Curriculum for B.Sc. Metallurgical and Materials Engineering program for Session 2024 and onward

First Semester

PHY 114 & 114 L Applied Physics 3(2,1)

Course Outlines:

Introduction

System of absolute units, CGS units, practical units, relationship between electrical, mechanical and thermal units

Waves

Waves and oscillations, wavelength and frequency, interference of waves and the resulting amplitude

Electricity and Magnetism

Magnetic effects of current, relationship between electricity and magnetism, electro-magnetic induction, induction-heating and effect of frequency, magnetic materials, B-H curves, hysteresis, soft and hard magnets

Atomic and Nuclear Physics

Atomic and nuclear physics, isotopes, radio-activity, fission and fusion

Modern Physics and Electronics

Introduction to quantum - mechanics, electrical conduction through metals, electron-emission, thermionic emission, field-emission, secondary-emission, photoelectric-emission, photocells and photo-multiplier tubes, semi-conductors, basics of insulators and dielectrics, plasma Physics

Lab Outlines:

Lab Manuals will be available in the concerned laboratory.

Recommended Books:

1. Fundamental of Physics by David Halliday, Robert Resnick, and Jearl Walker. 10th ed. Extended edition (2015)
2. Applied Physics (University Physics) by Sears, Zemansky and Young. 7th ed.
3. Physics for scientist and Engineers with Modern Physics by Dougles C. Giancol. 4th ed.

HU 111L Communication Skills 1(0,1)

Course Description:

This is a practical course which offers an opportunity to learn, apply and practice principles of interpersonal communication in daily life. Emphasis is placed on psychological, social, cultural and linguistic factors which affect both interpersonal and inter-organizational dealings.

Methodology:

The following methodology will be used to attain the overall course objectives.

1. Group discussions
2. Case studies
3. Presentations
4. A/V aids
5. Audio/video clips
6. Pair works
7. Handouts
8. Home assignments
9. Quizzes

Recommended Books:

1. Effective Business Communicatrion by Murphy, Hildebrandt and Thomas. 7th Edition
2. Basic Communication Skills for Technology by A.J. Rutherford. 2nd Edition
3. Baisc Business Communication by Lasiker. 8th Edition
4. A practical English Grammer by Thomas and Martinet
5. English for Undergraduates by Howe and Kirkpatrick.

ME 122L Engineering Drawing 2(0,2)

Course/Lab Outlines:

Introduction, types of lines, lettering, dimensioning, use of pencil and drawing instruments, planning of drawing sheet

Projections, types of projections, orthographic projections, plane of projections, four quadrants, Isometric and pictorial projections of solids/machine parts

Making of freehand sketches from solid objects and from orthographic projections

Sections of joints, screw thread systems, nuts and bolts, keys and cotter, coupling and simple bearings, pipe connections and engine details, preparation of assembly drawings.

Recommended Books:

1. First Year Engineering Drawing by Albert Charles Parkinson.

MME 101 & MME 101L Introduction to Metallurgy and Materials 4(3,1)

Course Outlines:

An overview of Metallurgical and Materials Engineering, Classification of materials: metals, ceramics, polymers, and composites. Structure-properties relationship, crystal structures and crystalline defects, mechanical properties of materials. An overview of characterization techniques in materials science. Introduction to metal processing techniques: casting, metal working, welding, powder metallurgy, and heat treatment processes. Corrosion and prevention. An introduction to various alloys and phase diagrams. An overview of polymeric and ceramics materials processing techniques. Introduction to electric and magnetic materials, nano, bio, and advance materials.

Lab Outlines:

Lab Manuals will be available in the concerned laboratory

Recommended Books:

1. Fundamentals of Materials Science and Engineering by W. D. Callister, D. G. Rethwisch, 10th ed. Wiley, (2018).
2. Foundations of Materials Science and Engineering by W. F. Smith, J. Hashemi. 5th ed. Mc Graw Hill (2010)
3. Engineering Materials 1 by D.R.H. Jones and M. F. Ashby. 5th ed. Elsevier (2019)
4. Engineering Materials 2 by M. F. Ashby and D.R.H. Jones. 4th ed. Elsevier (2012)

MA 111 Applied Mathematics-I 3(3,0)

Pre-requisites:

Derivative of a function; Differentiation; Rules of differentiation; Differentiation of algebraic, trigonometric, inverse trigonometric, exponential and logarithmic functions; Differentiation of implicit functions; Increasing and decreasing functions; Maxima and minima of a function. Anti-derivatives; Integration; Basic techniques of integration; The definite integral. Algebra of complex numbers; polar form of complex numbers; Algebra of vectors; Scalar and vector products; Algebra of matrices; Determinants and their properties; Crammer's rule.

Course Outlines:

A review of differentiation; Geometrical interpretation of a derivative; Infinitesimal; Differential coefficient; Derivatives of higher order; Indeterminate forms and L. Hopital's rule; Asymptotes; Curvature; Approximation and error estimates.

The concept of limit, continuity and differentiation in functions of several variables; Geometric interpretation of partial derivatives; Total differential; Chain rule; Implicit differentiation; Maxima and minima of functions of two independent variables.

Further techniques of Integration; Integration by reduction formula; Fundamental Theorem of Integral Calculus; Properties of definite integrals; Area enclosed between curves; Arc length; Volume of a solid; Volume of a solid of revolution; Area of surface of revolution; Moments; Centroids.

Cartesian, cylindrical and spherical coordinates; The ratio formula; Equations of a straight line in R3; Direction ratios and direction cosines; Angle between two straight lines, Distance of a point from a line; Equations of a plane; Angle between two planes; The sphere; Vector triple products. Differentiation and integration of vectors; Directional derivatives.

Product and quotient of complex numbers in polar form; Properties of complex numbers; Lograthim of a complex number; De Moivres Theorem, The nth roots of a number; Solution of equations; Circular and hyperbolic functions. Analytic functions.

A review of matrices, determinants and finding inverse of a matrix through elementary row operations: Solution of the system of linear equations; Eigenvalues and eigenvectors.

Motion along a straight line with uniform acceleration, motion along a carved path. Tangential and normal components of acceleration.

Recommended Books:

1. Calculus by Thomas and Finny. Addison Wesley
2. Advanced Engineering Mathematics by E. Kreyszig. John Wiley & Sons
3. Calculus by Howard Anton.
4. Calculus by Swokowski.
5. Introduction to Mechanics by Q.K Ghori. Published by Ilmi Kitab Khana, Urdu Bazar, Lahore.

MGTXXX: Social Science Electives 2(2, 0)

These courses are part of University requirement and the contents are designed by the Institute of Business and Management.

Second Semester

CY 151 Material Chemistry-I 3(2,1)

Course Outlines:

Introduction to chemistry, its scope and importance in Metallurgy and Materials Engineering.

Classification of elements, periodic table and electronic configuration. State of matter (gas, liquid, solid) kinetic theory of gases, solutions. Basic laws: Roult's law, Henry's law, Sievert's law, Law of diffusion.

Theory of crystallization, atomic bonding, crystal systems, properties of solid, liquid and gases. Chemical equilibrium: Chemical reaction and equilibrium, chemical kinetics, theory of electro-chemistry, heterogeneous equilibrium, phase-rule, quantum theory.

Introduction to oxidation and reduction reactions in iron and steel making, Oxygen potential diagrams.

Organic chemistry: Introduction, nature and sources of compounds, hydrocarbon compounds, chemistry of hydrocarbon compound cracking, introduction to biochemistry.

Analytical chemistry: Introduction, qualitative and quantitative analysis of ferrous and non-ferrous metals, analysis of various ores, coals, liquid solution, introduction to analytical instrumentation

Lab Outlines:

Lab Manuals will be available in the concerned laboratory

Recommended Books:

1. Chemistry for Engineer by Shultz. 1st ed. Brookes Cole, (2006).
2. Materials Chemistry by Fahlman. 2nd ed. Springer, (2011).
3. Applied Chemistry by Hyman D. Gasser. Springer, (2002)
4. Applied Chemistry by Edward Andrew Parnell. D. Appleton & Co., (2007)
5. Chemistry by Thodore E. Brown. Prentice Hall, (2005)
6. Industrial Chemistry by M. Farhat. McGraw-Hill, (2004)

EE 199 & 199L Basic Electrical and Electronics Engineering 4(3,1)

Course Outlines:

DC Machines: Types of Excitation, Operation and characteristics of series, Shunt and compound generators and motors, Armature reaction, Stators, Selection of motors, Elementary transmission and distribution, DC and AC systems transmission voltages, Elements of house wiring: its testing, distribution, switching and fusing from the utilization point of view

AC Circuits: Series and parallel circuits and their combinations, Improvement of power factor by condensers, Three phase AC: advantages of single phase, Vector diagrams for the balances three phase system, Earthing of apparatus.

Transformers: Basic principle, Ration of transformation, Iron and Copper losses, Efficiency and regulation. Brief discussion and uses of instrument transformers and auto transformers, Three phase transformers, Star and delta connections, Scott connections, Constructional features, Cooling and protection from fire hazards.

AC Generators: Construction and working principles of alternator frequency, simple emf equation. Polyphase generation.

AC Motors: Concept of rotating field, polyphase induction motors, production of torque, slip, squirrel cage and slipring motors, starting of motors, construction of synchronous motors, production of torque and starting characteristics, selection of AC motors, measuring instruments, basic principles of construction and operation of moving iron dynamometer and hot wire instruments, power and energy meters, elementary consideration.

Storage Batteries: Lead and Nickel Iron cells, charge and discharge, quantity and energy efficiencies.

