City & Guilds

Lesson 1: Atomic bonding **Suggested Teaching Time:** 3 hours

Learning Outcome: Understand the atomic theory of the structure of engineering materials

Topic	Suggested Teaching	Suggested Resources
Topic 1.1 The influence of atomic bonding on the properties of engineering materials	**Range:** **Processes**: addition process, condensation process **Mechanical properties:** stiffness, strength Introduce the unit, explaining that the purpose of this unit is to enable learners to develop knowledge and understanding of the effects that material properties have on the choice of materials for engineering applications. The main delivery method will be whole-class teaching: Using interactive periodic table at www.rsc.org/periodic-table explain the different atomic structure of a range of elements highlighting the uniqueness of noble gases and explain why they are so stable. Explain the three main material bond types (Ionic, covalent and metallic). Explain how the types of bonding affects the properties of different materials (e.g. conductivity of materials with metallic bonding opposed to covalent) **Opportunities for applied learning** **Research:** Provide learners with a list of materials. For each material the learner must state: type of material (Metal, polymer, ceramic etc.), the type of atomic bonding and typical properties associated with that material.	**Books:** Higgins, R. A., *Materials for Engineers and Technicians* Newnes, ISBN 0750668504 Timings, R. L., *Engineering Materials*, vol 2, 2nd Edn, Longman, 2000, ISBN 0582404665 Higgins, R. A., *Properties of Engineering Materials* 2nd Edn, Arnold, 1997, ISBN 0340700521 **Websites**: www.materials.eng.cam.ac.uk/mpsite/materials.html www.matweb.com www.rsc.org/periodic-table www.bbc.co.uk/bitesize/higher/chemistry/energy/bsp/revision/1/

Lesson 2: Effect of temperature on plain carbon steels **Suggested Teaching Time:** 3 hours

Learning Outcome: Understand the atomic theory of the structure of engineering materials

Topic	Suggested Teaching	Suggested Resources
Topic 1.2 The effect of temperature change on the microstructure of plain carbon steel	**Range:** **Processes**: addition process, condensation process, **Mechanical properties:** stiffness, strength. Illustrated by pictures, explain how pure metal crystallises, forming grains, as it cools from a liquid. Explain how metal atoms form into different lattice structures. Show **DVD:** BBC *Metal: How it Works*, Professor Mark Miodownik (1 hour) Set learners the task to work in small **Opportunities for applied learning** **Research:** Working in small groups, learners must produce a short presentation explaining the iron-carbon equilibrium diagram. They must explain the effects of temperature and carbon content on steel structure. They should also be able to explain why blacksmiths heat steel beyond its upper critical temperature before working with it.	**Books:** Higgins, R. A., *Materials for Engineers and Technicians* Newnes, ISBN 0750668504 Timings, R. L., *Engineering Materials*, vol 2, 2nd Edn, Longman, 2000, ISBN 0582404665 **Websites:** www.materials.eng.cam.ac.uk/mpsite/materials.html www.matweb.com

Lesson 3: Polymers

Suggested Teaching Time: 3 hours

Learning Outcome: Understand the atomic theory of the structure of engineering materials

Topic	Suggested Teaching	Suggested Resources
Topic 1.3 The processes by which polymer molecules are formed **Topic 1.4** The influence of crosslinking on the mechanical properties of polymers	**Range:** **Processes**: addition process, condensation process, **Mechanical properties:** stiffness, strength. Introduce the topic by reviewing previous learning on covalent bonding. Explain how monomers are formed into chains of linked polymers. Explain the difference between thermo plastics and thermo setting plastics. Show **DVD:** BBC, *Plastic: How it Works*, Professor Mark Miodownik (1 hour) Learners to carry out research task **Opportunities for applied learning** **Research:** provide learners with a list of polymers. Learners must state for each polymer: whether it is a thermo plastic or thermo setting plastic; How it manufactured; typical applications.	**Books:** Higgins, R. A., *Materials for Engineers and Technicians* Newnes, ISBN 0750668504 Timings, R. L., *Engineering Materials*, vol 2, 2nd Edn, Longman, 2000, ISBN 0582404665 Higgins, R. A., *Properties of Engineering Materials* 2nd Edn, Arnold, 1997, ISBN 0340700521 **Websites:** www.materials.eng.cam.ac.uk/mpsite/materials.html www.matweb.com http://www.bbc.co.uk/bitesize/higher/chemistry/energy/bsp/revision/1/

Lesson 4: Molecular structure **Suggested Teaching Time:** 3 hours

Learning Outcome: Understand the atomic theory of the structure of engineering materials

Topic	Suggested Teaching	Suggested Resources
Topic 1.5 Compare the cell structure of wood with a long chain polymer **Topic 1.6** How the molecular structure of glass affects its properties	**Range:** **Processes**: addition process, condensation process, **Mechanical properties:** stiffness, strength. Working within small groups learners are to research the cellular structure of three different types of wood and produce a short presentation explaining the typical cellular make up and structure of wood and how the three types they have identified differ. They should compare the typical structure against long chain polymer structure covered in the last lesson. Discuss all presentations as a whole group exercise. Show **DVD:** BBC, *Ceramic: How it Works*, Professor Mark Miodownik (1 hour). Following (or during) the DVD present learners with a gapped hand-out explaining how the molecular structure of glass affects its properties (such as why you can see through it). They should be able to complete it based on what they have learned. Work through the hand-out with the learners to ensure they have captured key points **Opportunities for applied learning** **Research and Presentation:** cellular structure of 3 types of wood.	**Books:** Higgins, R. A., *Materials for Engineers and Technicians* Newnes, ISBN 0750668504 Timings, R. L., *Engineering Materials*, vol 2, 2nd Edn, Longman, 2000, ISBN 0582404665 Higgins, R. A., *Properties of Engineering Materials* 2nd Edn, Arnold, 1997, ISBN 0340700521 **Websites:** www.materials.eng.cam.ac.uk/mpsite/materials.html www.matweb.com

