques

v Bulk processing, heat and mass transfer, and fluid mechanics

Application: vi Materials design - compositional variation and processing to achieve required microstructures, and hence properties

## LH Biomaterials

**Module Title:**LH Biomaterials

**Module Code:**17191

**Semester:**1

**Credits:**10

**Level:**LH

**Module Description:**The module introduces biocompatibility, biomaterials and their applications. Examples will be chosen from metals, ceramics composites and polymers in biomaterials applications. Mechanical and physical properties will be described that are used in specific applications such as hip prostheses, dental applications, blood bags, hip protectors, endoscopes, fixation devices, surgical devices and seating/beds. These relate to the QAA benchmark statements:

3.4 Properties: iv Mechanical behaviour - elastic and plastic deformation, creep and fatigue, fracture, strengthening, toughening and stiffening mechanisms

Application: xii Materials selection - consideration of all material types, materials processing methods, and product costs.

## LH Advanced Electronic Materials

**Module Title:**LH Advanced Electronic Materials

**Module Code:**17193

**Semester:**1

**Credits:**10

**Level:**LH

**Module Description:** Through this module students will develop a broad and deep understanding of the processing and properties of advanced functional materials. It will continue extend the concepts established in the LC DFA and LI DFA 2. The module will contain a detailed study of the processing and properties of several advanced electronic materials systems concentrating on the microstructure property relationships which allow the exploitation of specific functional properties in particular applications. Materials to be studied will include permanent magnetic materials, superconducting materials, ferroelectric and microwave dielectric materials. This links to the following topics from the 2017 QAA Subject Benchmark Statement for Materials:

3.4 v Functional behaviour - the control through composition and structure of electrical, optical and magnetic properties as well as biocompatibility, ix Techniques for determining electrical, optical and magnetic properties, xi Materials design - compositional variation and processing to achieve required microstructures, and hence properties, xii Materials selection - consideration of all material types, materials processing methods, and product costs.

## LH Advanced Polymer Systems

**Module Title:**LH Advanced Polymer Systems

**Module Code:**39152

**Semester:**1

**Credits:**10

**Level:**LH

**Module Description:** This module will consider a range of advanced topics in polymer science. The module will detail the following:

The ageing of polymers through secondary crystallisation and enthalpy relaxation, processing of polymers using super-critical fluids, advanced thermal analysis, crystallisation kinetics in polymers - secondary nucleation, polymer blends and the Flory-Huggins theory, copolymers, cyclic polymers and characterisation, plastics electronics - materials and mechanical reliability of flexible displays, polymer tribology - friction and wear of polymers.

These link to the following topics in the 2017 QAA Materials Subject Benchmark Statements:

i Atomic bonding, crystalline lattices, defects and disorder, amorphous materials

vi Structural characterisation - optical and electron microscopy techniques, electron and X-ray diffraction, scanning probe techniques, thermal analysis

vii Compositional analysis - spectroscopic methods (electron/X-ray probe/ infra-red/ultra-violet techniques), chemical analysis

vii Materials synthesis - vapour, liquid, colloidal, powder and solid-state deposition techniques

viii Bulk processing, heat and mass transfer, and fluid mechanics

ix Joining methods, surface treatment and the application of coatings

xii Materials selection - consideration of all material types, materials processing methods, and product costs

xiii Degradation/durability of materials - effect of environment upon performance, corrosion, wear, and biodegradation

## LH Intermetallics, Metal Matrix Composites and Ceramic Matrix Composites

**Module Title:**LH Intermetallics, Metal Matrix Composites and Ceramic Matrix Composites

**Module Code:**39159

**Semester:**1

**Credits:**10

**Level:**LH

**Module Description:**This module will give a detailed analysis of the development and use of strong solids (Intermetallics and ceramics), metal matrix composites (fibre and particulate) and ceramic matrix composites (fibres and particulates) in structural applications. The principles of damage tolerance, fatigue and environmental concerns in these materials are covered. The design limitations and potential applications will be a particular focus of the module. These link to the following topics in the 2017 QAA Materials Subject Benchmark Statements:

iv Mechanical behaviour - elastic and plastic deformation, creep and fatigue, fracture, strengthening, toughening and stiffening mechanisms, v Mechanical test methods, xii Materials selection - consideration of all material types, materials processing methods, and product costs

## LH Surface Engineering

**Module Title:**LH Surface Engineering

**Module Code:**39158

**Semester:**1

**Credits:**10

**Level:**LH

**Module Description:**This module introduces the principles of surface engineering and its application to the design and manufacturing of engineering components. It covers design aspects of tribology, an introduction to a range of surface engineering technologies (including thermal, thermochemical, ion beam, energy beam, thermal spraying, PVD/CVD techniques), a review of applications of advanced surface engineering technologies, surface analysis and testing techniques, and surface system design. Cost-effectiveness, fitness for purpose and environmental aspects of surface engineering are also discussed as appropriate throughout the course.