Lab Outlines:

Lab Manuals will be available in the concerned laboratory

Recommended Books:

1. Electricity: Principles and Applications by Richard Fowler. 8th ed. Mc-Graw Hill, (2012).

ME 100L Workshop Practice 1(0,1)

Course/Lab Outlines:

1. **Machine Shop:** Detailed study of centre lathe and accessories. Plain and Taper turning. Basic lath operations including turning, facing, simple screw cutting/treading, knurling, Grooving (Drilling and Boring), cutting tools and their grinding. Brief Introduction of shaper, milling Sharing and Surface Grinding Machine. Assigning of Practical Jobs.
2. **Fitting and Fabrication Shop:** The use and care of fitter's tools. Marking out of job. Practice in Metal filing. Sawing, Drilling, dieing, Tapping and reaming. Brief introduction and use of power Hack Saw, Arbor Press, Sheet Sharing Machine, Sheet Rolling Machine, Punching Machine and Drilling Machine. Assigning of practical Jobs.
3. **Carpentry Shop:** The use and care of tools. Type of Timber, its defects and preservation methods practice in planning and sawing. Different types of wood joints. Study of sawing, planning, turning mortise and tenon machines. Assigning of Practical Jobs.
4. **Electrical Shop:** Electric shocks and treatment. The use and care of tools used by Electrician. Types and uses of cable and electrical accessories for house wiring, practice in simple house wiring, testing methods. Switch gear used on domestic installation and DB system. Earthing System. Assigning of Wiring arrangements practical.

Recommended Books:

1. Workshop Technology part-1 by W.A.J Chapman.
2. Electrical Wring by Richter and Schwan
3. Wiring Manual by Pak Cables Limited.

MA 112 Applied Mathematics-II 3(3,0)

Pre-requisites:

Techniques of differentiation and integration (Applied Mathematics-I)

Course Outlines:

Double integration; Fubini's Theorems; Change of order; Geometrical Interpretation of double integral; Applications to find volumes and areas.

Formation of differential equations; Solution of various types of first order differential equations; Orthogonal trajectories, Application in physical problems; Linear differential equations of second order; Complementary function and particular integral; Methods of undetermined coefficients and variation of parameters.

Formation of partial differential equations; Equations reducible to ordinary differential equations; Equations of the form $Pp + Qq = R$; Solution by the method of separation of variables. Wave, heat and Laplace equations.

Laplace transforms of elementary functions. Basic properties. Inverse transform. Application in solution of initial value problems. Convolution theorem.

Periodic functions. Even and odd functions. Fourier series of functions of period 2. Arbitrary period, half range series.

Recommended Books:

1. Mathematics for Engineers and Scientists by Muhammad Nasir Ch. and Muhammad Iqbal Bhatti.
1. Published by Allied Book Centre, Urdu Bazar Lahore.
2. Advanced Engineering Mathematics by E. Kreyszig. John Wiley & Sons,
3. Calculus by Thomas & Finny. Addison Wesley
4. Calculus by Howard Anton.
5. Calculus by Swokowski.
6. Ordinary Differential Equations by N.A. Shah. A-one publishers, Urdu Bazar, Lahore.

QT 101 Translation of the Holy *Qur'ān* -I (1,0)

Week wise Course Contents:

Week	Details
Week 1	Translation of Part (*Parah*) 1, first ½ portion
Week 2	Translation of Part (*Parah*) 1, second ½ portion
Week 3	Translation of Part (*Parah*) 2, first ½ portion
Week 4	Translation of Part (*Parah*) 2, second ½ portion
Week 5	Translation of Part (*Parah*) 3, first ½ portion
Week 6	Translation of Part (*Parah*) 3, second ½ portion
Week 7	Translation of Part (*Parah*) 4, first ½ portion
Week 8	Translation of Part (*Parah*) 4, second ½ portion
Week 9	**Mid semester exam**
Week 10	Translation of Part (*Parah*) 5, first ½ portion
Week 11	Translation of Part (*Parah*) 5, second ½ portion
Week 12	Translation of Part (*Parah*) 6, first ½ portion
Week 13	Translation of Part (*Parah*) 6, second ½ portion
Week 14	Translation of Part (*Parah*) 7, first ½ portion
Week 15	Translation of Part (*Parah*) 7, second ½ portion
Week 16	Translation of Part (*Parah*) 8, first ½ portion
Week 17	Translation of Part (*Parah*) 8, second ½ portion
Week 18	**End semester exam**

List of recommended translations of the Holy *Qur'ān:*

1. موضح القرآن شاه عبدالقادر دہلوی 2. فتح القرآن فتح محمد جالندھری 3. ترجمہ قرآن مجیدحافظ نذر احمد
4. آسان ترجمہ قرآن سید شبیر حسین 5. احسن البیان مولانا محمد جونا گڑھی
6. ترجمہ ضیا القرآن پیر کرم شاہ الازہری
7. آسان ترجمہ قرآن مولانا محمد تقی عثمانی 8. ترجمہ قرآن مولانا اشرف تھانوی
9. کشف الرحمٰن مولانا احمد سعید دہلوی
10. ترجمہ تبیان القرآن مولانا غلام رسول سعیدی 11. مصباح القرآن ڈاکٹر عبدالرحمٰن طاہر 12. معانی القرآن دارالسلام
13. ترجمہ قرآن سید ابو الاعلیٰ مودودی 14.قرآن مجید ،لفظی ترجمہ ڈاکٹر فرحت ہاشمی 15.مقبول القرآن سید مقبول احمد دہلوی
16- آسان ترجمہ قرآن محمد ظفر
17. The meaning of Glorious *Qur'ān*. Marmaduke Pickthal
18. *Qur'ān* Translation English Abdullah Yousaf Ali
19. *Qur'ān* Translation English Dr. Mohammad Mahmood Ghali
20. *Qur'ān* Translation English Muhammad Asad

CS-103 & CS-103L Introduction of computer programming for data science 3(2,1)

Course Outlines:

This course serves as an introduction to computer programming. We will study and implement the standard introductory topics of Python. Besides that, we will learn the applications of programming to data science.

Lab Outlines:

Lab Manuals will be available in the concerned laboratory

Recommended Books:

1. Paul Deitel & Harvey Deitel, “Intro to Python® for Computer Science and Data Science: Learning to Program with AI, Big Data and the Cloud”, Pearson Education, Inc. 2020

Optional Books

1. Wes McKinney, “Python for Data Analysis”, O’Reilly Media, Inc, 2018
2. Jake VanderPlas, “Python Data Science Handbook”, O’Reilly Media, Inc, 2017

Third Semester

MME206: Mechanics of Materials 2(2, 0)

Course Outlines:

Short review of methods of statics, Stresses in the member of a structures, Analysis and design, Axial Loading: Normal Stress, Centric & Eccentric Loading, Shearing Stress, Bearing Stress in Connections, Stress Analysis & Design Example, Stress in Two Force Members, Stress on an Oblique Plane, Stress Under General Loadings, Normal Strain, Stress-Strain Test, Ductile vs. Brittle Behavior, Hooke's Law, Static Indeterminacy, Thermal Stresses, Poisson's Ratio, Dilatation: Bulk Modulus, Stress Concentration: Hole & Fillet, Torsional Loads on Circular Shafts, failure modes & stress-strain, Net Torque Due to Internal Stresses, Axial Shear Components, Shaft Deformations, Pure Bending, Symmetric Member in Pure Bending, Stress and Strain Due to Bending, Bending of Members Made of Several Materials, Reinforced Concrete Beams, Shear and Bending Moment Diagrams, Relations Among Load, Shear, and Bending Moment, Design of Prismatic Beams for Bending, Singularity Functions used to determine Shear and Bending Moment, Mohr's Circle.

Recommended Books:

1. Mechanics of Materials by Beer and Johnston. 8th ed. McGraw Hill Inc., (2020)
2. Mechanics of Materials by J.M. Gere and B.J. Goodno. 7th ed. (SI edition). CL Engineering, (2008)
3. Strength of Materials by Andrew Pytel and Ferdinand Leon Singer. 4th ed. Harper International, (1990)

MA 240 & 240L Numerical Analysis 3(2,1)

Course Outlines:

Basic concepts: round-off errors, floating point arithmetic, Convergence.
Solution of non-linear equations: Simple iterations; Bisection method; Newton's method; Secant method; Method of false position.
Solution of linear simultaneous equations: Jacobi's method; Gauss-Seidle method;
Finite differences: Difference operators and tables; Newton's interpolating techniques for equally spaced data; Newton divided difference table and interpolation; Lagrange's formulation of interpolation.
Numerical differentiation: approximating the derivative.
Numerical integration: Review of integration concept and their physical significance for engineering; Trapezoidal and Simpson's rules. Solution of differential equations : Euler's methods; Runge Kutta methods. Computations: Numerical techniques in context of engineering applications and solutions of problems by using Matlab.

Lab Outlines:

Lab Manuals will be available in the concerned laboratory

Recommended Books:

1. Numerical Methods for Engineers by S. C Chapra & R. P Canale, McGraw-Hill.
2. Numerical Methods using MATLAB by John H. Mathews, Pearson Education.
3. Applied Numerical Methods for Engineers using MATLAB by Robert J. Schilling & Sandra L. Harris, Brooks/Cole.
4. Numerical Methods for Engineers and Scientists by D. Joe Hoffman.

