



Confirmatory Exam Program Requirements Metallurgical Engineering

Metallurgical Engineering Technical Exams. You must choose three of your four exams from the Metallurgical Engineering Technical Exam list. Two of these exams must be from Group A and one from Group B listed below.

Metallurgical Engineering Technical Exams			
Group A		Group B	
10-Met-A1	Metallurgical Thermodynamics	10- Met-B1	Mineral Processing
10-Met-A2	Metallurgical Rate Phenomena	10- Met-B2	Hydrometallurgy & Electrometallurgy
10-Met-A3	Metal Extraction Processes	10- Met-B3	Ironmaking and Steelmaking
10-Met-A4	Structure of Materials	10- Met-B4	Non-Ferrous Extractive Metallurgy
10-Met-A5	Mechanical Behaviour & Fracture of Materials	10- Met-B5	Metal Fabrication
10-Met-A6	Phase Transformation & Thermal Treatment of Metals and Alloys	10- Met-B6	Physical Metallurgy of Iron & Steel
10-Met-A7	Corrosion and Oxidation	10- Met-B7	Physical Metallurgy of Non-Ferrous Metals & Alloys
		10- Met-B8	Ceramic Materials
		10- Met-B9	Structure & Properties of Polymers
		10-Met-B10	Advanced Electronic Materials

Complementary Studies. You must also choose one exam from the Complementary Studies below.

Complementary Studies	
11-CS-1	Engineering Economics
11-CS-2	Engineering in Society – Health & Safety
11-CS-3	Sustainability, Engineering and the Environment
11-CS-4	Engineering Management



PEO'S TECHNICAL EXAMINATION PROGRAMS

WHY A TECHNICAL EXAM PROGRAM?

The academic requirement for licensing as a professional engineer in Ontario is a bachelor's degree in engineering from an accredited program at a Canadian university or its equivalent.

The Canadian Engineering Accreditation Board (CEAB) accredits undergraduate engineering degree programs on behalf of the provincial/territorial engineering associations/order, including PEO.

Applicants who do not hold a bachelor's degree in engineering from a CEAB-accredited program may be required to pursue either PEO's *Confirmatory* or *Specific* exam program to demonstrate that they possess the equivalent academic background for licensing purposes.

PEO's TECHNICAL EXAM PROGRAMS *Confirmatory Exam Program (CEP)*. Applicants whose undergraduate Bachelor's engineering degree was obtained via a program that appears to be similar to the respective CEAB-accredited program are usually assigned a Confirmatory Exam Program, which consists of four exams. The intent is to give the applicant an opportunity to demonstrate that s/he has an academic preparation that is deemed to be equivalent to that of a graduate of a CEAB-accredited program.

***Specific Exam Program (SEP)*.** If PEO's assessment reveals that an applicant's academic qualifications are below the established Canadian standard, s/he will be assigned a Specific Exam Program aimed to remedy identified deficiencies for licensing purposes. A Specific Exam Program may consist of Basic Studies exams, discipline-specific exams, Complementary Studies exams and a thesis.

Basic Studies exams are a prerequisite and must be addressed first; PEO will re-evaluate the applicant's file following the successful completion of all Basic Studies exams and may modify the original exam program, and advise the applicant of the options available to address any outstanding exams.

TIME LIMITS FOR WRITING EXAMS

PEO's technical exams are offered twice annually (in May and December).

Applicants must write at least one exam within two academic years following the date of receipt of their exam program notification. Once the exam program is commenced, the applicant must write at least one exam each academic year or the file will be closed. All exam programs must be successfully completed within eight academic years of the date that the applicant was notified of his/her exam program. ("Academic Year" means the period starting September 1 in a year and ending August 31 in the following year.)

HAVING THE FILE CLOSED

An application file will be closed if any one of the following conditions applies:

- not completing all exam requirements within the specified time limit;
- not writing at least one exam in each academic year after writing the first exam;
- failing the same exam on three attempts;
- failing a total of five exams;
- failing two Basic Studies exams; or
- failing to write a failed exam within one academic year for CEP.

PERFORMANCE STANDARDS

The pass mark for all PEO exams is 50%.

