

**PART VII**  
**COURSE DESCRIPTIONS**  
**(Work Integrated Learning Programmes)**

## Course descriptions for Work-Integrated Learning & Collaborative Programmes

### **AAOC ZC111 Probability and Statistics 3**

Probability spaces; conditional probability and independence; random variables and probability distributions; marginal and conditional distributions; independent random variables; mathematical expectation; mean and variance; binomial, Poisson and normal distributions; sum of independent random variables; law of large numbers; central limit theorem (without proof); sampling distribution and test for mean using normal and student's t-distribution; test of hypothesis; correlation and linear regression.

### **AAOC ZC221 Graphs and Networks 3**

Basic concepts of graphs and digraphs behind electrical communication and other networks behind social, economic and empirical structures; connectivity, reachability and vulnerability; trees, tournaments and matroids; planarity; routing and matching problem; representations; various algorithms; applications.

### **AAOC ZC222 Optimization 3**

Optimization of functions of one and many variables with and without constraints; Kuhn-Tucker conditions; gradient methods; linear programming; simplex based and integer programming methods; duality theory; transportation and assignment problems; dynamic programming; branch and bound methods; models of linear production systems, sequencing and scheduling, PERT, CPM.

### **AE\* ZC442 Advanced Driver Assistance Systems 4**

Automotive safety systems, assist and autonomous systems, automotive sensors and actuators for ADAS (stereo and mono cameras ultrasonic sensors, LIDAR, RADAR), fundamentals of machine vision, data fusion for ADAS, mechatronics for ADAS, human – machine interface for ADAS, telematics and infotainment, ADAS system, legal and ethical aspects of ADAS, real time systems and development, advanced driver assistance systems, advanced computer systems, automated driving applications and systems.

### **AE\* ZC443 Connected Cars 4**

Fundamentals of IOT - Architecture, Sensors, Cloud and the trade-off between polling and storage requirements, Structure and implementation of CAN networks, CAN message, priority & arbitration and the control hardware involved in the network, data analytics by creating a simple data model using OBD tools, ethical and legal aspects of connected car applications including data theft, privacy and security vulnerabilities, building of predictive analytic model based on in-vehicle data.

### **AE\* ZG510 Automotive Control Systems 5**

Introduction to vehicle electronics, semiconductor diodes, FETs, rectifiers, small signal amplifiers, circuit models, automotive applications and case studies, automotive micro controllers, auto sensors and actuators, vehicle electronics, feedback control, control strategy, analog and digital controllers, expert systems and neural networks, advanced topics in EMC, vehicle communication networks, automotive control system design, transmission and powertrain, brake, traction, suspension, active safety and supplementary restraint systems, intelligent vehicle systems and ADAS.

### **AE\* ZG511 Mechatronics 5**

Concepts of measurement of electrical and non-electrical parameters; displacement, force, pressure etc. and related signal conditioning techniques, drives and actuators, concepts of microprocessors/ microcontrollers architecture and programming, memory and I/O interfacing. System design concepts through case studies.

### **AE\* ZG512 Embedded System Design 4**

Introduction to embedded systems; embedded architectures: Architectures and programming of microcontrollers and DSPs. Embedded applications and technologies; power issues in system design; introduction to software and hardware co-design.

### **AE\* ZG513 Maintenance Engineering 5**

Introduction, maintenance systems, methods and tools of maintenance analysis, eligibility and safety, maintainability, supportability, design for maintenance, maintenance integration, computerized maintenance management systems, TPM, world-class maintenance systems, and maintenance effectiveness and performance evaluation.

### **AE\* ZG514 Advanced Automotive Systems 4**

Frame, suspension, springs and wheels, clutch and gear box, propeller shaft, universal joint, final drive, differential and rear axle, front axle and steering mechanism, brakes, automotive air conditioning, electrical vehicles, automotive electrical systems, automotive electronics systems.

### **AE\* ZG515 Non-Destructive Testing 5**

Ultrasonic testing, X-radiography, eddy current testing, magnetic methods of crack detection, liquid penetrant inspection, acoustic emission and acousto-ultrasonic testing techniques.

### **AE\* ZG516 Advances in Internal Combustion Engines 4**

Air standard cycles, fuel air cycles, actual cycles and their analysis, fuels, alternative fuels, carburetion, mechanical and electronic injection systems, ignition, combustion and combustion chambers, engine friction and lubrication, heat rejection and cooling, engine emissions and their control, measurements and testing, performance parameters and characteristics, engine electronics, supercharging, two-stroke engines. Power-train auxiliary systems integration, newer engine technologies such as hybrid engines.

### **AE\* ZG517 Automotive Systems Engineering 4**

Automotive systems development and testing, compatibility issues, performance prediction, design requirements and engineering metrics, systems engineering process, life cycle standards and management, concurrent engineering, systems analysis applications, and advanced model based development.

### **AE\* ZG518 Electric and Hybrid Vehicles 4**

Electric motors, drives, control, batteries, architectures, energy storage, recovery, and management, characteristics of autonomous vehicles, modelling, simulation, analysis and comparison of relations among multiple parameters for electric, hybrid and autonomous vehicles, insights into regulations and norms with respect to electric, hybrid and autonomous vehicles, hybrid vehicle propulsion systems, sustainable automotive power technology.

### **AE\* ZG519 Automotive Security 4**

Security concepts, security attacks and risks, architectures, policy management, mechanisms, understanding the risks and advantages of vehicle to internet (V2I), vehicle to vehicle (V2V), vehicle to IoT (V2IoT) connectivity, issues concerning the security of intelligent transport systems that communicate with the vehicle, telematics, cryptography, security standards, security system interoperation and case studies of the automotive security systems and connectivity technologies, automotive cyber security and autonomous vehicles, connected vehicle driver responsibility, issues around liabilities related to automotive cyber security incidents.

**AE\* ZG521 World Class Manufacturing 5**

The world-class manufacturing challenge, developing a world-class manufacturing strategy, just-in-time, total quality, total employee involvement, world-class information systems, managing the change, methods and procedures; improved brainstorming methods, using the check-total quality - the first steps, getting people involved, monitoring world-class performance.

**AE\* ZG522 Advanced Vehicle Acoustics 4**

Fundamentals of noise sources, transfer paths, principles of noise and vibrations control, assessment and control of engine noise and vibration, road / tyre noise, vehicle body noise and vibration, evaluating the vibration and acoustic characteristics of future vehicle systems.

**AE\* ZG523 Project Management 4**

Concepts and techniques of project formulation, evaluation and implementation; Project planning and scheduling; Risk management; Time-cost trade off; Resource leveling and allocation; Project monitoring and control; Contract management.

**AE\* ZG524 Vehicle Dynamics 4**

Fundamentals of vehicle dynamics, steering, single and two degree-of-freedom systems, vibration isolation, absorbers, anti-vibration mounts, exhaust mount, tire properties, influence on vehicle dynamics, tire forces/moments & kinematics, modified SAE tire axes & terminology, introduction to tire modeling, suspension and steering effects, basic tire modeling consideration, brush tire model, steady state lateral/longitudinal slip force generation, interaction between lateral slip and longitudinal slip, transient tire forces, steady state cornering stability analysis, handling diagram, quasi steady state cornering, straight line braking stability analysis, transient cornering dynamic cornering, principles of anti-lock braking system (ABS), steady state cornering of single unit heavy trucks, effect of tandem axles and dual tires, equivalent wheelbase handling diagram of complex vehicles, vehicle parameters and states estimation, road and basic driver models principles, basic powertrain, modeling, brake system modeling, electronic stability control (ESC), vibration mounts, construction and heavy engineering equipment.

**AE\* ZG531 Product Design 5**

Introduction to creative design; user research and requirements analysis, product specifications, Computer Aided Design; standardization, variety reduction, preferred numbers and other techniques; modular design; design economics, cost analysis, cost reduction and value analysis techniques, design for production; human factors in design: anthropometric, ergonomic, psychological, physiological considerations in design decision making; legal factors, engineering ethics and society.

**AE\* ZG532 Computer Aided Engineering 5**

Mathematics and computer implementation methodologies of parametric geometric modeling for computer aided design including modeling of curves, surfaces, solids and NURBS, geometric transformations, concepts of elasticity and material behavior, theories of failure, finite element analysis (FEA) of one-, two- and three-dimensional problems with special emphasis on the application areas of noise and noise, vibration and harshness (NVH), durability, crash, occupant safety, computational fluid dynamics (CFD) and heat transfer, FEA of mechanical vibrations and fracture. In all implementation work and assignments, suitable commercial CAE software packages such as ABAQUS is required to be used.

**AE\* ZG535 Advanced Engineering Mathematics 5**

Boundary value problems; wave equations; nonlinear partial differential equations; calculus of variations; Eigen value problems; iteration problems including forward and inverse iteration schemes – Graham Schmidt deflation – simultaneous iteration method – subspace iteration –

Lanczo's algorithm – estimation of core and time requirements.

**AE\* ZG542 Just-in-time Manufacturing 4**

Introduction; Toyota production system; JIT implementation surveys; Design, development and implementation of JIT manufacturing systems; Supply management for JIT; Framework for implementation of JIT; Theoretical research in JIT systems; Various case studies.

**AE\* ZG611 Computational Fluid Dynamics and Heat Transfer 4**

Integral and differential conservation laws for mass, momentum, and energy, solution of Navier-Stokes equations, theory of potential flow, boundary layer theory, hydrodynamic stability turbulent flow, compressible flow quasi-one-dimensional nozzle flows numerical solution of a two-dimensional supersonic flow, incompressible Couette flow. supersonic flow over a flat plate, experimental techniques and uncertainty analysis, integral and differential forms of energy conservation law for heat transfer, heat transfer in internal laminar and turbulent flow, heat transfer in external laminar and turbulent flow, natural convection heat transfer, mixed convection heat transfer, convective heat transfer in porous media flow, condensation, evaporation, and boiling. radiation heat transfers in non-participating and participating media. radiation transport equation, heat transfer of engine cooling, exhaust manifold and HVAC for automobiles, computational analysis of fluid flow, heat transfer and multi-phase flow problems with special emphasis on problems relevant to automotive applications.

**AE\* ZG612 Advances in Materials, Composites & Plastics 4**

Definition of composite materials; classification; particulates and dispersion hardened composites, continuous and discontinuous fiber reinforced composites, metal-matrix composites, carbon-carbon composites, molecular composites, micro and multilayer composites, theory of reinforcement; reinforcement by continuous and discontinuous fibers, concept of microfibril; effect of orientation and adhesion; mechanical behaviour of composites, stress-strain relationship, strength, fracture toughness and fatigue; properties of fibre reinforcement and production technology of composites. Plastics and their processing technology including injection moulding, blow moulding etc. Mathematical modeling and simple computational techniques for the mechanics of composites and plastics. Applications of plastics and composite in automotive and aerospace structures. Advanced metals and alloys including titanium, aluminum and magnesium, Ceramic and metal alloys (CERMETS) including Aluminum based alloys and other ceramic components.

**AE\* ZG613 Tribology 5**

Introduction, lubricants and lubrication, surface texture, bearing materials, fundamentals of viscous flow, reynolds equation and applications, thrust bearings, journal bearings, squeeze-film bearings, hydrostatic bearings, gas bearings, dry and starved bearings, selecting bearing type and size, principles and operating limits, friction, wear and lubrication.

**AE\* ZG614 Fracture Mechanics 5**

Introduction, energy release rate, stress intensity factor and complex cases, anelastic deformation at the crack tip, elastic plastic analysis through J-integral, crack tip opening displacement, test methods, fatigue failure, numerical analysis, mixed mode crack initiation and growth.

**AE\* ZG615 Advanced Engine Technology 5**

Engine Design & Development: Design and development of various engine components viz. cylinder block, head, combustion chamber, pistons, crank shaft, connecting rod, cam shaft, valves, intake and exhaust systems, fuel supply systems, Engine balance and vibration; Engine Combustion: Process, analysis and diagnostics; Engine Emissions &

Controls: Analysis of gas emissions and control; Alternate Fuels: Alternative Fuels for Land, Rail, Marine and Aviation Transportation, Utilization of Alternative Fuels in Internal Combustion Engines; Engine Testing & Certification: Test facilities and methods, Instrumentation, Engine tests and quality standards; Vehicle Component Testing: Test facilities and methods for interior and exterior parts of an automotive vehicle.

#### **AE\* ZG621 Durability, Crash and Safety Engineering 4**

Classical failure theory, creep, fatigue, buckling, low and high cycle fatigue test, crack initiation and fracture mechanics, Effect of surface and metallurgical parameters on fatigue, EN-SN curves, plasticity corrections, Road load acquisition methods/instruments, Proving ground events & duty cycle preparation accordance with vehicle GVW, Joint Design, bolt slippage & torque relaxation methods in FEM. Durability of plastics - material failure criteria, Rattle & squeeze issues in automotive trims, IP panels. Optimization techniques/algorithms - Influence of space, size, weight etc., on form design, aesthetic and ergonomic considerations, Fundamentals of Crash Analysis, Transient Dynamic solutions, Lagrangian and Eulerian codes of solution, explicit and implicit methods of solving crash problems, crash worthiness, Contact theory and algorithms, Quasi-static and dynamic events for crash analysis, time-step computation and mass scaling of models, different element types, formulations and application, Material representations for Crash analysis, Human modeling and biomechanics, Human injuries and remedies, Impact sensor, types and developments, Active and Passive safety, Regulations for Automotive safety, Crash Worthiness Ratings, Model building and integration, Quasi-static load cases – Roof Strength, side door intrusion, Seating load cases, Internal head impacts, Whiplash, Airbag – types, modeling and applications.

#### **AE\* ZG622 Advanced Manufacturing Processes 4**

High strength material forming, tooling for high strength materials, Cold and hot stamping, hydro forming, vacuum forming, high speed stamping, Aluminum forming & tooling technology including progressive and transfer dies for sheet metal forming, Advanced Automotive BIW assembly/welding technology, laser welding technology, robotic hemming. Tooling for lightweight composites, Carbon fibre moulds & advanced plastic moulding technology, High speed machining, precision machining technology, Resistance welding. Aluminum part manufacturing technique including die casting, tailor-made blanking etc. Mathematical modelling and analytical and numerical computations for sheet metal forming processes using AutoForm. Newer sheet metal forming techniques.

#### **AE\* ZG629T Dissertation**

**16**

A student registered in this course must take a topic in an area of professional interest drawn from the on the job work requirement which is simultaneously of direct relevance to the degree pursued by the student as well as to the employing / collaborating organization of the student and submit a comprehensive report at the end of the semester working under the overall supervision and guidance of a professional expert who will be deemed as the supervisor for evaluation of all components of the dissertation. Normally the Mentor of the student would be the Dissertation supervisor and in case Mentor is not approved as the supervisor, Mentor may play the role of additional supervisor. The final grades for dissertation are Non-letter grades namely Excellent, Good, Fair and Poor, which do not go into CGPA computation.

#### **AE\* ZG633 Advances in Vehicle Body Structures 4**

Light Weight design of Vehicle Structure i.e. Front-End, Under Body etc; Materials Selection in Automotive Design; Material Matching and gauge Optimization; Lightweight Automotive Alloys; Mechanical Behaviour of Structural Polymers; Designing and Manufacturing with Lightweight Automotive Materials; Design and Manufacturing for Environment – Light Weight material perspective; Vehicle Crashworthiness - Light Weight material perspective; Advanced Light Weight Steels for Automobiles; Fuel Cell Materials and Manufacturing; Automotive Assembly Processes - Light Weight material perspective; Analysis of Lightweight Automotive Structures; Light Weight Power-train Materials and Design; Environmental Degradation of Materials - Light Weight material perspective; Application of Hybrid material and Joining methods.

#### **AEL\* ZC441 Automotive Vehicles**

**3**

Internal combustion engines; vehicle performance; analysis and design of vehicle components. Experimental or theoretical investigation of problems selected from the field of automotive vehicles.

#### **AEL\* ZC442 Advanced Driver Assistance Systems 4**

Automotive safety systems, assist and autonomous systems, automotive sensors and actuators for ADAS (stereo and mono cameras ultrasonic sensors, LIDAR, RADAR), fundamentals of machine vision, data fusion for ADAS, mechatronics for ADAS, human – machine interface for ADAS, telematics and infotainment, ADAS system, legal and ethical aspects of ADAS, real time systems and development, advanced driver assistance systems, advanced computer systems, automated driving applications and systems.

#### **AEL\* ZC443 Connected Cars**

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Fundamentals of IOT - Architecture, Sensors, Cloud and the trade-off between polling and storage requirements, Structure and implementation of CAN networks, CAN message, priority & arbitration and the control hardware involved in the network, data analytics by creating a simple data model using OBD tools, ethical and legal aspects of connected car applications including data theft, privacy and security vulnerabilities, building of predictive analytic model based on in-vehicle data.

#### **AEL\* ZG510 Automotive Control Systems**

**5**

Introduction to vehicle electronics, semiconductor diodes, FETs, rectifiers, small signal amplifiers, circuit models, automotive applications and case studies, automotive micro controllers, auto sensors and actuators, vehicle electronics, feedback control, control strategy, analog and digital controllers, expert systems and neural networks, advanced topics in EMC, vehicle communication networks, automotive control system design, transmission and powertrain, brake, traction, suspension, active safety and supplementary restraint systems, intelligent vehicle systems and ADAS.

#### **AEL\* ZG512 Embedded System Design**

**4**

Introduction to embedded systems; embedded architectures: Architectures and programming of microcontrollers and DSPs. Embedded applications and technologies; power issues in system design; introduction to software and hardware co-design.

#### **AEL\* ZG513 Automotive Communication Systems 5**

Introduction to communication engineering; automotive communication systems: basic, current and future generation automotive communication protocols and telematics, advanced communication, intersystem communication and multiplex systems, wireless and photonics systems engineering, communications and networking, signal propagation in a mobile environment, modulation, coding, equalization, multiple access techniques, spread spectrum systems, second and third generation systems, UMTS, IMT-2000; Intra Vehicular Buses - CAN, TTCAN, FTTCAN, RT and FT Ethernet, TTP/A, TTP/C, Flexray, LIN, MOST; Clock

Synchronization and Diagnostic Services in Intra Vehicular Buses.

#### **AEL\* ZG514 Robust and Intelligent Systems Design 5**

Principles of fault tolerant systems, redundancy, parallel and shared resources, spatial systems, configurations, design aspects, intelligent transport systems, neural networks and fuzzy logic, reconfigurable hardware system design, energy aware computing systems.

#### **AEL\* ZG517 Automotive Systems Engineering 4**

Automotive systems development and testing, compatibility issues, performance prediction, design requirements and engineering metrics, systems engineering process, life cycle standards and management, concurrent engineering, systems analysis applications, and advanced model based development.

#### **AEL\* ZG518 Electric and Hybrid vehicles 4**

Electric motors, drives, control, batteries, architectures, energy storage, recovery, and management, characteristics of autonomous vehicles, modelling, simulation, analysis and comparison of relations among multiple parameters for electric, hybrid and autonomous vehicles, insights into regulations and norms with respect to electric, hybrid and autonomous vehicles, hybrid vehicle propulsion systems, sustainable automotive power technology.

#### **AEL\* ZG519 Automotive Security 4**

Security concepts, security attacks and risks, architectures, policy management, mechanisms, understanding the risks and advantages of vehicle to internet (V2I), vehicle to vehicle (V2V), vehicle to IoT (V2IoT) connectivity, issues concerning the security of intelligent transport systems that communicate with the vehicle, telematics, cryptography, security standards, security system interoperability and case studies of the automotive security systems and connectivity technologies, automotive cyber security and autonomous vehicles, connected vehicle driver responsibility, issues around liabilities related to automotive cyber security incidents.

#### **AEL\* ZG531 Product Design 5**

Introduction to creative design; user research and requirements analysis, product specifications, Computer Aided Design; standardization, variety reduction, preferred numbers and other techniques; modular design; design economics, cost analysis, cost reduction and value analysis techniques, design for production; human factors in design: anthropometric, ergonomic, psychological, physiological considerations in design decision making; legal factors, engineering ethics and society.

#### **AEL\* ZG533 Autotronics 5**

Fundamentals of automotive EMC, control concepts, control design with the help of sensors and signal conditioning. Understanding of autotronics and vehicle intelligence, sensor technologies, intelligent systems and mechatronic modelling. Introduction, electricity and electronic fundamentals, sensors, sensor types, signal conditioning, system modelling, dynamic response of systems, feedback/closed loop controllers, electronic fuel control systems, actuators: fuel injectors, exhaust gas recirculation, motors and ignition systems, hydraulics.

#### **AEL\* ZG534 Automotive Networking 4**

Overview of TCP/IP systems, Disturbed and Networked Embedded systems, Embedded Internet, Real Time Networks and Fault Tolerant Networks – Issues and Design, Intelligent Transport Systems and IoT for Automotive Systems; Fault and Error Containment, Intra and Interworking in Vehicular Systems: Intra Vehicular Buses - an overview, Time Triggered and Event Triggered Networks in Intra Vehicular Systems, Automotive Network Domains – Power Train, Chassis, Body Domains – Network Characteristics and Domain Requirements, V2I/V2R, V2V, VANETS - MANETS vs VANETS, Safety Applications vs Comfort Applications of

VANETS, Network Architecture, Protocols, Network Stack, MAC protocols, IEEE Wave and DSRC, Routing Protocols, Network Security – Attacks and Solutions. Emerging and advanced automotive networks – Aerial Networks; Interconnection between various networks in ITS – Interconnection between Intra and Inter Vehicular Systems, Network Models in Automotive Systems – Publisher Subscriber Model, Producer Consumer Models, Device Interoperability Issues in Interconnected Vehicles, Middleware in Automotive Systems, Network Management Function, Objects and Device Management - AutoSar and Networked OS; Protocol-independent design methodology for distributed real-time networks in vehicles – Volcano.

#### **AEL\* ZG554 Reconfigurable Computing 5**

Overview of Programmable Logics. FPGA fabric architectures. Logic Elements and Switch Networks. Design and Synthesis of Combinational and Sequential Elements. Placement and Routing. Pipelining and other Design Methodologies. Fine-grained and Coarse-Grained FPGAs. Static and Dynamic Reconfiguration. Partitioning. Hardware/Software Portioning and Partial Evaluation; Systolic Architectures.

#### **AEL\* ZG557 Artificial and Computational Intelligence 5**

Agents and environments, Task Environments, Working of agents; Uninformed Search Algorithms: Informed Search. Local Search Algorithms & Optimization Problems: Genetic Algorithm; Searching with Non-Deterministic Actions, Partial Information and Online search agents, Game Playing, Constraint Satisfaction Problem, Knowledge Representation using Logics: TT-Entail for inference from truth table, Proof by resolution, Forward Chaining and Backward Chaining, Inference in FOL, Unification & Lifting, Forward chaining, Backward Chaining, Resolution; Probabilistic Representation and Reasoning : Inference using full joint distribution, Representation of Conditional Independence using BN, Reinforcement Learning; Difference between crisp and fuzzy logic, shapes of membership function, Fuzzification and defuzzification, fuzzy logic reasoning; Decision making with fuzzy information, Fuzzy Classification; Connectionist Models: Introduction to Neural Networks, Hopfield Networks, Perceptron Learning, Backpropagation & Competitive Learning, Applications of Neural Net: Speech, Vision, Traveling Salesman; Genetic Algorithms - Chromosomes, fitness functions, and selection mechanisms, Genetic algorithms: crossover and mutation, Genetic programming.

#### **AEL\* ZG621 Safety Critical Advanced Automotive Systems 4**

Functional safety, safety in electrical engineering, architecture / design practices for safety critical systems, ISO 26262: Road vehicles – functional safety, IEC 1508 standards; Methodology of certification and qualification for IEC 1508, modelling real time systems (UML-RT, and the tools), reliable, common system bus – VME, ASCB, safeBus, multiBus II etc. Real time and safety standard and certifications, FPGA and ASIC based design, low-power techniques in RT embedded systems on-chip networking; Hardware software partitioning and scheduling, co-simulation, synthesis and verifications, architecture mapping, HW-SW interfaces.

#### **AEL\* ZG626 Hardware Software Co-Design 5**

FPGA and ASIC based design, Low-Power Techniques in RT Embedded Systems On-chip networking. Hardware Software partitioning and scheduling, Co-simulation, synthesis and verifications, Architecture mapping, HW-SW Interfaces and Re-configurable computing.

**AEL\* ZG631 Automotive Diagnostics and Interfaces 5**

Sensors used in today's vehicles, such as temperature, pressure, position, distance, velocity, torque and flow; Designing and building analogue interfaces, regulation and control problem with reference to power electronic converters; converter models for feedback: basic converter dynamics, fast switching, piece-wise linear models, discrete-time models, On board diagnostics II (OBD II); Voltage mode and current mode controls for DC-DC converters, comparator based control for rectifier systems, proportional and proportional-integral control applications; Control design based on linearization: transfer functions, compensation and filtering, compensated feedback control systems; Hysteresis control basics, and application to DC-DC converters and inverters; Automotive diagnostics, electronic interfaces, sensors and interfacing, introduction to microsystems packaging, microcomputer control systems, reliability, diagnostics, and testing of vehicles.

**AEL\* ZG628T Dissertation 16**

A student registered in this course must take a topic in an area of professional interest drawn from the on the job work requirement which is simultaneously of direct relevance to the degree pursued by the student as well as to the employing / collaborating organization of the student and submit a comprehensive report at the end of the semester working under the overall supervision and guidance of a professional expert who will be deemed as the supervisor for evaluation of all components of the dissertation. Normally the Mentor of the student would be the Dissertation supervisor and in case Mentor is not approved as the supervisor, Mentor may play the role of additional supervisor. The final grades for dissertation are Non-letter grades namely Excellent, Good, Fair and Poor, which do not go into CGPA computation.

**AIML\* ZC416 Mathematical Foundations for Machine Learning 4**

Vector and matrix algebra, systems of linear algebraic equations and their solutions; Eigenvalues, eigenvectors and diagonalization of matrices, multivariate calculus, vector calculus, Jacobian and Hessian, multivariate Taylor series, gradient descent, unconstrained optimization, constrained optimization, nonlinear optimization, stochastic gradient descent, dimensionality reduction and PCA, optimization for support vector machines.

**AIML\* ZC418 Introduction to Statistical Methods 4**

Basic probability concepts, Conditional probability, Bayes Theorem, Probability distributions, Continuous and discrete distributions, Transformation of random variables, estimating mean, variance, covariance, Hypothesis Testing, Maximum likelihood, ANOVA – single factor, dual factor, time series analysis: AR, MA, ARIMA, SARIMA, sampling based on distribution, statistical significance, Gaussian Mixture Model, Expectation Maximization.

**AIML\* ZG511 Deep Neural Networks 4**

Introduction to neural networks, approximation properties, back propagation, deep network training, regularization and optimization, convolution neural networks, recurrent neural networks, attention models, transformers, neural architecture search, federated learning, meta learning, applications in time series modelling and forecasting, online (incremental) learning

**AIML\* ZG512 Deep Reinforcement Learning 4**

Introduction and applications. Markov decision processes(MDP), Tabular MDP planning, Tabular RL policy evaluation, Q-learning, model based RL, deep RL with function approximation, policy search, policy gradient, fast learning, applications in game playing, imitation learning, RL for neural architecture search, batch RL

**AIML\* ZG513 Advanced Deep Learning 4**

Introduction to Representation Learning, PCA and variants, likelihood based models, flow models, autoregressive models, latent variables, Deep autoencoders, Boltzmann Machines, Generative Adversarial learning, Variants of GAN and applications, DeepDream, neural style transfer, self-supervised learning, semi-supervised learning, language model learning, applications in time series modelling, representation learning for reinforcement learning, deep clustering

**AIML\* ZG514 Graph Neural Networks 4**

Basics of graph theory, machine learning on graphs, node embeddings, link analysis, representation learning for graphs, label propagation for node classification, empirical risk minimization, graph convolutional filters, composition with pointwise nonlinearities, permutations, dilation and stability, transferability, graph RNN, algebraic neural networks, applications of graph NN in subgraph mining, recommendation systems, community structures in networks, deep generative models, knowledge graph embeddings and reasoning.

**AIML\* ZG515 Distributed Machine Learning 4**

Introduction to parallel and distributed models of computation: Scalable frameworks to parallelize machine learning algorithms, Data and computation heterogeneity, Data parallelism vs Model parallelism, Challenges: consistency, fault tolerance, communication, resource management, programming models; Distributed ML algorithms: K-means, DBSCAN, Distributed association rule mining: FDM, Linear and logistic regression; Distributed DL Algorithms: Gradient descent techniques for empirical risk minimization, SGD in Neural Network Training and its convergence analysis, Distributed Synchronous SGD, Asynchronous SGD, Hogwild, Local-update SGD, Decentralized SGD, Overlap SGD, Quantized SGD, Adacommm Vs Distributed SGD, Elastic Averaging, AdaSyn, AdaQuant; Federated learning: Privacy and security in federated learning; Hyper parameter optimization; In depth case studies of a few algorithms.

**AIML\* ZG516 ML System Optimization 4**

Review of parallel and distributed systems, System Performance Trade-offs, Distributed machine learning for large models and datasets, general purpose distributed computing frameworks - Hadoop, map reduce and Apache Spark, Deep Learning frameworks and runtimes, deep learning hardware, Deep learning compilers with optimizations, scalable training and Inference Serving , parameter serving, Federated Learning, model compression for optimizing communication and resource constrained devices, Case studies of machine learning on single GPU systems, on GPU Clusters.

**AIML\* ZG517 Fair, Accountable, Transparent Machine Learning 4**

Biases and fairness, fair representation learning, Interpretability and Transparency, Example and Visualization Based Methods for Interpretability, Interpreting deep neural networks, Fairness Through Input Manipulation, Fair NLP/Vision, Robustness and adversarial attacks/defence, ML auditing, privacy

**AIML\* ZG518 Computational Learning Theory 4**

Introduction. The PAC model, Overfitting and Occam's razor, The Online Mistake-Bound model, Combining Expert Advice / Multiplicative Weights, Regret Minimization, sleeping experts, The Perceptron Algorithm, Margins, and introduction to Kernels. SVMs, Uniform Convergence and VC-Dimension, Rademacher Bounds. Boosting. Statistical Query Model, Computational Hardness Results for Learning. MDPs and Reinforcement Learning. Differential Privacy and Learning. Semi-Supervised Learning.

**AIML\* ZG519 NLP Applications****4**

Sentiment Analysis, Grammar and Spelling Checkers, Cross Lingual Language Models, Machine Translation including Indic Languages, Question answering and Chatbots, Information extraction (named entity recognition, relation extraction), Knowledge graph

**AIML\* ZG520 Speech Processing 4**

Introduction to statistical speech processing. HMM, WFST and neural net based acoustic modelling, language modelling, acoustic feature analysis, neural networks for speech recognition, search and decoding, speech synthesis

**AIML\* ZG521 Conversational AI 4**

Intro to conversational AI, Use cases of chatbots, NLU and Dialog Management, Design the flow of conversation, Crafting training data, Training the NLU model, Understanding Dialog Management, Intent classification and entity extraction, using slots for context understanding, Understanding NLU components, supporting multiple languages, Voice bots, Testing the bot, Failing gracefully with fall back action

**AIML\* ZG522 Social Media Analytics 4**

Social Media Platforms, NLP in SMA, Text Summarization, Opinion Science and dynamics, ML/DL in SMA- Community detection, Ethical Social Media, Case Studies- Role of social media in disaster management, SM driven mental health and behaviour Analysis

**AIML\* ZG523 MLOps 4**

Adaptation of DevOps for building and deploying machine learning systems, Model Deployment: Infrastructure requirements; Deployment patterns, Model CI/CD (Build, Test, Integration and Delivery of model); Model Serving tools and technologies; Model life cycle management, ML pipelines with data management support, model assessment, evolution and management in production, MLOps infrastructure and tools; Trends in Model deployment: ML on the Cloud / Edge / Browsers; VMs, Containers, Docker, Kubernetes (K8S), FaSS; ML-as-a-Service.

**AIML\* ZG524 Design of Algorithms 5**

Review of important data structures, Design techniques such as divide-and-conquer, greedy, recursion, backtracking, branch-and-bound, simulation, Dynamic Programming (Examples, Analysis, General Structure of Solutions, Limitations and Applicability); Illustrations dealing with problems in AI and machine learning; Computational complexity and bounds; NP-hard and NP-complete problems; Introduction to Approximation algorithms; Randomized algorithms.

**AIML\* ZG525 Computer Vision 4**

Image formation, structure, and transformations; Low-level(filters, features, texture), Mid-level(segmentation, tracking, morphology) and High-Level Vision (registration, contour geometry, object detection and classification, segmentation); deep learning for object detection; recognition; face detection and face recognition; Facial key point recognition; Optical Character recognition; visual annotation; Activity recognition; Applications for autonomous cars – Landmark detection and tracking, track pedestrians; 3D projection; Image search and retrieval; edge devices for computer vision

**AIML\* ZG526 Probabilistic Graphical Models 4**

HMM, Markov Random Field, Bayesian networks, Representation, Learning, Inference; Dynamic Bayesian Networks and Temporal Bayesian networks, applications.

**AIML\* ZG527 Audio Analytics 4**

Audio data; sound analysis using DFT, STFT, file formats; Spectrogram; Spectral features; Feature extraction from Audio signal; Sinusoidal model; Harmonic model; Sound transformations; Sound and music description; Automatic speech recognition - Acoustic Phonetics, Dialog, Speech Synthesis, Text to Speech (TTS); Meaning Extraction; Music genre classification; Indexing music collections;

Recommending music; Speech processing and synthesis — generating artificial voice for conversational agents; tagging and generation; Similarity search for audio files; HMM; AI for ultrasonic and infrasonic applications

**AIML\* ZG528 AI and ML for Robotics 4**

Fundamentals of robotics. Aerial robots, warehouse robots, under actuated robots. Sensor systems for robots. Effectors and actuators. Robot Operating System. Robot motion models. PID control, Beam model of range finders. Recursive state estimation - Bayes filters, Kalman, extended Kalman, information filters, and nonparametric filters such as particle filters. Mobile robot localization - extended Kalman filter, Grid and Monte Carlo. Simultaneous mapping and localization algorithms, path planning algorithms, Instance based learning, demonstration based path planning using reinforcement learning, deep learning and reinforcement learning based mapping, navigation and control of mobile robots.

**AIML\* ZG529 Data Management for Machine Learning 4**

Data Models and Query Languages: Relational, Object-Relational, NoSQL data models; Declarative (SQL) and Imperative(MapReduce) Querying; Data Encoding: Evolution, Formats, Models of dataflow; Machine learning workflow; Data management challenges in ML workflow; Data Pipelines and patterns; Data Pipeline Stages: Data extraction, ingestion, cleaning, wrangling, versioning, transformation, exploration, feature management; Modern Data Infrastructure: Diverse data sources, Cloud data warehouses and lakes, Data Ingestion tools, Data transformation and modelling tools, Workflow orchestration platforms; ML model metadata and Registry, ML Observability, Data privacy and anonymity.

**AIML\* ZG530 Natural Language Processing 4**

Natural Language Understanding and Generation, N-gram and Neural Language Models, Word to Vectors / Word Embedding (Skip gram/CBOW, Glove, BERT/ XLM, MURIL), Part of Speech Tagging, HiddenMarkov Models, Parsing - Syntactic, Statistical, Dependency, Word Sense Disambiguation, Semantic Web Ontology.

**AIML\* ZG531 Video Analytics 4**

Digital Video; Spatio temporal sampling; Low-Level Features to High-Level Semantics; Video enhancement technologies (denoising, stabilization, unsharp masking, super-resolution); background modelling and Foreground Detection; ML techniques for Video Motion Detection; tracking; compression; Indexing and Retrieval; Browsing and Summarization; Applications in License plate detection on moving vehicles, monitor traffic jams; Activity recognition; crowd management; gesture recognition.

**AIML\* ZG532 Automated Reasoning 4**

Propositional Logic: Propositions and logical connectives, Propositional logical consequence, Logical equivalence, Inductive definitions and structural induction and recursion; Deductive Reasoning in Propositional Logic: Axiomatic systems for propositional logic, Semantic Tableaux, Natural Deduction, Clausal Resolution, Resolution-based derivations; First-order Logic: Syntax and Semantics of first-order logic, Logical validity, consequence, and equivalence, Syllogisms; Deductive Reasoning in First-order Logic: Axiomatic system for first-order logic, Semantic Tableaux, Natural Deduction, Prenex and clausal normal forms, Resolution, Soundness and completeness; Limitations: Hilbert's programme, Tarski's theorem on the undefinability of truth, Incompleteness of axiom systems, Godel's incompleteness theorem, Definability and decidability, Church's theorem, Church-Turing hypothesis.

**AIML\* ZG537 Information Retrieval****4**

Organization, representation, and access to information; categorization, indexing, and content analysis; data structures for unstructured data; design and maintenance of such data structures, indexing and indexes, retrieval and classification schemes; use of codes, formats, and standards;

analysis, construction and evaluation of search and navigation techniques; search engines and how they relate to the above. Multimedia data and their representation and search.

#### **AIML\* ZG548 Advanced Data Mining 4**

Topics beyond conventional record data mining. Mining complex data structures. Tree/graph mining, sequence mining, web/text data mining, stream data mining, spatiotemporal data mining, mining multi-variate time series data, high-dimensional data clustering, and mining social networking sites. Mining data from multiple relations (Multi-relational Data Mining). Privacy preserving Data Mining. Distributed computing solutions for data intensive data mining.

#### **AIML\* ZG557 Artificial and Computational Intelligence 5**

Agents and environments, Task Environments, Working of agents; Uninformed Search Algorithms: Informed Search. Local Search Algorithms & Optimization Problems: Genetic Algorithm; Searching with Non-Deterministic Actions, Partial Information and Online search agents, Game Playing, Constraint Satisfaction Problem, Knowledge Representation using Logics: TT-Entail for inference from truth table, Proof by resolution, Forward Chaining and Backward Chaining, Inference in FOL, Unification & Lifting, Forward chaining, Backward Chaining, Resolution; Probabilistic Representation and Reasoning : Inference using full joint distribution, Representation of Conditional Independence using BN, Reinforcement Learning; Difference between crisp and fuzzy logic, shapes of membership function, Fuzzification and defuzzification, fuzzy logic reasoning; Decision making with fuzzy information, Fuzzy Classification; Connectionist Models: Introduction to Neural Networks, Hopfield Networks, Perceptron Learning, Backpropagation & Competitive Learning, Applications of Neural Net: Speech, Vision, Traveling Salesman; Genetic Algorithms - Chromosomes, fitness functions, and selection mechanisms, Genetic algorithms: crossover and mutation, Genetic programming.

#### **AIML\* ZG565 Machine Learning 4**

Introduction to Machine Learning, Various kinds of learning, Supervised Learning, Unsupervised Learning, Model Selection; Bayesian Learning, MAP Hypothesis, MDL Principle, Bias Variance Decomposition, Bayes Optimal Classifier, Naive Bayes Classifier; Linear Models for Regression, Linear Models for Classification; Non-Linear models, Decision trees; Instance Based Learning, KNN Algorithm, CBR Learning; Support Vector Machines, VC Dimension; Neural Networks, Perceptron Learning, Back Propagation Algorithm; Introduction to Genetic Algorithms.

#### **AIML\* ZG567 AI and ML Techniques for Cyber Security 5**

Introduction to Cyber-Security; Supervised Learning for Misuse/Signature Detection; Machine Learning for Anomaly Detection; Malware detection and classification; Network Intrusion detection and classification; Detection and categorization of domain names; Profiling Network Traffic; Adversarial Machine Learning for Malware detection

#### **AIML\* ZG577 Metaheuristics for Optimization 4**

Metaheuristics refers to class of approximation algorithms which can solve hard optimization problems within an acceptable time limit. This course covers principles behind such algorithms and application to real world problems. The algorithms covered in the courses include simulated annealing, evolutionary algorithms, ant colony method, and particle swarms.

#### **BA\* ZC411 Marketing 4**

Definition and scope, consumer behavior, competitive behavior, demand estimation, new product introduction, product/brand management, pricing policies, channels of distribution, credit management, advertising and other sales promotion, positioning, marketing regulation, market research basics of industrial marketing.

#### **BA\* ZC412 Models and Applications in Operations Research 4**

This course provides a survey of selected topics in operations research (OR). Emphasis is placed on the practical application of OR tools rather than on the mathematical properties. Application areas include: financial planning and portfolio selection, production, priority planning and marketing. Topics include linear programming and its applications; programming to achieve a set of goals or targets with applications in finance and production; capital budgeting and project selection; transportation and network models; and portfolio models.

#### **BA\* ZC413 Introduction to Statistical Methods 3**

Different types of data; Data Visualization; Data summarization methods; Tables, Graphs, Charts, Histograms, Frequency distributions, Relative frequency measures of central tendency and dispersion; Box Plot; Chebychev's Inequality on relationship between the mean and the standard deviation of a probability distribution. Basic probability concepts, Conditional probability, Bayes Theorem, Probability distributions, Continuous and discrete distributions, Transformation of random variables, Moments, Correlation and Covariance, Parameter Estimation, Hypothesis Testing.

#### **BA\* ZC414 Optimization Methods for Analytics 4**

This course will focus on development of analytical models using optimization (and simulation) techniques to analyze and recommend appropriate solutions for complex business problems across various functional areas including finance, economics, operations, and marketing. Key topics covered in this course are as follows: solving various problems related to planning, production, transportation, microeconomics, etc. using LP models. Decision making in the context of multi stage LP models. Application of Goal Programming (GP) and Analytic Hierarchy Process (AHP) for decisions relating to large teams and complex problems with long term implications. We will use various tools including spreadsheets and other software for the experiential components of this course to illustrate the application of these techniques to various industries.

#### **BA\* ZC415 Analytics for Competitive Advantage 4**

In today's competitive business environment, high performing companies are doing more than just collecting data, storing it and generating reports. They are developing competitive strategies using Business Analytics. In this course we will look at how to use data-driven insights to differentiate a firm's business/ product strategy from other companies that are making the same product or delivering the same service. This course is designed for analysts in any function: marketing, operations, quality, customer service, IT, finance/accounting or human resources. We will use case studies and other experiential components to study the application of data-driven insights in the context of various industries.

#### **BA\* ZC416 Investment Banking Analytics 4**

Modern portfolio theory, Capital Asset Pricing Model (CAPM), Arbitrage Pricing Theory (APT), and efficient market theory; Passive investing: indexing; Introduction to behavioral finance; Active investing: security analysis – fundamental analysis (strategic, financial, marketing tools) and technical analysis; Portfolio management including allocation, rebalancing and risk management; Transaction cost analysis; Fixed-Income and Credit Sensitive Instruments.



**BA\* ZC417 Financial Risk Analytics 4**

The course will first cover the basics of Financial Risk and then focus on applications such as: currency, interest rate derivatives, equity markets and products, and commodity markets and products. Major topics include methodologies for measuring and analyzing volatility (a key metric of risk) including EWMA, ARCH & GARCH processes, volatility clusters and the issue of time varying volatility; Extreme value theory; Measuring risk using Value-at-Risk, including computation of VaR by various methods, and stress testing; Monte Carlo simulation, address issues in generating price process (such as Brownian Motion, Ito Process), Cholesky decomposition in computing multi-asset VaR; Currency risk analysis in global investing, interest rate parity (covered and uncovered); Value at risk for fixed income portfolios; Credit Risk Analytics. The topics covered in this course will have inbuilt case studies in financial risk management so as to understand the practical implications of the methodologies covered in the course.

