

## Universitat Politècnica de Catalunya, Escola Tècnica Superior d'Enginyers Industrials des Barcelona, Barcelona, Spain,

### 1<sup>st</sup> Year (1<sup>st</sup> and 2<sup>nd</sup> Semester)

| Universitat Politècnica de Catalunya (UPC),<br>Escola Tècnica Superior d'Enginyeria Industrial de Barcelona (ETSEIB)<br>Courses  | ECTS-CP | Winter | Summer |
|--|---------|--------|--------|
| <u>Kinetic Theory and Statistical Thermodynamics</u> (J. Tamarit)<br>Contents: Kinetic-molecular theory of gases. Pressure, temperature and velocity probability distribution. Wall collisions and effusion. Transport processes and kinetics. Thermal conductivity, viscosity and electrical conductivity.<br>Statistical Thermodynamics. The Canonical ensemble. Partition function. Statistical Thermodynamics of Ideal monoatomic and diatomic Gases. The Linear Oscillator. The Einstein and Debye theory for crystals. Gas of electrons and the Fermi energy level. Applications to metals and engineering materials<br>Prerequisites: Basic Bachelor courses in Physics and Mathematics | 4,5     | ●      |        |
| <u>Materials Science and Technology</u> (Maspoeh)<br>Contents: Structure of solids. Crystals. Defects. Equilibrium phase diagrams. Physical and mechanical properties of solids. Solidification. Structure of alloys. Phase transformations, Engineering alloys. Polymer Materials. Structure, properties and applications. Ceramic materials: Structure, properties and applications. Composite materials. Polymer matrix composites. Fracture, fatigue, corrosion and protection. Materials Selection. Materials recycling<br>Prerequisites: Basic Bachelor courses in Physics and Mathematics.  | 6       | ●      |        |
| <u>Physical Metallurgy</u> (Anglada)<br>Contents: Structure of solids. Defects in solids. Equilibrium phase diagrams. Solidification and diffusion in the solid state. Phase transformations in the solid state. Kinetics diagrams of phase transformations. Thermal treatments.<br>Prerequisites: Basic Bachelor courses in Physics and Mathematics and Fundamentals of Materials Science   | 6       | ●      |        |
| <u>Metals and Alloys</u> (Tartera)<br>Contents: Study, description and applications of the most industrial alloys. Ferrous alloys. Steels. Carbon steels. Alloyed steels. Stainless steels. Heat treatments. Cast irons: Grey and Ductile iron. Copper and copper alloys: Brasses, Bronzes Cuproaluminium. Light alloys: Aluminium and aluminium alloys, Magnesium and magnesium alloys, Titanium and titanium alloys. Aging. Superalloys. Soft alloys: Lead Tin and Zinc alloys. Precious metals.<br>Prerequisites: Basic Bachelor courses in Physics and Mathematics and Fundamentals of Materials Science   | 6       |        | ●      |