These link to the following topics in the 2017 QAA Materials Subject Benchmark Statements:

iii Structure on the nano, micro, meso and macro scales.

iv Mechanical behaviour - elastic and plastic deformation, creep and fatigue, fracture, strengthening, toughening and stiffening mechanisms

vii Materials synthesis - vapour, liquid, colloidal, powder and solid-state deposition techniques

viii Bulk processing, heat and mass transfer, and fluid mechanics

ix Joining methods, surface treatment and the application of coatings

x Layered and additive manufacturing techniques, for example 3D printing, including the creation of 'intelligent' products by incorporating sensors and so on.

xi Materials design - compositional variation and processing to achieve required microstructures, and hence properties

xii Materials selection - consideration of all material types, materials processing methods, and product costs

xiii Degradation/durability of materials - effect of environment upon performance, corrosion, wear, and biodegradation

## LM Advanced Metallurgy and Manufacturing

**Module Title:**LM Advanced Metallurgy and Manufacturing

**Module Code:**38393

**Semester:**1

**Credits:**20

**Level:**PGT

**Module Description:** The aims of this module are to develop the student's knowledge of metallic alloys, in terms of their bonding, crystal structure, phase, grain size, defects and compositions, including how they relate to the functional and mechanical properties of materials. An understanding of binary and ternary phase diagrams will be developed, to include the thermodynamics and solidification processes of materials.

A range of techniques for characterising metallic materials will be discussed. These comprise microscopy (optical and electron), non-destructive testing, x-ray diffraction, surface analysis and various techniques for measuring electrical and magnetic properties. The manufacturing processes for these alloys and applications will be discussed in detail and will include; investment casing, additive manufacturing and advanced joining techniques amongst others.

## LM Non-metallic Materials

**Module Title:**LM Non-metallic Materials

**Module Code:**38391

**Semester:**1

**Credits:**20

**Level:**PGT

**Module Description:** This module will examine a broad range of non-metallic materials. The module content is divided into three sections relating to polymeric, ceramic and composite materials. Each section will consider the following key themes in materials science; synthesis, microstructure, processing/forming, mechanical properties and characterisation. Each section of the module will begin with introductory content that is suitable for students with a non-materials background, but will develop rapidly to enable students to achieve deep-learning in relation to these types of materials. The polymer section of the module will focus on thermoplastic polymers; the ceramics section on the interrelationships between starting materials, processing, microstructure and material/component properties; and the composites section on laminated fibre reinforced polymer composites for structural applications. The context of the module will be established through numerous examples of the application of these materials in industry.

## LH Materials Modelling

**Module Title:**LH Materials Modelling

**Module Code:**39155

**Semester:**2

**Credits:**10

**Level:**LH

**Module Description:** The module introduces concepts of modelling materials problems relating to structure, structure evolution of materials. A number of models are introduced and discussed across length scales, ranging from electronic/atomistic to continuum methods and methods for selecting the right model for a given problem will be introduced. It will also be demonstrated how these models can be used to solve both industrially relevant problems and questions in materials science and engineering. Selected aspects of computational materials design - especially for alloys - will be covered. These link to the following topics in the 2017 QAA Materials Subject Benchmark Statements:

vi Computational simulation of materials across the length-scales and corresponding time-scales, from atomistic (classical and quantum) to finite elements.

# **Semester 2 Modules:**

## LC Design for Structural Applications

**Module Title:**LC Design for Structural Applications

**Module Code:**31174

**Semester:**2

**Credits:**20

**Level:**LC

**Module Description:**The aims of this module are to provide quantitative and practical aspects for basic structural and mechanical property assessment, material and process selection. These will respect the intended operating environments and possible failure modes of each application. These link to the following topics in the 2017 QAA Materials Subject Benchmark Statement:

iv Mechanical behaviour - elastic and plastic deformation, creep and fatigue, fracture, strengthening, toughening and stiffening mechanisms;

vi Structural characterisation - optical and electron microscopy techniques, electron and X-ray diffraction, scanning probe techniques, thermal analysis;

viii Mechanical test methods;

xi Materials design - compositional variation and processing to achieve required microstructures, and hence properties;

xii Materials selection - consideration of all material types, materials processing methods, and product costs;

xiii Degradation/durability of materials - effect of environment upon performance, corrosion, wear, and biodegradation.

## LC Polymers, Glasses and Composites

**Module Title:**LC Polymers, Glasses and Composites

**Module Code:**31176

**Semester:**2

**Credits:**20

**Level:**LC

**Module Description:** The aim of this module is to introduce non-crystalline materials: including amorphous and semi-crystalline polymer structures and fibre reinforcements. This will include their production and characterisation as well as physical and mechanical properties. These link to the QAA Materials benchmark statements:

Structure: i Atomic bonding, crystalline lattices, defects and disorder, amorphous materials

iii Structure on the nano, micro, meso and macro scales.