**BA\* ZC418 Advanced Financial Modeling 4**

Valuation of equity securities, fixed income securities, and derivatives. Topics include Introduction to Financial Modelling and Spreadsheet Essentials, Measuring Risk (Testing market efficiency with regression analysis & pivot tables), Portfolio optimization (Mean-variance portfolio selection, Bond portfolio selection, Term structure estimation, Capital budgeting), Advanced risk analysis (Monte-Carlo simulation, Risk analysis of discounted cash flow models, Spreadsheet features using @Risk for Monte-Carlo simulation and combining macros with @Risk), Business and equity valuation modeling, LBO Analysis Model, Stock Merger Model, etc.

**BA\* ZC420 Data Visualization 3**

Information overload and issues in decision making. Design of visual encoding schemes to improve comprehension of data and their use in decision making; presentation and visualization of data for effective communication. elementary graphics programming, charts, graphs, animations, user interactivity, hierarchical layouts, and techniques for visualization of high dimensional data & discovered patterns.

**BA\* ZC421 Marketing Models 4**

The primary purpose of this course is to enhance your ability to develop and critically evaluate marketing models. The course will examine a variety of models, including models of consumer behavior, industrial buying and firm behavior, (aggregate) market models (e.g., competition, market entry), strategic marketing models, forecasting methods, new product models, marketing response models (e.g., channels, pricing, advertising, promotion), forecasting models and decision support systems.

**BA\* ZC422 Marketing Analytics 4**

This course discusses in detail how analytics can play a vital role in the various elements of the marketing research process viz. Problem Definition, Development of an approach to the problem, Research Design formulation, Fieldwork or Data collection, Data preparation & Analysis and finally Report preparation and Presentation. The emphasis of the course is proportionately focused on Concepts, Techniques & Methodology, and Marketing Research Applications.

**BA\* ZC423 Retail Analytics 4**

RFM (recency, frequency, monetary) analysis, chum modeling, retention modeling, shopper analytics, market basket association analysis, customer segmentation and profiling, propensity scoring models to identify prospective customers, best customers, lifetime value modeling, marketing campaign response modeling, cross sell modeling, etc.

**BA\* ZC424 Supply Chain Analytics 4**

Demand Management and Forecasting: static, adaptive and rolling plans. Supply chain Network design: Mathematical Programming Models for Selecting the right number, location, territory, and size of warehouses, plants, and production lines; and optimizing the flow of all products through the supply chain. Space Determination and Layout Methods. Inventory Management: Inventory aggregation Models, Dynamic Lot sizing Methods, Multi-Echelon Inventory models. Transportation Network Models and scheduling algorithms: Efficient and responsive supply chains. Maximal Flow Problems, Multistage Transshipment. Supply chain dynamics and integration: Cost analysis of supplier selection, order fulfillment process, levers for improved supply chain performance, pricing and revenue management and coordination in supply chain. Application of Analytic Hierarchy Process (AHP) to supply chain analytics.

**BA\* ZC425 HR Analytics 4**

In this course students will learn how to leverage analytic techniques in the context of the challenges faced by the HR and Talent Acquisition and Management functions. The primary goal is to leverage analytical techniques to deliver meaningful insights for effectively managing employees for achieving the goals of the organization. Applications include attracting right talent, forecasting future staffing needs, managing attrition and improving employee satisfaction levels. We will be extensively leveraging experiential components such as case studies to understand how various organizations have applied these concepts in practice.

**BA\* ZC426 Real-time Analytics 4**

Motivation and challenges of real-time, distributed, fault-tolerant data processing, distributed messaging architecture (Apache Kafka), Real time data processing platform: Storm, Storm basic programming skills, linking Spouts, and connecting to the live Twitter API to process real-time tweets, multi-language capability of storm (with Python scripts), Case study: Networking fault prediction. This course also helps a student to analyze and understand Big-data using visuals. Topics include, Design principles, Perception, color, statistical graphs, maps, trees and networks, high dimensional data, data visualization tools.

**BA\* ZC471 Management Information Systems 3**

Introduction to Information Systems; Concepts of management, concepts of information, systems concepts; Information Systems and Organizations; decision making process; database systems; data communications; planning, designing, developing and implementing information systems; quality assurance and evaluation of information systems; future developments and their organizational and social implications; decision support system and expert systems.

**BA\* ZG512 Predictive Analytics 4**

Basic concepts in predictive analytics / predictive modeling. Two core paradigms for predictive modeling: classification and regression. Identification of important variables and their relation to each another. Basic modeling techniques such as k-nearest neighbors, classification and regression trees (CART), and Bayesian classifiers. Ensemble techniques. Model selection techniques.

**BA\* ZG521 Financial Management 4**

Concepts and techniques of financial management decision; concepts in valuation – time value of money; valuation of a firm's stock, capital asset pricing model; investment in assets and required returns; risk analysis; financing and dividend policies, capital structure decision; working capital management, management of cash, management of accounts receivable; inventory management, short and intermediate term financing, long term financial tools of financial analysis, financial ratio analysis, funds analysis and financial forecasting, operating and financial leverages.

**BA\* ZG522 Business Data Mining 4**

Principles and current practices of data mining; data analytics tools and applications; acquiring and cleaning data, role of data warehousing in data mining; challenges and issues in data mining; Knowledge Discovery in Databases (KDD); role of data mining in KDD; algorithms for classification, association rules, and clustering; Time series analysis.

#### **BA\* ZG523 Introduction to Data Science 3**

Context and use of Data Science. High-dimensional data, graphs, vectors in high dimensional space and large matrices; Algorithms for massive data problems, sampling techniques. Techniques for extracting information/patterns from data.

#### **BA\* ZG524 Advanced Statistical Methods 4**

Point and interval estimation and hypothesis testing, chi-square tests, non-parametric statistics, analysis of variance, regression; linear and multiple linear, correlation, factor models, decision theory, Bayesian statistics and autocorrelation, multivariate regression, randomization and sampling processes, Markov processes with discrete/continuous state space, statistical simulation and pattern recognition, Time Series Analysis.

#### **BA\* ZG525 Big Data Analytics 4**

Big Data and its applications in various domains such as banking and finance, social media, e-commerce, and healthcare. Five V's of big data, namely Volume, Variety, Velocity, Veracity, and Value. Analysis of structured and unstructured data in various forms, including web logs, videos, e-mails, photographs, tweets etc. Uncovering hidden patterns and unknown correlations for better business decisions. Key technologies used in storing, manipulating, and analyzing big data. Tools for statistical analysis and key methods used in machine learning as applied to Big Data. Distributed computing techniques used in Big Data Analytics. Open source frameworks for data analysis including tools, languages, and platforms such as Hadoop, Pig, Hive, R, Spark, Mahout Etc.

#### **BA\* ZG537 Text Analytics 4**

Emerging methods of organizing, summarizing, and analyzing collections of unstructured and lightly-structured text. Basics of text processing and natural language processing. Applications of text analysis such as sentiment analysis and opinion mining. Text processing techniques stop word removal, text parsing, and other relevant tree processing steps; text preprocessing, feature selection, text classification, text clustering, and summarization. Natural language processing techniques/steps – Syntactic Analysis, Semantic analysis, and Pragmatic analysis. Case studies with focus on business processes.

#### **BA\* ZG621 Supply Chain Management 4**

Customer driven strategies in production and distribution systems; Integrated production and distribution networks; SCM in the context of JIT and MRP-II; Distribution Resource Planning; Management of dealer networks; Total Control & Product innovation across the supply chain; Incoming logistics and supplier relationships; Value addition analysis; Metrics for management of supply chain performance; Mathematical models and computer assisted decision support for SCM; Mathematical programming for SCM.

#### **BITS ZC411 Object Oriented Programming 3**

Object orientation concepts and principles: abstraction, encapsulation, modularity, inheritance, and polymorphism; classes and objects; static and dynamic binding; class utilities; metaclasses; object oriented software engineering; programming and problem solving using one or more of the popular object-oriented programming languages like C++ or Java.

#### **BITS ZC423T Project Work 20**

Consistent with the student's professional background and work-environment, the student will be required to carry out work-oriented projects. The student would be required to select an area of work that is considered vital to the sponsoring organization. The topic of the project and detailed project outline that is prepared by the student, in consultation with his/her Mentor, needs to be approved by the Dean, WILPD. On approval, the student carries on with the work-centered project, adhering to the guidelines provided in the detailed course handout, taking all the prescribed evaluation components on time. At the end of the semester, the student should submit a comprehensive Project Report, to the Institute for evaluation. The student will be evaluated on the basis of the various interim evaluation components, contents of the report and Seminar/Viva-Voce that may be conducted at Pilani or at any other Centre approved by the Institute.

#### **BITS ZC424T ProjectWork 10**

Consistent with the student's professional background and work-environment, the student will be required to carry out a work-oriented project. At the beginning of the semester, the student should select an area of work that is considered vital to the sponsoring organization, and prepare a detailed project outline, in consultation with his/her Mentor. The student carries on with the work-centered project, adhering to the guidelines provided in the detailed course handout, and taking all the prescribed evaluation components on time. At the end of the semester, the student should submit a comprehensive Project Report. The student will be evaluated on the basis of the various interim evaluation components, contents of the report and a final seminar and viva-voce.

#### **BITS ZC461 Software Engineering 3**

Software engineering concepts and methodology; formal requirements specification; estimation; software project planning; detailed design; techniques of design; productivity; documentation; programming languages styles, code review; tool, integration and validation; software quality assurance; software maintenance; metrics, automated tools in software engineering.

#### **BITS ZC463 Cryptography 3**

Objectives of cryptography; ciphers – block and stream; mathematical foundations – modular arithmetic, finite fields, discrete logarithm, primality algorithms; RSA; digital signatures; interactive proofs; zero-knowledge proofs; probabilistic algorithms; pseudo-randomness.

#### **BITS ZC471 Management Information Systems 3**

Introduction to Information Systems; Concepts of management, concepts of information, systems concepts; Information Systems and Organizations; decision making process; database systems; data communications; planning, designing, developing and implementing information systems; quality assurance and evaluation of information systems; future developments and their organizational and social implications; decision support system and expert systems.

#### **BITS ZC481 Computer Networks 3**

Introduction, history and development of computer networks; Reference models; Physical Layer: theoretical basis, transmission media, types of transmission; MAC sub-layer: local area networks, FDDI; Data Link Layer: Sliding Window protocols, design aspects; Network Layer: routing algorithms, congestion control algorithms, internetworking; Transport Layer: Integrated Services Digital Network (ISDN), Asynchronous Transfer Mode (ATM) - reference models, service classes, switch design, LAN emulation; Application Layer protocols.

#### **BITS ZG553 Real Time Systems 5**

Real time software, Real time operating systems-scheduling, virtual memory issues and file systems, real time data bases, fault tolerance and exception handling techniques, reliability evaluation, data structures and algorithms for real

time/embedded systems, programming languages, compilers and run time environment for real time/embedded systems, real time system design, real time communication and security, real time constraints and multi-processing and distributed systems.

#### **BITS ZG628TDissertation 16**

A student registered in this course must take a topic in an area of professional interest drawn from the on the job work requirement which is simultaneously of direct relevance to the degree pursued by the student as well as to the employing / collaborating organization of the student and submit a comprehensive report at the end of the semester working under the overall supervision and guidance of a professional expert who will be deemed as the supervisor for evaluation of all components of the dissertation. Normally the Mentor of the student would be the Dissertation supervisor and in case Mentor is not approved as the supervisor, Mentor may play the role of additional supervisor. The final grades for dissertation are Non-letter grades namely Excellent, Good, Fair and Poor, which do not go into CGPA computation.

#### **BITS ZG629T Dissertation 20**

A student registered in this course must take a topic in an area of professional interest drawn from the on the job work requirement which is simultaneously of direct relevance to the degree pursued by the student as well as to the employing / collaborating organization of the student and submit a comprehensive report at the end of the semester working under the overall supervision and guidance of a professional expert who will be deemed as the supervisor for evaluation of all components of the dissertation. Normally the Mentor of the student would be the Dissertation supervisor and in case Mentor is not approved as the supervisor, Mentor may play the role of additional supervisor. The final grades for dissertation are Non-letter grades namely Excellent, Good, Fair and Poor, which do not go into CGPA computation.

#### **BITS ZG659Technical Communication 4**

Roleand importance of communication; effectiveness in oral and written communication; technical reports; technical proposals; technical descriptions; definitions and classifications; business correspondence; precis writing; memorandum; notices, agenda and minutes; oral communication related to meetings, seminars, conferences, group discussions, etc.; use of modern communication aids.

#### **BSDC\* ZC111 Probability& Statistics 3**

Probability spaces; conditional probability and independence; random variables and probability distributions; marginal and conditional distributions; independent random variables; mathematical expectation; mean and variance; binomial, Poisson and normal distributions; sum of independent random variables; law of large numbers; central limit theorem (without proof); sampling distribution and test for mean using normal and student's t-distribution; test of hypothesis; correlation and linear regression.

#### **BSDC\* ZC112 Electrical Sciences 3**

**Course** covers basic passive circuit elements, dependent and independent sources, network theorems, circuit analysis techniques and response of first and second order circuits. Introduction to three - phase circuits, magnetic circuits, transformers, basics of rotating machines. Semiconductors - operation of diodes, zener diodes, bipolar junction transistors and field effect transistors. Biasing techniques and applications of diodes and transistors. Introduction to operational amplifiers and applications. Introduction to Digital Electronics.

#### **BSDC\* ZC142 Computer Programming 4**

Basic Model of a Computer; Problem Solving-Basic Computing Steps and Flow Charting (Assignment, Sequencing, Conditionals, Iteration). Programming Constructs – Expressions, Statements, Conditionals, Iterators/Loops, Functions/Procedures; Data Types –

Primitive Types, Tuples, Choices (Unions or Enumerations), Lists/Arrays, Pointers and Dynamically Allocated Data. Input output and Files.

#### **BSDC\* ZC151 Writing Practice 3**

The course aims to develop students' writing ability. It is assumed that students who will be part of this course have not received explicit and extensive training in academic writing. Therefore, the course begins with paragraph writing and goes on to cover areas such as elements of writing, language issues and vocabulary related to writing and ends with different models of writing. Effort has been made to provide students with a comprehensive background in writing so that they can write their assignments, examinations, letters, reports and essays more effectively.

#### **BSDC\* ZC211 Principles of Economics 3**

Nature and scope of economic science, its relationship with other social sciences; quantification of economic variables; theories of consumer behaviour and of the firm: linear economic models; market structures; social accounting and basic elements of economic planning.

#### **BSDC\* ZC214 Science, Technology and Modernity 3**

Interrelationship between science, technology and modern society; forms in which beliefs and values of a modern society shape sciences and technologies; forms in which scientific discoveries and technological developments influence and shape modern societies. Scientific Revolution and the emergence of modernity as a social condition; Enlightenment promise of progress within the economic system of capitalism. Some critiques of the received view; recent phase of capitalism and the role of technology in globalization.

#### **BSDC\* ZC215 Digital Design 4**

Boolean Algebra & logic minimization; combinational logic circuits: arithmetic circuit design, Design using MSI components; Sequential Logic Circuits: flip flops & latches, registers and counters, Finite state machine; HDL Implementation of Digital circuits; Digital Integrated Circuits; Programmable logic devices; Memory organization; Algorithmic State machine; Introduction to computer organization; The course will also have laboratory component on digital design.

#### **BSDC\* ZC222 Discrete Structures for Computer Science3**

Sets & operation on sets; relations & equivalence relations; number theory; weak & strong form of mathematical induction; principle of inclusion & exclusion, pigeonhole principle; recurrence relations & generating functions; digraphs & graphs, graph isomorphism & sub-graphs, spanning trees, Euler & Hamiltonian graphs, planar graphs, chromatic numbers & graph coloring; groups; Lagrange theorem finite groups; Rings & Fields.

#### **BSDC\* ZC224 Print and Audio-Visual Advertising 3**

The Dimensions of Advertising; Advertising and Marketing; Creative strategy and Creative process; Creative Execution: Art and copy; Media strategy; Advertising research; Relationship Building: Public relation and Corporate advertising; Ethical issues.

#### **BSDC\* ZC225 Environmental Studies 3**

Environment, human population, and industrialization; natural resources and the impact of man-made activities on them; structure and function of ecosystem, population ecology, biodiversity and its conservation, overview of natural resources, environmental pollution, social issues and the environment, and environmental impact assessment.

#### **BSDC\* ZC226 Creative Thinking 3**

Creative thinking & its importance, Process of creative thinking, Road blocks to creative thinking, Developing creative thinking, Brainstorming, Bloom's Taxonomy,

Assessment of creative thinking, Conceptual framework for Critical thinking, Aspects of critical thinking, Stages of critical thinking; Reasoning: Fountain head of critical thinking, Need & benefit of critical thinking, Critical thinking in decision making, Developing critical thinking in classroom, Assessment of critical thinking skills.

### **BSDC\* ZC231 Dynamics of Social Change 3**

Nature of society, social institutions; concept and nature of socio-cultural change, obstacles, rate and direction of change; factors of social change-ideological, economic, technological and political demographics; agencies of social change-education, leadership, propaganda, legislative reforms; five-year plans and social change, peasant and land reform, bhoodan and gramdan; changing pattern of family, marriage, caste and religion.

### **BSDC\* ZC234 Linear Algebra & Optimization 3**

Vector and matrix algebra, systems of linear algebraic equations and their solutions; eigenvalues, eigenvectors and diagonalization of matrices; Formulation of linear programming problems, Simplex method, Big-M method, two phase method, Sensitivity analysis, Revised and Dual Simplex Methods.

### **BSDC\* ZC236 Symbolic Logic 3**

A brief historical survey of the development of logic; nature and kinds of arguments; sentential connectives; symbolization of statements and arguments; truth tables, establishing validity of arguments by truth tables and different types of proofs, quantified statements; quantified arguments and their validity.

### **BSDC\* ZC242 Cultural Studies 3**

Introduction to Cultural studies, Importance of cultural studies, types of cultural studies, relation to Critical theory, relation to Literary Criticism. Introduction to theories such as Communication studies, Film studies, Feminist theory, Art history/Criticism, Societal impact, business relevance, introduction to myriad practices, institutions, beliefs and varied social structures within a given culture.

### **BSDC\* ZC311 – Information Security 3**

Course Description to be developed

### **BSDC\* ZC312 Evolution of Design 3**

Intellectual nature of design - two thousand years of design - three forms in which the design appears -mechanism, structure and systems – energy and design-materials and design- the aesthetic basis of design- evolution and design-economy, form and beauty- production and design in nature-The relation between manufacturing and design- verbal and visual thoughts-some aids to design- evolution of design in decorative arts.[Design as an activity will be an integral part of teaching and learning as well as evaluation for this course.]

### **BSDC\* ZC313 Object Oriented Programming and Design 4**

Object oriented concepts and design, abstraction, architecture and design patterns, GUI programming and frameworks, design of object oriented solutions using UML, design for concurrency, implementation of solutions using object oriented languages like C++ or Java; Language level mapping and realization of object oriented constructs, realization and performance issues versus abstraction and usability.

### **BSDC\* ZC314 Software Development for Portable Devices 3**

Introduction to mobile computing and emerging mobile application and hardware platforms; Developing and accessing mobile applications; Software lifecycle for mobile application – design and architecture, development – tools, techniques, frameworks, deployment; Human factors and emerging human computer interfaces (tangible, immersive, attentive, gesture, zero-input); Select application domains such as pervasive health care, m-Health; Mobile web browsing, gaming and social networking.

### **BSDC\* ZC315 Web Programming 3**

Technologies related to web development and associated technologies that make the web work. Scripting languages like HTML, CSS and JavaScript; Design of dynamic websites; on both client-side and server-side scripting technologies; full-stack web development. Design and development of web applications, web applications that could query database and fetch information over the network; development and testing of web applications.

### **BSDC\* ZC316 Computing and Design 3**

Design Principles - Separation of Concerns, Abstraction, and Modularity. Application of these principles in the design of Computers. Hardware and Components - Modularity. Instruction Set Architecture - Abstraction and Modularity. Computing Systems - Hardware, Operating Systems, and Communication. Highlights of Operating System Design: Abstraction and Interfaces in Operating Systems - Processes, System Calls; Modularity in Operating Systems - Kernels vs. external modules such as device drivers. Abstraction in Programming: Data Abstraction and Control Abstraction. Modularity and Reuse in Programming. Design Principle - Virtualization. Virtualization at the Architecture and OS level. Virtualization in Software.

[Design as an activity will be an integral part of teaching and learning as well as evaluation for this course.]

### **BSDC\* ZC317 Algorithm Design 3**

Effective construction and analysis of algorithms. Understanding, application, and implementation of algorithm design techniques like divide-and-conquer, greedy, dynamic programming, and back-tracking. Worst case and average case analysis of algorithms. Basic notions of complexity classes – P, NP, and NP-complete and Reduction.

### **BSDC\* ZC322 Critical Analysis of Literature and Cinema 3**

Creativity and Aesthetics; An overview of Major Movements in Literature and Cinema; Interpretation of Selected Works; Cinema & Art; Understanding Drama: Theme, Character, Plot, form; Understanding Poetry: Diction, Imagery, Symbolism, Structure and Form, Personification, Apostrophe, Sound and Rhythm; Understanding fiction: Setting, Point of View, Plot and Character; Understanding Short Fiction: Meaning and message, Style and Coherence; Understanding Cinema: Plot; Character; Screenplay; Linguistic, Social, Musical codes; Cinematic Codes; Camera Work.

### **BSDC\* ZC327 Systems Programming 3**

Batch processing Systems programs; operating characteristics and limitations; parallel processing of I/O and interrupt handling, multiprogramming; multiprocessing systems; design of system modules and interfaces; other selected topics.

### **BSDC\* ZC328 Humanities and Design 3**

Ideas and Designs, Thinking about New Designs, Perspectives to Design: Historical, Social, Technical and Creative Dimensions; Engineering Design and Problem Solving; Basic Concepts in Engineering Design; Design Skills, Abstraction, Identification of Patterns in Processes and Products, Application of Systematic Techniques to Problem Solving, Application and Adaptation of tools and technologies

to new problems; Core Principles of Design; Elements of Design, Form and Functionality, Central Activity of Engineering Designs; Language and Interface Design, Design Thinking: Influence of Context Vs. Conflict with Context.

**BSDC\* ZC329 Design for Social Media 3**

The course Design for Social Media will help understand the emerging role of Social Media as an important vehicle for promoting a culture of participation, interaction, persuasion and influence where social networks, news, photos, blogs and videos are used to harness collective intelligence and encourage active communication among users. The course will focus on – Emergence of Social Media, Types of Social Media, Functions and Dysfunctions of Social Media, Design aspects for Usability, Design aspects for Sociability, Presentation and Navigation schema of content, Information Handling, Design for Interactivity, Media Richness, Language aspects of Social Media, Content and Design Analysis of Media, Working with mime types in Social Media, Using software tools like Photoshop / Illustrator.

**BSDC\* ZC330 Appreciation of Art 3**

Visual perception and basic techniques used in art, compositional balance, space, movement form, light colour, texture, tensions, expressions lines; mainstreams of art; influence of Indian art abroad; various schools of art- Grecian, Medieval, Christian Renaissance, Baroque and Romanticism, impressionism and post impressionism, fauvism, futurism, expressionism, Dadaism and surrealism, metaphysical art, non-representational and abstract art; analysis of work of art and their evaluation.

**BSDC\* ZC342 Computer Mediated Communication3**

Computer Mediated Communication- Definitions and overview; Evolution of Computer Mediated Communication; Components of Computer Mediated Communication; Computer Mediated Discourse Analysis- Theories and faceted Approach; Information-Interactivity Dynamism in Computer Mediated Communication; Gender perspectives in Computer Mediated Communication; Privacy Issues in Computer Mediated Communication; Socialization in Social Media-Profiles, Identity and traversal; Computer Mediated Communication and technology acceptance; Computer Mediated Communication Theories; Human-Computer Interfaces.

**BSDC\* ZC343 Software Engineering 4**

Software engineering concepts and methodology; formal requirements specification; estimation; software project planning; detailed design; techniques of design; productivity; documentation; programming languages styles, code review; tool, integration and validation; software quality assurance; software maintenance; metrics, automated tools in software engineering.

**BSDC\* ZC344 Professional Ethics 3**

Ethics, nature and purpose; ethical theories; ethics in business and management; ethics in engineering, global ethical issues.

**BSDC\* ZC350 Human Rights: History, Theory and Practice 3**

The meaning and history of human rights; Human rights debates and controversies; Political, civil, social and economic rights; Culture and human rights; Themes - Democracy, dictatorship, and human rights; Science, technology, and human rights; Ethnicity; Gender; Children's rights and others; Evaluating the progress made and challenges in practice of human rights.

**BSDC\* ZC351 Organizational Behaviour 3**

A new perspective of management; conceptual model of organization behavior; the individual processes- personality, work attitude, perception, attribution, motivation, learning and reinforcement, work stress and stress management; the

dynamics of organizational behavior- group dynamics, power & politics, conflict & negotiation, leadership process & styles, communication; the organizational processes-decision making, job design; organizational theory and design, organizational culture, managing cultural diversity; organizational change & development.

**BSDC\* ZC352 Advanced Writing Course 3**

This course includes components related to development of creative content and writing skills required for professional communication and documentation purposes. In addition, the course also tries to enable students to become independent and effective writers by exposing them to citation and referencing conventions, document formatting, use of web platforms for writing, international laws related to plagiarism, etc.

**BSDC\* ZC353 Computer Organization and Architecture4**

Overview of logic design; Instruction set architecture; Assembly language programming; Pipelining; Computer Arithmetic; Control unit; Memory hierarchy; Virtual memory; Input and output systems; Interrupts and exception handling; Implementation issues; Case studies; This course covers the fundamentals of computer organization and architecture from a programmer's perspective.

**BSDC\* ZC354 Introduction to Architecture 3**

Origin and history of architecture; designing object, space, building, cities; form, space and order as fundamental design considerations; elements of architecture; iterative design process; developing concepts; tools and techniques for generating ideas; materials and perception of space; building structure and methods of construction; building systems; architectural practice and communication; allied fields

**BSDC\* ZC356 Data Structures 4**

Elementary data structures; Linked lists, stacks, queues; Searching and Sorting. A selection of sorting algorithms and their usage and context; Non-linear data structures: Trees, binary trees, and heaps – applications, construction and operations, traversals, implementation techniques. Dictionaries - Hash tables, Binary Search Trees, and Balanced Binary Search Trees; Introduction to analysis of algorithms and complexity.

**BSDC\* ZC364 Operating Systems 3**

Introduction to operating systems; Various approaches to design of operating systems ; Overview of hardware support for Operating systems; Process/thread management: synchronization and mutual exclusion, inter process communication, CPU scheduling approaches ;Memory management: paging, segmentation ,virtual memory, page replacement algorithms ; File systems: design and implementation of file systems; Input /Output systems; device controllers and device drivers; Security and protection ; Case studies on design and implementation of operating system modules.

**BSDC\* ZC365 Human Computer Interaction 3**

Principles of human-computer interaction; Evaluation of user interfaces; Usability engineering; Task analysis, user-centered design, and prototyping; Conceptual models and metaphors; Software design rationale; Design of windows, menus, and commands. Voice and natural language I/O; Response time and feedback; Color, icons, and sound; Internationalization and localization; User interface architectures and APIs.

**BSDC\* ZC412 Software Design Principles 4**

Software Development lifecycle; Role of high level and low level design in lifecycle. Object-Oriented Abstraction and Object Oriented Design. Design for Reuse and Design for Change – Refactoring. Design Patterns - History of Patterns in Building Architecture and Relevance to Software Design, Evolution of Software Design Patterns and Impact of Using Design Patterns in Lifecycle. Crosscutting Concerns and

Aspects – Aspect Oriented Design. High-level design vs. Low-level design. Basic Architectural Elements and Styles – Layered Architectures and Event-Driven Architectures, MVC architecture in User Interfaces.

[Design as an activity will be an integral part of teaching and learning as well as evaluation for this course.]

#### **BSDC\* ZC413 Database Design 4**

Introduction to database systems; DBMS Three-schema architecture; Conceptual data modelling-ER modelling and Extended ER modelling and use of UML in modelling databases; Relational query languages- Relational algebra and SQL; Database design- functional dependencies, normalization, normal forms and decomposition; Query processing and Optimization; Database tuning; Introduction to - Indexing, Transaction processing, Concurrency control and Recovery.

#### **BSDC\* ZC432 Applied Statistical Methods 3**

Review of estimation and testing of hypotheses; Simple and multiple regression methodology through method of least squares, Multicollinearity and residual analysis, Categorical data handling through logistic regression; Multivariate data analysis by Hotelling  $T^2$ , Mahalanobis  $D^2$ , discriminant analysis, cluster analysis and factor analysis; Data handling and forecasting time series data by various components time series methodology; Statistical Quality Control of variables and attributes control charts; Non parametric data handling through Kruskal walls test, Mann Whitney and KS two sample test.

#### **BSDC\* ZC481 Computer Networks 3**

Introduction, history and development of computer networks; Reference models; Physical Layer: theoretical basis, transmission media, types of transmission; MAC sub-layer: local area networks, FDDI; Data Link Layer: Sliding Window protocols, design aspects; Network Layer: routing algorithms, congestion control algorithms, internetworking; Transport Layer: Integrated Services Digital Network (ISDN), Asynchronous Transfer Mode (ATM) - reference models, service classes, switch design, LAN emulation; Application Layer protocols.

#### **BSDC\* ZC229T Design Project 5**

Operate, maintain, design and develop software in innovative areas and activities of the industry; the student's actual day-to-day task involvement would constitute the central thread of the learning process. The evaluation will recognize this aspect by demanding day-to-day engagement and productivity of the student.

#### **BSDC\* ZC499T Capstone Project 15**

Real life problems encompassing computing and design problems/requirements obtained from organizations/third party vendors; Jointly mentored by the industry experts and faculty; Presentation of the progress and results in appropriate forms; Periodic review of progress of the project.

#### **CBDA ZG511 The Hadoop Framework 1**

Distributed computing environments for Big Data; Distributed storage and processing of Big Data using the MapReduce programming model; High-level programming for the environment.

#### **CBDA ZG521 ETL & Batch Processing with Hadoop2**

Fundamentals of Data Warehousing and ETL, ETL vs. ELT, Data Lakes; Data Ingestion – Data Ingestion for structured and unstructured data, Data ingestion in the context of distributed and map-reduce execution platforms; Event processing – flows, tools and technologies for event processing, complex event processing applications; Workflow Management - workflow specifications and processing, tools, and interfaces with distributed platforms.

#### **CBDA ZG531 Big Data Analytics using Spark 3**

Introduction to Streaming Data – characteristics and sources, Processing of Streaming Data – components and architecture of a typical real-time / streaming processing system; Analytics Tasks – Regression, Classification, and Clustering; Tools and Platforms for implementing Analytics Tasks; Regression – definition, use-case and example, using a tool to implement regression; Classification – definition and use-cases; representing classes using a tree; Overcoming tree limitations with Random Forest; using a tool to implement a classifier; Clustering – definition and use-cases, notion of similarity, k-means clustering and hierarchical clustering, using a tool to implement a clustering solution; Case studies of Analytics.

#### **CBDA ZG541 Capstone Project 2**

Consistent with the student's professional background and work-environment, the student will be required to carry out a work-oriented project that demonstrates application of knowledge and skills acquired through the program. This is an unstructured open-ended course where under the supervision of a mentor, the student will carry out the project and must submit a project report and an artifact (such as a design, system, or software) as a culmination of his / her endeavor and investigation.

#### **CBDE ZG511 Foundations of Big Data Systems 2**

Understanding Big Data – Big Data Sources and Applications, Characteristics, Processing Requirements and Constraints; Structured and Unstructured Data. Storing and Exchanging Big Data – Review of Data Structure Design, Data Structures for exchanging large volumes of data, Search trees and Queries including range search. Algorithm Design for Big Data – Review of Divide-and-Conquer, Design of Distributed Algorithms using Divide-and-Conquer, Select Design Patterns for Distributed Algorithms including Map and Reduce.

#### **CBDE ZG521 Platforms for Big Data 2**

Distributed Computing Environments for Big Data – Clusters and Map-Reduce Execution, In-memory vs. Persistent Data Stores, Distributed FileSystems for Map-Reduce based processing, NoSQL databases, and high-level programming using parallel data flows. Programming environment and constructs for distributed in-memory processing. Data Store on the Cloud - introduction to Cloud as a platform for storage and execution, concept of virtualization and its usage in the context of deploying storage and applications on the cloud, simple object store and databases on cloud.

#### **CBDE ZG531 Processing Big Data - ETL & Batch Processing 2**

Data Warehousing – fundamentals of Data Warehousing and ETL, ETL vs. ELT, Data Lakes, Batch Processing. Data Ingestion – Data Ingestion for structured and unstructured data, Data ingestion in the context of distributed and map-reduce execution platforms. Event processing – flows, tools and technologies for event processing, complex event processing applications. Workflow Management - workflow specifications and processing, tools, and interfaces with distributed platforms. Batch processing on the Cloud – elastic processing and models.

#### **CBDE ZG541 Processing of Real-Time Data and Streaming Data 1**

Introduction to Streaming Data – characteristics and sources. Processing of Streaming Data – components and architecture of a typical real-time / streaming processing system. Stream Processing – sourcing and modeling, abstractions, platforms, and programming interfaces used for processing streams, windowing / micro-batching techniques. Case studies and applications.

#### **CBDE ZG551 Big Data Analytics 1**

Analytics Tasks and Cases – Regression, Classification, and Clustering. Tools and Platforms for implementing Analytics Tasks. Regression – definition, use-case and example, using

a tool to implement a solution based on regression, visualizing and interpreting the results. Classification – definition and use-cases; classifier models - line, curve, and plane separating classes; representing classes using a tree; probabilistic representation of classes; classifier performance; using a tool to implement a classifier; visualizing results. Clustering – definition and use-cases, notion of similarity, unsupervised grouping, k-means clustering and deciding k, using a tool to implement a clustering solution, visualizing and interpreting results. Case studies of Analytics.

### **CBDE ZG571 Capstone Project 3**

Consistent with the student's professional background and work-environment, the student will be required to carry out a work-oriented project that demonstrates application of knowledge and skills acquired through the program. This is an unstructured open-ended course where under the supervision of a mentor, the student will carry out the project and must submit a project report and an artifact (such as a design, system, or software) as a culmination of his / her endeavor and investigation.

### **CFSE ZG511 Overview of Full Stack Engineering 2**

Overview of the modern application landscape; Typical structure of an end-to-end application: components and connections; Design considerations and implementation choices; Case study for each of the topics discussed.

### **CFSE ZG521 Web Development 5**

Components of front-end web application development: User interfaces, rendering, Document Object Model, Event and State handling; Languages/tools such as HTML, CSS, JavaScript, AJAX; Web apps development frameworks; Components of back-end web development: Web Server essentials; Server Side scripting; REST architecture; Database interactions; Integration with code repositories.

### **CFSE ZG531 Mobile Application Development 2**

Mobile application building blocks such as the screens (UI), background services; Communication between the application components; Application development using native multi-platform development; Interaction of applications with Internet resources, REST APIs, databases; Unit testing of applications; Integration with code repositories.

### **CFSE ZG541 Cloud Native Development 3**

Basics of cloud computing. Different types of services; Virtual machines vs Containers deployment; Characteristics of cloud native application; Elements to build cloud-native applications; Cloud native architecture and micro-services; Design, decomposition of applications to micro-services; Developing micro-services; Interactions with data services and databases.

### **CFSE ZG551 Agile and DevOps 3**

Overview of Agile methodology: Scrum, Test driven development, DevOps, Continuous Integration/Continuous Delivery (CI/CD); Code repository: Multi-user, distributed development, version control; Continuous inspection of code quality; Build and build tools; Automated Testing; Integration tools; Implementing CI/CD.

### **CFSE ZG561 Deployment of Micro-services 2**

Containerizing applications by creating container configuration files and build processes; Manage deploying, scaling, and updating applications with micro-services using container management platforms such as Kubernetes; Configure and launch auto-scaling, self-healing clusters; Best practices for container management, when architecting and developing new micro-services.

### **CFSE ZG571 Capstone Project 4**

Full stack applications demonstrating the UI, server, and database components of an end-to-end multi-user application; Usage of one or more well-known development frameworks; Demonstration of scalability and reusability by

applying design concepts such as microservices and container-based deployment on the cloud; Demonstration of compliance with principles of agile and CI/CD.

### **CGM\* ZC411 Marketing 3**

Definition and scope, fundamentals of consumer behaviour, competitive behaviour, demand estimation, new product introduction, channels of distribution, advertising and other sales promotion, positioning, marketing regulation, market research, basics of industrial marketing.

### **CGM\* ZC421 Financial and Management Accounting 3**

Basic concepts, double entry accounting, journal, ledger, trial balance, profit & loss account, balance sheet, cash flow statement, fundamentals of financial statement analysis, ratio analysis, cost-volume-profit analysis, inventory valuation, inflation accounting, basics of cost accounting.

### **CGM\* ZC431 Quantitative Methods 3**

Grouping data, measures of central tendency and dispersion, probability distribution, sampling and estimation, testing hypotheses, chi-square and analysis of variance, regression and correlation, non-parametric methods, fundamentals of time series analysis, index numbers, decision theory, applications of various statistical software and spreadsheets.

### **CGM\* ZC414 Managerial Economics 3**

Fundamental concepts, supply, demand, market mechanism; theory of demand (consumer behaviour); production costs (theory of firm); market structures (perfect competition, monopoly, monopolistic competition, oligopoly); circular flow of income, fundamentals of money and banking, employment, interest, inflation; basic concepts relating to economics of information, adverse selection, moral hazard problem, market failure, externalities, public goods.

### **CIOT ZG511 IoT Technology and Applications 3**

Introduction to IoT and Cyber-Physical Systems; IoT Enabling Technologies; Different Levels of IoT Systems; IoT Design Methodology; Introduction to IoT Platforms and End Devices, Introduction to IoT Network and Cloud Services; IoT Applications - Design Challenges; Basic Architecture and Components.

### **CIOT ZG521 Hardware Architectures for IoT 4**

This course covers the concepts necessary for designing IoT device hardware and developing optimal firmware to meet the demands of IoT applications which include time critical response, low power consumption, fault tolerance etc. Topics include - Low power processor and microcontrollers – architecture, programming & interfacing; IoT platforms; Memory architectures- Cache, Memory Management and Memory protection, Speed Vs power optimizations; On-board / On-chip buses and I/O interfaces.

### **CIOT ZG531 Communication and Networking Technologies in IoT 3**

Wireless Communication & Network protocols – 802.11, BLE, NFC, LORA, Zigbee; Wireless Sensor and Ad hoc networks, Cross-Layer protocol optimization; Industrial and Automotive Networks, VANETS, Security issues and QoS in IoT Systems.

### **CIOT ZG541 Sensors, Actuators, and Signal Processing 3**

Sensing Technologies for remote data gathering; Sensors and actuators of varied complexity; Signal Acquisition, Processing and Conditioning; Sensor fusion, Smart Sensors and interface to the internet; Introduction to advanced Sensing technologies- HCI in IoT, BCI in IoT; Control of actuators via Internet.

### **CIOT ZG551 Software and Programming in IoT 4**

Operating Systems for IoT applications; Building Android applications; Web server implementation and deployment; Commonly used software tools and technologies for IoT

**CIOT ZG561 Data Management in IoT 2**

This course covers topics in management of data in the context of the Internet of Things. Specific topics include Data sources in IoT and Data Types in IoT, Data-centric IoT products, Flow of Data, Challenges in managing IoT Data; Data Models and Data acquisition in Wireless Sensor Networks (WSNs), Query Processing and Query Optimization in WSNs, Sensor Data Cleaning and Storage, Embedded Database Systems; Data Acquisition in RFID Networks – RFID data cleaning and data preparation; Stream Processing – Event Processing, Event Processing in RFID, Mining Data Streams – Clustering, Classification, Frequent Pattern Mining, Change Detection, Dimensionality Reduction, Forecasting; Big Data Management in IoT – Big Data Storage and Processing, Distributed Processing – Issues and solutions. Case studies.

**CIOT ZG571 Capstone Project 3**

Consistent with the student's professional background and work-environment, the student will be required to carry out a work-oriented project that demonstrates application of knowledge and skills acquired through the program. This is an unstructured open-ended course where under the supervision of a mentor, the student will carry out the project and must submit a project report and an artifact (such as a design, system, or software) as a culmination of his / her endeavour and investigation.

**CMP\* ZC411 Managing People & Organizations 3**

Fundamental concepts and principles of management as applied to a variety of organizations; elementary study of managerial roles, styles, activities and decision making; relationship with organizational effectiveness; basic concepts relating to planning activities, manpower development; basic concepts relating to organizational behaviour.

**CMP\* ZC426 Operations Management 3**

Fundamentals of production systems; product and process design; facility location & layout; operations scheduling and control; productivity of operations; fundamentals of inventory planning & independent demand systems; MRP; basic concepts relating to quality management; Japanese approach to operations management (JIT, TPM, continuous improvement).

**CMP\* ZC437 Lean Manufacturing 4**

Fundamentals of continuous improvement, value added and waste elimination, elements of lean production: small lot production, setup time reduction, maintaining and improving equipment, pull production systems, focused factories and group technologies, work cells and cellular manufacturing, standard operations, quality of design, systems for eliminating defects, basics of production planning and control systems: scheduling for smooth flow, synchronizing and balancing process, planning and control in pull production.

**CMP\* ZC422 Total Quality Management 3**

TQM principles and practices; leadership; customer satisfaction; employee involvement; continuous process improvement; supplier partnership; performance measures; statistical process control; ISO 9000; benchmarking; quality function deployment.

**CNSS ZG511 Sanitation Technology 5**

This course aims to give the participants a review of the fundamentals as well as the latest technological developments applied in the field of sanitation. Urban Drainage and Sewerage, Carbon, nitrogen and phosphorus removal & recovery; sludge treatment, Site evaluation; toilets; onsite sanitation systems; emptying and transport; established and transferring technologies for dewatering, stabilization, pathogen inactivation and nutrient management, urban low cost drainage, Innovation processes, Intro & Exercise technology selection tool / decision support system; discuss outcomes

**CNSS ZG512 Sanitation and Public Health 5**

This course will have four modules – Introduction to Sanitation, Sanitation system and services, Public Health and Analysis of sanitation flow. Background on urban sanitation, Material flow analysis, Monitoring frameworks, Shit Flow Diagrams, Human Health Hazards and Waste, Review and Assessment of Transmission Routes, Review and Assessment of Transmission Routes, Disease Cycles – Lifecycles & Vectors, Control Measures, Risk Evaluation Tools, Urban development trends, demography, Urban sanitation planning & programming

**CNSS ZG513 Sanitation Governance, Behavioral Change and Advocacy 5**

This particular course will have two modules – Sanitation Governance and Behaviour change & Advocacy. Water & sanitation governance: definitions, debates, controversies, Power relations among actors in the local and global levels: Gender, class & race relations and power asymmetries, Practices of coordination & decision, making around contested water distribution, Case studies on regulatory frameworks around the world – how is sanitation managed: where, how and why, Everyday sanitation from different perspectives. Behaviour with reference to Societal and cultural aspects, Types: Knowledge, motivations and reactions, Reinforcements: Norms and behaviour Settings

**CNSS ZG515 Emergency Sanitation & Leadership 5**

This course will have two modules – Emergency Sanitation and Leadership. The evolution of humanitarian aid: historical events and the humanitarian system as it stands today. Overview of the international legal framework (Refugee law, International Humanitarian Law-IHL, International Disaster Relief Law-IDRL), code of conduct and guiding principles of humanitarian action. Standards applied by relief agencies and global cluster, Sphere, WASH cluster. Disaster cycle, risk reduction/ response/ recovery/ development, emergency response phases. Overview of relief organizations, their mandates, their commitments and priorities in emergencies.

