

ANNEXURE – I
SYLLABI FOR THE ENTRANCE TEST
PART – I
ENGINEERING MATHEMATICS (Common to all Candidates)

Determinants and Matrices: Solving system of equations – Rank of the Matrix – Eigenvalues and eigenvectors – Reduction of quadratic form to canonical form.

Calculus and Differential Equations: Partial derivatives – Jacobians – Taylor's expansion – Maxima and Minima. Linear ordinary differential equations with constant coefficients – Simultaneous first order linear equations with constant coefficients. Formation of partial differential equation (PDE) – Solution of first order PDE – Solution of linear higher order PDE with constant coefficients.

Vector Calculus: Double and triple integrations and their applications – Gradient, Divergence, Curl and Laplacian – Green's, Gauss divergence and Stroke's theorem.

Functions of Complex Variables and Complex Integration: Analytic functions – Conformal Mapping – Bilinear transformation – Cauchy's integral theorem and integral formula – Taylor and Laurent Series – Singularities – Residues – Residue theorem and its applications.

Transforms: Laplace Transform – Inverse transforms – Application to solution of linear ordinary differential equations with constant coefficients. Fourier integral theorem – Fourier transform pair – Sine and Cosine transforms. - Transform – Inverse Z-transform – Solution of difference equations using Z- transform.

Numerical Methods: Solution of linear system by direct and iterative methods – Interpolation and approximation – Numerical Differentiation and Integration – Solving Ordinary Differential Equations.

Applied Probability: Probability and Random variables – Standard Discrete and Continuous distribution – Moments – Moment generating function and their properties. Two-Dimensional Random Variables – Covariance – Correlation and Regression.

PART – II
BASIC ENGINEERING & SCIENCES (Common to all Candidates)

Applied Mechanics: Law of Mechanics – Lamé's theorem – Forces, Moments and Couples – Displacement, velocity and Acceleration – Friction – Moment of Inertia.

Mechanical Engineering: Laws of thermodynamics – Open and closed systems – Equation of state – Heat and Work.

Physics: Sound – Lattices – Ultrasonic flaw detector – X-ray radiography – Interference Fringes – Planck's quantum theory – Laser and Fibre Optics.

Material Science: Fracture – Magnetic and Dielectric materials – Conductor and Semi conductor materials – Ceramic and Super conductor materials.

Civil Engineering: Fluid Statics and Dynamics – Boundary Layer – Pumps and Turbines – Environmental Pollution.

Electrical Engineering: Ohm's law – Kirchoff's law – A.C. circuits – D.C. machines – Transformers – Synchronous machines – Instrumentation.-

Computers: Computer organization – Architecture – Arrays – Pointers – User defined function – C program.

Chemistry: Adsorption – Chromatography – Chemical kinetics – Electrochemistry – Spectroscopy – Fuels and Combustion.

PART – III (Group A)

1. CIVIL ENGINEERING

Structural Engineering: Mechanics: Stress-Strain Relationships – Principal stresses and Principal strain in two dimension and three dimension. Composite Bars – Composite Beams – Elastic Constants. Beams and Bending – Shear Force and Bending Moment Diagrams – Flexural and shear Stresses. Slope and Deflection of Beams. Thin and Thick Cylinders. Torsion. Theories of Failure – Unsymmetrical Bending – Curved Beams – Theories of Columns. Combined Direct and Bending Stresses.

Structural Analysis: Static and Kinematic Indeterminacy – Energy Principles – Deflection of pin jointed plane frames – rigid frames. Classical Method of Analysis of indeterminate structures (Slope deflection and Moment Distribution) – Matrix Method. Arches and Suspension Bridges – Influence Line for Determinate and Indeterminate Structures. Plastic Analysis of Structures.

Building Materials: Cement – Concrete – properties of ingredients – Mix Design – Quality Control – Special Concrete – Concreting Methods – Brick – Brick Masonry – Stone – Timber – Steel.

Concrete Structures: Design Methods – Limit State Design for beams, slabs, columns and footings – retaining walls – water Tanks. Prestressed Concrete – Principles – Methods – Losses – Deflection – Design.

Steel Structures: Steel Sections – Connections – Design of Tension and Compression Members – Beams, Column Bases – Plate Girders and Trusses.

Soil Mechanics and Foundation Engineering:

Soil Mechanics: Nature of soil – phase relationships – soil classification; Soil water – static pressure – effective stress principle; permeability – seepage; Stress distribution in soil – Consolidation (Terzaghi's one dimension consolidation theory); Compaction shear strength of soil – Mohr - Coulomb theory – determination of shear strength by different methods; Slope stability analysis – protection measures.

Foundation Engineering: Site investigation – scope and objectives – drilling techniques – depth and spacing of boreholes – sampling techniques – penetration tests (SPT and SCPT) – plate load test – selection of foundation; Foundation types – shallow foundation – bearing capacity (Terzaghi's Theory and BIS formula) – allowable bearing pressure – bearing capacity from field tests – settlement of foundation – allowable settlement – Codal provisions; Design of foundations – Isolated, combined and raft foundation; Pile foundations – static and dynamic pile driving formulae (Engineering News and Hiley method) – Pile groups – capacity and settlement – Codal provisions – pile load test – negative friction on piles; Earth pressure theories – Earth pressure on retaining walls – stability analysis of retaining wall.

Transportation Engineering: Highway Planning: Road Classification, Geometric Design of Highways, Construction of Earth, WBM, Bituminous and concrete roads, Design of flexible and rigid pavements. Drainage of roads, Maintenance of roads. Railways, Airways, Docks and Harbour Planning: Railway alignment components of permanent way, geometric design Airport planning, components of airport, site selection, planning for terminal building, runways. Harbour planning, components of harbour, inland water transport. Traffic Engineering: Traffic characteristics, Traffic surveys, Traffic Signals, Road markings and signs.

Water Resources Engineering: Fluid Mechanics and hydraulics: Properties of fluids. Fluid statics and relative equilibrium. Basic concepts of fluid flow – kinematics and dynamics. Concept of system and control volume application to continuity, momentum and energy equations. Dimensional analysis and model studies. Laminar and turbulent flow through pipes. Boundary layers. Steady uniform and gradually varied flow in open channels. Rapidly varied flows. Turbines and pumps and positive displacement pumps.

Hydrology and Ground Water: Hydrometeorology. Hydrologic cycle. Precipitation and its measurements. Abstractions. Runoff estimation. Hydrograph analysis. Unit Hydrograph. Hydrologic extremes floods and droughts. Rainwater harvesting. Properties of aquifer. Groundwater development. GEC norms. Well hydraulics. Steady and unsteady flows. Ground water quality.

Irrigation Engineering: Irrigation system. National water policy. Components of irrigation network. Design of lined and unlined channels. Waterways, head works, gravity dams and spillways. Design of weirs on permeable foundation. Soil water relations. Crop water requirements. Irrigation scheduling and methods. Duty, delta and base period. Irrigation water quality. Irrigation water management. Participatory approach.

Environmental Engineering: Water and waste water Engineering; Water requirements; water demand; quality standards; Development of water supply source, conveyance system; basic unit processes and operations for water treatment; water distribution; sewage characteristics; sewage treatment, primary and secondary treatment of sewage, sludge disposal, sewage disposal.

Air Pollution and Control: Types of Pollutants, their sources and impacts, air pollution meteorology, air pollution control, air quality standards and limits.

Noise pollution and Control: Impacts of noise, permissible limits of noise pollution, measurement of noise and control of noise pollution.

Surveying: Chain surveying, compass surveying – plane table surveying – levelling – theodolite surveying – Temporary and permanent adjustments for level and theodolite – trigonometric levelling – tachemetry – traversing – contouring – Computation of areas and volumes. Curve Setting – simple, compound and reverse curves – transition curves – vertical curves – Electromagnetic distance measurement – Total station – construction surveying – hydrographic surveying – route survey – triangulation – astronomical survey.

2. COMPUTER SCIENCE AND ENGINEERING / INFORMATION TECHNOLOGY

Applied Probability And Operations Research: Random Processes, Probability Distributions, Queuing Models and Simulation, Testing of Hypothesis, Design of Experiments.

Discrete Mathematical Structures: Formal Language and Automata - Graph Theory.

Compiler Design: Optimization – Code Generation – Implementation – Principles of Programming Languages – Programming Paradigms.

Operating Systems And System Software: Process Management, Storage Management, I/O Systems, Design and Implementation of LINUX OS, assemblers, Loaders, Linkers, Macro Processors.

Distributed Systems: Communication and Distributed Environment, Distributed Operating Systems, Distributed Shared Memory, Protocols, Fault Tolerance and Distributed File Systems, Distributed Object Based Systems.

Programming And Data Structures: Problem Solving Techniques, Trees, Hashing and Priority Queues, Sorting, Graph, Heap Search.

Algorithm Analysis And Design Techniques: Dynamic Programming, Greedy Algorithms, Advanced Algorithms, NP Completeness and Approximation Algorithms.

Microprocessors And Microcontrollers - Computer Architecture And Organization : Digital Fundamentals, Combinational Circuits, Synchronous and Asynchronous Sequential Circuits, Instruction Set Architecture(RISC,CISC,ALU Design), Instruction Level Parallelism, Processing Unit and Pipelining, Memory Organization.

Digital Signal Processing: FFT, Filter Design.

Computer Networks: Data Communication Systems, Applications.

Database Management Systems: Relational Model, Database Design, Implementation Techniques, Distributed Databases, Object Oriented Databases, Object Relational Databases, Data Mining and Data Warehousing.