Confirmatory Exam Program. An applicant will be considered to have successfully completed the CEP if the average of the technical exam marks is at least 55% and a pass mark (at least 50%) was received on the Complementary Studies exam.

If an applicant fails two exams or fails the same exam twice in a CEP, s/he may be assigned a Failed-to-Confirm exam program, which may consist of additional exams in the Basic Studies, discipline-specific and Complementary Studies categories.

GOOD-PERFORMANCE REVIEW POLICY

Confirmatory Exam Program. To meet the "good-performance" review criterion, an applicant must have written two technical exams at the first sitting and achieved a minimum average of 65% with no mark below 60%.

After a second exam sitting, if an applicant has passed three technical exams with no mark below 60%, s/he may receive consideration for exemption from writing the Complementary Studies exam. If an applicant attempted two exams in the first sitting but failed one, s/he may still qualify for a "good-performance" review if s/he passes the failed exam with a mark of 70% or higher and achieves 60% or higher on the previously unwritten technical exam attempted at the second sitting.

Important: If an applicant has been assigned a **Directed Confirmatory Exam Program**, the good performance criteria are different; to be eligible, in addition to meeting the above criteria, all the directed exams must be addressed as well. Applicants are advised to contact the Exam Centre to discuss further.

Note:

- Good-Performance reviews are not applicable to Specific Exam Program and Failed-to-Confirm exam program applicants.

WHEN AND WHERE PEO EXAMS ARE OFFERED

PEO technical exams are held in May and December at 14 centres in Ontario. Exams are usually offered over a five-day period.

Registration packages to write are mailed in January for the May sitting and in July for the December sitting.

If the technical exam package is not received by the times indicated above, applicants should call the Exam Centre.

PROCUREMENT OF TEXTS AND OTHER MATERIALS FOR AN EXAM

To help in the procurement of all the suggested technical text books Contact customer service of Login Brothers at orders@lb.ca, through the website www.lb.ca or 1-800-665-1148 to assist you. It is recommended to always purchase the latest edition of any suggested textbook.

If an applicant does not have the current text listing or the text(s) is out of print, the applicant is advised to contact the Exam Centre (see below).

Recent written exams (i.e., reprints) are available on-line at PEO's website at www.peo.on.ca for free download. These past exams are available to provide the applicant with knowledge of the exam format, etc. The answers/solutions of past exams are not available at PEO.



PEO'S TECHNICAL EXAMINATION PROGRAMS

EXAM FEES

All Exam Fees are non-refundable.

First Exam Fee	\$700
Each Subsequent Exam Fee	\$200
Submission of an Engineering Thesis	\$360

COURSES-IN-LIEU

For all course(s)-in-lieu of PEO exam(s), applicants must get prior approval from PEO. A request must be in writing and should include a description of the proposed university calendar course and should be submitted at least two months in advance of the course's registration deadline.

Applicants must arrange for the official grade report(s) to be forwarded to the Licensing and Registration Department upon the completion of the course(s).

NOTE: *Courses-in-lieu are not acceptable for:*

- *Basic Exams,*
- *Confirmatory Exams,*
- *Directed Confirmatory Exams,*
- *Failed exams*

EXAM CENTRES

Exams are offered annually in May and December at the following centres in Ontario:

Belleville	London	Sudbury
Chalk River	Ottawa	Thunder Bay
Hamilton	Peterborough	Toronto
Kingston	Sarnia	Windsor
Kirkland Lake	St. Catharines	

The timetable information and exact location of exams are posted on PEO's website early in April to applicants writing exams in May, and early in November for those writing in December.

Applicants living inside Ontario must write at an Ontario centre. One of the centres listed may be selected. Applicants living outside Ontario may make special arrangements to write outside Ontario or Canada. Call the Exam Centre for further instructions if special arrangements are required.

ADDITIONAL INFORMATION

Order of exams. Basic Studies exams are a prerequisite and must be written first. Following the successful completion of all Basic Studies exams, applicants may write the remaining exams in any order. However, it is recommended that exams in less-advanced subjects be written first. Passing an exam in an advanced subject does not merit credit for a less-advanced subject.

English Language Skills. An acceptable level of English—both written and spoken—is required to practise engineering and to successfully complete PEO exams. If an applicant needs to improve English language skills, s/he should contact one of the many English as a Second Language Programs run by schools and community organizations throughout Ontario.