**CS ZC444 Real-Time Systems 3**

Introduction to real-time systems, clock synchronization, task assignment and scheduling, programming language with real-time support, ADA, real-time communication protocols, real-time databases, fault tolerant techniques, reliability evaluation methods; case studies in real-time operating systems, simulation of real-time systems, embedded system programming.

**CS ZG524 Real Time Operating Systems 5**

Introduction to real-time systems, clock synchronization task assignment and scheduling, programming language with real-time support, ADA, real-time communication protocols, real-time database, fault tolerant techniques, reliability evaluation methods; case studies in real-time operating systems, simulation of real-time systems, embedded system programming.

**CS ZG525 Advanced Computer Networks 5**

Topics in advanced networking – Quality of Service in IP networks, IPv6, Wireless and Mobile Networks, Carrier Technologies (Frame Relay, FDDI, ISDN, ATM), Peer-to-



Peer Networks and Overlays, Routing and QoS Issues in Optical Networks.

### **CS ZG551 Advanced Compilation Techniques 5**

Generic Code Optimization Techniques - loop optimization, inlining, and other transformations. Impact of architectures on code generation and optimization: RISC architectures, VLIW architectures, special-purpose architectures. Architecture-specific code optimizations – register allocation, instruction scheduling. Code Optimizations under real-time / embedded constraints - cacheless / diskless memory models, bounded time responses. Garbage Collection Techniques. Virtual Machines and Just-in-Time Compilation techniques - HotSpot-like optimizations. Implementation of exception handling, concurrency, and generic jumps (like call/cc).

### **CS ZG623 Advanced Operating Systems 5**

Overview of advanced operating systems: motivation for their design, and various types of advanced operating systems; Distributed operating systems: architecture of distributed systems, theoretical foundation of distributed systems, deadlock detection/resolution, agreement protocols, file systems, distributed shared memory, scheduling, fault tolerance and recovery; Multiprocessor operating systems: multiprocessor system architectures, multiprocessor operating system design issues, threads, process synchronization, process scheduling and memory management; Data base operating systems: introduction, concurrency control: theoretical and algorithmic aspects; Case Study: Amoeba and Mach.

### **CSI\* ZC132 Linear Algebra & Optimization 3**

Vector and matrix algebra, systems of linear algebraic equations and their solutions; eigenvalues, eigenvectors and diagonalization of matrices; Formulation of linear programming problems, Simplex method, Big-M method, two phase method, Sensitivity analysis, Revised and Dual Simplex Methods.

### **CSI\* ZC163 Computer Programming 4**

Basic Computing Steps and Flow Charting (Assignment, Sequencing, Conditionals, Iteration). Programming Constructs – Expressions, Statements, Conditionals, Iterators/Loops, Functions/ Procedures; Data Types – Primitive Types, Tuples, Choices (Unions or Enumerations), Lists/Arrays, Pointers and Dynamically Allocated Data. Input output and Files. Laboratory Component: Programming Exercises involving development and testing of iterative and procedural programs using bounded and unbounded iterations, function composition, random access lists, sequential access lists, dynamically allocated lists, and file access.

### **CSI\* ZC213 Probability & Statistics 3**

Probability spaces; conditional probability and independence; random variables and probability distributions; marginal and conditional distributions; independent random variables; mathematical expectation; mean and variance; binomial, Poisson and normal distributions; sum of independent random variables; law of large numbers; central limit theorem (without proof); sampling distribution and test for mean using normal and student's t-distribution; test of hypothesis; correlation and linear regression.

### **CSI\* ZC252 Discrete Structures for Computer Science 3**

Sets and relations; graphs and digraphs; trees, lists and their uses; partially ordered sets and lattices; Boolean algebras and Boolean expressions; semigroups and machines; codes and applications.

### **CSI\* ZC263 Digital Electronics & Microprocessors 4**

Binary logic gates; logic circuits; Boolean algebra and K-map simplification; number systems and codes; arithmetic logic units; flipflops; registers and counters; introduction to microprocessors; architecture; instruction set and programming; memory and I/O interfacing examples of system design.

### **CSI\* ZC311 Information Security 3**

Program security, Web security, Database security, Protection in operating systems, Cloud security fundamentals; Privacy and Anonymity in computing; Legal and ethical issues in security, Secure programming and Trusted systems design; policy, administration and procedures; auditing; physical security; content protection.

### **CSI\* ZC313 Object Oriented Programming & Design 4**

Object oriented concepts and design, abstraction, architecture and design patterns, GUI programming and frameworks, design of object oriented solutions using UML, design for concurrency, implementation of solutions using object oriented languages like C++ or Java; Language level mapping and realization of object oriented constructs, realization and performance issues versus abstraction and usability.

### **CSI\* ZC327 Systems Programming 4**

Batch processing; Systems programs; operating characteristics and limitations; parallel processing of I/O and interrupt handling, multiprogramming; multiprocessing systems; design of system modules and interfaces with focus on contemporary open source operating system-specific programming; laboratory experiments or programming assignments involving Unix/Linux System-specific Programming including shell-scripting via online laboratory facility.

### **CSI\* ZC337 Database Systems & Applications 4**

Introduction to Database Management Systems; File organization; Data Independence in databases; Data Models; Query processing systems; Database Design techniques; Concepts of security and integrity in databases; Distributed Databases; Applications using DBMS, database programming experiments involving use of SQL, database creation etc. via online laboratory facility.

### **CSI\* ZC353 Computer Organization & Architecture 4**

Overview of logic design; Instruction set architecture; Assembly language programming; Pipelining; Computer Arithmetic; Control unit; Memory hierarchy; Virtual memory; Input and output systems; Interrupts and exception handling; Implementation issues; Case studies; This course covers the fundamentals of computer organization and architecture from a programmer's perspective.

### **CSI\* ZC363 Data Structures & Algorithms 4**

Introduction to software design principles, modularity, abstract data types, data structures and algorithms; analysis of algorithms; Linear data structures – stacks, arrays, lists queues and linked representations; Pre-fix, in-fix and post-fix expressions; Recursion; Set operations; Hashing and hash functions; Binary and other trees, traversal algorithms, Huffman codes; Search trees, priority queues, heaps and balanced trees; Sorting techniques; Graphs and digraphs; Algorithmic design techniques; Data structures for external storage, multi-way search and B-trees.

### **CSI\* ZC364 Operating Systems 4**

Introduction to operating systems; Various approaches to design of operating systems; Overview of hardware support for operating systems; Process management: process synchronization and mutual exclusion, interprocess communication, process scheduling; CPU scheduling approaches; Memory management: paging, segmentation, virtual memory, page replacement algorithms; File systems:

design and implementation of file systems; input/output systems; device controllers and device drivers; Security and protection; Case studies on design and implementation of operating system modules, select laboratory experiments related to creating different elements of operating system and/or implementation of select scheduling, memory management and I/O related algorithms/schemes, using system calls for creating file system specific command, creating simple file system etc. via online laboratory facility.

### **CSI\* ZC424Software Development for Portable Devices** **3**

Introduction to mobile computing and emerging mobile application and hardware platforms; Developing and accessing mobile applications; Software lifecycle for mobile application – design and architecture, development – tools, techniques, frameworks, deployment; Human factors and emerging human computer interfaces (tangible, immersive, attentive, gesture, zero-input); Select application domains such as pervasive health care, m-Health; Mobile web browsing, gaming and social networking.

### **CSI\* ZC446Data Storage Technologies & Networks** **3**

Storage Media and Technologies – Magnetic, Optical and Semiconductor media, techniques for read/write operations, issues and limitations. Usage and Access – Positioning in the memory hierarchy, Hardware and Software Design for access, Performance issues. Large Storages – Hard Disks, Networked Attached Storage, Scalability issues, Networking issues. Storage Architecture. - Storage Partitioning, Storage System Design, Caching, Legacy Systems. Storage Area Networks – Hardware and Software Components, Storage Clusters/Grids. Storage QoS – Performance, Reliability, and Security issues.

### **CSI\* ZC462Network Programming** **3**

Overview of computer networks; inter-process communication; network programming; socket interface; client-server computing model: design issues, concurrency in server and clients; external data representation; remote procedure calls; network file systems; distributed systems design.

### **CSI\* ZC463Cryptography** **3**

Objectives of cryptography; ciphers – block and stream; mathematical foundations – modular arithmetic, finite fields, discrete logarithm, primality algorithms; RSA; digital signatures; interactive proofs; zero-knowledge proofs; probabilistic algorithms; pseudo-randomness.

### **CSI\* ZC467Computer Networks** **4**

Introduction, history and development of computer networks; Reference models; Physical Layer: theoretical basis, transmission media, types of transmission; MAC sub-layer: local area networks, FDDI; Data Link Layer: Sliding Window protocols, design aspects; Network Layer: routing algorithms, congestion control algorithms, internetworking; Transport Layer: Integrated Services Digital Network (ISDN), Asynchronous Transfer Mode (ATM) - reference models, service classes, switch design, LAN emulation; Application Layer protocols, Laboratory experiments / assignments related to simulation of network protocols, programming simple network applications, implementing select routing algorithms via online laboratory facility.

### **CSI\* ZG511IT Infrastructure Projects & Processes** **3**

Course description to be developed

### **CSI\* ZG513Network Security** **4**

This course examines issues related to network and information security. Topics include security concepts, security attacks and risks, security architectures, security policy management, security mechanisms, cryptography algorithms, security standards, security system interoperation and case studies of the current major security systems.

### **CSI\* ZG514Data Warehousing** **5**

Introduction, evolution of data warehousing; decision support systems; goals, benefit, and challenges of data warehousing; architecture; data warehouse information flows; software and hardware requirements; approaches to data warehouse design; creating and maintaining a data warehouse; Online Analytical Processing (OLAP) and multi-dimensional data, multi-dimensional modeling; view materialization; data marts; data warehouse metadata; data mining.

### **CSI\* ZG515Introduction to DevOps** **4**

Continual Service - continuous integration and continuous delivery; Scaling: automating infrastructure and infrastructure-as-code; DevOps and Cloud: platform-as-a service and DevOps, use of virtual machines and containers for deployment, Micro-services; application lifecycle management: deployment pipeline and application deployment, continuous deployment pipeline; stack management - life cycle of stack and events, resource and event monitoring, auto healing; Security: security of deployment pipeline, policy-as-code.

### **CSI\* ZG518 Database Design & Applications** **5**

DBMS architecture; Data models: Network model, Hierarchical model and Relational model; Database design & optimization; Query processing & Query optimization; Transaction Processing; Concurrency control; Recovery; Security & protection; Introduction to Object Oriented data model & Multimedia Databases.

### **CSI\* ZG520Wireless & Mobile Communication** **5**

Signal propagation in a mobile environment, modulation, coding, equalization; first generation systems; multiple access techniques like FDMA, TDMA, CDMA, spread spectrum systems; second & third generation systems, UMTS, IMT-2000; Wireless LAN, Wireless ATM and Mobile IP; emerging trends in Wireless & Mobile Communication.

### **CSI\* ZG522Design and Operation of Data Centers** **5**

Data Center Design: Principles (Scalability, Reliability, and Elasticity), Components - Computing Infrastructure (Processing, Storage, and Networking) and Physical Infrastructure (Power, Cooling, and Physical Security); Servers – Server Hardening, Server Optimization, Server Deployment and Consolidation, Converged and Hyper-Converged Infrastructure. Application monitoring and maintenance. Networking for data centers – device hardening, bandwidth aggregation, traffic management, redundancy, network isolation, deployment of internal security and peripheral security; Contingency Planning & Disaster Recovery: Backup, recovery, and redundancy/replication technologies and approaches. Data Center Architecture: Private, Public, and Hybrid models; Distributed Data Centers; Introduction to Software Defined Data Centers. Costing and Pricing– Costing and Cost Optimization, Pricing and Economics of Data Center Operation.

### **CSI\* ZG523Introduction to Data Science** **3**

Context and use of Data Science. High-dimensional data, graphs, vectors in high dimensional space and large matrices; Algorithms for massive data problems, sampling techniques. Techniques for extracting information/patterns from data

### **CSI\* ZG524 Middleware Technologies** **4**

Evolution of Middleware Technologies: Transaction Processing, Remote Procedure Calls, Message-Oriented-Middleware, Object Request Brokers, Web services and REST; Forms of Middleware: Enterprise Middleware, Web Middleware, and Cloud / Services Middleware; Middleware Elements: communication protocols, middleware protocols, data representation, server process control, naming and directory services, security, system management; Select case studies such as MS .NET, J2EE. Service Oriented Architecture: Loosely Coupled Systems, Business processes, Tiers, Architectural Choices; Resiliency in Middleware:

resiliency techniques, hardware failures, communication failures, software failures; Performance and scalability in Middleware; Security in Middleware; Implementation Aspects: business process implementation, enterprise integration, web and database middleware (e.g. NoSQL middleware) change management. Case studies of Enterprise application architecture (EAI) - Eg. Tibco, Websphere.

#### **CSI\* ZG525Advanced Computer Networks 5**

Topics in advanced networking – Quality of Service in IP networks, IPv6, Wireless and Mobile Networks, Carrier Technologies (Frame Relay, FDDI, ISDN, ATM), Peer-to-Peer Networks and Overlays, Routing and QoS Issues in Optical Networks.

#### **CSI\* ZG526Web Technologies 4**

Introduction to the World Wide Web. Web Application Architecture –2-tier and 3-tier architectures, RESTful applications, Web Services, and mash-ups; Hyper-Text Transfer Protocol (HTTP) and Web Servers – Case studies e.g. Apache and IIS; Deploying and tuning web servers. Web Application Front Ends: Markup (HTML and XML), Styling (CSS), and Scripting (Client Side and Server Side Scripts, Objects and Document Object Models – APIs for parsing documents, Event Handling and Asynchronous Scripting). Application Deployment on the Web: Dynamic Back-ends, Database Connectivity, Unstructured Data and NoSQL. Web Security – Typical Security Solutions for the Web.

#### **CSI\* ZG527Cloud Computing 5**

Concurrency and distributed computing, message passing over the network, connectivity and failure models, local vs remote connectivity, distributed resource modeling, distributed data models; replication & consistency; virtualization; CPU virtualization, memory and storage virtualization, virtualized networks, computing over WAN and Internet; computing on the cloud, computing models, service models and service contracts, programming on the cloud; Cloud infrastructure, LAN vs Wan issue, resource scaling and resource provisions, performance models, scalability, performance measurement and enhancement techniques; cloud applications and infrastructure services.

#### **CSI\* ZG528Cyber Physical Systems 4**

Course description to be developed.

#### **CSI\* ZG533Service Oriented Computing 4**

Course description to be developed.

#### **CSI\* ZG538Infrastructure Management 4**

Course description to be developed.

#### **CSI\* ZG582Telecom Network Management 5**

Network architecture and protocols; LAN, MAN and WANs; internetworking; network planning; network management concepts and standards; administrative, operational and fault management; security issues; remote network management.

#### **CSI\* ZG656Networked Embedded Applications 4**

Networked embedded systems, Clock synchronization, Protocol mechanisms protocol performance, CAN Bus architecture, USB Architecture, Embedded Internet, distributed computing, Use of Java in building networked systems, Reliability & Fault Tolerance etc. Mission-critical distributed real-time applications, e.g., military, air traffic control; Prototyping benchmark applications, e.g. simulated air traffic visualization, radar display; Networking: TCP/IP, distributed objects; Embedded system programming and middleware: I/O, analog / digital conversion, DSP, runtime monitoring of CPU, processes, network equipment; Modeling distributed real-time systems; Quality of service maintenance.

#### **DE\* ZC415 Introduction to MEMS 4**

Overview, history and industry perspective; working principles; mechanics and dynamics, thermos fluid engineering; scaling law; microactuators, microsensors and microelectromechanical systems; microsystem design,

modeling and simulation; materials; packaging; microfabrication: bulk, surface, LIGA etc; micromanufacturing; microfluidics; microrobotics; case studies.

#### **DE\* ZG511 Mechatronics 5**

Concepts of measurement of electrical and non-electrical parameters; displacement, force, pressure etc. and related signal conditioning techniques, drives and actuators, concepts of microprocessors/ microcontrollers architecture and programming, memory and I/O interfacing. System design concepts through case studies.

#### **DE\* ZG512 Finite Element Methods 5**

Element properties, Isoparametric elements, Finite element methods and analysis, Applications in design including continuum mechanics, Dynamic systems, Heat conduction and Electrical potentials, etc. will be taken up.

#### **DE\* ZG613 Tribology 5**

Introduction, lubricants and lubrication, surface texture, bearing materials, fundamentals of viscous flow, reynolds equation and applications, thrust bearings, journal bearings, squeeze-film bearings, hydrostatic bearings, gasbearings, dry and starved bearings, selecting bearing type and size, principles and operating limits, friction, wear and lubrication.

#### **DE\* ZG514 Fracture Mechanics 5**

Introduction, energy release rate, stress intensity factor and complex cases, anelastic deformation at the crack tip, elastic plastic analysis through J-integral, crack tip opening displacement, test methods, fatigue failure, numerical analysis, mixed mode crack initiation and growth.

#### **DE\* ZG515 Computational Fluid Dynamics 5**

Philosophy of computational fluid dynamics (CFD), governing equations of fluid dynamics, mathematical behavior of partial differential equations, basics of the numeric: basic aspects of discretization, grids with appropriate transformations, and simple CFD techniques, applications, numerical solutions of quasi-one-dimensional nozzle flows, numerical solution of a two-dimensional supersonic flow, incompressible couette flow, and supersonic flow over a flat plate, advanced topics in CFD.

#### **DE\* ZG521 World-Class Manufacturing 5**

The world-class manufacturing challenge, developing a world-class manufacturing strategy, just-in-time, total quality, total employee involvement, world-class information systems, managing the change, methods and procedures; improved brainstorming methods, using the check-total quality - the first steps, getting people involved, monitoring world-class performance.

#### **DE\* G522 Advanced Composites 5**

Definition of composite materials; classification; particulates and dispersion hardened composites, continuous and discontinuous fibre reinforced composites, metal-matrix composites, carbon-carbon composites, molecular composites, micro and multilayer composites, theory of reinforcement; reinforcement by continuous and discontinuous fibres, concept of microfibril; effect of orientation and adhesion; mechanical behaviour of composites, stress-strain relationship, strength, fracture toughness and fatigue; properties of fibre reinforcement and production technology of composites.

**DE\* ZG523 Project Management 4**

Concepts and techniques of project formulation, evaluation and implementation; Project planning and scheduling; Risk management; Time-cost trade off; Resource leveling and allocation; Project monitoring and control; Contract management.

**DE\* ZG525 Mechanical System Design 5**

Concept of system design; modeling of structural and kinematic systems, and determination of system characteristics; reliability of systems; design of machine elements for specified reliability; concepts of optimization; techniques of design optimization for linear and non-linear problems.

**DE\* ZG531 Concurrent Engineering 5**

Introduction of concurrent engineering and need, concurrent engineering tools, advances in design and manufacturing engineering, design for manufacture, design for assembly, rapid prototyping, simulation, concurrent approaches to design, manufacturing and other aspects of engineering.

**DE\* ZG532 Quality Assurance and Reliability 5**

Quality planning and control, economics of quality control, Specifications, tolerances and process capability studies, total quality control concepts in quality circles, quality incentives. Fundamental concepts of reliability engineering, Failure analysis, Reliability versus quality control, Systems reliability evaluation, reliability allocation, maintainability, and designing for reliability. Illustrative examples of design ensuring reliability to be taken up.

**DE\* ZG535 Advanced Engineering Mathematics 5**

Boundary value problems; wave equations; nonlinear partial differential equations; calculus of variations; Eigen value problems; iteration problems including forward and inverse iteration schemes – Graham Schmidt deflation – simultaneous iteration method – subspace iteration – Lanczo's algorithm – estimation of core and time requirements.

**DE\* ZG541 Product Design 5**

Introduction to creative design; user research and requirements analysis, product specifications, Computer Aided Design; standardization, variety reduction, preferred numbers and other techniques; modular design; design economics, cost analysis, cost reduction and value analysis techniques, design for production; human factors in design: anthropometric, ergonomic, psychological, physiological considerations in design decision making; legal factors, engineering ethics and society.

**DE\* ZG542 Machine Tool Engineering 5**

Design principles of machine tools; stiffness and rigidity of separate construction elements and their combined behaviour under load; design of stepped and stepless drives; electrical, mechanical and hydraulic drives; design of bearings and sideways; machine tool controls; machine tool dynamics; recent developments in machine tool design.

**DE\* ZG544 Design for Additive Manufacturing 5**

Fundamentals of computer aided design, part modeling and analysis using contemporary tools, design for manufacturing & assembly particularly in additive manufacturing, design considerations for additive manufacturing, support structures in metal-based systems and lightweight structures.

**DE\* ZG545 Advanced Control Engineering 5**

Modeling and classification of dynamical systems, properties and advantages of feedback systems, time-domain analysis, frequency-domain analysis, stability and performance analysis, state space analysis, controller design and root locus plot, compensator design and bode plot, non-linear plant control, model predictive control systems.

**DE\* ZG546 Model Based System Design 5**

Review of numerical methods, dynamic programming, data interpolation and statistical analysis, modeling, linearization of nonlinear systems, modeling and simulation of mechanical, electronic and electric drive systems, hardware in the loop (HIL), model in the loop (MIL), simulation and real-time control, design of engineering structures for minimum weight and maximum strength, dynamic models of multibody systems and analysis, thermal efficiency optimization using mathematical models, design of experiment methods to create models of physical systems.

**DE\* ZG548 Design for Industrial Internet of Things 5**

IoT overview and technologies, smart devices and smart products, cyber-physical systems, smart devices and control system, integrating smart concepts into existing products, programming using IoT, implementing a small IoT project, wireless communication and technologies, case studies.

**DE\* ZG561 Mechanisms & Robotics 5**

Classification of robots & manipulators; fields of application; synthesis of planar & spatial mechanisms; methods of function & path generation; coupler curve synthesis; linkages with open loop; actuators & drive elements; microprocessor application and control of robots.

**DE\* ZG611 Dynamics & Vibrations 5**

Steady and transient Vibration of single and multi-degree freedom systems. Systems with distributed mass and elasticity. Non-linear and self-excited vibrations, structural damping, Random vibrations, vibration analysis, vibration control - reduction, isolation and vibration absorbers.

**DE\* ZG612 Advanced Finite Element Modelling & Analysis 5**

Creation of FEA models, performing analysis and interpreting the results for the following cases using industrial examples and case studies, including selection of elements, boundary conditions and loading, static analysis (plane stress & plane strain), nonlinear analysis, dynamic (modal, harmonic transient analysis), thermal analysis (conduction, convection, mixed boundary conditions), coupled (thermal + structural), fluid flow analysis, fatigue creep and fracture, crash analysis.

**DE\* ZG621 Computer Aided Analysis and Design 5**

The course aims at developing complete self-reliance in solving analysis & design problems of engineering with the aid of computers. It stresses upon the use of more powerful tools including system planning, simulation and modelling. The student will take up a design project and will work independently on the project guided by the instructor or resource person as and when required. The effort must culminate with a CAAD program and a project report.

**DE\* ZG631 Materials Technology & Testing 5**

Study of characteristics and technology of metals, plastics, rubbers, ceramics, polymers, composites, optical fibres and other modern engineering materials and their application with particular reference to Railways. Destructive and non-destructive testing techniques and their applications in Railways.

**DE\* ZG641 Theory of Elasticity and Plasticity 5**

Basic equations of theory of elasticity; elementary elasticity problems in two and three dimensions; theories of plastic flow; problems in plastic flow of ideally plastic and strain hardening materials; theory of metal forming processes.

**DM ZG511 Mechatronics 5**

Concepts of measurement of electrical and non-electrical parameters; displacement, force, pressure etc. and related signal conditioning techniques, drives and actuators, concepts of microprocessors/ microcontrollers architecture and programming, memory and I/O interfacing. System design concepts through case studies.

**DM ZG521 Design for Additive Manufacturing 5**

Fundamentals of computer aided design, part modeling and analysis using contemporary tools, design for manufacturing & assembly particularly in additive manufacturing, design considerations for additive manufacturing, support structures in metal-based systems and lightweight structures.

#### **DM ZG531 High Precision Manufacturing 4**

Introduction to high precision manufacturing processes. Process and design considerations of both conventional and non-conventional processes in micro and nano manufacturing. Applications of high precision manufacturing in the fields such as semiconductor devices, medical devices. Common quality defects in high precision manufacturing. Emerging trends in the field.

#### **DM ZC472 Precision Engineering 3**

Concept of accuracy, accuracy of numerical control systems, tolerances and fits, acceptance tests for machine tools, static stiffness and its influence on machining accuracy, inaccuracies due to thermal effects, influence of forced vibrations on accuracy, dimensional wear of cutting tools and its influences on accuracy, clamping and setting errors, location principles and errors due to location, surface roughness and microfinishing processes, dimensioning and dimensional chains, methods of improving accuracy and surface finish, thread and gear measuring instruments, coordinate measuring machines, introduction to computer aided tolerancing.

#### **DM ZG612 Advances in Materials, Composites & Plastics 4**

Definition of composite materials; classification; particulates and dispersion hardened composites, continuous and discontinuous fiber reinforced composites, metal-matrix composites, carbon-carbon composites, molecular composites, micro and multilayer composites, theory of reinforcement; reinforcement by continuous and discontinuous fibers, concept of microfibril; effect of orientation and adhesion; mechanical behaviour of composites, stress-strain relationship, strength, fracture toughness and fatigue; properties of fibre reinforcement and production technology of composites. Plastics and their processing technology including injection moulding, blow moulding etc. Mathematical modeling and simple computational techniques for the mechanics of composites and plastics. Applications of plastics and composite in automotive and aerospace structures. Advanced metals and alloys including titanium, aluminum and magnesium, Ceramic and metal alloys (CERMETS) including Aluminum based alloys and other ceramic components.

#### **DM ZC622 Industrial IoT 4**

Workplace safety, industrial revolution 4.0, connected factories, smart industrial devices and products, cyber physical system in manufacturing, connecting industrial devices and equipment with each other and with internet, data acquiring and collection, communication technologies, RFID, QR codes and cellular technologies, protocols, hardware in IoT, software (IDE), cloud platform, connectivity and networking in IIoT, smart eyes on shop floor, integrating smart into existing equipment, programming using IoT, case study and implementation.

#### **DM ZG631 Additive Manufacturing Process 5**

Overview of additive manufacturing process, its importance to industries and its rapid development. Process, development and optimization for group of additive manufacturing technologies with special focus on metal based systems. Application of additive manufacturing technology in different settings for a given application. Additive manufacturing process from CAD file import till post processing and finishing. Emerging trends in additive manufacturing.

#### **DM ZC412 Flexible Manufacturing Systems 4**

Introduction CAD/CAM systems, overview of FMS, system hardware and general functions, material handling system,

work holding systems, cutting tools and tool management, physical planning of system, software structure functions and description, cleaning and automated inspection, communications and computer networks for manufacturing, quantification of flexibility, human factors in manufacturing, FMS and CIM in action (case studies), justification of FMS, modelling for design, planning and operation of FMS.

#### **DM ZG512 Embedded System Design 4**

Introduction to embedded systems; embedded architectures: Architectures and programming of microcontrollers and DSPs. Embedded applications and technologies; power issues in system design; introduction to software and hardware co-design.

#### **DM ZG522 Behavioral Operations 4**

Human behavior & cognition and their impacts on operating systems and processes. Heuristics used by operations managers to make spot decisions, their analysis using behavioral decision making literature with their potential implications for OM settings. The traditional operational issues (rational anomalies) such as bullwhip effect, explanation using behavioral operations theories. The impact of cognitive biases and methods of dealing with them in factory settings. Cognitive overload, decision making under uncertainty and ethical blindness in profession, which are relevant for modern digital factories.

#### **DM ZG532 Big Data Analytics in Manufacturing 4**

Big Data and its applications in manufacturing. Five V's of big data, analysis of structured and unstructured data in various forms, uncovering hidden patterns and unknown correlations for better operational decisions. Key technologies used in storing, manipulating, and analyzing big data. Tools for statistical analysis and data visualization. Open source frameworks for data analysis.

#### **DM ZG533 Manufacturing Planning & Control 5**

Planning and control of manufacturing operations; material flow planning; product and process planning; demand forecasting and forecasting models; facility location; plant layout planning and design; machine cells; capacity planning; designing work methods; material handling; line balancing; aggregate planning; inventory models and systems for independent demand; materials requirements planning; elements of monitoring and production control; current developments in operations management.

#### **DM ZG534 Sustainable Manufacturing 5**

Introduction to sustainable manufacturing, sustainable manufacturing design, practice and matrices, life cycle management and assessment, end of life (EOL) strategies, implementation framework, sustainable business models, waste minimization, case studies.

#### **DM ZG535 Cyber Security in Manufacturing 4**

Overview of cyber security for industry 4.0 landscapes with an emphasis on design and manufacturing application. Technological foundation of cyber security within manufacturing domain, existing threats faced by industry 4.0 sectors along with the existing solutions. Implementation of risk mitigation measures in industry.

#### **DM ZG541 Product Design 5**

Introduction to creative design; user research and requirements analysis, product specifications, Computer Aided Design; standardization, variety reduction, preferred numbers and other techniques; modular design; design economics, cost analysis, cost reduction and value analysis techniques, design for production; human factors in design: anthropometric, ergonomic, psychological, physiological considerations in design decision making; legal factors, engineering ethics and society.

#### **DM ZG561 Mechanisms & Robotics 5**

Classification of robots & manipulators; fields of application; synthesis of planar & spatial mechanisms; methods of function & path generation; coupler curve synthesis; linkages with open loop; actuators & drive elements; microprocessor application and control of robots.

#### **DM ZG629T Dissertation**

**16**

A student registered in this course must take a topic in an area of professional interest drawn from the on the job work requirement which is simultaneously of direct relevance to the degree pursued by the student as well as to the employing / collaborating organization of the student and submit a comprehensive report at the end of the semester working under the overall supervision and guidance of a professional expert who will be deemed as the supervisor for evaluation of all components of the dissertation. Normally the Mentor of the student would be the Dissertation supervisor and in case Mentor is not approved as the supervisor, Mentor may play the role of additional supervisor. The final grades for dissertation are Non-letter grades namely Excellent, Good, Fair and Poor, which do not go into CGPA computation.

#### **DSE\* ZC415 Data Mining**

**3**

Data Mining – introduction, fundamental concepts; motivation and applications; role of data warehousing in data mining; challenges and issues in data mining; Knowledge Discovery in Databases (KDD); role of data mining in KDD; algorithms for data mining; tasks like decision-tree construction, finding association rules, sequencing, classification, and clustering; applications of neural networks and machine learning for tasks of classification and clustering.

#### **DSE\* ZC416 Mathematical Foundations for Data Science**

**4**

Vector and matrix algebra, systems of linear algebraic equations and their solutions; Eigenvalues, eigenvectors and diagonalization of matrices, multivariate calculus, vector calculus, Jacobian and Hessian, multivariate Taylor series, gradient descent, unconstrained optimization, constrained optimization, nonlinear optimization, stochastic gradient descent, dimensionality reduction and PCA, optimization for support vector machines.

#### **DSE\* ZC418 Introduction to Statistical Methods 4**

Basic probability concepts, Conditional probability, Bayes Theorem, Probability distributions, Continuous and discrete distributions, Transformation of random variables, estimating mean, variance, covariance, Hypothesis Testing, Maximum likelihood, ANOVA – single factor, dual factor, time series analysis: AR, MA, ARIMA, SARIMA, sampling based on distribution, statistical significance, Gaussian Mixture Model, Expectation Maximization.

#### **DSE\* ZC420 Data Visualization**

**3**

Information overload and issues in decision making. Design of visual encoding schemes to improve comprehension of data and their use in decision making; presentation and visualization of data for effective communication. elementary graphics programming, charts, graphs, animations, user interactivity, hierarchical layouts, and techniques for visualization of high dimensional data & discovered patterns.

#### **DSE\* ZC426 Real Time Analytics**

**4**

Motivation and challenges of real-time, distributed, fault-tolerant data processing, distributed messaging architecture (Apache Kafka), Real time data processing platform: Storm, Storm basic programming skills, linking Spouts, and connecting to the live Twitter API to process real-time tweets, multi-language capability of storm (with Python scripts), Case study: Networking fault prediction. This course also helps a student to analyze and understand Big-data using visuals. Topics include, Design principles, Perception, color, statistical graphs, maps, trees and networks, high dimensional data, data visualization tools.

#### **DSE\* ZC444 Artificial Intelligence**

**3**

The object of this course is to give an introduction to the problems and techniques of A.I. along with the applications of A.I. techniques to the fields like natural language understanding, image processing, game theory and problem solving. The course also aims at understanding its implementation using LISP and PROLOG languages.

#### **DSE\* ZC465 Machine Learning**

**4**

Introduction to Machine Learning, Various kinds of learning, Supervised Learning, Unsupervised Learning, Model Selection; Bayesian Learning, MAP Hypothesis, MDL Principle, Bias Variance Decomposition, Bayes Optimal Classifier, Naive Bayes Classifier; Linear Models for Regression, Linear Models for Classification; Non-Linear models, Decision trees; Instance Based Learning, KNN Algorithm, CBR Learning; Support Vector Machines, VC Dimension; Neural Networks, Perceptron Learning, Back Propagation Algorithm; Introduction to Genetic Algorithms.

#### **DSE\* ZG515 Data Warehousing**

**5**

Introduction, evolution of data warehousing; decision support systems; goals, benefit, and challenges of data warehousing; architecture; data warehouse information flows; software and hardware requirements; approaches to data warehouse design; creating and maintaining a data warehouse; Online Analytical Processing (OLAP) and multi-dimensional data, multi-dimensional modeling; view materialization; data marts; data warehouse metadata; data mining.

#### **DSE\* ZG516 Computer Organization & Software Systems**

**5**

Programmer model of CPU; Basic concept of buses and interrupts; Memory subsystem organization; I/O organization; Concept of assembler, linker & loader; Types of operating systems; Concept of process; OS functions: Process scheduling, Memory management, I/O management and related issues.

#### **DSE\* ZG517 Systems for Data Analytics**

**5**

Fundamentals of data engineering - data engineering vs data science; Data processing concepts - partitioning, replication, grouping and sorting, data locality; Flynn's taxonomy; Task vs Data Parallelism; Databases, parallel vs distributed databases, architecture – performance; Distributed computing architecture; Processing frameworks - batch, map-reduce, stream processing, parallel processing, real time processing; Cloud fundamentals - virtualization, batch-transactional-continuous workloads, execution models and examples- AWS , Azure etc..

#### **DSE\* ZG519 Data Structures and Algorithms Design5**

Introduction to Abstract Data Types, Data structures and Algorithms; Analysis of Algorithms – Time and Space Complexity, Complexity Notation, Solving Recurrence Relations.; Divide-and-Conquer as a Design Technique; Recursion – Design of Recursive Functions / Procedures, Tail Recursion, Conversion of Recursive Functions to Iterative Form. Linear data structures – Lists, Access Restricted Lists (Stacks and Queues) – Implementation using Arrays and Linked Lists; Searching and Order Queries. Sorting – Sorting Algorithms (Online vs. Offline, In-memory vs. External, In-space vs. Out-of-space, Quick Sort and Randomization). Unordered Collections: Hash tables (Separate Chaining vs. Open Addressing, Probing, Rehashing). Binary Trees – Tree Traversals. Partially Ordered Collections: Search Trees and Height Balanced Search Trees, Heaps and Priority Queues. Algorithm Design: Greedy Algorithms and Dynamic Programming. Graphs and Graph Algorithms: Representation schemes, Problems on Directed Graphs (Reachability and Strong Connectivity, Traversals, Transitive Closure. Directed Acyclic Graphs - Topological Sorting), Problems on Weighted Graphs (Shortest Paths. Spanning Trees). Introduction to Complexity Classes (P and NP) and NP-completeness. NP-Hard problems. Designing Algorithms for Hard Problems – Back tracking, Branch-and-Bound, and Approximation Algorithms.

**DSE\* ZG521 Graphs - Algorithms and Mining 5**

Basic concepts of graphs and digraphs connectivity, reachability and vulnerability; Trees, tournaments and matroids; Planarity; Routing and matching problems; Representations; Various algorithms; applications, introduction to graph mining, Graph Pattern Mining, Graph Classification, Graph Compression, graph model, graph dynamics, social network analysis, visualization, summarization, graph clustering, link analysis, applications of graph patterns.

**DSE\* ZG522 Big Data Systems 5**

What is big data - are existing systems sufficient?; Data Warehouse v/s Data Lakes; Hadoop – Components; Storage - Relational DBs/ NoSQL dbs / HDFS / HBase / Object Data stores - S3; Serialization; Interfaces - Hive/ Pig; Stream Processing; Spark; Mahout.

**DSE\* ZG524 Deep Learning 4**

Common Architectural Principles of Deep Networks; Building Blocks of Deep Networks; Convolutional Neural Networks (CNNs); Recurrent Neural Networks; Recursive Neural Networks; Building Deep Networks with ND4J; Applications to Sequence Data, Anomaly Detection; Tuning Deep Networks; Vectorization.

**DSE\* ZG526 Probabilistic Graphical Models 4**

HMM, Markov Random Field, Bayesian networks, Representation, Learning, Inference; Dynamic Bayesian Networks and Temporal Bayesian networks, applications.

**DSE\* ZG527 Ethics for Data Science 4**

Nature of data - data as a by-product of computing, operations data (e.g., sales/marketing), surveillance data (business or government), data collected for research; Ethics - What are ethics, need for ethics, Ethical concerns in computing and analytics. Why data science needs ethics? ; Issues -political/social, liberty and justice, fairness and equality, business competitiveness, privacy, anonymity, and security; Data Ownership, Informed Consent, Security Risks (Privacy, Anonymity, Integrity, and Provenance); Ethical methods for sourcing/collecting data, and for storage/distribution of data. Data validation. Algorithmic Fairness and Case Studies; Solutions to address ethical issues for government, corporations/organizations, research, public use of data, social norms, legal compliance, and case studies. Data ethics in specific domains - e.g. health care, finance, and social studies/research.

**DSE\* ZG528 Optimization Techniques for Analytics 5**

Role of optimization in different types of analytics, Introduction to Linear Programming, LP Model and graphical solution, Primal Simplex method, Dual Simplex and Post Optimality Analysis, Revised Simplex method with examples, Application of linear programming in transportation, assignment problems, Integer linear programming, mixed integer programming, complexity analysis, branch and bound techniques, goal programming, Network models - critical path method and PERT, Dynamic programming, game theory, additional meta heuristic techniques, 2-3 case studies from relevant industry domains.

**DSE\* ZG529 Data Management for Machine Learning 4**

Data Models and Query Languages: Relational, Object-Relational, NoSQL data models; Declarative (SQL) and Imperative (Map Reduce) Querying; Data Encoding: Evolution, Formats, Models of dataflow; Machine learning workflow; Data management challenges in ML workflow; Data Pipelines and patterns; Data Pipeline Stages: Data extraction, ingestion, cleaning, wrangling, versioning, transformation, exploration, feature management; Modern Data Infrastructure: Diverse data sources, Cloud data warehouses and lakes, Data Ingestion tools, Data transformation and modelling tools, Workflow orchestration platforms; ML model metadata and Registry, ML Observability, Data privacy and anonymity.

**DSE\* ZG530 Natural Language Processing 4**

Natural Language Understanding and Generation, N-gram and Neural Language Models, Word to Vectors / Word Embedding (Skip gram/CBOW, Glove, BERT/ XLM, MURIL), Part of Speech Tagging, HiddenMarkov Models, Parsing - Syntactic, Statistical, Dependency, Word Sense Disambiguation, Semantic Web Ontology.

**DSE\* ZG531 Design of Experiments for Data Science 4**

Introduction and importance of Experimental Design, Testing of Hypothesis, Designs with One Source of Variation, Multiple Comparison Testing, Interaction Effect, Factorial Experiment, Fractional Factorial Designs & Confounding, Latin Squares and Graeco-Latin Squares, Fractional-Factorial Designs, Taguchi Design, Designs with Random Effects, Optimal Designs and Model Uncertainty, Design for Nonlinear Model, Sequential Designs.

**DSE\* ZG532 Introduction to Data Science 5**

Data Analytics, Data and Data Models, Data wrangling, Feature Engineering, Classification and Prediction, Association Analysis, Clustering, Anomaly Detection, exploratory / explanatory data analysis with visual storytelling, Ethics for Data Science.

**DSE\* ZG537 Information Retrieval 4**

Organization, representation, and access to information; categorization, indexing, and content analysis; data structures for unstructured data; design and maintenance of such data structures, indexing and indexes, retrieval and classification schemes; use of codes, formats, and standards; analysis, construction and evaluation of search and navigation techniques; search engines and how they relate to the above. Multimedia data and their representation and search.

**DSE\* ZG554 Distributed Data Systems 4**

Distributed File Systems - File System Models; Replication and Synchronization - Caching; Failure & Recovery; File System Security. Distributed Databases - Distributed Data Sources and Updates; Database Connectivity; Concurrency Control and Distribution mechanism; Distributed indexing schemes. Database security. Data on the Web - Web as a distributed data repository. Data Collection and Use Crawlers, Search Engines, and Indexing Schemes. Information Retrieval Techniques. Data Exchange - Hierarchical Data Models, XML, and query languages. Semi-structured / Unstructured data -querying and synchronization. Pervasive Data - Data distribution and access for non-computing devices, small computing devices, embedded computing devices and sensory devices.

**DSE\* ZG555 Data visualization and Interpretation 5**

Visualization as a Discovery tool, Visualization skills for the masses, The Visualization methodology, Visualization design objectives, Exploratory vs. explanatory analysis, Understanding the context for data presentations, 3 minute story, Effective Visuals, Gestalt principles of visual perception, Visual Ordering, Decluttering, Story Telling, Visualization Design; Taxonomy of Data Visualization Methods: Exploring Tableau, Dashboard and Stories, Bullet graphs, Pareto charts, Custom background images; Dashboard : Dashboard categorization and typical data, Characteristics of a Well-Designed Dashboard, Key Goals in the Visual Design Process; Power of Visual Perception: Visually Encoding Data for Rapid Perception, Applying the Principles of Visual Perception to Dashboard Design.