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|--|---------|--------|--------|
| <p><u>Ceramic Materials</u> (Alcala)</p> <p>Contents: 1. Model crystalline structures and glasses. Covalent vs. ionic bonding. 2. Phase transformations: criteria for solid-solution formation; thermodynamics of phase transformations (stability criteria, influence of interfaces in equilibrium); binary diagrams; ternary diagrams; examples of phase diagrams. 3. Glasses: Kinetic and thermodynamic aspects in glass formation; TTT diagrams and its thermodynamic foundation; viscosity vs. temperature graphs and its thermodynamic background; properties of selected glasses. 4. Sintering: powder preparation and sintering techniques; thermodynamics of sintering. 5. Microstructure: Techniques for microstructural characterization; optical micrographs vs SEM and TEM images. Applications to clays and structural ceramics. 6. Mechanical properties: statistical design with ceramics; creep; environmentally assisted cracking.</p> <p>Prerequisites: Basic Bachelor courses in Physics and Mathematics and Fundamentals of Materials Science</p> | 6       |        | ●      |
| <p><u>Microstructural Materials Characterisation</u> (Gil)</p> <p>Contents: Optical microscopy. Fundamentals and techniques. Examples of microstructures. Properties of X-rays. Geometry of Crystals. Diffractometer measurements: determination of Crystal Structure. Indexing patterns of cubic and non cubic crystals. Electron microscopy of materials. Fundamentals and techniques (SEM, TEM, ESEM). Samples preparation. Electron diffraction. Indexing single-crystal pattern. Metallography of ferrous and non ferrous alloys. Natural material, ceramics and polymers.</p> <p>Prerequisites: Basic Bachelor courses in Physics and Mathematics and Fundamentals of Materials Science</p>  | 6       |        | ●      |
| <p><u>Numerical Calculus</u> (Susin)</p> <p>Contents: Iterations and zeros of functions. Iterative methods. Differential equations: numerical integration. Numerical integration.</p> <p>Prerequisites: Basic Bachelor courses in Physics and Mathematics</p>  | 3,5     | ●      |        |
| <p><u>Quality Control in Materials Technology</u> (Mateo)</p> <p>Contents: Procedures, methods and techniques on the research and analysis of failures during engineering service of all types of materials are the objective of this course. An important part of the course is devoted to non-destructive testing (dye penetrant, ultrasonic, x-ray, magnetic particles, etc) as a procedure to inspect, identify and prevent failures in service. Different types of usual destructive testing (mainly mechanical tests) are explained from the viewpoint of standardized techniques and procedures.</p> <p>Prerequisites: Fundamentals of Materials Science.</p>   | 4,5     | ●      |        |
| <p><u>Mechanical Behaviour of Materials</u> (Planell)</p> <p>Contents: Mechanical behaviour of materials: metals, polymers, ceramics and composites. Influence of temperature, strain rate, process and microstructure. Characterisation methods. Constitutive equations. Relationships between stress and strain. Elasticity. Elastic constants. Yielding. Yield criteria. Yield surface. Viscoelastic linear behaviour. Creep and stress relaxation. Boltzman superposition principle. Mechanical models. Dynamic mechanical measurements. Complex moduli. Plastic behaviour and strengthening mechanisms. Slip systems. Twinning. Dislocations. Plastic deformation of polycrystals. Solid solution strengthening. Second phase strengthening. Other strengthening methods.</p> <p>Prerequisites: Basic Bachelor courses in Physics and Mathematics and Fundamentals of Materials Science</p>   | 6       | ●      |        |

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|--|---------|--------|--------|
| <p><u>Corrosion and Degradation of Materials</u> (Fernandez)</p> <p>Contents: This course devotes 3 credits to electrolytic corrosion (Corrosion of Materials) and 3 credits to the fundamentals of creep, high-temperature oxidation and wear in ceramic and metallic materials (degradation of materials).</p> <p>Prerequisites: Basic Bachelor courses in Physics and Mathematics and Fundamentals of Materials Science</p>   | 6       |        | ●      |
| <p><u>Surface Protection</u> (Herrero)</p> <p>Contents: Introduction. Changes by surface plastic deformation. Treatments that induce changes in the surface chemical composition. Treatments that change the surface microstructure. Coatings. Hard coatings. CVD, PVD, ion implantation.</p> <p>Prerequisites: Fundamentals of Materials Science.</p>   | 6       | ●      |        |
| <p><u>Fracture and Fatigue</u> (Anglada)</p> <p>Contents: Failure of materials and structures. Stress concentrators. Introduction to linear elastic fracture mechanics. Strain energy release rate and specific fracture energy. R-curves. Stress intensity factor and fracture toughness. Plastic zone. Standards methods for measuring plain strain fracture toughness. Introduction to elastic-plastic fracture mechanics: CTOD and J-Integral. Micromechanisms of fracture. Microstructure and fracture toughness. Fatigue under constant amplitude cyclic loading. Cyclic deformation under strain control. Low and High Cycle Fatigue. Influence of surface conditions on fatigue life. Crack initiation. Crack propagation. Mechanisms influencing crack growth. Short cracks. Fatigue of non-ductile materials. Corrosion fatigue. Fatigue at high temperatures. Fatigue under variable amplitude cyclic loading.</p> <p>Prerequisites: Fundamentals of Materials Science and Technical Mechanics.</p> | 6       | ●      |        |
| <p><u>Materials Selection</u> (Cabrera)</p> <p>Contents: The course is oriented to explain the materials selection method in mechanical design by prof. Ashby. After description of the design process, the student is introduced into the Ashby maps. A wide range of problems is solved to provide clear understanding. The effect of shape factor is also introduced. Finally, the selection of fabrication method is shown. The course is evaluated through a project where students must carry out a specific design and appropriate materials selection.</p> <p>Prerequisites: Basic Bachelor courses in Physics and Mathematics and Fundamentals of Materials Science</p>   | 6       |        | ●      |
| <p><u>Casting</u> (Tartera)</p> <p>Contents: Description of foundry processes and casting alloys. Solidification of metals and alloys. Gating and risering. Cast metals: Steel castings. Grey and ductile cast iron. cast Cooper alloys: Brasses and bronzes. Cast aluminium alloys. Cast Magnesium Alloys. Zamak. Melting and melting furnaces: Cupola, Electric arc furnace. Induction furnaces. Crucible furnaces. Moulding procedures. Green sand moulding. Chemical moulding and coremaking. Lost foam. Permanent moulding. Precision castings.</p> <p>Prerequisites: Basic Bachelor courses in Physics and Mathematics and Fundamentals of Materials Science</p>   | 4,5     |        | ●      |