Lesson 5: Thermo mechanical treatments **Suggested Teaching Time:** 3 hours

Learning Outcome: Understand the changes in the properties of metals as a result of further processing

Topic	Suggested Teaching	Suggested Resources
Topic 2.1 Analyse the effect of thermo-mechanical treatments on the microstructure of plain carbon steels	**Range:** **Thermo-mechanical treatment:** work hardened, quenching, flame hardening, induction hardening, case hardening, and hardening. **Alloying elements:** nickel, chromium, molybdenum, manganese, cobalt, niobium, titanium, vanadium, boron, combination. **Surface hardening treatment:** carburising, casehardening, nitriding. Review the learning from lesson 2 regarding iron-carbon equilibrium diagram. Explain the effect on the grain structure of increasing carbon percentage in steels (ferrite, pearlite, cementite and martensite). Working in small groups, learners are to produce a presentation explaining, with the use of an iron-carbon diagram, the following heat treatments of a 0.4% carbon steel. Hardening, tempering, annealing and normalising. Learners must state temperatures and cooling rates Each group should be provided with three pieces of identical 0.4% carbon steel round bars (approx. 6mm–10mm diameter). Each piece should be hardened in the same way. One of the test pieces should then be tempered and another normalised. Each piece should be impact tested and the results recorded. Learners should produce a report on the activity explaining the effects of heat treatment on the impact strength and what happened to the structure of the steel in each case. **Opportunities for applied learning** **Research:** learners to research the heat treatment of steels and plan for the practical activity. **Practical:** heat treatment and destructive testing of steel samples.	**Books:** Higgins, R. A., *Materials for Engineers and Technicians* Newnes, ISBN 0750668504 Timings, R. L., *Engineering Materials*, vol 2, 2nd Edn, Longman, 2000, ISBN 0582404665 **Websites**: www.materials.eng.cam.ac.uk/mpsite/materials.html www.matweb.com

Lesson 6: Surface hardening **Suggested Teaching Time:** 3 hours

Learning Outcome: Understand the changes in the properties of metals as a result of further processing

Topic	Suggested Teaching	Suggested Resources
Topic 2.6 The surface hardening treatment processes. **Topic 2.7** How nitriding improves the surface hardness of nitralloy steels	**Range:** **Thermo-mechanical treatment:** work hardened, quenching, flame hardening, induction hardening, case hardening, and hardening. **Alloying elements:** nickel, chromium, molybdenum, manganese, cobalt, niobium, titanium, vanadium, boron, combination. **Surface hardening treatment:** carburising, casehardening, nitriding. Refer back to the results from the practical session of lesson 5 and lead discussion on which heat-treatment processes would be required for a mechanical gear, where the teeth must be as hard as possible to resist wear and the body must be tough to resist impact. Explain the process of flame surface hardening and typical applications. Learners to research five types of case hardening steels. They must state benefits and limitations for each along with typical applications. **Opportunities for applied learning** **Discussion:** types of heat treatments **Research / Discussion:** methods of case hardening	**Books:** Higgins, R. A., *Materials for Engineers and Technicians* Newnes, ISBN 0750668504 Timings, R. L., *Engineering Materials*, vol 2, 2nd Edn, Longman, 2000, ISBN 0582404665 Higgins, R. A., *Properties of Engineering Materials* 2nd Edn, Arnold, 1997, ISBN 0340700521 **Websites:** www.materials.eng.cam.ac.uk/mpsite/materials.html www.matweb.com

Lesson 7: Cast iron

Suggested Teaching Time: 3 hours

Learning Outcome: Understand the changes in the properties of metals as a result of further processing

Topic	Suggested Teaching	Suggested Resources
Topic 2.2 The effect of cooling rates on the grain structure of different types of cast iron. **Topic 2.3** The effect of chilling upon cast iron **Topic 2.4** How alloying affects the mechanical properties of cast iron	**Range:** **Thermo-mechanical treatment:** work hardened, quenching, flame hardening, induction hardening, case hardening, and hardening. **Alloying elements:** nickel, chromium, molybdenum, manganese, cobalt, niobium, titanium, vanadium, boron, combination. **Surface hardening treatment:** carburising, casehardening, nitriding. Review some of the key points raised in the DVD: *Metal: How it Works*; regarding how cast iron is produced and its strength and weaknesses (strong in compression and weak in tension. Learners to research the weldability of grey cast iron and the problems associated with fast cooling rates. They should detail two methods of overcoming this problem. Explain the different types of cast iron (grey, white, malleable and ductile) their properties and typical application. Show pictures of grain structures explaining how they are effected by heat treatment and alloying elements to improve properties. **Opportunities for applied learning** **Research / group work with presentations:** weldability of cast iron	**Books:** Higgins, R. A., *Materials for Engineers and Technicians* Newnes, ISBN 0750668504 Timings, R. L., *Engineering Materials*, vol 2, 2nd Edn, Longman, 2000, ISBN 0582404665 **Websites**: www.materials.eng.cam.ac.uk/mpsite/materials.html www.matweb.com http://www.lincolnelectric.com/en-us/support/welding-how-to/Pages/welding-cast-iron-detail.aspx