**DSE\* ZG556 Stream Processing and Analytics 5**

Real Time , Streaming Data & Sources, Real time streaming system architecture , Characteristics of a Real Time Architecture and Processing ; Configuration and Coordination Systems: Distributed State and Issues, Coordination and Configuration using Apache ZooKeeper; Data Flow Management : Distributed Data Flows , Various Data Delivery and Processing Requirements, N+1 Problem, Apache Kafka (High-Throughput Distributed Messaging); Processing Stream Data with Storm; Overview of Data Storage –

Requirements: Need for long-term storage for a real time processing framework, In-memory Storage, No-Sql Storage Systems, Choosing a right storage solution; Visualizing Data :Requirements, Principles and tools; Bounds of Random variables, Poisson Processors, Maintaining Simple Statistics from Data Streams, Sliding Windows and computing statistics over sliding windows, Data Synopsis (Sampling, Histograms, Wavelets, DFT), Exact Aggregation, Timed Counting and Summation, Multi Resolution Time Series Aggregation, Stochastic Optimization; Statistical Approximation to Streaming Data: Probabilities and Distributions, Sampling Procedures for Streaming Data, Approximating Streaming Data with Sketching, Registers and Hash Functions, Working with Sets, The Bloom Filter, Distinct Value Sketches, The Count-Min Sketch; Clustering techniques for Streaming Data; Classification methods : Decision Tree (VFDT); Evaluating stream processing algorithms; Case Studies in Designing solutions to streaming data

#### **DSE\* ZG557 Artificial and Computational Intelligence 5**

Agents and environments, Task Environments, Working of agents; Uninformed Search Algorithms: Informed Search. Local Search Algorithms & Optimization Problems: Genetic Algorithm; Searching with Non-Deterministic Actions, Partial Information and Online search agents, Game Playing, Constraint Satisfaction Problem, Knowledge Representation using Logics: TT-Entail for inference from truth table, Proof by resolution, Forward Chaining and Backward Chaining, Inference in FOL, Unification & Lifting, Forward chaining, Backward Chaining, Resolution; Probabilistic Representation and Reasoning : Inference using full joint distribution, Representation of Conditional Independence using BN, Reinforcement Learning; Difference between crisp and fuzzy logic, shapes of membership function, Fuzzification and defuzzification, fuzzy logic reasoning; Decision making with fuzzy information, Fuzzy Classification; Connectionist Models: Introduction to Neural Networks, Hopfield Networks, Perceptron Learning, Backpropagation & Competitive Learning, Applications of Neural Net: Speech, Vision, Traveling Salesman; Genetic Algorithms - Chromosomes, fitness functions, and selection mechanisms, Genetic algorithms: crossover and mutation, Genetic programming.

#### **DSE\* ZG568 Applied Machine Learning 4**

Need for machine learning. Prediction and classification methods. Use cases in application domains. Interpretation of results. Limitations of various techniques. End to end Machine learning - data collection, data preparation, model selection.

#### **EA ZC412 Flexible Manufacturing Systems 4**

Introduction CAD/CAM systems, overview of FMS, system hardware and general functions, material handling system, work holding systems, cutting tools and tool management, physical planning of system, software structure functions and description, cleaning and automated inspection, communications and computer networks for manufacturing, quantification of flexibility, human factors in manufacturing, FMS and CIM in action (case studies), justification of FMS, modelling for design, planning and operation of FMS.

#### **EA ZC451 Internetworking Technologies 3**

Introduction to internetworking concepts; the internet architecture; goals and key issues related to internetworking technologies; design aspects; HTTP and other relevant protocols; agent technology and tools relevant to the internet; techniques of data compression; voice, video, and interactive video-on-demand over the internet; multimedia operating systems and their impact; multimedia networking; mobile computing; internet security, case studies.

#### **EA ZC473 Multimedia Computing 3**

Introduction to multimedia; media & data streams; image, video & audio file formats; image & video processing, synthesis of sound signal; image coding & compression, video & audio codes, low bit rate video telephony; audio-visual integration, lip reading, face animation; augmented reality; multimedia search services, content based image & video indexing; access to multimedia, human-machine interfaces, spoken language interface; algorithm vs. architecture based approaches, multimedia processors, performance quantification; case studies, vision 2010.

#### **EBCT ZG511 Overview of e-Business 3**

E-Business Environment and Opportunities: Background; E-Business evolution; E-Business environment; Diverse opportunities in E-Business; E-Businesses on the Internet. Categories of E-Business - B2B/E2E, B2C, C2C; Overview of E-Business implementation technologies. E-Business Models - Enterprise portal, CRM, ERP, Supply Chain Planning (SCP), Transport Management System (TMS), Warehouse Management System (WMS), Content Management. E-Business Products- Development products; integration products; generic tools; performance analyzer tools; content management tools; component generator tools. Electronic Transaction and Security – Online payment system and security issues; Secure Transport Protocols, Secure Transactions, Secure Electronic Payment Protocol (SEPP), Secure Electronic Transaction (SET); Security features – certificates for authentication (SSL, third party certifications); security on Web servers and Enterprise Network. Emerging E-Businesses Scenario- Changing economic considerations; Emerging business opportunities and revenue models; emerging technologies; Social aspects.

#### **ED\* ZC164 Computer Programming 4**

Basic Computing Steps and Flow Charting (Assignment, Sequencing, Conditionals, Iteration). Programming Constructs – Expressions, Statements, Conditionals, Iterators/Loops, Functions/ Procedures; Data Types – Primitive Types, Tuples, Choices (Unions or Enumerations), Lists/Arrays, Pointers and Dynamically Allocated Data. Input output and Files. Laboratory Component: Programming Exercises involving development and testing of iterative and procedural programs using bounded and unbounded iterations, function composition, random access lists, sequential access lists, dynamically allocated lists, and file access.

#### **ED\* ZC211 Electrical & Electronics Technology 3**

Electric circuit, electromagnetism, magnetic circuit, electrostatics, AC voltage and current, single-phase circuits, semiconductor devices, amplifiers, digital systems, microprocessors, DC machines, polyphase circuits, transformers, synchronous machines, induction motors, power electronics, measurements, illumination.

#### **ED\* ZC231 Principles of Management 3**

Fundamental concepts of management - planning; organizing; staffing; directing and controlling; production, financial, personnel, legal and marketing functions; accounting and budgeting, balance sheets.



**ED\* ZC232 Engineering Materials 3**

Mechanical, electrical, electronic and chemical properties and applications of common engineering materials; ferrous and non-ferrous metals and alloys; thermosetting and thermoplastic plastics; natural and synthetic resins; rubber; glass; abrasives and ceramics; common building materials, namely, timber, stone, lime and cement; corrosion of metals and methods of preventing corrosion; protective and decorative coatings; insulating materials; testing of materials.

**ED\* ZC233 Calculus 4**

Limits, continuity, differentiation, integration, Fourier series, ordinary differential equations for initial and boundary value problems, solution through Laplace transforms, numerical solution using Picard's iteration and higher order methods, partial derivatives, partial differential equations, analytical solution techniques.

**ED\* ZC235 Linear Algebra & Optimization 3**

Vector and matrix algebra, systems of linear algebraic equations and their solutions; eigenvalues, eigenvectors and diagonalization of matrices; Formulation of linear programming problems, Simplex method, Big-M method, two phase method, Sensitivity analysis, Revised and Dual Simplex Methods.

**ED\* ZC241 Technical Report Writing 3**

Elements of effective writing; art of condensation; business letter writing; memos; formal reports; technical proposals; conducting, and participating, meetings; agenda and minutes; strategies for writing technical descriptions, definitions, and classifications; oral presentation; use of graphic and audio-visual aids; editing.

**ED\* ZC245 Fluid Mechanics and Machines 4**

Introduction and fundamental concepts, fluid statics, kinematics and dynamics of fluid flow, inviscid flows, pipe flow and network design, open channel flow, incompressible viscous flow, laminar boundary layers, turbulent flows, essentials of compressible flow, dimensional and model analysis, orifice, venturi, notches and weirs, hydraulic turbines, centrifugal and reciprocating pumps, fluid couplings and torque converters, compressors.

**ED\* ZC251 Engineering Measurements 4**

Performance characteristics of measuring instruments, measurement methods for mechanical, electrical, radiant, chemical, magnetic and thermal energy variables. Emphasis in this course shall be on the operation and use of instruments.

**ED\* ZC261 Mechanical Technology 4**

Fundamental concepts of heat, work and energy; second law of thermodynamics; properties of gases and vapors; basic cycles; flow of liquids; steam boilers; steam engines and pumps; steam turbines and condensers; hydraulic pumps and turbines; internal combustion engine.

**ED\* ZC311 Manufacturing Process 4**

Fundamentals of casting process; forging; powder metallurgy; soldering; brazing and welding technology; metal forming process, its analysis and design; Introduction to Metal cutting, machine tools; mechanics of metal cutting; other machining processes; grinding and finishing operations; non convention machining; chipless machining processes; NC machines programming; control system in CNC; CNC, DNC; FMS and machining center.

**ED\* ZC321 Mechanics of Solids 3**

Fundamental principles of mechanics; introduction of mechanics of deformable bodies; forces and moments transmitted by slender members; stress and strain; stress-strain-temperature relations; torsion; stresses and deflections due to bending; stability of equilibrium.

**ED\* ZC322 Kinematics & Dynamics of Machines 3**

Kinematics of mechanism: introduction to mechanisms, position, displacement, velocity, acceleration analysis, cam design, gear trains, synthesis of linkages. Dynamics of machines: static force analysis, dynamic force analysis (planar), dynamics of reciprocating engines, balancing, cam dynamics, flywheels, governors and gyroscopes, free and forced vibrations.

**ED\* ZC324 Mechatronics & Automation 4**

Mechatronics design approaches, interfacing, instrumentation and control systems, modeling of mechanical and electromechanical systems, sensors and actuators, introduction to automation, pneumatics and hydraulics in automation, pneumatic circuits for automation, PLC programming and interfacing with pneumatic and hydraulic systems, introduction to MEMS, modeling and simulation of MEMS, CNC machines, automated material handling, introduction to FMS.

**ED\* ZC325 Fluid Power Systems 4**

Introduction to Fluid power, advantages of fluid power, applications, Introduction to Pneumatics, Air preparation and Components, Pneumatics Circuits and Applications, Electro pneumatics, Electrical Controls for fluid power circuits, Physical properties of hydraulic fluids, Energy and Power in Hydraulic Systems, Frictional Losses in Hydraulic Pipelines, Hydraulic Pumps, Hydraulic Cylinders and Cushioning Devices, Hydraulic Motors, Hydraulic Valves, Hydraulic Circuit Design and Analysis, Ancillary Hydraulic Devices, Hydraulic Conductions and Fittings, Maintenance of Hydraulic Systems, Use of PLC programming for interfacing pneumatics and Hydraulic Circuits.

**ED\* ZC332 Mechanical Engineering Design I 4**

Introduction to mechanical engineering design, stress and strain, deflection and stiffness, introduction to materials and manufacturing, failures resulting from static loading, failures resulting from variable loading, design of mechanical elements: screws, fasteners, permanent joints, nonpermanent joints and mechanical springs. Practice of machine part and assembly drawings using Pro/Engineer or similar solid modeling environment.

**ED\* ZC342 Mechanical Engineering Design-II 4**

Lubrication and journal bearings, rolling contact bearings, introduction to gearing, spur helical, bevel and worm gears, clutches, brakes, couplings, flywheels, belts, chains, wire rope, shafts and axles. Practice of machine part and assembly drawings using Pro/Engineer or similar solid modeling environment.

**ED\* ZC423T Project Work 20**

Consistent with the student's professional background and work-environment, the student will be required to carry out work-oriented projects. The student would be required to select an area of work that is considered vital to the sponsoring organization. The topic of the project and detailed project outline that is prepared by the student, in consultation with his/her Mentor, needs to be approved by the Dean, WILPD. On approval, the student carries on with the work-centered project, adhering to the guidelines provided in the detailed course handout, taking all the prescribed evaluation components on time. At the end of the semester, the student should submit a comprehensive Project Report, to the Institute for evaluation. The student will be evaluated on the basis of the various interim evaluation components, contents of the report and Seminar/Viva-Voce that may be conducted at Pilani or at any other Centre approved by the Institute.

**ED\* ZC433 Mechanical Vibrations & Acoustics 4**

Introduction, single degree-of-freedom systems: free and forced vibration problems, concept of resonance and damping, vibration isolation, multi-degree-of-freedom systems: modeling of multi-degree-of-freedom systems, eigen value problem and calculation of normal modes of a system,

forced response using modal superposition techniques, introduction to acoustics - terminology used in acoustics and definitive of fundamental quantities 1D wave, equation (plane waves) & 3D wave equation, formulation and fundamental solution to the equations, measurement of noise & vibration – vibration measurement principles.

#### **ED\* ZC434, Quality Control, Assurance & Reliability** 4

Basic concepts of probability and probability distributions, standard probability distribution, sampling and sampling distributions, confidence intervals, testing significance, statistical tolerance, various types of control charts, statistical process control techniques, value analysis, defect diagnosis and prevention, basic concepts of reliability, reliability design evaluation and control, methods of applying total quality management, production process. Practical assignments on statistical quality control using suitable statistical software tools such as R-software, MS Excel, SAS, Minitab or SPSS.

#### **ED\* ZC436 Computer Aided Design** 4

CAD software and CAD hardware. Mathematical modeling of parametric curves, surfaces and solids, and their computer simulation on spreadsheets and using specialized solid modeling packages. CAD/CAM data exchange. Introduction to finite element analysis and FEM practice on a specialized CAE package. Rapid prototyping. Hands-on in assignments and CAD project.

#### **ED\* ZC441 Automotive Vehicles** 3

Internal combustion engines; vehicle performance; analysis and design of vehicle components. Experimental or theoretical investigation of problems selected from the field of automotive vehicles.

#### **ED\* ZC452 Composite Materials and Design** 4

Introduction to composites, concepts of reinforcement, strengthening mechanisms, fibrous reinforcements, matrix materials, micromechanical aspects of composites, manufacturing methods, composite production design methods design of tensile members, pressure vessels, storage tanks, and other chemical process equipment made of FRP, design of joints, damage of composites by impact, FRP grids, recent development in manufacturing of composites and technologies. Simulation of mechanics of composite materials using suitable software tools.

#### **ED\* ZC453 Product Design & Development** 4

Introduction to product design and development, product development planning and process tools, technical and business concerns, understanding customer needs, function modeling, product teardown and experimentation, benchmarking and engineering specifications, product architecture, concept generation, concept selection, concept embodiment, modeling of product metrics, design for X, physical prototypes, physical models and experimentation, robust design, case studies.

#### **ED\* ZC454 Reverse Engineering and Rapid Prototyping** 4

Introduction to reverse engineering, methodologies and techniques for reverse engineering, reverse engineering hardware and software, selecting reverse engineering system, introduction to rapid prototyping, relationship between reverse engineering and rapid prototyping. Reverse engineering in automotive engineering, aerospace engineering, medical device industry. Legal aspects and barriers for reverse engineering. Practice of virtual and physical rapid prototyping of simple models.

#### **ED\* ZC471 Management Information Systems** 3

Introduction to Information Systems; Concepts of management, concepts of information, systems concepts; Information Systems and Organizations; decision making process; database systems; data communications; planning, designing, developing and implementing information systems; quality assurance and evaluation of information systems;

future developments and their organizational and social implications; decision support system and expert systems.

#### **EE\* ZG511 Environmental Chemistry** 5

Fundamentals of Physical Chemistry, Water Chemistry, Water pollution, Green Chemistry, Fundamentals of Analytical Chemistry, Atmospheric Chemistry and air pollution, Energy and climate change, Toxic compounds, Metals, soils, sediments and waste disposal, Case studies

#### **EE\* ZG512 Environmental Biotechnology** 5

Principles, concepts and applications of Biotechnology to the management of environmental problems, Microbial technologies for waste management, Bioremediation of toxicants, Microbial systems for detoxification, Microbial technologies for waste management, Biochemical kinetics and engineering, Concept of rDNA technology, Regulation and ethics

#### **EE\* ZG513 Applied Transport Phenomena** 5

Introduction to fluid, heat and mass transport, Newton's laws of viscosity, Fourier's laws of heat conduction, Fick's laws of diffusion, Continuity equation, Concept of laminar and turbulent flow, Convective heat and mass transfer, Introduction to transport equations for fluid, heat and mass transport, Sedimentation, Packed beds, Fluidization, Pumps and compressors, piping networks, Heat and mass transfer equipment related to environmental systems, Dimensionless numbers and their significance

#### **EE\* ZG514 Environmental Sampling and analytical methods** 5

Principles of sample collection and data analysis / interpretation, Gravimetric methods, titrimetric methods, electrochemical methods, Spectrometric methods of analysis, Chromatographic methods of analysis, Sampling techniques for air and water pollution, Biological methods of analysis, Interpretation of data in environmental monitoring

#### **EE\* ZG515 Environmental Management Systems** 5

Study of environmental policies, Environmental laws, Environmental regulations and permit procedures; ISO series; Life Cycle analysis; Environmental audit; Environmental impact assessment, Risk assessment, Hazardous waste management, Integrating environmental and safety management; Case studies.

#### **EE\* ZG521 Physico – Chemical treatment principles & design for wastewater systems** 4

Pollutant classification, Source selection process, Selection of treatment chain, Plant siting, Physical treatment methods like screening, sedimentation, filtration, etc., Chemical treatment principles like precipitation, coagulation, ozonation etc., adsorption, Novel processes like membranes, electrodialysis, etc., Design of physico-chemical systems for wastewater treatment, Case studies.

#### **EE\* ZG522 Biological treatment principles & design for wastewater systems** 4

Fundamentals of biological treatment, Biochemistry and kinetics of biochemical processes like oxidation, nitrification & denitrification, Dephosphatization, Acedogenesis and methogenesis, Aerobic and anaerobic treatment processes, Basic description of equipment and design methodologies, Design of reactors and configurations; Case studies for industrial and wastewater treatment.

#### **EE\* ZG523 Environmental Statistics** 4

Introduction to probability and Statistics, Probability concepts and probability distributions, Fundamentals of data analysis, Uncertainty in Measurement, Precision and accuracy, Reproducibility/repeatability, Types of errors, Error propagation, Confidence intervals, Hypothesis testing for equality of mean and standard deviation: t-test, chi-square test and F-test, Errors in hypothesis testing, Experiment design and analysis of variances, Autocorrelation, cross-

correlation and sensitivity analysis in data sets, Linear least-squares regression. Precision of parameter estimates, Coefficient of determination; Interpreting statistical results, documentation and recommendations, Theory of attributes, Time series analysis, Case studies

#### **EE\* ZG532 Pumps and Automation Systems 4**

Pumps and Pumping stations: Need of pumping, classification and type of pumps, Pumping power, Head and capacity of pump, site selection pump specification and selection; Distribution system: Type of distribution system, different layout of distribution system, methods of supplying water, pressures in distribution system, distribution resources and its capacity, type of reservoirs & accessories; Valves and Fittings: Different type of valves, hydrants, meters, stop cock & water tap, pipe fittings, leakage & waste of water factors, affecting losses & wastes. Introduction to Automation: Sensors and actuators for pumping, basic control concepts, micro controllers and PLC's, Introduction to SCADA and HMI interface; Pump Drivers: Basics of AC motors, Types, starting methods, types coupling, motor and coupling selection; Water Automation systems: Automatic switching systems, control of Submersible Pumps, timer based control, level based control, Tank to Tank Flow Automation System.

#### **EE\* ZG533 Industrial Pollution Abatement 4**

Different types of wastes generated in an industry, their effects on living and non-living things; environmental regulatory legislations and standards and climate changes; quantification and analysis of wastewater and treatment; different unit operations and unit processes involved in conversion of highly polluted water to potable standards; atmospheric dispersion of air pollutants, and operating principles, design calculations of particulate control devices; analysis and quantification of hazardous and non-hazardous solid wastes, treatment and disposal.

#### **EE\* ZG534 Urban Water Management 4**

The urban water cycle (description, social imperatives, environmental considerations, and economic challenges); water supply (availability, service levels, and technical options); free basic water, demand management, loss control, use of recycled water; sewage (public health considerations, service levels and technical options, the dry-versus-wet sanitation debate, social acceptance, and grey water management); drainage (service levels and technical options, sustainable urban drainage systems (SUDS), urban litter management, urban rivers, risk management, and groundwater issues); management (water sensitive urban design, introduction to asset management, GIS as a water management tool, and sustainability indicators).

#### **EE\* ZG611 Energy generation and management in waste treatment Plants 4**

Energy audit and minimization in waste treatment facilities; Novel energy conservation technologies, Estimation of energy potential of waste; Selection of energy generation technologies coupled with waste treatment, e.g. incinerators, pyrolysis units, bio-digesters and purification and enrichment of off gases from these units; Utilization of fuel & fertilizer value of gases & liquids from bio-digesters and pyrolysis units; Energy generation from waste sludge.

#### **EE\* ZG612 Environmental remote sensing and GIS4**

Principles of remote sensing, Components of GIS: Hardware, Software and Organization Context, Types of Maps; Spatial and Non Spatial, Types of Projections, Editing the Raster and Vector data structures, Analysis using raster and Vector Data, Data Retrieval, Data Reclassification, Data Overlaying and Buffering; Data Output; Pollution data gathering in GIS area under consideration through terrestrial and aerial stations, unmanned aerial vehicles (UAV) equipped with imaging and spectroscopic probes; Pollution mapping coupled to GIS through wireless network; Water body pollution monitoring instruments coupled to GIS through wireless network, Thermal and microwave remote sensing,

Space imaging, Case studies on various applications of GIS for environmental management.

#### **EE\* ZG613 Environmental systems modeling 4**

Introduction to air quality models, Atmospheric stability and turbulence, Gaussian dispersion models, single source and multisource models, Transport and fate of pollutant in aquatic systems, Introduction to modeling of river, lake and estuarine hydrodynamics, Stratification and eutrophication of water bodies, Dissolved oxygen model for water streams, Computational methods in environmental modeling and simulation, Transport and fate of pollutants in soils and ground water, Applications of public domain models and software; Case studies.

#### **EE\* ZG614 Air Pollution Control Technologies 4**

Introduction to air pollution, Atmospheric diffusion of air pollutants, Particulate control, Gaseous pollutant control, Methods for monitoring and control, Selection and design of control equipments, Meteorological aspects of air pollution, Applications and case studies

#### **EE\* ZG621 Solid Waste Management 4**

Introduction to solid waste management: Sources and classification, Composition and Properties of Solid Waste and emerging e-waste, Onsite handling, storage and processing including segregation, Collection of solid waste, Transfer and transport, Recycling, Incineration pyrolysis and composting, Processing technique and equipment, Recovery of resources, conversion products, and energy, Biomedical and hazardous waste, Electronic waste, Regulatory framework, categorization, generation, collection, transport, treatment and disposal, Leachate collection and treatment, Bioleaching and bioremediation; Case studies.

#### **EE\* ZG622 Environmental Process Engineering 4**

Origin, Nature and composition of solid, liquid and gaseous emissions from various processes in Industries, institutions and human habitats, Assessment of pollution potential through study of process chemistry and process engineering, Understanding block flow diagrams (BFD), Process Flow Diagrams (PFD) and Piping and Instrumentation Diagram (P&ID) and Process Pollution Flow Diagram (PPFD), Maximum Attainable Control Technologies (MACT) and Best Available Control Technologies (BACT), Reasonably Available Control Technology (RACT) and Lowest Attainable Emission Rate (LAER), List of equipment and processes for BACT/RACT/LAER and their description, Estimating thermo-physical and thermodynamic data for pollutants, Use of software in Environmental Process Engineering Equipment design and datasheet generation, Technical audit of Existing process technology, Environmental carrying capacity calculations; Interpretation of field/on-site and laboratory data, Case studies.

#### **EE\* ZG623 Environmental Impact and Risk Assessment4**

Introduction to Environmental Impact Assessment (EIA), Environmental assessment framework, Impact assessment methodologies; Air and water quality Impact analysis (AQIA / WQIA), Energy and noise impact analysis (EnIA / NIA), Vegetation, wild life and socio-impact analysis, Environment risk assessment, Environmental Impact statement.

#### **EE\* ZG624 Advanced Water Treatment Technology and Water Supply Systems 4**

The course will cover estimation of water demand, characterization of water quality (physical, chemical and biological), different unit operations for treatment of water (screening, sedimentation, coagulation, filtration, disinfection etc.), nature of emerging contaminants (types of contaminants and sources, physical & chemical characteristics and their health hazard), advanced techniques for water purification (includes advanced process such as reverse osmosis, desalinization process, membrane filtration etc., and advanced material such as nanomaterial, composite

material etc.), water distribution system, pumping at the mains, water leakage and their detection, water auditing.

#### **EE\* ZG625 Advanced Wastewater Engineering 4**

The course will cover design of sewer system (including pumping of sewage, sewer hydraulic, layout and construction), Characterization of waste (physical, chemical and biological characteristics), Natural attenuation, Wastewater unit operation (preliminary treatment, secondary or biological treatment), Sludge disposal, Industrial waste and their characterization (physical, chemical characteristics, health hazard), Advanced wastewater treatment (nature of waste, application of nanotechnology, biotechnology, and other advanced material etc.), Solid waste management (source and nature of waste, disposal method, recycle and reuse, guideline and legislation); Water and wastewater sampling and laboratory analysis.

#### **EEE ZG512 Embedded System Design 4**

Introduction to embedded systems; embedded architectures: Architectures and programming of microcontrollers and DSPs. Embedded applications and technologies; power issues in system design; introduction to software and hardware co-design.

#### **EEE ZG571 Optical Communication 4**

Optical communication systems and components; optical sources and transmitters (basic concept, design and applications); modulators (electro-optic, acousto-optic and laser modulation techniques); beam forming; focusing and coupling schemes to optical repeaters; optical amplifiers; optical field reception; coherent and non-coherent light wave systems; fibre optic communication system design and performance; multichannel light wave systems; long haul communications; fibre optic networks.

#### **EEE ZG572 Satellite Communication 5**

Review of microwave communications and LOS systems; the various satellite orbits like GEO, MEO, LEO; the satellite link analysis and design; the communication transponder system like INSAT, INELSAT etc; the earth segment and earth station engineering; the transmission of analog and digital signals through satellite and various modulation techniques employed; the multiple access techniques like FDMA, TDMA, CDMA, DAMA, etc; the INSAT program; salient features of INSAT – systems and services offered; satellite services offered by INTELSAT, INMARSAT and future satellites like IRIDIUM etc; future trends in satellite communications.

#### **EEE ZG573 Digital Signal Processing 3**

Introduction; design of analog filters; design of digital filters (IIR and FIR); structures for the realization of digital filters; random signals and random processes; linear estimation and prediction; Wiener filters; DSP processor architecture; DSP algorithms for different applications.

#### **EEE ZG582 Telecom Network Management 5**

Network architecture and protocols; LAN, MAN and WANs; internetworking; network planning; network management concepts and standards; administrative, operational and fault management; security issues; remote network management.

#### **ENGG ZC111 Electrical & Electronics Technology 4**

Electric circuit, electromagnetism, magnetic circuit, electrostatics, AC voltage and current, single-phase circuits, semiconductor devices, amplifiers, digital systems, microprocessors, DC machines, polyphase circuits, transformers, synchronous machines, induction motors, power electronics, measurements, illumination.

#### **ENGG ZC232 Engineering Materials 4**

Mechanical, electrical, electronic and chemical properties and applications of common engineering materials; ferrous and non-ferrous metals and alloys; thermosetting and thermoplastic plastics; natural and synthetic resins; rubber; glass; abrasives and ceramics; common building materials,

namely, timber, stone, lime and cement; corrosion of metals and methods of preventing corrosion; protective and decorative coatings; insulating materials; testing of materials.

#### **ENGG ZC241 Mechanical Technology 4**

Fundamental concepts of heat, work and energy; second law of thermodynamics; properties of gases and vapors; basic cycles; flow of liquids; steam boilers; steam engines and pumps; steam turbines and condensers; hydraulic pumps and turbines; internal combustion engine.

#### **ENGG ZC242 Maintenance & Safety 3**

Objectives, functions, and types of maintenance; defects due to wear; lubrication and surfacing techniques to reduce wear; maintenance of different equipment's and their elements; spares planning; overhauling; TPM; safety and safety management; environmental safety; chemical safety; occupational health management; control of major industrial hazards; managing emergencies; employee participation in safety; HRD for maintenance and safety.

#### **ES\* ZC111 Probability & Statistics 3**

Probability spaces; conditional probability and independence; random variables and probability distributions; marginal and conditional distributions; independent random variables; mathematical expectation; mean and variance; binomial, Poisson and normal distributions; sum of independent random variables; law of large numbers; central limit theorem (without proof); sampling distribution and test for mean using normal and student's t-distribution; test of hypothesis; correlation and linear regression.

#### **ES\* ZC115 General Physics I 3**

Units, Physical Quantities and Vectors; Motion along a straight line; Motion in two and three dimensions; Newton's Laws of Motion; Applying Newton's Laws; Work and Kinetic Energy; Potential Energy and Energy Conservation; Momentum, Impulse and Collisions; Rotation of Rigid Bodies; Dynamics of Rotational Motion; Equilibrium and Elasticity; Fluid Mechanics; Gravitation; Periodic Motion; Mechanical Waves; Sound and Hearing

#### **ES\* ZC116 English Language Practice 3**

Writing Grammar and usage, sentence completion, jumbled sentences, emphatic word order, vocabulary building, message organization, paragraph development techniques and note taking. Reading: Skimming, scanning, rapid reading, analytical reading, factual reading, and aesthetic reading. Listening: Content listening, critical listening, aesthetic listening, empathetic listening, listening to short conversations, stories, lectures.

#### **ES\* ZC117 Chemistry-I 3**

Structure of atoms; formation of molecules and related bonding theories with the help of quantum chemistry; properties of solid, liquid and gas; chemical thermodynamics and its applications to solutions, equilibrium and electrochemical systems and chemical kinetics.

#### **ES\* ZC118 General Physics II 3**

Electric Charge and Electric Field; Gauss's Law; Electric Potential; Capacitance and Dielectrics; Current, Resistance and Electromotive Force; Direct Current Circuits; Magnetic Fields and Magnetic Forces; Sources of Magnetic Field; Electromagnetic Induction; Inductance; Alternating Current; Electromagnetic Waves; Nature and Propagation of Light; Geometric Optics; Interference; Diffraction

#### **ES\* ZC119 General Physics III 3**

Temperature and Heat; Thermal Properties of Matter; The First Law of Thermodynamics; The Second Law of Thermodynamics; Relativity; Photons - Light waves behaving as particles; Particles behaving as Waves; Quantum mechanics I - Wave functions; Quantum Mechanics II - Atomic Structure; Molecules and Condensed Matter; Nuclear Physics; Particle Physics and Cosmology.

#### **ES\* ZC131 Engineering Mathematics - I 3**

Differential and integral calculus in one dimension, vector algebra, calculus of several variables, partial derivatives, directional derivatives, maxima and minima in higher dimensions, constrained maxima and minima using Lagrange

multipliers, vector calculus – properties of grad, div and curl, line, surface and volume integrals, Green's, Gauss and Stokes theorems, Complex variables – Continuity and Differentiability, analytic functions, harmonic functions, Cauchy Riemann equations.

**ES\* ZC142 Computer Programming 4**

Basic Model of a Computer; Problem Solving-Basic Computing Steps and Flow Charting (Assignment, Sequencing, Conditionals, Iteration). Programming Constructs – Expressions, Statements, Conditionals, Iterators/Loops, Functions/Procedures; Data Types – Primitive Types, Tuples, Choices (Unions or Enumerations), Lists/Arrays, Pointers and Dynamically Allocated Data. Input output and Files.

**ES\* ZC212 Engineering Mathematics - II 3**

First order ordinary differential equations, Second order linear differential equations: initial conditions, boundary conditions, Applications of differential equations, Computer implementation of Euler's method, Runge-Kutta methods and Finite difference method for two point boundary value problem, Sturm-Liouville problem, Laplace transforms, Fourier series, Classification of second order partial differential equations, Analytical solutions of heat, wave and Laplace equations using method of separation of variables. Numerical experiments will be carried out/performed using MATLAB.

**ES\* ZC120 Chemistry - II 3**

Industrially important reactions; homogeneous and heterogeneous catalysis; important materials and its applications, especially polymer materials; alternative energy applications; wide range of characterization tools of molecules and materials for industrial applications.

**ES\* ZC217 Materials Science - I 3**

Fundamentals of materials: elastic moduli; atomic bonding; crystalline structure; imperfections; application of elastic deformation; Strength of materials: yield strength, tensile strength & ductility; modification of properties; Failure: fracture; fatigue; creep; corrosion; friction & wear; Properties of materials: thermal, electrical, magnetic; Material selection: functional, environmental, cost & availability.

**ES\* ZC218 Introduction to Thermodynamics & Applications 4**

Fundamental concepts, thermodynamic properties, equations of state, laws of thermodynamics and their application to industrial systems, entropy and its significance, basics concepts of thermodynamics applied to chemical reactions, reaction equilibrium and combustion calculations.

**ES\* ZC219 Materials Science - II 3**

Metal structures; phase diagrams; structural change; kinetics; alloys; carbon steel; alloy steels; metal processing – materials science perspective; ceramics; cement & concrete; polymers; composites; wood; material characterization supported by lab.

**ES\* ZC220 Introduction to Economics 3**

Big ideas in economics; Functioning of economy; Scarcity and choice; Consumer behaviour; Firm behaviour; Competitive markets; Labour markets; Unemployment; Capital market; Banking and non-banking financial institution; Central banking; Economic growth; Inflation; Monetary policy; Fiscal Policy.

**ES\* ZC225 Environmental Studies 3**

Environment, human population, and industrialization; natural resources and the impact of man-made activities on them; structure and function of ecosystem, population ecology, biodiversity and its conservation, overview of natural resources, environmental pollution, social issues and the environment, and environmental impact assessment.

**ES\* ZC227 Basic Electrical and Electronics Engineering 4**

Passive circuit elements; network theorems and analysis; introduction to single and three phase systems; DC/AC machines; electrical installation; semiconductors - operation of diodes, bipolar junction transistors and field effect transistors.

**ES\* ZC232 Fundamentals of Engineering Measurements 4**

Introduction to measurement techniques; the basic concept of units, static & dynamic performance characteristics and error analysis; the construction and design of measuring devices and circuits; measuring instruments and their applications; Instrument design aspects, techniques and specifications of electronic instruments; types of transducers used in instrumentation and measurement particularly for Temperature, Pressure, Flow and level variables.

**ES\* ZC234 Linear algebra & Optimisation 3**

Vector and matrix algebra, systems of linear algebraic equations and their solutions; eigenvalues, eigenvectors and diagonalization of matrices; Formulation of linear programming problems, Simplex method, Big-M method, two phase method, Sensitivity analysis, Revised and Dual Simplex Methods.

**ES\* ZC319 Mechanisms 4**

Overview of the various means to effectively convert force into desired motion, Classical mechanisms, mechanisms of mechatronics devices; concept of Mechanical Advantage; Physics of mechanisms such as, inclined planes, jacks, levers, linkages, gears, chains, pulleys, Geneva, cams, and clutches; Safety mechanisms; Torque, speed, tension & amp; limit control mechanisms; Free and forced vibrations; vibration control; Hydraulic & pneumatic mechanisms; Bio-mechanics.

**ES\* ZC320 Introduction to Industrial Instrumentation 4**

Importance and objectives of process control; process modelling; system dynamics (first order and second order); control structures: ON-OFF control, Proportional Integral and Derivative control; tuning; analog signal conditioning; PID implementation; actuators and final control elements; other control configurations; Piping and Instrumentation Diagram; Programmable Logic Controllers.

**ES\* ZC321 Manufacturing Sciences 4**

Principles, methods and equipment; product disassembly studies; science and engineering principles of metal casting, metal forming, joining, and metal cutting; common defects and the physics behind them.

**ES\* ZC333 Introduction to Transport Phenomena 3**

Introduction and basic concepts in fluid mechanics; fluid statics and fluid kinematics; dimensional analysis; mass, momentum and energy balance; internal flows, external flow, pressure losses and flow devices; basics of heat transfer: conduction, convection and radiation; convective heat transfer coefficients radiation view factor; and heat transfer equipment. Introduction to mass transfer; molecular diffusion; mass transfer coefficient.

**ES\* ZC334 Numerical & Computational Methods 3**

Numerical solution of differential equations including fundamentals: roots of single nonlinear and simultaneous (Matrix) equations, least squares fitting and statistical goodness, interpolation, finite differences, differentiation, integration, eigen solutions. Engineering problem solving using MATLAB; Working with Variables: creating variables, data import from external sources, data entry, scalars, vector and matrix data, vector and matrix arithmetic, plotting and visualization. Lab component: Exercises drawn from

engineering industry, solved using the various tools and methods learnt in the course.

#### **ES\* ZC335 Integrated Engineering Science 3**

This is a cross-disciplinary course, aims to integrate the various engineering science concepts and practices learned in the earlier semesters. The course adopts a problem-based learning approach, wherein industry scale problems from the specialization streams are drawn and discussed with a particular emphasis on the environmental and ethical dimensions.

#### **ES\* ZC336 Contemporary Manufacturing Processes 4**

Manufacturing process, attributes and equipment: Investment & die castings; metal forming and machining. The classroom learning is augmented with virtual labs. Additive manufacturing: The distinctive features; technology; methods; applications. Students will execute team project designing and developing simple products using additive process. Non-traditional manufacturing: Classifications; applications and limitations.

#### **ES\* ZC337 Digital Electronics & Microcontrollers 3**

Introduction to Digital Systems: Combinational circuits: Logic gates; decoders; encoders; Mux/Demux; Sequential Circuits: Latches & Flip-flops; Design of combinational and sequential circuits; Microcontrollers; Controller architecture; Assembly programming; Peripheral devices – Parallel & Serial I/O interfacing.

#### **ES\* ZC338 Digital Manufacturing 4**

Manufacturing, a historic perspective; Internet of Things & associated technologies: Smart sensors and actuators, smart things/ devices, connected factories, cobots, material & information flow; Digital transformation: preparing and aligning organizations for digital transformation and cyber physical production systems; development, characteristics and framework; Case studies and examples of digital factories. Students will gain hands-on experience of various IOT devices and manufacturing systems through remote lab experiments.

#### **ES\* ZC339 Engineering Design and drawing 4**

The course introduces the subject with a real-life illustrative project, deducing the product design process, concept to model to detailed design to manufacturing to disassembly. The course then proceeds in developing simple models using engineering modelling tools. The student will undertake a team project to design and model a simple product or assembly using modelling software.

#### **ES\* ZC340 Introduction to Supply Chain Management 3**

Overview of the supply chain concept, its elements and interactions; integrated view of the supply chain; global supply chains, benefits and challenges; make-buy-outsourcing decisions; forecasting, aggregate planning and scheduling, materials requirement planning, inventory management systems, distribution systems.

#### **ES\* ZC345 Maintenance for productivity and safety 3**

The major industrial disasters, their causes and consequences, learnings from the history, predictive and preventive maintenance practices, statistical measure of equipment uptime, TPM as an integrated approach to maintenance.

#### **ES\* ZC346 Manufacturing Systems Design & Analysis 4**

Historical evolution of manufacturing systems, mass production and its attributes, the need for new production system; Toyota way, how Toyota went about discovering, designing, developing and deploying the Toyota production systems, the challenges; Tool and techniques: JIT, Pull, Kanban, level production, 5S, throughput & takt, SMED, Jidoka. Finally, the course concludes by providing an integrated view of Toyota Production Systems. The concepts are illustrate using simple models.

#### **ES\* ZC347 Quality Control & Metrology 4**

Overview of quality control, quality management and dimensional metrology; Quality control: Statistical basis of sampling & process control; Quality management: Principles & practices including quality system standards; Metrology: Measurement system nomenclature, measurement of distance, form and surface; calibration.

#### **ES\* ZC348 Robotics and Automation 3**

Fundamentals of automation and robotics such as types of automation, history of robotics, robot anatomy, end-effectors and sensors. Application of basic mathematics in the motion analysis and control of robots using forward and inverse kinematics and control theory. Fundamentals and applications of machine vision and artificial intelligence. Programming the robot for performing simple tasks using motion, end-effector and sensor commands. Social issues, future and the applications of robotics.

#### **ES\* ZC229T Project 5**

Apply the knowledge of the foundation in the workplace to design/ improve an existing process or product as a team; demonstrate team working & communication skills, and ethical & environmental concerns in addition to critical thinking abilities; the student's actual day-to-day task involvement would constitute the central thread of the learning process. The evaluation will recognize this aspect by demanding day-to-day engagement and productivity of the student.

#### **ES\* ZC498T Capstone Project 10**

Real life problems encompassing design, analysis, and improvement projects obtained from the workplace/ third party vendors; jointly mentored by the industry experts and faculty; to learn and demonstrate the various skills and competencies gained throughout the program with a particular emphasis on team-working, communication, planning, ethics and environmental concerns. Presentation of the progress and results in appropriate forms; Periodic review of progress of the project.

#### **ES ZC263 Digital Electronics and Microprocessors 4**

Binary logic gates; logic circuits; Boolean algebra and K-map simplification; number systems and codes; arithmetic logic units; flipflops; registers and counters; introduction to microprocessors; architecture; instruction set and programming; memory and I/O interfacing examples of system design.

#### **ES ZC343 Microprocessors & Microcontrollers 3**

Introduction to microprocessors and microcontrollers. Architecture of 8086 microprocessors; Assembly directives, Assembly language programs with algorithms, Memory interfacing and timing diagrams; Architecture of 8-bit microcontrollers; Assembly language programming for microcontrollers; Interfacing I/O devices; System design examples.

#### **ES\* ZG629T Dissertation 20**

A student registered in this course must take a topic in an area of professional interest drawn from the on the job work requirement which is simultaneously of direct relevance to the degree pursued by the student as well as to the employing / collaborating organization of the student and submit a comprehensive report at the end of the semester working under the overall supervision and guidance of a professional expert who will be deemed as the supervisor for evaluation of all components of the dissertation. Normally the Mentor of the student would be the Dissertation supervisor and in case Mentor is not approved as the supervisor, Mentor may play the role of additional supervisor. The final grades for dissertation are Non-letter grades namely Excellent, Good, Fair and Poor, which do not go into CGPA computation.

#### **ES\* ZC424 Software for Embedded Systems 3**

Real-time and Embedded Systems; Software issues in Embedded Systems; Software Development Process; Requirements Analysis– Use Cases, Identification and Analysis of use cases, Use Case Diagrams. Design – Architectural Design, Design Patterns, Detailed Design. Implementation – Languages, Compilers, Runtime Environments and Operating Systems for embedded software. Testing – Methodologies, Test Cases.

#### **ES\* ZC441 Robotics 3**

The objective of this course is to make the students familiar with Robotics, the main components of kinematics, sensors, transmission and drives, control systems, intelligence and vision, geometric modelling and reasoning, assembly planning, grasping, collision avoidance, mobile robots, force strategies, uncertainty analysis, and representation of visual world.

#### **ES\* ZC446 Data Storage Technologies & Networks 3**

Storage Media and Technologies – Magnetic, Optical and Semiconductor media, techniques for read/write operations, issues and limitations. Usage and Access – Positioning in the memory hierarchy, Hardware and Software Design for access, Performance issues. Large Storages – Hard Disks, Networked Attached Storage, Scalability issues, Networking issues. Storage Architecture. - Storage Partitioning, Storage System Design, Caching, Legacy Systems. Storage Area Networks – Hardware and Software Components, Storage Clusters/Grids. Storage QoS – Performance, Reliability, and Security issues.

