

# PAKISTAN ENGINEERING COUNCIL

## Syllabus for Engineering Practice Examination (EPE)

### Materials & Metallurgical Engineering

Total Marks: 60

#### PART-II

This is an open book breadth and depth examination, comprising 60 Multiple Choice Questions (MCQs) of one mark each (total 60 marks) with a duration of three hours. There shall be two sections of Part-II for each major discipline of EPE. Qualifying Marks for this part shall be *sixty per cent*.

#### SECTION-A / BREADTH

This section will generally confirm to latest (updated) B.E./equivalent qualification of Materials & Metallurgical Engineering. The examination of this section shall comprise 25 MCQs (total 25 marks).

#### 1. MATH, PROBABILITY AND STATISTICS

10%

##### i. Calculus

- Functions of one variable, limits and continuity, differentiation and integration of functions with applications, polar coordinates, complex numbers
- Generalization of the ideas of differentiation and integration of higher dimensions, infinite series and their convergence, power series, Taylors series
- Vector calculus including theorems of Green, Gauss and Stokes.

##### ii. Differential Equations

- Matrix algebra, solution of linear algebraic equations, Eigen values, Eigen vectors
- First order differential equations, second and higher order linear differential equations, power series solutions, systems of linear differential equations.

##### iii. Numerical Analysis

- Error and computer arithmetic, root finding for non-linear equations, interpolation of polynomial approximation, interactive methods for solution of linear systems
- Numerical differentiation and integration and numerical solution of ordinary differential equations.

##### iv. Engineering Statistics and Measurement

- Measurement, uncertainty and errors in measurement, propagation of errors, systematic vs random error
- Data collection and analysis, frequency distribution and histograms; graphical representation
- Descriptive statistical measures of central tendency, standard deviation, probability, probability distribution and special probability distributions
- Curve fitting, regression and correlation.

### **Suggested Books:**

- D.G. Zill, Michael R. Cullen “Differential Equations with Boundary Value Problems” 7th edition, 2008, ISBN: 9780495108367
- Erwin Kreyszig, “Advanced Engineering Mathematics,” Ninth Edition, 2005, International Edition, John Wiley & Sons, ISBN: 0471728977.
- Glyn James “Modern Engineering Mathematics” 4th Edition, ISBN-10: 0132391449
- Numerical analysis by R. L. Burden & J.D. Fairs, Publisher: Orchard, Publications 2007, ISBN: 1934404047
- Jay L. Devore, “Probability and Statistics for Engineering and the Sciences” 2nd Ed. ISBN: 0813334152

## **2. INDUSTRIAL CHEMISTRY**

**7%**

- i. Periodic Table and Trends
- ii. Reaction Chemistry and Kinetics
- iii. Stoichiometry, concentration, solutions,
- iv. Electrochemistry, cells, batteries (thermal batteries)
- v. Major chemical industries and the production processes
- vi. Intermolecular forces
- vii. Soap & detergent
- viii. Propellants and explosives
- ix. Fuels (coal, natural gas, crude oil)
- x. Organic chemistry (functional groups in organic chemistry, plastics, elastomers and fibers)
- xi. Liquid crystals
- xii. Paints & thin films
- xiii. Water management (drinking water, waste water treatment)
- xiv. Chemistry of atmospheric pollution (troposphere, stratosphere)

### **Suggested Books:**

- R Gopalan, D Venkappayya Sulochana, , “Engineering Chemistry” 2nd Ed, 1999
- Colin Baird and Michael Cann “Environmental Chemistry” , 3<sup>rd</sup> Ed, 2005
- David R. Klein, 2005, “General Chemistry as Second Language” ISBN: 9780471716624
- Olmsted and William, 1994, “Chemistry: The Molecular Science”
- Kenneth W. Whitten “General Chemistry” , 6<sup>th</sup> Ed, 2000
- Theodore L. Brown , “Chemistry, The Central Science” , 7<sup>th</sup> Ed, 1997
- Francis Marion Miller , “Chemistry, Structure and Dynamics”, 1<sup>st</sup> Ed.1984, ISBN: 9780070419834
- David W. Oxtoby, “Chemistry, Science of change”, 2<sup>nd</sup> Ed, 1994
- Philip Matthews, ‘Advanced Chemistry’ , 1996
- Philip J. Chenier, “ Survey of Industrial Chemistry” , 3<sup>rd</sup> Ed, 2002
- George T. Austin, “ Shreve’s Chemical Process Industries” , 5<sup>th</sup> Ed, 1994
- Manahan, “ Environmental Chemistry” , 6<sup>th</sup> Ed, 1994