Lesson 8: Alloying elements **Suggested Teaching Time:** 3 hours

Learning Outcome: Understand the changes in the properties of metals as a result of further processing

Topic	Suggested Teaching	Suggested Resources
Topic 2.5 The effect of alloying elements on the mechanical properties of alloy steels	**Range:** **Thermo-mechanical treatment:** Work hardened, quenching, flame hardening, induction hardening, case hardening, and hardening. **Alloying elements:** nickel, chromium, molybdenum, manganese, cobalt, niobium, titanium, vanadium, boron, combination. **Surface hardening treatment:** carburising, casehardening, nitriding. Define what an alloy is and why metals are mixed together. Use example of copper and tin to make bronze. Explain that all steels are an alloy of iron and carbon (a non-metal) but alloy steels refer to steel with other additional alloying elements. Exercise: provide list of alloying elements for steel. Learners must explain typical percentages, effect on properties and typical application for each. They should also define the terms: • **Low-alloy** steel • **High-strength low-alloy** steel • **High-alloy** steel • **Micro-alloyed** steel Explain the effects of adding chromium to steel protects steel from corrosion **Opportunities for applied learning** **Exercise:** Effects of alloying elements on steel	**Books:** Higgins, R. A., *Materials for Engineers and Technicians* Newnes, ISBN 0750668504 Timings, R. L., *Engineering Materials*, vol 2, 2nd Edn, Longman, 2000, ISBN 0582404665 Higgins, R. A., *Properties of Engineering Materials* 2nd Edn, Arnold, 1997, ISBN 0340700521 **Websites:** www.materials.eng.cam.ac.uk/mpsite/materials.html www.matweb.com

Lesson 9: Stainless steels **Suggested Teaching Time:** 3 hours

Learning Outcome: Understand the changes in the properties of metals as a result of further processing

Topic	Suggested Teaching	Suggested Resources
Topic 2.8 How processing of stainless steel affects its properties. **Topic 2.9** The role played by niobium in stabilising stainless steels against weld decay.	**Range:** **Thermo-mechanical treatment:** Work hardened, quenching, flame hardening, induction hardening, case hardening, and hardening. **Alloying elements:** nickel, chromium, molybdenum, manganese, cobalt, niobium, titanium, vanadium, boron, combination. **Surface hardening treatment:** carburising, casehardening, nitriding. Introduce the topic by explaining its history and benefits compared to carbon steels. Providing typical applications and properties for each, explain the types of stainless steels: • Austenitic • Ferritic • Martensitic Explain the effects of processing stainless steels. Use a case study similar to following example: A company produced stainless steel (304) hand rails for Hong Kong harbour. After several months many of the pipes had failed due to corrosion in a small area alongside the welds. Explain the mechanism of the failure and how the use of a niobium containing alloy (347) would have prevented the failure. **Opportunities for applied learning** **Case Study / Group work with presentations:** austenitic weld decay	**Books** Higgins, R. A., *Materials for Engineers and Technicians* Newnes, ISBN 0750668504 Timings, R. L., *Engineering Materials*, vol 2, 2nd Edn, Longman, 2000, ISBN 0582404665 Higgins, R. A., *Properties of Engineering Materials* 2nd Edn, Arnold, 1997, ISBN 0340700521 **Websites:** www.materials.eng.cam.ac.uk/mpsite/materials.html www.matweb.com

Lesson 10: Metallic protective coating **Suggested Teaching Time:** 3 hours

Learning Outcome: Understand the application of non-ferrous metals and their alloys

Topic	Suggested Teaching	Suggested Resources
Topic 3.1 Evaluate different methods of metallic protective coatings	**Range:** **Methods:** electrochemical scale, electrolytic corrosion, sacrificial anode, cathode, anodising, electroplating, phosphating. **Coatings:** Zinc, tin. **Applications:** Tubing, conductor, plain bearings. **Forms:** Sheet, strip, plate, extrusion, rod, tube. **Processes:** Sand cast, gravity die cast, pressure die cast. **Structural changes:** Resulting from heat treatment and ageing. Review how chromium helps to protect steel from corrosion. Explain: • The process of electrolytic corrosion and the galvanic series • How zinc provides two types of protection from is oxide layer and through galvanic protection • How sacrificial anodes are used to protect ships, oil rigs etc. • The dangers of galvanic pairing where two dissimilar metals are in contact Ask learners to research the different types of protective coatings available for steel and different methods of coating. **Opportunities for applied learning** Research: types of protective coating **Case Study / Discussion:** painting the Forth Bridge.	**Books** Higgins, R. A., *Materials for Engineers and Technicians* Newnes, ISBN 0750668504 Timings, R. L., *Engineering Materials*, vol 2, 2nd Edn, Longman, 2000, ISBN 0582404665 **Websites**: www.materials.eng.cam.ac.uk/mpsite/materials.html www.matweb.com

Lesson 11: Copper and its alloys **Suggested Teaching Time:** 3 hours

Learning Outcome: Understand the application of non-ferrous metals and their alloys