Penalties. Using notes or other aids in an exam where these are not allowed is strictly forbidden. Applicants caught doing so will have their paper confiscated and risk having their licence application withdrawn.

Exam Results. Exam results are normally mailed within 45 working days following writing of the exam. No results will be given over the telephone or in person at PEO office. Exam papers will not be returned to applicants and answers are not available. Failed exams are automatically re-read. However, applicants may request a formal re-read

of an exam paper. A non-refundable fee of \$330 is charged in the event a formal re-read is requested by an applicant. Requests for a re-read must be received within 30 days after an applicant has been notified of the exam mark.

Reapplying After A File Has Been Closed. If a file has been closed, an applicant may reapply with the understanding that the regulations and policies in effect at the time of the new application will be enforced.

An application for licence fee and all other associated fees will be required.

If a file was closed for poor academic performance, the applicant may be required to show that s/he has taken course(s) in the subject(s) covered by any failed exam(s).

All recorded failed exams from a previous application must be successfully addressed before an applicant will be allowed to pursue the new program.

WORKING IN ENGINEERING BEFORE LICENSURE

Applicants may work in engineering provided a licensed professional engineer takes responsibility for the work. It is illegal to use the title "professional engineer" or any variation thereof (project engineer, systems engineer, etc.) as an occupational or business title that might lead to the belief that a person is a licensed professional engineer.

NEED MORE INFORMATION?

For more information about licensing/registration requirements, please contact:

Licensing and Registration Department
Professional Engineers Ontario
40 Sheppard Avenue West, Suite 101
Toronto, ON M2N 6K9
Tel: (416) 224-1100 / 1-800-339-3716
Fax: (416) 224-8168 / 1-800-268-0496
<http://www.peo.on.ca>

PEO'S CONFIRMATORY EXAMINATION PROGRAM

Confirmatory Exam Program (CEP)

PEO's **Confirmatory Exam Program** (CEP) consists of three technical exams in the applicant's engineering discipline and a *Complementary Studies* exam.

- This program must be completed within eight academic years following the date of receipt of the exam program notification. ("Academic Year" means the period starting September 1 in a year and ending August 31 in the following year.)
- Applicants will have successfully completed the *Confirmatory Exam Program* if the average of their three technical exams is at least 55% with no mark below 50% and they achieve a pass (50%) on the *Complementary Studies* exam.
- To qualify for the good performance review, applicants must address all the directed exams, if the applicant is assigned a *Directed Confirmatory Exam Program*

Good-Performance review for CEP applicants may be warranted as follows:

- Applicants who pass any two technical exams at their first sitting, with a minimum average of 65% and with no mark below 60%, may be exempted from completing the remaining exams in the *Confirmatory Exam Program*.
- Applicants who complete three technical exams in two sittings with no mark below 60% may be exempted from the *Complementary Studies* exam.
- Applicants who fail one technical exam and achieve a mark of 70% or higher on the failed exam on their second attempt, and 60% or higher on a previously unwritten technical exam attempted at the same sitting, may be exempted from completing the remaining exams in their *Confirmatory Exam Program*.

A **Failed-to-Confirm** Exam Program for CEP applicants, consisting of additional exam(s), will be assigned to applicants who do not confirm their engineering knowledge via their *Confirmatory Exam Program*. At least one of the following will apply:

- Applicants who do not achieve an average mark of at least 55% on the three technical exams will be assigned a *Failed-to-Confirm* Exam Program and one additional technical exam will be assigned.
- Applicants, who failed the same exam twice or failed two different exams will be assigned a *Failed-to-Confirm* Exam Program where an additional exam will be assigned for each exam failure. They must also pass the failed exams.

Please note: For applicants who are assigned a **Failed-to-Confirm** Exam Program, their engineering experience does not begin until after the academic requirements for licencing are met, and they will be required to demonstrate 48 months of engineering experience from that time.

A **file will be closed** under the following circumstances:

- If there is loss of contact (no active mailing address), the applicant's file will be closed.
- Applicants who do not attempt any exams within two academic years after notification of their exam program will have their file closed.
- Once an exam program commences, applicants must write at least one exam each academic year or their file will be closed even if the applicant has successfully passed exams in the past.
- Applicants who fail a technical/Complementary Studies exam on their first sitting must pass the failed exam within one academic year or their file will be closed.

