

OBJECTIVE SYLLABUS FOR MATERIALS SCIENCE MODULE

SECTION A – PROPERTIES OF MATERIALS

Lesson 1 Classification of Materials

At the end of Lesson 1, you should be able to:

- 1.1 Distinguish between metals, ceramics, polymers and composites.

Lesson 2 - Bulk and surface properties

At the end of Lesson 2, you should be able to:

- 2.1 Distinguish between mechanical, physical and chemical properties of materials.
- 2.2 Be able to calculate stress and tensile strength of a material.
- 2.3 Distinguish between elastic and plastic strain.
- 2.4 Understand the meaning of Young's Modulus of a material.
- 2.5 Be able to define hardness of material.
- 2.6 Be aware of the concept of resistivity and the magnetic materials.
- 2.7 Appreciate the importance of strength/weight ratio in the selection of materials.
- 2.8 Understand the importance of chemical properties such as corrosion and oxidation resistance in selection of materials.

SECTION B – MECHANICAL PROPERTIES AND THEIR EVALUATION

Lesson 3 - Property – correlation of applications

At the end of lesson 3, you should be able to:

- 3.1 Appreciate the factors which govern the selection of a material for a particular application.

Lesson 4 – Stress and strain

At the end of lesson 4 you should be able to:

- 4.1 Define tensile stress in a material.
- 4.2 Differentiate between different forms of stress.
- 4.3 Define strain in a material.
- 4.4 Appreciate the significance of the elastic moduli and their relationship to stress and strain.
- 4.5 Recognise that stress can occur in coatings and how this may be measured.

Lesson 5 - Mechanical properties and their measurement

At the end of lesson 5 you should be able to:

- 5.1 Interpret the shapes of force-extension diagrams obtained from the mechanical testing of materials.
- 5.2 Define yield stress, plastic deformation, tensile strength and ductility.
- 5.3 Calculate Young's Modulus, yield stress, tensile strength and ductility using data obtained from force-extension data.
- 5.4 Appreciate the mechanical behaviour of ceramic and polymeric materials.
- 5.5 Be familiar with a practical method of evaluating the ductility of materials.

Lesson 6 - Toughness

At the end of Lesson 6, you should be able to:

- 6.1 Define toughness in a material and appreciate how it is measured.
- 6.2 Distinguish between ductile and brittle failure.
- 6.3 Appreciate the nature of creep in materials.
- 6.4 Appreciate the nature of fatigue.

Lesson 7 – Hardness, adhesion and wear

At the end of Lesson 7 you should be able to:

- 7.1 Define hardness and appreciate how it may be measured.
- 7.2 Appreciate the variety of bonding forces involved in adhesion and the difficulty of measuring adhesion.
- 7.3 Define wear and describe its measurement.

SECTION C - ARCHITECTURE OF SOLIDS

Lesson 8 – Bond formation

At the end of Lesson 8 you should be able to:

- 8.1 Describe the nature of the atom, core and valence electrons.
- 8.2 Know the nature of ionic bonds and their formation.
- 8.3 Understand the nature of covalent bonds and their formation.
- 8.4 Describe the nature of metallic bonds and their formation.
- 8.5 Appreciate the partial ionic character of some covalent bonds.
- 8.6 Differentiate between thermoplastic and thermosetting polymers in terms of the different bonding involved.

Lesson 9 – Amorphous and crystalline solids

At the end of Lesson 9 you should be able to:

- 9.1 Recognise the nature of crystalline and amorphous structures in materials in terms of the configuration and arrangement of atoms, ions and molecules within these structures and give examples of materials having such structures.
- 9.2 Explain how crystallinity may arise in thermopolymers.
- 9.3 Define and appreciate the significance of the melting temperature.

Lesson 10 – Lattice structures and orientation

At the end of Lesson 10 you should be able to:

- 10.1 Explain the three-dimensional nature of lattices and the concept of the unit cell.
- 10.2 Describe the structure of simple cubic, body centred cubic (b.c.c.), face centred cubic (f.c.c.) and close packed hexagonal (c.p.h.) materials.
- 10.3 Know how impurities may take up interstitial positions in lattices causing distortion and stress in the structure, and relate such changes to the properties found in coatings.
- 10.4 Recognise the occurrence of preferred orientation and its significance in relation to the properties of coatings.