5. A First Course in Numerical Analysis with FORTRAN and C. by Saeed Akhtar Bhatti.

MME 202 Applied Thermodynamics 3(3,0)

Course Outlines:

Introduction to Metallurgical Thermodynamics, concept of system and surroundings, extensive and intensive properties.
First Law of Thermodynamics, concept of Enthalpy, calculation of heat of reactions, concept of heat capacity and its variation with temperature, Kirchoff's equation and its applications in the calculation of heat of reaction at high temperatures.
Concept of Entropy, Second Law of thermodynamics, Third law of thermodynamics, calculation of entropy of elements and reactions at various temperatures.
Free-energy, and the concept of driving-force behind a chemical or physical reaction, Free energy of mixing.
Equilibrium constant, Le-Chatlier's Principle, Factors affecting the equilibrium position Relationship of equilibrium constant with free energy, Calculations of equilibrium partial pressures. Ellingham diagrams and their application to commercially important reactions
Behavior of solutions, concept of activity, ideal and non-ideal solutions, Raoult's and Henry's Law, Gibbs Phase Rule, Clausius Clapeyron Equation, Concept of diffusion, Phase diagrams.

Recommended Books:

1. Metallurgical Thermodynamics Kinetics And Numericals by Dutta S.K. (Author), Lele A.B. (2017)
2. An introduction to Chemical Metallurgy by R. H. Parker. 2nd ed. Elsevier, (2013)
3. Phase Transformation in Metals and Alloys by D.A. Porter and K.E. Easterling. 4th ed. CRC Press,, (2021)

MME-207L Occupational Health and safety 1(0, 1)

Lab outlines:

This lab course includes Occupational Health and Safety (OHS) and its culture, OHS approach and legislation, occupational accident and disease concept, risk factors in safety, individual and organizational factors, record keeping. The students will be trained on OHS and they will explore the OHS issues of various types of working environments.

MME208 & MME208L: Polymeric Materials 3(2, 1)

Course Outlines:

Introduction to and classification of polymeric materials. Molecular structure. Principles, kinetics and mechanisms of polymerization. Homogenous and Heterogeneous polymerization. Bulk, Solution, Suspension, and Emulsion techniques of polymerization.Different Additives for polymers: Fillers, Plasticizers, Stabilizers, Coloring matters, Lubricants, Flow promotors, Crosslinking agents. Glass transitioning temperature. Polymers' crystallinity. Liquid crystal polymers. Visco-elastic behavior. Thermal, Oxidative, Ultra Violet, Chemical (swelling, Dissolution), Radiation, Mechanical, and Biological degradation of polymers. Fabrication techniques for thermoplastics and thermosets. Polymeric composites.

Recommended Books:

1. Polymer Science and Technology by Joel R. Fried. 3rd ed. Prentice Hall, (2014)

2. Foundations of Materials Science and Engineering by William F. Smith, Javaid Hashemi. 5th ed. (2009)
3. Fundamentals of Materials Science and Engineering by William D. Callister, David G. Rethwisch: An Integrated Approach. 5th ed. Wiley (2022)

Fourth Semester

MME 213 Extractive Metallurgy 2(2,0)

Course Outlines:

Brief history of ferrous and non-ferrous metals, Sources of ferrous/non-ferrous metals, Mineral Processing of ores. Principles of metals extraction: Thermodynamic principles, homogeneous and heterogeneous reactions, Ellingham diagrams, kinetic principles, principles of electro-chemistry. General methods of extraction: pyro-metallurgy, hydrometallurgy, and electrometallurgy. Charge and energy calculations. General methods of refining.
Extraction of metals from oxide sources: Basic approaches and special features of specific extraction processes, extraction of metals such as magnesium, aluminum, tin, chromium and ferro-alloying elements, production of ferro-alloys. Extraction of metals from sulphide ores: Pyro-metallurgy and hydro-metallurgy of sulphides, production of metals such as copper, lead, zinc, nickel etc. Extraction of metals from halides: Production of halides and refining methods, production of reactive and nuclear reactor metals. Methods of extraction of metals such as titanium, rare earths, uranium, thorium, plutonium, beryllium, zirconium etc. Production of precious metals: Methods applied for gold, silver, and Pt group metals. Secondary production of metals and utilization of wastes, Energy and environmental issues in nonferrous metals extraction.

Recommended Books:

1. Non-Ferrous Extractive Metallurgy - Industrial Practices by Roger Rumbu. (2010)
2. Extraction of Nonferrous Metals by H.S. Ray, R. Sridhar and K.P. Abraham. Affiliated East West Press Pvt Ltd., New Delhi, (2007).
3. Principles of Extractive Metallurgy by T. Rosenqvist. 2nd ed. (reprinted), McGraw Hill, New York, (2004)

MME 217a & 217aL Physical Metallurgy 4(3,1)

Course Outlines:

Introduction to Physical Metallurgy; structure properties relationship; Atomic and crystalline structure; crystal symmetry; crystallographic defects; Allotropy and polymorphism; Miller indexing system; stacking of planes; Atomic, linear and planar densities; concept of Interstitial Voids.
Solidification (Homogeneous and heterogeneous); Nucleation and growth; Grain-boundaries and grain structure; Role of Metallurgical microscope in the analysis of microstructure; theory of etching and concept of grain boundary energy.
Phase-rule; Solid solutions; limits of solid solubility; types of Compounds; different types of binary phase diagrams: Isomorphous system, Eutectic and eutectoid reactions, coherent/in-coherent precipitates, Peritectic and peritectoid reactions; Ordered and disordered solutions; Iron-Iron carbide system, microstructure and properties of plain carbon steels and cast-irons; microstructure of common copper-base and aluminum-base alloys.

Lab Outlines:

Lab Manuals will be available in the concerned laboratory

Recommended Books:

1. Physical Metallurgy: Principles and Design by Gregory N. Haidemenopoulos. CRC Press, (2018)
2. Physical Metallurgy: Metals, Alloys, Phase Transformations by Vadim M. Schastlivtsev, Vitaly I. Zel'dovich, Walter de Gruyter GmbH (2022)

3. Materials Science and Engineering: An Introduction by Williams D. Callister, 10th Edition, Wiley (2018)

MME 219 & 219L Inspection and Testing of Materials 4(3, 1)

Course Outlines:

Introduction to inspection and testing of Materials. Hardness Testing (Arbitrary or indentation, Rebound of dynamic, Scratch, Abrasion, and File hardness testing methods. Macro-hardness Testing (Brinell, Rockwell), Micro-hardness Testing (Knoop, Vickers, Ultrasonic).

Tensile testing (Engineering Stress Strain Curve. Resilience, Toughness, True-stress-strain concepts, ductile & brittle fracture, Power law or Holloman's relationship, Effect of strain rate & temperature, Tensile vs Compression test.

Three/four point Bend test. Torsion test (Rotational-Linear Parallels, Polar Moment of inertia, torsion properties, Torque Twist Diagram, Torsional stresses for large plastic strains, Mohr's Circle, Hot Torsion Test.

Fatigue test (SN curve), Creep test (creep curve), Impact Test (Izod, Charpy), Temperature Transition Curve (Ductile to Brittle Transition Temperature)

Non-destructive testing (Visual Testing, Leak Testing, Radiographic method, Magnetic particle method, Magnetic flux leakage, Eddy Current Testing, Dye penetrant method, ultrasonic method, Phase array testing, Thermal/infrared testing, Vibration Analysis, Boroscopy.

Reliability and maintainability, inspection of different types of materials and products for evaluation. Common standards used for material inspection and testing.

Recommended Books:

1. Inspection of Metals: Understanding the Basics by F. C. Campbell, ASM International (2020)
2. Mechanical Metallurgy by George E. Dieter. McGraw-Hill Book Company (UK) Ltd., (2002)
3. Introduction to Non-Destructive Testing, a training guide by Paul E. Mix. 2nd ed. Wiley, (2005)

MA 242 Engineering Statistics 3(3,0)

Course Outlines:

Introduction & role of statistics in engineering.

Population & samples, Variables, Methods of displaying data sets, Stem & leaf display, Histogram, Histogram shapes, Boxplot, Bar chart, Pareto diagram, Dot diagram, Frequency distributions & their graphs, Outlier.

Mean, Median, Quartile, Percentile, Range, Deviation from mean, Sample variance, Sample standard deviation, Coefficient of variation.

Probability, Concepts & definitions, Basic theorems of probability, Law of total probability, Bayes theorem, Discrete and continuous random variables and their probability distributions, Density and distribution functions; Expectation.

Mean & variance of discrete & continuous random variables, Binomial distribution, Poisson distribution, Normal distribution, t-distribution, Chi- square distribution, F-distribution.

Sampling techniques and sampling distribution; Point estimation and interval estimation of parameters, Least square linear & polynomial regression, Linearization of nonlinear models, Correlation, Design of experiments, Analysis of variance.

Recommended Books:

1. Applied Statistics for Engineers & Scientists by Devore/Farnum. 3rd ed. Thomas.
2. Probability and Statistics for Engineers and Scientists by Ronald E. Walpole. 8th ed. Pearson Educational International, (2007).
3. Probability and Statistics for Engineering and Sciences. 8th ed. CENGAGE Learning.
4. Advanced Engineering Mathematics by Erwin Kreyszig. 11th ed. John and Wiley and Sons.
5. Applied Statistics and Probability for Engineers by Montgomery and Runger. 3rd ed. John and Wiley and Sons.
6. Probability and Random Variables and Stochastic Processes by Papoulis Athanasios, 3rd ed. McGraw-Hill Inc.
7. Introduction to Statistical Theory by Muhammad Shehzad and Sher Muhammad. Ilmi Kitab Khana Urdu Bazar Lahore.

