OxfordMaterials

Materials Science (MS)

Prelims Lecture Course Synopses

2016 - 2017

Department of Materials

Materials Science (MS)

Prelims Lecture Course Synopses 2016-17

Materials Science 1: Structure of Materials

MS1: Structure of Materials Michaelmas Term

1st year MS

Prof A I Kirkland

2 lectures

Introduction to Materials Structure

- Importance of material structure.

- Physical properties:
  - Intrinsic (lattice/bonding-controlled).
  - Extrinsic (defect-controlled).

- Different types of interatomic bonds:
  - Ionic.
  - Covalent.
  - Metallic.

- Effect of bond type on material structure.

- Defects in lattices.
  - Plane defects, line defects, point defects.

MS1: Structure of Materials Michaelmas & Hilary Terms

1st year MS

Prof A I Kirkland

14 lectures

Crystallography & Diffraction

Geometrical Crystallography

Characteristics of the crystalline state. Crystal lattices. Types of two-dimensional lattices. Unit Cells. Lattice planes. Miller indices. Extension to three dimensions. Symmetry elements. Rotations, mirrors and inversion. Stereographic projection. Properties of projection. Great circles. Small circles. Zones. Preservation of angular truth. Wulff net. Zone axes. Zone symbols. Weiss zone law. Addition rule. Use in plotting stereogram. Point groups. Two-dimensional point groups. Two-dimensional Bravais lattices. Three-dimensional Bravais lattices. Seven crystal systems. 3D Point groups. Crystallographic calculations. Cosine formula for systems with orthogonal axes. Axial ratios of tetragonal and orthorhombic systems. Hexagonal systems.

Diffraction

Waves - Travelling and standing waves. Interference of waves. Superposition. Group velocity. Electromagnetic spectrum. Photon description of light. Wavefronts - Huygens construction. Rays. Reflection, refraction. Snell's Law. Diffraction, diffraction gratings. Laue and Bragg equations. Diffraction limited resolution. Scattering by atoms. Scattering factors. Structure factors. Intensities of reflections. X-ray, neutron and electron diffraction. Reciprocal space and the Ewald sphere construction. Powder patterns. Indexing cubic diffraction patterns. Production of X-rays. X-ray tubes. X-ray spectrum. Continuous and characteristic X-rays. X-ray spectrometers. Filters. Applications of powder diffraction. Identification of phases. Thermal effects on diffraction patterns. Effects of disorder.

Required reading:

The Basics of Crystallography and Diffraction, 2nd edition, C Hammond, IVC/OUP

Background reading:

An Introduction to Crystallography, F C Phillips, Oliver & Boyd, 30PHI/F.
Crystallography & Crystal Defects, A Kelly & G W Groves, Longman 30KEL/F.
Structure of Metals, C S Barratt & T B Massalski, Pergamon, 31BAR/1H.
Elements of X-Ray Diffraction, B D Cullity, Addison-Wesley, 31 CUL/F.
Fundamentals of Optics, F A Jenkins & H E White, McGraw-Hill, 33JEN/A.

MS1: Structure of Materials Trinity Term

1st year MS

Dr C Nörenberg

4 lectures

Metals & Alloys

1. Structures of the metallic elements: trends across the Periodic Table. Typical metallic structures (FCC, BCC, HCP); atomic packing factor, unit cell volume, theoretical density. Crystal structures of non-close packed elements. Relationship between structure, bonding and properties of pure metals.

2. Alloy systems: Interstitial and substitutional alloys. Hume-Rothery Rules: size factor, electrochemical factor & relative valency factor.

3. The role of valence electron-to-atom ratios in determining phase stability in alloys (“electron concentration”).
   Classification of intermediate phases in alloy systems: electron compounds; normal valency compounds; size factor compounds - interstitial compounds, Laves phases; transition metal phases, Sigma phase.

4. Ordered structures and the order-disorder transition.

Required reading:

An Introduction to Metallurgy, chapter 14, Cottrell, Inst. of Materials, 1996, 50COT/3.

An Introduction to Crystal Chemistry, chapters 5, 7 and 13, Evans, CUP, 30EVA.

The Structure and Properties of Materials, chapters 1 to 3, Moffatt, Pearsall and Wulff, Wiley, 50WUL/Ba.

The Structure of Metals and Alloys, Parts II to V, Hume Rothery, Smallman and Haworth, 50HUM/2.

Structure of Metals, chapters 10 & 11, Barrett and Massalski, McGraw-Hill, 31BAR/1.

Background Reading:

Modern Physical Metallurgy, Smallman, 50SMA.

MS1: Structure of Materials Trinity Term

1st year MS

Dr C Nörenberg

4 lectures

Ceramics & Semiconductors

1. Basic concepts - definition of ceramics and semiconductors.
   Types of bonding: ionic, covalent, metallic, van der Waals. Dependence of interatomic forces on distance. Non-directional bonds: van der Waals, metallic; close packing. Directional bonds: the covalent bond, hybrids. Electronegativity, ionic bonding, co-ordination. Trends in the periodic table.

