



Professional Engineers  
and Geoscientists of BC  
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# **2010 METALLURGICAL ENGINEERING SYLLABUS and Checklist for Self-Evaluation**

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## **INTRODUCTION**

The Canadian Engineering Qualifications Board of Engineers Canada issues the Examination Syllabus that includes a continually increasing number of engineering disciplines.

Each discipline examination syllabus is divided into two examination categories: compulsory and elective. A full set of Metallurgical Engineering examinations consists of ten, three-hour examination papers. Candidates will be assigned examinations based on an assessment of their academic background. Examinations from discipline syllabi other than those specific to the candidates' discipline may be assigned at the discretion of the constituent association.

Before writing the discipline examinations, candidates must have passed, or have been exempted from, the Basic Studies Examinations.

The constituent association will supply information on examination scheduling, textbooks, materials provided or required, and whether the examinations are open or closed book.

**METALLURGICAL ENGINEERING EXAMINATIONS**  
**GROUP A**  
**COMPULSORY EXAMINATIONS**  
**SEVEN REQUIRED**

**10-Met-A1 Metallurgical Thermodynamics**

Phase relationships and phase rule. First, second and third laws of thermodynamics, enthalpy and heat balances, entropy, free energy, and chemical equilibrium. Solution chemistry and solution models, chemical potential, relationships between phase diagrams and thermodynamic properties. Thermochemical analyses of metallurgical and electrochemical processes. Computational thermodynamics.

**10-Met-A2 Metallurgical Rate Phenomena (Suggested Prerequisite: A1)**

Transport equations for momentum, heat and mass transfer. Thermodynamic and physical boundary conditions. Interphase mass transfer: gas-solid, gas-liquid, liquid-liquid, and liquid-solid applied to metallurgical systems. Mathematical models. Radiation heat transfer: black and grey body, emissivity and view factors. Heat transfer in casting processes: mould properties, continuous casting. Reactor theory applied to metallurgical operations: mixed flow, plug flow, residence time.

**10-Met-A3 Metal Extraction Processes**

Principles of mineral processing: comminution, physical separation techniques, flotation, dewatering. Selection of extraction processes. Hydrometallurgy and electrometallurgy including leaching, solution purification, solvent extraction, metal winning and refining. Pyrometallurgical operations including roasting, smelting, converting and refining and refractory issues. Calculations based on flow sheets, heat and mass balances. Environmental impact of processing operations.

**10-Met-A4 Structure of Materials**

Structure of metals (description of crystal structures). Analytical methods to determine structure including metallography, X-ray diffraction, and scanning and transmission electron microscopes. Introductory dislocation theory. Elements of grain boundaries. Vacancies. Phases and binary phase diagrams.

**10-Met-A5 Mechanical Behaviour and Fracture of Materials (Suggested Prerequisite: A4)**

Tensile response of materials. Elements of dislocation theory. Slip and twinning in crystalline solids. Strengthening mechanisms in metals. High temperature deformation response of crystalline solids. Fracture. Elements of fracture mechanics. Cyclic stress and strain fracture. Fatigue crack propagation.

**10-Met-A6 Phase Transformation and Thermal Treatment of Metals and Alloys (Suggested Prerequisite: A4)**

Annealing of Metals (Recovery, recrystallization, grain growth, secondary recrystallization, and heat treatments based on these phenomena.) Nucleation and growth processes and the solidification of metals. Solidification phenomena in metals. Nucleation and growth kinetics. Precipitation hardening.

### **10-Met-A7 Corrosion and Oxidation (Suggested Prerequisite: A1)**

Basic corrosion theory. Electrochemical corrosion theory. Metallurgical cells. Environmental cells. Stress assisted corrosion. Materials selection. Protective coatings. Corrosion inhibitors. Cathodic and anodic protection. Oxidation.

## **GROUP B ELECTIVE EXAMINATIONS THREE REQUIRED**

### **10-Met-B1 Mineral Processing**

Sources and nature of metallic and industrial minerals of importance. Comminution techniques, size classification. Hydrocyclones, gravity and magnetic separations. Flotation: surface chemistry, reagents, analysis. Tailings disposal, water pollution control, closed circuit operation. Plant design, process analysis and optimization.