#### **ES\* ZC481 Computer Networks 3**

Introduction, history and development of computer networks; Reference models; Physical Layer: theoretical basis, transmission media, types of transmission; MAC sub-layer: local area networks, FDDI; Data Link Layer: Sliding Window protocols, design aspects; Network Layer: routing algorithms, congestion control algorithms, internetworking; Transport Layer: Integrated Services Digital Network (ISDN), Asynchronous Transfer Mode (ATM) - reference models, service classes, switch design, LAN emulation; Application Layer protocols.

#### **ES\* ZG511 Mechatronics 5**

Concepts of measurement of electrical and non-electrical parameters; displacement, force, pressure etc. and related signal conditioning techniques, drives and actuators, concepts of microprocessors/ microcontrollers architecture and programming, memory and I/O interfacing. System design concepts through case studies.

#### **ES\* ZG512 Embedded System Design 4**

Introduction to embedded systems; embedded architectures: Architectures and programming of microcontrollers and DSPs. Embedded applications and technologies; power issues in system design; introduction to software and hardware co-design.

#### **ES\* ZG513 Network Security 4**

This course examines issues related to network and information security. Topics include security concepts, security attacks and risks, security architectures, security policy management, security mechanisms, cryptography algorithms, security standards, security system interoperability and case studies of the current major security systems.

#### **ES\* ZG514 Mechanisms & Robotics 5**

Classification of robots & manipulators; fields of application; synthesis of planar & spatial mechanisms; methods of function & path generation; coupler curve synthesis; linkages with open loop; actuators & drive elements; microprocessor application and control of robots.

#### **ES\* ZG520 Wireless & Mobile Communication 5**

Signal propagation in a mobile environment, modulation, coding, equalization; first generation generation systems; multiple access techniques like FDMA, TDMA, CDMA, spread spectrum systems; second & third generation systems, UMTS, IMT-2000; Wireless LAN, Wireless ATM and Mobile IP; emerging trends in Wireless & Mobile Communication.

#### **ES\* ZG523 Project Management 4**

Concepts and techniques of project formulation, evaluation and implementation; Project planning and scheduling; Risk management; Time-cost trade off; Resource leveling and

allocation; Project monitoring and control; Contract management.

#### **ES\* ZG524 Real Time Operating Systems 5**

Introduction to real-time systems, clock synchronization task assignment and scheduling, programming language with real-time support, ADA, real-time communication protocols, real-time database, fault tolerant techniques, reliability evaluation methods; case studies in real-time operating systems, simulation of real-time systems, embedded system programming.

#### **ES\* ZG525 Avionics Systems 5**

Civil avionics systems, fly-by-wire technology, flight control systems, engine control systems, fuel systems, hydraulic systems, electrical systems, pneumatic systems, environmental control systems, navigational systems, emergency systems, rotary wing systems, advanced systems, system design and development, avionics technology, environmental conditions, flight management systems, vehicle health management systems, communication protocols, hardware certification process, software certification process, certification considerations for highly integrated / complex aircraft systems.

#### **ES\* ZG526 Advanced Computer Networks 5**

Topics in advanced networking – Quality of Service in IP networks, IPv6, Wireless and Mobile Networks, Carrier Technologies (Frame Relay, FDDI, ISDN, ATM), Peer-to-Peer Networks and Overlays, Routing and QoS Issues in Optical Networks.

#### **ES\* ZG531 Pervasive Computing 4**

Select application architectures; hardware aspects; human-machine interfacing; device technology: hardware, operating system issues; software aspects, java; device connectivity issues and protocols; security issues; device management issues and mechanisms; role of web; wap devices and architectures; voice-enabling techniques; PDAs and their operating systems; web application architectures; architectural issues and choices; smart card-based authentication mechanisms; applications; issues and mechanisms in WAP-enabling; access architectures; wearable computing architectures.

#### **ES\* ZG532 Testability for VLSI 5**

BIST, boundary scan, stuck-at faults, test generation algorithms for combinatorial logic circuits and sequential circuits, logic simulation and fault simulation, synthesis for test, built in self-test, pseudo-random test techniques, other test methods - IDDQ testing, boundary scan etc.

#### **ES\* ZG545 Control & Instrumentation for Systems 5**

The regulation and control problem with reference to power electronic converters. Converter models for feedback: basic converter dynamics, fast switching, piece-wise linear models, discrete-time models. Voltage mode and current mode controls for DC-DC converters, comparator based control for rectifier systems, proportional and proportional-integral control applications. Control design based on linearisation: transfer functions, compensation and filtering, compensated feedback control systems. Hysteresis control basics, and application to DC-DC converters and inverters. General boundary control: behaviour near a boundary, and choice of suitable boundaries. Basic ideas of fuzzy control techniques, and performance issues. Sensors for power electronic circuits, speed and torque transducers.

**ES\* ZG553 Real Time Systems****5**

Real time software, Real time operating systems-scheduling, virtual memory issues and file systems, real time data bases, fault tolerance and exception handling techniques, reliability evaluation, data structures and algorithms for real time/embedded systems, programming languages, compilers and run time environment for real time/embedded systems, real time system design, real time communication and security, real time constraints and multi-processing and distributed systems.

**ES\* ZG554 Reconfigurable Computing****5**

Overview of Programmable Logics. FPGA fabric architectures. Logic Elements and Switch Networks. Design and Synthesis of Combinational and Sequential Elements. Placement and Routing. Pipelining and other Design Methodologies. Fine-grained and Coarse-Grained FPGAs. Static and Dynamic Reconfiguration. Partitioning. Hardware/Software Portioning and Partial Evaluation; Systolic Architectures.

**ES\* ZG556 DSP Based Control of Electric Drives****3**

State space and transfer matrix representations, representation of nonlinear systems by update of parameters, output feedback and state feedback control, basic notion of state estimation. Sampling of signals, discrete representation of signals, z-transforms. Nature of discrete time poles and zeros. A/D and D/A converters as system elements. FIR and IIR behaviour, noise and its nature. AR, MA, and ARMA models of systems. The Fourier transform and what it conveys. Processing requirements of a DSP, floating point DSP's: the TMS320C3x family. Memory organization, interrupt systems, and I/O interface with the TMS320C3x family. The TMS320C31 as an embedded controller, drive control features. Applications in vector and direct torque control of synchronous motors, vector and direct torque control of induction motors, torque control of SRM's.

**ES\* ZG571 Optical Communication****5**

Optical communication systems and components; optical sources and transmitters (basic concept, design and applications); modulators (electro-optic, acousto-optic and laser modulation techniques; beam forming; focusing and coupling schemes to optical repeaters; optical amplifiers; optical field reception; coherent and non-coherent lightwave systems; fibre optic communication system design and performance; multichannel lightwave systems; long haul communications; fibre optic networks.

**ES\* ZG573 Digital Signal Processing****3**

Introduction; design of analog filters; design of digital filters: (IIR and FIR); structures for the realization of digital filters; random signals and random processes; linear estimation and prediction; Wiener filters; DSP processor architecture; DSP algorithms for different applications.

**ES\* ZG611 Advanced Control Systems****5**

Review of State variable modelling of linear continuous, linear discrete and nonlinear control systems; Time varying systems; Time domain solution; Controllability and observability; Stability; direct method of Lyapunov; Modal control; Optimal Control System; Calculus of variation, Minimum principle, dynamic programming, search techniques, Ricatti equation, Stochastic processes and Stochastic estimation and control; Adaptive Control system.

**ES\* ZG612 Fault Tolerant System Design****5**

Principles of fault tolerant systems, redundancy, parallel and shared resources, spatial systems, configurations, design aspects etc.

**ES\* ZG613 Advanced Digital Signal Processing****5**

Review of stochastic processes, models and model classification, the identification problem, some field of applications, classical methods of identification of impulse response and transfer function models, model learning

techniques, linear least square estimator, minimum variance algorithm, stochastic approximation method and maximum likelihood method, simultaneous state and parameter estimation of extended kalman-filter, non-linear identification, quasi linearization, numerical identification methods.

**ES\* ZG621 VLSI Design****5**

Introduction to NMOS and CMOS circuits; NMOS and CMOS processing technology; CMOS circuits and logic design; circuit characterization and performance estimation; Structured design and testing; Symbolic layout systems; CMOS subsystem design; System case studies.

**ES\* ZG625 Safety Critical Embedded System Design****4**

Architecture / Design practices for Safety critical systems; DO178B standards. Methodology of Certification and Qualification for DO178B, Modelling real time systems (UML-RT, and the tools), Reliable, common system bus – VME, ASCB, SafeBus, MultiBus II etc. Safety critical system busses & protocols, ARINC 429, 629, Mil-1553B & 1773, Ethernet based switched network for safety critical applications, Real time and safety standard and certifications, Reliability Maintainability & Safety of Embedded Systems. FPGA and ASIC based design, Low-Power Techniques in RT Embedded Systems On-chip networking. Hardware Software partitioning and scheduling, Co-simulation, synthesis and verifications, Architecture mapping, HW-SW Interfaces and Re-configurable computing.

**ES\* ZG641 Hardware Software Co-Design****4**

FPGA and ASIC based design, Low-Power Techniques in RT Embedded Systems On-chip networking. Hardware Software partitioning and scheduling, Co-simulation, synthesis and verifications, Architecture mapping, HW-SW Interfaces and Re-configurable computing.

**ES\* ZG642 VLSI Architecture****4**

Overview of CISC processor architectures; Instruction set architecture of CISC processor; hardware flow-charting methods; implementing microprocessor logic from hardware flowcharts; RISC instruction set architecture; pipelined execution of RISC instructions; pipeline execution unit design; control hazards; design of memory hierarchy.

**ES\* ZG651 Networked Embedded Applications****4**

Networked embedded systems, Clock synchronization, Protocol mechanisms protocol performance, CAN Bus architecture, USB Architecture, Embedded Internet, distributed computing, Use of Java in building networked systems, Reliability & Fault Tolerance etc. Mission-critical distributed real-time applications, e.g., military, air traffic control; Prototyping benchmark applications, e.g. simulated air traffic visualization, radar display; Networking: TCP/IP, distributed objects; Embedded system programming and middleware: I/O, analog / digital conversion, DSP, runtime monitoring of CPU, processes, network equipment; Modeling distributed real-time systems; Quality of service maintenance.

**ET ZC234 Manufacturing Processes****4**

Fundamentals of casting process; forging; powder metallurgy; soldering; brazing and welding technology; metal forming process, its analysis and design; Introduction to Metal cutting, machine tools; mechanics of metal cutting; other machining processes; grinding and finishing operations; non convention machining; chipless machining processes; NC machines programming; control system in CNC; CNC, DNC; FMS and machining center.

**ET ZC323 Mechatronics and Automation****4**

Introduction to mechatronics, sensors and transducers, pneumatic and hydraulic actuation systems, mechanical actuation systems, electrical actuation systems, digital logic, microprocessors and programmable logic controllers; Introduction to automation, features of numerical control machine tools, numerical control part programming, control loops for numerical control systems,



computerized numerical control, adaptive control systems, industrial robots, automatic identification and data capture, automated production lines and automated assembly systems.

#### **ET ZC341 Instrumentation & Control 3**

Measurement systems, transducers, feedback control, components: electrical, hydraulic, pneumatic; Signal conditioning and processing, controllers, display, recording, direct digital control, programmable logic controllers, PC based instrumentation.

#### **ET ZC342 Materials Management 4**

Integrated materials management, policy aspects, purchasing management, warehousing and storage of inventory control systems; appraisal and control; just in time (JIT); automation in materials management.

#### **ET ZC344 Instrumentation & Control 4**

Generalized measurement system and performance characteristics, Transducers - principles and applications, Signal conditioning circuits – bridges, amplifiers, data converters, filters; Process control – control schemes, controllers, multi-loop control configuration, Control valves; Programmable Logic Controllers, DCS and SCADA, Simulation, Case Studies.

#### **ET ZC352 Energy Management 4**

Energy management principles; energy conservation; energy auditing; analysis; formulation of energy management options; economic evaluation, implementation & control; energy conservation techniques – conservation in energy intensive industries; steam generation, distribution systems, and electrical systems; integrated resource planning; demand-side management; cogeneration; total energy schemes; thermal insulation; energy storage; economic evaluation of conservation technologies; analysis of typical applications.

#### **ET ZC362 Environmental Pollution Control 3**

Air and water pollutants; sampling and analysis; control methods for air & water pollutants; modeling of different control techniques; advanced wastewater treatment processes; solid waste management, noise pollution; case studies.

#### **ET ZC348 ADDITIVE MANUFACTURING 4**

Introduction to Additive Manufacturing, CAD for Additive Manufacturing; Material Science Aspects in Additive Manufacturing, Different materials used in AM, Use of multiple materials, multifunctional and graded materials in AM, Role of solidification rate; Various Additive Manufacturing Processes Powder-based AM processes involving sintering and melting, Printing processes (droplet based 3D printing), Fused deposition modelling (FDM), Laminated object manufacturing, Stereolithography, Micro and nanoadditive manufacturing processes; Modelling in Additive Manufacturing Transport phenomena models: temperature and fluid flow, molten pool formation, Various case studies modelling of fusion based AM process, powder bed melting based process, droplet based printing process; Applications of Additive Manufacturing in Aerospace, Automotive, Electronics industries and Biomedical applications

#### **ET ZC349 IoT in MANUFACTURING 4**

Safe work practices and workplace safety, Industrial revolution 4.0, Forces behind Industry 4.0 (IoT, big data and cloud computing, robotics and artificial intelligence), Connected factories (what is connected factory and criteria for connected factory), Smart devices and smart products, cyberphysical system, definition; cps in manufacturing, Connecting devices with each other and with internet, Data acquiring and collection, Communication technologies (WIFI, IEEE 802.15.4), RFID, QR codes and cellular technologies, Protocols, Hardware in IoT, Software (IDE), Cloud platform,

Smart devices and control system, Connectivity and networking in IoT, Smart eyes on shop floor, Integrating smart into existing, Programming using IoT, Case study and implementation.

#### **ET ZC412 Production Planning & Control 4**

Generalized model of production systems; types of production flows; life cycle concepts; facilities location and layout planning; aggregate and batch production planning; inventory systems; materials requirements planning; elements of monitoring & production control.

#### **ET ZC413 Engineering Design 4**

The Engineering Design Process, Current Practices in Engineering Design, Establishing Need, Design Proposal, Formulating the Problem, Structuring the Search for a Solution: Design Goals and Specifications; Applying and Protecting Technical Knowledge, Abstraction and Modeling, Synthesis in Engineering Design, Ethics and Product Liability Issues, Hazard Analysis and Failure Analysis, Design Analysis - Alternative Designs, Prioritizing the Design Goals, Decision Matrix and Economic Analysis, Implementation - Transforming a Design Concept into Reality, Materials Selection in Design, Common Fabrication Materials, Materials Testing, Manufacturing Processes, Communicating the Design, Case Studies.

#### **ET ZC414 Project Appraisal 3**

Overview of project and project phases; project formulation aspects in terms of market studies, technical studies, financial studies, economic studies, environmental studies, etc.; project evaluation aspects in terms of commercial profitability prospects, national economic profitability prospects; issues of project preparation in project implementation.

#### **ET ZC415 Manufacturing Excellence 4**

Introduction, frameworks of manufacturing excellence, practices for manufacturing excellence: leadership and change management, manufacturing strategy, innovative product planning, total productive maintenance, total quality management, lean manufacturing, customer relations management, green manufacturing, supply chain management, knowledge management and social responsibility.

#### **ET ZC423 Essentials of Project Management 3**

Programmes project management, project manager: role and responsibilities, project management and organization, project planning and scheduling, graphical techniques and PERT, CPM, price estimation and cost control; proposal, control valuation monitoring and trade off analysis in a project environment, pitfalls and future scenario.

#### **ET ZC426 Plant Layout & Design 4**

Factors affecting plant layout, Types of layout, procedure for plant layout, techniques and tools for planning layout, quantitative layout analysis, material handling equipment, improving and revising existing layout, evaluation of layout, plant location, evaluation of location, design of layout, computer applications in layout design.

#### **ET ZC434 Quality Control, Assurance & Reliability 3**

Basic concepts of probability and probability distributions, standard probability distribution, sampling and sampling distributions, confidence intervals, testing significance, statistical tolerance, various types of control charts, statistical process control techniques, value analysis, defect diagnosis and prevention, basic concepts of reliability, reliability design evaluation and control, methods of applying total quality management, production process.

#### **ET ZC442 Advanced Driver Assistance Systems 4**

Automotive safety systems, assist and autonomous systems, automotive sensors and actuators for ADAS (stereo and mono cameras ultrasonic sensors, LIDAR, RADAR),

fundamentals of machine vision, data fusion for ADAS, mechatronics for ADAS, human – machine interface for ADAS, telematics and infotainment, ADAS system, legal and ethical aspects of ADAS, real time systems and development, advanced driver assistance systems, advanced computer systems, automated driving applications and systems.

#### **ET ZC443 Connected Cars 4**

Fundamentals of IOT - Architecture, Sensors, Cloud and the trade-off between polling and storage requirements, Structure and implementation of CAN networks, CAN message, priority & arbitration and the control hardware involved in the network, data analytics by creating a simple data model using OBD tools, ethical and legal aspects of connected car applications including data theft, privacy and security vulnerabilities, building of predictive analytic model based on in-vehicle data.

#### **FIN ZC415 Financial and Management Accounting 4**

Basic concepts, double entry accounting, journal, ledger, trial balance, profit & loss account, balance sheet, cash flow statement, financial statement analysis, ratio analysis, cost-volume-profit analysis, inventory valuation, inflation accounting, cost accounting and budgetary control systems, financial analysis and forecasting.

#### **FIN ZG512 Global Financial Markets and Products 4**

Capital markets; stock markets, bond markets, derivative markets; operations of these markets from a global perspective; Overview and features of key financial products, equities, fixed income securities and derivatives; bond features, indenture, coupon, maturity, YTM, zero coupon, valuation, duration, convexity; Equities, product features, basic valuation concepts; derivatives, forwards, futures, options, swaps, commodity derivatives, cost of carry, concepts, basic features, payoff, put call parity, basic option strategies; relevant case studies, simulations, modeling.

#### **FIN ZG513 Management of Banks & Financial Institutions 4**

Overview and operation of financial institutions and banks; Commercial banking, Investment banking; Define, quantify, and manage various types of risks faced by financial institutions; asset liability management - overview, strategies; off balance sheet activities of banks; sovereign risk; deposit insurance; capital adequacy; study current best practices using selected case studies; bank management failures; insights from collapse of Lehman Brothers; introduction to bank regulation; international considerations; relevant case studies, simulations, modeling.

#### **FIN ZG514 Derivatives and Risk Management4**

Overview of Financial Markets. Introduction to derivatives. Definition of future, forward, option and swap. Difference between various players of derivative market, their motives and types of position they can hold. Mechanics of future, option & swap markets. Hedging strategies. Option Pricing and understanding of various factors affecting option price. Calculations of Greeks. Introduction to interest rates, yield, term structure and forward rates. Mechanics of Bond Market. Review of concept of compounding and time value of money. Difference between floating rate and fixed income bonds. Price quotes and accrued interest. Pricing of Bonds. Computation of yield. Bond Price volatility. Duration, Modified Duration and convexity. Factors affecting Bond Yields and the Term Structure. Concept of Risk. Perspective of Risk from view point of individuals, companies & financial institutions. Commercial Banks and risks faced by them. Different types of Insurance and risk faced insurance companies. Introduction to various risks: Market Risk, Credit Risk, Operational Risk, Liquidity risk & Model Risk. Concept of Value at Risk.

#### **FIN ZG518 Multinational Finance 4**

Effective financial decision making in a multinational corporation; issues in global financial management, international monetary system, balance of payments, foreign

exchange markets, international parity conditions, foreign currency options, transaction exposure, operating exposure, translation exposure, sourcing capital globally, foreign investment decisions, basics of multinational taxation, transfer pricing, principles of multinational capital budgeting, and managing multinational operations . Extensive use of case studies and simulations to connect theory with practice.

#### **FIN ZG519 Business Analysis and Valuation 4**

Theory of finance, value maximization, stakeholder theory, and corporate objective function: value creation – ways and means, business analysis: The techniques of strategy and competitive analysis, value chain analysis for competitive advantages, business valuation – approaches and methods, the dark side of valuation: strategic investment decisions.

#### **FIN ZG520 Security Analysis and Portfolio Management 4**

Introduction to investment and securities; profile of financial assets; new issue market or primary market, initial public offerings (IPO); secondary market; framework of risk & return; fundamental analysis- economy, industry; company analysis; stock evaluation models; multiple holding period and multiple growth rate; bond analysis and bond management strategies; technical analysis; efficient market theory; portfolio management; Markowitz model; Sharpe's Single Index model; capital asset pricing model; financial derivatives, options & futures.

#### **FIN ZG521 Financial Management 4**

Concepts and techniques of financial management decision; concepts in valuation – time value of money; valuation of a firm's stock, capital asset pricing model; investment in assets and required returns; risk analysis; financing and dividend policies, capital structure decision; working capital management, management of cash, management of accounts receivable; inventory management, short and intermediate term financing, long term financial tools of financial analysis, financial ratio analysis, funds analysis and financial forecasting, operating and financial leverages.

#### **FIN ZG522 Mergers, Acquisitions, and Corporate Restructuring 4**

Basics of M&A (corporate finance, strategy, economics), merger types, trends; theories underlying M&A; legal aspects; evaluating an acquisition target; valuation of mergers and acquisitions, MVA, relative valuation, multiples, DCF, FCFF, FCFE; M&A deal structuring; synergy analysis; break-up valuation; sensitivity analysis; terms of merger; financing considerations; capital structure decisions; structuring and valuing of Leveraged Buy-out (LBO) transaction; financing considerations; exit strategies; extensive use of relevant case studies, simulations, modeling.

#### **FIN ZG523 Market Risk Management 4**

Market risk measurement and management in foreign exchange markets, debt markets, equity markets, commodities markets; application of Value-at-Risk (VaR) to market risk management, VaR methods, VaR mapping, stress testing, multi factor VaR, limitations of VaR, alternative metrics to VaR, expected shortfall; market risk in bank trading strategies; market risk management in fixed income securities, duration, convexity, advanced term structure models, mortgage backed securities, pre-payment risk, burnout, modeling pre-payment risk; volatility smiles, exotic options; measuring and managing corporate risk, cash flow exposures; extensive use of relevant case studies, simulations, modeling.

#### **FIN ZG524 Credit Risk Management 4**

Default, charge-off, bankruptcy; loan restructuring, loan moratorium; counterparty credit risk, measurement, management; credit risk modeling, quantitative models, Probability of Default, Exposure at Default, Loss Given Default, Expected and Unexpected losses; qualitative framework, five Cs of credit; application of Value-at-Risk

(VaR) to credit risk management, i.e. Credit VaR, default risk measurement and management in Fixed Income securities, and securitization; extensive use of relevant case studies, simulations, modeling.

#### **FIN ZG525 Operational Risk Management 4**

Topics covered include: operational risk measurement, management framework; internal loss data, external loss data; key risk indicators; scenario analysis, stress testing; risk appetite; reputational risk and operational risk; application of value-at-risk (VaR) to operational risk management; liquidity risk, definition, measurement and management; liquidity adjusted VaR; liquidity and leverage; legal risk, compliance risk; fraud risk (internal and external); model risk; enterprise risk management; extensive use of relevant case studies, simulations, modeling.

#### **FIN ZG526 Advanced Risk Models 4**

Advanced VaR models, expected shortfall, stressed VaR, historical simulation, delta/ gamma models, full revaluation, risk factor selection, volatility clustering, structured Monte Carlo analysis, stress testing, scenario analysis, back testing; country and sovereign risk models; management of country and sovereign risks, external and internal credit ratings methodology and framework; expected and unexpected loss framework and related metrics; extensive use of relevant case studies, simulations, modeling.

#### **FIN ZG527 International Regulatory Framework for Banks 4**

Three pillars of the Basel II framework; key elements of risk management in banks; various methodologies used to calculate capital and provision requirements under Basel III framework, capital conservation buffer, counter cyclical capital buffer; liquidity coverage ratio, NSFR, leverage ratio; implications for the management of credit risk, market risk and operational risk; basic approach, standardized approach, advanced approach, etc.; extensive use of relevant case studies relating to bank failures and 2008 financial crisis.

#### **FIN ZG528 Venture Capital & Private Equity 4**

This course will lay a strong foundation in core concepts, features and characteristics of the venture capital and private equity markets; specialized services provided by VC's and PE funds; stages in VC investing; deal flow; deal sourcing, evaluation; risk return tradeoff of VC/ PE investments; valuation of VC/ PE transactions; structuring and execution of deals; exit options, distributions; Course will make extensive use of case studies to understand industry best practices and current trends.

#### **HHSM ZG513 Biostatistics & Epidemiology 4**

Methods of collection and presentation of statistical data; calculation and interpretation of various measures like mean, median, mode, standard deviation, kurtosis, correlation coefficient; probability distributions; sampling and estimation of parameters; tests of hypothesis; data analysis. Introduction to the principles and methods of epidemiology. Epidemiology of some illustrative infectious diseases (of bacterial, rickettsial and viral origins), sexually transmitted diseases, chronic diseases such as cancer, cardiovascular diseases, neurological disorders etc. Use of biostatistics in epidemiology.

#### **HHSM ZG516 Epidemic & Disaster Management 4**

Disaster management; impact and response; relief phase; disaster mitigation in health sector; disaster preparedness; policy development; man-made disasters; international agencies providing health based humanitarian assistance; and strategies for disaster management.

#### **HHSM ZG517 Health Care Management 4**

Basis of organizational culture and management techniques for efficient administration of health delivery; general principles of HR, materials and operation management; understanding the organizational culture that exists in public, private and non-Govt. sector agencies; management information system.

#### **HHSM ZG614 Hospital Operations Management 4**

Operations Management aspects connected with outpatient ward, casualty, operation theatres, diagnostic laboratories, pathology laboratories, pharmacy, diet and nutrition, blood bank, laundry, medical records, security, scheduling and deployment of doctors, nurses and other staff, accounts among others; Equipment planning and management, Materials management, Management of human resources in hospitals, Hospital Management Information Systems, Licensing and legal compliance, Quality and accreditation of hospitals and healthcare organizations. The course will involve onsite visits in a hospital, discussions and presentations on the practical aspects of hospital operations management.

#### **HHSM ZG615 Service Quality Excellence in Healthcare 4**

Quality in healthcare, Leadership for Quality, Customer satisfaction in healthcare, Continual improvement, cost of quality, Benchmarking, Performance measures, Statistical process control, Experimental design, Quality tools, Lean tools applied in healthcare, Case study in healthcare.

#### **HHSM ZG617 Strategic Management of Healthcare Organizations 4**

Strategic management function within contemporary health services organization with focus on organizational strategic planning processes including principles and methods of strategic assessment, strategy formulation, evaluation, implementation, and control, Case studies in healthcare systems.

#### **HHSM ZG631 Introduction to Health Systems & Environmental Health 4**

Introduction to health systems; functions of health systems; managing health systems; problems of health systems management; Major environmental health problems including quality of water, waste disposal food production and processing, vector control etc. Air pollution and its controlling, Hazards of radiation, municipal and other wastes, Occupational health hazards.

#### **IS ZC313 Object Oriented Programming & Design 4**

Object oriented concepts and design, abstraction, architecture and design patterns, GUI programming and frameworks, design of object oriented solutions using UML, design for concurrency, implementation of solutions using object oriented languages like C++ or Java; Language level mapping and realization of object oriented constructs, realization and performance issues versus abstraction and usability.

#### **IS ZC314 Software Development for Portable Devices 3**

Introduction to mobile computing and emerging mobile application and hardware platforms; Developing and accessing mobile applications; Software lifecycle for mobile application – design and architecture, development – tools, techniques, frameworks, deployment; Human factors and emerging human computer interfaces (tangible, immersive, attentive, gesture, zero-input); Select application domains such as pervasive health care, m-Health; Mobile web browsing, gaming and social networking.

**IS ZC323 Systems Programming 3**

Batch processing Systems programs; operating characteristics and limitations; parallel processing of I/O and interrupt handling, multiprogramming; multiprocessing systems; design of system modules and interfaces; other selected topics.

**IS ZC327 Systems Programming 4**

Batch processing; Systems programs; operating characteristics and limitations; parallel processing of I/O and interrupt handling, multiprogramming; multiprocessing systems; design of system modules and interfaces with focus on contemporary open source operating system-specific programming; laboratory experiments or programming assignments involving Unix/Linux System-specific Programming including shell-scripting via online laboratory facility.

**IS ZC328 Software Testing 3**

Brief description of importance of software, Life cycle model and process, Basic software testing, all definitions, Types of testing and techniques (CFG, CDG etc.), Black Box & white box Testing Methodologies, Finite State Machine Model, State based Testing, Static Testing and analysis, Test cases, Test Data Generation ,Test selection ,Minimizations and Prioritization, Test adequacy criteria, Software Testing on Web Engineering, Object based Software Testing, Architecture of Testing tool, Software Test Effort Estimation, Testing behavior and process model, Qualitative analysis, Quality factors in software testing, Selection of testing tools.

**IS ZC332 Database System & Application 3**

Introduction to Database Management Systems; File organization; Data Independence in databases; Data Models; Query processing systems; Database Design techniques; Concepts of security and integrity in databases; Distributed Databases; Applications using DBMS.

**IS ZC337 Database Systems & Applications 4**

Introduction to Database Management Systems; File organization; Data Independence in databases; Data Models; Query processing systems; Database Design techniques; Concepts of security and integrity in databases; Distributed Databases; Applications using DBMS, database programming experiments involving use of SQL, database creation etc. via online laboratory facility.

**IS ZC343 Software Engineering 4**

Software engineering concepts and methodology; formal requirements specification; estimation; software project planning; detailed design; techniques of design; productivity; documentation; programming languages styles, code review; tool, integration and validation; software quality assurance; software maintenance; metrics, automated tools in software engineering.

**IS ZC353 Computer Organization & Architecture 4**

Overview of logic design; Instruction set architecture; Assembly language programming; Pipelining; Computer Arithmetic; Control unit; Memory hierarchy; Virtual memory; Input and output systems; Interrupts and exception handling; Implementation issues; Case studies; This course covers the fundamentals of computer organization and architecture from a programmer's perspective.

**IS ZC362 Operating Systems 3**

Introduction to operating systems; Various approaches to design of operating systems; Overview of hardware support for operating systems; Process management: process synchronization and mutual exclusion, interprocess communication, process scheduling; CPU scheduling approaches; Memory management: paging, segmentation, virtual memory, page replacement algorithms; File systems: design and implementation of file systems; input/output systems; device controllers and device drivers; Security and

protection; Case studies on design and implementation of operating system modules.

**IS ZC363 Data Structures & Algorithms 4**

Introduction to software design principles, modularity, abstract data types, data structures and algorithms; Analysis of algorithms; Linear data structures – stacks, arrays, lists, queues and linked representations; Pre-fix, in-fix and post-fix expressions; Recursion; Set operations; Hashing and hash functions; Binary and other trees, traversal algorithms, Huffman codes; Search trees, priority queues, heaps and balanced trees; Sorting techniques; Graphs and digraphs; Algorithmic design techniques; Data structures for external storage, multi-way search and B-trees; Implementation techniques for different data structures including trees, graphs and search structures; Performance evaluation of data structures and algorithms; Implementation issues in large data structures.

**IS ZC364 Operating Systems 4**

Introduction to operating systems; Various approaches to design of operating systems; Overview of hardware support for operating systems; Process management: process synchronization and mutual exclusion, interprocess communication, process scheduling; CPU scheduling approaches; Memory management: paging, segmentation, virtual memory, page replacement algorithms; File systems: design and implementation of file systems; input/output systems; device controllers and device drivers; Security and protection; Case studies on design and implementation of operating system modules, select laboratory experiments related to creating different elements of operating system and/or implementation of select scheduling, memory management and I/O related algorithms/schemes, using system calls for creating file system specific command, creating simple file system etc. via online laboratory facility.

**IS ZC365 Human Computer Interaction 3**

Principles of human-computer interaction; Evaluation of user interfaces; Usability engineering; Task analysis, user-centered design, and prototyping; Conceptual models and metaphors; Software design rationale; Design of windows, menus, and commands. Voice and natural language I/O; Response time and feedback; Color, icons, and sound; Internationalization and localization; User interface architectures and APIs.

**IS ZC373 Compiler Design 4**

Introduction to Programming Languages and Compilers, Programming Language Features, Front End of a Compiler, Back End of a Compiler, Special aspects of compilers and runtime.

**IS ZC415 Data Mining 3**

Data Mining – introduction, fundamental concepts; motivation and applications; role of data warehousing in data mining; challenges and issues in data mining; Knowledge Discovery in Databases (KDD); role of data mining in KDD; algorithms for data mining; tasks like decision-tree construction, finding association rules, sequencing, classification, and clustering; applications of neural networks and machine learning for tasks of classification and clustering.

**IS ZC422 Parallel Computing 3**

Introduction to parallel computing; Models of parallel computers; Interconnection networks, basic communication operations; Introduction to parallel algorithms; Parallel programming paradigms; issues in implementing algorithms on parallel computers; Parallel programming with message passing interface; Performance analysis; Scalability analysis; Basic design techniques for parallel algorithms; Parallel algorithms for selected topics like sorting, searching and merging, matrix algebra, graphs, discrete optimization problems and computational geometry.

**IS ZC423 Software Development for Portable Devices 3**

Introduction to mobile computing and emerging mobile application and hardware platforms; Developing and accessing mobile applications; Software lifecycle for mobile application – design and architecture, development – tools, techniques, frameworks, deployment; Human factors and emerging human computer interfaces (tangible, immersive, attentive, gesture, zero-input); Select application domains such as pervasive health care, m-Health; Mobile web browsing, gaming and social networking.

#### **IS ZC424 Software for Embedded Systems 3**

Real-time and Embedded Systems; Software issues in Embedded Systems; Software Development Process; Requirements Analysis– Use Cases, Identification and Analysis of use cases, Use Case Diagrams. Design – Architectural Design, Design Patterns, Detailed Design. Implementation – Languages, Compilers, Runtime Environments and Operating Systems for embedded software. Testing – Methodologies, Test Cases.

#### **IS ZC425 Data Mining 3**

Data Mining – introduction, fundamental concepts; motivation and applications; role of data warehousing in data mining; challenges and issues in data mining; Knowledge Discovery in Databases (KDD); role of data mining in KDD; algorithms for data mining; tasks like decision-tree construction, finding association rules, sequencing, classification, and clustering; applications of neural networks and machine learning for tasks of classification and clustering.

#### **IS ZC444 Artificial Intelligence 3**

The object of this course is to give an introduction to the problems and techniques of A.I. along with the applications of A.I. techniques to the fields like natural language understanding, image processing, game theory and problem solving. The course also aims at understanding its implementation using LISP and PROLOG languages.

#### **IS ZC446 Data Storage Technologies & Networks 3**

Storage Media and Technologies – Magnetic, Optical and Semiconductor media, techniques for read/write operations, issues and limitations. Usage and Access – Positioning in the memory hierarchy, Hardware and Software Design for access, Performance issues. Large Storages – Hard Disks, Networked Attached Storage, Scalability issues, Networking issues. Storage Architecture. - Storage Partitioning, Storage System Design, Caching, Legacy Systems. Storage Area Networks – Hardware and Software Components, Storage Clusters/Grids. Storage QoS – Performance, Reliability, and Security issues.

#### **IS ZC462 Network Programming 3**

Overview of computer networks; inter-process communication; network programming; socket interface; client-server computing model: design issues, concurrency in server and clients; external data representation; remote procedure calls; network file systems; distributed systems design.

#### **IS ZC464 Machine Learning 3**

Neural networks; neuro-computing theory and applications, knowledge representation; computational learning theory; statistical/probabilistic methods, genetic algorithms; inductive/analytic/reinforcement learning and bayesian networks; selected topics such as alpha-beta pruning in game trees, computer models of mathematical reasoning, natural language understanding and philosophical implications.

#### **IS ZC465 Machine Learning 4**

Introduction to Machine Learning, Various kinds of learning, Supervised Learning, Unsupervised Learning, Model Selection; Bayesian Learning, MAP Hypothesis, MDL Principle, Bias Variance Decomposition, Bayes Optimal Classifier, Naive Bayes Classifier; Linear Models for Regression, Linear Models for Classification; Non-Linear models, Decision trees; Instance Based Learning, KNN Algorithm, CBR Learning; Support Vector Machines, VC Dimension; Neural Networks, Perceptron Learning, Back Propagation Algorithm; Introduction to Genetic Algorithms.

#### **IS ZC467 Computer Networks 4**

Introduction, history and development of computer networks; Reference models; Physical Layer: theoretical basis, transmission media, types of transmission; MAC sub-layer: local area networks, FDDI; Data Link Layer: Sliding Window protocols, design aspects; Network Layer: routing algorithms, congestion control algorithms, internetworking; Transport Layer: Integrated Services Digital Network (ISDN), Asynchronous Transfer Mode (ATM) - reference models, service classes, switch design, LAN emulation; Application Layer protocols, Laboratory experiments / assignments related to simulation of network protocols, programming simple network applications, implementing select routing algorithms via online laboratory facility.

#### **IS ZC471 Management Information Systems 3**

Introduction to Information Systems; Concepts of management, concepts of information, systems concepts; Information Systems and Organizations; decision making process; database systems; data communications; planning, designing, developing and implementing information systems; quality assurance and evaluation of information systems; future developments and their organizational and social implications; decision support system and expert systems.

#### **IS ZC472 Computer Graphics 3**

Generation of dots, lines, arcs and polygons; color graphics, shades and levels; image transformation, windowing and clipping; 2-D and 3-D graphics; data structures, algorithms and optimization methods; case studies using GKS, CORE, etc; graphic languages and compilers.

#### **IS ZC481 Computer Networks 3**

Introduction, history and development of computer networks; Reference models; Physical Layer: theoretical basis, transmission media, types of transmission; MAC sub-layer: local area networks, FDDI; Data Link Layer: Sliding Window protocols, design aspects; Network Layer: routing algorithms, congestion control algorithms, internetworking; Transport Layer: Integrated Services Digital Network (ISDN), Asynchronous Transfer Mode (ATM) - reference models, service classes, switch design, LAN emulation; Application Layer protocols.

#### **MATH ZC161 Engineering Mathematics I 3**

Limit concept; derivatives of elementary functions and their applications; introduction to ordinary and partial differential equations and initial/boundary value problems. Convergence tests for series; power series and interval of convergence; series solution of differential equations. Approximation and error, interpolation; roots of algebraic and transcendental functions, Newton's method.

#### **MATH ZC222 Discrete Structure for Computer Science 3**

Sets and relations; graphs and digraphs; trees, lists and their uses; partially ordered sets and lattices; Boolean algebras and Boolean expressions; semigroups and machines; codes and applications.

#### **MATH ZC232 Engineering Mathematics II 3**

Algebra of vectors and matrices; Gauss's row-reduction process; applications of simultaneous linear equations and matrix inversion; determinants and Cramer's rule. Numerical

differentiation and integration; numerical methods for solving ordinary and partial differential equations.

**MATH ZC233 Calculus 4**

Limits, continuity, differentiation, integration, Fourier series, ordinary differential equations for initial and boundary value problems, solution through Laplace transforms, numerical solution using Picard's iteration and higher order methods, partial derivatives, partial differential equations, analytical solution techniques.

**MATH ZC234 Linear Algebra & Optimization3**

Vector and matrix algebra, systems of linear algebraic equations and their solutions; eigenvalues, eigenvectors and diagonalization of matrices; Formulation of linear programming problems, Simplex method, Big-M method, two phase method, Sensitivity analysis, Revised and Dual Simplex Methods.

**MBA ZC411 Marketing 4**

Definition and scope, consumer behavior, competitive behavior, demand estimation, new product introduction, product/brand management, pricing policies, channels of distribution, credit management, advertising and other sales promotion, positioning, marketing regulation, market research basics of industrial marketing.

**MBA\* ZC413Analytics for Competitive Advantage4**

In today's competitive business environment, high performing companies are doing more than just collecting data, storing it and generating reports. They are developing competitive strategies using Business Analytics. In this course we will look at how to use data-driven insights to differentiate a firm's business/ product strategy from other companies that are making the same product or delivering the same service. This course is designed for analysts in any function: marketing, operations, quality, customer service, IT, finance/accounting or human resources. We will use case studies and other experiential components to study the application of data-driven insights in the context of various industries.

**MBA ZC415 Financial and Management Accounting 4**

Basic concepts, double entry accounting, journal, ledger, trial balance, profit & loss account, balance sheet, cash flow statement, financial statement analysis, ratio analysis, cost-volume-profit analysis, inventory valuation, inflation accounting, cost accounting and budgetary control systems, financial analysis and forecasting.

**MBA ZC416 Managerial Economics 4**

Fundamental concepts, supply, demand, market mechanism; theory of demand (consumer behaviour); production, costs (theory of the firm); market structures (perfect competition, monopoly, monopolistic competition, oligopoly); circular flow of income, national income accounting, national income determination; money and banking, employment, interest, inflation, economics of information, problem of adverse selection, moral hazard problem, market failure, externalities, public goods.

**MBA ZC417 Quantitative Methods 4**

Grouping data, measures of central tendency and dispersion, probability distribution, sampling and estimation, testing hypotheses, chi-square and analysis of variance, regression and correlation, non-parametric methods, time series and forecasting, index numbers, decision theory, linear programming, transportation and assignment problems, queuing theory, network problems, simulation; application of statistical software (SYSTAT, SPSS, SIMULA8, etc.) and spreadsheets.

**MBA\* ZC419Financial Risk Analytics 4**

The course will first cover the basics of Financial Risk and then focus on applications such as: currency, interest rate derivatives, equity markets and products, and commodity markets and products. Major topics include methodologies for measuring and analyzing volatility (a key metric of risk) including EWMA, ARCH & GARCH processes, volatility clusters and the issue of time varying volatility; Extreme value theory; Measuring risk using Value-at-Risk, including computation of VaR by various methods, and stress testing; Monte Carlo simulation, address issues in generating price process (such as Brownian Motion, Ito Process), Cholesky decomposition in computing multi-asset VaR; Currency risk analysis in global investing, interest rate parity (covered and uncovered); Value at risk for fixed income portfolios; Credit Risk Analytics. The topics covered in this course will have inbuilt case studies in financial risk management so as to understand the practical implications of the methodologies covered in the course.

**MBA ZG511 Managing People & Organizations 4**

Concepts and principles of management as applied to a variety of organizations; study of managerial roles, styles, activities and decision making; relationship with organizational effectiveness; planning activities, leadership & control; manpower development; organizational behavior and theory.

**MBA\* ZG512Predictive Analytics 4**

Basic concepts in predictive analytics / predictive modeling. Two core paradigms for predictive modeling: classification and regression. Identification of important variables and their relation to each other. Basic modeling techniques such as k-nearest neighbors, classification and regression trees (CART), and Bayesian classifiers. Ensemble techniques. Model selection techniques.

**MBA ZG513 Enterprise Resource Planning 4**

Course description to be developed.

**MBA ZG514 Leadership & Managing Change 4**

Individuals as leaders, team leadership and organizational leadership. Introduction to managing change, management of change: organizational structure, culture, recruitment, performance management, human resource development, reward management, employee relations and involvement, downsizing, and evaluating and promoting.