If you have any questions concerning the above listed, please contact the Exam Centre
416-840-1097, 1057, 1096, 1095 or 1(800) 339-3716 1097, 1057, 1096, 1095
e-mail: exams@peo.on.ca

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METALLURGICAL ENGINEERING EXAMINATIONS

INTRODUCTION

Each discipline examination syllabus is divided into two examination categories: compulsory and elective. A full set of Metallurgical Engineering examinations consists of seventeen, three-hour examination papers and an engineering report. 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 PEO's Academic Requirement Committee.

Information on examination scheduling, textbooks, materials provided or required, and whether the examinations are open or closed book, will be provided by PEO's examinations Centre.

BASIC STUDIES

04-BS-1 Mathematics

Calculus, Vector, and Linear Algebra: Applications involving matrix algebra, determinants, eigenvalues; first and second order linear ordinary differential equations, Laplace transforms. Vector algebra; vector functions and operations; orthogonal curvilinear coordinates; applications of partial derivatives, Lagrange multipliers, multiple integrals, line and surface integrals; integral theorems (Gauss, Green, Stokes). Power series.

04-BS-2 Probability and Statistics

Concepts of probability, events and populations, probability theorems, concept of a random variable, continuous and discrete random variables, probability distributions, distributions of functions of a random variable, sampling and statistical estimation theory, hypothesis testing, simple regression analysis.

04-BS-3 Statics and Dynamics

Force vectors in two- and three-dimensions, equilibrium of a particle in two- and three-dimensions; moments and couples; equilibrium of rigid bodies in two- and three-dimensions; centroids, centres of gravity; second moment of area, moment of inertia; truss, frame and cable static analysis; friction. Planar kinematics of particles and rigid bodies; planar kinetics of particles and rigid bodies; work and energy, impulse, and momentum of particles and rigid bodies.

04-BS-4 Electric Circuits and Power

Basic laws, current, voltage, power; DC circuits, network theorems, network analysis; simple transients, AC circuits. Impedance concept, resonance; use and application of phasors and complex algebra in steady-state response; simple magnetic circuits; basic concepts and performance characteristics of transformers; an introduction to diodes and transistors; rectification and filtering; simple logic circuits.

04-BS-6 Mechanics of Materials

Definitions of normal stress, shearing stress, normal strain, shearing strain; shear force and bending moment diagrams; members subjected to axial loading; members subjected to torsional loading; compound stresses, Mohr's circle; deformation of flexural and torsional members; failure theories; elastic and inelastic strength criteria; columns.

04-BS-7 Mechanics of Fluids

Fluid characteristics, dimensions and units, flow properties, and fluid properties; the fundamentals of fluid statics, engineering applications of fluid statics; the one-dimensional equations of continuity, momentum, and energy; laminar and turbulent flow, flow separation, drag and lift on immersed objects; wall friction and minor losses in closed conduit flow; flow of incompressible and compressible fluids in pipes; dimensional analysis and similitude; flow measurement methods.

04-BS-10 Thermodynamics

Thermodynamic states of simple systems; the laws of thermodynamics; equilibrium, PVT and other thermodynamic diagrams; equation of state; compressibility charts and steam tables; calculation of property changes; enthalpy; applications of thermodynamics, cycles, reversibility; thermodynamics of phase changes, Gibbs phase rule, gas-vapour mixtures.

04-BS-11 Properties of Materials

Properties of materials for mechanical, thermal and electrical applications. Atomic bonding, solid solutions, crystallization. Equilibrium phase diagrams, applications to steel and aluminium alloys, heat treatments. Structure and special properties of polymers and ceramic materials. General characteristics of metallic composites, polymeric composites and concrete. Introduction to materials in hostile environments: corrosion, creep at high temperature, refractory materials, subnormal temperature brittle fracture.

GROUP A

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

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-Fe₃C 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.