### **3. ELECTRICITY AND MAGNETISM**

**7%**

- i. Fundamental Laws and Maxwell Equation
- ii. Electric potential and magnetic field
- iii. Electric energy and properties of conductors, insulators and dielectric materials
- iv. Circuit analysis, electronic devices and condensers
- v. Conduction in semiconductors
- vi. DC circuits
- vii. Self-induced EMF’s and self inductance
- viii. Energy transfers in LR circuits, mutual inductance, transforms
- ix. Magnetic effect of current, relation between magnetism and electricity
- x. Force on a current carrying conductor in magnetic field, Laws of electromagnetic induction
- xi. Magnetic materials, B-H curves, hysteresis, magnetic circuits calculations
- xii. Solenoids, pull of an electromagnet
- xiii. Principles of diode & triode, cathode-ray tube and photo-multiplier tube

### **Suggested Books:**

- Halliday, Resnick, Krane:, “ Physics”, Volume 2, 5th edition
- Kittle C, “ Introduction to Solid State Physics”, 2000, Willey New York
- Stan Gibilisco, “Applied Physics”, McGraw-Hill, 2002, ISBN 0071382011

#### **4. ENVIRONMENT AND SAFETY**

**7%**

- i. Environmental organization, legislation, standards, monitoring and compliance assurance
- ii. National and International Laws and Codes (Pakistan Environment Protection Act 1997, NEQS, ISO 14000)
- iii. Environment pollution, control and management
- iv. Environment dispersion of pollutants
- v. Safety management, understanding accident and hazard, Hazard control and loss control
- vi. Accident prevention and control, accident reporting and investigation
- vii. Risk analysis.

#### **Suggested Books:**

- Christopher J. Barrow, "Environmental Management & Control" Rutledge, 2006
- Thomas J. Anton, "Occupational Safety & Health Management", 2<sup>nd</sup> ed., McGraw Hill, 2006
- Ronald Packman, "A Guide to Industrial Safety and Health" Longmans, 2007
- James S. Angle, "Occupational Safety", Thomson Delmar Learning, 2004, ISBN:1401859038
- Wood C. Environmental Impact (A Comparative Review), Longman Scientific and Technical.1995, Longman House, Essex, UK
- Petts J. and Aduljee, G., "Environmental Impact Assessment for Waste Treatment and Disposal Facilities" 1994. John Wiley & Sons Inc UK
- Khan, M.I; Tahir. B.A. and Akhtar N., "Integrated Environmental Management: Urban and Rural" 2004, Allama Iqbal Open University
- Asian Development Bank. A Manual for Environmental Impact Assessment
- GoP, 2000, IEE/EIA Regulations, Ministry of Environment
- North K, "Environmental Business Management: An Introduction", Oxford & IBH Publishing Co. Pvt. Ltd, 1997.
- Therivel R: Glasson J and Chadwick A: Introduction to Environmental Impact Routledge; 3<sup>rd</sup> ed. 2005.

#### **5. STRENGTH OF MATERIALS**

**7%**

- i. Fundamental concepts of force, balance, equation of equilibrium
- ii. Frictional forces, moments and inertia
- iii. Concept of stress and strain, axial loading, torsion, pure bending
- iv. Shear and bending stresses in beams and thin-walled members
- v. Transformation of stress and strain, principal stresses

- vi. Energy methods – elastic strain energy for normal and shearing stresses, impact loading.