### **10-Met-B2 Hydrometallurgy and Electrometallurgy**

Unit processes of hydrometallurgy: acid, alkaline and pressure leaching. Thermodynamic and kinetic aspects. Pourbaix diagrams. Purification of leach liquors by ion exchange, solvent extraction and selective precipitation operations. Solid-liquid separation techniques. Principles of electrometallurgy. Recovery of metal values by cementation, electrowinning and refining from aqueous solutions. Electrolyte preparation, cell potential, effect of additives. Hydrogen precipitation methods. Application of processes for the recovery of copper, nickel, zinc, cobalt, gold and uranium.

### **10-Met-B3 Ironmaking and Steelmaking**

Thermodynamics and kinetics of iron and steelmaking reactions. Direct reduction processes. Blast furnace operations. Chemical properties of fluxes, slags and refractories. Converter processes and electric furnace steelmaking. Treatment of hot metal, ladle metallurgy including desulfurization, deoxidation, inert gas and vacuum treatment. Continuous casting. Secondary refining processes including AOD, VAD, VOD, VAR, and ESR. Analysis of new and emerging steelmaking technologies. Environmental control.

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

The application of principles of thermodynamics, kinetics, and transport phenomena to the extraction and refining of non-ferrous metals using pyrometallurgical processes. Production of

copper, nickel, lead, and zinc from sulphides. Converting and flash smelting operations. Production of aluminum and magnesium using fused salt electrolysis. Reduction cell operation. Production of refractory metals by chlorination and purification. Recent developments in non-ferrous pyrometallurgy. Environmental impact.

### **10-Met-B5 Metal Fabrication**

Fundamentals of solidification: phase diagrams, cooling curves, cast structures, solidification shrinkage, molten metal characteristics. Casting methods including ingot casting, continuous casting, sand casting, die casting, investment casting, counter gravity, lost foam, mould casting, squeeze and semi-solid casting. Hot working: hot rolling, extrusion, and forging. Bending and sheet metal operations: roll bending and forming, shearing operations, stretch forming and drawing, hydroforming, and superplasticity. Powder metallurgy processes.

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

Iron-Carbon Alloys (Fe-Fe<sub>3</sub>C Alloys system and isothermal transformation of austenite to ferrite and cementite and martensite, annealing and normalizing, cold working and process annealing, tempering, austempering and martempering). Carbon steels including microalloyed steels. Alloy steels. Stainless steels. Cast irons. Tool steels. Surface hardening and modification.

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

Aluminum and its alloys. Copper and its alloys. Titanium and its alloys. Nickel and Cobalt alloys. Magnesium and Zinc alloys. Refractory metals and alloys and structural intermetallics.

### **10-Met-B8 Ceramic Materials**

Bonding in ceramics. Ceramic structures. Effect of chemical forces and structure on physical properties. Defects in ceramics. Diffusion and electrical conductivity. Phase equilibria. Sintering and grain growth. Mechanical properties: fast fracture, creep, slow crack growth and fatigue. Thermal stresses and thermal properties. Dielectric properties.

### **10-Met-B9 Structure and Properties of Polymers**

Chain architecture: chain dimensions, Gaussian segment density distribution, polymer conformation.

Molar mass determination: osmometry, light scattering, gel permeation chromatography, capillary viscometry. Polymer phase equilibria: solvent quality, polymer blending. Polymer structure/transitions: melting and glass transition temperatures, free volume. Crystallization: crystal structure, fractional crystallinity. Mechanical properties: testing methods, compliance, viscoelasticity, dynamic testing, time-temperature superposition, mastercurve, rubber elasticity, crazing. Polymer flow properties: viscosity, rheology, shear thinning, analysis of flow fields. Polymer processing techniques.

### **10-Met-B10 Advanced Electronic Materials**

Band theory: energy levels in solids, effective mass, Fermi-Dirac statistics. Semiconductors: doping, activation, diffusion, P-n junctions, and solar cells. Dielectrics and polarization: capacitance, dielectric materials, Lorentz field, dielectric breakdown, piezoelectricity,

ferroelectricity and pyroelectricity. Magnetism: field intensity, permeability, exchange interaction, saturation magnetization, magnetic domains and anisotropy, hysteresis loop. Superconductivity: Meissner effect, superconducting materials, critical field and current density, BCS theory. Metals: contact potential, Seebeck and thermocouple effect, thermoelectrics, electromigration.

