



## ***METALLURGICAL ENGINEERING*** ***SYLLABUS OF EXAMINATIONS*** **1998 EDITION**

For textbook information please refer to the **Textbooks** section on page 3 of the document entitled **Information for Students and Examinations Candidates**.

### **GROUP A** **COMPULSORY EXAMINATIONS (SIX REQUIRED)**

#### **98-Met-A1 Metallurgical Thermodynamics**

First, second, and third laws, enthalpy and heat balances, entropy, free energy, chemical equilibrium, equilibrium constant, phase rule, solution chemistry, chemical potential, activities. Application of the laws of thermodynamics to metallurgical processes, electrochemistry, interfacial phenomena, extraction and refining of materials, corrosion, and electrodeposition. Computational thermodynamics.

#### **98-Met-A2 Metallurgical Rate Phenomena**

Fluid flow, heat transfer, mass transfer as applied to metallurgical processes. Laws of viscosity, conduction and diffusion. Equations for the conservation of heat, mass and momentum transfer. Process engineering metallurgy and reactor theory (plug flow and well-mixed) as applied to hydrometallurgical, pyrometallurgical, electrochemical, and corrosion processes.

#### **98-Met-A3 Metal Extraction Processes**

Principles of mineral dressing: comminution, physical separation techniques, flotation, dewatering.

Extraction processes: hydrometallurgy and electrometallurgy including leaching, solution purification, solvent extraction, metal winning, refining; pyrometallurgy including roasting, smelting, converting, and refining. Fuels, furnaces, metallurgical reactors, refractories, energy efficiency. Calculations based on flow sheets, heat and mass balances. Environment protection. Automatic control.

#### **98-Met-A4 Structure of Materials**

Atomic and molecular structure. Metallic, ionic, covalent and Van der Waals's, Crystal structure, space lattices and Miller indices. Crystalline and non-crystalline (amorphous). Solidification (crystallisation) and associated microstructures of cast metals and phenomena of grain boundaries. Observations of material structure (X-ray techniques, metallography, optical and electron microscopy). Defects in solids, dislocation and slip, vacancies and diffusion. Basic mechanisms of deformation processes of materials. Phase diagrams (solid solution systems, eutectic and eutectoid systems, monotectic peritectic reaction, intermetallic compounds). Application of lever rule to phase proportions in common single- and binary-phase systems.

**98-Met-A5 Mechanical Behaviour and Processing and Performing of Materials**

Mechanical properties and mechanical testing. Stress-strain-time relations, work hardening, toughness, fatigue, and stress-rupture. Principles in the forming of materials: sintering, melting and casting, extrusion, injection moulding, drawing, rolling and forging. Moulding techniques for particulate and fibre reinforcing. Theoretical strength, defects and fracture mechanics theory. Environmental aspects and materials performance; stress corrosion, corrosion fatigue, hydrogen embrittlement, degradation due to nuclear and ultra-violet radiation. Other degradation and service failure and their prevention (wear, friction, etc.).

**98-Met-A6 Thermal Treatment of Metals and Alloys**

The cold-worked state; recovery, recrystallization, grain growth, secondary recrystallization, and heat treatments based on these phenomena. Nucleation and growth kinetics. Precipitation in alloy systems and precipitation hardening. The iron-carbon alloy system and the eutectoid reaction in Fe-C alloys. The hardening of steel.

**GROUP B****ELECTIVE EXAMINATIONS (THREE REQUIRED)****98-Met-B1 Mineral Processing**

Minerals of economic importance (metallic and industrial). Comminution techniques, size classification, hydrocyclones. Flotation: surface chemistry, reagents, on-stream analysis, process optimization, oxide flotation. Gravity and magnetic separations. Tailings disposal, water pollution control, closed circuit operation. Mineral processing plant design. Process analysis, simulation, optimization, and control.