Software Engineering Methodologies : Software Product and Processes - Software Requirements Management - Requirement Engineering, Elicitation, Analysis, Requirements Development and Validation, Requirements Testing - Object Oriented Analysis And Design – Modular Design, Architectural Design, User Interface Design, Real Time Software Design, System Design, Data acquisition System - Software Testing And Quality Assurance - SQA Fundamentals, Quality Standards, Quality Metrics, Software Testing Principles, Defects, Test Case Design Strategies, Software Quality and reusability, Software Project Management, Software Cost Estimation, Function Point Models, Software Configuration Management, Software Maintenance.

Artificial Intelligence: Intelligent Agents, Search Strategies, Knowledge Representation, Learning, Applications.

Mobile Computing: Wireless Communication Fundamentals, Telecommunication Systems, Wireless Networks.

Security In Computing : Program Security, Security in Operating Systems, Database and Network Security, Scientific Computing, Information Coding Techniques, Cryptography, Network Security.

3. ELECTRICAL AND ELECTRONICS ENGINEERING

Electrical Circuits and Fields: KCL, KVL, Nodal & Mesh analysis, transient response of D.C and A.C networks; sinusoidal steady-state analysis; resonance in electrical circuits; concepts of ideal voltage and current sources, network theorems, driving point admittance and transfer functions of two port network, three phase circuits; Fourier series and its application; Gauss theorem, electric field intensity and potential due to point, line plane and spherical charge distribution, dielectric, capacitance calculations for simple configurations; Ampere's and Biot-Savart' law, inductance calculations for simple configurations.

Electrical Machines: Single phase transformer – equivalent circuit, phasor diagram, tests, regulation and efficiency; three phase transformer –connections; auto transformer; principles of energy conversion, windings of rotating machines; D.C generators and motors-characteristics, starting and speed control, armature reaction and commutation: three phase induction motors-performance characteristics, starting and speed control; single-phase induction motors; synchronous generators – performance, regulation; synchronous motors – starting characteristics, applications, synchronous condensers; fractional horsepower motors: permanent magnet and stepper motors.

Power Systems: Electric power generation – thermal, hydro, nuclear; transmission line parameters; steady –state performance of overhead transmission lines and cables and surge propagation; distribution system, insulators , bundle conductors, corona and radio interferences effects; per-unit quantities; bus admittance and impedance matrices; load flow; voltage control and power factor correction; economic operation; symmetrical components, analysis of symmetrical and unsymmetrical faults; principle of over current, differential and distance protections; concepts and solid state relays and digital protection; circuit breakers; principles of system stability –swing curves and equal area criterion; HVDC system – Principle of operation, control and design consideration, HVDC circuit breaking; FACTS - Reactive power control, Uncompensated transmission line, Series compensation, SVC, thyristor control, series capacitor, static synchronous compensator, UPFC and applications.

Control Systems: Principles of feedback; transfer function; block diagram; steady –state errors; stability-Routh and Nyquist criteria; Bode plots; compensation; root loci; elementary state variable formulation; state transition matrix and response for Linear time Invariant systems.

Power Electronics and Drives: Semiconductor power devices-diodes, transistors, thyristors, triacs, GTO, MOSFETs and IGBTs-static characteristic and principles of operation; triggering circuits; phase control rectifiers; bridge converters-fully controlled and half controlled; principles of choppers and inverters, basic concepts of adjustable speed dc and ac drives.

Microprocessor and Microcontrollers: Microprocessor : General 8 bit microprocessor Architecture-8085, 8086 processor – Architecture, Memory, I/O interfacing, Instruction set, Addressing modes, Timing diagram & delays, Machine cycles, Interrupts, counters, Assembly language programming. Microcontrollers: 8 bit microcontroller -8051 architecture, bus configuration, Instruction sets, programming & applications.

Digital Signal Processing: Analog signals - sampling & Aliasing- Discrete time signals & systems – LTI systems – Convolution sum-Difference equation representation-Z Transform & its Inverse – Discrete Fourier series & Fourier transform- Radix 2 FFT – Decimation in me and frequency – Inverse DFT using FFT – Analog Butterworth & Chebyshev filter design –IIR & FIR filter design and Realization.

High Voltage Engineering: Causes of overvoltages and its effects on power system – Lightning, switching surges and temporary overvoltages – concepts of reflections and refraction of travelling waves. Dielectric breakdown- Gaseous breakdown – Vacuum breakdown, Corona discharges – Generation of high voltage, High current and its measurements – DC, AC, impulse voltages and currents; High Resistance with series ammeter – Dividers, Resistance, Capacitance and Mixed dividers – Peak Voltmeter , CVT, Electrostatic Voltmeters – Sphere Gaps – High current shunts; High voltage testing of electrical power apparatus as per International and Indian standards – Insulation Coordination.

Electric energy – Conservation and utilization: Fundamentals of Electric drives – choice and applications; traction motors – characteristic features – electric braking train movement and energy consumption; Design of illumination systems and various lighting schemes; Electric heating – methods of electric heating and its types – Electric welding - Principles of the conversion of solar radiation into heat; Solar Collectors-flat-plate collectors – concentrating collector – cylindrical parabolic; Wind energy conversion system – basic principles – site selection – basic components – Classification of WECS – Types of wind machines.

4. ELECTRONICS AND COMMUNICATION ENGINEERING

Circuit Analysis: DC Circuit analysis, Thevenin’s and Norton’s equivalent circuits, Sinusoidal steady state analysis, Transient and resonance in RLC circuits.

Electronic Devices: Diodes, Bipolar Junction Transistors, FET, MOSFET, UJT, Thyristor.

Electronic Circuits: Small signal amplifiers using BJT and FET devices, Large signal amplifiers, Power supplies, Feed back amplifiers, Oscillators, Pulse shaping circuits. **Digital Electronics:** Logic gates, Combinational circuits, Sequential circuits. **Linear Integrated Circuits:** Operational amplifiers and its applications, PLL, Voltage regulators, A/D and D/A converters. **Measurements and Instrumentation:** Transducers, Digital Instruments, Display and Recording systems. **Microprocessor and its applications:** Microprocessors-8085 and 8086 architectures and interfaces, Micro-controller and applications.

Electromagnetic Fields: Static Electric and Magnetic fields, Time varying Electric and Magnetic fields, Maxwell equations. **Transmission Lines and Networks:** Transmission line equations, impedance matching, Filters. **EM waves and waveguides:** Guided waves, Rectangular and cylindrical waveguides. **Antennas and Propagation:** Aperture antennas, arrays, Propagation of radio waves. **Microwave Engineering:** Microwave tubes, semiconductor devices, Passive components, Microwave measurements.

Communication Theory and Systems: AM, FM and PM, Sampling and Quantization, PCM, DM, ADM, Multiplexing. **Digital Communication:** Base band signaling, Band pass signaling, Error control coding, Spread spectrum techniques. **Computer Communication Networks:** Definition of layers, data link protocols, Network interconnection. Message routing technologies, End-End protocols.

Optical Communication: Optical Fibers, optical transmitters and receivers.

Signals and Systems: Continuous time signals and systems-Fourier Transform, Laplace transform, Discrete time signals and systems-DTFT, DFT, Z-Transform. **Digital Signal Processing:** IIR and FIR filters, Realization and implementation, Quantization effects. **Control Systems:** Transfer function, Time and frequency response analysis, Stability analysis, state variable analysis

5. MECHANICAL ENGINEERING

Mechanics, Kinetics and Dynamics :

Statics of Particles, Equilibrium of Rigid bodies, Properties of Surfaces and Solids, Dynamics of Particles, Friction and Elements of Rigid Body Dynamics, Basics of Mechanisms, Gears and Gear Trains, Friction in Machine Elements, Force Analysis, Balancing, Single Degree Free Vibration, Forced Vibration, Mechanisms for Control and Vibration.

Strength of Materials and Design :

Stress, Strain and Deformation of Solids, Transverse Loading on Beams and Stresses in Beams, Torsion, Deflection of Beams, Energy Principles, Thin Cylinders and Thick Cylinders, Spherical Shells, Fundamentals of Design for Strength and Stiffness of Machine Members, Design of Shafts and Couplings, Design of Fasteners and Welded Joints, Design of Springs, Design of Engine parts, Design of Bearings, Design of Flywheels, Design of Transmission Systems for Flexible Elements, Spur Gears and Parallel Axis Helical Gears, Bevel Gears, Worm Gears and Crossed Helical Gears, Design of Gear Boxes, Design of CAM, Clutches and Brakes.

CAD / CAM / CIM / FEA :

Fundamentals of Computer Graphics, Geometric Modeling, Visual Realism, Assembly of Parts, CAD Standards, Fundamentals of CIM, Production Planning and Control and Computerized Process Planning, Cellular Manufacturing, Flexible Manufacturing System and Automated Guided Vehicle System, Industrial Robotics, One Dimensional Problems in FEA, Two Dimensional Scalar Variable Problems, Two dimensional vector variable Problems, Isometric Parametric Formulation.

Materials Science and Metallurgy :

Constitution of alloys and phase diagrams, steels, cast iron, TTT diagram, heat treatment of ferrous and non-ferrous metal, surface modification techniques, non-metallic materials, mechanical properties and testing, crystal defects and strengthening mechanisms, conducting and semi conducting materials, magnetic and dielectric materials, Engineering ceramics, Engineering and commodity polymers.