Topic	Suggested Teaching	Suggested Resources
Topic 3.2 The engineering applications of copper and its alloys.	**Range:** **Methods:** electrochemical scale, electrolytic corrosion, sacrificial anode, cathode, anodising, electroplating, phosphating. **Coatings:** zinc, tin. **Applications:** tubing, conductor, plain bearings. **Forms:** sheet, strip, plate, extrusion, rod, tube. **Processes:** sand cast, gravity die cast, pressure die cast. **Structural changes:** resulting from heat treatment and ageing. Introduce the topic by explaining how copper was the first metal used by man and how its alloy, bronze, led to a huge technological step forward. Explain its typical properties (ductility, corrosion resistance, conductivity etc.) and the range of applications. Research: learners are to research how copper is heat treated compared to steel. They should explain the difference in hardness and tensile strength for H040 and H110 grade copper and provide a typical application for each. Explain the range of copper alloys and the purpose of a range of alloying elements. **Opportunities for applied learning** **Research:** the heat treatment of copper.	**Books:** Higgins, R. A., *Materials for Engineers and Technicians* Newnes, ISBN 0750668504 Timings, R. L., *Engineering Materials*, vol 2, 2nd Edn, Longman, 2000, ISBN 0582404665 **Websites:** www.materials.eng.cam.ac.uk/mpsite/materials.html www.matweb.com www.copper.org/ www.copperalliance.org.uk/

Lesson 12: Aluminium and its alloys **Suggested Teaching Time:** 3 hours

Learning Outcome: Understand the application of non-ferrous metals and their alloys

Topic	Suggested Teaching	Suggested Resources
Topic 3.3 The engineering applications of aluminium and its alloys in different forms.	**Range:** **Methods:** electrochemical scale, electrolytic corrosion, Sacrificial anode, cathode, anodising, electroplating, phosphating. **Coatings:** zinc, tin. **Applications:** tubing, conductor, plain bearings. **Forms:** sheet, strip, plate, extrusion, rod, tube. **Processes:** sand cast, gravity die cast, pressure die cast. **Structural changes:** resulting from heat treatment and ageing. Introduce the topic by explaining a brief history of the use of aluminium, which has only been in use since the late 19th century. Review how duralumin was discovered and what this meant as an engineering material. Explain its typical properties (light weight, corrosion resistance, conductivity etc.) and the range of applications. Research: strength-to-weight ratio and cost are two key considerations when designing a bicycle frame. Working in small groups learners should compare the properties of AISI 4130 alloy steel, 6061 aluminium and titanium 3AL-2.5V alloy. They then must recommend one of the alloys to be used for manufacturing a bicycle frame explaining the reason for their selection. **Opportunities for applied learning** **Research / Presentation:** Bicycle frame (part 1).	**Books:** Higgins, R. A., *Materials for Engineers and Technicians* Newnes, ISBN 0750668504 Timings, R. L., *Engineering Materials*, vol 2, 2nd Edn, Longman, 2000, ISBN 0582404665 **Websites:** www.materials.eng.cam.ac.uk/mpsite/materials.html www.matweb.com http://www.world-aluminium.org www.alueurope.eu www.aluminum.org

Lesson 13: Aluminium and its alloys **Suggested Teaching Time:** 3 hours

Learning Outcome: Understand the application of non-ferrous metals and their alloys

Topic	Suggested Teaching	Suggested Resources
Topic 3.4 Evaluate the application of wrought and cast processes on aluminium alloys. **Topic 3.5** Classification of aluminium alloys.	**Range:** **Methods:** electrochemical scale, electrolytic corrosion, sacrificial anode, cathode, anodising, electroplating, phosphating. **Coatings:** zinc, tin. **Applications:** Tubing, conductor, plain bearings. **Forms:** sheet, strip, plate, extrusion, rod, tube. **Processes:** sand cast, gravity die cast, pressure die cast. **Structural changes:** resulting from heat treatment and ageing. Explain the various forms that aluminium is supplied (sheet, strip, plate, extrusion, rod, tube and casting) and describe the production processes involved. Research: learners are to research international alloy designation for wrought alloys. They must state for each series; the alloying elements added and typical properties. They must also explain the temper designations **Opportunities for applied learning** **Research:** international classification of aluminium alloys *Tutors should note BS1490 has been superseded by BS 1676, BS 1559 and, BS 1760.*	**Books** Higgins, R. A., *Materials for Engineers and Technicians* Newnes, ISBN 0750668504 Timings, R. L., *Engineering Materials*, vol 2, 2nd Edn, Longman, 2000, ISBN 0582404665 **Websites:** www.materials.eng.cam.ac.uk/mpsite/materials.html www.matweb.com http://www.world-aluminium.org www.alueurope.eu www.aluminum.org

Lesson 14: Precipitation hardening alloys **Suggested Teaching Time:** 3 hours

Learning Outcome: Understand the application of non-ferrous metals and their alloys