Lesson 11 – Nucleation and growth and the formation of polycrystalline materials

At the end of Lesson 11 you should be able to:

- 11.1 Differentiate between single and polycrystalline materials.
- 11.2 Appreciate and describe the nature of grain boundaries in ionic and metallic crystalline materials.
- 11.3 Relate the relative rates of the nucleation and growth processes to the grain size of a material.
- 11.4 Appraise how process parameters may be used to control the structure of a material deposited from a fluid.

SECTION D - PHASE COMPOSITION

Lesson 12 – Solidification of metals

At the end of Lesson 12 you should be able to:

- 12.1 Explain that melting and casting of metals is very important in the metallurgical industry.
- 12.2 Identify examples of high and low melting point metals.
- 12.3 Describe the method used to find the melting point of a pure metal.
- 12.4 Explain what happens when molten metal changes to solid.
- 12.5 Define the term 'latent heat of fusion'.

Lesson 13 – Dendrites, grain boundaries, defects

At the end of lesson 13 you should be able to:

- 13.1 Describe the growth of dendrites.
- 13.2 Describe the formation of grain boundaries.
- 13.3 State the effect of grain size on mechanical properties and surface finish.
- 13.4 Predict casting defects; micro-porosity, shrinkage and hot tearing.

Lesson 14 – Phase diagrams for the formation of solid solutions in binary alloys

At the end of lesson 14, you should be able to:

- 14.1 Discuss the reason for the use of Phase Diagrams.
- 14.2 Explain how Phase Diagrams are constructed.
- 14.3 Compare cooling curves for a pure metal and an alloy.
- 14.4 Explain the meaning of the term 'Solid Solution'.
- 14.5 Describe the cooling of an alloy in the Copper/Nickel system.
- 14.6 Describe the cooling of an alloy in the Lead/Tin system.
- 14.7 Explain the terms: binary, liquidus, equilibrium and eutectic

Lesson 15 – The Phase Rule, The Lever Rule, metallography, segregation and its effects

At the end of lesson 15, you should be able to:

- 15.1 Apply the Phase Rule to any binary diagram.
- 15.2 Apply the Lever Rule to determine the proportion of solid and liquid present in a two-phase field at a given temperature.
- 15.3 Explain the phenomenon of 'coring'.
- 15.4 Explain what can be done to eliminate coring or to rectify coring.
- 15.5 Sketch the microstructure of an homogeneous solid solution.
- 15.6 Sketch the structure of a cast tin/lead alloy showing dendrites of solid solution in a background of eutectic.
- 15.7 Sketch the structure of a 62% tin/38% lead alloy (covered in Lesson 14).

- 15.8 Explain the following terms: homogeneous, coring, equi-axed grains, solid state diffusion.

SECTION E - MANUFACTURE OF MATERIALS

Lesson 16 – Working and heat treatment

At the end of lesson 16 you should be able to:

- 16.1 Define and appreciate the significance of proof stress.
- 16.2 Discuss work hardening and the structural changes associated with it.
- 16.3 Classify the different processes involved in heat treatment and relate these to changes in the properties of the metal.

Lesson 17 – Metal fabrication processes

At the end of Lesson 17 you should be able to:

- 17.1 Appreciate the range of processes available for the fabrication of metals and alloys in the solid state.
- 17.2 Outline rolling processes.
- 17.3 Outline forging processes.
- 17.4 Outline extrusion as applied to metals.
- 17.5 Outline drawing processes.
- 17.6 Outline pressing processes

Lesson 18 – Metal casting processes

At the end of Lesson 18 you should be able to:

- 18.1 Outline and evaluate the sand casting and gravity diecasting processes.
- 18.2 Outline the pressure die-casting process and appraise its application to zinc alloy diecasting.
- 18.3 Describe the lost-wax casting process and recognise its application to the production of intricately shaped castings and to high melting point alloys.