Production Technology :

Foundry Technology, Hot and Cold working, metal forming processes, metal joining processes, welding metallurgy, welding defects, Metal cutting, center lathe and special purpose lathe, drilling, milling, grinding, gear cutting, broaching unconventional machining processes, CNC machine tools, Part programming.

Metrology and Measurements :

Linear and angular measurements, Interferometry-laser interferometers – Types, Computer Aided Inspection, Basic concept of CMM- Types of CMM, Machine vision, Form measurement-Straightness-Flatness, Roundness, Surface finish measurement, Measurement of power, flow and temperature.

Thermodynamics: Basic concepts, Zeroth, First and Second laws of thermodynamics; thermodynamic system and processes; Carnot cycle. irreversibility and availability; behaviour of ideal and real gases, thermodynamic relations, properties of pure substances, calculation of work and heat in ideal processes; analysis of thermodynamic cycles related to energy conversion, Fuel and combustion.

Heat and Mass Transfer: Modes of heat transfer; one dimensional heat conduction, resistance concept, electrical analogy, unsteady heat conduction, fins; dimensionless parameters in free and forced convective heat transfer, various correlations for heat transfer in flow over flat plates and through pipes; thermal boundary layer; effect of turbulence; radiative heat transfer, black and grey surfaces, shape factors, network analysis; heat exchanger performance, LMTD and NTU methods.

Basic Concepts of Mass transfer – Diffusion Mass Transfer – Fick's Law of Diffusion – Steady state Molecular diffusion – Convective Mass Transfer – Momentum, Heat and Mass Transfer Analogy – Convective Mass Transfer Correlations.

Applications: Power Engineering: Steam Tables, Rankine, Brayton cycles with regeneration and reheat. I.C. Engines: air-standard Otto, Diesel cycles. Refrigeration and air-conditioning: Vapour refrigeration cycle, heat pumps, gas refrigeration, Reverse Brayton cycle; moist air: psychrometric chart, basic psychrometric processes. Turbomachinery: Pelton-wheel, Francis and Kaplan turbines – impulse and reaction principles – velocity diagrams

Fluid Mechanics: Fluid properties; fluid statics, manometry, buoyancy; control-volume analysis of mass, momentum and energy; fluid acceleration; differential equations of continuity and momentum; Bernoulli's equation; viscous flow of incompressible fluids; boundary layer; elementary turbulent flow; flow through pipes, head losses in pipes, bends etc.

PART – III (Group B)**6. AUTOMOBILE ENGINEERING**

Mechanics: Statics of Particles, Equilibrium of Rigid Bodies, Properties of surfaces and Solids, Dynamics of particles, Friction and Element of Rigid Body Dynamics – Basics of Mechanism, Kinematics of Linkage Mechanism, Kinematics of Cam Mechanism, Gears and Gear Trains, Friction, Force Analysis, Balancing and Vibration.

Strength of Materials and Design: Stress, Strain and Deformation of solids, Transverse Loading on Beams and Stresses in Beams, Deflection of Beams, Energy Principles, Thin Cylinders and Spherical vessels Torsion – Fundamentals of design for strength and Stiffness of Machine members, Design of Shaft and Couplings, Design of Fasteners and Welded Joints, Design of Spring and Engine parts, Design of Engine parts, Bearing and Flywheel, Design of Transmission system for flexible elements, Spur Gears and Parallel Axis Helical Gears, Bevel, Worm Gears and Crossed Helical Gears, Design of Gear boxes, Design of Cam, Clutches and Brakes.

Thermodynamics: Basic concepts and First Law, Second Law, Entropy and Availability, Properties of Steam, Air standard cycles, Otto, Diesel and Dual cycles, Air compressors, Rankine cycle, Brayton cycle, Steam Turbines, Gas Turbine – Steam Nozzle, Refrigeration and air Conditioning, Conduction, Phase Change Heat Transfer and heat Exchangers, Radiation, Refrigeration Cycles, Refrigerants, System Components, VAR, Psychrometry, Air Conditioning system.

Production Technology: Foundry Technology, Hot and Cold Working, Forging, Principles and Application of Joining Process, Centre Lathe and Special purpose Lathes, Reciprocating Machines, Milling Machines and Gear Cutting, CNC Machine Tools, Part Programming.

Automotive Chassis: Front axle types front wheel geometry condition for true rolling motion steering geometry Ackermann and Davis steering. Types of steering gear box. Propeller shaft Universal joints. Final drive differential types. Type of brakes and constructional details. Types of suspension, Independent suspension-front and rear Rubber, pneumatic, hydro-elastic suspension.

Automotive Transmission: Construction and operation of friction clutches. Different types of gear boxes. Fluid couplings and torque converters. Wilson gear box. Hydrostatic drive systems. Electric drive. Continuously Variable Transmission (CVT) types of car bodies classification of bus bodies.

Vehicle Body Engineering: Body optimization techniques for minimum drag. Wind tunnel technology. Classification of vibration, definitions. Single degree of freedom, free, forced and damped vibrations. Rolling resistance, cornering properties of tyres. Directional stability of vehicle Choice of suspension spring rate calculation of effective spring rate. Vehicle suspension in fore and aft. Vehicle ride model, Load distribution.

Automotive Electrical and Electronics: Types of Batteries, Principle, Construction, Starting System. D.C. Generators and Alternators. Regulations for charging Electronic ignition systems. Types of sensors and actuators for automobiles. Microprocessor controlled devices in automobiles. Components for electronic engine management system. PID control types of solid state ignition systems and their operation. Fuel control maps open loop control of fuel injection and closed loop lambda control-integrated engine control system. Onboard diagnosis system.

Pollution and Control: Emission formation in SI and CI Engines. Effects of design and operating variables controlling techniques constant volume sampling systems. Measurement techniques of HC, CO, NOx and Smoke emission. Dilution Tunnel and Sound level meters.

Alternate Fuels: Properties alcohols, vegetable oils, biogas natural gas LPG and hydrogen as engine fuels methods of using all the fuels in SI and CI engines. Performance, emission and combustion behaviour of the fuels in SI and CI engines.

7. AERONAUTICAL AND AEROSPACE ENGINEERING

Fluid Flow Equations – Incompressible Viscous and Inviscid flows – Dimensional analysis – Fluid Machinery – Basic concepts in thermodynamics – Basics of propulsion and heat transfer – Air standard cycles – Properties of pure substance – Stresses in beams – Deflection of beams – Torsion – springs and columns – Biaxial stress system – Statically determinate and indeterminate structures – Energy methods – Failure theories- Induced stresses Basic aspects of boundary layer theory – Flow through compressors, combustion chambers, gas turbines and nozzles of gas turbine engines – Unsymmetrical bending – Shear flow in open and closed sections – Buckling of plates and stress analysis – Fundamentals of computational fluid dynamics – Grid generation – Time dependent methods and finite volume methods-finite element methods – discrete. Continuum and isoparametric elements – Field problem and method of solutions – composite materials.

Basics of flight mechanics – Aircraft configurations – Airplane structures – Airplane power plants – Airplane control systems – Aircraft instruments – Aircraft engine, air conditioning and pressurization system – Airfoil theory – Subsonic wing theory – Steady level flight, gliding and climbing flight and accelerated flight of airplanes – Fundamentals of hypersonic air breathing and rocket propulsion systems – Stability and control of airplanes – Fundamentals of supersonic flows – High speed flows over airfoils, wings and airplanes – Experimental techniques for high speed flows.

8. ARCHITECTURE

Building Materials, Construction and Technology : Lime, Brick, Stone, Clay products; Timber, Industrial timber; Paints and varnishes, Concrete, Special concrete and light weight concrete; Ferrous metals; non ferrous metals; Glass; Plastics; Eco friendly materials; Thermal insulation materials and acoustic materials. Construction techniques and practices using the above listed materials; Damp and water proofing; Pest control;; Construction systems and equipment; Pre- stressed concrete and Tensile Structures; Grids domes; folded plates; Flat Slabs. Low cost construction & appropriate technologies.

History of Architecture : Indian architecture- Hindu and Islamic; Indo Saracenic; Secular architecture of the princely states; Colonial and Post Independence Architecture; Works of masters such as Charles Correa; B V Doshi; Ananth Raje; Raj Rewal; Laurie Baker; Nari Gandhi; Kanvinde. Western architecture- Ancient Greek and Rome; Early Christian; Gothic and Renaissance; Baroque; Neo Classicism; Chicago School and development of skyscraper; Modern architecture: Art and Crafts; Art Nouveau; Expressionism and Cubism; Bauhaus; International style; Post Modernism and De constructivism; Critical Regionalism; Theories and projects of F L Wright; Le Corbusier; Gaudi; Gropius; Aalto; Mies; Eisenmann; Zaha Hadid; Soleri; Hasan Fathy; Ando; Bawa; Gehry; Libeskind; Toyo Ito; Louis Khan; Tschumi; Greg Lynn; Assymptote.

Theory and principles of Architecture: Elements and ordering principles; Organisation of form and space; Design methodology and Creative thinking; Pattern language; Contemporary process: Diagrams, Shape grammar, fractals, Digital hybrid, Liquid architecture.

Building Services: Water supply and distribution systems; water and waste management; Sewerage system; Electrical systems; Illumination and lighting; Air conditioning; Fire Safety; building automation and IBMS.

Building Science : Climate responsive architecture; design of solar shading devices; acoustics & building design; Architecture & Energy- Active & passive solar architecture, Day lighting & natural ventilation, Landscape designs; Landscape & environment control.