2. Ionic structures. Structures of composition AX (CsCl, NaCl, ZnS). Principles of ionic bonding: radius ratio criterion, energy considerations, Madelung constant. Structures of composition AX_2. Pauling's Rules.

3. Covalent structures. Simple covalent structures (diamond, graphite). Structure of non-metallic elements (8 – *N* rule). Molecular crystals. Structures of some ceramics.

4. Relationship between structure and properties. Thermal, mechanical and electrical properties of ceramics and semiconductors. Some applications of ceramics. Structure and properties of semiconductors.

Required reading:

An Introduction to Crystal Chemistry, R C Evans, CUP, 30EVA.

Crystallography and Crystal Defects, chapter 3, A Kelly and G W Groves, Longman, 30KEL.

Introduction to Solid State Physics, chapters 1 & 3, C Kittel, Wiley, 22KIT.

Bonding and Structure of Molecules and Solids, chapter 1, D G Pettifor, Clarendon Press, 22PET.

MS1: Structure of Materials Hilary Term

1st year MS

Prof M R Castell

6 Lectures

Defects in Crystals

1. Linear defects - Dislocations

- Why are they important and how do we know they exist?
- Dislocation types and definition of Burgers vector.
- Self energy of a dislocation.
- Dislocations in cubic materials.
- Partial dislocations and stacking faults.
- Forces on dislocations.
- Dislocation sources.

2. Point defects

- Concentration of point defects.
- Vacancy motion and solid state diffusion.
- Diffusion mechanisms and Fick's laws.

3. Planar defects

- Classification of grain boundaries, twins and anti-phase boundaries.

Background reading:

All the general metallurgical reading cover this subject in detail. Amongst the best are:

Introduction to Metallurgy, Cottrell.

Modern Physical Metallurgy, Smallman and Bishop.

Structure of Metals, Barrett and Massalski.

MS1: Structure of Materials Trinity Term

1st year MS

Dr B J Gabrys

4 Lectures

Polymers & Composites

The main objectives of this course are to introduce the elements of structure and properties, especially mechanical, of polymers and composites. The role of polymers and fibres in strengthening composites is discussed. The influence of composite fabrication on their properties is outlined, and rule of mixtures used to calculate the spread of a load carried by the fibres and matrix.

Introduction to polymers. Materials: their usage, resources and life cycle. Current challenges in polymer science and technology. Polymer structure and classification - thermoplastics, thermosets and elastomers. Their properties: M_w, conformation, glass transition, viscoelasticity.

Composites. What makes a composite. Types of composite - polymer matrix, ceramic matrix and metal matrix composites. Property objectives for composites. Reinforcements and the reinforcement - matrix interface. Longitudinal composite strength.

Structure and properties of reinforcing fibres. Glass, carbon, Kevlar, SiC, alumina.

Polymer matrix composites. Various structures. Processing routes.

Other composite systems. Short fibre composites. Laminates. Platelet reinforcement. Rubber toughened polymers. Reinforced rubber. Metal matrix composites. Ceramic matrix composites.

Required reading:

Introduction to Physical Polymer Science, L H Sperling, 2006 Wiley-Interscience – reference book

Materials and the Environment: Eco-informed material choice, Ashby, M.F. Butterworth- Heinemann, 2009 (Chapters 1-3)

Composite Materials Engineering and Science, F L Matthews & R D Rawlings, Chapman and Hall, 50MAT/1 – reference book

Background reading:

The Chemistry of Polymers, J W Nicholson, 2006 RSC Publishing

An Introduction to Composite Materials, D Hull & W T Clyne, CUP 45HUL/B

The New Science of Strong Materials or Why You don't Fall through the Floor, J E Gordon, 1991, Penguin Books

Principles of Polymer Engineering, N G McCrum, C P Buckley & C B Bucknall, OUP 45McC/3A (REF)

MS1: Structure of Materials Trinity Term

1st year MS

Dr P Dallas

6 Lectures

Elementary Quantum Theory & Bonding

Wave-particle duality: photoelectric effect, electron diffraction, the Bohr model of the atom.

Travelling waves: mathematical description of travelling waves; interference and diffraction; wave packets, phase and group velocities and Heisenberg's uncertainty principle.

Standing waves: Waves in one-dimensional box and Schrodinger's equation; quantisation of energy levels in potential wells – atoms and quantum dots; tunnelling and bonding/anti-bonding in a double well potential.

Required reading:

The following three texts cover most of the core topics in the lecture course:

Quantum Physics, chapters 1 and 2, Gasiorowicz, Wiley, 20GAS.

Introduction to Quantum Mechanics, chapters 1 to 3, Phillips, Wiley, 20PHI.

Lectures on Physics: Vol. III, Quantum Mechanics, chapters 1 and 2, Feynman, Leighton and Sands, Addison-Wesley, 20FEY/C.