Topic	Suggested Teaching	Suggested Resources
Topic 3.6 Represent structural changes of aluminium-copper alloys on a heat treatment graph. **Topic 3.7** Analyse the effect on tensile strength of the precipitation treatment of a duralumin type aluminium alloy.	**Range:** **Methods:** electrochemical scale, electrolytic corrosion, sacrificial anode, cathode, anodising, electroplating, phosphating. **Coatings:** zinc, tin. **Applications:** tubing, conductor, plain bearings. **Forms:** sheet, strip, plate, extrusion, rod, tube. **Processes:** sand cast, gravity die cast, pressure die cast. **Structural changes:** resulting from heat treatment and ageing. Research: working in small groups, learners must describe the process of precipitation hardening in some aluminium alloys. This should include the effects on tensile strength. They must produce a heat treatment graph that shows the structural changes that take place in aluminium alloys. They must also explain the difference and benefits of 7000 over 2000 series alloys. The learners must then present their findings back to the whole group for discussion. **Opportunities for applied learning** **Case Study / Discussion:** precipitation hardening	**Books** Higgins, R. A., *Materials for Engineers and Technicians* Newnes, ISBN 0750668504 Timings, R. L., *Engineering Materials*, vol 2, 2nd Edn, Longman, 2000, ISBN 0582404665 Higgins, R. A., *Properties of Engineering Materials* 2nd Edn, Arnold, 1997, ISBN 0340700521 **Websites:** www.materials.eng.cam.ac.uk/mpsite/materials.html www.matweb.com http://www.world-aluminium.org www.alueurope.eu www.aluminum.org

Lesson 15: Glass **Suggested Teaching Time:** 3 hours

Learning Outcome: Understand how properties affect the application of composite materials

Topic	Suggested Teaching	Suggested Resources
Topic 4.3 Evaluate the mechanical properties of different types of glass from design tables.	**Range:** **Conditions:** laboratory, commercial production. **Glass reinforced products:** matrix, uniaxial. **Mechanical properties:** ultimate tensile strength, compressive strength, density **Types of glass:** E glass, R glass, D glass, C glass. **Fibres:** Aramid fibre (Kevlar), carbon fibre. Referring back to the DVD (Ceramic: How it Works) from lesson 4, explain the importance of glass as a material. Describe the different types of glass and processes used to manufacture it. Discuss why it tends to be brittle and what treatments are available to increase the toughness of glass. Ask whether glass is a liquid or a solid. Research: learners to produce a chart showing a range of mechanical properties for a range of glass types. **Opportunities for applied learning** **Topic assignment:** provide a project brief to each learner for which they have to produce a project plan, Gantt chart and Critical Path Analysis using software. As a second part of the task learners must amend their schedules etc. to allow for unforeseen changes.	**Books** Higgins, R. A., *Materials for Engineers and Technicians* Newnes, ISBN 0750668504 Timings, R. L., *Engineering Materials*, vol 2, 2nd Edn, Longman, 2000, ISBN 0582404665 **Websites:** www.materials.eng.cam.ac.uk/mpsite/materials.html www.matweb.com www.britglass.org.uk www.glassforeurope.com

Lesson 16: Glass reinforced plastic **Suggested Teaching Time:** 3 hours

Learning Outcome: Understand how properties affect the application of composite materials

Topic	Suggested Teaching	Suggested Resources
Topic 4.1 The difference in ultimate tensile strength of a single glass fibre produced in different conditions. **Topic 4.2** Analyse the role of the glass fibres in glass reinforced products	**Range:** **Conditions:** laboratory, commercial production. **Glass reinforced products:** matrix, uniaxial. **Mechanical properties:** ultimate tensile strength, compressive strength, density **Types of glass:** E glass, R glass, D glass, C glass. **Fibres:** Aramid fibre (Kevlar), carbon fibre. Introduce the topic of fibre-reinforced material by showing DVD: *Richard Hammond's Engineering Connections: Super Jumbo – A380* (50minutes). This shows how glass fibres are formed and how they have been used to increase the strength of thin aluminium sheet (GLARE). Explain how: • Glass fibre is produced • How different types of glass fibres have different properties and different applications (e.g. S Glass for high tensile strength) • The properties of materials differ from bulk form to fibre form Discuss the development of fibre composites including glass fibre, carbon fibre and aramid fibres. Research: learners to find five different applications for glass-fibre reinforced plastics (GFRP) and explain why that material was chosen. **Opportunities for applied learning** **Research:** GFRP applications	**Books** Higgins, R. A., *Materials for Engineers and Technicians* Newnes, ISBN 0750668504 Timings, R. L., *Engineering Materials*, vol 2, 2nd Edn, Longman, 2000, ISBN 0582404665 **Websites:** www.materials.eng.cam.ac.uk/mpsite/materials.html www.matweb.com

Lesson 17: Fibre reinforced composites **Suggested Teaching Time:** 3 hours

Learning Outcome: Understand how properties affect the application of composite materials

Topic	Suggested Teaching	Suggested Resources
Topic 4.4 Compare the suitability of different fibres for composite material products.	**Range:** **Conditions:** Laboratory, commercial production. **Glass reinforced products:** Matrix, uniaxial. **Mechanical properties:** Ultimate tensile strength, compressive strength, density **Types of glass:** E glass, R glass, D glass, C glass. **Fibres:** Aramid fibre (Kevlar), carbon fibre. Explain the production methods of fibre reinforced products. Explain the benefits and limitations of carbon fibre as compared to glass fibre for reinforced plastics. Discuss trends in material costs Research: explore the benefits and disadvantages of using carbon fibre bicycle frames instead of the metal tubes compared in lesson 12. Explain what an Aramid fibre is and its benefits over other types of fibre. Describe the range of applications such as ballistic and stab-resistant body armour. **Opportunities for applied learning** **Research / Presentation:** bicycle frame (part 2)	**Books** Higgins, R. A., *Materials for Engineers and Technicians* Newnes, ISBN 075066850 Timings, R. L., *Engineering Materials*, vol 2, 2nd Edn, Longman, 2000, ISBN 0582404665 **Websites:** www.materials.eng.cam.ac.uk/mpsite/materials.html www.matweb.com www.aramid.eu