**Suggested Books:**

- F.P.Beer, E R Johnston and J T DeWolf, “Mechanics of Materials”, 4<sup>th</sup> Ed. McGraw Hill Publications
- R.C.Hibbeler, “Engineering Mechanics – Statics”, 11<sup>th</sup> Ed. 2007, Prentice Hall Publications.

**6. THERMODYNAMICS AND HEAT TRANSFER**

**7%**

- Laws of thermodynamics and their applications
- Chemical equilibrium, relations pertaining to multiphase equilibria, electrochemical equilibria and surface thermodynamics
- Phase rule and thermodynamics of solution
- Statistical thermodynamics
- Physical origins of rate equations
- Conduction – 1D and 2D conduction, steady-state conduction, transient conduction
- Convection – external flow, internal flow, free convection
- Heat transfer during phase changes
- Radiation – processes and properties, heat transfer due to radiating surfaces and angle of view.

**Suggested Books:**

- David R Ragone, “Materials Thermodynamics”, MIT series on materials, ISBN-10: 0471308854
- Gaskell, David R. “Introduction to Metallurgical Thermodynamics”, 2<sup>nd</sup> Ed. ISBN: 9780891164869
- F P Incropera and D P DeWitt, Fundamentals of Heat and Mass Transfer, John Wiley and Sons, 3<sup>rd</sup> Ed.

**7. ENGINEERING MATERIALS AND PROPERTIES**

**10%**

- Fundamentals of engineering materials, their classification and types
- Crystal structure, structure-properties relation
- Properties of materials (physical, chemical, mechanical, electromagnetic etc.)
- Phase diagrams and heat treatment
- Metallic and non-metallic materials
- Minerals processing and extraction

vii. Advanced and Nano materials.

**Suggested Books:**

- William D. Callister Jr. “Materials Science and Engineering: An Introduction” Publication Date: 2006, ISBN: 9780471736967
- William F Smith, “ Foundation of Materials Science and Engineering” 3<sup>rd</sup> Ed. 1983, ISBN: 0387908943
- M. F. Ashby and D. R. H. Jones, “Engineering Materials: An Introduction to Microstructures, Processing and Design”, Butterworth-Heinemann, 3rd Ed. 2005, ISBN: 0750663812
- Charles P Poole Jr, Frank J Owens, “Introduction to nanotechnology”, Publisher: John Wiley, 2003, ISBN-10: 0471079359

**8. MANUFACTURING PROCESSES**

**13%**

- i. Shaping Processes: metal casting and foundry practices, plastic molding processes, composite materials processing
- ii. Particulate Processing: Powder Metallurgy (PM), Powder Injection Molding (PIM), Processing of Ceramics, Hot Iso-static Pressing
- iii. Bulk Deformation Processes: Forging, rolling, extrusion, rod, wire and tube drawing
- iv. Sheet Metal Forming Processes: Shearing/cutting, bending, stretching and deep drawing operations, flow forming
- v. Material Removal Processes: Conventional and non-conventional operations (including electro polishing)
- vi. Joining and Assembly Processes: mechanical, chemical and thermal joining, Welding, brazing, soldering and joining of similar and dissimilar materials, Adhesive Bonding, friction welding and diffusion bonding
- vii. Surface Treatment and Coatings: surface hardening processes, tribological and protective coatings, passivation treatment processes
- viii. Rapid Prototyping: stereo lithography, solid form processes, inkjet fabrication process
- ix. Quality and standardization of Products: statistical control charts, life assessment and reliability.

**Suggested Books:**

- Serope Kalpakjian and Steven R. Schmid, “Manufacturing Processes for Engineering Materials”, Pearson Education, Inc., 2003.
- Mikell P. Groover, “Fundamentals of Modern Manufacturing: Materials, Processes, and Systems”, John Wiley & Sons, Inc., 2007.
- George E. Dieter, “Mechanical Metallurgy”, McGraw-Hill, 1988.

- Robert W. Messler Jr., “Joining of Advanced Materials and Structures” Butterworth–Heinemann, 2004.