Background reading:

The remaining texts are more concerned with applications of quantum theory and intersect with the course material in the final lecture on bonding/anti-bonding:

Bonding and Structure of Molecules and Solids, chapters 1 and 2, Pettifor, OUP, 22PET.

Quantum Mechanics for Chemists, chapters 1 to 3, Hayward, Roy. Soc. Chemistry, 40HAY.

Introduction to Quantum Mechanics in Chemistry, Materials Science and Biology, chapters 1, 2 and 11, Blinder, Elsevier 40BLI.

Materials Science 2: Properties of Materials

MS2: Properties of Materials — Michaelmas Term

1st year MS

Prof A J Wilkinson

1 lecture

Introduction to Materials Properties

Introduction to the relationship between structure, microstructure and properties.

How we control properties.

What are the fundamental limitations of materials properties?

Strength of materials:

- Mechanical testing & the stress-strain curve.
- Elastic deformation: atomic bonding.
- Plastic deformation: dislocation motion.
- Fracture: breaking bonds versus dislocation motion.

Intrinsic and extrinsic properties.

Increasing the yield stress.

- Solid solution hardening.
- Age hardening.
- Work hardening.

MS2: Properties of Materials   Michaelmas Term

1st year MS

Prof A J Wilkinson

8 Lectures

Elasticity & Structures

- Equilibrium – resolving forces, taking moments.
- Internal forces – shear force and bending moment diagrams.
- Stress – definitions, normal stress, shear stress, notation.
- Transformation of axes – resolving stress onto an inclined plane, Mohr's circle for stress, Principal stresses, maximum shear stress.
- Strain – definitions, normal strain, shear strain (engineering & tensor strains), notation.
- Transformation of axes – resolving strain to an inclined axis, Mohr's circle for strain, Principal strains, maximum shear strain.
- Hooke's law – relating stress and strain, Young's modulus, Shear modulus, Bulk modulus, Poissons ratio.
- Elasticity and interatomic forces (physical basis for Hooke's law).
- Thin-walled pressure vessels, bending of beams, torsional deformation.

Background reading:

Mechanical Metallurgy, chapter 2, George E Dieter, McGraw-Hill, SI Metric Edition, 1988, 50DIE. * ♥♥

The Mechanical Properties of Matter, chapters 4 and 5, A H Cottrell, Wiley, 1964, 50COT/2D. *** ♥♥♥

Mechanics of Materials, 5th edition, J M Gere, Brooks/Cole, 2001, 50GER. ** ♥♥

Mechanics of Materials vol. 1, 2nd edition, E J Hearn, Pergamon Press, 1985, 50HEAa ** ♥♥

Elementary Mechanics of Deformable Bodies, J O Smith & O M Sidebottom, Collier-Macmillan. ** ♥♥

Depth of Coverage:	* low	** solid	*** comprehensive
Readability :	♥ OK with effort	♥♥ OK	♥♥♥ a (relative) pleasure

MS2: Properties of Materials Hilary Term

1st year MS

Prof S C Speller

8 Lectures

Electrical and Magnetic Properties

1. **Introduction to quantities:** Symbols & units. Vector notation.

2. **Electrostatics**: Introducing the concepts of charge and forces on charge, Electric Field, Electric Potential and Capacitance. Using different methods such as superposition principle and Gauss' law to calculate these quantities for simple geometries.

3. **Polarisation of media**: Electric Field and Potential due to dipoles and the concept of dipole moment. Introduction to the electrical properties of media including concepts of Dielectric Permittivity, Electric displacement D and Polarisation. Solving problems concerning capacitors with simple geometry containing dielectric media. Boundary conditions of electric field and electric displacement at interfaces between different dielectric media.

4. **Magnetostatics & Magnetism:** Introduction to the concepts of **m**agnetic field, flux and potential. Methods for calculating magnetic field distributions for simple geometries: Biot-Savart law and Ampere's law. Lorentz Force on charges moving in magnetic fields. Definition of an Ampere. Introduction to the concept of electromagnetic induction – Faraday's & Lenz's laws. Magnetic materials – magnetisation, permeability & magnetic intensity H.

5. **General Theory of Electromagnetism**: Formulation of Maxwell's equations and basic concept of electromagnetic waves.

6. **Circuits**: Ohm's Law, resistivity and conductivity and Kirchhoffs laws. I-V characteristics for inductors and capacitors. Concept of impedance and its complex representation. LCR circuit responses and resonance.

Required reading:

Good basic texts with similar level of mathematical complexity as lecture course:

Fundamentals of Electricity and Magnetism, A E Kip, McGraw-Hill, 21KIP (Ch. 1-12, 14)

- Clear explanations but rather dated.

Electricity and Magnetism, W J Duffin, McGraw-Hill, 21DUF

- Additional commentaries on interesting related topics eg. Superconductivity.