QT 201 Translation of the Holy Quran-II 1(1,0)

Week wise Course Contents

Week	Details
Week 1	Translation of Part (*Parah*) 9, first ½ portion
Week 2	Translation of Part (*Parah*) 9, second ½ portion
Week 3	Translation of Part (*Parah*) 10, first ½ portion
Week 4	Translation of Part (*Parah*) 10, second ½ portion
Week 5	Translation of Part (*Parah*) 11, first ½ portion
Week 6	Translation of Part (*Parah*) 11, second ½ portion
Week 7	Translation of Part (*Parah*) 12, first ½ portion
Week 8	Translation of Part (*Parah*) 12, second ½ portion
Week 9	**Mid Semester Exam**
Week 10	Translation of Part (*Parah*) 13, first ½ portion
Week 11	Translation of Part (*Parah*) 13, second ½ portion
Week 12	Translation of Part (*Parah*) 14, first ½ portion
Week 13	Translation of Part (*Parah*) 14, second ½ portion
Week 14	Translation of Part (*Parah*) 15, first ½ portion
Week 15	Translation of Part (*Parah*) 15, second ½ portion
Week 16	Translation of Part (*Parah*) 16, first ½ portion
Week 17	Translation of Part (*Parah*) 16, second ½ portion
Week 18	**End Semester Exam**

List of recommended translations of the Holy *Qur'ān:*

1. موضح القرآن شاہ عبدالقادر دہلوی 2. فتح القرآن فتح محمد جالندھری 3. ترجمہ قرآن مجیدحافظ نذر احمد
4. آسان ترجمہ قرآن سید شبیر حسین 5. احسن البیان مولانا محمد جونا گڑھی 6. ترجمہ ضیا القرآن پیر کرم شاہ الازہری
7. آسان ترجمہ قرآن مولانا محمد تقی عثمانی 8. ترجمہ قرآن مولانا اشرف تھانوی 9. کشف الرحمٰن مولانا احمد سعید دہلوی
10. ترجمہ تبیان القرآن ,مولانا غلام رسول سعیدی 11. مصباح القرآن ڈاکٹر عبدالرحمٰن طاہر 12. معانی القرآن دارالسلام
13. ترجمہ قرآن سید ابو الاعلیٰ مودودی 14.قرآن مجید،لفظی ترجمہ ڈاکٹر فرحت ہاشمی 15.مقبول القرآن سید مقبول احمد دہلوی
16- آسان ترجمہ قرآن
17. The meaning of Glorious *Qur'ān*. Marmaduke Pickthal محمد ظفر
18. *Qur'ān* Translation English Abdullah Yousaf Ali
19. *Qur'ān* Translation English Dr. Mohammad Mahmood Ghali

MME209 Electrical and Magnetic Materials (2,0)

Course Outlines:

Classification and concept of Electrical and Electronic Materials. Metallic materials and their electrical properties. Semiconductor materials and their electrical properties. Semiconductor devices. Ceramic materials used in electronic applications.
Magnetic materials and their classification. Magnetization curve, hysteresis loop. Types of magnetic behavior. Ferromagnetic domains. Experimental evidence for domains. Domain wall motion. Hindrances to wall motion. Soft Magnetic Materials: Desirable properties for soft magnetic materials. Potential applications of soft magnetic materials. Hard Magnetic Materials: Properties of Hard magnetic materials. Origin of Ferromagnetism in Rare Earth based permanent magnets. Potential applications of permanent magnets.

Recommended Books:

1. Fundamentals of Materials Science and Engineering by William D. Callister, David G. Rethwisch, An Integrated Approach. 10trh edition, Wiley (2018)
2. Foundations of Materials Science and Engineering by William Smith, Javed Hashemi. 5th ed. (2009)
3. The Science and Engineering of Materials by Donald R. Askeland, Pradeep P. Fulay, Wendelin J. Wright. 6th ed. (2010)

Fifth Semester

MME312a & MME312aL Ceramic Materials 4(3,1)

Course Outlines:

Introduction to various classes of ceramics, Traditional versus advance ceramics, History, applications.
Bonding Characteristics of Ceramics, Crystal Structures–Binary ionic compounds, Composite crystal structure, Covalent Ceramics, Pauling's Rules, Silicate Structures.
Ceramics as refractories in metallurgical industries, their types and classifications. Production of refractory bricks and other shapes of traditional ceramics, structural changes during processing/sintering of refractories. Selection of refractories for ferrous and non-ferrous industries.
Production and processing of ceramics, Basic principles and techniques of consolidation and shaping of ceramics: powder pressing – uni-, bi-axial and cold & hot isostatic pressing, injection molding, slip casting, tape-casting.
Sintering and sintering theory of ceramics. Defects in Ceramics, Types of defects and Quasichemical Defect Reactions, Kroger Vink notation and use in defect equations, Electronic Defects and Band Structure.
Glasses, glass-system, vitrification process in glasses, Structures of Glasses, Zachariasen's Rules)

Lab Outlines:

Lab Manuals will be available in the concerned laboratory

Recommended Books:

1. Fundamentals of Ceramics by M W Barsoum. 2nd ed. CRC Press, (2020)
2. Modern Ceramic Engineering: Properties, Processing, and Use in Design by David Richerson. 4th ed. CRC Press, (2018)
3. Ceramic and Glass Materials: Structure, Properties and Processing by James F. Shackelford (Editor), Robert H. Doremus. 1st ed. Springer, (2008)

MME329 Mechanical Behavior of Engineering Materials 3(3,0)

Pre-requisite: MME 219

Course Outlines:

A review of the structure of materials and crystalline imperfections. Elasticity (review of stress and strain concepts, Hooke's law, Elastic strain energy); Plasticity (Analysis of Stress-strain behavior, Yielding criteria of Metals and Hardness); Notches (Stress concentration factor, Neuber's rule, Tensile testing of notched specimens).
Fracture Mechanics (Fracture modes; Linear elastic fracture mechanics: stress intensity factor and fracture toughness); Theoretical cohesive strength and Griffith criteria; Plain strain toughness testing; crack tip opening displacement (CTOD).
Plastic deformation and role of Dislocations; types of dislocations; Slip systems; Critical resolved shear stress; Taylor factor; Dislocation interaction; Thermally activated processes; Intersection of dislocations. Ductile-brittle transition. Strengthening Mechanisms. Severe plastic deformation. Fracture behavior of metallic materials (ductile, brittle fractures); different types of embrittlements; Stress-corrosion cracking. Fatigue and creep deformation and fracture (Structural changes; theories and mechanism of crack initiation and propagation; Materials' selection).
Mechanical behavior of thin films and coatings; Mechanical behavior of Polymers, Ceramics, glasses and composites; Weibull Modulus

Recommended Books:

1. Mechanical Behavior of Material by Norman E. Dowling (Author), Stephen L. Kampe (Author), Milo V. Kral, Global Edition 5th Edition, Pearson (2019)
2. Mechanical Behaviour of Engineering Materials: Metals, Ceramics, Polymers by Joachim Roesler, Harald Harders, Martin Baeker. Springer, (2007)
3. Mechanical Metallurgy by George E. Dieter. SI Metric ed. McGraw Hill Inc., (2002)

MME 313 & 313L Foundry Engineering 4(3,1)

Course Outlines:

Introduction to Foundry Engineering and Practice; Scope and importance; Foundry industry in Pakistan; Types and different sections of a foundry; foundry tools, machines and types of furnaces; Furnace Charges and Calculations.
Pattern; pattern design, materials and pattern making techniques. Selection, properties and testing of suitable molding and core materials. Molding Processes: Green sand and dry sand molding; Shell molding; Core sand molding; CO_2 molding; water glass molding; resin sand molding; alpha set and no bake process; molding sand properties and testing. Pit and floor molding; Loam molding; Molding machines and equipment; Mold coatings; 3D printing in sand molding. Molding Cores: Ingredients and Properties of core sand; Binders; core design, coatings; baking and finishing; core testing.
Mold designing: Design and essentials of gating system; design of pouring cups sprue; runners types and gates; Gating ratio; riser shape, location and design; pressure-less and pressurized gating systems
Other foundry techniques: Plaster casting; Investment casting; low pressure die casting; high pressure die casting; Permanent mold casting; Centrifugal casting; Slush casting; Ingot as casting; Gravity die casting
Ferrous and non-ferrous casting techniques; selection and control of melting processes; Casting and fettling operation; Metal gas interaction; Solidification of pure metal and alloys; Solidification in a mold; Directional and non-directional solidification
Casting Defect types; remedies; inspection of castings; Role of casting simulations to control defects and minimize losses. Casting Cleaning methods

Lab Outlines:

Lab Manuals will be available in the concerned laboratory

Recommended Books:

1. Principles of Metal Casting by Mahi Sahoo, Sudhari "Sam" Sahu, McGraw Hill (2014)
2. Complete Casting Handbook: Metal Casting Processes, Metallurgy, Techniques and Design by John Campbell, 2nd Edition, Butterworth Heinemann (2015)
3. Principles of Foundry Technology by P L Jain. 8th ed. Tata McGraw-Hill, (2008)

MME317: Entrepreneurship 2(2, 0)

Course outlines:

Introduction to entrepreneurship. Commercialization of innovations and ideas, generating ideas, generic and transferable skills required to become an entrepreneur, awareness of the legal, business, managerial, creative, analytical and interpersonal skills relevant to setting up and running an innovative organization. Entrepreneurial motivation, characteristics, Contexts of entrepreneurial activity, Opportunity recognition, Opportunity assessment, Acquiring resources, Business models, case studies, Entrepreneurial activities, Leadership and social entrepreneurship, Exits and outcomes.