Properties: iv Mechanical behaviour - elastic and plastic deformation, creep and fatigue, fracture, strengthening, toughening and stiffening mechanisms

Characterisation: vi Structural characterisation - optical and electron microscopy techniques, electron and X-ray diffraction, scanning probe techniques, thermal analysis

Processing: vii Materials synthesis - vapour, liquid, colloidal, powder and solid-state deposition techniques

viii Bulk processing, heat and mass transfer, and fluid mechanics

## LI Design for Functional Applications 2

**Module Title:**LI Design for Functional Applications 2

**Module Code:**31186

**Semester:**2

**Credits:**20

**Level:**LI

**Module Description:**This module builds on level C material to expand from fundamental functional properties of conductors, insulators and semiconductors to more complex topics related to hydrogen, strong magnets and superconductors. This links to the 2017 QAA Subject Benchmark Statement for Materials:

3.4 i Atomic bonding, crystalline lattices, defects and disorder, amorphous materials, iii Structure on the nano, micro, meso and macro scales, v Functional behaviour - the control through composition and structure of electrical, optical and magnetic properties as well as biocompatibility, ix Techniques for determining electrical, optical and magnetic properties.

## LH High-performance Materials and Advanced Manufacturing

**Module Title:**LH High-performance Materials and Advanced Manufacturing

**Module Code:**31194

**Semester:**2

**Credits:**20

**Level:**LH

**Module Description:**The aim of this module is to discuss high performance materials used in demanding applications. This will cover a range of materials (Ti based alloys, Steels, Ni-based superalloys and Al based alloys) designed for very specific application i.e. Creep-resistant Ni-based alloys for gas turbine blades. The manufacturing processes for these alloys and applications will be discussed in detail and will include; investment casing, additive manufacturing and advanced joining techniques amongst others. Industry requirements and constraints as well as performance indices for these materials will be covered. These link to the following topics in the 2017 QAA Materials Subject Benchmark Statement:

ii Phase equilibria and phase transformations, multiphase materials, thermodynamic and kinetic aspects

iii Structure on the nano, micro, meso and macro scales.

iv Mechanical behaviour - elastic and plastic deformation, creep and fatigue, fracture, strengthening, toughening and stiffening mechanisms

vii Materials synthesis - vapour, liquid, colloidal, powder and solid-state deposition techniques

viii Bulk processing, heat and mass transfer, and fluid mechanics

ix Joining methods, surface treatment and the application of coatings

x Layered and additive manufacturing techniques, for example 3D printing, including the creation of 'intelligent' products by incorporating sensors and so on.

xi Materials design - compositional variation and processing to achieve required microstructures, and hence properties

xii Materials selection - consideration of all material types, materials processing methods, and product costs

xiii Degradation/durability of materials - effect of environment upon performance, corrosion, wear, and biodegradation

iv Engineering principles: including design, manufacturing and processing

x An awareness of health and safety, sustainability and environmental issues, and of ethical considerations

## LH Materials for Challenging Environments

**Module Title:**LH Materials for Challenging Environments

**Module Code:**31198

**Semester:**2

**Credits:**20

**Level:**LH

**Module Description:** The module will cover extreme environments for all materials classes such as extreme local atmospheres; localised stresses; extreme temperatures. Examples studied include friction and wear, irradiation (both UV and ionising) and gas-solid, liquid-solid, solid-solid reactions at extreme temperatures.Surfaces at the atom / molecule level and origins of frictionMechanisms of adhesive or abrasive wear and strategies for avoidance of both types of wear. Surface engineering, wear resistant coatings, implantation and coating technologies.Ion - material interactions related to radiation damage in nuclear and space applications. Moderators and strategies for mitigating ion damage. Gas-solid reactions: kinetics and thermodynamics. Strategies to mitigate corrosion damage.Very high temperature structural materials.These link to the 2017 QAA Materials subject benchmark statements:Properties iv mechanical behaviour - elastic and plastic deformation, creep and fatigue, fracture, strengthening, toughening and stiffening mechanisms Application xi materials design - compositional variation and processing to achieve required microstructures, and hence properties xii materials selection - consideration of all material types, materials processing methods, and product costs xiii degradation/durability of materials - effect of environment upon performance, corrosion, wear, and biodegradation.

## LH Alloy and Microstructure Design

**Module Title:**LH Alloy and Microstructure Design

**Module Code:**38276

**Semester:**2

**Credits:**10

**Level:**LH

**Module Description:** For advanced engineering materials to be used in application, particularly when they are used in demanding structural environments, composition selection, processing methods and subsequently microstructure determine performance. This course will describe modern strategies to create new materials systems, with a focus on those that are critical to address 21st century engineering challenges. You will be taught how these materials are processed, and how this insight can be used to tailor & optimise performance through the careful control of microstructure.