**98-Met-B2 Hydrometallurgy**

Unit processes in hydrometallurgy: acid, alkaline, and pressure leaching methods. Thermodynamic and kinetic aspects. Purification of leach liquors by ion exchanges, solvent extraction, and selective precipitation operations. Solid-liquid separation techniques. Recovery of metal values by cementation, electrowinning, and hydrogen precipitation methods.

**98-Met-B3 Iron and Steelmaking**

Fundamental thermodynamic and kinetic aspects of iron and steelmaking reactions. Composition, structure, properties and performance of fluxes, slags and refractories. Direct reduction processes. Ironmaking in the blast furnace. External treatment of hot metal. Converter processes and electric furnace steelmaking. Ladle metallurgy operations including deoxidation, desulfurization, sulfide shape control, inert gas rinsing, and vacuum reactors. Factors affecting the formation and removal of inclusions. Secondary refining processes including AOD, VAD, VOD, VAR, and ESR. Ingot manufacture and continuous casting. Plasma applications in iron and steelmaking. Environmental control, automation, energy minimization, and process optimization.

### **98-Met-B4 Non-Ferrous Extractive Metallurgy**

The application of the principles of thermodynamics, kinetics, and heat and mass transfer to the extraction and refining of non-ferrous metals. These include the common base metals (copper, nickel, lead, and zinc), light metals (magnesium, aluminum), and refractory metals (titanium, zirconium, and chromium). Recent process developments in non-ferrous metallurgy, for example flash smelting. Environmental problems associated with the non-ferrous industry.

### **98-Met-B5 Metal Fabrication**

Casting methods including ingot casting, continuous casting, sand casting, die casting, investment casting, and shell moulding. Cast structures, grain refinement and casting defects. Hot working: hot rolling, extrusion, and forgings. Cold working: cold rolling, pressing, impact extrusion, drawing, and sheet metal forming. Joining techniques: welding methods, weld defects, weld inspection, brazing, and soldering. Powder metallurgy processes.

### **98-Met-B6 Physical Metallurgy of Iron and Steel**

The Fe-C diagram. Structures of slowly cooled steels. Specialized heat treatments including full annealing, normalizing, process annealing. Batch and continuous annealing. Martensite formation: quenching and tempering. Bainite formation. Austempering and martempering. TTT curves. Hardenability and the Jominy test. Alloy steels, HSLA steels, and stainless steels. Surface hardening. Cast irons, their structure and heat treatment.

### **98-Met-B7 Physical Metallurgy of Non-Ferrous Metals and Alloys**

Aluminum and its alloys: properties, effects of alloying elements, heat treatment, modification of properties, corrosion resistance.

Magnesium and its alloys: cast and wrought alloys — effect of alloying elements, grain refinement, corrosion resistance.

Copper and its alloys: properties — brasses, bronzes.

Low melting point alloys: diecasting alloys, type metals, solder, bearing metals. Nickel-base super alloys. Cobalt base alloys. Titanium.

### **98-Met-B8 Ceramic Materials**

Crystal structure of ceramics. Glass formation and structure of oxide glasses. Processing and shaping of crystalline materials and glasses. Phase diagrams in ceramic systems. Microstructure of ceramics. Mechanical properties of ceramics: strength, fracture toughness, creep, fatigue, thermal shock resistance, viscous flow, tempering and annealing of glass. Thermal, optical, electrical, and magnetic properties of ceramic materials.

### **98-Met-B9 Polymers and Fibre-Reinforced Polymers**

Fundamental properties and applications of polymers; characterization of polymers; properties of polymers, including crystallization, thermal and oxidative degradation, specific heat, thermal conductivity, and thermal expansion; polymer processing techniques; failure mechanisms; and introduction to fibre-polymer composites.

**98-Met-B10 Corrosion Control**

Electrochemical cells, their reactions, and polarization. Pourbaix diagrams; polarization diagrams. Corrosion products and their effects on corrosion. Metal-gas reactions. Galvanic corrosion and effects of metallurgical structure. Crevice corrosion, pitting erosion corrosion, and environmental cracking. Test methods and electronic probes. Corrosion control by inhibitors, coatings, cathodic and anodic protection, equipment design.

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