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|---|---------|--------|--------|
| <p><u>Polymers and Composites</u> (Martinez)</p> <p>Contents: Polymer synthesis and structure. Classification. Relationship between structure and thermal, rheological, chemical and mechanical properties. Viscoelasticity. Yielding process in polymers: deformation mechanisms. Introduction to main manufacturing process: extrusion, injection moulding and other processes. Introduction to Polymer composites: polymer-polymer and polymer-inorganic fillers and fibers.</p> <p>Prerequisites: Basic Bachelor courses in Physics and Mathematics and Fundamentals of Materials Science</p> | 6       | ●      |        |
| <p><i>Seminar I (Invited researchers and lectures from the consortium, Coordinator Prof. Anglada)</i></p> <p>Contents: Variable from course to course. Several short specific courses, each one of at least 0, 5 ECTS, given mainly by invited personnel of the other universities of the consortium and by other visiting lecturers and researchers at UPC.</p>  | 3       |        | ●      |

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### 2<sup>nd</sup> Year (3<sup>rd</sup> and 4<sup>th</sup> Semester)

| Universitat Politècnica de Catalunya (UPC),<br>Escola Tècnica Superior d'Enginyeria Industrial de Barcelona (ETSEIB)<br>Courses   | ECTS-CP | Winter | Summer |
|---|---------|--------|--------|
| <p>Metallurgical Technology (Prado)</p> <p>Contents: Forming by plastic deformation: Principles. Mechanical analysis of plastic deformation. Influence of strain rate and temperature. Effect of friction. Static and dynamic recrystallization. Texture and fiber. Forming by plastic deformation: Processes. Rolling. Forging. Extrusion. Sheet forming. Casting: Principles. Solidification: Nucleation and growth. Effect of alloying. Solidification of castings. Casting: Processes. Non-permanent moulds: Filling and feeding. Types of non-permanent moulds. Permanent moulds: Gravity and injection. Welding: Principles. Thermal analysis of the welded union. Solidification of the melted zone. Transformations in the heat affected zone. Weldability. Welding: Processes. Electric arc welding. TIG; MIG and MAG. Electric resistance welding. Plasma and laser welding. Powder Metallurgy.</p> <p>Prerequisites: Fundamentals of Materials Science</p>                                   | 6       | ●      |        |
| <p>Fracture and Fatigue (Anglada)</p> <p>Contents: Failure of materials and structures. Stress concentrators. Introduction to linear elastic fracture mechanics. Strain energy release rate and specific fracture energy. R-curves. Stress intensity factor and fracture toughness. Plastic zone. Standards methods for measuring plain strain fracture toughness. Introduction to elastic-plastic fracture mechanics: CTOD and J-Integral. Micromechanisms of fracture. Microstructure and fracture toughness. Fatigue under constant amplitude cyclic loading. Cyclic deformation under strain control. Low and High Cycle Fatigue. Influence of surface conditions on fatigue life. Crack initiation. Crack propagation. Mechanisms influencing crack growth. Short cracks. Fatigue of non-ductile materials. Corrosion fatigue. Fatigue at high temperatures. Fatigue under variable amplitude cyclic loading.</p> <p>Prerequisites: Fundamentals of Materials Science and Technical Mechanics.</p> | 6       | ●      |        |
| <p>Structural Materials (Llaner)</p> <p>Contents: Introduction: structural integrity and durability considerations. Elasticity and plasticity. Dislocation theory. Plastic deformation of crystalline materials. Strengthening mechanisms. Fracture: basic concepts. Fracture mechanics, stress intensity factor, fracture toughness and microstructural effects. Fatigue: cyclic deformation, crack nucleation and fatigue crack growth. Environmentally assisted cracking and corrosion fatigue. Creep and superplasticity. Oxidation. Selection of materials for structural applications: case studies.</p> <p>Prerequisites: Fundamentals of Materials Science and Technical Mechanics.</p>   | 6       | ●      |        |
| <p>Polymer and Composite Technology (MasPOCH)</p> <p>Contents: Contents: Main families of thermoplastics and thermosets. Additive technology. Rheology in polymers: elongational and shear viscosity, rheological curves, elastic effects. Polymer extrusion: operation curves, manufacturing methods, related defects. Mixing technology. Injection Moulding: Process description and parameters, introduction to mould design, defects, manufacturing methods related. Thermoforming. Rotomoulding. Manufacturing technology in polymer composites.</p> <p>Prerequisites: Fundamentals of Materials Science and Technical Mechanics.</p>  | 6       | ●      |        |