**MBA ZG515 Consulting & People Skills 4**

Facilitation skills, Communication skills, Presentation and Interviewing skills, Analytical Skills, Creativity, Partnership and networking skills, Critical thinking skills, Emotional Intelligence Development, Stress Management, Ethics and respect for the client, Vision and Framing of issues, Synthesizing Skills, Leadership skills.

**MBA\* ZG516 Introduction to FinTech 4**

Overview of FinTech, Current disruptions in Financial Services, Fintech in the Context of the Digital Economy, Landscape of Fintech, Disruptions in Asset Servicing, Disruptions in the Capital Markets, Disruptions in Investment Management, Alternative Data in Portfolio Management, Lending and Crowdfunding, Robo-Advisory, Overview of Technologies - Big Data, Machine Learning and AI, Cloud Computing, Future of FinTech

**MBA\* ZG517 Financial Analytics 4**

Different sources of Financial Data, Statistical characteristics of financial data, Distributions of Financial Data, Statistical Applications in Finance, Exploratory Data Analysis, Modelling using Financial Statements Data, Modelling stock price behaviour, Modelling Credit Default using classification algorithms, Introduction to Machine Learning for price forecasting and Portfolio Modelling, Introduction to Monte Carlo simulation, Bootstrapping, Cross validation, Sentiment Analysis in Finance

**MBA\* ZG518 Multinational Finance 4**

Effective financial decision making in a multinational corporation; issues in global financial management, international monetary system, balance of payments, foreign exchange markets, international parity conditions, foreign currency options, transaction exposure, operating exposure, translation exposure, sourcing capital globally, foreign investment decisions, basics of multinational taxation, transfer pricing, principles of multinational capital budgeting, and managing multinational operations. Extensive use of case studies and simulations to connect theory with practice.

**MBA ZG519 Business Analysis and Valuation 4**

Theory of finance, value maximization, stakeholder theory, and corporate objective function: value creation – ways and means, business analysis: The techniques of strategy and competitive analysis, value chain analysis for competitive advantages, business valuation – approaches and methods, the dark side of valuation: strategic investment decisions.

**MBA\* ZG520 Security Analysis & Portfolio Management 4**

Introduction to investment and securities; profile of financial assets; new issue market or primary market, initial public offerings (IPO); secondary market; framework of risk & return; fundamental analysis- economy, industry; company analysis; stock evaluation models; multiple holding period and multiple growth rate; bond analysis and bond management strategies; technical analysis; efficient market theory; portfolio management; Markowitz model; Sharpe's Single Index model; capital asset pricing model; financial derivatives, options & futures.

**MBA ZG521 Financial Management 4**

Concepts and techniques of financial management decision; concepts in valuation- time value of money; valuation of a firm's stock, capital asset pricing model; investment in assets and required returns; risk analysis; financing and dividend policies, capital structure decision; working capital management, management of cash, management of accounts receivable; inventory management, short and intermediate term financing, long term financial tools of financial analysis, financial ratio analysis, funds analysis and financial forecasting, operating and financial leverages.

**MBA ZG522 Total Quality Management 4**

TQM principles and practices; leadership; customer satisfaction; employee involvement; continuous process improvement; supplier partnership; performance measures; statistical process control; ISO 9000; benchmarking; quality function deployment; concurrent engineering; experimental design; Taguchi's quality engineering; product liability.

**MBA ZG523 Project Management 4**

Concepts and techniques of project formulation, evaluation and implementation; Project planning and scheduling; Risk management; Time-cost trade off; Resource leveling and allocation; Project monitoring and control; Contract management.

**MBA ZG525 Business Process Analysis 4**

Course description to be developed.

**MBA ZG526 Operations Management 4**

Operations strategy; process view vs. functional view in operations; factors in product and process design and selection; facility configuration; demand planning and forecasting; capacity planning; aggregate planning; planning service operations; productivity of operations; inventory planning and independent demand systems; materials requirements planning; quality management; uncertainty and variability; project management; current developments in operations management.

**MBA\* ZG527 Entrepreneurship in FinTech 4**

FinTech Themes, Changing landscape in raising capital, FinTech Hubs, Early stage funding, Integrated FinTech

Ecosystems, Emerging Markets and Social Impact, Valuation of FinTech Firms, FinTech Solutions - Case Studies, Legal, Regulatory, Data privacy and Ethical aspects of FinTech startups, Capital and Investment for new businesses, Enterprise Innovation.

**MBA\* ZG528 Venture Capital and Private Equity 4**

This course will lay a strong foundation in core concepts, features and characteristics of the venture capital and private equity markets; specialized services provided by VC's and PE funds; stages in VC investing; deal flow; deal sourcing, evaluation; risk return tradeoff of VC/ PE investments; valuation of VC/ PE transactions; structuring and execution of deals; exit options, distributions; Course will make extensive use of case studies to understand industry best practices and current trends.

**MBA\* ZG529 Machine Learning for Finance 4**

Univariate and Multivariate Financial Time series and their characteristics, Applications of Support Vector Machines, Neural Networks and Gradient-Based Optimization, Applications of Tree based ensemble methods (Random Forests, Boosting), Dimension reductions using PCA and Auto Encoders, Feature Engineering, Cross validations, Credit Scoring, Predicting Bankruptcy, Fraud Identification models, Applications of Clustering Algorithms, Introduction to Sequential Learning.

**MBA\* ZG530 InsurTech 4**

Digital Transformation in Insurance, Insurance of Things, From Insurance Premium to Discrete Event, Telematics, Collaborative Approach, InsurTech Value Chain, Business Models, Practical Robotics in Insurance, Claims Handling, Applications of Technology in Underwriting, New Business Generation and Policy Processing.

**MBA ZG531 Statistical Quality Control 5**

Sources of Variation: Common and Assignable Causes, Descriptive Statistics, Statistical Process Control Methods, Control Charts for Variables, Control Charts for Attributes, C-Charts, Process Capability, Acceptance Sampling, Operating characteristic curve, Statistical Quality Control in Services.

**MBA\* ZG532 Deep Learning Application in Finance 4**

Review of Machine Learning, Foundations of Neural networks and deep learning, Fundamentals of deep networks, Multilayer Perceptron, Convolutional neural networks (CNN), Recurrent neural networks (RNN) frameworks – LSTM, GRU. Hands on building Deep Learning networks, Auto-encoders, Parameter tuning, Generative Adversarial Networks (GAN), Semantic Segmentation, Unsupervised Learning, Applications of Deep Learning in FinTech.

**MBA\* ZG533 Technology Disruptions in FinTech 4**

Big Data in the Financial Services Industry, Internet of Things, Impact of IoT on Businesses, IoT in Financial Services, Cyber Security, Cybersecurity Categories and Players, Data Privacy and Governance, Cloud Computing, Networks, Mobile Applications and Smart Phones

**MBA\* ZG534 Sustainable Manufacturing 4**

Introduction to sustainable manufacturing, sustainable manufacturing design, practice and matrices, life cycle management and assessment, end of life (EOL) strategies, implementation framework, sustainable business models, waste minimization, case studies.

**MBA ZG535 Decision Analysis 4**

Introduction to quantitative techniques and statistics, Decision making, intelligence design and choice phases, basic theory of decision making under uncertainty; decision trees, qualification of judgments and preferences, Bayes theorem, the structuring of complex decisions, and multi-attribute utility theory. Statistical estimation and forecasting.

**MBA\* ZG536 Foundations of Data Science 4**

Introduction, Role of a Data Scientist, Statistics vs. Data Science, Fundamentals of Data Science, Data Science process and life cycle, Exploratory Data Analysis, Data Engineering and shaping, Overview of Data Science Techniques and Models, Introduction to Regression, Classification, Shrinkage, Dimension Reduction, Tree-based models, Support Vector Machines, Unsupervised learning, Choosing and evaluating models, Featurization, Overview of Neural Networks, Data mining, and pattern recognition techniques, Documentation, Deployment, and Presentations of the insights.

#### **MBA ZG537 Lean Manufacturing 5**

Birth of Toyota production system, house of Toyota production system, stability, standardization, just-in-time, jidoka, involvement, hoshin planning, Toyota culture, Toyota way, Case Studies.

#### **MBA\* ZG538 Advanced Statistical Methods 4**

Point and interval estimation and hypothesis testing, chi-square tests, non-parametric statistics, analysis of variance, regression; linear and multiple linear, correlation, factor models, decision theory, Bayesian statistics and autocorrelation, multivariate regression, randomization and sampling processes, Markov processes with discrete/continuous state space, statistical simulation and pattern recognition, Time Series Analysis.

#### **MBA\* ZG539 Data Visualization and Communication 4**

Need for visualization, Presentation and visualization of data for effective communication, the importance of context and audience, choosing an effective visual, Visualizations of a single number, Visualizations for comparisons, Displaying relative performances, Visualizing survey results, Visualizations for Ranking and Branching, Visualizations for parts of a whole, Visualizing correlations and regression, Visualizing Qualitative Data, Visualizing Trends, Tree-based visualizations, Visualizing Geo Data, Techniques for visualization of high dimensional data & discovered patterns, Common mistakes in dashboards, Visual perception, Create interactive Dashboards and Stories

#### **MBA\* ZG540 International Business and Trade 4**

Overview of International Business and Globalization, Culture, Governmental and Legal Systems, Economic Systems and Market Methods, Trade and Factor Mobility Theory, Trade Protectionism, Economic Integration and Cooperation, Markets for Foreign Exchange, Factors that Influence Exchange Rates, Global Debt and Equity Markets, Ethics and Social Responsibility, Strategies for International Business, Evaluation of Countries for Operations, Modes of Trading Internationally

#### **MBA ZG541 Consultancy Practice 4**

Strategic planning and marketing of consultancy services, client consultant relationships, technology transfers, negotiations, agreements, guarantees, organizing and executing consultancy services, quality in consultancy services, technical audit, government policies such as industrial policy, trade policy, technology policy, patent and trademarks etc.

#### **MBA\* ZG542 Entrepreneurship and New Ventures 4**

Innovation, Entrepreneurship and Intrapreneurship; Creativity & Lateral Thinking; Design Thinking; Effectual Thinking; Market Validation; Development and Evaluation of Business Idea; Introduction to Business Model Generation; Developing Lean Business Model for the Business Idea; Developing Prototype and Evaluating assumptions in Business Model using prototype cheaply; Presentation of Business Model; Raising Finance; NDAs and Term Sheets; Exit Strategies; Scaling up the venture; Developing Business Plan; Business Fair

#### **MBA\* ZG543 Family Business Management 4**

Nature, Importance and Uniqueness of Family Business – Various Perspectives, Zero sum dynamics and family culture, Family systems perspective, Family Genograms, Family Emotional Intelligence, Family Business interaction factor, Unity and continuity, Family employment policy, Conflict management, Shareholder priorities, effective governance of the shareholder–firm relationship, Profile of successful successors - rewards and challenges for latter-generation family members, crafting the next generation career plan, Sources of Value creation, Three states of evolution, Business Rejuvenation matrix

#### **MBA\* ZG544 Mergers, Acquisitions, and Corporate Restructuring 4**

Basics of M&A (corporate finance, strategy, economics), merger types, trends; theories underlying M&A; legal aspects; evaluating an acquisition target; valuation of mergers and acquisitions, MVA, relative valuation, multiples, DCF, FCFF, FCFE; M&A deal structuring; synergy analysis; break-up valuation; sensitivity analysis; terms of merger; financing considerations; capital structure decisions; structuring and valuing of Leveraged Buy-out (LBO) transaction; financing considerations; exit strategies; extensive use of relevant case studies, simulations, modeling.

#### **MBA ZG545 Product Design and Development 4**

Product Development Process and Tools; Scoping Product Development; Understanding Customer Needs; Establishing Product Function; Product Teardown and Experimentation; Benchmarking and Establishing Engineering Specifications; Product Portfolios and portfolio architecture; Product Architecture; Generating Concepts; Concept Selection; Concept Embodiment; Modelling of Product Metrics; Design for Manufacturing and Assembly; Design for Environment; Physical Prototypes, and Models and Experimentation.

#### **MBA\* ZG547 Modern Manufacturing 4**

Computer Integrated Manufacturing, ASRS, Robotics, Mass Customization, Additive manufacturing, Internet of Things and distributed manufacturing, Managing Global manufacturing systems and Global sourcing.

#### **MBA\* ZG548 Manufacturing Strategy 4**

Corporate strategy; Missing links in manufacturing strategy; Audit approach; Restructuring; Manufacturing strategy process in practice; Formulation as a process; Operating strategies; Methodology framework; Lean production; Competitive priorities; Strategic value of response time and product variety; Flexibility in context of manufacturing strategy; Manufacturing focus; Business process reengineering; Theory of constraints; Link between strategy and organizational culture; Evolution of manufacturing systems; Operations management strategic perspective.

#### **MBA ZG549 Managing Quality in Services Industry 4**

Key Differences between Services Sector and Manufacturing Sector, and the implications for Quality Management, Key quality metrics in services sector, quality measurement scales in service sector (INSTAQUAL, SERVEQUAL, MEQUAL), Concept of Net Promoter Score, Components of quality in services sector, Importance of human element in quality management in services, Establishment of quality management system for services sector, Designing the service encounter, Quality management as driver of innovation in service industry, Business process excellence in services industry, process blueprinting, benchmarking, Applications of Six Sigma in services industry



**MBA ZG550 Quality Management Systems 4**

ISO 9000 series of standards, formation of ISO (1947), background & development of ISO 9000. ISO 9000 family of standards, selection & use of appropriate model of ISO 9000. Requirements of ISO 9001; System demonstration & documentation, how to organize a formal quality assurance system, other quality system standards, relating ISO 9000 with QS 9000 and ISO 14000, Understanding ISO 16949 and PPAP/APQP/FAI/Configuration Management.

**MBA\* ZG551 Quality Analytics 4**

Systems approach to Quality, Systems engineering- (RAMS Framework, Reliability, Availability, Maintainability, Safety, Testability), Safety engineering and systems safety, Fault tolerant systems, redundancy, Types of failures by attribution: Manufacturing and assembly induced failures, storage induced failures, transport induced failures, maintenance induced failures, human errors, TCO Approach of making decisions, Quality, Simulations, Systematic methodology of Research, Sampling techniques, Research design, Sampling design, Data Collection for measuring quality, Applications of statistics (univariate and bivariate) in quality management, Hazard rate modelling, Applications of Machine Learning and Artificial Intelligence in Quality Management

**MBA\* ZG552 Business Acumen for Managing Quality4**

Aligning quality strategy with the overall business strategy, Quality and the target Customer segment, concept of perceived quality and optimal quality, Economics of Quality, Costs related to quality, Taguchi Loss Function, Quality as a competitive advantage, Defining Quality metrics for BI dashboards, Communicating the product quality to the consumer, Differential Quality SLAs for different segments, Business Ethics and Quality, Managing Quality in the era of Industry 4.0, Quality and Regulation, Introduction to Weights and Measures Act, Consumer Rights and regulatory implications of quality imperfections, Quality for Safety, Health and Environment, How organizations can go safe?

**MBA\* ZG553Block Chain and Applications4**

Introduction, Evolution of Block chain, Building blocks of block chain, Smart contracts, Block chain Principles, Asset Monetization in Block Chain, Building a block chain network, Use cases of Block chain in different sectors across the world (Manufacturing and Industrial, Government and Public Sector, Consumer Goods and Retail Industry, Food Industry, Cryptocurrencies in detail), Limitations of existing block chains, Regulatory Aspects, Strategy to implement across the enterprise, Best Practices in implementing Block chain, Different types of Block chain architectures – Hyper Ledger, Ethereum, Future challenges.

**MBA\* ZG554Digital Banking and Beyond 4**

Traditional Banking landscape, First principles of Banking, Effect of Digital Technology, New Operating Models for Banking, Regulation vs. Innovation, Reframing identity through Technology, Embedded Banking, Banking Chatbots, From products and channels to experiences, Designing Digital banks without branches, Building Relationships through digital banking, Technologies enabling digital banking, Security, New economics of digital bank, Beyond digital banking, Role of AI and Big Data in Banking.

**MBA\* ZG555Algorithmic and High Frequency Trading4**

Introduction to Algorithmic trading, Users of Algorithmic Trading, Currently Popular trading Algorithms, Algo trades for individual investors, Optimization, Stock personality clusters, Selecting a Cohort of Trading Stocks, Stock Profiling, Volatility, Alpha Algo strategies, Benchmarks and Performance Measures, Technical Analysis (TA), Heuristics, AI, Artificial Neural Networks and Other Avenues, From the Efficient Market Hypothesis to Prospect Theory, Mean Reversion strategies, Momentum strategies, risk management.

**MBA\* ZG556 Advanced Risk Models 4**

Advanced VaR models, expected shortfall, stressed VaR, historical simulation, delta/ gamma models, full revaluation, risk factor selection, volatility clustering, structured Monte Carlo analysis, stress testing, scenario analysis, back testing; country and sovereign risk models; management of country and sovereign risks, external and internal credit ratings methodology and framework; expected and unexpected loss framework and related metrics; extensive use of relevant case studies, simulations, modeling.

**MBA\* ZG557FinTech in Wealth Management 4**

Introduction, Traditional wealth management industry, Digitization in wealth management, Digitizing client advisory, Robo advisors, Gamification, Digitizing wealth management operations, Digital platforms, products and eco systems, Block chain applications in asset and wealth management, Algorithms of Automated Portfolio Rebalancing, Digital Financial Advisor, Future of Digital Advice, Personalize the Investment Experience, Future of wealth tech.

**MBA\* ZG558 Financial Risk Management 4**

Introduction to Financial Risk Management, Financial Institutions and their trading, Credit Crisis of 2008, Market Risk (Risk Management by traders, Interest rate risk, volatility, Correlation and Copulas, Value at Risk and Expected Shortfall, Historical Simulation and Extreme Value Theory, Model-Building Approach), Credit Risk (Estimating Default Probabilities, CVA, DVA, Credit Value at Risk), Regulation (BASEL I, II and III), Fundamental Review of the Trading Book, Scenario Analysis and Stress Testing, Overview of Operational Risk, Liquidity Risk, Economic Capital and RAROC.

**MBA\* ZG559 Management of Banks & Financial Institutions4**

Overview and operation of financial institutions and banks; Commercial banking, Investment banking; Define, quantify, and manage various types of risks faced by financial institutions; asset liability management - overview, strategies; off balance sheet activities of banks; sovereign risk; deposit insurance; capital adequacy; study current best practices using selected case studies; bank management failures; insights from collapse of Lehman Brothers; introduction to bank regulation; international considerations; relevant case studies, simulations, modeling.

**MBA\* ZG560Global Financial Markets and Products4**

Capital markets; stock markets, bond markets, derivative markets; operations of these markets from a global perspective; Overview and features of key financial products, equities, fixed income securities and derivatives; bond features, indenture, coupon, maturity, YTM, zero coupon, valuation, duration, convexity; Equities, product features, basic valuation concepts; derivatives, forwards, futures, options, swaps, commodity derivatives, cost of carry, concepts, basic features, payoff, put call parity, basic option strategies; relevant case studies, simulations, modeling.

**MBA\* ZG561 Behavioural Finance 4**

Introduction, Rational Market Hypothesis, Foundations of Rational Finance (Expected Utility, MPT, CAPM, EMH), Challenges to rational behaviour, Heuristics, Cognitive Biases, Self-Deception, Prospect Theory, Mental Accounting, Emotional Factors, Challenges to Efficient Market Hypothesis, Investor Behaviour, Market Outcomes, Value Investing, Applications of Behavioural Finance, Introduction to Behavioural Corporate Finance.

**MBA\* ZG562 Derivatives & Financial Engineering4**

Introduction to derivatives market, forward, futures, options, swaps, Pricing and valuation of derivatives, options trading strategies, Elementary Stochastic calculus, binomial tree model, Black Scholes Merton model, option Greeks, Exotic Options, Volatility Smiles, credit risk, credit derivatives, credit default swaps, collateralized debt obligations, valuation of synthetic CDO, Interest rate Derivatives.

**MBA\* ZG563 Analytics for HR 4**

Leveraging analytic techniques in the context of the challenges faced by the HR and Talent Acquisition and Management functions. Applying analytical techniques to deliver meaningful insights for effectively managing employees for achieving the goals of the organization. Attracting right talent, forecasting future staffing needs, managing attrition and improving employee satisfaction levels. Case Studies, simulations, hands-on exercises using tools like R / Python.

**MBA\* ZG564 Models in Marketing 4**

Introduction to Marketing Models, Models of consumer behavior, industrial buying and firm behaviour, (aggregate) market models (e.g., competition, market entry), strategic marketing models, forecasting methods, new product models, marketing response models (e.g., channels, pricing, advertising, promotion), forecasting models and decision support systems. Case Studies, simulations, hands-on modeling.

**MBA\* ZG565 Supply Chain Analytics 4**

Introduction to supply chain analytics, Data understanding and data preparation, Supply chain performance, Descriptive analytics, Predictive analytics and setting up the problem, Supply chain forecasting, studying holt, winter and ARIMA models, Supply chain Network Planning, Multi echelon network optimization, Supply chain sales and operations planning, Supply chain segmentation, Vehicle routing problems, Supervised and Unsupervised learning, Use of Bayesian networks in supply chain, Simulation and SC models, Supply chain risk management.

**MBA\* ZG566 Analytics for Marketing 4**

Introduction to Marketing Research, Research Methodology, Problem definition, research design formulation, Field work and Data Collection, Data preparation and Analysis, Final report preparation and presentation, Case Studies, simulations, hands-on exercises using tools like R / Python.

**MBA\* ZG567 Analytics for Retail Industry 4**

RFM (measuring customer recency, frequency and monetary) Analysis, churn modeling, retention modeling, shopper analytics, market basket association analysis, customer segmentation and profiling, propensity scoring models to identify prospective customers, best customers, lifetime value modeling, marketing campaign response modeling, cross sell modeling, etc., Case Studies, simulations, hands-on exercises using tools like R / Python.

**MBA\* ZG568 Operations Research Models 4**

Practical application of OR tools. Application areas include: financial planning and portfolio selection, production, supply chain, priority planning and marketing. Linear programming and its applications; programming to achieve a set of goals or targets with applications in finance and production; capital budgeting and project selection; transportation and network models; and portfolio models, Case Studies, simulations, hands-on exercises using tools like R / Python.

**MBA\* ZG569 Analytics for Investment Banking 4**

Modern portfolio theory, Capital Asset Pricing Model (CAPM), Arbitrage Pricing Theory (APT), and efficient market theory; Passive investing: indexing; behavioral finance; Active investing: security analysis – fundamental analysis (strategic, financial, marketing tools) and technical analysis; Portfolio management including allocation, rebalancing and risk management; Transaction cost analysis; Fixed-Income and Credit Sensitive Instruments. Case Studies, simulations, hands-on exercises using tools like R / Python.

**MBA\* ZG570 Financial Risk Models 4**

Basics of financial risk, Its applications in the form of derivatives- Currency and interest rate derivatives, equity markets and products, commodity markets and products, Measuring and Analysing Volatility- EWMA, ARCH, GARCH,

Volatility clusters and the issue of time-varying volatility, Extreme Value Theory, Correlation and Copula, Introduction to Multivariate Forecasting), VaR Computation, Stress testing, Monte Carlo simulation, address issues in generating price process (such as Brownian Motion, Ito Process), Cholesky decomposition in computing multi-asset VaR; Currency risk analysis in global investing, interest rate parity (covered and uncovered); Value at risk for fixed income Credit Risk Analytics Case Studies, simulations, hands-on exercises using tools like R / Python.

**MBA\* ZG571 Analytical Models in Finance 4**

Modelling and valuation of equity securities, fixed income securities, and derivatives, Introduction to Financial Modelling, and Spreadsheet Essentials, Measuring Risk (Testing market efficiency with regression analysis & pivot tables), Portfolio optimization (Mean-variance portfolio selection, Bond portfolio selection, Term structure estimation, Capital budgeting), Advanced risk analysis (Monte-Carlo simulation, Risk analysis of discounted cash flow models, Monte- Carlo simulation, Business and equity valuation modelling, LBO Analysis Model, Stock Merger Model, etc., Case Studies, simulations, hands-on modelling exercises.

**MBA\* ZG572 Digital Business Design 4**

Design Thinking in Digital Business, Components of ecommerce, Usability and information architecture, Product Design, Product Management, Mastering Disruptive Business Models, Platform Business Models, Network of platform economies, relevant technologies, Innovation through Experimentation: A/B Tests and Minimum Viable Products, building scalable digital businesses

**MBA\* ZG573 Digital Strategies for Business 4**

Digital transformation of conventional enterprises, mastering disruption, Digital Transformation, Culture for Digital Business, Business Process Re-engineering, Frameworks to invent/reinvent business models for a digital world, Big Data and How to Build Data as a Strategic Asset, Translating the lean start-up to enterprise scale innovation, Applications of these frameworks through case studies

**MBA\* ZG574 Digital Customer Experience Management 4**

Customer relationship management, Understanding the customer journey, making plans to improve the user experience, assessing the strategic options for channel selection, Understanding relevant insights into digital customers, Understanding how digital channels are managed effectively in practice, Defining requirements for legal compliance in digital campaigns.

**MBA\* ZG575 Digital Technologies and Analytics 4**

Intro to Industry 4.0, IOT, Cloud Computing, AR, VR, AI, Machine Learning, Foundations of data science, glimpse of blockchain, fintech and crypto-currency, CRISP DM Framework, Applications of data analytics in business, data pre-processing and cleaning, types of data analytics, text analytics topic modeling, realtime analytics, data privacy and protection, legal aspects of data in digital businesses.

**MBA\* ZG576 Digital Marketing 4**

3C Framework, Content Marketing, Web Analytics, Search Engine Marketing, Search Engine Optimisation, Email Marketing, Mobile Marketing, Affiliate Marketing, Social Media Marketing, Mobile Marketing, Marketing Spend Optimization, Pay-per-click, Their advantages and disadvantages, Link building campaigns, Online Reputation Management, Sponsored content, Push notification, In-game advertising, Sharing economies in digital marketing.

**MBA\* ZG577 Artificial Intelligence and Machine Learning 4**

Applications of A.I. techniques to the business and management fields like natural language understanding, image processing, game theory and problem solving, Introduction to Machine Learning, Various kinds of learning,

Supervised Learning, Unsupervised Learning, Feature Engineering, Classification, Model Selection; Bayesian Learning, Bayes Optimal Classifier, Naive Bayes Classifier; Linear Models for Regression, Linear Models for Classification; Non-Linear models, Decision trees; KNN Algorithm, Support Vector Machines, Neural Networks, Deep Learning, Text Mining, Association Rule Mining, and Introduction to Genetic Algorithms.

#### **MBA\* ZG578 Digital Manufacturing and Logistics 4**

Industrial revolution 4.0, connected factories, smart industrial devices and products, cyber physical system in manufacturing, connectivity and communication technologies, RFID, QR codes and cellular technologies, protocols, hardware in IoT, software (IDE), cloud platform, connectivity and networking in IoT, smart eyes on shop floor, integrating smart into existing equipment, programming using IoT, Digital Supply Chains, Warehousing automation.

#### **MBA\* ZG579 Entrepreneurial Finance 4**

Principles of entrepreneurship, Changing landscape in raising capital, characteristics of the venture capital and private equity markets, specialized services provided by VC's and PE funds, stages in VC investing, deal flow, deal sourcing, evaluation, risk return trade off of VC/ PE investments, valuation of VC/ PE transactions, structuring and execution of deals, exit options, distributions, Early stage funding, Integrated Financing tech Solutions - Case Studies, Legal, Regulatory, Capital and Investment for new businesses, Enterprise Innovation.

#### **MBA ZG611 Strategic Management & Business Policy 4**

Strategic management elements; internal, external, external environment. assessment of corporate strengths, weaknesses and opportunities; planning and deployment of capital assets; profit planning and control functions problems, pressures, responsibilities, limits of the chief executive; evaluation of one's own business undertaking; formulating objectives, strategies, policies and programmes for improving company's present situation; personnel strength and implementation of the policies and programmes, development, implementation, evaluation and control of strategies, strategic management of MNCs, management style and behavior, corporate style, behavior and culture.

#### **MBA ZG621 Supply Chain Management 4**

Customer driven strategies in production and distribution systems; Integrated production and distribution networks; SCM in the context of JIT and MRP-II; Distribution Resource Planning; Management of dealer networks; Total Control & Product innovation across the supply chain; Incoming logistics and supplier relationships; Value addition analysis; Metrics for management of supply chain performance; Mathematical models and computer assisted decision support for SCM; Mathematical programming for SCM.

#### **MBA ZG634 Strategic Change Management 4**

Results-based management, managing for outcomes—objectives and targets; strategy; indicator, performance information; environmental scan and SWOT analysis; planning, budgeting, implementation, review - the (strategic) management cycle Models and theories of planned change, Strategic management: transformational leadership or change management (or learning), Strategic management in a context of joint action and networks, Participation and Empowerment, Teams and Teamwork, Parallel learning structures, OD Interventions, Team Interventions, Intergroup and third party interventions, Structural and Comprehensive interventions, Action research, Socio-clinical and Socio-technical Approaches, Issues in Consultant-Client Relationships, Power Politics and Organization Development.

#### **MBA ZG661 Software Quality Management 4**

Software quality challenges and expectations; quality dilemma; software life cycle and link to quality; quality gates, formal reviews, system requirement reviews, preliminary

design reviews, critical design reviews, test reviews; engineering reviews, walkthroughs, inspections, internal reviews; quality gate categories; technical environment and quality; planning for software quality, quality requirements for planning, quality needs, elements of quality planning, quality assessments during planning, software quality organization requirements; quality evaluation of software development process, process quality attributes, measuring software process quality; software process metrics; quality gate integrity; software product quality, standards and conventions, metrics; quality hierarchy, factors; quality assessment; quality evaluation techniques, reviews, walkthroughs, audit, inspections, analytical evaluation techniques; quality systems.

#### **MBA ZG623T Project 12**

Consistent with the student's professional background and work-environment, the student will be required to carry out work-oriented projects. The student would be required to select an area of work in Engineering / Management aspects that are considered vital to the sponsoring organization. At the end of the semester, the student should submit a comprehensive Project Report. The student will be evaluated on the basis of the various interim evaluation components, contents of the report and a final seminar & viva-voce.

#### **ME\* ZC112 Electrical and Electronics Technology 3**

Electric circuit, electromagnetism, magnetic circuit, electrostatics, AC voltage and current, singlephase circuits, semiconductor devices, amplifiers, digital systems, microprocessors, DC machines, polyphase circuits, transformers, synchronous machines, induction motors, power electronics, measurements, illumination.

#### **ME\* ZC113 Probability and Statistics 3**

Probability spaces; conditional probability and independence; random variables and probability distributions; marginal and conditional distributions; independent random variables; mathematical expectation; mean and variance; binomial, Poisson and normal distributions; sum of independent random variables; law of large numbers; central limit theorem (without proof); sampling distribution and test for mean using normal and student's t-distribution; test of hypothesis; correlation and linear regression.

#### **ME\* ZC164 Computer Programming 4**

Basic Computing Steps and Flow Charting (Assignment, Sequencing, Conditionals, Iteration). Programming Constructs – Expressions, Statements, Conditionals, Iterators/Loops, Functions/ Procedures; Data Types – Primitive Types, Tuples, Choices (Unions or Enumerations), Lists/Arrays, Pointers and Dynamically Allocated Data. Input output and Files. Laboratory Component: Programming Exercises involving development and testing of iterative and procedural programs using bounded and unbounded iterations, function composition, random access lists, sequential access lists, dynamically allocated lists, and file access.

#### **ME\* ZC213 Engineering Measurements 3**

Performance characteristics of measuring instruments, measurement methods for mechanical, electrical, radiant, chemical, magnetic and thermal energy variables. Emphasis in this course shall be on the operation and use of instruments.

**ME\* ZC231 Principles of Management** 3  
Fundamental concepts of management - planning; organizing; staffing; directing and controlling; production, financial, personnel, legal and marketing functions; accounting and budgeting, balance sheets.

**ME\* ZC233 Calculus** 4  
Limits, continuity, differentiation, integration, Fourier series, ordinary differential equations for initial and boundary value problems, solution through Laplace transforms, numerical solution using Picard's iteration and higher order methods, partial derivatives, partial differential equations, analytical solution techniques.

**ME\* ZC234 Maintenance & Safety** 3  
Objectives, functions, and types of maintenance; defects due to wear; lubrication and surfacing techniques to reduce wear; maintenance of different equipments and their elements; spares planning; overhauling; TPM; safety and safety management; environmental safety; chemical safety; occupational health management; control of major industrial hazards; managing emergencies; employee participation in safety; HRD for maintenance and safety.

**ME\* ZC235 Linear Algebra & Optimization** 3  
Vector and matrix algebra, systems of linear algebraic equations and their solutions; eigenvalues, eigenvectors and diagonalization of matrices; Formulation of linear programming problems, Simplex method, Big-M method, two phase method, Sensitivity analysis, Revised and Dual Simplex Methods.

**ME\* ZC236 Engineering Materials** 3  
Mechanical, electrical, electronic and chemical properties and applications of common engineering materials; ferrous and non-ferrous metals and alloys; thermosetting and thermoplastic plastics; natural and synthetic resins; rubber; glass; abrasives and ceramics; common building materials, namely, timber, stone, lime and cement; corrosion of metals and methods of preventing corrosion; protective and decorative coatings; insulating materials; testing of materials.

**ME\* ZC241 Technical Report Writing** 3  
Elements of effective writing; art of condensation; business letter writing; memos; formal reports; technical proposals; conducting, and participating, meetings; agenda and minutes; strategies for writing technical descriptions, definitions, and classifications; oral presentation; use of graphic and audio-visual aids; editing.

**ME\* ZC242 Manufacturing Process** 3  
Fundamentals of casting process; forging; powder metallurgy; soldering; brazing and welding technology; metal forming process, its analysis and design; Introduction to Metal cutting, machine tools; mechanics of metal cutting; other machining processes; grinding and finishing operations; non convention machining; chipless machining processes; NC machines programming; control system in CNC; CNC, DNC; FMS and machining center.

**ME\* ZC251 Mechanical Technology** 3  
Fundamental concepts of heat, work and energy; second law of thermodynamics; properties of gases and vapors; basic cycles; flow of liquids; steam boilers; steam engines and pumps; steam turbines and condensers; hydraulic pumps and turbines; internal combustion engine.

**ME\* ZC261 Mechanics of Solids** 3  
Fundamental principles of mechanics; introduction of mechanics of deformable bodies; forces and moments transmitted by slender members; stress and strain; stress-strain-temperature relations; torsion; stresses and deflections due to bending; stability of equilibrium.

**ME\* ZC271 Manufacturing Excellence** 3  
Introduction, frameworks of manufacturing excellence, practices for manufacturing excellence: leadership and change management, manufacturing strategy, innovative product planning, total productive maintenance, total quality management, lean manufacturing, customer relations management, green manufacturing, supply chain management, knowledge management and social responsibility.

**ME\* ZC311 Automobile Technology** 3  
Introduction; working and construction of IC Engines; its components; cycles; fuel air cycle; diesel cycles; combustion in SI and CI Engines; fuels and combustion; fuel supply systems; scavenging process; engine cooling and lubrication; engine cooling system, friction and lubrication, engine testing and performance; super charging, analytical method of performance and estimation; emission controls; alternate fuels; modern trends in engine development.

**ME\* ZC312 Automobile Technology-II** 3  
Vehicle classification; chassis construction; clutches-friction clutches, fluid coupling; gear box-arrangement and design of gear boxes; epicyclic gear box; torque converters, semiautomatic and automatic gear boxes; propeller shaft; universal joint; differential; rear axle suspension systems; front axle and steering mechanisms – power steering mechanism; brakes –mechanical, hydraulic and air brakes; servo and power operated brake systems; wheels and tyres; testing and performance of automobiles; vehicle vibration; and human comfort; auto-electrical systems; ignition system-conventional and electronic system, alternators; charging system; storage batteries; wiper motors; lighting system; electrical vehicles; automobile law.

**ME\* ZC323 Design of Machine Elements** 4  
Fundamentals and principles of design; properties of engineering materials; design of simple machine parts; shafts, keys and couplings; power screws; threaded joints, welded and riveted joints, bearings and seals, gears, cams and followers; design of mechanisms.

**ME\* ZC324 Mechatronics and Automation** 4  
Introduction to mechatronics, sensors and transducers, Concepts of measurement of electrical and nonelectrical parameters; displacement, force, pressure etc. and related signal conditioning techniques , pneumatic and hydraulic actuation systems, mechanical actuation systems, electrical actuation systems, digital logic, microprocessors and programmable logic controllers; Introduction to automation, control loops for numerical control systems, adaptive control systems, industrial robots, automatic identification and data capture, automated production lines and automated assembly systems, System design concepts through case studies.

**ME\* ZC331 Production Planning & Control** 3  
Types of production systems and problems of planning and control, product planning, forecasting, product demand, process planning, project management, capacities location and layout of facilities, aggregate planning and scheduling, materials requirement, planning, inventory management, systems and recent trends in production management.

**ME\* ZC332 Operations Research** 3  
Sampling, simulation, design of experiments and analysis of variance, nonparametric tests; correlation and regression analysis; quality control, reliability; decision theory; queuing theory; deterministic and probabilistic inventory systems.

**ME\* ZC343 Materials Management** 3  
Integrated materials management, policy aspects, purchasing management, warehousing and storage of inventory control systems; stores management; material planning, make or buy decisions; scheduling, strategic sourcing, JIT, Kanban system; inventory costing principle; concept of MRP II;

vendor development; central excise, customs, importing, sales tax.

#### **ME\* ZC412 Flexible Manufacturing Systems 4**

Introduction CAD/CAM systems, overview of FMS, system hardware and general functions, material handling system, work holding systems, cutting tools and tool management, physical planning of system, software structure functions and description, cleaning and automated inspection, communications and computer networks for manufacturing, quantification of flexibility, human factors in manufacturing, FMS and CIM in action (case studies), justification of FMS, modelling for design, planning and operation of FMS.

#### **ME\*ZC418 Lean Manufacturing 3**

Fundamentals of continuous improvement, value added and waste elimination, elements of lean production: small lot production, setup time reduction, maintaining and improving equipment, pull production systems, focused factories and group technologies, work cells and cellular manufacturing, standard operations, quality of design, systems for eliminating defects, simplified production planning and control systems: scheduling for smooth flow, synchronizing and balancing process, planning and control in pull production, beyond the production systems: managing the supply chain, activity based costing, performance measurement.

#### **ME\* ZC421 Essentials of Project Management 3**

Programmes project management, project manager: role and responsibilities, project management and organization, project planning and scheduling, graphical techniques and PERT, CPM, price estimation and cost control; proposal, control valuation monitoring and trade off analysis in a project environment, pitfalls and future scenario.

#### **ME\* ZC432 Quality Control, Assurance & Reliability 3**

Basic concepts of probability and probability distributions, standard probability distribution, sampling and sampling distributions, confidence intervals, testing significance, statistical tolerance, various types of control charts, statistical process control techniques, value analysis, defect diagnosis and prevention, basic concepts of reliability, reliability design evaluation and control, methods of applying total quality management, production process.

#### **ME\* ZC471 Management Information Systems 3**

Introduction to Information Systems; Concepts of management, concepts of information, systems concepts; Information Systems and Organizations; decision making process; database systems; data communications; planning, designing, developing and implementing information systems; quality assurance and evaluation of information systems; future developments and their organizational and social implications; decision support system and expert systems.

#### **MEL\* ZC415 Introduction to MEMS 4**

Overview, history and industry perspective; working principles; mechanics and dynamics, thermofluid engineering; scaling law; microactuators, microsensors and microelectromechanical systems; microsystem design, modeling and simulation; materials; packaging; microfabrication: bulk, surface, LIGA etc; micromanufacturing; microfluidics; microrobotics; case studies.

#### **MEL\* ZG510 RF Microelectronics 5**

Introduction; application of RF electronics in modern systems; basic concepts in RF circuit design, active RF components: various RF diodes and transistors and their circuit models, matching and biasing networks, RF amplifier design: low power, low noise and broadband amplifiers, RF oscillator design; negative resistance oscillator; dielectric resonator oscillators, phase noise. RF Mixers: Balanced mixers; low noise mixers; noise in RF circuits, microwave transmitters and receivers.

#### **MEL\* ZG511 Design & Analysis of Algorithms 5**

Design techniques such as divide-and-conquer, recursion, backtracking, branch-and-bound, simulation; Analysis in terms of average level and worst level efficiency; Relationship to appropriate data structures; Illustrations dealing with problems in computer science, graph theory and mathematics; Computational complexity and bounds; NP-hard and NP-complete problems.

#### **MEL\* ZG512 Optoelectronic Devices, Circuit & Systems 5**

Physics of optical radiation and principles of calculation in radiation physics & optics, fundamental laws of photometry. Interaction between optical radiation and matter. Radiation sources. Parameters of IR detectors and junction photodetectors, parameters common to emitters and receiver, radiation measurements, optoelectronic components, optoelectronic integrated devices, photodetector circuits, methods of modulation and optoelectronic system design and applications.

#### **MEL\* ZG520 Wireless & Mobile Communication 5**

Signal propagation in a mobile environment, modulation, coding, equalization; first generation systems; multiple access techniques like FDMA, TDMA, CDMA, spread spectrum systems; second & third generation systems, UMTS, IMT-2000; Wireless LAN, Wireless ATM and Mobile IP; emerging trends in Wireless & Mobile Communication.

#### **MEL\* ZG524 Real Time Operating Systems 5**

Introduction to real-time systems, clock synchronization task assignment and scheduling, programming language with real-time support, ADA, real-time communication protocols, real-time database, fault tolerant techniques, reliability evaluation methods; case studies in real-time operating systems, simulation of real-time systems, embedded system programming.

#### **MEL\* ZG526 Embedded System Design 4**

Introduction to embedded systems; embedded architectures: Architectures and programming of microcontrollers and DSPs. Embedded applications and technologies; power issues in system design; introduction to software and hardware co-design.

#### **MEL\* ZG531 Testability for VLSI 5**

BIST, boundary scan, stuck-at faults, test generation algorithms for combinatorial logic circuits and sequential circuits, logic simulation and fault simulation, synthesis for test, built in self-test, pseudo-random test techniques, other test methods - IDDQ testing, boundary scan etc.

#### **MEL\* ZG553 Real Time Systems 5**

Real time software, Real time operating systems-scheduling, virtual memory issues and file systems, real time data bases, fault tolerance and exception handling techniques, reliability evaluation, data structures and algorithms for real time/embedded systems, programming languages, compilers and run time environment for real time/embedded systems, real time system design, real time communication and security, real time constraints and multi-processing and distributed systems.

#### **MEL\* ZG554 Reconfigurable Computing 5**

Overview of Programmable Logics. FPGA fabric architectures. Logic Elements and Switch Networks. Design and Synthesis of Combinational and Sequential Elements. Placement and Routing. Pipelining and other Design Methodologies. Fine-grained and Coarse-Grained FPGAs. Static and Dynamic Reconfiguration. Partitioning. Hardware/Software Portioning and Partial Evaluation. Systolic Architectures.

#### **MEL\* ZG573 Digital Signal Processing 3**

Introduction; design of analog filters; design of digital filters: (IIR and FIR); structures for the realization of digital filters; random signals and random processes; linear estimation and

prediction; Wiener filters; DSP processor architecture; DSP algorithms for different applications.