Recommended Books:

1. Absolute Essentials of Business and Economics by Nerys Fuller-Love, Absolute Essentials of Entrepreneurship-Routledge, (2020).
2. Disciplined Entrepreneurship Startup Tactics: 15 Tactics to Turn Your Business Plan into a Business by Paul Cheek, 1st Edition, Willey (2024)
3. From Idea to Execution: The Ultimate Business Startup Guide by Tye Theats (2023)

MME 305 & MME 305L Welding and Joining of Materials 4(3,1)

Course Outlines:

Introduction to Joining Processes and Classification.
Fusion Welding: Arc Welding Processes; Resistance Welding processes; Special Welding processes
Solid State Welding: Brazing, Soldering, Adhesive Bonding, Friction stir welding etc.
Metallurgy of Welding: Weld-ability of Ferrous and Non-ferrous Alloy Systems, Stresses in Welds, Testing and Non-Destructive Evaluation of Welds.
Formulation of WPS, WPQ and WPR, Fabrication and Repair procedures for Weld Assemblies, Welding of Dissimilar Materials with special emphasis on Metal-Ceramic and Ceramic-Ceramic Joining, recent Trends in Joining Technologies.
Polymers as joining materials, glasses as joining materials

Lab Outlines:

Lab Manuals will be available in the concerned laboratory

Recommended Books:

1. Welding Principles and Applications, Larry Jeffus, 9th ed. Cengage Learning; 9th edition, (2020)
2. Principles of Welding: Processes, Physics, Chemistry and Metallurgy, Robert W. Messler, Wiley & Sons, (2015)
3. Joining of Materials and Structures: From Pragmatic Process to Enabling Technology, Robert W. Messler. 1st ed. Butterworth-Heinemann, (2004)

QT 301 Translation of the Holy Quran-III 1(1,0)

Week wise Course Contents

Week	Details
Week 1	Translation of Part (*Parah*) 25, first ½ portion
Week 2	Translation of Part (*Parah*) 25, second ½ portion
Week 3	Translation of Part (*Parah*) 26, first ½ portion
Week 4	Translation of Part (*Parah*) 26, second ½ portion
Week 5	Translation of Part (*Parah*) 27, first ½ portion
Week 6	Translation of Part (*Parah*) 27, second ½ portion
Week 7	Translation of Part (*Parah*) 28, first ½ portion
Week 8	Translation of Part (*Parah*) 28, second ½ portion
Week 9	**Mid Semester Exam**
Week 10	Translation of Part (*Parah*) 29, first ¼ portion

Week 11	Translation of Part (*Parah*) 29, second ¼ portion
Week 12	Translation of Part (*Parah*) 29, third ¼ portion
Week 13	Translation of Part (*Parah*) 29, fourth ¼ portion
Week 14	Translation of Part (*Parah*) 30, first ¼ portion
Week 15	Translation of Part (*Parah*) 30, second ¼ portion
Week 16	Translation of Part (*Parah*) 30, third ¼ portion
Week 17	Translation of Part (*Parah*) 30, fourth ¼ portion
Week 18	**End Semester Exam**

List of recommended translations of the Holy *Qur'ān:*

1. موضح القرآن شاہ عبدالقادر دہلوی 2. فتح القرآن فتح محمد جالندھری 3. ترجمہ قرآن مجیدحافظ نذر احمد
4. آسان ترجمہ قرآن سید شبیر حسین 5. احسن البیان مولانا محمد جونا گڑھی 6. ترجمہ ضیا القرآن پیر کرم شاہ الازہری
7. آسان ترجمہ قرآن مولانا محمد تقی عثمانی 8. ترجمہ قرآن , مولانا اشرف تھانوی 9. کشف الرحمٰن مولانا احمد سعید دہلوی
10. ترجمہ تبیان القرآن , ولانا غلام رسول سعیدی 11. مصباح القرآن, ڈاکٹر عبدالرحمٰن طاہر 12. معانی القرآن دارالسلام
13. ترجمہ قرآن سید ابو الاعلیٰ مودودی 14.فہم القرآن،لفظی ترجمہ ڈاکٹر فرحت ہاشمی 15.مقبول القرآن سید مقبول احمد دہلوی 16- آسان ترجمہ قرآن محمد ظفر
17. The meaning of Glorious *Qur'ān* Marmaduke Pickthal
18. *Qur'ān* Translation English Abdullah Yousaf Ali
19. *Qur'ān* Translation English Dr. Mohammad Mahmood Ghali
20. *Qur'ān* Translation English Muhammad Asad

Sixth Semester

MME 310a Characterization of Engineering Materials 3(3,0)

Course Outlines:

Introduction to characterization techniques and their application in Materials science and Engineering
Production and absorption of X-rays; use of filters; X-ray diffraction and Bragg's law; structure factor calculations; diffraction methods; Debye-Scherer camera; Laue back-reflection; and rotating-crystal method. XRD spectrum and its Indexing; Precise lattice parameter determination; Particle size and micro/macro strains calculations. Chemical analysis by X-ray fluorescence.
Stereographic projections; orientation of crystal with respect to a reference; rotation of crystal around an axis; planes of a zone. Crystal structure determination; single crystals orientation; pole figures; Applications of X-ray diffraction.
Scanning electron microscope (SEM); construction and working principle; interaction of electrons with matter; modes of operation; image formation of plane and fractured surfaces. Energy Dispersive X-rays and wavelength dispersive X-rays systems;
Electron diffraction and basics of transmission electron microscopy (TEM); Image formation; resolving power and magnification; depth of focus; elementary treatment of image contrasts; important lens defects and their correction. Bright field and dark field images. Introduction to Scanning Tunneling microscope and its various types e.g Atomic force microscopy; Piezo-force microscopy; Magnetic force microscopy etc. Introduction to Raman spectroscopy and its use in materials science. Spectroscopic techniques, spark emission spectroscopy, absorption spectroscopy etc.

Recommended Books:

1. Materials Characterization: Modern Methods and Applications Edited By N. (Mohan) Ranganathan, 1st Edition, Jenny Stanford Publishing (2016)
2. Characterization of Materials by Elton N. Kaufmann. 3 Volume Set, Wiley, (2012)
3. X-Ray Diffraction by B. D. Cullity. 3rd ed. Prentice Hall, (2001)

MME327a & MME327aL: Heat Treatment and Phase Transformation 3(2, 1)

Pre-requisite: MME 217a

Course Outlines:
Thermodynamics of Phase Transformation: Gibbs free energy and phase equilibrium. Clausius Clapeyron equation. Gibbs free energy changes in unary system and binary alloys, Free energy of mixing, Ordered-disordered phases. G vs X_B curves and phase diagrams. Driving Force for diffusion, Fick's first and second laws of diffusion. Interfaces: Structure and types of interfaces, free energy of grain boundary, Nucleation and Growth: Nucleation of precipitates from a supersaturated matrix. Diffusion and diffusion less transformations: Kinetics and mechanisms of Austenitic, Pearlitic, Bainitic and martensitic transformations. Time temperature transformation and continuous cooling diagrams.
Heat Treatment processes: Annealing, normalizing, and quenching processes. Hardenability measurement techniques. Surface hardening methods. Precipitation hardening (ageing). Heat treatment of different types of steels and cast-irons, heat treatment of common non-ferrous alloys.

Lab Outlines:

Lab Manuals will be available in the concerned laboratory

Recommended Books:

1. Heat Treatment: Principles and Techniques by T.V. Rajan, C.P Sharma, Ashok Sharma. 2nd ed. Prentice Hall, India, (2011)
2. Phase Transformation in Metals and Alloys by D. A. Porter, K. E. Easterling and M. Y. Sherif. 3rd ed., CRC press (2009)
3. Physical Metallurgy: Metals, Alloys, Phase Transformations by Vadim M. Schastlivtsev, Vitaly I. Zel'dovich, Walter de Gruyter GmbH (2022)

MME309a & MME309aL: Computational Methods in Materials Engineering 3(1, 2)

Course outlines:

Introduction to computational material science and engineering. Types of stress/strain components (elastic/plastic). Introduction to modelling and simulation software (Abaqus / Solidworks); 3D part and assembly modelling, finite element analysis; stress analysis using finite element modeling. 1D Structural Analysis (Truss Elements – Overhead Hoist); 3D Mechanical (Elastic/Plastic) Analysis; deformation of basic structure (Cantilever Beam); 3D Mechanical (Elastic) Analysis; deformation of mechanical parts (Connecting Lug); 2D Heat Transfer + Mechanical Analysis (Plane Stress/Strain) (2D Trapezoidal Plate); Tensile Test – Axisymmetric, 2D or 3D – Elastic, Elasto-plastic with/without damage (Tensile Test of a Ductile Material); Contact analysis including rigid and deformable bodies (3 Points Bend Test;, Modelling of elastic properties; plastic deformation and mechanical behavior of engineering materials. Data analysis and plotting using Microsoft excel and Origin.