Lesson 18: Effects of production processes on materials **Suggested Teaching Time:** 3 hours

Learning Outcome: Understand the relationship between the physical properties of materials and their behaviour

Topic	Suggested Teaching	Suggested Resources
Topic 5.1 Analyse the adverse effects of production processes on materials.	**Range:** **Processes:** rolling, extrusion, forging, deep drawing. **Conditions:** fatigue, creep, tensile strength under critically elevated and low temperature, environmental stress cracking, ultraviolet, microorganisms, acids, alkalis, pollution. **Materials:** TRIP, DP and HSLA steels **Conditions:** sudden changes in section, incorrect surface finish specifications, manufacturing defects. **Manufacturing defects:** microscopic flaws, microcracks, internal pores, atmospheric contaminants, thermal expansion. **Industry standard procedures:** British Standard, CEN-CENELEC, ASMI, API, IET. Explain the different effect on metal grain structures and mechanical properties due to hot rolling and cold rolling. Demonstrate the effect of work hardening on a paper clip by bending it backwards and forwards. Explain the processes of extrusion, forging and deep drawing. Research: working in small groups, learners to research and present back on the effects on grain structure and mechanical properties of the production processes identified (extrusion, forging and deep drawing) **Opportunities for applied learning** **Research / Presentation:** each group to provide presentation regarding the effects of production processes.	**Books** Higgins, R. A., *Materials for Engineers and Technicians* Newnes, ISBN 0750668504 Timings, R. L., *Engineering Materials*, vol 2, 2nd Edn, Longman, 2000, ISBN 0582404665 **Websites:** www.materials.eng.cam.ac.uk/mpsite/materials.html www.matweb.com

Lesson 19: Effects of service conditions on materials **Suggested Teaching Time:** 3 hours

Learning Outcome: Understand the relationship between the physical properties of materials and their behaviour

Topic	Suggested Teaching	Suggested Resources
Topic 5.2 Analyse the effects of in service conditions imposed on a material.	**Range:** **Processes:** rolling, extrusion, forging, deep drawing. **Conditions:** fatigue, creep, tensile strength under critically elevated and low temperature, environmental stress cracking, ultraviolet, microorganisms, acids, alkalis, pollution. **Materials:** TRIP, DP and HSLA steels **Conditions:** sudden changes in section, incorrect surface finish specifications, manufacturing defects. **Manufacturing defects:** microscopic flaws, microcracks, internal pores, atmospheric contaminants, thermal expansion. **Industry standard procedures:** British Standard, CEN-CENELEC, ASMI, API, IET. Explain a range of material failure modes based on service conditions. Short assignment: • Learners to produce an assignment explaining the mechanism and methods of preventing fatigue failure and creep failure • Learners to identify and explain 4 different environmental factors that can lead to the degradation of some plastics **Opportunities for applied learning** **Short assignment:** failure mechanisms	**Books** Higgins, R. A., *Materials for Engineers and Technicians* Newnes, ISBN 0750668504 Timings, R. L., *Engineering Materials*, vol 2, 2nd Edn, Longman, 2000, ISBN 0582404665 **Websites:** www.materials.eng.cam.ac.uk/mpsite/materials.html www.matweb.com

Lesson 20: Steel Alloys **Suggested Teaching Time:** 3 hours

Learning Outcome: Understand the relationship between the physical properties of materials and their behaviour

Topic	Suggested Teaching	Suggested Resources
Topic 5.3 Compare multiphase structural steels with micro-alloyed high strength low alloy (HSLA) steels.	**Range:** **Processes:** rolling, extrusion, forging, deep drawing. **Conditions:** fatigue, creep, tensile strength under critically elevated and low temperature, environmental stress cracking, ultraviolet, microorganisms, acids, alkalis, pollution. **Materials:** TRIP, DP and HSLA steels. **Conditions:** sudden changes in section, incorrect surface finish specifications, manufacturing defects. **Manufacturing defects:** microscopic flaws, microcracks, internal pores, atmospheric contaminants, thermal expansion. **Industry standard procedures:** British Standard, CEN-CENELEC, ASMI, API, IET. Feedback on assignments from lesson 19 Referring back to lesson 8, discuss the range of steel alloys and alloying elements. Referring to a steel phase diagram explain the various phases and their properties. Explain what multi-phase steels are and how they are produced. Research / Discussion: Learners are to compare multiphase steels with micro alloyed HSLA steels (covered in lesson 8) **Opportunities for applied learning** **Research / Discussion:** compare types of steel	**Books** Higgins, R. A., *Materials for Engineers and Technicians* Newnes, ISBN 0750668504 Timings, R. L., *Engineering Materials*, vol 2, 2nd Edn, Longman, 2000, ISBN 0582404665 **Websites:** www.materials.eng.cam.ac.uk/mpsite/materials.html www.matweb.com

Lesson 21: Tensile testing of materials **Suggested Teaching Time:** 3 hours

Learning Outcome: Understand the relationship between the physical properties of materials and their behaviour