Housing; Urban Design and Town Planning : National Housing Policy; Indra Awas Yogana; Housing standards; housing projects in India; Urban morphology of early and contemporary cities; Case Studies on urban revitalization from developed and developed economies; Planning concepts- Patrick Geddes, Ebenezer Howard, Le Corbusier, C A Perry; Urban planning, regional planning and Urban renewal in the Indian context.

9. AGRICULTURAL AND IRRIGATION ENGINEERING

Machine Design: Design and selection of machine elements – gears, pulleys, chains and sprockets and belts; shafts and couplings, temporary and permanent joints, energy storing elements and engine components, bearings – measurement of force, torque, speed, displacement and acceleration on machine elements.

Farm Machinery: Soil tillage forces acting on a tillage tool; hitch systems and hitching of tillage implements; functional requirements, principles of working, construction and operation of manual, animal and power operated equipment for tillage, sowing, planting, fertilizer application, inter-cultivation, spraying, mowing, chaff cutting, harvesting, threshing and transport; calculation of performance parameters – field capacity, efficiency, application rate and losses; cost analysis of implements and tractors.

Sources of Power: Sources of power on the farm – human, animal mechanical, electrical, wind, solar and biomass; bio-fuels.

Farm Power: Thermodynamic principles of I.C. engines; I.C. engine cycles; engine components; fuels and combustion; lubricants and their properties; I.C. engine systems – fuel, cooling, lubrication, ignition, electrical, intake and exhaust.

Tractors and Power Tillers: Type, selection, maintenance, and repair of tractors and power tillers; tractor clutches and brakes; power transmission systems – gear trains, differential, final drives and power take-off; mechanics of tractor chassis; traction theory; three point hitches; mechanical steering and hydraulic control systems used in tractors.

Fluid Mechanics: Ideal and real fluids, properties of fluids; hydrostatic pressure and its measurement; hydrostatic forces on plane and curved surface; continuity equation; Bernoulli's theorem; laminar and turbulent flow in pipes, Darcy- Weisbach and Hazen Williams equations, Moody's diagram; flow through orifices and notches; flow in open channels.

Soil Mechanics: Engineering properties of soils; fundamental definitions and relationships; index properties of soils permeability and seepage analysis; shear strength, Mohr's circle of stress, active and passive earth pressures; stability of slopes.

Hydrology: Hydrological cycle and components; meteorological parameters, their measurement and analysis of precipitation data; runoff estimation; hydrograph analysis, unit hydrograph theory and application; stream flow measurement; flood routing.

Surveying and Leveling: Measurement of distance and area; instruments for surveying and leveling; chain surveying, methods of traversing; measurement of angles and bearings, plane table surveying; types of leveling; theodolite traversing; contouring; computation of areas and volume.

Erosion Control: Mechanics of soil erosion, soil erosion types, wind and water erosion, factors affecting erosion; soil loss estimation; biological and engineering measures to control erosion; terraces and bunds; vegetative waterways; gully control structures, drop, drop inlet and chute spillways; earthen dams; land use capability classification; rainwater harvesting structures, check dams and farm ponds.

Soil-Water-Plant Relationship: Water requirement of crops; consumptive use and evapotranspiration; measurement of infiltration, soil moisture and irrigation water infiltration.

Irrigation Engineering: Design of irrigation channels and underground pipelines; irrigation scheduling; surface, sprinkler and micro irrigation methods, design and evaluation of irrigation methods; irrigation efficiencies.

Agricultural Drainage: Drainage coefficient; planning, design and layout of surface and sub-surface drainage systems; leaching requirement and salinity control; irrigation and drainage water quality and reuse.

Groundwater Hydrology: Groundwater occurrence; Darcy's Law, steady flow in confined and unconfined aquifers, evaluation of aquifer properties; groundwater recharge.

Wells and Pumps: Types of wells, steady flow through wells; classification of pumps; pump characteristics; pump selection and installation.

Drying: Steady state heat transfer in conduction, convection and radiation; Psychrometry; concentration and drying of liquid foods- evaporators, tray, drum and spray dryers; hydrothermal treatment; drying and milling of cereals, pulses and oilseeds.

Size Reduction and Conveying: Mechanics and energy requirement in size reduction of granular solids, particle size analysis for comminuted solids; size separation by screening; pneumatic, bucket, screw and belt conveying; cleaning and grading; effectiveness of grain cleaners; centrifugal separation of solids, liquids and gases.

Storage Systems: Controlled and modified atmosphere storage; godowns, bins and grains silos.

Preservation of Food: Water activity, sorption and desorption isotherms; kinetics of microbial death – pasteurization and sterilization of milk and other liquid foods; preservation of food by cooling and freezing.

Systems Analysis: Linear programming, Irrigation water allocation – cropping pattern optimization; Dynamic Programming – Application to design and operation of reservoirs, Irrigation management; Simulation, application to irrigation scheduling; Decision support systems.

IT in Agricultural Systems: Precision farming; Crop production modeling; on-line measurement of plant growth in the greenhouse, models of plants production and expert systems in horticulture; e-governance, e-commerce, e-business systems & applications, Technology enhanced learning systems and solutions.

Management of Water Resources: IWRM framework, emerging issues in water management, watershed development, capacity building; participatory approach, Water Users Association, Farmers Association, CADP, water delivery systems, people's participation.

10. BIOTECHNOLOGY

Bioprocess Engineering: Analysis of STR, Analysis of other configurations, Bioreactor scale-up, Modeling and simulation of Bioprocesses, Bioreactor considerations in Enzyme systems.

Cell and Molecular Biology: Cells, Cell lines, Cell culture, Cell Organelles and its functions, types of Cell divisions, cell cycle and its regulation mechanism. Transport mechanism (passive, Active, ATPase pumps and Na^+/K^+ pumps), receptors, signal Transduction, models of signal Amplification Secondary messengers, Structure of Nucleic Acids, Replication, Transcription, Translation and DNA repair mechanism in Prokaryotes and Eukaryotes. Promoters, Enhancers and Transcription factors. Genetic Codes and Lac & trp operons.

Biochemistry and Microbiology: Structure, function and metabolism of carbohydrates, lipids, Nucleic Acids and proteins. Enzymes and its mechanism. Electron Transport Chain system, High energy compound and reducing equivalents. History of Microbiology, Classification of Microorganism, structural organization and multiplication of microorganism. Physical and chemical control of microorganisms, Primary and Secondary metabolites and their applications.

Genetic Engineering: Genes, Control of gene expression, Restriction enzymes, Vectors (prokaryotic and Eukaryotic) construction of cDNA and genomic Library. Screening of DNA libraries, PCR, RACE, PCR, RAPD, RFLP, AFLP, site directed mutagenesis, Methods of Nucleic acid sequencing. Cloning vectors in plants, Transgenic and Knockout animals.

Immunology: Immune system, immunity, lymphoid organs, antigens, adjuvants, types of immune response. Activation and differentiation of T-cells and B-cells, Antibodies, Genes and generation of diversity, monoclonal antibodies. MHC APC, regulation of T-cell and B-cell responses. Immunity to viruses, Bacteria fungi and parasites, cytokines, complements, immunosuppression, allergy and hypersensitivity. Vaccines, Transplantation, Tumor, Immunology, Autoimmunity and Autoimmune disorders.

Bioinformatics: Search engines and algorithms, data management, data technology, biological databases and their uses. Pair wise sequence alignment (local and global), multiple sequence alignment, dot matrix, dynamic programming and Bayesian methods. BLAST, FASTA, machine learning and Hidden Markov models. Phylogenetic tree analysis. Biomolecular and cellular computing, microarray analysis and system Biology.

11. BIO MEDICAL ENGINEERING

Physiology: Cell, cell potentials, sodium potassium pump, joints, respiratory mechanism conducting system of heart, volume and pressure changes, regulation of heart rate, structure of neuron conduction of action potential in neuron, brain lobes.

Biochemistry: Carbohydrates, structural importance, metabolic pathways and metabolic disorders, lipid chemistry, its metabolic pathways and disorders.

Circuit analysis: DC circuit analysis, Thevenin's and Norton's equivalent circuits, sinusoidal steady state analysis, Transient and resonance in RLC circuits.

Electron devices and circuits: Diodes, Bipolar junction transistor, FET, MOSFET, UJT, Thyristor, Feedback amplifier, oscillators, Differential amplifier, common mode and difference mode analysis.

Digital Electronics: Logic gates, combinational circuits, sequential circuits.

Linear Integrated Circuits: Operational amplifiers and its applications, voltage regulators, A/D and D/A converters.

Microprocessor and Applications: Microprocessors – 8085 and 8086 architectures and interfaces, microcontrollers and applications.

Signals and Systems: Continuous time signals and systems, Fourier transform, Laplace transform, Discrete time signals and systems, DTFT, DFT, Z transforms.

Digital signal processing: IIR and FIR filters, realisation and implementation.

Control systems: Transfer function, Time and frequency response analysis, stability analysis.

Communication theory: AM, FM, PM, sampling and quantisation, TDM, FDM, Entropy, Huffman coding, FDMA, TDMA.

Bio Medical Instrumentation: Strain gauge, applications, capacitive transducer, RTD, Scintillation counter, Photo multiplier tube, phototransistor, piezoelectric transducer, thermal recorder, indirect measurement of blood pressure, pH electrode, GSR, spirometer, Electrodes, Half cell potential, offset potential, types of electrodes and their equivalent circuits, artifacts during biopotential recording, characteristics of bio amplifier. ECG and EEG, lead system.