**The Association of  
PROFESSIONAL ENGINEERS AND GEOSCIENTISTS  
of British Columbia**

**2010 METALLURGICAL ENGINEERING SYLLABUS**

Checklist for Self Evaluation

(Not required for candidates who are assigned  
confirmatory exams)

Name: \_\_\_\_\_

Exam Number	Exam Name	Applicant's Self-Evaluation - Course Equivalent	For Office Use Only
<i>Basic Studies (6 Required)</i>			
04-BS-1	Mathematics		
04-BS-2	Probability and Statistics		
04-BS-6	Mechanics of Materials		
04-BS-7	Mechanics of Fluids		
98-BS-10	Thermodynamics		
98-BS-11	Properties of Materials		
<i>Basic Studies (2 required)</i>			
04-BS-3	Statics and Dynamics		
04-BS-4	Electric Circuits and Power		
04-BS-5	Advanced Mathematics		
04-BS-8	Digital Logic Circuits		
<i>Group A (7 required)</i>			
10-Met-A1	Metallurgical Thermodynamics		
10-Met-A2	Metallurgical Rate Phenomena		

10-Met-A3	Metal Extraction Processes		
10-Met-A4	Structure of Materials		
10-Met-A5	Mechanical Behaviour and Fracture of Materials		
10-Met-A6	Phase Transformation and Thermal Treatment of Metals and Alloys		
10-Met-A7	Corrosion and Oxidation		
<b>Group B (3 Required)</b>			
10-Met-B1	Mineral Processing		
10-Met-B2	Hydrometallurgy and Electrometallurgy		
10-Met-B3	Ironmaking and Steelmaking		
10-Met-B4	Non-Ferrous Extractive Metallurgy		
10-Met-B5	Metal Fabrication		
10-Met-B6	Physical Metallurgy of Iron and Steel		
10-Met-B7	Physical Metallurgy of Non-Ferrous Metals and Alloys		
10-Met-B8	Ceramic Materials		
10-Met-B9	Structure and Properties of Polymers		
10-Met-B10	Advanced Electronic Materials		
<b>Complementary Studies (All Required)</b>			
11-CS-1	Engineering Economics		
11-CS-2	Engineering in Society – Health and Safety		
11-CS-3	Sustainability, Engineering and the Environment		
11-CS-4	Engineering Management		

## **METALLURGICAL ENGINEERING TEXT LIST - 2010**

### ***10-Met-A1 Metallurgical Thermodynamics***

#### ***Prime Text***

Gaskell, David, Introduction to Metallurgical Thermodynamics. CRC Press, 2008. ISBN: 9781591690436. Chapters 2, 3, 6, 8-14.

#### ***Supplementary References***

De Hoff, Robert, Thermodynamics in Materials Science.. Second edition, CRC Press, 2006. ISBN: 979849340659

Lee, H. G., Chemical Thermodynamics for Metals and Materials. Imperial College Press, 2001. ISBN: 1-86094-X.

Rosenquist, T., Principles of Extractive Metallurgy. Second edition, Tapir Academic Press, 2004. ISBN: 9788251919227.

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

#### ***Prime Text***

Poirier, D.R., and Geiger, G.H., Transport Phenomena in Material Processing. TMS Publications, 1998. ISBN: 0873392752. Chapters 1, 2, 3, 6-15.

#### ***Supplementary References***

Gaskell, D.R., Transport Phenomena in Materials Engineering. Prentice-Hall, 1991. ISBN: 97800234070208.

Guthrie, R.I.L., Engineering in Process Metallurgy. Oxford University Press, 1992. ISBN: 0198563671.

Powell IV, A., “*Transport Phenomena in Materials Engineering*”. MIT Open Courseware. <http://ocw.mit.edu/courses/materials-science-and-engineering/3-185-transport-phenomena-in-materials-engineering-fall-2003/>.

Szekely, J. and N.J. Themelis, Rate Phenomena in Process Metallurgy, Wiley-Interscience, 1971. ISBN: 0471843030.

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

#### ***Prime Text***

Rosenquist, T. Principles of Extractive Metallurgy. Tapir Academic Press, 2004. ISBN: 9788251919227. Chapters 4-14.

#### ***Supplementary References***

Gilchrist, J.D., Extraction Metallurgy. (3rd edition) Pergamon Press, 1989. ISBN: 0-08-036611-2.