Background reading:

Text books covering the concepts studied in this course but using some more complex mathematical formalisms not required for this course which also discuss interesting topics beyond the scope of this course such as microscopic theories of dielectrics and magnetism (covered in 2nd year electrical, optical and magnetic properties courses) and devices (eg. filters):

Electromagnetism, I S Grant and W R Phillips, Wiley, 21GRA (Ch. 1-7, 10)

Foundations of Electromagnetic theory, J Reitz and F Milford, Addison-Wesley, 21REI (Ch. 1-4, 6-9, 11, 13, 16)

Bleaney & Bleaney 21BLE (Ch.1-10)

- Standard (but old-fashioned) electromagnetism text book.

For a different approach to understanding electromagnetism, the Feynman Lectures on Physics (Vol II, Ch. 1-22 (20FEY)) are worth reading. The mathematical formalism is more complex, but is clearly explained in the text. The chapters on oscillators (Vol 1, Ch.21-25) are also helpful for the AC circuit theory section of this course, and Vol. 1, Ch. 2 gives an interesting historical overview of “Basic Physics” which helps set the classical physics discussed in this course in context.

MS2: Properties of Materials Hilary Term

1st year MS

Dr D M Collins & Prof A J Wilkinson

10 lectures

Mechanical Properties

Mechanical testing (DMC):

Materials Parameters we might need and why.

Tensile testing and the stress-strain curve.

Stress-strain curves of different materials classes.

Bend tests & compressive tests, hardness tests, fracture tests.

Yield and Plasticity (DMC):

Yield, controlling the yield stress, plasticity in polycrystals, variation of yield stress with temperature, hardening mechanisms, work-hardening, annealing, deformation twinning, plasticity vs. fracture.

Review (AJW):

Stiffness, strength, toughness, ductile & brittle materials, importance of fracture, some disasters.

Brittle Fracture (AJW):

A simple theory for cohesive tensile strength (stress to break bonds).

An experiment - fracture of glass (testing the theory).

Importance of small flaws (stress concentrations).

Griffith theory - crack propagation.

Toughening Mechanisms (AJW):

Orowan's modification of Griffith theory.

Energy dissipation during failure of metals, ceramics, polymers and composites.

Introduction to Materials Selection (AJW):

Materials selection charts.

Figures of merit.

Background reading:

Introduction to Dislocations, Hull and Bacon,**, **♥♥**

Modern Physical Metallurgy, Smallman, **, **♥♥**

Metals, Ceramics and Polymers, Wyatt & Dew-Hughes, **, **♥♥♥**

Strong Solids, Kelly, ***,**♥**

Mechanical Properties of Matter, Cottrell, *, **♥♥**

Metallurgy for Engineers, Rollason, *, **♥♥**

Depth of Coverage:	* low	** solid	*** comprehensive
Readability :	♥ OK with effort	♥♥ OK	♥♥♥ a (relative) pleasure

MS2: Properties of Materials Trinity Term

1st year MS

Prof J H Warner

4 lectures

Kinetic Theory of Gases

Kinetic theory of gases: rapid, random motion of point particles. Simple derivations of pressure and temperature: ideal gas behaviour.

Statistical distributions for the motion of gas molecules. Derivation of gas properties using statistical averaging. Effusion. Maxwell–Boltzmann distribution of velocities.

Collisions in the gas – atomic size and mean free paths. Transport properties: diffusion and thermal conductivity.

Non–ideal gas behaviour. Interaction between molecules. Heat capacities. Effect of temperature and pressure on transport properties.

Background reading:

The material in this course is covered in a large number of standard texts on physical chemistry and thermodynamics. Try any or all of the following:

Physical Chemistry, P W Atkins, Oxford.

Thermal Physics, C Kittel, Wiley.

Thermodynamics, Kinetic Theory and Statistical Thermodynamics, F W Sears and G L Salinger, Addison-Wesley.

Alternatively, have a look in the appropriate sections of your library for a book that suits you.

Materials Science 3: Transforming Materials

MS3: Transforming Materials Michaelmas Term

1st year MS

Prof K A Q O'Reilly

4 lectures

Introduction to Processing

An introduction to the shaping and forming of materials, including:

Casting:

- solidification.
- structures of cast metals.
- casting processes, incl. ingot and shape casting.

Plastic working:

- hot and cold working.
- forging, rolling, extrusion, sheet metal working.

Heat treatment.

Machining and finishing:

- turning, drilling, milling, grinding.
- surface coatings.

Joining:

- mechanical fastening, adhesives, soldering, brazing, welding.

Processing of polymers.

Processing of ceramics.

Background reading:

NB. There is no need to read ALL of these books – they are largely alternatives for each other – see which ones you can get hold of, or which ones suit you.

Metals in the service of man, W Alexander & A Street, 50ALE.

An old book covering metals only, but full of really interesting, practical information about how things are made – a good read!

Chapter 8 deals with shaping metals – casting, extrusion, rolling, sheet metal working and a bit on machining.

Chapter 24 covers joining of metals.

Engineering metallurgy: Metallurgical processing technology v. 2, R A Higgins, 50HIG.