## LH Self-sensing Materials and Advanced Condition Monitoring

**Module Title:**LH Self-sensing Materials and Advanced Condition Monitoring

**Module Code:**39157

**Semester:**2

**Credits:**10

**Level:**LH

**Module Description:** The module will give a detailed analysis of smart self-sensing and self-healing materials. This will include advanced NDT and remote condition monitoring techniques as well as basic methods for estimating remaining lifetime, maintenance strategies and reliability. These link to the following topics in the 2017 QAA Materials Subject Benchmark Statements:

v Functional behaviour - the control through composition and structure of electrical, optical and magnetic properties as well as biocompatibility.

vii Compositional analysis - spectroscopic methods (electron/X-ray probe/ infra-red/ultra-violet techniques), chemical analysisix techniques for determining electrical, optical and magnetic properties

vii Materials synthesis - vapour, liquid, colloidal, powder and solid-state deposition techniques

xi Materials design - compositional variation and processing to achieve required microstructures, and hence properties

xii Materials selection - consideration of all material types, materials processing methods, and product costs xiii degradation/durability of materials - effect of environment upon performance, corrosion, wear, and biodegradation

 xiv Lifecycle analysis, sustainability and environmental impact.

## LH Irradiation Materials Science

**Module Title:**LH Irradiation Materials Science

**Module Code:**39154

**Semester:**1

**Credits:**10

**Level:**LH

**Module Description:** The purpose of this module is to provide a foundation for understanding the theory and mechanism behind the effects of irradiation on structural materials and fuel. The module will be divided into two parts: Part A focuses on the radiation damage process and provides the formalism for the prediction of the amount and spatial configuration of the damage produced by bombarding particles. Part B focuses on the physical and mechanical effects of radiation damage on materials. These link to the following topics in the 2017 QAA Materials Subject Benchmark Statement: iv mechanical behaviour - elastic and plastic deformation, creep and fatigue, fracture, strengthening, toughening and stiffening mechanisms vi structural characterisation - optical and electron microscopy techniques, electron and X-ray diffraction, scanning probe techniques, thermal analysis vii compositional analysis - spectroscopic methods (electron/X-ray probe/ infra-red/ultra-violet techniques), chemical analysis vi computational simulation of materials across the length-scales and corresponding time-scales, from atomistic (classical and quantum) to finite elements. xi materials design - compositional variation and processing to achieve required microstructures, and hence properties xii materials selection - consideration of all material types, materials processing methods, and product costs xiii degradation/durability of materials - effect of environment upon performance, corrosion, wear, and biodegradation.

## LH Nuclear Fuel Cycles, Life Extension and Nuclear Waste

**Module Title:**LH Nuclear Fuel Cycles, Life Extension and Nuclear Waste

**Module Code:**TBC

**Semester:**2

**Credits:**10

**Level:**LM

**Module Description:** The module will introduce the nuclear fuel cycle, nuclear plant life extension and management and disposal of nuclear waste. This will include describing both the thorium and uranium fuel cycles from extraction, use and disposal. A understanding of the key aspects of nuclear plant lifetime extension will be developed and current issues with life extension in AGR's will be discussed. The management and disposal of low, medium and high-level radioactive waste in the UK, including technical issues such as corrosion in interim and long-term storage will be covered.

These link to the following topics in the 2017 QAA Materials

Subject Benchmark Statement:

i Atomic bonding, crystalline lattices, defects and disorder, amorphous materials

ii Phase equilibria and phase transformations, multiphase materials, thermodynamic and kinetic aspects

iii Structure on the nano, micro, meso and macro scales

iv Mechanical behaviour - elastic and plastic deformation, creep and fatigue, fracture, strengthening, toughening and stiffening mechanisms.

vii Materials synthesis - vapour, liquid, colloidal, powder and solid-state deposition techniques

viii Bulk processing, heat and mass transfer, and fluid mechanics

ix Joining methods, surface treatment and the application of coatings

xi Materials design - compositional variation and processing to achieve required microstructures, and hence properties

xii Materials selection - consideration of all material types, materials processing methods, and product costs

xiii Degradation/durability of materials - effect of environment upon performance, corrosion, wear, and biodegradation

xiv Lifecycle analysis, sustainability and environmental impact.

## LH Materials for Sustainable Environment Technology

**Module Title:**LH Materials for Sustainable Environment Technology

**Module Code:**39156

**Semester:**2

**Credits:**10

**Level:**LH

**Module Description:** This module will relate to the materials issues related to sustainable environmental technologies. The module will focus on the hydrogen economy and battery technology in relation to the materials requirements required for both energy delivery systems, specifically for use in transport (both infrastructure and propulsion). The sustainability and criticality of the main elements used in these technologies will be discussed.

These link to the following topics in the 2017 QAA Materials Subject Benchmark Statement:

v Functional behaviour - the control through composition and structure of electrical, optical and magnetic properties as well as biocompatibility.

vi Functional analysis - biocompatibility testing (acellular, cellular, and in vivo), accelerated ageing, environmental wear testing.

vii Materials synthesis - vapour, liquid, colloidal, powder and solid-state deposition techniques.

xi Materials design - compositional variation and processing to achieve required microstructures, and hence properties.

xii Materials selection - consideration of all material types, materials processing methods, and product costs.

xiii Degradation/durability of materials - effect of environment upon performance, corrosion, wear, and biodegradation.

xiv Lifecycle analysis, sustainability and environmental impact.

iii Competence in using information technology effectively, for example to support oral presentation, literature searches and report writing.

iv An awareness of health and safety, sustainability and environmental issues, and of ethical considerations.