Bio Medical Equipment : Blood cell counter, Holter monitor, pacemaker and types, Need for defibrillator, types of defibrillator, biofeedback, Waveforms in stimulators, need for telemetry, modulation schemes used in telemetry, parameters to be monitored in heart lung machine and hemodialyser units, tissue response to different types of diathermy, physiological effects of electricity.

Bio Mechanics: Elasticity, Viscoelasticity, Flow properties of blood, mechanical properties of bones, types of joints, lubrication of joints.

Medical Imaging Systems: Ionising radiation and non ionising radiation, effects, cavitation effect, types of radioactive decay, interaction with matter, attenuation, annihilation, Compton scattering, Production of X- Ray, radiation units: Roentgen, Gray Sievert, CT generations, MR signal generation, T1 and T2 relaxation processes, Doppler shift, ultrasound Echo generation, PACS.

12. CHEMICAL ENGINEERING

Fluids Mechanics and Particle Technology: Classification of fluids, flow patterns, manometry, continuity equation, Navier-Stokes' equation, Bernoulli equation, Dimensional analysis, Flow through pipes, Boundary layer concepts, Flow through fixed and fluidized beds, pumps – classification affinity laws, performance curves. Characteristics of solids, size analysis, screening, storage, Conveyance, Size reduction, Classifier, Centrifuges, Cyclones. Filtration, Mixing and agitation.

Chemical Technology and Process Calculations: Gas calculations, Material balance and Energy balance – Steady and unsteady state, Humidity and Saturation, Combustion, Thermo chemistry,

Role of chemical Engineers in process industry, Cement, glass and ceramic industries, paper industry – oil, soap, detergent industries, petroleum refining and petrochemicals – polymer industry, Fertilizers, Food industry and other important process industries.

Thermodynamics and Kinetics: Laws of thermodynamics, PVT behaviour of fluids, Thermodynamic formulations, compression of fluids, Phase equilibria – Application of the correlation and prediction. Free energy change and reaction equilibria. Refrigeration- principles, performance. Reaction rate – laws, theories, analysis. Design of reactors, Factors affecting design, Thermal reactors and rates of heat exchanges. Non-ideal reactors, Hetrogenous reactors and solid catalysts, Gas – solid catalytic reactors, Gas-solid non-catalytic reactors, Gas-liquid reactors.

Heat and Mass Transfer: Modes of Heat transfer. Heat conduction- steady and unsteady state, Natural and forced convection, Heat transfer to fluids with phase change, heat transfer coefficients, evaporation, heat exchangers – design and construction.

Diffusion, Mass transfer coefficients, humidification, drying, absorption, distillation, extraction, leaching, crystallization, adsorption and ion exchange, analogies.

Process control and Computer Applications in Chemical Engineering: Open loop systems, closed loop systems, Frequency response, Advanced control systems, Instrumentation. Application of spread sheet packages in chemical engineering, Process flow sheeting, Development of software for design of equipments. Dynamic programming in Chemical Engineering.

Organic and Surface Chemistry: Carbohydrates, Oils, Fats and Waxes, Heterocyclic compounds, proteins, dyes and dyeing, pharmaceutical chemistry. Adsorption – types, adsorption of gases over solids, isotherms, applications, ion exchange, adsorption chromatography, Catalysis – types, Equations.

Environmental Pollution and Control: Various methods of reduction of pollution, types of pollution, Air pollution- sources and effects – control techniques, water pollution – sources and effects – control techniques, Soil pollution – sources and effects – control techniques and solid waste disposal.

13. CHEMISTRY

PHYSICAL CHEMISTRY

Structure : Hydrogen and hydrogen-like atoms : atomic orbitals; radial distribution function. Multi-electron atoms

Equilibrium : Laws of thermodynamics. Standard states. Thermochemistry. Thermodynamic functions and their relationships: Gibbs-Helmholtz and Maxwell relations, Gibbs-Duhem equation, van't Hoff equation. Criteria of spontaneity and equilibrium. Absolute entropy. Partial molar quantities. Standard electrode potentials and electrochemical cells. Nernst Equation and its application, relationship between Electrode potential and thermodynamic quantities, Potentiometric and conductometric titrations. Phase rule. Clausius- Clapeyron equation. Phase diagram of one component systems: CO₂, H₂O, S; two component systems: liquid- vapour, liquid-liquid and solid-liquid systems.

Kinetics : Elementary, parallel, opposing and consecutive reactions. Steady state approximation. Mechanisms of complex reactions. Unimolecular reactions. Transition state theory: Eyring equation, thermodynamic aspects. Catalysis concepts and enzyme catalysis. Kinetic isotope effects. Fast reaction kinetics: relaxation and flow methods. Diffusion controlled reactions. Kinetics of photochemical and photophysical processes.

Surfaces and Interfaces: Physisorption and chemisorption. Langmuir, Freundlich and Brunauer–Emmett–Teller (BET) isotherms. Surface catalysis: Langmuir-Hinshelwood mechanism.

INORGANIC CHEMISTRY

Main Group Elements: Hydrides, halides, oxides, oxoacids, nitrides, sulfides – shapes and reactivity. Structure and bonding of boranes, carboranes, silicones, silicates, boron nitride, borazines and phosphazenes. Acid-base concepts and principles (Lewis, Bronsted, HSAB and acid-base catalysis).

Transition Elements: Coordination chemistry – structure and isomerism, theories of bonding (VBT, CFT, and MOT). Energy level diagrams in various crystal fields, CFSE, applications of CFT, Jahn-Teller distortion. Electronic spectra of transition metal complexes: spectroscopic term symbols, selection rules, Orgel and Tanabe-Sugano diagrams, nephelauxetic effect and Racah parameter, charge-transfer spectra. Magnetic properties of transition metal complexes.

Lanthanides and Actinides: Recovery. Periodic properties, spectra and magnetic properties.

Organometallics: 18-Electron rule; metal-alkyl, metal-carbonyl, metal-olefin and metal- carbene complexes and metallocenes. Fluxionality in organometallic complexes. Types of organometallic reactions. Homogeneous catalysis – Hydrogenation, hydroformylation, acetic acid synthesis, metathesis and olefin oxidation. Heterogeneous catalysis – Fischer- Tropsch reaction, Ziegler-Natta polymerization.

Radioactivity: Detection of radioactivity, Decay processes, half-life of radioactive elements, fission and fusion processes.

Solids: Crystal systems and lattices, Miller planes, crystal packing, crystal defects, Bragg's law, ionic crystals, structures of AX, AX₂, ABX₃ type compounds, spinels, band theory, metals and semiconductors.

ORGANIC CHEMISTRY

Stereochemistry: Chirality and symmetry of organic molecules with or without chiral centres and determination of their absolute configurations. Relative stereochemistry in compounds having more than one stereogenic centre. Homotopic, enantiotopic and diastereotopic atoms, groups and faces. Stereoselective and stereospecific synthesis.

Reaction Mechanisms: Nucleophilic and electrophilic substitution reactions (both aromatic and aliphatic). Addition reactions to carbon-carbon and carbon-heteroatom (N and O) multiple bonds. Elimination reactions. Reactive intermediates – carbocations, carbanions, carbenes, nitrenes, arynes and free radicals. Molecular rearrangements.

Pericyclic Reactions and Photochemistry: Electrocyclic, cycloaddition and sigmatropic reactions. Orbital correlations – FMO and PMO treatments, Woodward-Hoffmann rule. Photochemistry of alkenes, arenes and carbonyl compounds. Photooxidation and photoreduction. Di- π -methane rearrangement, Barton-McCombie reaction, Norrish type-I and II cleavage reaction.

Heterocyclic Compounds: Structure, preparation, properties and reactions of furan, pyrrole, thiophene, pyridine, indole, quinoline and isoquinoline.

14. EARTH SCIENCES

Physical Geology and Geomorphology: Weathering process, kinds, products. Internal structure of the earth, fundamentals of plate tectonics. Landforms produced by River, winds, glacier and sea. Drainage pattern, Drainage Index, geomorphic features.

Mineralogy, Petrology, Stratigraphy, Paleontology and Structural Geology: Physical properties of Industrial minerals classification, origin and description of Igneous, sedimentary and Metamorphic rocks. Origin of Himalayas major earth geological events through time scale. Origin of life, types of fossils evolution of mammals & Man. Joints, Folds, Faults and structures.

Economic Geology, Ore Geology, Geochemistry : Origin, occurrence and distribution of Economic mineral deposits-Iron, manganese, gold, zinc, graphite, lead, coal and petroleum deposits. Ore-dressing, ore-reserves, estimation. Major elements, application in environmental studies REE-its implication in genesis/ provenance of rocks.

Remote Sensing, Geophysics and Hydrogeology : Sensors & Platforms- Indian Remote Sensing – Spectral system characterizes of rocks & minerals – Photogeology – Photogrammetry - Hydrogeology – Groundwater – occurrence, movement, Aquifer, field parameters & Lab methods of estimations.

Engineering Geology, Environment Geology and Marine Geology: Engineering properties of Rock. Geological investigation required for Dam, Tunnel, highways and building constructions. Renewable and non-renewable resources, pollution. Continental and marine environmental studies. Ocean features, physical, chemical & biological resources of the ocean.