## **9. CHARACTERIZATION TECHNIQUES 10%**

- i. Principles of Materials Characterization
- ii. Mechanical Testing Techniques: hardness, tensile, compression, bending, fatigue, creep, impact, fracture toughness (CT, COD etc.) and surface roughness
- iii. Electronic, ions, thermal, spectral characterization techniques
- iv. Analytical Techniques: molecular, emission and absorption spectroscopy, laser spectroscopy, magnetic resonance, X-ray and photoelectron spectroscopy
- v. Electron microscopy, scanning and transmission electron microscopy
- vi. Particle size analysis
- vii. Non-destructive Testing Techniques: X-ray/gamma/neutron radiography, ultrasonic testing, dye-penetration testing, acoustic emission, eddy currents and Magnetic Particle Inspection (MPI).

### **Suggested Books:**

- Norman E. Dowling, “Mechanical Behavior of Materials”, 2nd Edition, Prentice Hall, 1999
- R.E. Green, T. Kishi, T. Saito, and N. Takeda, “Nondestructive Characterization of Materials” 2001, ISBN-10: 0080437990
- Robert Cahn, “Concise Encyclopedia of Materials Characterization”, 2nd Edition, Elsevier Science, ISBN: 780080445472

## **10. QUALITY ASSURANCE AND STANDARDS 3%**

- i. Quality Assurance and Control (QA/QC)
- ii. Quality Management Systems (ISO 9000, ISO 17025)
- iii. Quality assurance function, development of quality system standards
- iv. Tolerance and statistical process control, sample size and probability distribution, Quality Functions Deployment (QFD)
- v. Acceptable Quality Level (AQL), Average Outgoing Quality Limit (AOQL)
- vi. Reliability and maintainability (ASTM, DIN, BS, Chinese, JIS, and ISO).

### **Suggested Books:**

- Dale H. Besterfield, Carol Besterfield-Michna, Glen Besterfield, Mary Besterfield-Sacre, “Total Quality Management”, 3rd Ed. Pearson Education, Prentice Hall, 2002
- Barrie Dale and Heather Bunney “Total Quality Management blueprint” Blackwell Publishers Inc. 1999
- Dale H. Basterfield, “Quality Control”, 7<sup>th</sup> Ed. Pearson Education Inc, 2004

- Montgomery C. Douglas, "Introduction to Statistical Quality Control", 6<sup>th</sup> Ed. John Wiley & Sons, 2009.

## **11. CORROSION AND ITS CONTROL**

**7%**

- Basic Concepts in Corrosion: anodic and cathodic reactions, electrochemical cell and electrode potential, types of corrosion, mechanism of corrosion, thermodynamics of corrosion, pourbaix diagrams
- Forms of Corrosion: uniform corrosion, galvanic corrosion, high temperature corrosion, crevice corrosion, filiform corrosion, pitting corrosion, inter-granular corrosion, erosion corrosion, fretting corrosion, stress corrosion cracking, stray current corrosion, microbiological influenced corrosion, corrosion fatigue and fretting corrosion
- Polarization and Kinetics of Corrosion: corrosion kinetics, Polarization (activation, concentration and resistance), effect of various factors on polarization, determination of corrosion rates by electrochemical measurements, corrosion testing and monitoring
- Passivity: types of passivity, conditions for passivation, kinetics of passivity
- Corrosion Control Methods: cathodic protection, anodic protection, metallic, inorganic and organic coatings, inhibitors and passivators, alloying for corrosion resistance, corrosion prevention by design, concrete corrosion
- Materials Selection: selection of materials for corrosive environments.

### **Suggested Books:**

- Herbert H. Uhlig and R. Winston Revie, "Corrosion and Corrosion Control", John Wiley & Sons, Inc., 2008.
- Mars G. Fontana, "Corrosion Engineering", Tata McGraw-Hill, Inc., 2006.
- Corrosion Engineering, J Scully

## **12. PHASE TRANSFORMATIONS**

**7%**

- Thermodynamics and Phase Diagrams: binary and tertiary systems
- Equilibrium in heterogeneous systems
- Diffusion, crystal interfaces and microstructures, grain boundaries, Phase coherence, second phase interface energy
- Solidification and heat flow, nucleation and growth
- Diffusional transformation in solids, eutectoid transformations, GP zones, spinodal decomposition, Time-Temperature and Transformation (TTT) diagrams, maraging
- Recovery, recrystallization and grain growth processes
- Diffusionless transformations, glass transformation.