## LM Design Against Failure

**Module Title:**LM Design Against Failure

**Module Code:**17678

**Semester:**2

**Credits:**10

**Level:**PGT

**Module Description:** The module will describe how stresses are used in combination with materials behaviour to prevent failure under both monotonic and cyclic loading. Failure within the creep regime will not be considered within this module. An in-depth analysis of the intrinsic (materials) factors and extrinsic (geometrical) factors which can affect failure criteria will be presented. Micromechanisms of failure and other influence of microstructure will be highlighted. The units will cover the following:Conventional engineering design, stress systems and assessment methods.Modes of failure: deflection, elastic instability, plastic instability, plastic collapse, fast fracture, fatigue. Safety factors and strength of materials. Principle of superposition, principal planes, yield criteria, stress concentrations. Plasticity - friend or foe? Fracture mechanics: crack shapes and stress sytems - mode I, mode II, mode III. Plane stress and plane strain. Elastic-plastic fracture.Defect tolerance design: S-N curves, notches and pre-cracked testpieces. Paris equation and its use.Micromechanisms of brittle and ductile fracture. Transgranular cleavage: the importance of tensile stress and microstructure. The ductile-brittle transition and ferritic steels. Ductile failure: void initiation, growth and coalescence. Ductile crack growth ahead of a sharp-crack: inclusions and carbides, work-hardening.Accelerated mechanisms of crack growth and degradation mechanisms below the creep regime.

## LM Functional Materials

**Module Title:**LM Functional Materials

**Module Code:**18511

**Semester:**2

**Credits:**10

**Level:**PGT

**Module Description:** The module will introduce the important role played by functional materials in a wide range of application areas including energy, communications and transport. Materials to be studied will encompass a selection from ferroelectric, piezoelectric and dielectric ceramics; ionic and electronic conducting ceramics; semiconductors; magnetic, superconducting and magnetostrictive materials.

The important underlying scientific concepts for each material and application area will be elucidated. A number of key technologically important applications such as fuel cells, solar cells and optical and magnetic data storage media will be studied in detail. The transport area will include the role of magnets and superconductors in magnetic levitation (maglev), and magnets, magnetostrictives and piezoelectrics for automobile applications. Functional ceramic materials will be introduced for a range of communication and environmental monitoring applications. In each case fabrication and processing routes appropriate for each group of materials in the particular application area or device will be introduced and the important links between processing, microstructure and properties will be quantified. The range of applications will require detailed exploration of thin film, thick film, bulk and fibre processing routes, and exploration of specialised fabrication routes for magnetic, superconductor and functional ceramic materials.

## LM Biomaterials

**Module Title:**LM Biomaterials

**Module Code:**18510

**Semester:**2

**Credits:**10

**Level:**PGT

**Module Description:** The aim of this module is to introduce students to materials that can be used in the human body. The following will be covered in this module:Natural tissues in the human body - materials and structure;General considerations for synthetic biomaterials - biocompatible, sterile;Biomaterials for use in orthopedics: joint replacement, fracture fixation;Biomaterials for use in the heart: artificial heart valves;Biomaterials for use in dentistry;Tissue engineering: scaffolds, cell culture. By the end of the module the student should be able to:Understand the structure of natural tissue;Describe the general requirements for synthetic biomaterials;Select and justify appropriate biomaterials for use in orthopedic medical devices;Select and justify appropriate biomaterials for use in dentistry;Understand the concept of tissue engineering and its current limitations;Describe the biomaterials used in artifical heart valves.

## LM Introduction to Materials Modelling

**Module Title:**LM Introduction to Materials Modelling

**Module Code:**32194

**Semester:**2

**Credits:**10

**Level:**PGT

**Module Description:** The module introduces concepts and methods that are widely used in the field of materials modelling and their application. Emphasis is covering methods across length and timescales, in order to allow students to develop understanding of the choice of appropriate tools when addressing practical materials challenges. Different models are introduced, along with commonly used numerical methods to solve the underlying equations. A number of widely used models will be introduced through hands on sessions using market leading, commercial software packages. By the end of the module, student should be able to:

* Demonstrate critical awareness of current materials modelling tools, their capabilities and limitations, which input is needed and output that is obtained as well as computational effort required.
* Judge which numerical method is appropriate for solving the equations of common materials models, such as for example, Finite-Difference Method (FDM), Verlet methods, Monte Carlo methods
* Critically explain the difference between a model and the numerical method to solve the model equations
* Demonstrate the ability to apply computer software to solve a materials problem by solving an unknown problem within a given amount of time.

## LM Materials for Hydrogen and Fuel Cell Technologies

**Module Title:**LM Materials for Hydrogen and Fuel Cell Technologies

**Module Code:**19688

**Semester:**2

**Credits:**10

**Level:**PGT

**Module Description:** The aim of the module is to provide an insight into the critical role materials science plays in a range of hydrogen and fuel cell technologies. The following will be included: 1. Materials in the Hydrogen Energy Economy - overview; 2. Methods of Hydrogen Production; 3. Hydrogen Storage; 4. PEM Fuel Cells; 5. Solid Oxide Fuel Cells; 6. Design of integrated hydrogen and fuel cell energy systems.