Another old book which thoroughly covers all of the relevant metal processes excluding machining and finishing.

Chapters 1-5 cover various casting processes.

Chapter 7 covers rolling.

Chapter 8 covers forging.

Chapter 9 covers extrusion.

Chapter 11 covers deep drawing of sheet metal.

Chapters 13-15 cover heat treatments.

Chapters 16-19 cover joining.

Manufacturing processes, B H Amstead et al, 50AMS.

This book covers, in more detail than required here, virtually all of the course except ceramics processing.

Chapters 5 and 6 cover casting.

Chapters 12 and 13 cover hot and cold working, including rolling, forging, extrusion and sheet metal working.

Chapter 7 covers heat treatment.

Chapters 15-25 cover machining and finishing.

Chapter X covers soldering, brazing and welding.

Chapter 10 covers polymer processing.

Manufacturing with materials, L Edwards and M Endean, 50MAS.

This is the book from which I've copied the data cards I've given you, covering lots of different processes. It also has some good case studies and very clear diagrams. It is not laid out in the same way as most other books, so you'll need to dig around a bit to find relevant information. But generally:

Chapter 2 covers casting.

Chapter 3 covers forming.

Chapter 4 covers cutting.

Chapter 5 covers joining.

There isn't much of relevance on polymers, but there is some on powder processing of ceramics.

Engineering materials 2, M F Ashby and D R H Jones, 50ASH.

A very wide ranging text book – but you'll need more than what is given here.

Chapter 14 briefly covers the production, forming and joining of metals.

Chapter 19 does similarly for ceramics and glasses.

Chapter 24 does similarly for polymers.

Mechanical metallurgy, G E Dieter, 50DIE.

A very useful book covering mechanical behaviour of metals (useful for other courses too). Of relevance here:

Chapter 16 covers forging.

Chapter 17 covers rolling.

Chapter 18 covers extrusion.

Chapter 20 covers sheet metal forming.

Chapter 21 covers machining.

Principles of metal manufacturing processes, J Beddoes and M J Bibby, 56BED.

A relatively new book compared to others in this list which includes some interesting case studies.

Chapter 2 covers casting.

Chapter 4 covers forging, extrusion and rolling.

Chapter 5 covers sheet metal working.

Chapter 7 covers machining.

Chapter 8 covers joining.

Chapter 6 covers powder metallurgy, some of which is relevant to the powder processing of ceramics.

Process selection – from design to manufacture, K G Swift and J D Booker, 56SWI.

Another relatively new book, very clearly laid out, giving lots of information about applicability, applications, economic considerations and quality issues. So a good book to help you decide which process to choose to manufacture a particular item.

Chapter 1 covers casting.

Chapter 3 covers forming processes.

Chapters 4 and 5 cover machining.

Chapter 7 covers joining, including adhesives and mechanical fasteners.

Chapter 2 covers polymer processing.

MS3: Transforming Materials Michaelmas Term

1st year MS

Prof M P Moody

10 lectures

Thermodynamics

Thermodynamics of Materials:

1. **First Law of Thermodynamics**. Thermodynamic Definitions: work, heat, internal energy, state and path functions. Simple gas expansion. Reversible and irreversible processes.
2. **Enthalpy and heat capacity**. Heat capacity at constant volume. Storage of internal energy. Constant pressure processes. Heat capacity at constant pressure. Enthalpy variation with temperature. Hess's law. Kirchhoff's equation.
3. **Entropy and the Second Law of Thermodynamics**. Definition of a spontaneous process. Entropy variation with temperature. Entropy of phase changes. Definition of the Gibbs function. Thermodynamic Master Equations. Gibbs function variation with temperature and pressure. Gibbs Helmholtz equation. Statistical mechanics definition of entropy.
4. **Mixtures and Equilibria**. Dealing with mixtures. Chemical Potential. The Van't Hoff isochore.
5. **Applications of Thermodynamics to Metallurgy**. Ellingham diagrams. Stability of oxides. Thermodynamics of the Blast Furnace. Extraction of metals from Sulphides. Predominance diagrams.
6. **Phase Changes**. The phase rule and phase diagrams. The Clausius-Clapeyron equation. Vapour pressure. Ideal solutions. Non-ideal solutions. Free energy of mixing. Regular solutions. The quasi chemical model.

Required reading:
Physical Chemistry, P W Atkins and J De Paula, Oxford.

Background reading:

The Laws of Thermodynamics – A Very Short Introduction, P W Atkins, Oxford.

Introduction to Metallurgical Thermodynamics, D R Gaskell, McGraw-Hill.

MS3: Transforming Materials Michaelmas Term

1st year MS

Dr D J Haley

4 lectures

Kinetics

Kinetics:

1. **Kinetics**. Rate laws. Determination of reaction order and rate constants. The Arrhenius equation.
   With examples of industrially relevant cutting-edge research in practical applications.

Required reading:

Physical Chemistry, P W Atkins and J De Paula, Oxford.