Recommended books:

1. Introduction to Materials Modelling by Zoe H. Barber. Maney Publishing, (20015)
2. Computational Materials Science by Dierk Raabe. Wiley VCH Verlag GmbH, (1998)
3. An Introduction to Computer Simulation by M.M. Wolfson, G.J. Pert. Oxford, (1999)

MME 316 & MME 316L Corrosion and Corrosion Control 4(3,1)

Course Outlines:

Introduction to Corrosion – Electrochemical Nature; Electrochemical cell and Principles; corrosion rate expressions (based on weight loss & penetration); EMF & Galvanic Series; Nernst Equation & its application; Reference electrodes.
Pourbaix Diagrams (Al, Fe, Zn E-pH diagrams); thermodynamic approach to pourbaix diagrams; equilibrium conditions; limitations of pourbaix diagrams.
Corrosion Kinetics; Polarization; different types of corrosion and their control.
Passivity; Cathodic protection & design of CP system; Anodic Protection.
Electrochemical parameters & their use in corrosion studies.
Corrosion Prevention Methods (Corrosion control) by: Inhibition, Coatings, Corrosion testing through weight loss and electrochemical methods. Selection of materials
Introduction to API methods of Corrosion evaluation.

Lab Outlines:

Lab Manuals will be available in the concerned laboratory

Recommended books:

1. Corrosion Science and Engineering by Pietro Pedeferri, Springer link (2018)
2. Corrosion Engineering by Mars G. Fontana. 3rd ed. Tata McGraw-Hill, (2005)

3. API-571 Document.

MME 323 Iron and Steel Making Processes 3(3,0)

Pre-requisite: MME 213

Course Outlines:

A brief review of solution thermodynamics. Mineral processing of iron ores, agglomeration processes for iron ores, blast furnace process and reactions, blast furnace gas cleaning system and blast furnace stoves. Recent developments in BF process. Alternate iron making processes. Introduction to steelmaking fundamentals, oxidation reactions in steelmaking processes. Primary steelmaking processes: basic oxygen furnace (BOF) and electric arc furnace (EAF), design and process description, latest trends in BOF and EAF Processes. Induction furnace, design, and process description. Secondary steelmaking processes: argon purging, ladle de-oxidation, degassing, and emerging ladle metallurgy processes. Continuous casting of steel. Charge calculations for iron and steel making processes. Environmental impacts of steel industry. Concepts of standards and specification of ferrous alloy systems.

Recommended Books:

1. Basic Concepts of Iron and Steel Making by S. K. Dutta and Y. B. Chokshi, (eBook), Springer Nature, (2020).
2. An Introduction to Modern Iron Making by R.H. Tupkary and V.R. Tupkary. 4th ed. Khana Publications India, (2013).
3. An Introduction to Modern Steel Making by R. H. Tupkary and V. R. Tupkary. 7th ed. Khana Publications India, (2008).

MME306a: Industrial and Financial Management 2(2, 0)

Course outlines:

Introduction to management, operation functions and management, production management strategy. Classification of production system, Functions of Production Management Department.

Operations Management (Framework, Objectives, Global operations, Functions, Planning & controlling the operations). Manufacturing system design, Production management strategy, Forecasting requirements, Approaches to forecasting (Based on judgment & opinion, Time series, historical data). Decision making, Management in service environments, Plant (Location, Layout, Design, Equipment & Maintenance).

Financial Management, corporate finance and capital markets, emphasizing the financial aspects of managerial decisions, the valuation of real and financial assets, risk management, corporate financing and dividend policy.

Project Management (project life cycle, work breakdown structure, Gantt charts, Activity-on-node diagram, PERT, CPM)

Quality, Quality Control, Quality assurance, Fundamental factors affecting quality, Inspection (purpose, type, methods, drawbacks), seven tools for QC, Total quality management, Quality management systems, ISO-9000, ISO-14000

Recommended Books

1. Operations Engineering and Management: Concepts, Analytics and Principles for Improvement by Seyed M. R. Iravani, 1st edition, McGraw Hill (2020)
2. Production and Operations Management by Keith Lockyer. Pitman, ELBS ed., (2000)
3. Financial Management by Dr. F. C. Sharma, , C S Rachit Mittal, SPBD Publications (2021)

Seventh Semester

MME423a: Solidification of Metals and Alloys 2(2, 0)

Pre-requisite: MME 313

Course outlines:

Freezing patterns in metals and alloys. Nucleation and growth in alloys. The effects of mold material and alloy composition upon freezing pattern. Centerline feeding resistance. The rate of solidification.
Segregation and its types, Shrinkage & its distribution, Gas porosity. Use of Chills in casting. Solidification defects. Fluidity and its measurements (Factors Affecting Fluidity; Pouring Time and Cross Sectional area of in-gates; Chvorinov rule; critical velocity and critical height; Effect of surface tension and impurities; Determining fill time required for a casting; Sievert's law)
Metallurgy, design and production of important alloys (e.g., cast irons, alloy steels, aluminum, copper alloys, Titanium and super alloys etc.)

Recommended Books:

1. Principles of Metal Casting by Mahi Sahoo, Sudhari "Sam" Sahu, McGraw Hill (2014)
2. Complete Casting Handbook: Metal Casting Processes, Metallurgy, Techniques and Design by John Campbell, 2nd Edition, Butterworth Heinemann (2015)
3. Principles of Foundry Technology by P L Jain. 8th ed. Tata McGraw-Hill, (2008)
4. New Trends in Alloy Development, Characterization and Application by Zaki Ahmad, Intechopen Publishing (2021)

MME427: Advanced Ceramics 2(2, 0)

Pre-requisite: MME 312a

Course outlines:

Review of ceramic fundamentals and introduction to advanced ceramics; Engineering applications of ceramics at room and high temperatures. Oxide and non-oxide ceramics; crystal and defect structures; non-stoichiometry and typical properties; Microstructure-properties relationship, Preparation of single crystal, thick and thin film ceramics. Characterization of ceramics. Aerogels. Alumina ceramics. Zirconia ceramics. SiC ceramics. Si_3N_4 ceramics. Nuclear ceramics. Bio-medical applications of ceramic materials. Ceramics for energy and environment technologies – fuel cell, Thermoelectrics etc. Ferroelectric, Piezoelectric and Pyro-electric ceramics, semi-conducting and super-conducting applications. Li-Ion Batteries. Smart and nano-ceramics.

Recommended Books:

1. Advanced Ceramics for Versatile Interdisciplinary Applications by Editors: Shiv Singh, Pradip Kumar, D.P. Mondal, Elsevier (2022)
2. Fundamentals of Ceramics by M W Barsoum. 2nd ed. CRC Press, (2020)
3. Electroceramics by A.J. Moulson. Wiley, (2003)

QT 401 Translation of the Holy Quran-III 1(1,0)

Week wise Course Contents

Week	Details
Week 1	Translation of Part (*Parah*) 25, first ½ portion
Week 2	Translation of Part (*Parah*) 25, second ½ portion
Week 3	Translation of Part (*Parah*) 26, first ½ portion
Week 4	Translation of Part (*Parah*) 26, second ½ portion
Week 5	Translation of Part (*Parah*) 27, first ½ portion
Week 6	Translation of Part (*Parah*) 27, second ½ portion
Week 7	Translation of Part (*Parah*) 28, first ½ portion
Week 8	Translation of Part (*Parah*) 28, second ½ portion
Week 9	**Mid Semester Exam**
Week 10	Translation of Part (*Parah*) 29, first ¼ portion
Week 11	Translation of Part (*Parah*) 29, second ¼ portion
Week 12	Translation of Part (*Parah*) 29, third ¼ portion
Week 13	Translation of Part (*Parah*) 29, fourth ¼ portion
Week 14	Translation of Part (*Parah*) 30, first ¼ portion
Week 15	Translation of Part (*Parah*) 30, second ¼ portion
Week 16	Translation of Part (*Parah*) 30, third ¼ portion
Week 17	Translation of Part (*Parah*) 30, fourth ¼ portion
Week 18	**End Semester Exam**

List of recommended translations of the Holy *Qur'ān:*

1. موضح القرآن شاہ عبدالقادر دہلوی 2. فتح القرآن فتح محمد جالندھری 3. ترجمہ قرآن مجیدحافظ نذر احمد
4. آسان ترجمہ قرآن سید شبیر حسین 5. احسن البیان مولانا محمد جونا گڑھی 6. ترجمہ ضیا القرآن پیر کرم شاہ الازہری
7. آسان ترجمہ قرآن مولانا محمد تقی عثمانی 8. ترجمہ قرآن , مولانا اشرف تھانوی 9. کشف الرحمٰن مولانا احمد سعید دہلوی
10. ترجمہ تبیان القرآن , ولانا غلام رسول سعیدی 11. مصباح القرآن, ڈاکٹر عبدالرحمٰن طاہر 12. معانی القرآن دارالسلام
13. ترجمہ قرآن سید ابو الاعلیٰ مودودی 14.فہم القرآن،لفظی ترجمہ ڈاکٹر فرحت ہاشمی 15.مقبول القرآن سید مقبول احمد دہلوی 16- آسان ترجمہ قرآن محمد ظفر
17. The meaning of Glorious *Qur'ān* Marmaduke Pickthal
18. *Qur'ān* Translation English Abdullah Yousaf Ali
19. *Qur'ān* Translation English Dr. Mohammad Mahmood Ghali
20. *Qur'ān* Translation English Muhammad Asad

MME 429 Metal Working and Removal Processes 3(3,0)

Pre-requisite: MME 329

Course Outlines:

Principles of metal forming processes, Softening and Hardening Mechanism, Metal-Working in the Re-crystallization, Non-recrystallization and Two-Phase regions, Concept of dynamic, static recovery & re-crystallization, Aspect Ratio.