By the end of the module the student should be able to: 1. Appreciate and describe the use of functional materials in a range of hydrogen production, hydrogen storage and fuel cell technologies; 2. Understand the key materials challenges that need to be overcome, in order for the viable introduction of hydrogen and fuel technologies into the market; 3. Understand and describe the materials fabrication, characterization techniques that are required for the development of hydrogen production, hydrogen storage and fuel cell technology components; 4. Understand how the hydrogen and fuel cell technologies studied, might fit into a number of possible hydrogen energy-based economies.

## LM Materials for Sustainable Environment Technologies

**Module Title:**LM Materials for Sustainable Environment Technologies

**Module Code:**17684

**Semester:**2

**Credits:**10

**Level:**PGT

**Module Description:** This module will relate to the materials issues related to sustainable environmental technologies. The module will be based on the concept of a Hydrogen Economy and the production of the hydrogen will be from clean energy sources such as wind or solar. The materials issues relating to these will be described and discussed. The hydrogen will be produced largely by electrolysis and materials issues relating to this technology will be considered. Hydrogen from biomass will also be examined. Materials for hydrogen storage and transmission will be discussed. Fuel cells will be considered in depth and more general issues such as energy efficiency will be discussed, focusing on soft and hard magnets. The energy content of materials will also form a part of this module.

By the end of the module the student should be able to: Appreciate the various aspects of a Hydrogen Economy and materials aspects of clean energies; Understand the nature of electrolysis and materials problems and developments; Appreciate alternative routes such as biomass; Understand various aspects of hydrogen storage; Understand various fuel cells and associated challenges; Appreciate efficiences: energy content and role of magnets.

## LM Net Shape Manufacturing

**Module Title:**LM Net Shape Manufacturing

**Module Code:**17688

**Semester:**2

**Credits:**10

**Level:**PGT

**Module Description:** Rapid manufacturing is designated for manufacturing components from their CAD files directly without using a mould or a die. It includes: direct laser fabrication, selective laser sintering, rapid prototyping, 3D printing, laminate manufacturing and net shape HIPping.This course will introduce the state-of-art of various rapid manufacturing techniques, including the mechanism of individual techniques, their pros and cons, their applications and limitations. During the course, students will be asked to design their own components and create CAD files of those components and manufacture them using DTM laser Sintersation in the IRC.

By the end of the module the student should be able to:Understand the mechanism of various rapid manufacturing techniques;Create CAD files of simple components;Manufacture those components from their CAD files using laser and selected powder.

## LM Physical Metallurgy (Titanium and Nickel)

**Module Title:**LM Physical Metallurgy (Titanium and Nickel)

**Module Code:**21929

**Semester:**2

**Credits:**10

**Level:**PGT

**Module Description:** This module looks at the applications of nickel and titanium alloys in aero-engines and the land-based gas turbine. The basic operation is first considered: thermodynamics, adiabatic heating in the compressor, efficiency and the need for high temperature resistant materials. For nickel-based alloys, temperature resistance and oxidation resistance in Ni and Ni/Cr alloys are described. Other main topics covered are: developing high temperature strength through second-phase particles; slip in the A3B system, involving disordering/re-ordering; the investment casting process; living with high gas temperatures and lifing issues with creep and fatigue; powder discs and the role of shot-peening. For titanium alloys - phase diagrams and the main classifications of the alloys; Widmanstatten structures; higher strength alloys; defects in Ti alloys, and Ti alloy development, will be included. The potential for inter-metallics and MMCs is also be described.

By the end of the module the student will be able to:

* Define the operation of gas turbines and understand the functional requirements of the materials used for their construction;
* Describe the principles of alloy design for turbine blade and disc applications and critically assess the material strengthening and degradation mechanisms;
* Detail the principles of blade and disc fabrication, process developments for improved performance and integrity. Specify manufacturing processes;
* Perform calculations to determine the life of components made of nickel and titanium alloys.

## LM Polymer Science and Soft Matter

**Module Title:**LM Polymer Science and Soft Matter

**Module Code:**18515

**Semester:**2

**Credits:**10

**Level:**PGT

**Module Description:** This module is an introduction to modern advanced topics in polymer science and soft matter. It includes: Preparatory reading on polymer structure, properties and processing; Polymer synthesis. Step-growth and free radical polymerisation. The glass transition temperature and spherulites. DSC and FT-ir. `Rough guides¿ to the techniques. Factors affecting Tg, miscibility and crystallisation. TPE and thermally-reversible cross-links. Thermodynamics of mixing applied to polymer blends. Flory-Huggins theory of miscibility. Principles of cyclic polymers. In situ polymerisation, crystallisation and blending. Case study of blending and instrumental techniques. Thermodynamics of melting applied to thermotropic liquid crystal polymers. Examples of thermotropic, mouldable polyesters. Lyotropic liquid crystal polymers. Summary of block copolymer features and morphologies. Case studies on a variety of advanced topics such as: block copolymers, dendrimers, polymer brushes and surfaces, liquid crystalline polymers, cyclic polymers, polymers for displays, OLEDs and functional polymers, supercritical fluid processing, polymer optical fibres and sensors, biodegradable polymers and polymers for drug delivery, polymer tribology, crystallisation, physical ageing and structure development, polymer blends. Laboratory work with examples of the use of characterisation techniques including: microscopy (optical, SEM, TEM, AFM), FTIR, DSC, TGA, NMR, neutron scattering, SAXD and WAXD, SCF processing, reactive blending, specialised mechanical testing, tribological testing.