Lesson 19 – Polymer fabrication processes

At the end of Lesson 19 you should be able to:

- 19.1 Appreciate the range of processes used to fabricate polymers.
- 19.2 Outline the extrusion process.
- 19.3 Outline the formation of polymer sheets.
- 19.4 Outline the blow-moulding process.
- 19.5 Outline the vacuum-forming process.
- 19.6 Outline the injection-moulding process and appreciate how process variables affect product quality.
- 19.7 Outline compression moulding

Lesson 20 – Electroforming

At the end of Lesson 20 you should be able to:

- 20.1 Outline the electroforming process.
- 20.2 Understand the benefits and limitations of electroforming.
- 20.3 Know the metals that can be used for electroforming.
- 20.4 Discuss the different types of mandrel used for electroforming

Lesson 21 – Surfaces and surface hardening

At the end of Lesson 21 you should be able to:

- 21.1 Define surface roughness and appreciate its significance.
- 21.2 Recognise that machining leads to mechanical working of the surface.
- 21.3 Be familiar with surface-hardening processes.
- 21.4 Differentiate between different surface blasting processes and appreciate their use in surface finishing.

SECTION F CORROSION AND PROTECTION

Lesson 22 – The basic corrosion cell

At the end of Lesson 22 you should be able to:

- 22.1 Discuss reasons for corrosion control.
- 22.2 Explain how equilibrium is set up between a metal and a solution.
- 22.3 Explain how the Standard Electrode Potential of a metal is measured.
- 22.4 Calculate the value of cell voltage by combining half-cells.
- 22.5 Distinguish between electrode polarity in electroplating and corrosion.
- 22.6 Discuss anode and cathode reactions and the role of the electrolyte.

Lesson 23 – Thermodynamics and kinetic principles

At the end of Lesson 23 you should be able to:

- 23.1 Discuss the thermodynamic approach to corrosion using Pourbaix diagrams.
- 23.2 Explain the connection between cell current and corrosion rate.
- 23.3 Interpret polarisation diagrams.
- 23.4 Discuss polarisation curves for metals which passivate.

Lesson 24 Methods of corrosion protection

At the end of Lesson 24 you should be able to:

- 24.1 Predict the effect of geometric design of components and plant upon corrosion resistance.
- 24.2 Evaluate materials for a given application in a corrosive environment.
- 24.3 Distinguish between different environments in which corrosion is possible.
- 24.4 Explain how corrosion may be prevented by cathodic protection and other electrical methods.
- 24.5 Explain how coatings reduce or prevent corrosion.

Lesson 25 Types of corrosion damage and their prevention/reduction

At the end of Lesson 25 you should be able to:

- 25.1 Discuss the phenomenon of uniform corrosion.
- 25.2 Explain the ways in which galvanic corrosion can affect metallic structures and explain how problems may be overcome.
- 25.3 Explain how crevice and pitting corrosion affect metals and explain means of overcoming related problems.
- 25.4 Discuss the de-alloying of metals and show how this problem may be solved.
- 25.5 Discuss the intergranular attack of metals by corrosion and explain the means to overcome this problem
- 25.6. Explain the effect of erosion and corrosion acting together and explain how problems may be minimised or eliminated.
- 25.7 Explain the effect of conjoint action of stress and corrosion and explain how problems may be minimised or eliminated.

SECTION G EXAMINATION OF MATERIALS

Lesson 26 Visual observation

At the end of Lesson 26 you should be able to:

- 26.1 Explain the reason for modifying the surface of materials prior to their visual examination with or without magnification.
- 26.2 Discuss the limitations of the examination of materials using the naked eye.
- 26.3 Describe the main features of the metallurgical microscope and the preparation of cross-sections ready for examination using the microscope.
- 26.4 Appreciate the usefulness of the metallurgical microscope in the optical examination of materials.

Lesson 27 Scanning electron microscopy, energy dispersive x-ray analysis and transmission electron microscopy

At the end of Lesson 27 you should be able to:

- 27.1 Describe the transmission electron microscope and scanning electron microscope.
- 27.2 Categorise the effects of electron bombardment on a material in terms of the resulting electron and x-ray emissions.
- 27.3 Discuss how the electrons and x-rays emitted as a result of the electron bombardments of material in the SEM can provide structural and analytical information.
- 27.4 Describe the preparation techniques used to prepare material for inspection in the SEM and TEM.

Lesson 28 X-ray and electron diffraction

At the end of Lesson 28 you should be able to:

- 28.1 Explain the nature of x-ray diffraction.
- 28.2 Describe a method for determining x-ray diffraction plots at intensity versus 2θ (2θ) where θ is the Bragg angle.
- 28.3 Interpret the main features of x-ray plots and obtain relative intensities and 'd' values from simple plots.
- 28.4 Discuss the application of x-ray diffraction to the examination of surface coatings.