### **Suggested Books:**

- David A. Porter and Kenneth E. Easterling, "Phase Transformations in Metals and Alloys", 3<sup>rd</sup> Ed. ISBN:1420062107
- Mats Hillert, Phase Equilibria, Phase Diagrams and Phase Transformations: Their Thermodynamic Basis, Cambridge University Press
- Reed Hill "Physical Metallurgy", 3<sup>rd</sup> Ed. ISBN: 0534921736

### **13. MECHANICAL BEHAVIOR OF MATERIALS AND FRACTURE**

**7%**

- i. Simple continuum mechanics and elasticity; stress, strain, stress concentrations, elastic deformation
- ii. Plastic deformation, stress-strain curves/constitutive behavior, brittle fracture
- iii. Bending & shearing, shearing stresses, shear flow, flow deflection due to shear, photoelastic method, plasticity, relationship between stress & deformation
- iv. Strain energy in tension & compression
- v. Mohr's circles of bi-axial stresses, torsion of circular shafts, plain strain plain stress conditions
- vi. Plastic instability, defects in solids, concept of dislocations and dislocation theory, dislocation movement, slip/ twinning
- vii. Hardening mechanisms, creep deformation mechanisms, creep constitutive laws, life prediction
- viii. Griffith and Orowan theories of ideally brittle fracture, fracture in ductile and brittle materials, fractography, concept of fracture toughness
- ix. Environmentally assisted cracking, mechanisms, fatigue failure, mechanisms of fatigue in metals and non-metals, stress-strain / life prediction (S/N curves, endurance strengths, fatigue limits, fatigue strength reduction factors), stress intensity factor, application of fracture mechanics to fatigue-crack growth mechanisms.

### **Suggested Books:**

- M. A. Meyers and K. K. Chawala: "Mechanical Behavior of Materials", Cambridge Univ. Press, 2<sup>nd</sup> ed., 2009.
- George E. Dieter Jr: "Mechanical Metallurgy", McGraw Hill Kogakusha Ltd. International Student Edition.
- R. W. Hertzberg: "Deformation and Fracture Mechanics of Engineering Materials", Wiley, 4<sup>th</sup> ed., 1989)
- S. Suresh: "Fatigue of Materials", Cambridge Univ. Press, 2<sup>nd</sup> ed., 1998.
- Mechanical Testing: Metals Handbook, 9<sup>th</sup> ed., vol. 8 (American Society for Metals)
- Failure Analysis / Fractography: Metals Handbook, 9<sup>th</sup> ed., vol. 12 (American Society for Metals)

## **PART-II**

### **SECTION-B / DEPTH**

This section shall be based on practical concepts framed to judge the practical experience and field based knowledge of Registered Engineers (REs). The examination of this section shall comprise 35 MCQs. Each candidate may attempt the only opted area of practice, among the followings.

#### **1. METALLURGICAL ENGINEERING**

- i. Mineral Processing and Extraction: ores and beneficiation processes, extraction (ferrous and non ferrous)
- ii. Alloy Production and Special Steels: steel making and refining processes, alloy steel and special steels, super-alloys, non-ferrous alloys production
- iii. Furnaces and fuels: melting and heat treatment furnaces, solid, liquid and gaseous fuels
- iv. Heat Treatment and Surface Modification Techniques: annealing, normalizing, quenching, tempering, aging, hardenability, case hardening, carburizing, nitriding, nitro-carburizing, microstructures and case depth, phase transformation, TTT and ITT diagrams
- v. Rolling, forging, extrusion and welding
- vi. Pipelines fabrication and protection
- vii. Production of automotive, pressure vessels and power plants
- viii. Quality assurance and ASTM/ ASME Codes and procedures.