## LM Sensors and Composites

**Module Title:**LM Sensors and Composites

**Module Code:**21364

**Semester:**2

**Credits:**10

**Level:**PGT

**Module Description:** This module will provide an introduction to fibre reinforced organic matrix composites and optical fibre sensors. With reference to fibre reinforced composite materials, the lecture series will provide basic information on the constitutive materials and their mechanical, chemical and physical properties. Non-destructive techniques will also be covered briefly. Emphasis will be placed on linking the processing chemistry to the development of sensors. Typical failure modes will be discussed and once again these will be linked to the design and development of sensor systems. With reference to optical fibre sensors, this module will provide a basic introduction to optical fibres and as to how the properties of the lightguide can be modified or engineered to design sensors. The sensors systems to be addressed will include intensity, polarisation and interferometric devices. The construction of sensors for monitoring strain, temperature, vibration and specified chemical species will be considered. The demonstration for this element of the module will include infrared spectroscopy using optical fibres and their sensors and light sources and detectors. The students will be given hand-on experience on handling fibres and in constructing specified optical fibre sensors.

## LM Surface Engineering

**Module Title:**LM Surface Engineering

**Module Code:**17690

**Semester:**2

**Credits:**10

**Level:**PGT

**Module Description:** This module is designed to introduce the principles of surface engineering and its application to the design and manufacturing of engineering components. It covers design aspects of tribology, an introduction to a range of surface engineering technologies (including thermal, thermochemical, ion beam, energy beam, thermal spraying, PVD/CVD techniques), a review of applications of advanced surface engineering technologies, surface analysis and testing techniques, and surface system design. Cost-effectiveness, fitness for purpose and environmental aspects of surface engineering are also discussed as appropriate throughout the course.

By the end of the module the student should be able to:Explain what is meant by surface engineering;Describe the principles of typical Surface Engineering technologies;Demonstrate typical applications of surface engineering technologies;Appreciate the technological, economic and social impact of surface engineering;Compare and contrast surface engineering technologies;Apply surface engineering principles to the solution of problems;Select an optimum process for a specific application;Measure and evaluate the performance of surface systems;Synthesise surface engineering information/data from various resources.

# **Full Term Modules:**

**Attention:**

The following modules are taught across the full academic year, semester one and two. Students MUST take BOTH modules (A+B)!

## LI Fracture, Fatigue and Degradation A+B

**Module Title:**LI Fracture, Fatigue and Degradation A+B

**Module Code:**34056 + 34060

**Semester:**1+2

**Credits:**10+10

**Level:**LI

**Module Description:**Semester 1introduces students to how components can fail by fracture (rapid crack growth) and fatigue (slow crack growth), dependent on their microstructure and residual stress state, and methods to characterise and predict these.It links to the following statements in the 2017 QAA Subject Benchmark Statement for Materials:3.4 iii Structure on the nano, micro, meso and macro scales;iv mechanical behaviour - elastic and plastic deformation, creep and fatigue, fracture, strengthening, toughening and stiffening mechanisms;vi structural characterisation - optical and electron microscopy techniques, electron and X-ray diffraction, scanning probe techniques, thermal analysis;viii mechanical test methods.

Semester 2 introduces students to how components can fail by corrosion (reaction with external chemicals), dependent on their microstructure and the environment, and methods to characterise and predict these.It links to the following statements in the 2017 QAA Subject Benchmark Statement for Materials:3.4 iii structure on the nano, micro, meso and macro scales;vi structural characterisation - optical and electron microscopy techniques, electron and X-ray diffraction, scanning probe techniques, thermal analysis;xiii degradation/durability of materials - effect of environment upon performance, corrosion, wear, and biodegradation.

## LI Physical Materials Science A+B

**Module Title:**LI Physical Materials Science A+B

**Module Code:**34065 + 34066

**Semester:**1 + 2

**Credits:**10 + 10

**Level:**LI

**Module Description:** The module will build on the description of phase diagrams, bonding and diffusion from level C to introduce time dependence and the factors controlling driving forces in metallic and non-metallic systems. Aspects of processing will be introduced as well as solid state thermodynamics and kinetics for nucleation and growth (diffusional) leading to JMAK, reconstructive, displacive and mixed transformations using steel and ceramic examples, TTT and CCT diagrams. These link to the requirements in the QAA Materials benchmark statement of 2017, in particular:

3.4.ii Phase equilibria and phase transformations multiphase materials, thermodynamic and kinetic aspects; 3.4.iii Structure on the nano, micro, meso and macro scales; 3.4.xi Materials design compositional variation and processing to achieve required microstructures, and hence properties.