15. FOOD TECHNOLOGY

Food Chemistry & Nutrition

Carbohydrates, Protein & Lipids and its functional properties, Pigments, Food flavors, Enzyme activity, enzymatic and non-enzymatic browning. Nutrition: balanced diet, essential amino acids and essential fatty acids, water soluble and fat soluble vitamins, role of minerals in nutrition, co-factors, anti-nutrients, nutraceuticals, food acids, moisture relations in food, Chemical and biochemical changes during processing and storage. Food Additives, Role of JECFA in safety assessment of food additives, definition, chemical structure, role in food processing and product end characteristics, Nutritional disorders, Diet therapy, probiotic and prebiotic foods, Therapeutic, organic foods, nutraceutical and functional foods

Food Microbiology, Food Analysis, Safety & Quality Management

Characteristics and morphology of microorganisms, Microbial growth, Importance of microorganisms in food – primary sources in food – intrinsic and extrinsic parameters of food affecting microbial growth - Microbial spoilage of foods ,Fermented and microbial foods - Food borne diseases and safety, Toxins from microbes, natural contaminants and health hazards associated with foods. Food analytical methods, statistical evaluation of analytical data, Principle and methods for subjective and objective quality evaluation of foods, Measurement techniques and instruments for food quality determination, destructive and non-destructive quality evaluation, International & National Food laws and standards

Food Product Processing & Preservation Technology

High temperature processing, Use of non-thermal technologies for preservation Properties, Processing and preservation of milk and milk products, Meat products, Fish and Egg Products, fruit and vegetable products, fermented foods and beverages from fruit and vegetables, Aerated drinks, processing of cereal, pulse and oil seed products, spices and plantation crops processing, Extraction of essential oils & oleoresins and encapsulation technologies, Value addition and byproducts utilizations

Fluid mechanics & Process Calculations

Classification of fluids, flow patterns, Dimensional and non-dimensional analysis, Flow through pipes, Flow through fixed and fluidized beds, turbines and pumps. Principles of Stoichiometry - material balance and energy balance, Stoichiometric principles and Application Heat capacity of solids, liquids, gases and solutions

Food Engineering, Process Control & Food Packaging

Heat transfer, momentum transfer, mass transfer, Unit operations, membrane separation processes, mechanical separation process, thermal operations, thermodynamics, Refrigeration-principles and applications, cold chain logistics, Engineering properties of food, food plant equipment design, Static and dynamic characteristics of instruments, Open loop systems, closed loop systems, Frequency response, advanced control systems, Instrumentation
Food Packaging – materials and their properties, equipment, testing, and its applications. Recent trends in packaging, labelling requirements.

16. GEO INFORMATICS ENGINEERING

Surveying: Chain surveying – compass surveying – plane table surveying – levelling – theodolite surveying – Temporary and permanent adjustments for level and theodolite – trigonometric levelling – tacheometry – traversing - contouring – Computation of areas and volumes.

Curve setting – simple, compound and reverse curves – transition curves – vertical curves - construction surveying – hydrographic surveying – route survey – triangulation – astronomical survey – Electromagnetic distance measurement – Total station and GPS surveying – adjustment of errors in surveying.

Remote Sensing: Components of RS – electromagnetic spectrum – wave theory, particle theory, Stefan Boltzmann law and Wien's law – radiation sources – radiation quantities – EMR interaction with atmosphere and earth materials – platforms and sensors – data product types- digital data file formats – resolution concept – elements of visual interpretation – interpretation keys.

Advanced remote sensing: Principles, Characteristics and applications of thermal, hyperspectral, microwave and LIDAR images.

Digital Image Processing: Sources of Image degradation and correction procedures – preprocessing – image enhancement techniques – image classification – spectral discrimination – pattern recognition concepts – Baye's approach – signature and training sets – separability test – supervised classification – minimum distance to mean, parallelepiped, MLC – unsupervised classifiers – ISODATA, K-means – support vector machine – segmentation (spatial, Spectral) – tree classifiers – accuracy assessment.

Advanced classifiers – fuzzy set classification – sub – pixel classifier – hybrid classifiers, texture based classification – object based classifiers – artificial neural nets – hebbian leaning – expert system, types and examples – knowledge systems.

Photogrammetry: Types of photographs – photographic overlaps – film – based and digital aerial cameras – construction – camera accessories – Camera calibration – geometric properties of aerial photographs – stereo plotters & orientation – aerotriangulation – terrain modeling – orthophoto – digital photogrammetry work station and its components – analytical stereo plotters vs digital photogrammetry – work station basic system function – storage system – stereoscopic viewing and measuring system – photogrammetry project planning – other acquisition systems – UAV – terrestrial imaging, oblique photography, close range photogrammetry, terrestrial and mobile LIDAR.

Cartography: Cartography: Functions, uses and types of maps – map scales and contents – map projections – shape, distance, area and direction properties – map co-ordinate systems – elements of a map – map Layout principles – symbols and conventional signs – map lettering – map production and reproduction – map generalization – geometric transformations.

Digital Cartography: Data capture and representation – digital map design – geovisualization – digital map modelling.

Geographical information system: Components of a GIS – data and attributes – scales/levels of measurements – spatial data models – raster and vector data structures – data entry – scanner – raster data Input – raster data file formats – georeferencing – vector data input – digitiser – datum projection and reprojection – coordinate transformation – topology – adjacency, connectivity and containment – topological consistency – non topological file formats – attribute data linking – linking external databases – GPS data integration – raster to vector and vector to raster conversion – data quality – completeness, logical consistency, positional accuracy, temporal accuracy, thematic

accuracy and lineage – metadata – GIS standards – interoperability – OGC – spatial data infrastructure – data output – map compilation – chart/graphs.

Spatial analysis and applications: raster analysis – vector analysis – network analysis – surface and geostatistical analysis – customization – web gis – mobile mapping.

RS and GIS Applications: RS and GIS applications in the fields of agriculture and forestry, urban planning, hydrology and water resources, oceanography, geology, meteorology, environmental management, climate change and disaster mitigation & management.

17. INSTRUMENTATION, ELECTRONICS & CONTROL ENGINEERING

Electrical Circuits :

Voltage and current sources: independent, dependent, ideal and practical; v-i relationships of resistor, inductor, and capacitor; transient analysis of RLC circuits with dc excitation.

Kirchoff's laws, mesh and nodal analysis, superposition, Thevenin, Norton, maximum power transfer and reciprocity theorems.

Peak, average and rms values of ac quantities; apparent, active and reactive powers; phasor analysis, impedance and admittance; series and parallel resonance, realization of basic filters with R, L and C elements.

One-port and two-port networks, driving point impedance and admittance, open - circuit, and short circuit parameters.

Signals and Systems :

Periodic, aperiodic and impulse signals; Laplace, Fourier and z-transforms; transfer function, time response and frequency response of first and second order linear time invariant systems; convolution and correlation.

Discrete time system: impulse response, frequency response, pulse transfer function; DFT and FFT; basics of IIR and FIR filters.

Analog Electronics :

Characteristics and applications of diode, Zener diode, BJT and MOSFET; small signal analysis of transistor circuits; feedback amplifiers.

Characteristics of operational amplifiers; applications of opamps: difference amplifier, adder, subtractor, integrator, differentiator, instrumentation amplifier, precision rectifier, active filters and other circuits.

Oscillators, signal generators, voltage controlled oscillators and phase locked loop.

Digital Electronics :

Combinational logic circuits, minimization of Boolean functions; IC families: TTL and CMOS; Arithmetic circuits, comparators, Schmitt trigger, multi-vibrators, sequential circuits, flip-flops, shift registers, timers and counters.

Sample-and-hold circuit, multiplexer, analog-to-digital (successive approximation, integrating, flash and sigma-delta) and digital-to-analog converters (weighted R and R-2R ladder). Characteristics of ADC and DAC (resolution, quantization, significant bits, conversion/settling time).

8-bit microprocessor and microcontroller: applications, memory and input-output interfacing; basics of data acquisition systems.

Measurements :

SI units; systematic and random errors in measurement, expression of uncertainty, accuracy and precision, propagation of errors; PMMC, MI and dynamometer type instruments; dc potentiometer; bridges for measurement of R, L and C; Q-meter; Measurement of voltage, current and power in single and three phase circuits; true rms meters; instrument transformers; time, phase and frequency measurements; digital voltmeter and digital multi-meter; oscilloscope; shielding and grounding.

Sensors and Industrial Instrumentation:

Resistive, capacitive, inductive, piezoelectric, Hall effect sensors and associated signal conditioning circuits; transducers for industrial instrumentation: displacement (linear and angular), velocity, acceleration, force, torque, vibration, shock, pressure (including low pressure), flow (differential pressure, variable area, electromagnetic, ultrasonic, turbine and open channel flow meters) temperature (thermocouple, RTD (3/4 wire), thermistor, pyrometer and semiconductor); liquid level, pH, conductivity and viscosity measurement.

Analytical Instrumentation:

Spectral methods of analysis: Spectro-Photometers, sampling systems, source detectors and applications; conductivity and pH meters; Chromatography; NMR & X ray spectroscopy; GM and proportional counters; Mass spectrometer.

Communication and Optical Instrumentation:

Amplitude and frequency modulation and demodulation; Shannon's sampling theorem; frequency and time division multiplexing; Digital Communication : PCM, DPC, amplitude, phase, frequency, pulse shift keying for digital modulation; optical sources and detectors: LED, laser, photo-diode, light dependent resistor and their characteristics; Basics of fiber optic sensing.

Control System and Computer Control of Processes:

Feedback principles, signal flow graphs, transient response, steady-state-errors, Bode plot, phase and gain margins, Routh and Nyquist criteria, root loci, design of lead, lag and lead-lag compensators, state-space representation of systems; time-delay systems; mechanical, hydraulic and pneumatic system components, synchro- pair, servo and stepper motors; on-off, P, P-I, P-I-D, cascade, feed-forward, and ratio controllers.