Background reading:

Chemical Kinetics, Laidler

MS3: Transforming Materials Trinity Term

1st year MS

Prof A A R Watt

4 lectures

Electrochemistry

Electrochemistry:

1. **Electrochemistry**. Cell conventions. Thermodynamic properties from cell potentials. The Nernst equation. Examples of half cells. The electrochemical series. Pourbaix diagrams.

Background reading:

Introduction to Metallurgical Thermodynamics, D R Gaskell, McGraw-Hill.

Physical Chemistry, P W Atkins and J De Paula, Oxford.

MS3: Transforming Materials Hilary Term

1st year MS & MEM

Dr A Huang

4 lectures

Polymer Synthesis

Polymerisation mechanisms

Step-growth polymerisation, chain polymerisation, radical polymerisation, ionic polymerisation, emulsion polymerisation, reaction kinetics.

Polymer properties

Degree of polymerisation, molecular weight distribution, stereoregularity.

Characterisation techniques

Measurement of molecular weight and its distribution – end-group analysis, colligative properties, scattering methods, viscosity, GPC.

Background reading:

Principles of Polymer Chemistry, Paul Flory, Cornell University Press
Polymers (Oxford Chemistry Primers), David Walton and Phillip Lorimer, Oxford University Press.

MS3: Transforming Materials Hilary Term

1st year MS

Prof K A Q O'Reilly

12 lectures

Microstructure of Materials

Introduction to Microstructures: case studies from everyday life.

Phases: solutions, compounds and mixtures; Gibbs phase rule; simple phase diagrams; tie lines and invariant points.

Free energy-composition curves: ideal and regular solution models; tangent and lever rules.

Phase diagrams: derivation from free energy-composition curves; continuous solutions, immiscibility and ordering; eutectic, peritectic and eutectoid reactions.

Solidification of pure materials: driving force for solidification; homogeneous and heterogeneous nucleation; normal and faceted growth mechanisms.

Solidification of solutions: partition coefficient; Scheil equation and segregation; cells and dendrites.

Cast microstructures: eutectic and peritectic microstructures; ingot solidification and cooling curves.

Solid state phase transformations: homogeneous and heterogeneous nucleation; interface coherency and anisotropy.

Precipitation: Widmanstätten growth; metastable precipitation and age hardening; diffusion and interface control; the Avrami equation.

Steel microstructures: eutectoid decomposition; martensite and bainite; TTT curves.

Heat treatment: deformation and annealing; recovery, recrystallisation and grain growth; coarsening and spheroidisation.

Required reading:

Phase transformations in metals and alloys, D A Porter & K E Easterling, 53POR.

A key text for all phase transformations throughout your degree course.

Chapter 1 covers phases, free energy-composition curves and phase diagrams.

Chapter 4 covers solidification or pure materials and solutions and cast microstructures.

Chapter 5 covers solid state transformations, precipitation and steel microstructures.

Chapter 6 covers martensite (in far more detail than required here) and some aspects of heat treatment.

Background reading:

Physical Metallurgy, 2nd edition, W F Hosford, 50HOS/3

A newly revised (2010) book covering phase transformations and more. It covers most of the areas needed for this course, though is a little weak on phase diagrams and growth mechanisms. The material is presented in a different order to that of the course, which may be helpful for those struggling with some concepts.

Chapter 2 covers solidification of pure materials and solutions, and cast microstructures.

Chapter 5 covers solid solutions.

Chapter 7 briefly covers phase diagrams (but not their derivation).

Chapter 9 deals with heat treatments.

Chapter 10 covers precipitation and age hardening.

Chapter 16 includes pearlite and martensite formation and TTT curves.

An introduction to metallurgy, A H Cottrell, 50COT.

A more general text book which covers material in a less in-depth way than Porter and Easterling. A good first introduction, but doesn't go much beyond 1st year work.

Chapter 14 covers phases and free energy-composition curves.

Chapter 15 covers phase diagrams.

Chapter 13 covers solidification of pure materials and solutions and cast microstructures.

Chapter 20 covers solid state transformations, precipitation, steel microstructures and heat treatment.

Metallography of phase transformations, G A Chadwick, 53CHA.

This is an old book that goes well beyond the scope of the current course, but it does explain phenomena clearly and thoroughly and it contains lots of pictures of microstructures.

Chapter 2 covers phases, phase diagrams and then free energy-composition curves.

Chapters 3 and 4 cover solid state transformations, precipitation and steel microstructures.

Chapter 5 covers some of recrystallisation and grain growth.

Mathematics for Materials

Maths for Materials | Michaelmas Term

1st year MS

Prof S C Benjamin

11 lectures

Vectors, Matrices & Determinants

Vectors

Scalars and vectors: Addition and subtraction of vectors. Multiplication of a vector by a scalar. Position vectors. Resolution of a vector and rectangular components of a vector. Lattice basis vectors and lattice vectors. Linear dependence.
Applications: centres of mass, resolving lattice vectors onto different basis vectors, vector equations of a straight line and a plane. Relative velocities, resolving forces and mechanical equilibrium, triple junctions between plates.