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These link to the requirements in the QAA Materials benchmark statement of 2017, in particular:

3.4.ii phase equilibria and phase transformations multiphase materials, thermodynamic and kinetic aspects;

3.4.iii structure on the nano, micro, meso and macro scales;

3.4.xi materials design compositional variation and processing to achieve required microstructures, and hence properties.

# **Aerospace: Semester 1 only Modules:**

## LH Flight Dynamics & Control A

**Module Title:**LH Flight dynamics and control A

**Module Code:**35313

**Semester:**1

**Credits:**10

**Level:**LH

**Module Description:** In this module students will extend the concepts of stability from LI Airframe Design and Flight Dynamics into dynamic applications. Students will explore methods to predict and control the stability of aircraft and study the effects of aircraft design on stability, control and performance.

## LH Computational Fluid Dynamics for Aerospace

**Module Title:**LH Computational Fluid Dynamics for Aerospace

**Module Code:**39223

**Semester:**1

**Credits:**10

**Level:**LH

**Module Description:** In this module students will study the theoretical bases and use of numerical codes for modelling fluid flow from low to high (supersonic) speeds.

# **Aerospace: Semester 2 or Full Year Modules:**

## LI Space Systems Engineering & Design

**Module Title:**LI Space System Engineering and Design

**Module Code:**32551

**Semester:**2

**Credits:**20

**Level:**LI

**Module Description:** The objective of this module is to provide an introduction to systems engineering (SE) with an emphasis (i.e. motivating examples) drawn from space mission engineering. Topics to be covered will include requirements development, trade studies, the project life cycle, system hierarchy, risk analysis, and cost analysis. The module will prepare the student for the space mission analysis and design module in yr3

Content

* Introduction: Overview of module, Intro to SE, teamworking.
* Background mathematics: population sampling, distributions, probability, regression, extreme values
* Project lifecycle:
* Requirements: Scoping and conops, requirements capture
* Design: Introduction to the formal design process for structural components, Case studies and exercises on design process, Functional analysis, System architecture, interfaces, system synthesis, margins and contingency
* Optimisation: trending, heuristics, mathematical, genetic algorithms, Monte Carlo
* Cost: distribution, estimation, challenges
* Risk: risks, TRLs, reliability
* Monitoring: Performance measures, Verification, Review cycle
* Management: schedule, roles, documentation

## LH Finite Element Analysis for Aerospace

**Module Title:**LH Finite Element Analysis for Aerospace

**Module Code:**39224

**Semester:**2

**Credits:**10

**Level:**LH

**Module Description:** In this module students will study the theoretical bases and use of numerical codes for modelling the behaviour of structures. This will include a situation in which "aeroelasticity" is important, ie the combination of fluid flow, inertia, and elastic deformation.

## LH Aerospace Power Systems

**Module Title:** LH Aerospace Power Systems

**Module Code:**35311

**Semester:**2

**Credits:**10

**Level:**LH

**Module Description:** In this module students will be introduced to the means by which power is generated, distributed and controlled in aerospace applications. This includes, for example, turbine engines, piston engines, electric power, fuel cells, nuclear batteries, solar cells etc. Distribution can be electrical or mechanical (e.g. via gearboxes). Heating, ventilation, and air conditioning will be included too.

## LH Air Safety Lessons Learnt

**Module Title:**LH Air Safety Lessons Learnt

**Module Code:**TBA

**Semester:**2

**Credits:**10

**Level:**LH

**Module Description:** TBA

# **Aerospace: Semester Full Year Modules:**

## LI Airframe Design & Flight Dynamics

**Module Title:**LI Airframe Design and Flight Dynamics

**Module Code:**32781

**Semester:**1

**Credits:**20

**Level:**LI

**Module Description:** Airframe design is strongly linked to aircraft mission and performance. This module will cover the influences of these for subsonic, fixed wing aircraft in order to design airframes and their controls to deal with a range of ‘dead’ and ‘live’ loads through the complete flight envelope. This module will develop students’ ability and confidence to use practical, mathematical and numerical methods to analyse and solve a set of requirements related to aero-structures and flight mechanics, and to judge the validity of their solutions.

This links to the requirements for students in the QAA Materials benchmark statement 2017 of “fluency in mathematics, and familiarity with a range of mathematical and computational methods, for expressing the laws of science, for formulating and solving problems” and the AHEP3 learning outcomes

## LH Space Mission Analysis and Design

**Module Title:**LH Space Mission Analysis and Design

**Module Code:**33304

**Semester:**1

**Credits:**20

**Level:**LH

**Module Description:** In this module students will learn about spacecraft design and development. The course will cover typical mission requirements, such as payload and orbit and how these determine choices for the main spacecraft sub-systems and overall spacecraft design.