Topic	Suggested Teaching	Suggested Resources
Topic 5.4 Evaluate stress-strain graphs of different materials.	**Range:** **Processes:** rolling, extrusion, forging, deep drawing. **Conditions:** fatigue, creep, tensile strength under critically elevated and low temperature, environmental stress cracking, ultraviolet, microorganisms, acids, alkalis, pollution. **Materials:** TRIP, DP and HSLA steels **Conditions:** sudden changes in section, incorrect surface finish specifications, manufacturing defects. **Manufacturing defects:** microscopic flaws, microcracks, internal pores, atmospheric contaminants, thermal expansion. **Industry standard procedures:** British Standard, CEN-CENELEC, ASMI, API, IET. Practical: using a Hounsfield tensile tester test a range of materials (which should include at least plain carbon steel (normalised), copper (annealed), and cast iron). Learners are to measure and record all data (including % elongation and % reduction of CSA). Learners should then record the data on a stress / strain graph. Explain how it is possible to identify a ductile or brittle material by the shape of the graph. Learners must identify elastic limit, yield point, ultimate tensile strength and fracture point. Explain how to use proof stress where it there is no clear yield point on the graph. Learners to calculate Young's modulus of elasticity for each material tested. **Opportunities for applied learning** **Practical:** tensile test.	**Books** Higgins, R. A., *Materials for Engineers and Technicians* Newnes, ISBN 0750668504 Timings, R. L., *Engineering Materials*, vol 2, 2nd Edn, Longman, 2000, ISBN 0582404665 Higgins, R. A., *Properties of Engineering Materials* 2nd Edn, Arnold, 1997, ISBN 0340700521 **Websites:** www.materials.eng.cam.ac.uk/mpsite/materials.html www.matweb.com

Lesson 22: Stress concentrations **Suggested Teaching Time:** 3 hours

Learning Outcome: Understand the relationship between the physical properties of materials and their behaviour

Topic	Suggested Teaching	Suggested Resources
Topic 5.5 The importance of stress concentrations in different conditions.	**Range:** **Processes:** rolling, extrusion, forging, deep drawing. **Conditions:** fatigue, creep, tensile strength under critically elevated and low temperature, environmental stress cracking, ultraviolet, microorganisms, acids, alkalis, pollution. **Materials:** TRIP, DP and HSLA steels. **Conditions:** sudden changes in section, incorrect surface finish specifications, manufacturing defects. **Manufacturing defects:** microscopic flaws, microcracks, internal pores, atmospheric contaminants, thermal expansion. **Industry standard procedures:** British Standard, CEN-CENELEC, ASMI, API, IET. Explain about stress flow through a material and how it is stronger the more evenly distributed the stresses are. Explain how stress concentration due to cracks or rapid shape change can concentrate stress and reduce strength. Discuss how the design of an object can affect its stress concentration / strength reduction. **Opportunities for applied learning** **Case Study Review:** learners will work in small teams to investigate the historic failures of the WW2 liberty ships (most famously the SS Schenectady) and the De Havilland Comet, and report back their findings.	**Books:** Higgins, R. A., *Materials for Engineers and Technicians* Newnes, ISBN 0750668504 Timings, R. L., *Engineering Materials*, vol 2, 2nd Edn, Longman, 2000, ISBN 0582404665 Higgins, R. A., *Properties of Engineering Materials* 2nd Edn, Arnold, 1997, ISBN 0340700521 **Websites:** www.materials.eng.cam.ac.uk/mpsite/materials.html www.matweb.com

Lesson 23: Fracture mechanics **Suggested Teaching Time:** 3 hours

Learning Outcome: Understand the relationship between the physical properties of materials and their behaviour

Topic	Suggested Teaching	Suggested Resources
Topic 5.6 The concept of fracture mechanics.	**Range:** **Processes:** rolling, extrusion, forging, deep drawing. **Conditions:** fatigue, creep, tensile strength under critically elevated and low temperature, environmental stress cracking, ultraviolet, microorganisms, acids, alkalis, pollution. **Materials:** TRIP, DP and HSLA steels. **Conditions:** sudden changes in section, incorrect surface finish specifications, manufacturing defects. **Manufacturing defects:** microscopic flaws, microcracks, internal pores, atmospheric contaminants, thermal expansion. **Industry standard procedures:** British Standard, CEN-CENELEC, ASMI, API, IET. Introduce the topic by explaining how investigating the liberty ship failures lead to a big step forward in facture mechanics. Explain that fracture mechanics is concerned with the study of crack propagation in materials and is used to improve performance of mechanical components and prevent future failures. Explain the underlying principles behind fracture mechanics **Opportunities for applied learning** **Research / Discussion:** learners to describe the CTOD test and explain what information can be obtained.	**Books** Higgins, R. A., *Materials for Engineers and Technicians* Newnes, ISBN 0750668504 Timings, R. L., *Engineering Materials*, vol 2, 2nd Edn, Longman, 2000, ISBN 0582404665 Higgins, R. A., *Properties of Engineering Materials* 2nd Edn, Arnold, 1997, ISBN 0340700521 **Websites:** www.materials.eng.cam.ac.uk/mpsite/materials.html www.matweb.com

Lesson 24: Manufacturing defects **Suggested Teaching Time:** 3 hours

Learning Outcome: Understand the relationship between the physical properties of materials and their behaviour