Ghosh, A. and H. S. Ray, Principles of Extractive Metallurgy. New Age International, 1991. ISBN: 8122403220.

Habashi, F., Principles in Extractive Metallurgy: General Principles. Gordon & Breach Science Publishers, 1969. ISBN: 0677017707.

Napier-Munn, T. and B.A. Wills, Mineral Processing Technology (7th edition). Butterworth-Heinemann, 2006. ISBN: 0750644508

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

#### ***Prime Text***

Reed-Hill, R.E. and R. Abbaschian, Physical Metallurgy Principles. (3rd edition) PWS Kent Publishers, Boston, 1992. ISBN 0534921736. Chapters 1-4, 6, 7, 11 and 14

#### ***Supplementary References***

Barrett, C.S. and T.B. Massalski, Crystallographic Methods, Principles and Data. (3rd revised) Pergamon, 1980.

Cullity, BD and Stock, SR., Elements of X-ray Diffraction 3<sup>rd</sup> Edition. Prentice Hall, Upper Saddle River NJ, 2001 ISBN 0-201-61091-4 Chaps 1-3.

Flinn, R.A. and P.K. Trojan, Engineering Materials and Their Applications. (4th edition), Houghton Mifflin Company, Boston, 1990.

Shackelford, J.F., Introduction to Materials Science for Engineers. Latest edition, MacMillan Publishing Company, New York.

### ***10-Met-A5 Mechanical Behaviour and Fracture of Materials***

#### ***Prime Text***

Hertzberg R.W., Deformation and Fracture Mechanics of Engineering Materials. (4<sup>th</sup> edition) John Wiley, New York, 1996. ISBN 0-471-01214-9. Chaps 1-5, 7, 8, 12 and 13.

#### ***Supplementary References***

Courtney, T.H., Mechanical Behaviour of materials, 2nd Edition. 2000. ISBN #0-070-28594-2.

Dieter, G., Mechanical Metallurgy. (3rd edition) McGraw-Hill Book Co., New York, 1986. ISBN 0070168938.

### ***10-Met-A6 Phase Transformation and Thermal Treatment of Metals and Alloys***

#### ***Prime Text***

Reed-Hill, R.E. and R. Abbaschian, Physical Metallurgy Principles. (3rd edition), PWS Kent, Boston, 1991. ISBN 0534921736. Chapters 8, 14, 15, and 16.

#### ***Supplementary References***

ASM Handbook (Revised). Vol. 4, Heat Treating.

ASM Handbook. Vol. 2, Properties and Selection Nonferrous Alloys.

ASM Handbook. Vol. 1. Properties and Selection Iron and Steels.

Brooks, C.R., Heat Treatment Structure and Properties of Nonferrous Alloys. American Society for Metals, Metals Park, OH, 44073, USA, 1984.

Krauss, G., Steels: Heat Treatment Processing Principles. ASM International, 1990.

### ***10-Met-A7 Corrosion and Oxidation***

#### ***Prime Text***

Bradford SA, Corrosion Control (2<sup>nd</sup> edition), Casti Publishing, Edmonton. ISBN 1-894038-58-4. Chapters 1-6, 9-12, 14.

### ***10-Met-B1 Mineral Processing***

#### ***Prime Text***

Napier-Munn, T. and B.A. Wills, Mineral Processing Technology. Butterworth-Heinemann, 2006. ISBN: 0750644508. Chapters 2-16.

#### ***Supplementary References***

Kelly, E.G. and D.J. Spottiswood, Introduction to Mineral Processing. Wiley Interscience, 1992. ISBN-10: 0471033790.

Mular, A.L. and D. Halbe and D. Barrat, Mineral Processing Plant Design, Practice and Control. Society for Mining, Metallurgy and Exploration, 1992. ISBN: 0873352238.

### ***10-Met-B2 Hydrometallurgy and Electrometallurgy***

#### ***Prime Text***

Jackson, E, Hydrometallurgical Extraction and Reclamation. Ellis Horwood Limited, 1986. Halstead Press, John Wiley & Sons. SBN: 0-7458-0048-3 and 0-470-2034-5. Chapters: 1, 2, 3, 4, 5.

#### ***Supplementary References***

Habashi, F., Textbook of Hydrometallurgy. Les copies de la capitale inc., 1995. Distributed by Laval University Bookstore. ISBN : 2-980-3247-7-9.