State models and state equations, controllability and observability, pole assignment.

Programmable logic controllers, SCADA, Distributed Control System and HART & Foundation Fieldbus.

18. LEATHER TECHNOLOGY

Pre Tanning Operations : Hides & Skins – Histological characteristics structure of hides & skins defects – curing & preservation methods – Animal by products – soaking, unhairing, liming, deliming, bating, pickling, depickling and degreasing– Their objectives & principles involved. Biochemistry of collagen and other substances – chemicals & auxiliaries used in pre-tanning operations – General pretanning processes for manufacture of different types of heavy and light leathers - Process control in pretanning – Ecofriendly pretanning operations – Physical and chemical testing - Standards and quality control measures in pretanning. By products of animal and tannery operations.

Tanning Operations: Tanning materials – Vegetable, mineral and organic - their classification – chemistry & Technology of tanning materials & methods – characterization manufacture & analysis of

various tanning materials. Theory & mechanism of vegetable, chrome, Aluminium, Zirconium, Iron, Titanium, Aldehyde, Oil and other organic tanning. Various unit operations involved in tanning processes their objectives & principles – cleaner processing options – Analysis & characterization of various types of leathers - Physical and chemical testing - Standards and quality control measures in tanning operations.

Post Tanning and Finishing Operations : Retanning, dyeing – fatliquoring and finishing operations – Their objectives & principles – chemicals used for the above unit operations – Syntans, fatliquors, dyes, dye-auxiliaries, pigments, acrylic and protein binders, wax emulsion, fillers, topcoats, NC, CAB lacquers and lacquer emulsions, feel modifiers, their nature & properties in finishing – machinery & methods for post tanning and finishing operations – upgradation methods – chemical and physical properties required for various finished leathers – physical & chemical testing of finished leathers – Tannery Effluent treatment –Effluent treatment plant - Liquid and solid waste management.

Leathers & Leather Products : Various types of leathers – upper, sole, garment, leather goods, sports & specially leathers – their characteristics. Leather supplement and synthetics - Design & manufacture of footwear, leather goods & garments. Leather Economics and Industrial Management – Project feasibility reports – organization & management of leather sector – marketing & export of leather & products - Machines for leather products manufacture - mechanics & operation - IT applications for leather & product design. Professional Ethics and human values.

19. MATERIAL SCIENCE AND CERAMIC TECHNOLOGY

Atomic structure and chemical bonding – crystal structure of materials – Miller indices of directions and planes – packing geometry in metallic, ionic and covalent solids – determination of crystal structures by X-ray diffraction – crystal growth techniques – imperfections in crystalline solids and their role in influencing various properties – Strengthening mechanisms – Diffusion: Fick's laws and application of diffusion in sintering, doping of semiconductors and surface hardening of metals.

Metals and Alloys: Solid solutions, Solubility limit, phase rule, binary phase diagrams, lever rule, intermediate phases, intermetallic compounds, iron-iron carbide phase diagram, heat treatment of steels, cold, hot working of metals, recovery, recrystallization and grain growth-microstructure, properties and applications of ferrous and non-ferrous alloys. Polymers: Classification, polymerization, structure, properties, processing and applications. Composites: properties, processing and applications of various composites. Nanomaterials: synthesis, properties and applications – Biomaterials – shape memory alloys.

Mechanical Properties: Modulus of elasticity, yield strength, tensile strength, toughness, plastic deformation, viscoelasticity, hardness, impact strength, creep, fatigue, ductile, and brittle fracture. Thermal Properties: heat Capacity, thermal conductivity, thermal expansion of materials. Electronic properties: concept of energy band diagram for materials – conductors, semiconductors and insulators, Electrical conductivity – effect of temperature on conductivity, intrinsic and extrinsic semiconductors. Dielectric properties and applications – Magnetic Properties: Origin of magnetism, paramagnetism, diamagnetism, antiferro magnetism, ferromagnetism, ferrimagnetism – domain theory of ferromagnetism – hysteresis – hard and soft magnetic materials – applications.

Ceramic Raw materials: Occurrence, properties and uses of clays, feldspar, quartz, sillimanite, bauxite, limestone, dolomite, magnesite, rutile, zircon. Synthesis, properties and applications of calcined alumina, mullite, silicon carbide, boron carbide, tungsten carbide, silicon nitride, boron nitrate, silicides, SiAlON, cermet, Carbon compounds.

Conventional ceramics: Body formulation and preparation of tiles, sanitary ware, tableware,

insulators, stoneware products. Glaze raw materials, fritting process, glaze application methods, causes and remedies for glaze defects. Formation and structure of glass, glass batch preparation and melting annealing, special glasses. Different types of refractories, important refractory properties and applications. Coated abrasives preparation, types of bonds in bonded abrasives, different types of grinding wheels and grinding process.

Special Ceramics: Preparation and properties of glass fibers, alumina fibers, carbonaceous fibers, boron fibers. Composites with different matrices and their properties. Basic principle and fabrication of ceramic capacitors, ferroelectric ceramics, Magnetic ceramics, Varistors and fuel cells. Special coatings by PVD, CVD, plasma spray, dip coating, electro coatings. Calcium phosphate based and non calcium phosphate based bio-ceramic materials and their applications.

20. Pharmaceutical Technology

BIOCHEMISTRY and MICROBIOLOGY

Biochemistry: Cell, Enzymes, Nucleic acids, Carbohydrates, Proteins and Lipids.

Microbiology: Introduction to Microbiology, Microscopy and staining techniques, Sterilization & Disinfection, Microbial Assay.

BIOTECHNOLOGY

Fermentation methods and Fermenter design, Biopharmaceuticals, Types of immunity- humoral immunity, cellular immunity, Structure of Immunoglobulins, Hypersensitivity reactions, Immune stimulation and Immune suppressions. General method of preparation of bacterial vaccines and viral vaccines.

PHARMACEUTICAL TECHNOLOGY

Introduction to dosage forms - Tablets, Parenterals, Suspensions, Emulsions, Suppositories, Semisolids, Capsules, Liquids, Stability of formulated products and Novel drug delivery systems. Biopharmaceutics and Pharmacokinetics-Bioavailability and Bioequivalence studies. Pharmaceutical engineering-Fluid flow, Heat transfer, Evaporation, Distillation, Drying, Size reduction and size separation, Filtration and Centrifugation.

INSTRUMENTAL METHOD OF ANALYSIS

Theory, Practice, working and pharmaceutical applications of the following analytical techniques: UV Visible Spectroscopy, IR Spectroscopy, NMR Spectroscopy and other important absorption and emission spectroscopic techniques. Mass spectrometric technique. Conventional chromatographic techniques, Gas Chromatography, High Performance Thin Layer and Liquid Chromatographic techniques and recent advances in chromatography.

MEDICINAL CHEMISTRY

Classification, mechanism of action, uses, Structure activity relationship of Cardiovascular, Anti-diabetic, Analgesics, CNS drugs and Anti-hyperlipidemic drugs. . Introduction to Drug Design, Various approaches used in drug design, physicochemical parameters used in quantitative structure activity relationship (QSAR), Pharmacophore modeling and Docking techniques.

21. PHYSICS

Mechanics, Heat and Sound : Vectors – equilibrium - moment of a force – Newton's laws of motion – gravitation – work – energy – power – Impulse and momentum – collisions – recoil. Thermometry of thermal expansion – calorimetry and specific heats – transfer for heat – thermal process of matter - Law and processes of thermodynamics - Applications. Travelling waves – oscillations – spring – simple pendulum – forced oscillations – resonance – sound waves –Acoustic Phenomena and its applications- Doppler effect.

Light and Properties of matter : The nature and propagation of light – reflection of refraction at plane surfaces – interference – diffraction – polarization. Elasticity – Stress-strain diagram -- hydrostatics – Pressure in a fluid – Pumps – Archimede’s principle – Surface tension – Contact angle – Capillarity - hydrodynamics - Bernoulli’s equation – Applications and viscosity – Poiseuille’s law – Stokes law – Reynolds number.

Electricity and Magnetism : Coloumb’s law – Gauss’s law – Applications - electrostatic potential – capacitors – dielectrics - current – resistance – emf – Kirchoff’s law – thermo electric effect – applications. Magnetism - magnetic effects of current – motion of charge particles in magnetic field – cyclotron – magnetic forces on current carrying conductor – Hall effect – electromagnetic induction – Faraday’s law – Lenz’s law – eddy current – Inductance – mutual and self inductance – magnetic properties of matters – diamagnetism – paramagnetism – ferromagnetism - domains– Hysteresis - alternating current – circuits containing resistance, inductance or capacitance – transformer.

Modern physics : Emission and absorption of light – thermionic emission – photoelectric effect – atomic spectra - atom models – molecular spectra – dual nature of matter and radiation – nuclear structure – properties – natural radioactivity – nuclear stability - nuclear reactions – fission – fusion – fundamental particles – high energy physics.

Solid State Electronics : Structure and bonding in solids - properties of solids – semiconductors – intrinsic – extrinsic – PN junction – diode characteristics – Zenar diode – LED, laser diode – Photodiode – Transistor – action and characteristics – amplifier – oscillator – basic logic gates.

Electron theory of solids: Classical free electron theory – density of states- electron in a periodic potential – origin of energy band gap – electrical conductivity – thermal conductivity – Widemann-Franz law

Dielectric and magnetic materials: Different types of polarization – Internal field – Clausius-Mosotti equation- dielectric breakdown- applications of dielectric materials – Different types of magnetic materials – domain theory of ferromagnetism – hysteresis - hard and soft magnetic materials- applications of magnetic materials.