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| <p>Surface Protection (Herrero)</p> <p>Contents: Introduction. Changes by surface plastic deformation. Treatments that induce changes in the surface chemical composition. Treatments that change the surface microstructure. Coatings. Hard coatings. CVD, PVD, ion implantation.</p> <p>Prerequisites: Fundamentals of Materials Science.</p>   | 6       | ●      |        |
| <p>Non-Ferrous Alloys (Gil)</p> <p>Contents: General introduction. Physical metallurgy of aluminium alloys. Wrought aluminium alloys: (work-hardening of aluminium and its alloys and non-heated-treatable alloys, heat treatable alloys). Cast aluminium alloys (alloys based Al-Si system, Al-Cu system, Al-Mg and Al-Zn-Mg). Magnesium alloys (melting and casting, influence of the Zr, wrought magnesium alloys), Titanium alloys (<math>\alpha</math>, <math>\alpha+\beta</math> and <math>\beta</math> alloys, fabrication and engineering performance). Copper alloys (Fabrication, physical properties, influence of the oxygen on the properties, copper alloys (brass, bronzes, shape memory alloys...)).</p> <p>Prerequisites: Fundamentals of Materials Science.</p> | 6       | ●      |        |
| <p>New Perspectives in Materials Science and Technology (Planell)</p> <p>Contents: 1.- Introduction 2.- Revision to some aspects of the structure of matter: Basic elements. Two states of matter: order and disorder. The perfect gas. Crystals. Crystalline solids. Liquids. Non-crystalline solids. Between order and disorder. Composite materials, suspensions and colloidal solutions. 3 Challenges and perspectives: Photonic Materials. Materials for Information Storage. Smart Materials. Biological Materials and Biomimetics. Biomedical Materials. Materials for Clean Energy. Porous Materials. Diamond and Hard Materials. The New Polymers. Surfaces, Interfaces and Nanotechnology.</p> <p>Prerequisites: Fundamentals of Materials Science.</p>                 | 3       | ●      |        |
| <p>Natural Materials and Biomaterials (Planell)</p> <p>Contents: Natural or biologic materials: composition, structure and properties. The biomimetic approach: learning from nature how to design and produce materials. Biological tissues: wood, soft animal tissues, hard animal tissues. Biomaterials for organ and tissue replacement and tissue regeneration. Description of the different families of materials used in medical applications. Biomaterial-host Interactions. Techniques of biocompatibility evaluation. Materials for Tissue Engineering.</p> <p>Prerequisites: Fundamentals of Materials Science.</p>  | 6       | ●      |        |
| <p>Quality Control in Materials Technology (Mateo)</p> <p>Contents: Procedures, methods and techniques on the research and analysis of failures during engineering service of all types of materials are the objective of this course. An important part of the course is devoted to non-destructive testing (dye penetrant, ultrasonic, x-ray, magnetic particles, etc) as a procedure to inspect, identify and prevent failures in service. Different types of usual destructive testing (mainly mechanical tests) are explained from the viewpoint of standardized techniques and procedures.</p> <p>Prerequisites: Fundamentals of Materials Science.</p>   | 4,5     | ●      |        |
| <p><i>Seminar II (Invited researchers and lecturers from the consortium, Coordinator Prof. Anglada)</i></p> <p>Contents: Variable from course to course. Several short specific courses, each one of at least 0,5 ECTS, given mainly by invited personnel of the other universities of the consortium and by other visiting lecturers and researchers at UPC.</p> <p>Prerequisites: Fundamentals of Materials Science</p>   | 3       | ●      |        |

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|--|---------|--------|--------|
| <i>Master Thesis (Compulsory)</i><br>To be selected from the research laboratories' scientific or industry-related projects.<br>Prerequisites: For registration: Lectures/exercises/laboratory work in the field of the thesis. For presentation of Master thesis only after 90 ECTS have been successfully completed. | 30      |        | ●      |