#### **MEL\* ZG611 IC Fabrication Technology 5**

Material properties; Crystal growth and doping; diffusion; oxidation; epitaxy; Ion implantation; Deposition of films using CVD, LPCVD and sputtering techniques; Wet and dry etching and cleaning; Lithographic process; Device and circuit fabrication; Process modeling and simulation.

#### **MEL\* ZG613 Advanced Digital Signal Processing 4**

Review of stochastic processes, models and model classification, the identification problem, some field of applications, classical methods of identification of impulse response and transfer function models, model learning techniques, linear least square estimator, minimum variance algorithm, stochastic approximation method and maximum likelihood method, simultaneous state and parameter estimation of extended kalmanfilter, non-linear identification, quasi linearization, numerical identification methods.

#### **MEL\* ZG621 VLSI Design 5**

Introduction to NMOS and CMOS circuits; NMOS and CMOS processing technology; CMOS circuits and logic design; circuit characterization and performance estimation; Structured design and testing; Symbolic layout systems; CMOS subsystem design; System case studies.

#### **MEL\* ZG623 Advanced VLSI Design 5**

Deep submicron device behavior and models, interconnect modeling for parasitic estimation, Clock signals and system timing--Digital phase locked loop design, memory and array structures, Input/output circuits design, ASIC technology, FPGA technology, High speed arithmetic circuits design, - Parallel prefix computation, Logical effort in circuit design, Low power VLSI Circuits-Adiabatic logic circuits, Multi threshold circuits, Digital BICMOS circuits, Design of VLSI systems.

#### **MEL\* ZG625 Advanced Analog and Mixed Signal Design 5**

Design of high speed comparators and Op-amps; analog buffers; different architectures of A/D and D/A converters; analog multipliers and dividers; design of PLLS; design methods for switched capacitor filters sample and hold circuits; mixed signal design issues; noise coupling from substrate and its reduction; cross talk and shielding; analog layout techniques for mixed signal designs.

#### **MEL\* ZG631 Physics & Modelling of Microelectronic Devices 5**

Physics and properties of semiconductor - a review; pn junction diode; bipolar transistor; metalsemiconductor contacts; JFET and MESFET; MOSFET and scaling; CCD and photonic devices.

#### **MEL\* ZG632 Analog IC Design 5**

Basic concepts; BICMOS process and technology; current and voltage sources; Differential and Operational Amplifiers; Multipliers and modulators; phase-lock techniques; D-to-A and A- to-D converters; Micropower circuits; High voltage circuits; Radiation Resistant Circuits; Filter design considerations.

#### **MEL\* ZG641 CAD for IC Design 5**

Introduction to VLSI design methodologies and supporting CAD tool environment; Overview of 'C', Data structure, Graphics and CIF; Concepts, structures and algorithms of some of the following CAD tools; Schematic editors; Layout editors; Module generators; Silicon compilers; Placement and routing tools; Behavioral, functional, logic and circuit simulators; Aids for test generation and testing.

#### **MEL\* ZG642 VLSI Architecture 4**

Overview of CISC processor architectures; Instruction set architecture of CISC processor; hardware flow-charting methods; implementing microprocessor logic from hardware

flowcharts; RISC instruction set architecture; pipelined execution of RISC instructions; pipeline execution unit design; control hazards; design of memory hierarchy.

#### **MEL\* ZG651 Hardware Software Co-Design 4**

FPGA and ASIC based design, Low-Power Techniques in RT Embedded Systems On-chip networking. Hardware Software partitioning and scheduling, Co-simulation, synthesis and verifications, Architecture mapping, HW-SW Interfaces and Re-configurable computing.

#### **MEL\* ZG652 Networked Embedded Applications 4**

Networked embedded systems, Clock synchronization, Protocol mechanisms protocol performance, CAN Bus architecture, USB Architecture, Embedded Internet, distributed computing, Use of Java in building networked systems, Reliability & Fault Tolerance etc. Mission-critical distributed real-time applications, e.g., military, air traffic control; Prototyping benchmark applications, e.g. simulated air traffic visualization, radar display; Networking: TCP/IP, distributed objects; Embedded system programming and middleware: I/O, analog / digital conversion, DSP, runtime monitoring of CPU, processes, network equipment; Modeling distributed real-time systems; Quality of service maintenance.

#### **MGTS ZC211 Principles of Management 3**

Fundamental concepts of management - planning; organizing; staffing; directing and controlling; production, financial, personnel, legal and marketing functions; accounting and budgeting, balance sheets.

#### **MM ZC412Flexible Manufacturing Systems 4**

Introduction CAD/CAM systems, overview of FMS, system hardware and general functions, material handling system, work holding systems, cutting tools and tool management, physical planning of system, software structure functions and description, cleaning and automated inspection, communications and computer networks for manufacturing, quantification of flexibility, human factors in manufacturing, FMS and CIM in action (case studies), justification of FMS, modelling for design, planning and operation of FMS.

#### **MM ZC441 Human Resource Management 4**

Introduction, manpower planning, career and succession planning, procurement of personnel, performance appraisal, job satisfaction and morale, job rotation, employee communication, audit and control, management training and development, wage and salary administration, welfare administration, trade unions and collective bargaining, industrial dispute and worker participation in management.

#### **MM ZC448 ADDITIVE MANUFACTURING 4**

Introduction to Additive Manufacturing, CAD for Additive Manufacturing; Material Science Aspects in Additive Manufacturing, Different materials used in AM, Use of multiple materials, multifunctional and graded materials in AM, Role of solidification rate; Various Additive Manufacturing Processes Powder-based AM processes involving sintering and melting, Printing processes (droplet based 3D printing), Fused deposition modelling (FDM), Laminated object manufacturing, Stereolithography, Micro- and nano- additive manufacturing processes; Modelling in Additive Manufacturing Transport phenomena models: temperature and fluid flow, molten pool formation, Various case studies - modelling of fusion based AM process, powder bed melting based process, droplet based printing process; Applications of Additive Manufacturing in Aerospace, Automotive, Electronics industries and Biomedical applications

#### **MM ZC449 IoT in Manufacturing 4**

Safe work practices and workplace safety, Industrial revolution 4.0, Forces behind Industry 4.0 (IoT, big data and cloud computing, robotics and artificial intelligence), Connected factories (what is connected factory and criteria for connected factory), Smart devices and smart products,

cyberphysical system, definition; cps in manufacturing, Connecting devices with each other and with internet, Data acquiring and collection, Communication technologies (WIFI, IEEE 802.15.4), RFID, QR codes and cellular technologies, Protocols, Hardware in IoT, Software (IDE), Cloud platform, Smart devices and control system, Connectivity and networking in IoT, Smart eyes on shop floor, Integrating smart into existing, Programming using IoT, Case study and implementation.

#### **MM ZC472 Precision Engineering 3**

Concept of accuracy, accuracy of numerical control systems, tolerances and fits, acceptance tests for machine tools, static stiffness and its influence on machining accuracy, inaccuracies due to thermal effects, influence of forced vibrations on accuracy, dimensional wear of cutting tools and its influences on accuracy, clamping and setting errors, location principles and errors due to location, surface roughness and microfinishing processes, dimensioning and dimensional chains, methods of improving accuracy and surface finish, thread and gear measuring instruments, coordinate measuring machines, introduction to computer aided tolerancing.

#### **MM ZG512 Manufacturing Strategy 4**

Corporate strategy; Missing links in manufacturing strategy; Audit approach; Restructuring; Manufacturing strategy process in practice; Formulation as a process; Operating strategies; Methodology framework; Lean production; Competitive priorities; Strategic value of response time and product variety; Flexibility in context of manufacturing strategy; Manufacturing focus; Business process reengineering; Theory of constraints; Link between strategy and organizational culture; Evolution of manufacturing systems; Operations management strategic perspective.

#### **MM ZG513 Maintenance Engineering 5**

Introduction, maintenance systems, methods and tools of maintenance analysis, reliability and safety, maintainability, supportability, design for maintenance, maintenance integration computerized maintenance management systems, TPM, world-class maintenance systems, and maintenance effectiveness and performance evaluation.

#### **MM ZG514 Leadership and Managing Change 4**

Individuals as leaders, team leadership and organizational leadership. Introduction to managing change, management of change: organizational structure, culture, recruitment, performance management, human resource development, reward management, employee relations and involvement, downsizing, and evaluating and promoting.

#### **MM ZG515 Quantitative Methods 4**

Basic concepts in Operations Research; Analytical & Mathematical Modeling Techniques; Model Building; Inventory Control, queuing theory; Linear Programming; Transportation and assignment problems, simulation, index numbers, decision theory, etc.

#### **MM ZG522 Total Quality Management 4**

TQM principles and practices; leadership; customer satisfaction; employee involvement; continuous process improvement; supplier partnership; performance measures; statistical process control; ISO 9000; benchmarking; quality function deployment; concurrent engineering; experimental design; Taguchi's quality engineering; product liability

#### **MM ZG523 Project Management 4**

Concepts and techniques of project formulation, evaluation and implementation; Project planning and scheduling; Risk management; Time-cost trade off; Resource leveling and allocation; Project monitoring and control; Contract management.

#### **MM ZG533 Manufacturing Planning & Control 5**

Planning and control of manufacturing operations; material flow planning; product and process planning; demand forecasting and forecasting models; facility location; plant layout planning and design; machine cells; capacity planning; designing work methods; material handling; line balancing; aggregate planning; inventory models and systems for independent demand; materials requirements planning; elements of monitoring and production control; current developments in operations management.

#### **MM ZG534 Sustainable Manufacturing 4**

Introduction to sustainable manufacturing, sustainable manufacturing design, practice and matrices, life cycle management and assessment, end of life (EOL) strategies, implementation framework, sustainable business models, waste minimization, case studies.

#### **MM ZG535 Decision Analysis 4**

Introduction to quantitative techniques and statistics, Decision making, intelligence design and choice phases, basic theory of decision making under uncertainty; decision trees, qualification of judgments and preferences, Bayes theorem, the structuring of complex decisions, and multi-attribute utility theory. Statistical estimation and forecasting.

#### **MM ZG537 Lean Manufacturing 5**

Course description to be developed.

#### **MM ZG539 Six Sigma 4**

History of Six Sigma, Implementing Six Sigma, Becoming a Customer and Market-Driven Enterprise, Customer Expectations and Needs, Linking Six Sigma Projects to Strategies, Attributes of Good Metrics, Using resources wisely, Project Management Using the DMAIC and DMADV Models, The Define Phase, The Measure Phase, Measurement System Analysis, Analyzing Data: Value Streams and Dealing with Variations, Designing Experiments, The Improve Phase, The Control Phase.

#### **MM ZG541 Product Design 5**

Introduction to creative design; user research and requirements analysis, product specifications, Computer Aided Design; standardization, variety reduction, preferred numbers and other techniques; modular design; design economics, cost analysis, cost reduction and value analysis techniques, design for production; human factors in design: anthropometric, ergonomic, psychological, physiological considerations in design decision making; legal factors, engineering ethics and society.

#### **MM ZG611 Strategic Management & Business Policy 4**

Strategic management elements; internal, external, external environment. assessment of corporate strengths, weaknesses and opportunities; planning and deployment of capital assets; profit planning and control functions problems, pressures, responsibilities, limits of the chief executive; evaluation of one's own business undertaking; formulating objectives, strategies, policies and programmes for improving company's present situation; personnel strength and implementation of the policies and programmes, development, implementation, evaluation and control of strategies, strategic management of MNCs, management style and behavior, corporate style, behavior and culture.

**MM ZG621 Supply Chain Management 4**

Customer driven strategies in production and distribution systems; Integrated production and distribution networks; SCM in the context of JIT and MRP-II; Distribution Resource Planning; Management of dealer networks; Total Control & Product innovation across the supply chain; Incoming logistics and supplier relationships; Value addition analysis; Metrics for management of supply chain performance; Mathematical models and computer assisted decision support for SCM; Mathematical programming for SCM.

**MM ZG627 Managerial Corporate Finance 4**

Introduction to corporate finance; financial statements - analysis and interpretation; value creation – ways and means; time value of money; risk and return; understanding and analyzing various cost concepts and behaviour; analysis and impact of leverage; cost of capital; project appraisal and management - emphasis on technology projects (Diamond framework: NTPC - Novelty, Technology, Pace and Complexity); dimensions of adaptive technology project management; measuring and controlling assets employed in a project; project risk analysis; management control of projects; project financing – leasing and hire purchase; management control system - budget preparation; analyzing financial performance reports (variance analysis) and performance measurement system; working capital management – managing operating capital.

**MM ZG628 TD Dissertation 16**

A student registered in this course must take a topic in an area of professional interest drawn from the on the job work requirement which is simultaneously of direct relevance to the degree pursued by the student as well as to the employing / collaborating organization of the student and submit a comprehensive report at the end of the semester working under the overall supervision and guidance of a professional expert who will be deemed as the supervisor for evaluation of all components of the dissertation. Normally the Mentor of the student would be the Dissertation supervisor and in case Mentor is not approved as the supervisor, Mentor may play the role of additional supervisor. The final grades for dissertation are Non-letter grades namely Excellent, Good, Fair and Poor, which do not go into CGPA computation.

**MT\* ZC112 Electrical and Electronics Technology 3**

Electric circuit, electromagnetism, magnetic circuit, electrostatics, AC voltage and current, single phase circuits, semiconductor devices, amplifiers, digital systems, microprocessors, DC machines, polyphase circuits, transformers, synchronous machines, induction motors, power electronics, measurements, illumination.

**MT\* ZC213 Engineering Measurements 4**

Performance characteristics of measuring instruments, measurement methods for mechanical, electrical, radiant, chemical, magnetic and thermal energy variables. Emphasis in this course shall be on the operation and use of instruments.

**MT\* ZC221 Computer Programming 4**

Elementary computer organization; introduction to Number Systems; Representation of integers, real numbers and characters on computers; concept of range and accuracy; Arithmetic Overflow; Algorithms and algorithm development; structured program development through step wise refinement. Introduction to C language; Functions; Recursion; Data structure & algorithms; File management & file handling; Problem solving using C.

**MT\* ZC231 Principles of Management 3**

Fundamental concepts of management - planning; organizing; staffing; directing and controlling; production, financial, personnel, legal and marketing functions; accounting and budgeting, balance sheets.

**MT\* ZC233 Calculus 4**

Limits, continuity, differentiation, integration, Fourier series, ordinary differential equations for initial and boundary value problems, solution through Laplace transforms, numerical solution using Picard's iteration and higher order methods, partial derivatives, partial differential equations, analytical solution techniques.

**MT\* ZC234 Maintenance & Safety 3**

Basic maintenance systems and practice; maintenance planning; estimating and budgeting; scheduling maintenance jobs; importance of safety; factors affecting safety; safety aspects of site and plant; hazards of commercial chemical reaction and operation; instrumentation for safe operation; safety education and training; personnel safety; disaster planning and measuring safety effectiveness; future trends in industrial safety; maintenance of components and equipments; new dimensions in maintenance covering plant engineering, tribology, materials technology, terotechnology (life cycle costing) etc.; extensive case studies.

**MT\* ZC235 Linear Algebra & Optimization 3**

Vector and matrix algebra, systems of linear algebraic equations and their solutions; eigenvalues, eigenvectors and diagonalization of matrices; Formulation of linear programming problems, Simplex method, Big-M method, two phase method, Sensitivity analysis, Revised and Dual Simplex Methods.

**MT\* ZC236 Engineering Materials 3**

Mechanical, electrical, electronic and chemical properties and applications of common engineering materials; ferrous and non-ferrous metals and alloys; thermosetting and thermoplastic plastics; natural and synthetic resins; rubber; glass; abrasives and ceramics; common building materials, namely, timber, stone, lime and cement; corrosion of metals and methods of preventing corrosion; protective and decorative coatings; insulating materials; testing of materials.

**MT\* ZC241 Technical Report Writing 3**

Elements of effective writing; art of condensation; business letter writing; memos; formal reports; technical proposals; conducting, and participating, meetings; agenda and minutes; strategies for writing technical descriptions, definitions, and classifications; oral presentation; use of graphic and audio-visual aids; editing.

**MT\* ZC245 Fluid Mechanics and Machines 4**

Introduction and fundamental concepts, fluid statics, kinematics and dynamics of fluid flow, inviscid flows, pipe flow and network design, open channel flow, incompressible viscous flow, laminar boundary layers, turbulent flows, essentials of compressible flow, dimensional and model analysis, orifice, venturi, notches and weirs, hydraulic turbines, centrifugal and reciprocating pumps, fluid couplings and torque converters, compressors.

**MT\* ZC251 Mechanical Technology 4**

Fundamental concepts of heat, work and energy; second law of thermodynamics; properties of gases and vapors; basic cycles; flow of liquids; steam boilers; steam engines and pumps; steam turbines and condensers; hydraulic pumps and turbines; internal combustion engine.

**MT\* ZC261 Mechanics of Solids 3**

Fundamental principles of mechanics; introduction of mechanics of deformable bodies; forces and moments transmitted by slender members; stress and strain; stress-strain-temperature relations; torsion; stresses and deflections due to bending; stability of equilibrium.

**MT\* ZC311 Automobile Technology-I 4**

Introduction; working and construction of IC Engines; its components; cycles; fuel air cycle; diesel cycles; combustion in SI and CI Engines; fuels and combustion; fuel supply systems; scavenging process; engine cooling and lubrication; engine cooling system, friction and lubrication, engine testing



and performance; super charging, analytical method of performance and estimation; emission controls; alternate fuels; modern trends in engine development. Virtual demonstration of automobile parts and assemblies may be demonstrated. Some amount of Pro/Engineer (CREO) modeling of automobile structures may be practiced.

**MT\* ZC312 Automobile Technology-II 4**

Vehicle classification; chassis construction; clutches-friction clutches, fluid coupling; gear box arrangement and design of gear boxes; epicyclic gear box; torque converters, semiautomatic and automatic gear boxes; propeller shaft; universal joint; differential; rear axle suspension systems; front axle and steering mechanisms – power steering mechanism; brakes – mechanical, hydraulic and air brakes; servo and power operated brake systems; wheels and tyres; testing and performance of automobiles; vehicle vibration; and human comfort; auto-electrical systems; ignition system-conventional and electronic system, alternators; charging system; storage batteries; wiper motors; lighting system; electrical vehicles; automobile law. Virtual demonstration of automobile parts and assemblies may be demonstrated. Some amount of Pro/Engineer (CREO) modeling of automobile structures may be practiced.

**MT\* ZC315 Casting and Welding 4**

Casting: fundamentals of casting processes, design of castings, furnaces, foundry mechanization, special casting processes, economics of casting, inspection and defects of casting. Powder metallurgy: introduction, methods of powder production, characteristics and properties of powder, manufacturing methods, furnaces, finishing processes, economics of powder metallurgy. Welding: various welding processes, design for welding, safe practices in welding, inspection and defects of welding, economics of welding, brazing and soldering. Virtual simulation of casting and welding processes.

**MT\* ZC316 Transport Phenomena 4**

Fundamental concepts of fluid flow, concept of momentum transfer, Newton's law of viscosity, Continuity and Bernoulli's equation, concept of pressure drop and drag; Heat transfer: steady state and unsteady state heat conduction; analytical and empirical relations for forced and free convection heat transfer; heat exchanger analysis and design, heat transfer by radiation; Elements of mass transfer; one dimensional compressible flow; associated laboratory on condenser, boiler, economizer, super heater etc.

**MT\* ZC324 Mechatronics & Automation 4**

Introduction to mechatronics, sensors and transducers, Concepts of measurement of electrical and nonelectrical parameters; displacement, force, pressure etc. and related signal conditioning techniques, pneumatic and hydraulic actuation systems, mechanical actuation systems, electrical actuation systems, digital logic, microprocessors and programmable logic controllers; Introduction to automation, control loops for numerical control systems, adaptive control systems, industrial robots, automatic identification and data capture, automated production lines and automated assembly systems, System design concepts through case studies. Virtual demonstration of mechatronics elements, their assembly to obtain devices and products etc.

**MT\* ZC331 Production Planning & Control 4**

Types of production systems and problems of planning and control, product planning, forecasting, product demand, process planning, project management, capacities location and layout of facilities, aggregate planning and scheduling, materials requirement, planning, inventory management, systems and recent trends in production management. Simulations using software tools such as FlexSim or Quest may be conducted.

**MT\* ZC332 Operations Research 4**

Sampling, simulation, design of experiments and analysis of variance, nonparametric tests; correlation and regression analysis; quality control, reliability; decision theory; queuing theory; deterministic and probabilistic inventory systems. FlexSim and Lingo/Lindo based virtual simulations.

**MT\* ZC342 Machine Design 4**

Fundamentals and principles of design, design and selection of machine elements such as shafts, spindle supports, gears, bearings; etc.; design of mechanism; design of machine tool structure; dynamics of machine tools; introduction to CAD, CAM, CIM; Design of jigs and fixtures; press tools for blanking; punching; drawing; combination tools and progressive tools. Machine Drawing of part and assembly drawing using Pro/Engineer (CREO) or similar software tools are to be conducted.

**MT\* ZC343 Materials Management 4**

Integrated materials management, policy aspects, purchasing management, warehousing and storage of inventory control systems; stores management; material planning, make or buy decisions; scheduling, strategic sourcing, JIT, Kanban system; inventory costing principle; concept of MRP II; vendor development; central excise, customs, importing, sales tax. FlexSim/Quest based simulations.

**MT\* ZC344 Metal Forming and Machining 4**

Metal forming: introduction, metal forming machines, metal forming process analysis and design. Machining: introduction, metal cutting machine tools, mechanics of metal cutting, other aspects of machining processes, grinding and finishing operations, non-conventional machining processes and processing of plastics. It may consist of virtual practical work using software tool CNC Simulator-Pro (<http://cncsimulator.info/>). Similarly, we need to get metal forming process animations in 3DS-Max, Maya or similar software tools. Virtual simulation of metal forming and machining processes.

**MT\* ZC411 Tool and Fixture Design 3**

Tool-design methods, tool making practices, tooling materials and heat treatment, design of cutting tools, gages and gage design, locating and clamping methods, design of drill jigs, design of fixtures, design of sheet metal blanking and piercing dies, design of sheet metal bending, forming and drawing dies, using plastics as tooling materials, tool design for numerically controlled machine tools and automatic screw machines.

**MT\* ZC412 Flexible Manufacturing Systems 4**

Introduction CAD/CAM systems, overview of FMS, system hardware and general functions, material handling system, work holding systems, cutting tools and tool management, physical planning of system, software structure functions and description, cleaning and automated inspection, communications and computer networks for manufacturing, quantification of flexibility, human factors in manufacturing, FMS and CIM in action (case studies), justification of FMS, modelling for design, planning and operation of FMS. FlexSim/Quest based simulations.

**MT\* ZC418 Lean Manufacturing 4**

Fundamentals of continuous improvement, value added and waste elimination, elements of lean production: small lot production, setup time reduction, maintaining and improving equipment, pull production systems, focused factories and group technologies, work cells and cellular manufacturing, standard operations, quality of design, systems for eliminating defects, simplified production planning and control systems: scheduling for smooth flow, synchronizing and balancing process, planning and control in pull production, beyond the production systems: managing the supply chain, activity based costing, performance measurement. Logistics case studies using software tools such as FlexSim may be conducted.

**MT\* ZC421 Essentials of Project Management 3**

Programmes project management, project manager: role and responsibilities, project management and organization, project planning and scheduling, graphical techniques and PERT, CPM, price estimation and cost control; proposal, control valuation monitoring and trade off analysis in a project environment, pitfalls and future scenario.

#### **MT\* ZC432 Computer Aided Manufacturing 3**

Introduction, features of NC machine tools, NC part programming, CAM system devices, interpolators for manufacturing systems, control loops of NC systems, computerized numerical control, adaptive control systems, CAD to CAM, CAPP, industrial robots, computer aided production planning & control, computer aided inspection and quality control, CIM systems.

#### **MT\* ZC434 Quality Control, Assurance & Reliability 4**

Basic concepts of probability and probability distributions, standard probability distribution, sampling and sampling distributions, confidence intervals, testing significance, statistical tolerance, various types of control charts, statistical process control techniques, value analysis, defect diagnosis and prevention, basic concepts of reliability, reliability design evaluation and control, methods of applying total quality management, production process. Practical assignments on statistical quality control using suitable statistical software tools such as R-software, MS Excel, SAS, Minitab or SPSS.

#### **MT\* ZC448 ADDITIVE MANUFACTURING 4**

Introduction to Additive Manufacturing, CAD for Additive Manufacturing; Material Science Aspects in Additive Manufacturing, Different materials used in AM, Use of multiple materials, multifunctional and graded materials in AM, Role of solidification rate; Various Additive Manufacturing Processes Powder-based AM processes involving sintering and melting, Printing processes (droplet based 3D printing), Fused deposition modelling (FDM), Laminated object manufacturing, Stereolithography, Micro- and nano-additive manufacturing processes; Modelling in Additive Manufacturing Transport phenomena models: temperature and fluid flow, molten pool formation, Various case studies - modelling of fusion based AM process, powder bed melting based process, droplet based printing process; Applications of Additive Manufacturing in Aerospace, Automotive, Electronics industries and Biomedical applications

#### **MT\* ZC449 IoT in MANUFACTURING 4**

Safe work practices and workplace safety, Industrial revolution 4.0, Forces behind Industry 4.0 (IoT, big data and cloud computing, robotics and artificial intelligence), Connected factories (what is connected factory and criteria for connected factory), Smart devices and smart products, cyberphysical system, definition; cps in manufacturing, Connecting devices with each other and with internet, Data acquiring and collection, Communication technologies (WIFI, IEEE 802.15.4), RFID, QR codes and cellular technologies, Protocols, Hardware in IoT, Software (IDE), Cloud platform, Smart devices and control system, Connectivity and networking in IoT, Smart eyes on shop floor, Integrating smart into existing, Programming using IoT, Case study and implementation.

#### **MT\* ZC452 Composite Materials and Design 4**

Introduction to composites, concepts of reinforcement, strengthening mechanisms, fibrous reinforcements, matrix materials, micromechanical aspects of composites, manufacturing methods, composite production design methods design of tensile members, pressure vessels, storage tanks, and other chemical process equipment made of FRP, design of joints, damage of composites by impact, FRP grids, recent development in manufacturing of composites and technologies. Simulation of mechanics of composite materials using suitable software tools.

#### **MT\* ZC471 Manufacturing Excellence 4**

Introduction, frameworks of manufacturing excellence, practices for manufacturing excellence: leadership and change management, manufacturing strategy, innovative product planning, total productive maintenance, total quality management, lean manufacturing, customer relations management, green manufacturing, supply chain management, knowledge management and social responsibility. FlexSim/Quest based simulations.

#### **PCAM\* ZC211 Regression 2**

Regression as a type of supervised learning technique where the target attribute is a continuous variable; regression models from theoretical and implementation perspectives. Model selection and performance measures; Issues with regression models such as overfitting and the ways of combatting overfitting like ridge and lasso regression; Interpretability/explicability of the models;

#### **PCAM\* ZC111 Feature Engineering 1**

Feature Engineering as a step to develop and improve performance of Machine Learning models; Data wrangling techniques that help transforming the raw data to an appropriate form for learning algorithms; Data preprocessing techniques such as normalization, discretization, feature subset selection etc. and dimension reduction techniques such as PCA. Different ways of visualizing the data such as Box plots, Contour plots, Heat maps etc.

#### **PCAM\* ZC311 Classification 3**

Classification is a type of supervised learning techniques where the target attribute takes discrete values; Three types of techniques to solve classification problems – discriminant function, generative, and probabilistic discriminative approaches. Algorithmic perspective of popular classification algorithms - k-NN, Naïve Bayes, Decision Tree, Logistic Regression and SVM. Implementation details of these models along with tuning of parameters. Ensemble methods, bagging, boosting, Random Forest and eXtreme Gradient Boosting. Interpretability/explicability of the models;

#### **PCAM\* ZC221 Unsupervised Learning and Association Rule Mining 2**

Unsupervised learning algorithms for finding regularities in the absence of explicit labels or supervised outputs; Clustering as an unsupervised learning task to find natural grouping in the data. Various clustering algorithms such as K-Means, EM Algorithm, Single Linkage Algorithm, Complete Linkage algorithm and DBSCAN. Various ways of assessing the quality of clustering and detecting outliers. Typical industrial applications of unsupervised learning algorithms; Introduction to HMM in the context of performing time series prediction; role of EM algorithm in estimating the parameters. Algorithms to learn association or discover dependencies between the data items; Apriori algorithm and different metrics to measure the interestingness of the rules.

#### **PCAM\* ZC231 Text Mining 2**

Unstructured or semi structured data and their forms; Extracting the relevant text data and identifying patterns therein. Converting documents to vectors using TF-IDF, Parts of Speech Tagging, Topic modelling using LDA, sentiment analysis and recommender systems.

#### **PCAM\* ZC241 Deep Learning and Artificial Neural Networks 2**

Details of neural networks as well as deep learning architectures. An algorithmic perspective and implementation details of ANN, RNN, LSTM, CNN, RCNN, Faster RCNN, Autoencoders, Generative deep learning models like Boltzmann Machine, Deep Belief Machines and GAN etc.

#### **PCAM\* ZC321 Capstone Project 3**

Real life problems encompassing a typical data science pipeline obtained from organizations/third party vendors; Jointly mentored by the industry experts and faculty; Comparative study of the relevant techniques covered in the

course; Presenting the results in the required format; Fortnightly review of progress of the project.

**PCGM\* ZC411 Marketing 4**

Definition and scope, consumer behavior, competitive behavior, demand estimation, new product introduction, product/brand management, pricing policies, channels of distribution, credit management, advertising and other sales promotion, positioning, marketing regulation, market research basics of industrial marketing.

**PCGM\* ZC415 Financial and Management Accounting4**

Basic concepts, double entry accounting, journal, ledger, trial balance, profit & loss account, balance sheet, cash flow statement, financial statement analysis, ratio analysis, cost-volume-profit analysis, inventory valuation, inflation accounting, cost accounting and budgetary control systems, financial analysis and forecasting.

**PCGM\* ZC417 Quantitative Methods 4**

Grouping data, measures of central tendency and dispersion, probability distribution, sampling and estimation, testing hypotheses, chi-square and analysis of variance, regression and correlation, non-parametric methods, time series and forecasting, index numbers, decision theory, linear programming, transportation and assignment problems, queuing theory, network problems, simulation; application of statistical software (SYSTAT, SPSS, SIMULA8, etc.) and spreadsheets.

**PCGM\* ZC416 Managerial Economics 4**

Fundamental concepts, supply, demand, market mechanism; theory of demand (consumer behaviour); production, costs (theory of the firm); market structures (perfect competition, monopoly, monopolistic competition, oligopoly); circular flow of income, national income accounting, national income determination; money and banking, employment, interest, inflation, economics of information, problem of adverse selection, moral hazard problem, market failure, externalities, public goods.

**PCMP\* ZG511 Managing People & Organizations 4**

Concepts and principles of management as applied to a variety of organizations; study of managerial roles, styles, activities and decision making; relationship with organizational effectiveness; planning activities, leadership & control; manpower development; organizational behavior and theory.

**PCMP\* ZG526 Operations Management 4**

Operations strategy; process view vs. functional view in operations; factors in product and process design and selection; facility configuration; demand planning and forecasting; capacity planning; aggregate planning; planning service operations; productivity of operations; inventory planning and independent demand systems; materials requirements planning; quality management; uncertainty and variability; project management; current developments in operations management.

**PCMP\* ZG537 Lean Manufacturing 5**

Course description is same as given under MBA ZG537

**PCMP\* ZG522 Total Quality Management 4**

TQM principles and practices; leadership; customer satisfaction; employee involvement; continuous process improvement; supplier partnership; performance measures; statistical process control; ISO 9000; benchmarking; quality function deployment; concurrent engineering; experimental design; Taguchi's quality engineering; product liability.

**PDBA\* ZC413 Analytics for Competitive Advantage4**

In today's competitive business environment, high performing companies are doing more than just collecting data, storing it and generating reports. They are developing competitive strategies using Business Analytics. In this course we will look at how to use data-driven insights to differentiate a firm's

business/ product strategy from other companies that are making the same product or delivering the same service. This course is designed for analysts in any function: marketing, operations, quality, customer service, IT, finance/accounting or human resources. We will use case studies and other experiential components to study the application of data-driven insights in the context of various industries.

**PDBA\* ZC417 Quantitative Methods 4**

Grouping data, measures of central tendency and dispersion, probability distribution, sampling and estimation, testing hypotheses, chi-square and analysis of variance, regression and correlation, non-parametric methods, time series and forecasting, index numbers, decision theory, linear programming, transportation and assignment problems, queuing theory, network problems, simulation; application of statistical software (SYSTAT, SPSS, SIMULA8, etc.) and spreadsheets.

**PDBA\* ZG512 Predictive Analytics 4**

Basic concepts in predictive analytics / predictive modeling. Two core paradigms for predictive modeling: classification and regression. Identification of important variables and their relation to each another. Basic modeling techniques such as k-nearest neighbors, classification and regression trees (CART), and Bayesian classifiers. Ensemble techniques. Model selection techniques.

**PDBA\* ZG517 Financial Analytics 4**

Different sources of Financial Data, Statistical characteristics of financial data, Distributions of Financial Data, Statistical Applications in Finance, Exploratory Data Analysis, Modelling using Financial Statements Data, Modelling stock price behavior, Modelling Credit Default using classification algorithms, Introduction to Machine Learning algorithms for price forecasting and Portfolio Modelling, Introduction to Monte Carlo Bootstrapping, simulation and cross validation, Sentiment Analysis in Finance.

**PDBA\* ZG523 Project Management 4**

Concepts and techniques of project formulation, evaluation and implementation; Project planning and scheduling; Risk management; Time-cost trade off; Resource leveling and allocation; Project monitoring and control; Contract management.

**PDBA\* ZG536 Foundations of Data Science 4**

Introduction, Role of a Data Scientist, Statistics vs. Data Science, Fundamentals of Data Science, Data Science process and life cycle, Exploratory Data Analysis, Data Engineering and shaping, Overview of Data Science Techniques and Models, Introduction to Regression, Classification, Shrinkage, Dimension Reduction, Tree-based models, Support Vector Machines, Unsupervised learning, Choosing and evaluating models, Featurization, Overview of Neural Networks, Data mining, and pattern recognition techniques, Documentation, Deployment, and Presentations of the insights

**PDBA\* ZG538 Advanced Statistical Methods 4**

Point and interval estimation and hypothesis testing, chi-square tests, non-parametric statistics, analysis of variance, regression; linear and multiple linear, correlation, factor models, decision theory, Bayesian statistics and autocorrelation, multivariate regression, randomization and sampling processes, Markov processes with discrete/continuous state space, statistical simulation and pattern recognition, Time Series Analysis.

**PDBA\* ZG539 Data Visualization and Communication4**

Need for visualization, Presentation and visualization of data for effective communication, the importance of context and audience, choosing an effective visual, Visualizations of a single number, Visualizations for comparisons, Displaying relative performances, Visualizing survey results,

Visualizations for Ranking and Branching, Visualizations for parts of a whole, Visualizing correlations and regression, Visualizing Qualitative Data, Visualizing Trends, Tree-based visualizations, Visualizing Geo Data, Techniques for visualization of high dimensional data & discovered patterns, Common mistakes in dashboards, Visual perception, Create interactive Dashboards and Stories.

**PDBA\* ZG563 Analytics for HR 4**

Leveraging analytic techniques in the context of the challenges faced by the HR and Talent Acquisition and Management functions. Applying analytical techniques to deliver meaningful insights for effectively managing employees for achieving the goals of the organization. Attracting right talent, forecasting future staffing needs, managing attrition and improving employee satisfaction levels. Case Studies, simulations, hands-on exercises using tools like R or Python.

**PDBA\* ZG564 Models in Marketing 4**

Introduction to Marketing Models, Models of consumer behavior, industrial buying and firm behaviour, (aggregate) market models (e.g., competition, market entry), strategic marketing models, forecasting methods, new product models, marketing response models (e.g., channels, pricing, advertising, promotion), forecasting models and decision support systems. Case Studies, simulations, hands-on modeling.

**PDBA\* ZG565 Supply Chain Analytics 4**

Customer driven strategies in production and distribution systems; Integrated production and distribution networks; SCM in the context of JIT and MRP-II; Distribution Resource Planning; Management of dealer networks; Total Control & Product innovation across the supply chain; Incoming logistics and supplier relationships; Value addition analysis; Metrics for management of supply chain performance; Mathematical models and computer assisted decision support for SCM; Mathematical programming for SCM.

**PDBA\* ZG566 Analytics for Marketing 4**

Introduction to Marketing Research, Research Methodology, Problem definition, research design formulation, Field work and Data Collection, Data preparation and Analysis, Final report preparation and presentation, Case Studies, simulations, hands-on exercises using tools like R/ Python.

**PDBA\* ZG567 Analytics for Retail Industry 4**

RFM (measuring customer recency, frequency and monetary) Analysis, churn modeling, retention modeling, shopper analytics, market basket association analysis, customer segmentation and profiling, propensity scoring models to identify prospective customers, best customers, lifetime value modeling, marketing campaign response modeling, cross sell modeling, etc., Case Studies, simulations, hands-on exercises using tools like R/ Python.

**PDBA\* ZG568 Operations Research Models 4**

Practical application of OR tools. Application areas include: financial planning and portfolio selection, production, supply chain, priority planning and marketing. Linear programming and its applications; programming to achieve a set of goals or targets with applications in finance and production; capital budgeting and project selection; transportation and network models; and portfolio models, Case Studies, simulations, hands-on exercises using tools like R/ Python.

**PDBA\* ZG569 Analytics for Investment Banking4**

Modern portfolio theory, Capital Asset Pricing Model (CAPM), Arbitrage Pricing Theory (APT), and efficient market theory; Passive investing: indexing; behavioral finance; Active investing: security analysis – fundamental analysis (strategic, financial, marketing tools) and technical analysis; Portfolio management including allocation, rebalancing and risk management; Transaction cost analysis; Fixed-Income and

Credit Sensitive Instruments. Case Studies, simulations, hands-on exercises using tools like R/ Python.

**PDBA\* ZG570 Financial Risk Models 4**

Basics of financial risk, Its applications in the form of derivatives- Currency and interest rate derivatives, equity markets and products, commodity markets and products, Measuring and Analysing Volatility- EWMA, ARCH, GARCH, Volatility clusters and the issue of time-varying volatility, Extreme Value Theory, Correlation and Copula, Introduction to Multivariate Forecasting), VaR Computation, Stress testing, Monte Carlo simulation, address issues in generating price process (such as Brownian Motion, Ito Process), Cholesky decomposition in computing multi-asset VaR; Currency risk analysis in global investing, interest rate parity (covered and uncovered); Value at risk for fixed income Credit Risk Analytics Case Studies, simulations, hands-on exercises using tools like R/ Python.

**PDBA\* ZG571 Analytical Models in Finance 4**

Modelling and valuation of equity securities, fixed income securities, and derivatives, Introduction to Financial Modelling, and Spreadsheet Essentials, Measuring Risk (Testing market efficiency with regression analysis & pivot tables), Portfolio optimization (Mean-variance portfolio selection, Bond portfolio selection, Term structure estimation, Capital budgeting), Advanced risk analysis (Monte-Carlo simulation, Risk analysis of discounted cash flow models, Monte- Carlo simulation, Business and equity valuation modelling, LBO Analysis Model , Stock Merger Model, etc., Case Studies, simulations, hands-on modelling exercises.

**PDFI ZG517 Financial Analytics 4**

Different sources of Financial Data, Statistical characteristics of financial data, Distributions of Financial Data, Statistical Applications in Finance, Exploratory Data Analysis, Modelling using Financial Statements Data, Modelling stock price behaviour, Modelling Credit Default using classification algorithms, Introduction to Machine Learning for price forecasting and Portfolio Modelling, Introduction to Monte carlo simulation, Bootstrapping, cross validation, Sentiment Analysis in Finance

**PDFI ZG516 Introduction to FinTech 4**

Overview of FinTech, Current disruptions in Financial Services, Fintech in the Context of the Digital Economy, Landscape of Fintech, Disruptions in Asset Servicing, Disruptions in the Capital Markets, Disruptions in Investment Management, Alternative Data in Portfolio Management, Lending and Crowdfunding, Robo-Advisory, Overview of Technologies - Big Data, Machine Learning, and Artificial Intelligence, Cloud Computing, Future of FinTech.

**PDFI ZG558 Financial Risk Management 4**

Introduction to Financial Risk Management, Financial Institutions and their trading, Credit Crisis of 2008, Market Risk (Risk Management by traders, Interest rate risk, volatility, Correlation and Copulas, Value at Risk and Expected Shortfall, Historical Simulation and Extreme Value Theory, Model-Building Approach), Credit Risk (Estimating Default Probabilities, CVA, DVA, Credit Value at Risk), Regulation (BASEL I, II and III), Fundamental Review of the Trading Book, Scenario Analysis and Stress Testing, Overview of Operational Risk, Liquidity Risk, Economic Capital and RAROC.

**PDFI ZG561 Behavioural Finance 4**

Introduction, Rational Market Hypothesis, Foundations of Rational Finance (Expected Utility, MPT, CAPM, EMH), Challenges to rational behaviour, Heuristics, Cognitive Biases, Self-Deception, Prospect Theory, Mental Accounting, Emotional Factors, Challenges to Efficient Market Hypothesis, Investor Behaviour, Market Outcomes, Value Investing, Applications of Behavioural Finance, Introduction to Behavioural Corporate Finance.

**PDFI ZG562 Derivatives & Financial Engineering 4**

Introduction to derivatives market, forward, futures, options, swaps, Pricing and valuation of derivatives, options trading strategies, Elementary Stochastic calculus, binomial tree model, Black Scholes Merton model, option Greeks, Exotic Options, Volatility Smiles, credit risk, credit derivatives, credit default swaps, collateralized debt obligations, valuation of synthetic CDO, Interest rate derivatives.

#### **PDFI ZC415 Financial and Management Accounting 4**

Basic concepts, double entry accounting, journal, ledger, trial balance, profit & loss account, balance sheet, cash flow statement, financial statement analysis, ratio analysis, cost-volume-profit analysis, inventory valuation, inflation accounting, cost accounting and budgetary control systems, financial analysis and forecasting.

#### **PDFI ZG518 Multinational Finance 4**

Effective financial decision making in a multinational corporation; issues in global financial management, international monetary system, balance of payments, foreign exchange markets, international parity conditions, foreign currency options, transaction exposure, operating exposure, translation exposure, sourcing capital globally, foreign investment decisions, basics of multinational taxation, transfer pricing, principles of multinational capital budgeting, and managing multinational operations. Extensive use of case studies and simulations to connect theory with practice.

#### **PDFI ZG520 Security Analysis and Portfolio Management 4**

Introduction to investment and securities; profile of financial assets; new issue market or primary market, initial public offerings (IPO); secondary market; framework of risk & return; fundamental analysis- economy, industry; company analysis; stock evaluation models; multiple holding period and multiple growth rate; bond analysis and bond management strategies; technical analysis; efficient market theory; portfolio management; Markowitz model; Sharpe's Single Index model; capital asset pricing model; financial derivatives, options & futures.

#### **PDFI ZG521 Financial Management 4**

Concepts and techniques of financial management decision; concepts in valuation – time value of money; valuation of a firm's stock, capital asset pricing model; investment in assets and required returns; risk analysis; financing and dividend policies, capital structure decision; working capital management, management of cash, management of accounts receivable; inventory management, short and intermediate term financing, long term financial tools of financial analysis, financial ratio analysis, funds analysis and financial forecasting, operating and financial leverages.