Peters, E. G. L. Bolton, D.B. Dreisinger and B. Conard, Hydrometallurgy: Theory and Practice. TMS-AIME Press, 1992. ISBN: 0444986562.

Rosequist, T., Principles of Extractive Metallurgy. Tapir Academic Press, 2004. ISBN: 9788251919227.

### ***10-Met-B3 Ironmaking and Steelmaking***

#### ***Prime Text***

Turdogan, E.T., Fundamentals of Steelmaking. Woodhead Publishing Limited, 1996. ISBN: 1861250045. Chapters: All.

#### ***Supplementary References***

Fruehan, R.J., The Making Shaping and Treating of Steel. 11th edition, ironmaking Volume. AIST Publications, 1992. ISBN: 978-0-930767-03-7.

Fruehan, R.J., The Making Shaping and Treating of Steel. 11th edition, Steelmaking and Refining Volume. AIST Publications, 1992. ISBN: 978-0-930767-02-0.

Fruehan, R.J. and E.T. Turkdogan, Proceedings of the Ethem T. Turkdogan Symposium: Fundamentals and analysis of New and Emerging Steelmaking Technologies, Pittsburgh, 1994. The Metals and Materials Society, Iron and Steel Society

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

#### ***Prime Text***

Gill, C.B., Non-Ferrous Extractive Metallurgy. John Wiley and Sons, 1998. ISBN: 0894642642. Chapters: all.

#### ***Supplementary References***

Davenport, W.G., Extractive Metallurgy of Copper. Pergamon Press, Oxford, 1994. ISBN: 0080421245.

Evans, J.W. and Z.C. Dejonghe, The Production of Inorganic Material. TMS Press, Warrendale, 2002. ISBN: 0873395417.

Rosenquist, T., Principles of Extractive Metallurgy. Tapir Academic Press, 2004. ISBN: 9788251919227.

### ***10-Met-B5 Metal Fabrication***

#### ***Prime Text***

DeGarmo, E. Paul, J.T. Black, and Ronald A. Kohser, Materials and Processes in Engineering, 10th Edition. 2007. ISBN: 0-470-05512-X. Chapters 4, 7, 13-19.

#### ***Supplementary References***

Kapakjian, Serope and Steve Schmid, Manufacturing Engineering and Technology, 6th edition, Prentice Hall. 2009. ISBN # 0136081681.

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

#### ***Prime Text***

Smith, W.F., Structure and Properties of Engineering Alloys (2nd edition), McGraw Hill, New York, 1993. Chapters 1-4, 7-9 and 14.

#### ***Supplementary References***

Krause, G., Steels: Heat Treatment and Processing Principles. (3rd edition) ASM Int., 1990 ISBN 087170370X

Metals Handbook Volume 4 – Heat Treating (10th edition) ASM Materials Park, 1991.

Metals Handbook Volume 1 – Properties and Selection: Iron, Steels and High Performance Alloys. (10th edition), AMS, Materials Park, Ohio, 1990 ISBN 0871703777.

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

#### ***Prime Text***

Smith, W.F., Structure and Properties of Engineering Alloys, 2nd edition. McGraw Hill, New York, 1993. Chapters 5-6, and 10-13.

### ***10-Met-B8 Ceramic Materials***

#### ***Prime Text***

Barsoum, M.W., Fundamentals of Ceramics. IOP Publishing, Bristol, 2003. ISBN #0 07503 0902 4. Chapters 1-4, 6-8, and 10-14.

#### ***Supplementary Reference***

Kingery, W.D., H.K. Bowen, and D.R. Uhlmann, Introduction to Ceramics. (2nd edition) Wiley, New York, 1976. ISBN 0471478601.

### ***10-Met-B9 Structure and Properties of Polymers***

#### ***Prime Text***

Young, R.J. and P.A. Lovell. Introduction to Polymers. CRC Press, 2nd edition, 1991. Chapters 1, 3-5.

#### ***Supplementary Reference***

McCrum, N.G., Buckley, C.P. Bucknall, C.B. "Principles of Polymer Engineering", Oxford, 2nd ed., 1997.

### ***10-Met-B10 Advanced Electronic Materials***

#### ***Prime Text***

Kasap, S.O., Principles of Electronic Materials and Devices, 3rd edition. McGraw-Hill Science, 2002. Chapters 4-8.