Rolling, process and equipment, forces in rolling, metal flow, defects and their prevention.
Forging, process and equipment, Forces in Forging, grain flow, forging defects and their prevention.
Extrusion, Processes and equipment, extrusion-defects. Wire-drawing.
Sheet-metal working, stretch forming, deep drawing, continuous roll forming.
Machining (Turning), Vertical and Horizontal Milling, Friction stir processing,
Machinability, tool design, chip formation, factors affecting machinability.

Recommended Books:

1. Manufacturing Processes for Engineering Materials by Serope Kalpakjian. 6th ed. Pearson, (2017)
2. Introduction to Manufacturing Processes by Mikell P. Groover. Wiley (2011)
3. Mechanical Metallurgy by George E. Dieter. SI metric edition. McGraw Hill, (2002)

MME-XXX (Engineering Elective 01) 2(2,0)

MME-XXX (Engineering Elective 02) 2(2,0)

Final Project-I MME 424 3(0,3)

Eighth Semester

MME403a: Composite Materials 2(2, 0)

Course outlines:
Introduction to composite materials, Classification of Composites, Role of Interface Fibers, whiskers and particulates in composites: Synthesis and properties of glass fibers, carbon fibers, aramid fibers, metallic and ceramic fibers and particulates. Matrixes and interface developments. Manufacturing of PMC's (Polymeric Matrix Composites), MMCs (Metal Matrix Composites) and CMCs (Ceramic Matrix Composites). Mechanical Properties of Composites, Factors effecting mechanical properties, rule of mixture, multi-ply laminates, Halpin-Tsai equations. Recycling of composites, Material Selection.

Recommended Books:

1. Introduction to Composite Materials Design by Ever J. Barero. 3rd ed. (2018)
2. Principles of Composite Material Mechanics by Ronald F. Gibson. 4th ed. (2016)
3. Composite Materials by Deborah D L Chung. Springer, (2010)

MME-XXX (Engineering Elective 03) 2(2,0)

MME-XXX (Engineering Elective 04) 2(2,0)

MME-XXX (Engineering Elective 05) 2(2,0)

MME-XXX (Engineering Elective 06) 2(2,0)

MME-XXX (Engineering Elective 07) 2(2,0)

MME 425 Final Project-II 3(0,3)

Pre-requisite: MME 424

Course Contents of Engineering Elective Courses to be offered in final year:

MME 401 Nuclear Materials 2(2,0)

Course Outlines:

Introduction of nuclear energy, Nuclear fission reaction, Breeding ratio, breeding gain.

Classification of nuclear fission reactors, Gas cooled reactors, Light water reactors, Heavy water reactors, Liquid metal fast breeder reactors.

Nuclear fuel materials, structural materials, moderator, reflector and blanket materials, Control element materials, coolants, shielding materials

Crystal imperfections or defects, Radiation effects or damages by fast neutron, irradiation effect on nuclear, physical, and thermal properties, Irradiation effect on mechanical properties, Creep, Fatigue, and Corrosion.

General properties in the selection of nuclear reactor materials, Special properties in the selection of nuclear reactor materials

Classification of primary components and main materials for nuclear fission reactors. Structural Materials (cladding), Moderator, Reflector, Blanket and Coolant Materials

Metallic uranium as fuel, Ceramics uranium fuels, Plutonium fuel, Thorium as fuel.

Recommended Books:

1. Nuclear Material Science by Karl Whittle. IOP Science (2020)
2. Nuclear Materials by Hemsworth. Nova science PUB inc. (2011)
3. Introduction to Nuclear Reactor Theory by J. Lemarsh. Addison-Wesley, (2002)

MME 402 Nano Materials 2(2,0)

Course Outlines:

Overview of Nanostructures and Nanomaterials; Bottom up and Bottom Down approaches; Surface Energy concept; Chemical potential of surface; different types of stabilizations.

Nanostructures: Zero Dimensional nanomaterials: Nanoparticles, Quantum Dots, One-Dimensional nano-materials**:** Nanowires nano-rods, carbon nanotubes, Two-Dimensional nanomaterials: Thin films and monolayers, Carbon-based nanomaterials: Carbon nanotubes, Graphene, Nanostructured carbon. Synthesis of Nano-materials.

Applications of nanostructures: Reinforcement in Ceramics, Drug delivery, Giant magneto- resistance, etc. Cells response to nanostructures. Overview of characterization of nanostructures and nanomaterials.

Surfaces and interfaces in nanostructures. Ceramic interfaces, Superhydrophobic surfaces, Grain boundaries in Nano-crystalline materials, Defects associated with interfaces.

Recommended Books:

1. Nanomaterials: The original product of nanotechnology by Maria Benelmekki. IOP Science (2019)
2. Nanostructures and Nanomaterials: Synthesis properties and applications by Cao, G., Wang, Y. 2nd ed. World Scientific, Singapore, (2011).
3. Nanoscale Science and Technology by Kelsall, Hamely & Geoghegan,. Wiley, (2005)

MME 405 Surface Science and Engineering 2(2,0)

Course Outlines:

Tribology of surfaces: surface integrity; surface roughness and waviness; measurement of surface roughness and texture; friction and theories; types of wear and their mechanisms; lubrication and its regimes; applications of lubrications in wear

Mechanical surface treatment: Propelling abrasive media; blasting techniques; selection of abrasive media; different peening techniques. Surface finishing methods: selection and applications; tumbling; vibratory finishing; belt Sanding; wire brushing, buffing and electro-polishing. Chemical cleaning of surfaces: selection and applications; alkaline cleaning; solvent cleaning and vapor degreasing; molten salt bath cleaning; ultrasonic cleaning; acid cleaning; pickling and descaling.

Coatings: Paints and organic coatings; powder coating; hot-dip coating; chemical conversion coatings; blackening; coloring of metals; electroplating, electrophoretic deposition; anodizing; electroless-plating; mechanical plating; Chemical vapor deposition (CVD) and Physical vapor deposition (PVD) techniques; Thermal and cold spraying methods; Sputtering; sol gel method. A brief overview of surface hardening methods. Cladding techniques; roll bonding; explosive welding; applications of cladding in nuclear, marine and other technological fields

Recommended Books:

1. Surface Engineering: Enhancing Life of Tribological Components by Dheerendra Kumar Dwivedi, Springer (2018)
2. Tribology and Surface Engineering for Industrial Applications by Catalin I. Pruncu, Amit Aherwar, Stanislav Gorb, 1st Edition, CRC Press (2021)
3. Manufacturing Engineering & Technology by Serope Kalpakjian and Steve R. Schmid, 7th Edition, Pearson (2013)

MME 406 Bio Materials 2(2,0)

Course Outlines:

Introduction to biomaterials and biochemistry; biocompatibility and bioactivity, bio-reabsorable & bio-erodible materials. Hydrogels & smart polymers.

Cell biology, surface properties of materials, intermolecular forces in biology. Response of materials in human body; effect of mechanical forces on cells & tissues; biomematic materials; Importance of water in biomaterials.

In-vivo and In-vitro testing. Biocompatible metals: Ti-based, Stainless Steels, Co-Cr-Mo alloys, nitinol; biomaterials surface & protein; textured & porous materials; Bio active glasses; Bioreabsorbale ceramics; adhesives & sealants.

Applications (Orthopedic, Dental, cardiovascular, soft tissue replacement, hard tissue replacement); Drug delivery system (nano-carriers, polymer-drug conjugates, nucleic acids, etc.),

Biomaterial corrosion; blood & materials interaction; tumors associated with biomaterials

Recommended books:

1. Biomaterials Science: An Introduction to Materials in Medicine by William R. Wagner, Shelly E. Sakiyama-Elbert, ... Michael J. Yaszemski. Elsevier (2020)
2. Biomaterials: principles & applications by Joon B. Park, Joseph D. Bronzino. 1st ed. CRC Press (2002)
3. An Introduction to Biomaterials by Jeffrey O. Hollinger. 2nd ed. CRC Press, (2012)

MME 407 Vacuum Technology 2(2,0)

Course Outlines:

Vacuum technology: Vacuum classification, Kinetic picture of a gas; Velocity Distribution, Mean free path, Collision frequency, Particle Flux, Monolayer Formation Time, Flow characteristics of gas (Knudsen number).

Vacuum pumps: Positive displacement pumps; Diaphragm pump, Water ring pump, rotary and roots pump, vapour ejector and vapour entrainment pumps, diffusion pump, turbo-molecular pump, ion pumps, sieve pumps, adsorption pumps.

Vacuum measuring devices: Manometers, McLoad gauge, Penning gauge, Pirani gauge, Ionization gauges.

Calculation of vacuum systems; conductance and throughput, effective pumping speed, gas flow through pipes and orifices. Sources of leakage, leakage detection and remedies.

Application of vacuum in materials processing; Vacuum induction melting, vacuum arc melting. Metal refining in vacuum, degassing in liquid state, vacuum sintering, vacuum coatings.

Recommended books:

1. Vacuum Technology by Alexander Roth. North-Holland, (2012)
2. Vacuum technology: practice for scientific instruments by Nagamitsu Yoshimura. Springer, (2008).
3. Vacuum Metallurgy by Choudhury, A. ASM Intl, (2000)

MME 408 Energy Materials 2(2,0)

Course Outlines:

Photovoltaic (PV) materials: electromagnetic waves, light absorption, Solar radiation, solar spectra, solar energy concentration, solar cell parameters, losses and efficiency limits, crystalline silicon solar cells, thin-film solar cells, and other types, PV modules and systems, PV system economics and ecology.