Topic	Suggested Teaching	Suggested Resources
Topic 5.7 The effect of manufacturing defects on the brittle fracture failure of ceramic products. **Topic 5.8** The remedies for reducing manufacturing defects that could lead to brittle fracture failure in ceramic products.	**Range:** **Processes:** rolling, extrusion, forging, deep drawing. **Conditions:** fatigue, creep, tensile strength under critically elevated and low temperature, environmental stress cracking, ultraviolet, microorganisms, acids, alkalis, pollution. **Materials:** TRIP, DP and HSLA steels. **Conditions:** sudden changes in section, incorrect surface finish specifications, manufacturing defects. **Manufacturing defects:** microscopic flaws, microcracks, internal pores, atmospheric contaminants, thermal expansion. **Industry standard procedures:** British Standard, CEN-CENELEC, ASMI, API, IET. Discussion: types of ceramic materials and their applications in modern engineering. Explain a range of production methods for a range of ceramic materials. Research and presentation: learners to work in small groups to look at the effect of manufacturing defects on the brittle fracture failure of ceramic products. Learners must also state the possible remedies to prevent the stated failure. **Opportunities for applied learning** **Research / presentation: Brittle** failure of ceramic products.	**Books** Higgins, R. A., *Materials for Engineers and Technicians* Newnes, ISBN 0750668504 Timings, R. L., *Engineering Materials*, vol 2, 2nd Edn, Longman, 2000, ISBN 0582404665 Kalpakjian, S., *Manufacturing Processes for Engineering Materials*, Pearson, 2002, ISBN 0130408719 **Websites:** www.materials.eng.cam.ac.uk/mpsite/materials.html www.matweb.com www.ceramics.net

Lesson 25: Degradation of polymeric materials **Suggested Teaching Time:** 3 hours

Learning Outcome: Understand the relationship between the physical properties of materials and their behaviour

Topic	Suggested Teaching	Suggested Resources
Topic 5.9 The mechanisms by which stress corrosion cracking can occur in polymeric materials. **Topic 5.10** The gradual degradation of polymeric materials caused by environmental factors.	**Range:** **Processes:** Rolling, extrusion, forging, deep drawing. **Conditions:** Fatigue, creep, tensile strength under critically elevated and low temperature, environmental stress cracking, ultraviolet, microorganisms, acids, alkalis, pollution. **Materials:** TRIP, DP and HSLA steels. **Conditions:** Sudden changes in section, incorrect surface finish specifications, manufacturing defects. **Manufacturing defects:** Microscopic flaws, microcracks, internal pores, atmospheric contaminants, thermal expansion. **Industry standard procedures:** British Standard, CEN-CENELEC, ASMI, API, IET. Explain that stress corrosion cracking (SCC) can occur in a range material types, including metals and plastics, and is crack formation in a corrosive environment. Explain how some polymers can suffer from SCC in the presence of aggressive chemicals with different polymers susceptible to different chemicals. Stress the importance of using the right material for the environmental service required. Research / Discussion: learners to investigate the effect of ozone on rubber tyres and what can be done to prevent Ozone cracking. Learners also describe four other types of degradation of polymeric materials. **Opportunities for applied learning** **Research / Discussion:** environmental degradation of polymers.	**Books** Higgins, R. A., *Materials for Engineers and Technicians* Newnes, ISBN 0750668504 Timings, R. L., *Engineering Materials*, vol 2, 2nd Edn, Longman, 2000, ISBN 0582404665 **Websites:** www.materials.eng.cam.ac.uk/mpsite/materials.html www.matweb.com

Lesson 26: Fitness for purpose of mechanical equipment **Suggested Teaching Time:** 3 hours

Learning Outcome: Understand the relationship between the physical properties of materials and their behaviour

Topic	Suggested Teaching	Suggested Resources
Topic 5.11 Compare the industry standard procedures for determining the 'fitness-for-purpose' of mechanical equipment.	**Range:** **Processes:** rolling, extrusion, forging, deep drawing. **Conditions:** fatigue, creep, tensile strength under critically elevated and low temperature, environmental stress cracking, ultraviolet, microorganisms, acids, alkalis, pollution. **Materials:** TRIP, DP and HSLA steels. **Conditions:** sudden changes in section, incorrect surface finish specifications, manufacturing defects. **Manufacturing defects:** microscopic flaws, microcracks, internal pores, atmospheric contaminants, thermal expansion. **Industry standard procedures:** British Standard, CEN-CENELEC, ASME, API, IET. Explain that a standard is a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose. Explain the various standard organisations and the drive for harmonisation of standards across Europe and the world. **Opportunities for applied learning** **Research / Presentation:** learners to research the various organisation and find what current standards are available for determining the fitness for purpose of mechanical equipment. Learners must provide the standard reference and a brief outline of what the standard covers.	**Books:** Higgins, R. A., *Materials for Engineers and Technicians* Newnes, ISBN 0750668504 Timings, R. L., *Engineering Materials*, vol 2, 2nd Edn, Longman, 2000, ISBN 0582404665 Kalpakjian, S., *Manufacturing Processes for Engineering Materials*, Pearson, 2002, ISBN 0130408719 **Websites:** www.materials.eng.cam.ac.uk/mpsite/materials.html www.matweb.com www.iso.org www.bsigroup.com www.cen.eu www.asme.org