#### **Suggested Books:**

- George E. Dieter “Mechanical Metallurgy”, latest edition, McGraw Hill Publishers
- George Krauss, “Steels: Processing, Structure, And Performance”, 2005, ASM Intl (oh)
- Terkel Rosenqvist, “Principles of Extractive Metallurgy”, latest ed. 2004. Tapri Academic Press
- “Handbook of Extractive Metallurgy” edited by Fathi Habashi vols I – III
- Mars G. Fontana, “Corrosion Engineering”, 2006, Tata McGraw Hill Inc
- ASM Handbook: Welding, Brazing and Soldering, vol. 6, ASM Intl.
- George E. Dieter Jr: “Mechanical Metallurgy”, McGraw Hill Kogakusha Ltd. International Student Edition
- CASTI Guide Book for ASME published by CASTI Canada ([www.cati.ca](http://www.cati.ca))
- ASTM Guide Book

## 2. FOUNDRY ENGINEERING

- i. Patterns, Mould and Core making: design/ types of patterns, testing of molding sand, coatings, contraction and shrinkage allowance; molding machines and other equipments
- ii. Gating and Riser Design: gating system and its requirement, casting design, casting defects, riser design, directional solidification
- iii. Casting Processes: investment casting, die casting, centrifugal casting, CO<sub>2</sub> molding process, foundry mechanization, casting of ferrous and non-ferrous metals/alloys, casting of automotive and locomotive parts
- iv. Melting and Refining: melting techniques and furnaces, melt refining, fluidity of liquid metal, de-gassing
- v. Solidification: nucleation and growth, grain refinement, casting structures, freezing of pure metals and alloys, modeling and simulation of casting processes
- vi. Casting defects and their remedial measures
- vii. Post-cast Processing: cleaning operations and equipment, inspection and evaluation and heat treatment of castings.

### Suggested Books:

- John Campbell, "Castings", Butterworth-Heinemann, 2003.
- ASM Metals Handbook, "Casting", Volume 15, ASM International, 1991.
- Richard W. Heine, Carl R. Loper and Philip C. Rosenthal, "Principles of Metal Casting", Tata McGraw-Hill, Inc., 1976.
- John R. Brown, "Foseco Ferrous Foundryman's Handbook", Butterworth-Heinemann, 2000.

## 3. ADVANCED MATERIALS

- i. **Metallic:** functional material and shape memory alloys, super-alloys, maraging steels, magnetic alloys, aerospace material, titanium alloys, aluminum lithium and boron alloys, nano structured materials.
- ii. **Ceramics:** electro-ceramics, bio and nano ceramics, refractory and engineering ceramics, ceramic coatings, kinetics of glass transition, viscous and visco-elastic behavior, phase transformation, production techniques and heat treatment.
- iii. **Polymers:** manufacturing, properties and applications of polymers, polystyrene, polybutadiene, polyester, Poly Methyl Metha Acrylate (PMMA), nylon, Acrylonitrile-Butadiene-Styrene (ABS), manufacturing of foams, adhesives, formaldehyde, polyurethane and other advanced polymers, testing and identification of polymers, high density and high molecular weight polymers, aramid fibers.
- iv. **Composites:** classification, properties of matrix and fiber, composite processing and manufacturing of polymer matrix composites, ceramic matrix composites, metal matrix composites, machining of composites, specific applications.

**v. Biomedicals:** metallic implant materials, ceramic implant materials, polymeric implant materials, composites as biomaterials, structure and property relationships of biological materials, tissue response to implants, soft tissue replacement, sutures, skin, and maxillofacial implants, hard tissue replacement, tissue engineering materials and regeneration