Scalar (or dot) product: distributive law. Geometrical meaning. **a**.**b** in terms of Cartesian components of **a** and **b**.
Applications: Another equation of a plane, distance of a point from a plane, equation of a sphere. Work done by a force.

Vector (or cross) product: distributive law. Geometrical meaning. Cartesian components of **a**×**b**.
Applications: Finding normals to planes, Finding equation of a plane containing two lines, another equation of a straight line, moment of a force about a point, angular velocity of a body about an axis. Vector areas and areas of triangles.

Scalar triple product: volume of a parallelepiped. Cyclic permutivity. Linear dependence of 3 vectors. **a**.**b**×**c** in terms of Cartesian components of **a**, **b** and **c**. Introduction to determinants. Vector product expressed as a determinant.
Applications: Resolving a vector into 3 arbitrary non-coplanar vectors. Solution of 3 simultaneous equations. Reciprocal lattice. Plane normals and interplanar spacings in cubic and non-cubic lattices.

Required reading:

The geometrical aspects of vectors are covered exceptionally well in this classic:

Elementary vector analysis, C E Weatherburn, G Bell & Sons, London, 1955.

Background reading:

The following general reading may also be helpful:

Mathematics for Physical Chemistry, Robert G Mortimer, 2nd edition, Harcourt Academic Press, 1999.

Mathematics for Chemistry, Doggett and Sutcliffe, Longman, 1996.

Applied Mathematics for Physical Chemistry, James R Barrante, 2nd edition, Prentice-Hall, 1998.

The Chemistry Maths Book, E Steiner, Oxford Science Publications, OUP, 1996.

Matrices & Determinants

Definition of a matrix. Linear simultaneous equations expressed in matrix form: multiplication of a vector by a matrix. Matrices as operators on vectors: rotations, pure shears, simple shears, dilations of lattices. The identity matrix. Transpose of a matrix and symmetric matrices. Successive operations on a vector: matrix multiplication.

Applications: Finding matrix representations of rotations of Cartesian coordinate systems in terms of new and old coordinate axes.

Matrix representations of physical properties of crystals. Matrix representations of fields in crystals.

Applications: matrix representations of diffusivity, electrical conductivity, stress and strain.

Properties of determinants.

Applications: Cramer's rule. Linear dependence of equations and geometrical interpretation using vectors.

The inverse of a matrix as the undoing of an operation. Evaluating the inverse of a 2x2 matrix. The adjoint matrix and evaluating the inverse of a 3x3 matrix. Orthogonal matrices and their inverses.

Applications: Solution of linear simultaneous equations. Inverse of a rotation, a simple shear and a dilation. Expressing matrix representations of physical properties of crystals in rotated coordinate systems.

Eigenvalues and eigenvectors of 2x2 and 3x3 matrices. Matrix diagonalisation.
Applications: Principal axes and principal values of matrices representing physical properties such as diffusivity and electrical conductivity. Principal moments of inertia. Stress invariants (hydrostatic stress and von Mises stress).

Required reading:
The main textbook for the 40 lecture course is:
Advanced Engineering Mathematics, Erwin Kreyszig, 8th edition, John Wiley, 1999.

Background reading:
The following general reading may also be helpful:
Mathematics for Physical Chemistry, Robert G Mortimer, 2nd edition, Harcourt Academic Press, 1999.
Mathematics for Chemistry, Doggett and Sutcliffe, Longman, 1996.
Applied Mathematics for Physical Chemistry, James R Barrante, 2nd edition, Prentice-Hall, 1998.
The Chemistry Maths Book, E Steiner, Oxford Science Publications, OUP, 1996.

Maths for Materials Michaelmas Term

1st year MS

Dr J Barnes

7 lectures

Ordinary & Partial Differentiation

Limits, continuity and differentiability. Differentiation from first principles. Derivatives of x^a, $\log_e x$, e^x, $\sin x$, $\cos x$, $\tan x$, $\sec x$, $\operatorname{cosec} x$, $\operatorname{cotan} x$, $\sinh x$, $\cosh x$, $\sin^{-1}(x/a)$, $\cos^{-1}(x/a)$, $\tan^{-1}(x/a)$, $\sinh^{-1}(x/a)$, $\cosh^{-1}(x/a)$, $\tanh^{-1}(x/a)$. Differentiation of a function of a function. Differentiation of a product and of a quotient of functions. Maxima, minima and points of inflection. Sketching functions.

Partial differentiation. Functions of more than one independent variable. First and higher partial derivatives. Total derivatives. Implicit differentiation. Homogeneous functions and Euler's theorem. Changes of variable and the chain rule.

Applications: Thermodynamic state functions and Maxwell relations. Chain rule applications involving circular polar, cylindrical and spherical polar coordinates.