Battery materials: Electrochemical fundamentals, electrochemical cell, charging and discharging, phase transition, order-disorder transition, electrode processes at equilibrium, energy efficiency, cycle life, Materials for electrode, Materials for non-rechargeable batteries, Materials for rechargeable batteries.

Fuel cell applications: Overview of fuel cell types, charge transfer and mass transport, Thermodynamics and reaction kinetics, Proton exchange membrane and solid oxide fuel cell materials, Fuel cell system design and characterization.

Materials for hydrogen technology: Methods of Hydrogen production, hydrogen from the decomposition of materials, Hydrogen storage in solids: metal hydrides, ammonia and related materials, reversible organic liquids.

Lighting and Light Emitting Diodes: Rare Earth Ions for LED Lighting Devices, Synthesis and luminescence study of phosphors, Synthesis and characterization of energy efficient organometallic complexes for OLED display applications

Recommended Books

1. Energy Materials: Fundamentals to Applications by Sanjay Dhoble, N. Kalyani, B. Vengadaesvaran, Abdul Arof. Elsevier (2021)
2. Fuel Cell Fundamentals, O'Hayre, Cha, Colella, and Prinz. Wiley, (2016)
3. Energy Materials, D. W. Bruce, D. O'Hare, R. I. Walton. Wiley, (2011)

MME 409 Advanced Steels 2(2,0)

Course Outlines:

Review of microstructure-property relationships in steels. Types of steels and their classification.

High strength low Alloy (HSLA), micro-alloyed, stainless steels, duplex, super duplex, high yield steels, IF (interstitial-free), Maraging Steels, TRIP steels, Ultra Low carbon steels, nitrogen containing fine grained steels, tool steels, die steels, Quenched and partitioned steels (QPS). Steels for low and high temperature applications, Orthopaedic steels, super alloys etc.

Production routes for advanced steels (VIM, VAR, ESR etc.), Processing of steels: thermo-mechanical processing, advantages and limitations, TMT steels, dual phase steels.

Recommended Books:

1. Advanced Steels: From Materials Science to Structural Engineering by Wei Sha. Springer (2013)
2. Steels: Microstructure & Properties by Robert Honeycomb and Harry Bhadeshia. Elsevier (2005)
3. Physical Metallurgy and Design of Steels by Pickering, F. B. Applied Science Publishers (2000)

MME 410 High Temperature Materials 2(2,0)

Course Outlines:

Introduction to high temperature materials; applications; the phenomena and problems associated with high temperatures applications of materials.

High Temperature behaviour of Mechanical Materials: Plasticity, Fatigue and thermal fatigue, Creep.

High temperature chemical behaviour: Oxidation and Corrosion.

Design of alloys for high temperature. Refractory Metals, Inter-metallics, Stainless Steels, Nickel and Cobalt-based Superalloys, Ceramics and Cermets for High Temperature Applications. Alloy Theory, Heat Treatment and Hardening Mechanisms. Oxidation Resistant and Thermal Barrier Coatings.

Recommended Books:

1. High Temperature materials and mechanisms by Yoseph Bar-cohen, Taylor & Francis Group (2014)
2. High Temperature Coatings by Bose. 2nd ed. Butterworth Heinemann (2017)
3. Materials for High Temperature Engineering Applications by Meetham, G.W., Van de Voorde, M.H. Springer (2000).

MME 413 Fracture and Failure Analysis 2(2,0)

Course Outlines:

Fracture and its types, ductile, brittle (intergranular and transgranular), Plane stress and plane strain conditions, Griffith's and Orowon theory of fracture.

Linear elastic and elastoplastic fracture mechanics. Fracture Toughness Testing, stress intensity factor and its range. Paris Law. Determination of K_{1c}, Compact Tension, J-integral and Crack Opening Displacement (COD) methods. Tensile, Creep, Fatigue and environmental fractures. Stress corrosion cracking. Ductile to Brittle Transition Temperature and its determination. Fracture toughness testing of composites materials. Fracture toughness testing of reinforced/composite materials.

Failure analysis procedures; Fractography and Case studies of fractured components; different types of mechanical/industrial failures; root cause analysis and remedial actions

Recommended Books:

1. Deformation and fracture mechanics of engineering materials by Hertzberg. 5th Edition.Wiley (2012)
2. ASM Handbook on Failure Analysis and Prevention, Volume 11, Latest edition
3. ASM Handbook on Fractography, Volume 12, Latest edition

MME 414 Functional Materials 2(2,0)

Course Outlines:

Introduction to functional materials; Crystal structure and functional properties relationship. Quantum Theory.

Electrical and thermal (vibration and phonons) conduction mechanism. Insulation, electrical, optical, photovoltaic and magnetic properties and applications of functional materials. Design and selection of materials

Surface properties; Surface and interfaces; growth of nano-structures; Photo-catalysis; antibacterial and biologically inert surfaces; Self-cleaning, easy-to-clean surfaces, bio ceramics. Functional materials coatings: anti-microbial coatings, air curable coatings, anti-ice coating; Functional coatings for metals, polymers and glasses: hydrophobic and hydrophilic surfaces; transparent conductive coating; barrier coatings; integrated functional coatings. Bio functional coatings: biocompatible and bioactive coatings. Material challenges and their implementation in devices, an introduction to the synthesis of some common functional materials

Recommended Books:

1. Advanced Functional Materials by Tiwari, L. Uzun. Wiley (2015)
2. Biofunctional Surface Engineering by Martin Scholz. Pan Stanford Publishing (2014)
3. Handbook of Biofunctional Surfaces by Wolfgang Knoll. Pan Stanford (2013)

MME 415 Thin Film Technology 2(2,0)

Course Outlines:

Introduction to thin film technology. Thin film deposition and growth mechanism by Physical vapour deposition (PVD) techniques like evaporation, sputtering, ion-plating etc. Chemical coating methods such as chemical vapour deposition (CVD) and atomic layer deposition (ALD). Plasma based methods for thin film deposition. Molecular Beam Epitaxial (MBE) growth. Different physical and chemical processes. Substrate effects of coating deposition. Tribological and hard thin coatings. Functional coatings for devices. Models for nucleation and film growth. Morphology and texture. Applications of thin film materials and deposition technologies.

Recommended Books:

1. Thin Film Coatings: Properties, Deposition, and Applications by Fredrick Madaraka Mwema, Tien-Chien Jen, Lin Zhu. Taylor and Francis (2022)
2. Handbook of Thin Film Technology by Hamid R. Khan. 1st Edition. Springer (2015)
3. Recent Advances in Thin Films by Editors: Sushil Kumar, D. K. Aswa. Springer (2020)

MME 416 Additive Manufacturing 2(2,0)

Course Outlines:

An overview of additive manufacturing: how it is different from conventional manufacturing processes; history. Process fundamentals; structure shaping and creation; applications of additive manufacturing. Role of CAD and laser scanning. Final component geometry. Different techniques used for 3D printing of metallic (SLM, EBM, LMD, powder DED, wire DED, binder jetting, BPE etc.) polymeric (FDM, SLS, stereolithogrpahy etc.) and other materials. Design implications; surface finish; microstructure' mechanical and other properties; residual stresses and effects on fatigue life.

Recommended Books:

1. Additive Manufacturing by The Open University. The open learn (2019)
2. Introduction to Additive Manufacturing: technologies, materials, benefits, challenges and applications by Nicola Accialini. (2022)
3. Additive Manufacturing Technologies by by Ian Gibson, David Rosen, Brent Stucker, Mahyar Khorasani. 3rd edition. Springer (2021)

MME 418 Powder Metallurgy 2(2,0)

Course Outlines:

Introduction to powder metallurgy, Applications of powder metallurgy. Advantages and design limitations of powder metallurgy
Powder particles sampling, dispersion & de-agglomeration; Sieve and microscopic analysis; sedimentation; laser light; particle size distributions; data presentation
Characterization of powders: microstructure; particle shape; pycnometer; surface area test; internal structure and chemistry
Production of powders: mechanical methods; electrolytic methods; Atomization techniques; chemical methods
Powders modification and handling; mixing and blending; different lubricants and binders; Powders molding, shaping and compaction (cold and hot compacting methods physical characteristics of powder compacts, compaction defects).
Sintering theory and practices, solid state and liquid phase sintering, modern sintering techniques, sintering atmospheres, thermodynamics of sintering.
Inspection and quality control for P/M parts, the economics of P/M production, new development in powder metallurgy processes

Recommended books:

1. Powder Metallurgy: Science, Technology, and Materials by Anish Upadhyaya, Gopal Shankar Upadhyaya. University Press, (2011)
2. Powder metallurgy: science, technology and applications by P. C. Angelo, R. Subramanian. (2009)
3. Fundamentals of Powder Metallurgy by West, William G, F. Leander, Pease. Metal Powder Industries Federation, (2002)

MME 419: Construction and Building Materials 2(2, 0)

Course outlines:
Overview: Materials for construction and building, principal properties, and classification. Evaluation of materials' choices and their impact. Processing/Manufacturing, properties, practice, challenges/issues, and

future of construction and building materials: Wood, sands, clay, stones, aggregates, asphalt and bituminous materials, bricks and blocks, tiles, glass, cements, admixtures, mortars, concretes, pavement materials, pozzolanas, thermal insulations, and finishings. Concretes: Materials for making concrete, concrete mix designs, reinforcements, special concretes. Green construction and building materials. Recycling of construction and building materials.

Recommended Books:

1. Building Materials by S. K. Duggal, 3rd revised edition. New Age International Publishers, (2021).
2. Construction Materials by Peter Domone and John Illston, 4th edition, Spon Press (Talor & Francis Group), (2010).