#### **Suggested Books:**

- Michel Barsoum, “Fundamentals of Ceramics”, McGraw Hill Publications
- W. D. Kingery, H. K. Bowen, D. R. Uhlmann, “Introduction to Ceramic”, John Wiley and Sons,
- James, Reed, “Principles of Ceramic Processing”, 2<sup>nd</sup> Edition, 1995, John Wiley and Sons
- V. Tobolsky “Properties and Structure of Polymers”, John Wiley and Sons
- N. G. McGrum, C. P. Buckley, C. B. Bucknall, “Principles of Polymer Engineering”, Chapman and Hall Publishers, 1991
- Stanley Manaham, “Environmental Chemistry”, latest ed. 2008, LEWIS Pub.
- Paul C. Painter, Michael M. Coleman, “Essentials of Polymers Science and Engineering”, 2<sup>nd</sup> Ed. 2009, DEStech Pub. Inc.
- Richard M. Christensen, Mechanics of Composite Materials, 2005
- F.L. Mathews and R.D Rawlings, “Composite Materials: Engineering and Science”, Chapman Hall 1994
- ASM Handbook, Composites, vol. 21,2001
- Handbook of Composites edited by S.T. Petress Chapman Hall, 1998
- Joon Park & R.S. Lakes, Springer “Biomaterials an Introduction”, by Joon Park & R.S. Lakes, Springer, 3rd Edition , 2007.
- J. W. Nicholson “Chemistry of Medical and Dental Materials”, Royal Society of Chemistry, 2002.
- B D Ratner and A S Hoffman “Biomaterials Science”, , Elsevier, 2004

#### **4. SURFACE ENGINEERING**

- i. Surface Science and Properties: elements of material surface interactions and surface tension, Young’s sessile drop model, particle surface interactions and surface analysis by ions, electrons and photons
- ii. Surface Modification: quenching, hardenability, case hardening, carburizing, nitriding, nitro-carburizing
- iii. Deposition Techniques: Physical Vapor Deposition (PVD), Chemical Vapor Deposition (CVD), laser, plasma and thermal spray techniques
- iv. Advanced Coatings: coatings for corrosion resistance, aesthetic appearance, optical and electronic applications, Electro and Electroless Deposition, thermal barriers and composite coatings
- v. Characterization: AFM, AUGER, nano-indentation, nano-scratch, ellipso-metry, profile-metry, adhesion and wear testing, thickness measurement.

### **Suggested Books:**

- J. B. Hudson, "Surface Science: An Introduction" 1998
- W. D. Sproul, K. O. Legg, "Opportunities for Innovation: Advanced Surface Engineering", CRC Press, 1994)
- William E. Bryson, "Heat Treatment, Selection, and Application of Tool Steels", 2<sup>nd</sup> Edition, Gardner Publications 2005
- Gwidon Stachowiak and A W Batchelor, "Engineering Tribology", 2nd Edition, Butterworth and Heinman, 2005. ISBN: 0750678364

### **5. NANOTECHNOLOGY:**

- i. Nanotechnology: basic concepts, future prospects, initiatives, research and development in nanotechnology
- ii. Nanostructures: nanoparticles, nanowires, 0-3 dimensional materials, fullerenes C<sub>60</sub> materials and their applications, atomic structure, crystallography, surface structure, Nano lithographic techniques
- iii. Carbon nanotubes: introduction to CNT, single and multiwall nanotubes, catalysts synthesis and fabrication processes, synthesis of diamond and nanodiamond particles
- iv. Characterization: Scanning Tunneling Microscopy (STM) - Atomic Force Microscopy (AFM), X-ray Photo Electron Spectroscopy (XPS), Auger spectroscopy, FEG-SEM, ESEM, and STEM, High Resolution Transmission Electron Microscopy (HRTEM) and Energy Dispersive spectroscopy (EDS)
- v. Organic and Inorganic Compounds, Polymers and Biomaterials: polymerization and size of polymers, nanoparticles grafting, composites, conductive polymers, sol-gel process
- vi. Self Assembly and Catalysts: processing, nature of catalysis, surface area of nanoparticles, colloids
- vii. Nanotribology: micro- and nano- tribology, friction and wear at atomic scale, ultrathin and amorphous carbon monolayers and nanoscale mechanical properties
- viii. Safety: social and ethical implications related to nanotechnology.

### **Suggested Books**

- Charles P Poole Jr, Frank J Owens, "Introduction to nanotechnology", Publisher: John Wiley, 2003, ISBN-10: 0471079359
- "Handbook of nanotechnology" by Bhushan, Springer, 2003.