Reading list:

The main textbook for the 40 lecture course is:

Advanced Engineering Mathematics, Erwin Kreyszig, 8th edition, John Wiley, 1999. However this course is not covered in the book.

Required reading:

Mathematical Methods in Physics Sciences, Mary L. Boas, 2nd (1983) or 3rd edition (2005), John Wiley. Chapter 4 covers the partial differentiation part of this course

Mathematical Methods for Physics and Engineering: A comprehensive guide, KF Riley, MP Hobson, SJ Bence, 3rd edition, Cambridge University Press, 2006. Course covered in chapters 2 and 5, and whilst the book covers much more than is required in the course, it should be in most College libraries.

Background reading:

The following general reading may also be helpful:

Mathematics for Physical Chemistry, Robert G Mortimer, 2nd edition, Harcourt Academic Press, 1999. (chapters 6 and 8)

Mathematics for Chemistry, Doggett and Sutcliffe, Longman, 1996. (chapters 4 and 9)

Applied Mathematics for Physical Chemistry, James R Barrante, 2nd edition, Prentice-Hall, 1998. (chapter 4)

The Chemistry Maths Book, E Steiner, Oxford Science Publications, OUP, 1996. (chapters 4 and 9)

Maths for Materials Hilary Term

1st year MS

Dr J A Mol

4 lectures

Indefinite & Definite Integrals

Integration as the inverse of differentiation. Standard integrals: x^a , $1/x$, e^{ax} , $\sin ax$, $\cos ax$, $\sinh ax$, $\cosh ax$, $1/\sqrt{a^2 - x^2}$, $1/(a^2 + x^2)$, $1/\sqrt{a^2 + x^2}$. Evaluation of indefinite integrals by substitution, partial fractions, integration by parts, reduction formulae.

A definite integral as the area under a curve. Properties of definite integrals (splitting the range of integration, swapping the limits of integration). Definite integrals of even and odd functions. Evaluation of definite integrals over infinite ranges.

Applications: Areas, centres of gravity, moments of inertia, of planar objects. Volume, and moment of inertia of solids of revolution.

Required reading list (course lecturer will provide chapter details)**:**

The main textbook for the 40 lecture course is:

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The chapters/sections must be determined individually since the college libraries have many different editions. This can be done by comparing the titles of section in the lecture notes by chapter/section titles in whichever edition of the book in use.

Background reading:

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Maths for Materials Hilary Term

1st year MS

Dr N Ares

2 lectures

Taylor & MacLaurin Series

Taylor's theorem.

Applications: Expansions, about $x = 0$, of e^x, $\sin x$, $\cos x$, $\log_e(1 \pm x)$, $\tan x$, $\sinh x$, $\cosh x$. Evaluation of limits and l'Hôpital's rule.

Required reading (course lecturer will provide chapter details)**:**

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Maths for Materials Hilary Term

1st year MS

Dr J A Mol

4 lectures

Complex Numbers

Solutions of quadratic equations. Definition of a complex number. The Argand diagram: the complex plane and the real and imaginary numbers. Addition, subtraction, multiplication and division of complex numbers and their representation on the Argand diagram. Modulus and argument. Multiplication using modulus-argument form. $e^{i\theta} = \cos\theta + i\sin\theta$. De Moivre's theorem.

Applications: *n*th roots of unity, trigonometric identities, summation of trigonometric series, evaluation of integrals of the type $e^{ax}\cos bx$ and $e^{ax}\sin bx$.

Required reading (course lecturer will provide chapter details)**:**

The main textbook for the 40 lecture course is:

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Maths for Materials Hilary Term
1st year MS
Dr N Ares
6 lectures

Ordinary Differential Equations

Newton's law of cooling, radioactive decay. Classification of differential equations. Order and degree of a differential equation.

First order equations. Separable variables. Homogeneous equation, equations reducible to homogeneous form. Exact equations. The linear equation and integrating factors, equations reducible to linear form.

Second order equations. Linear homogeneous equations with constant coefficients: auxiliary equation. Linear inhomogeneous equations with constant coefficients: complementary function, particular integrals when the function on the right of the equation is ae^{bx}, $a\sin bx$ or $a\cos bx$, ax^s.

Required reading (course lecturer will provide chapter details)**:**
The main textbook for the 40 lecture course is:
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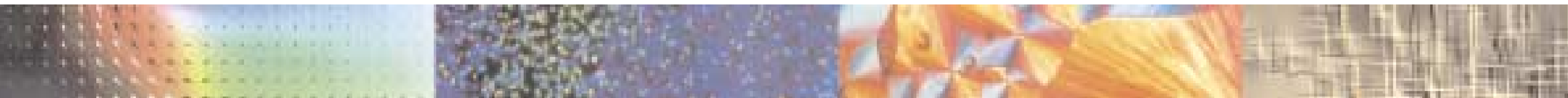
OxfordMaterials

Materials Science (MS)

Prelims Lecture Course Synopses

2016 - 2017



Department of Materials