COMPLEMENTARY STUDIES

11-CS-1 Engineering Economics

Basic concepts of engineering economics through understanding of the theoretical and conceptual financial project analysis. Types and applications of engineering economic decisions. Capital, cash flow, and the time value of money concepts. Nominal and effective interest rates when considering loans, mortgages, and bonds. The application of present worth analysis, annual equivalent analysis and rate of return analysis in evaluating independent projects, comparing mutually exclusive projects, analyzing lease vs. buy alternatives and making decisions. After-tax financial analysis requiring an understanding of capital cost allowance (depreciation) and corporate income tax. Understanding methods of financing and capital budgeting. Break-even, sensitivity and risk analyses.

11-CS-2 Engineering in Society – Health and Safety

The duties and legal responsibilities for which engineers are accountable; safety laws and regulations; and a basic knowledge of potential hazards and their control: biological hazards – bacteria, viruses; chemical hazards – gases, liquids and dusts; fire and explosion hazards; physical hazards – noise, radiation, temperature extremes; safety hazards – equipment operation; workplace conditions – equity standards, human behaviour, capabilities, and limitations; managing safety and health through risk management, safety analyses, and safety plans and programs; practices and procedures to improve safety. The roles and social responsibilities of an engineer from a

professional ethics point of view, as applied in the context of Canadian values. The integration of ethics into engineering practice, and its effect on public safety and trust.

11-CS-3 Sustainability, Engineering and the Environment

Basic knowledge of soil, water and air quality engineering: soil and water interaction, water supply issues, human activities and their interaction on soil, air and water resources. Fundamentals of: soil erosion, water quality, atmospheric pollution (carbon and nitrogen cycle), climate change, risk assessment. Basic knowledge of renewable energy sources: solar, photovoltaic, wireless electricity, thermal, wind, geothermal, and biofuels. **Introduction to** renewable materials engineering; nano materials, new material cycles. Eco-product development, and product life cycle assessment; recycling technologies; reuse of products; design for disassembly, recycling, e-waste, and reverse manufacturing. Consumption patterns; transportation; environmental communication; consumer awareness. Optimized energy and resources management. Sustainable methods: sustainability indicators; life cycle assessment; regulatory aspects of environmental management, ecological planning.

11-CS-4 Engineering Management

Introduction to management principles and their impact upon social and economic aspects of engineering practice. Engineering management knowledge topics including: market research, assessment and forecasting; strategic planning; risk and change management; product, service and process development; engineering projects and process management; financial resource management; marketing, sales and communications management; leadership and organizational management; professional responsibility. New paradigms and innovative business models, including: sustainable production, products, service systems and consumption; best practices and practical examples of successful implementations of sustainable scientific and engineering solutions.

3.2 ENGINEERING REPORT

Upon passing the examination(s) assigned by PEO's Academic Requirements Committee, a candidate may be required to write an Engineering Report. The report must demonstrate the candidate's ability to present an engineering problem, observation, or idea, and to analyze it logically and accurately using engineering principles, and to draw conclusions or make recommendations. The work must include acceptable technical content involving engineering analysis, design, development, or research. The report must also demonstrate a satisfactory level of writing and graphical skills, thus the quality of the presentation will be a factor in determining the acceptability of the report.

The report itself need not prove originality of ideas, but the candidate should demonstrate his/her ability to appreciate, present, differentiate between and draw conclusions from observations and ideas. The definition of a "report" is flexible and could also include discussion and judgement of opposed theories or methods, or a description of a novel technique or process and a discussion of the practicality of its application. The key consideration is that the report address a new issue, and not repeat the coverage of the

particular subject available in textbooks. It is the current state of the art, the novel or the contentious that is expected to be explored in the report.

While no rigid rules of format are specified, it is recommended that the report be suitably subdivided and include:

- a) A title page and date
- b) A signed declaration of authorship
- c) A table of contents
- d) A summary of the report and its conclusions
- e) Technical content including analysis, design, development or research
- f) Conclusions and/or recommendations
- g) A list of the technical literature cited
- h) A list of acknowledgements, contributors, reviewers and sources of information

The report should be about 5,000 words long, not including tables and graphs. Diagrams, illustrations, etc. should be clearly and properly identified. It is preferable to locate graphs, diagrams, etc. necessary for the understanding of the text at the place where reference to them is made.

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, B.D. and Stock, S.R., Elements of X-ray Diffraction 3rd 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

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