Superconducting materials: General properties of superconducting materials – Meissner effect – types of superconductors – Hi T_c superconductors- applications

Nanomaterials: Preparation – properties – applications – Carbon nanotubes.

22. PRINTING TECHNOLOGY

Prepress: Principles of Graphic Design, Designing for Print Media, Package Design, Imaging Technology, Colour reproduction, Digital Prepress, Image carrier preparation for different Printing process, Quality control in Prepress, Electronic Publishing.

Press: Principles of Print Process, Principle and press configurations for commercial, Newspaper, Package, Digital Prepress and Press Consumables, Quality control in Press.

Post Press: Finishing operations for different jobs, Mail room operations, Print finishing machines, Print finishing Consumables, Converting operation for packaging, Surface finishing operation, Quality in post press operation.

Printing and Packaging Materials: Manufacturing of printing and packaging substrates – Properties

and Testing, Printing Inks for major printing processes – Manufacturing properties and testing, Quality control aspects.

Print Management: Print operation Management, Cost estimation for various Printing jobs, Design Management, Financial, Quality and Maintenance, Management for Printing.

23. PRODUCTION AND INDUSTRIAL ENGINEERING

Basic Mechanisms and Elements of Design : Mechanisms, Friction, Gearing and Cams, Balancing, Vibration, Fundamentals of Design, Design of Basic Machine Elements, Design of Mechanical drives, Design of Automotive components, Recent Advances.

Casting, metal forming and metal joining processes : Casting Processes, Welding Processes, Special Casting Processes, Testing of Castings & Weldments - Fundamentals of Metal Forming, Forging and Rolling, Extrusion and Drawing Processes, Sheet Metal Forming Processes, Recent Advances, Mechanisms, Friction, Gearing and Cams, Balancing, Vibration, Fundamentals of Design, Design of Basic Machine Elements, Design of Mechanical drives, Design of Automotive components, Recent Advances.

Tool Engineering, Machine tool operation, Metrology and Inspection : Mechanics of Metal Cutting, Tool Material, Tool Wear and Tool Life, Gear Manufacture, General Concepts of measurements, Linear and Angular measurements, Measurement of Surface Finish Measuring Machines, Metrology of Screw Thread & Gears, Computer Aided Inspection and Laser Metrology - Strength and rigidity of machine tool structures, Sideways, Spindles and spindle supports, Machine Tool Dynamics.

Engineering Materials : Introduction and Constitution of Alloys and Phase Diagrams, Heat Treatment, Ferrous and Non Ferrous Metals, Mechanical Properties and Testing, Welding and Foundry Metallurgy, Manufacturing Processes for Plastic, Mechanical, Chemical and Electro-chemical energy based processes, Electrical Energy based Waste Processes, Thermal Energy Process, Polymer Matrix Composites, Metal Matrix Composites, Ceramics Matrix Composites, Advances in Polymers & Composites.

Product and Process Design, Design of Jigs and Fixtures and Press Tools : Product Design Concepts, Recent Advances, Process Planning, Estimating, Costing and Elements of Cost, Analysis of Overhead Expenses, Estimation of Costs for Forging, Casting and Welding, Estimation of Machining Time, Purpose Types and Functions Of Jigs and Fixtures, Jigs, Fixtures, Press working Terminologies and Elements of dies and Strip Layout, Design and Development of Dies.

CAD/CAM and CIM: Computer Aided Design, Computer Graphics, Geometric Modelling, Rapid Prototyping, Concept & Programming of CNC machines, Robotics-anatomy and specifications, Automated production lines, GT and FMS.

Operations Research: Linear Programming, Transportation, Assignment CPM/PERT, Inventory Models, Decision Analysis, Game Theory, Waiting Line Models.

Operations Management: Concept of Productivity, Method Study and work measurement, Ergonomics, Forecasting, Aggregate Planning, Capacity Management, MRP, Production Activity Control, Estimation and Costing, Costing Methods.

Quality, Reliability and Maintenance : Quality Concepts, Total Quality Management and Six Sigma Concepts, Statistical Process Control, Process Capability Analysis, Acceptance Sampling, Reliability Concepts, Failure Data Modeling, Reliability Prediction and Modeling, Maintenance Concept, Maintenance Models, Total Productive Maintenance.

24. SOCIAL SCIENCES

Geography: Settlement geography-rank-size relationship, urban environment- physical and social, regional delimitation, central place theory, urbanization in India and Tamilnadu, relationship, concept and types of region, regional development planning in India, globalization and economics reforms and competitiveness.

Sociology : Social institution, society, community, social roles, norms, status, values, social structure in India, social change and its relevance to economic development, urbanization as a way of life, social problems of developed and developing countries, impact of urbanization on society and rural development, impact of IT industry on society and development.

Economics : Agglomeration economics- internal, external and urbanization economics, economic base of cities- meaning, types of economic base and methods of identifying economic base, multiplier concept, and approaches of development, Indian national economy –five year plans, environmental economics, economic geography of India. Land economics and industrialization policy, SEZs, IT, ITES industries

Social work: Role of social worker and NGO's in development – community, rural, social, and national level; public participation in developmental framework- city, regional, and national level, awareness programme on policies, counseling- rational emotive therapy, behavior modification therapy, family counseling, group work- treatment group, task group, community work- rural and urban community developments/micro credit/micro finance\SHGs.

25. TEXTILE TECHNOLOGY

Fibre Science and Technology : Cotton varieties and their properties; silk – pre and post cocoon operations; varieties of silk and their properties; varieties of wool and their properties; properties of other natural fibres.

Production and properties of viscose rayon and other regenerated fibres.

Requirements of fibre forming polymers; structural principles of polymeric fibres; fluid flow during spinning; technology of melt, wet, dry, dry jet wet, liquid crystal and gel spinning of polymeric fibres.

Production, properties and applications of PET polyester, nylon 6, nylon 66, polyacrylonitrile and polypropylene.

Spin finishes; drawing; heat setting; crimping and texturisation; tow to tow converters and tow to staple converters.

Structural investigation of fibres; study of moisture absorption, tensile behaviour, torsional rigidity and flexural rigidity, and optical, frictional, electrical and thermal properties of fibres.

Yarn Engineering: Yarn numbering systems- direct, indirect and conversions.

Description and working of short staple spinning machinery - blow-room machinery, card, comber preparatory machines, comber, draw-frame, speed-frame, ring-frame; calculation of process parameters and process efficiencies; production calculations.

Methods of mixing and blending; two-folding of yarns; two for one twist principle; man-made fibre processing.

Principle and details of yarn formation in condensed yarn spinning, rotor spinning, friction spinning, air-jet spinning and other new spinning systems; structure of yarns produced from different spinning systems. Control of waste, productivity and quality.

Fabric Engineering : Fundamental concepts in winding, modern automatic winders; yarn clearing; winding synthetic and blended yarns and sewing threads; weft winding; Creels used in warping machines; beam and sectional warping machines; Sizing materials and recipes: size preparation and application; control systems used in sizing machine; sizing filament yarns; combined dyeing and sizing; energy conservation in sizing; process control in weaving preparation; preparation of warp beam for weaving.

Yarns quality requirements and preparations for high speed weaving machines.

Principles and limitations of various shedding, picking mechanisms; power required for picking; timing different mechanisms; automation and modern developments in weaving machine; cloth formation; loom accessories; process control in weaving.

Cloth geometry; cover factor; concepts in fundamental and advanced woven fabric designs.

Quality and preparation of yarn required for knitting; basic weft knitted structures and their production; needle control in weft knitting machines; factors affecting the formation of loop; effect of loop length and shape on fabric properties; process control in knitting; warp knitting fundamentals.

Web forming techniques for dry method of web preparation; production of bonded fabrics by mechanical, chemical and thermal methods; productions of spun bonded and melt blown fabrics; end uses of bonded fabrics.

Chemical Processing : Chemical structure and chemical properties of natural and man-made fibres; singeing; desizing; scouring; bio preparatory operations; Mercerization; bleaching; heat setting; processing machines.

Adsorption isotherms; dye-fibre interaction; properties and application of direct, azoic, vat, sulphur, reactive, acid, mordant, metal-complex, disperse and basic dyes; dyeing of blends; garment dyeing; assessment of colour fastness.

Fundamentals of colour measurement; whiteness and yellowness indices; colour matching; spectrophotometers.

Methods and styles of printing; printing machines; printing paste; printing with direct, reactive, acid and disperse dyes and pigments.

Calendering; crease proofing; anti-shrinking; softening; felting and non-felting of wool; bio-polishing; assessment of finishes; assessment of eco-friendliness of textiles; finishing of knits; garment washing.

Quality Evaluation: Textile quality parameters; online and off line testing methods.

Measurement of length and length uniformity, fineness, strength, maturity, trash content, moisture content of fibres using conventional and modern testing methods; advanced fibre information systems, high volume testing; measurement of lap, sliver and roving irregularity.

Assessment of count, twist, hairiness, strength and extension, evenness, imperfection, friction, crimp rigidity, work of rupture, fatigue, abrasion resistance of yarn; classification of yarn faults.

Determination of fabric construction parameters; assessment of tensile, bursting and tear strengths, low-stress mechanical properties, permeability, insulation properties, durability, comfort and handle properties of fabrics; grading of fabrics based on defects. Sampling; statistical significance tests; control charts.