#### **PDFI ZG560 Global Financial Markets and Products 4**

Capital markets; stock markets, bond markets, derivative markets; operations of these markets from a global perspective; Overview and features of key financial products, equities, fixed income securities and derivatives; bond features, indenture, coupon, maturity, YTM, zero coupon, valuation, duration, convexity; Equities, product features, basic valuation concepts; derivatives, forwards, futures, options, swaps, commodity derivatives, cost of carry, concepts, basic features, payoff, put call parity, basic option strategies; relevant case studies, simulations, modeling.

#### **PDFI ZG559 Management of Banks & Financial Institutions 4**

Overview and operation of financial institutions and banks; Commercial banking, Investment banking; Define, quantify, and manage various types of risks faced by financial institutions; asset liability management - overview, strategies; off balance sheet activities of banks; sovereign risk; deposit insurance; capital adequacy; study current best practices using selected case studies; bank management failures; insights from collapse of Lehman Brothers;

introduction to bank regulation; international considerations; relevant case studies, simulations, modeling.

#### **PDFI ZG519 Business Analysis and Valuation 4**

Theory of finance, value maximization, stakeholder theory, and corporate objective function: value creation – ways and means, business analysis: The techniques of strategy and competitive analysis, value chain analysis for competitive advantages, business valuation – approaches and methods, the dark side of valuation: strategic investment decisions.

#### **PDFI ZG528 Venture Capital & Private Equity 4**

This course will lay a strong foundation in core concepts, features and characteristics of the venture capital and private equity markets; specialized services provided by VC's and PE funds; stages in VC investing; deal flow; deal sourcing, evaluation; risk return tradeoff of VC/ PE investments; valuation of VC/ PE transactions; structuring and execution of deals; exit options, distributions; Course will make extensive use of case studies to understand industry best practices and current trends.

#### **PDFI ZG544 Mergers, Acquisitions, and Corporate Restructuring 4**

Basics of M&A (corporate finance, strategy, economics), merger types, trends; theories underlying M&A; legal aspects; evaluating an acquisition target; valuation of mergers and acquisitions, MVA, relative valuation, multiples, DCF, FCFF, FCFE; M&A deal structuring; synergy analysis; break-up valuation; sensitivity analysis; terms of merger; financing considerations; capital structure decisions; structuring and valuing of Leveraged Buy-out (LBO) transaction; financing considerations; exit strategies; extensive use of relevant case studies, simulations, modeling.

#### **PDFI ZG556 Advanced Risk Models 4**

Advanced VaR models, expected shortfall, stressed VaR, historical simulation, delta/ gamma models, full revaluation, risk factor selection, volatility clustering, structured Monte Carlo analysis, stress testing, scenario analysis, back testing; country and sovereign risk models; management of country and sovereign risks, external and internal credit ratings methodology and framework; expected and unexpected loss framework and related metrics; extensive use of relevant case studies, simulations, modeling.

#### **PDFI\* ZC417 Quantitative Methods 4**

Grouping data, measures of central tendency and dispersion, probability distribution, sampling and estimation, testing hypotheses, chi-square and analysis of variance, regression and correlation, non-parametric methods, time series and forecasting, index numbers, decision theory, linear programming, transportation and assignment problems, queuing theory, network problems, simulation; application of statistical software (SYSTAT, SPSS, SIMULA8, etc.) and spreadsheets.

#### **PDFI\* ZC419 Financial Risk Analytics 4**

The course will first cover the basics of Financial Risk and then focus on applications such as: currency, interest rate derivatives, equity markets and products, and commodity markets and products. Major topics include methodologies for measuring and analyzing volatility (a key metric of risk) including EWMA, ARCH & GARCH processes, volatility clusters and the issue of time varying volatility; Extreme value theory; Measuring risk using Value-at-Risk, including computation of VaR by various methods, and stress testing; Monte Carlo simulation, address issues in generating price process (such as Brownian Motion, Ito Process), Cholesky decomposition in computing multi-asset VaR; Currency risk analysis in global investing, interest rate parity (covered and uncovered); Value at risk for fixed income portfolios; Credit Risk Analytics. The topics covered in this course will have inbuilt case studies in financial risk management so as to understand the practical implications of the methodologies covered in the course.

**PDFT\* ZG516 Introduction to FinTech 4**

Overview of FinTech, Current disruptions in Financial Services, Fintech in the Context of the Digital Economy, Landscape of Fintech, Disruptions in Asset Servicing, Disruptions in the Capital Markets, Disruptions in Investment Management, Alternative Data in Portfolio Management, Lending and Crowdfunding, Robo-Advisory, Overview of Technologies - Big Data, Machine Learning and AI, Cloud Computing, Future of FinTech.

**PDFT\* ZG517 Financial Analytics 4**

Different sources of Financial Data, Statistical characteristics of financial data, Distributions of Financial Data, Statistical Applications in Finance, Exploratory Data Analysis, Modelling using Financial Statements Data, Modelling stock price behaviour, Modelling Credit Default using classification algorithms, Introduction to Machine Learning algorithms for price forecasting and Portfolio Modelling, Introduction to Montecarlo Bootstrapping, simulation and cross validation, Sentiment Analysis in Finance

**PDFT\* ZG521 Financial Management 4**

Concepts and techniques of financial management decision; concepts in valuation – time value of money; valuation of a firm's stock, capital asset pricing model; investment in assets and required returns; risk analysis; financing and dividend policies, capital structure decision; working capital management, management of cash, management of accounts receivable; inventory management, short and intermediate term financing, long term financial tools of financial analysis, financial ratio analysis, funds analysis and financial forecasting, operating and financial leverages.

**PDFT\* ZG527 Entrepreneurship in FinTech 4**

FinTech Themes, Changing landscape in raising capital, FinTech Hubs, Early stage funding, Integrated FinTech Ecosystems, Emerging Markets and Social Impact, Valuation of FinTech Firms, FinTech Solutions - Case Studies, Legal, Regulatory, Data privacy and Ethical aspects of FinTech startups, Capital and Investment for new businesses, Enterprise Innovation

**PDFT\* ZG529 Machine Learning for Finance 4**

Univariate and Multivariate Financial Time series and their characteristics, Applications of Support Vector Machines, Neural Networks and Gradient-Based Optimization, Applications of Tree based ensemble methods (Random Forests, Boosting), Dimension reductions using PCA and Auto Encoders, Feature Engineering, Cross validations, Credit Scoring, Predicting Bankruptcy, Fraud Identification models, Applications of Clustering Algorithms, Introduction to sequential Learning

**PDFT\* ZG530 InsurTech 4**

Digital Transformation in Insurance, Insurance of Things, From Insurance Premium to Discrete Event, Telematics, Collaborative Approach, InsurTech Value Chain, Business Models, Practical Robotics in Insurance, Claims Handling, Applications of Technology in Underwriting, New Business Generation and Policy Processing.

**PDFT\* ZG532 Deep Learning Applications in Finance 4**

Review of Machine Learning, Foundations of Neural networks and deep learning, Fundamentals of deep networks, Multilayer Perceptron, Convolutional neural networks (CNN), Recurrent neural networks (RNN) frameworks – LSTM, GRU. Hands on building Deep learning networks, Auto-encoders, Parameter tuning, Generative Adversarial Networks (GAN), Semantic Segmentation, Unsupervised Learning, Applications of Deep Learning in FinTech.

**PDFT\* ZG533 Technology Disruptions in FinTech 4**

Big Data in the Financial Services Industry, Internet of Things, Impact of IoT on Businesses, IoT in Financial Services, Cyber Security, Cybersecurity Categories and

Players, Data Privacy and Governance, Cloud Computing, Networks, Mobile Applications and Smart Phones

**PDFT\* ZG553 Block Chain and Applications 4**

Introduction, Evolution of Block chain, Building blocks of block chain, Smart contracts, Block chain Principles, Asset Monetization in Block Chain, Building a block chain network, Use cases of Block chain in different sectors across the world (Manufacturing and Industrial, Government and Public Sector, Consumer Goods and Retail Industry, Food Industry, Cryptocurrencies in detail), Limitations of existing block chains, Regulatory Aspects, Strategy to implement across the enterprise, Best Practices in implementing Block chain, Different types of Block chain architectures – Hyper Ledger, Ethereum, Future challenges.

**PDFT\* ZG554 Digital Banking and Beyond 4**

Traditional Banking landscape, First principles of Banking, Effect of Digital Technology, New Operating Models for Banking, Regulation vs. Innovation, Reframing identity through Technology, Embedded Banking, Banking Chatbots, From products and channels to experiences, Designing Digital banks without branches, Building Relationships through digital banking, Technologies enabling digital banking, Security, New economics of digital bank, Beyond digital banking, Role of AI and Big Data in Banking.

**PDFT\* ZG555 Algorithmic and High Frequency Trading 4**

Introduction to Algorithmic trading, Users of Algorithmic Trading, Currently Popular trading Algorithms, Algo trades for individual investors, Optimization, Stock personality clusters, Selecting a Cohort of Trading Stocks, Stock Profiling, Volatility, Alpha Algo strategies, Benchmarks and Performance Measures, Technical Analysis (TA), Heuristics, AI, Artificial Neural Networks and Other Avenues, From the Efficient Market Hypothesis to Prospect Theory, Mean Reversion strategies, Momentum strategies, risk management.

**PDFT\* ZG557 FinTech in Wealth Management 4**

Introduction, Traditional wealth management industry, Digitization in wealth management, Digitizing client advisory, Robo advisors, Gamification, Digitizing wealth management operations, Digital platforms, products and eco systems, Block chain applications in asset and wealth management, Algorithms of Automated Portfolio Rebalancing, Digital Financial Advisor, Future of Digital Advice, Personalize the Investment Experience, Future of wealth tech.

**PDFT\* ZG560 Global Financial Markets & Products 4**

Capital markets; stock markets, bond markets, derivative markets; operations of these markets from a global perspective; Overview and features of key financial products, equities, fixed income securities and derivatives; bond features, indenture, coupon, maturity, YTM, zero coupon, valuation, duration, convexity; Equities, product features, basic valuation concepts; derivatives, forwards, futures, options, swaps, commodity derivatives, cost of carry, concepts, basic features, payoff, put call parity, basic option strategies; relevant case studies, simulations, modeling.

**PDMM\* ZG511 Managing People & Organizations 4**

Concepts and principles of management as applied to a variety of organizations; study of managerial roles, styles, activities and decision making; relationship with organizational effectiveness; planning activities, leadership & control; manpower development; organizational behavior and theory.

**PDMM\* ZG522 Total Quality Management 4**

TQM principles and practices; leadership; customer satisfaction; employee involvement; continuous process improvement; supplier partnership; performance measures; statistical process control; ISO 9000; benchmarking; qualityfunction deployment; concurrent engineering;

experimental design; Taguchi's quality engineering; product liability.

**PDMM\* ZG526 Operations Management 4**

Operations strategy; process view vs. functional view in operations; factors in product and process design and selection; facility configuration; demand planning and forecasting; capacity planning; aggregate planning; planning service operations; productivity of operations; inventory planning and independent demand systems; materials requirements planning; quality management; uncertainty and variability; project management; current developments in operations management.

**PDMM\* ZG537 Lean Manufacturing 5**

Course description is same as given under MBA ZG537

**PDMM\* ZC411 Marketing 4**

Definition and scope, consumer behavior, competitive behavior, demand estimation, new product introduction, product/brand management, pricing policies, channels of distribution, credit management, advertising and other sales promotion, positioning, marketing regulation, market research basics of industrial marketing.

**PDMM\* ZC415 Financial and Management Accounting 4**

Basic concepts, double entry accounting, journal, ledger, trial balance, profit & loss account, balance sheet, cash flow statement, financial statement analysis, ratio analysis, cost-volume-profit analysis, inventory valuation, inflation accounting, cost accounting and budgetary control systems, financial analysis and forecasting.

**PDMM\* ZC416 Managerial Economics 4**

Fundamental concepts, supply, demand, market mechanism; theory of demand (consumer behaviour); production, costs (theory of the firm); market structures (perfect competition, monopoly, monopolistic competition, oligopoly); circular flow of income, national income accounting, national income determination; money and banking, employment, interest, inflation, economics of information, problem of adverse selection, moral hazard problem, market failure, externalities, public goods.

**PDMM\* ZC417 Quantitative Methods 4**

Grouping data, measures of central tendency and dispersion, probability distribution, sampling and estimation, testing hypotheses, chi-square and analysis of variance, regression and correlation, non-parametric methods, time series and forecasting, index numbers, decision theory, linear programming, transportation and assignment problems, queuing theory, network problems, simulation; application of statistical software (SYSTAT, SPSS, SIMULA8, etc.) and spreadsheets.

**PE\*ZC112 Electrical and Electronics Technology 3**

Electric circuit, electromagnetism, magnetic circuit, electrostatics, AC voltage and current, singlephase circuits, semiconductor devices, amplifiers, digital systems, microprocessors, DC machines, polyphase circuits, transformers, synchronous machines, induction motors, power electronics, measurements, illumination.

**PE\* ZC113 Probability and Statistics 3**

Probability spaces; conditional probability and independence; random variables and probability distributions; marginal and conditional distributions; independent random variables; mathematical expectation; mean and variance; binomial, Poisson and normal distributions; sum of independent random variables; law of large numbers; central limit theorem (without proof); sampling distribution and test for mean using normal and student's t-distribution; test of hypothesis; correlation and linear regression.

**PE\* ZC164 Computer Programming 4**

Basic Computing Steps and Flow Charting (Assignment, Sequencing, Conditionals, Iteration). Programming Constructs – Expressions, Statements, Conditionals, Iterators/Loops, Functions/ Procedures; Data Types – Primitive Types, Tuples, Choices (Unions or Enumerations), Lists/Arrays, Pointers and Dynamically Allocated Data. Input output and Files. Laboratory Component: Programming Exercises involving development and testing of iterative and procedural programs using bounded and unbounded iterations, function composition, random access lists, sequential access lists, dynamically allocated lists, and file access.

**PE\* ZC211 Principles of Management 3**

Fundamental concepts of management - planning; organizing; staffing; directing and controlling; production, financial, personnel, legal and marketing functions; accounting and budgeting, balance sheets.

**PE\* ZC213 Engineering Measurements 3**

Performance characteristics of measuring instruments, measurement methods for mechanical, electrical, radiant, chemical, magnetic and thermal energy variables. Emphasis in this course shall be on the operation and use of instruments.

**PE\*ZC214 Pharmaceutical Analysis 3**

Basic techniques of pharmaceutical analysis, data handling and analysis, sources of error in analysis. The analytical methods would comprise of various titrimetric methods, such as acid-base, complexometric, non-aqueous, oxidation-reduction, precipitation, conductometric; physical and instrumental analysis such as gravimetric, polarography, nephelometry, amperometry, turbidometry, potentiometry; chromatographic separations such as TLC, column, ion-exchange, extraction methods such as gel-filtration, fractionation processes, analysis of metallic and non-metallic elements; water content, as well as evaluation of drug constituents in various pharmaceutical preparation.

**PE\* ZC221 Disinfection & Sterilization Processes3**

Common sources of microbes, contamination methods; processes involved in disinfection of materials; enclosed space, sanitation; sterilization methods – dry heat, moist heat, air, filtration; aseptic processing, sterility testing, indicators and sampling methods; skin disinfection.

**PE\* ZC231 Engineering Materials 3**

Mechanical, electrical, electronic and chemical properties and applications of common engineering materials; ferrous and non-ferrous metals and alloys; thermosetting and thermoplastic plastics; natural and synthetic resins; rubber; glass; abrasives and ceramics; common building materials, namely, timber, stone, lime and cement; corrosion of metals and methods of preventing corrosion; protective and decorative coatings; insulating materials; testing of materials.

**PE\* ZC233 Calculus 4**

Limits, continuity, differentiation, integration, Fourier series, ordinary differential equations for initial and boundary value problems, solution through Laplace transforms, numerical solution using Picard's iteration and higher order methods, partial derivatives, partial differential equations, analytical solution techniques.

**PE\* ZC234 Manufacturing Processes 3**

Fundamentals of casting process; forging; powder metallurgy; soldering; brazing and welding technology; metal forming process, its analysis and design; Introduction to Metal cutting, machine tools; mechanics of metal cutting; other machining processes; grinding and finishing operations; non convention machining; chipless machining processes; NC machines programming; control system in CNC; CNC, DNC; FMS and machining center.

**PE\* ZC235 Linear Algebra & Optimization 3**

Vector and matrix algebra, systems of linear algebraic equations and their solutions; eigenvalues, eigenvectors and diagonalization of matrices; Formulation of linear programming problems, Simplex method, Big-M method, two phase method, Sensitivity analysis, Revised and Dual Simplex Methods.

**PE\* ZC241 Mechanical Technology 3**

Fundamental concepts of heat, work and energy; second law of thermodynamics; properties of gases and vapors; basic cycles; flow of liquids; steam boilers; steam engines and pumps; steam turbines and condensers; hydraulic pumps and turbines; internal combustion engine.

**PE\* ZC242 Thermodynamics& Kinetics 3**

Importance and Fundamental concepts of Thermodynamics, concept of states, systems, equilibrium, extensive and intensive properties, homogeneous and heterogeneous systems, First Law of Thermodynamics, Internal energy, heat capacity, isothermal, and adiabatic processes, Second law of Thermodynamics, criteria of equilibrium, Maxwell's relations, Gibbs-Helmholtz equation, Entropy, Kinetic Theory, Auxiliary Functions, Heat Capacity, Enthalpy, Phase Equilibrium in one component system, Concept of Third law, relation between  $C_p$  and  $C_v$ , Fugacity, equilibrium constant, use of  $\gamma$  - functions, Ellingham-Richardson diagrams, phase stability diagrams, Behaviour of Solutions, Thermodynamics of non-reacting mixtures, reaction rate theory, Introduction to metallurgical kinetics, heterogeneous reaction kinetics-gas-solid, solid-liquid, liquid-liquid and solid-solid systems, concept of Johnson-Mehl equation, effect of temperature on reaction rates, energy of activation, Solutions, partial molal quantities, ideal and non-ideal solutions, Henry's law, Gibbs - Duhem equation, regular solution, Change of standard state, Phase relations and phase rule, Free energy composition diagrams for binary alloy systems, determination of liquidus, solidus and solvus lines, Effect of pressure on phase transformation and phase equilibria.

**PE\* ZC252 Mineral Beneficiations and Agglomeration 3**

Early development in Metal Extraction, General methods of extraction, The necessity and methods of beneficiation, mineralogical assessment, Minerals and ores, refining, importance of mineral dressing, principles of flotation, Refractories, different comminution methods-fracture, Crushing and Grinding machines, liberation, size-criteria, energy-size relationships, crushing grinding and attrition, screening and classification, cyclones, concentration processes-density, electrical, magnetic separators and other physical methods, Interfacial phenomenon, surfactants, Flotation principles and froth floatation, liquid-solid separation-flocculation, thickening, classification, free and hindered settling, Dry and wet sizing, Jigging, surface chemistry of minerals, dewatering, Pollution in beneficiation plants, Agglomeration: Basic processes-Nodulization, briquetting, Pelletization, sintering, Material Balances in

process flows: Component and total mass balances of reactive and non-reactive systems including recycling, Batch and steady state flows, Unit Processes in pyrometallurgy: calcination, roasting, sintering, smelting, converting, distillation, Metallothermic reduction and hydrogen reduction, refining processes with examples for metals like copper, nickel, lead, zinc, etc. Unit processes in hydrometallurgy: leaching, purification of leach liquor, solvent extraction and ion exchange process, metal recovery from aqueous phase. Unit processes in electrometallurgy: Faraday's laws of electrolysis, concept of overvoltage, limiting current density, overall cell voltage, series and parallel electrical circuits in refining, Electrowinning and electrorefining with reference to Cu, Zn, Al, Mg.

**PE\* ZC262 Iron Making 3**

World production of Iron and steel, occurrence and distribution of iron ore, coal and limestone in India and world, General layout of integrated steel plant, Raw materials in ferrous production metallurgy, coke production, agglomeration of iron ores. Technology of blast furnace iron making - operational details, Study of blast furnace processes and blast furnace slag, Blast furnace reactions, Raceway, Cohesive zone, Thermodynamics of slag-metal reactions, high top pressure, oxygen enrichment, injection of auxiliary fuels. Blast furnace design, Furnace productivity, the coke rate, hot metal quality. Alternate routes of iron making, Temperature profile, Aerodynamics, different factors, Irregularities etc., Heat exchange zones in blast furnace.

**PE\* ZC272 Furnace Technology 3**

Conventional, non-conventional and newer sources of energy, energy management problems in metallurgical Industries, role of high temperature systems and materials, deposits, manufacturing, properties and testing of solid, liquid and gaseous fuels; Principles of fuel combustion and burner design. Classification of refractory, manufacturing and properties of common refractories such as silica, fire clay, high alumina, dolomite, magnesite and chrome refractories. Furnaces, Types, Design of high temperature furnaces, waste heat utilization, heat recuperators and refrigerators, stack design, gas cleaning, heat balance diagrams; furnace dynamics: fluid flow calculations, fuel fired furnaces, electric arc furnaces, vacuum, electron beam, plasma, laser furnaces.

**PE\* ZC311 Chemical Engineering Thermodynamics4**

Concept of heat and work, Ideal and real gas systems, Thermodynamic Laws, P-V-T behaviour of real gases, Concept of entropy, Heat effects, First and Second law analysis of processes including power plants and refrigeration systems, Thermodynamic Property relations, Vapour liquid equilibrium, Solutions thermodynamics: Theory and applications, Chemical Reaction equilibria, Special topics in Phase equilibrium, Role of thermodynamics in process simulation, Case studies.

**PE\* ZC312 Steel Making & Casting 3**

Fundamentals of Steel making, Historical development of steel making processes. Open hearth, basic oxygen, electric arc and induction furnace steel making, processes, Thermodynamics, kinetics and transport phenomena in steel making, Introduction to ladle metallurgy. Refining of Steel. Continuous Casting, near net shape making, clean steel practices, stainless steel making and emerging trends in steel making and continuous casting. Introduction to casting, Molding Equipment Processes, Molding Sand, Cores, Core Materials, Solidification of Metals.



**PE\* ZC313 Technical Report Writing 3**

Elements of effective writing; art of condensation; business letter writing; memos; formal reports; technical proposals; conducting, and participating, meetings; agenda and minutes; strategies for writing technical descriptions, definitions, and classifications; oral presentation; use of graphic and audio-visual aids; editing.

**PE\* ZC314 Power Plant Engineering 3**

Classification of power plants. Components and layout of; thermal, nuclear, hydroelectric power plants. Site selection for various power plants. Combined cycle power plants. Magneto Hydro Dynamics (MHD) systems. Economics of power generation, economic loading of power stations. Load curve analysis; load factor, diversity factor. Power plant instrumentation and controls.

**PE\* ZC316 Transport Phenomena- I 4**

Diffusional transport of fluid heat and mass (a comparison), Fluid statics, Laminar and turbulent flows, Boundary layer concept (hydrodynamic, thermal and concentration), Continuity equation, Bernoulli's equation, Introduction to equations of motion, Laminar and turbulent flow in pipes, concept of drag, packed beds and fluidization, steady state heat conduction, concept of heat transfer coefficient, convective heat transfer (forced and natural convection correlations), introduction to radiative heat transfer, interphase mass transfer and mass transfer coefficients, analogy between fluid flow, heat and mass transfer.

**PE\* ZC317 Transport Phenomena – II 4**

Transportation and metering of fluids (pumps, fittings, valves and compressors), flow measurement, Condensation and boiling, heat exchange equipment, absorption, concept of equilibrium stage operations, distillation, extraction selected operations like crushing, grinding, drying, filtration, evaporation, etc.

**PE\* ZC318 Fundamentals of Transport Processes 4**

Concept of momentum transfer, Newton's law of viscosity, Continuity and Bernoulli's equation, Concept of pressure drop and drag, Introduction to conduction, convection (free and forced) and radiation including Fourier's law of heat conduction, Newton's law of cooling, Stefan Boltzmann and Kirchhoff's laws, concept of resistance and lumped capacitance; Boundary layer theory (momentum, thermal and mass), Heat transfer correlations; Phase change heat transfer, Diffusion fundamentals including Fick's law, Interphase mass transfer, Concept of mass transfer coefficient, Momentum, heat and mass transfer analogies, Introduction to transport equations.

**PE\* ZC319 Unit Operations - I 4**

Pumps and compressors, Flow measurement devices, piping networks, Agitation and mixing, Packed and fluidized beds, Heat exchangers including boilers and condensers, LMTD, epsilon-NTU method, Co-current counter-current and cross flows, NTU – epsilon method for exchanger evaluation, Distillation, Absorption, Leaching, Humidification and drying, Cooling towers.

**PE\* ZC320 Unit Operations - II 4**

Sedimentation, Evaporation, Liquid – Liquid extraction, adsorption, Mechanical separations like filtration, centrifugation, froth floatation etc., Solid separations based on size reduction including sieving operations and related equipment like crushers, mills, pulverizers etc., special separation processes like ion-exchange, membranes, chromatography etc.

**PE\* ZC321 Chemical Process Calculations 3**

Properties of gases, liquids and solids; material and energy balances; elementary process analysis involving phase equilibria and chemical reactions; recycling and unsteady state processes; combustion calculations and typical industrial applications.

**PE\* ZC322 Process Design Principles 4**

Process invention using heuristics and analysis (The Design process, Process creation and heuristics for process synthesis), Sequencing of separation trains, concept of pinch technology and heat exchanger network analysis, Cost estimation and profitability analysis, Role of simulators in process engineering, Case studies.

**PE\* ZC323 Corrosion Engineering 3**

Corrosion principles: electrochemical aspects, environmental effects, metallurgical & other aspects; various forms of corrosion. Materials: metals and alloys, non-metallics (polymers and ceramics). Corrosion prevention: Materials selection, alteration of environment, design, cathodic and anodic protection, Coatings, Case Studies.

**PE\* ZC324 Chemical Reaction Engineering 3**

Ideal reactor concepts, design equations for batch and continuous reactors (constant and variable volume), Kinetics and interpretation of batch reactor data, Catalytic reactors including external diffusion and intra-particle diffusion effects, Non-ideal reactor concepts, Industrial reactor systems.

**PE\* ZC331 Quality Control Assurance & Reliability 3**

Basic concepts of probability and probability distributions, standard probability distribution, sampling and sampling distributions, confidence intervals, testing significance, statistical tolerance, various types of control charts, statistical process control techniques, value analysis, defect diagnosis and prevention, basic concepts of reliability, reliability design evaluation and control, methods of applying total quality management, production process.

**PE\* ZC342 Materials Management 3**

Integrated materials management, policy aspects, purchasing management, warehousing and storage of inventory control systems; appraisal and control; just in time (JIT); automation in materials management.

**PE\* ZC343 Industrial Pharmacy 3**

Pharmaceutical processes and equipment commonly used in pharmaceutical industries; drug extraction and clarification; mixing and granulation; pharmaceutical preparations such as aromatic waters, spirits, syrups, elixirs, lotions, liniments, official solutions etc.; galenical products like infusions, decoctions, tinctures, extracts, etc, glandular preparations and blood plasma substitutes.

**PE\* ZC344 Thermodynamics & Reaction Engineering 4**

Development and applications of the combined first and second laws; relations between state properties; chemical equilibria in reacting and non-reacting systems; Kinetics of homogeneous, heterogeneous reactions; ideal reactors; selectivity; analysis and design of chemical reactors.

**PE\* ZC345 Pharmaceutical Quality Control & Regulatory Affairs 3**

Course description to be developed.

**PE\* ZC352 Energy Management 4**

World and Indian Energy scenario including production, consumption and pricing, Energy conservation and its importance, Energy conservation act and its features, Energy Management and Audit including energy audit instruments, Energy action planning, Energy monitoring and targeting, Energy economics, Energy efficiency in thermal utilities, Energy efficiency in electrical utilities, Energy performance assessment for equipment and utilities, Application through case studies.

**PE\* ZC353 Industrial Engineering 3**

Industrial systems and organization; engineering economy; work measurement techniques; motivation and time studies; factory planning and materials handling; industrial standardization; critical path methods; quality control; reliability; maintenance and management planning; scheduling; job analysis (evaluation); value engineering.

**PE\* ZC361 Environmental Pollution Control 3**

Air and water pollutants; sampling and analysis; control methods for air & water pollutants; modeling of different control techniques; advanced wastewater treatment processes; solid waste management, noise pollution; case studies.

**PE\* ZC362 Steel Processing 3**

Introduction to metal casting, Moulding, materials and processes, patterns, sand and binders. directional solidification, rapid solidification. Solidification of short & long freezing range alloy castings, Gating and Riser of castings, Cupola, rotary furnace, induction furnace, crucible furnace melting, Introduction to cast alloys, classification, microstructures and properties of cast irons, plain carbon and Hadfield Manganese steels, Heat treatment of cast alloys, Casting defects and remedy, Special casting processes, Introduction to metal joining processes, welding, Fundamentals of metal working, Temperature, strain rate, friction & lubrication, Rolling, Classification & processes Forging, Extrusion, Drawing, cold working and warm working, Bulk and sheet metal forming, Mechanical and Hydraulic Presses, Stretching, drawing and bending of sheet metal, Metallurgical changes during metal working; thermo-mechanical processes. Slab analysis of plane strain and axisymmetric upsetting.

**PE\* ZC382 Cement Technology 3**

Indian & Global Cement Industries; Geological classification of rock; Geo-chemistry of lime stone; Crushing, Grinding and Raw material handling process; different type of milling systems and applications - Raw mill, Coal mill, Cement mill; Kiln system and process, Fuel and firing system, Clinker cooling, storage, grinding and packing; merging trends in cement manufacture.

**PE\* ZC385 Fertilizer Technology 3**

Introduction, fertilizer industry in India during last few decades; technology / production of fertilizer products such as intermediates, nitrogenous fertilizers, phosphatic fertilizers, potassic fertilizers, complex fertilizers; guidelines for mixing fertilizers.

**PE\* ZC383 Extractive Metallurgy 3**

Introduction, Methods of extraction and refining of metals, principles of pyrometallurgy, heat transfer and fluid flow, rates of metallurgical reactions, analysis of unit processes, principles of electro and hydrometallurgy.

**PE\* ZC411 Production Planning & Control 3**

Generalized model of production systems; types of production flows; life cycle concepts; facilities location and layout planning; aggregate and batch production planning; inventory systems; materials requirements planning; elements of monitoring & production control.

**PE\* ZC412 Process Equipment Design 4**

Process design of major fluid, heat and separation equipment including pumps and heat exchangers, Mechanical Design considerations and material of construction, Pressure vessel design, Storage vessel design, Design of flange and vessel heads, Mechanical design of specific equipment like heat exchangers, distillation columns etc., Case studies.

**PE\* ZC423 Essentials of Project Management 3**

Programmes project management, project manager: role and responsibilities, project management and organization, project planning and scheduling, graphical techniques and

PERT, CPM, price estimation and cost control; proposal, control valuation monitoring and trade off analysis in a project environment, pitfalls and future scenario.

**PE\* ZC423T ProjectWork 10**

Consistent with the student's professional background and work-environment, the student will be required to carry out a work-oriented project. At the beginning of the semester, the student should select an area of work that is considered vital to the sponsoring organization, and prepare a detailed project outline, in consultation with his/her Mentor. The student carries on with the work-centered project, adhering to the guidelines provided in the detailed course handout, and taking all the prescribed evaluation components on time. At the end of the semester, the student should submit a comprehensive Project Report. The student will be evaluated on the basis of the various interim evaluation components, contents of the report and a final seminar and viva-voce.

**PE\* ZC434 Quality Control, Assurance & Reliability 4**

Basic concepts of probability and probability distributions, standard probability distribution, sampling and sampling distributions, confidence intervals, testing significance, statistical tolerance, various types of control charts, statistical process control techniques, value analysis, defect diagnosis and prevention, basic concepts of reliability, reliability design evaluation and control, methods of applying total quality management, production process. Practical assignments on statistical quality control using suitable statistical software tools such as R-software, MS Excel, SAS, Minitab or SPSS.

**PE\* ZC442 Advances in Materials Science 3**

Deformation of materials, deformation at high temperatures and creep, recovery, recrystallization and grain growth, fracture of materials and fatigue failure, deterioration of materials, corrosion and oxidation, surface properties, surface energy and tribology, polymers and fibre reinforced polymeric composites, mechanical testing, nondestructive testing techniques.

**PE\* ZC452 Process Plant Safety and Environment4**

Role of safety in society; engineering aspects of process plant safety; chemical hazards and workers safety; hazardous properties of chemicals; safety aspects in site selection and plant layout; design and inspection of pressure vessels; storage, handling and transportation of hazardous chemicals; risk assessment methods; toxic release, fire and explosions; boiling liquid expanding vapor explosions; safety audit; emergency planning and disaster management; Introduction to air pollutants, water pollutants and solid wastes; sampling & analysis techniques; impact of these on environment; national and international regulations, case studies.

**PE\* ZC453 Process Control & Instrumentation 4**

Importance of Process Control; Process dynamics, modeling and transient response; Control actions and feedback control; Hydraulic-, pneumatic- and electronic controllers; Controller design, tuning and stability; Measuring instruments and their working principles; Instrument characteristics and transmission; Transducers, sensor and actuators; Control valves; Piping and Instrumentation diagrams; Signal conditioning and processing; Display and recording; Signal-flow graph and Mason's gain formula; Feed forward, cascade and ratio control; Direct digital control; Programmable logic controllers; DCS and SCADA systems; PC based instrumentation; Introduction to multivariable control system.

**POM\* ZC441 Human Resource Management 4**

Introduction, manpower planning, career and succession planning, procurement of personnel, performance appraisal, job satisfaction and morale, job rotation, employee communication, audit and control, management training and development, wage and salary administration, welfare administration, trade unions and collective bargaining, industrial dispute and worker participation in management.

**POM\* ZC471 Management Information Systems 3**

Introduction to Information Systems; Concepts of management, concepts of information, systems concepts; Information Systems and Organizations; decision making process; database systems; data communications; planning, designing, developing and implementing information systems; quality assurance and evaluation of information systems; future developments and their organizational and social implications; decision support system and expert systems.

**POM\* ZG511 Disinfection and Sterilisation 4**

Theories and kinetics of the disinfection reaction, study of the principles involved in vivo and in vitro evaluation of disinfectants and antiseptics, structure activity relationships of the representative groups of disinfectants, sterilization, heat, ionizing and ultraviolet radiations, ultrasonic waves, filtration, gaseous sterilization and cellular dessication methods, controls used and special problems involved.

**POM\* ZG512 Dosage Form Design 5**

A study of physical and chemical, pharmacological and biopharmaceutic factors involved in the design and stability of dosage forms; transport of drugs across biological membranes; absorption, distribution and elimination of drugs; formulation additives, closures and containers and sustained release dosage forms; micro-encapsulation; radio pharmaceuticals.

**POM\* ZG513 Financial Management 4**

Concepts and techniques of financial management decision; concepts in valuation – time value of money; valuation of a firm's stock, capital asset pricing model; investment in assets and required returns; risk analysis; financing and dividend policies, capital structure decision; working capital management, management of cash, management of accounts receivable; inventory management, short and intermediate term financing, long term financial tools of financial analysis, financial ratio analysis, funds analysis and financial forecasting, operating and financial leverages.

**POM\* ZG515 Pharmaceutical Administration and Management 5**

Technology innovation and creativity, new drugs and products planning, strategic considerations, project implementation, product development, production management and scale up, preparation of product literature and marketing strategy, IPR processes, human resource development, industrial relations, documentation, R & D management, ethical aspects.

**POM\* ZG521 Statistical Process Control 5**

What is SPC, history & development of SPC, averages & measures of dispersion, process variation, variable & attribute data, simple statistical problem solving tools: check sheets, histograms, Pareto diagrams, stratification graph, scatter plots, cause & effect diagram; Various types of control charts, control chart for attributes, cumulative sum charts, X bar R charts; construction & interpretation of control charts process capability; Lot try lot acceptance sampling for attributes, acceptance sampling variables, other acceptance sampling procedures.

**POM\* ZG522 Quality Assurance & Regulatory Affairs 5**

Quality control, quality assurance, quality management, various parameters for achieving quality pharmaceutical products, application of statistics in quality assurance, reliability, current good manufacturing practice (cGMP) for pharmaceutical

manufacturing, pharmaceutical process validation, drug regulatory affairs, clinical research protocols, new drug applications, drug product labeling.

**POM\* ZG523 Project Management 4**

Concepts and techniques of project formulation, evaluation and implementation; Project planning and scheduling; Risk management; Time-cost trade off; Resource leveling and allocation; Project monitoring and control; Contract management.

**POM\* ZG525 Pharmaceutical Process Development & Scale-up 4**

Optimization techniques in pharmaceutical processing; development of test systems to evaluate performance of dosage forms and unit operations; Scale-up of unit operations related to various pharmaceutical formulations; process analytical technology (PAT) and its applications in solving problems of scale-up.

**POM\* ZG531 Manufacturing Organization and Management 5**

Manufacturing environment; Engineering considerations; Design and planning of manufacturing systems; Manufacturing cost control; Material flow control; Quality; Human resources; Financial management; Marketing management.

**POM\* ZG532 Supply Chain Management 4**

Customer driven strategies in production and distribution systems; Integrated production and distribution networks; SCM in the context of JIT and MRP-II; Distribution Resource Planning; Management of dealer networks; Total Control & Product innovation across the supply chain; Incoming logistics and supplier relationships; Value addition analysis; Metrics for management of supply chain performance; Mathematical models and computer assisted decision support for SCM; Mathematical programming for SCM.

**POM\* ZG534 Advanced Pharmaceutical Technology 5**

Overview of pharmaceutical processes used in pharmaceutical manufacturing; advanced manufacturing equipments for various pharmaceutical dosage forms; current manufacturing techniques for large scale production of tablets, hard and soft gelatin capsules, aerosols, semi-solid preparations including ophthalmic formulations, small and large volume parenterals, and multiparticulate systems; approaches of in-process quality assurance and documentation in automated manufacture; advanced packaging technology for various pharmaceutical dosage forms.

**POM\* ZG541 Modern Analytical Techniques 4**

Fundamentals and applications of sophisticated analytical instruments like NMR, Mass spectrometer; X-ray crystallography; GC, HPLC, UV, IR, Atomic absorption spectrophotometer, High voltage electrophoresis, gel electrophoresis, ultracentrifuge, spectrofluorimeter, DTA, DSC polarimeter in pharmaceutical industry including spectral data analysis and molecular characterization

**POM\* ZG542 Production and Operations Management 4**

Production & operations management functions; capacity requirement planning; inventory control; layout, handling & location decisions; resource procurement & operation control; project scheduling & resource allocation; the production & operating function; methods of forecasting demand; financial analysis of operating plans; determination of economic order quantity; development of efficient work methods, quality control, management of R&D, technological forecasting, equipment replacement and interfaces with other functional areas.

**POM\* ZG545 Intellectual Property Rights and Pharmaceuticals 3**

Key aspects of intellectual property law and their impact on Pharmaceutical industry; concept of property with respect to intellectual creativity; emerging debates, policy issues and law reforms related to IPR with respect to pharmaceuticals; Issues of Intellectual Property such as Patents, Copyright, Trademarks, and Design; rules and regulations of marketing and competition; Patent processing, infringement of patents, ethics and economic issues related to IPR.

#### **POM\* ZG551 Advanced Physical Pharmaceutics 5**

Preliminary evaluations and molecular optimization, Drug substance considerations including protein, peptide and biological products, Bulk characterization, Solubility analysis, Rheology and dispersed systems, Micromeritics and shape factor analysis, Compression and compaction, Principles of dissolution, Dissolution test design and release kinetics evaluation, Compatibility testing, Stability analysis and test design according to international standard, Studies of broad category of polymers used in drug delivery, Rationale basis of formulation recommendation.

#### **POM\* ZG611 Strategic Management & Business Policy5**

Strategic management elements; internal, external, external environment, assessment of corporate strengths, weaknesses and opportunities; planning and deployment of capital assets; profit planning and control functions problems, pressures, responsibilities, limits of the chief executive; evaluation of one's own business undertaking; formulating objectives, strategies, policies and programmes for improving company's present situation; personnel strength and implementation of the policies and programmes, development, implementation, evaluation and control of strategies, strategic management of MNCs, management style and behavior, corporate style, behavior and culture.

#### **POM\* ZG628T Dissertation 16**

A student registered in this course must take a topic in an area of professional interest drawn from the on the job work requirement which is simultaneously of direct relevance to the degree pursued by the student as well as to the employing / collaborating organization of the student and submit a comprehensive report at the end of the semester working under the overall supervision and guidance of a professional expert who will be deemed as the supervisor for evaluation of all components of the dissertation. Normally the Mentor of the student would be the Dissertation supervisor and in case Mentor is not approved as the supervisor, Mentor may play the role of additional supervisor. The final grades for dissertation are Non-letter grades namely Excellent, Good, Fair and Poor, which do not go into CGPA computation.

#### **POM\* ZG631 TQM Tools and Techniques 5**

Benchmarking; introduction, why benchmark; Planning: what to benchmark, benchmarking partners, data collection methods; Analysis: determining the current competitive gap, projecting future performance levels; Integration: developing action plan, implementing specific actions & monitoring progress, re-calibration; Maturity: beyond benchmarking; Quality function deployment, QFD concept, overview & QFD process, the voice of customer developing a QFD matrix, reviewing the matrix for priority items, organizing teams & planning QFD projects; Process RE-engineering, BPR philosophy, possibilities & pitfalls, BPF framework, opportunity assessment, planning & BPR project, risk & impact assessment, planning & implementing the transition; Failure mode & effect analysis; FMEA: concepts & applications in TQM; Quality cost, concepts, quality cost definitions, quality cost program implementation use of quality cost, reducing quality cost.

#### **POW\*ZC112 Electrical and Electronics Technology3**

Electric circuit, electromagnetism, magnetic circuit, electrostatics, AC voltage and current, singlephase circuits, semiconductor devices, amplifiers, digital systems, microprocessors, DC machines, polyphase circuits, transformers, synchronous machines, induction motors, power electronics, measurements, illumination.

#### **POW\* ZC164 Computer Programming 4**

Basic Computing Steps and Flow Charting (Assignment, Sequencing, Conditionals, Iteration). Programming Constructs – Expressions, Statements, Conditionals, Iterators/Loops, Functions/ Procedures; Data Types – Primitive Types, Tuples, Choices (Unions or Enumerations), Lists/Arrays, Pointers and Dynamically Allocated Data. Input output and Files. Laboratory Component: Programming Exercises involving development and testing of iterative and procedural programs using bounded and unbounded iterations, function composition, random access lists, sequential access lists, dynamically allocated lists, and file access.

#### **POW\* ZC231 Thermodynamics 3**

Concepts and laws of thermodynamics; macroscopic thermodynamic properties; application to closed and open system; microscopic approach to entropy; equations of state; thermodynamics of non-reacting mixtures.

#### **POW\* ZC232 Principles of Management 3**

Fundamental concepts of management - planning; organizing; staffing; directing and controlling; production, financial, personnel, legal and marketing functions; accounting and budgeting, balance sheets.

#### **POW\* ZC233 Calculus 4**

Limits, continuity, differentiation, integration, Fourier series, ordinary differential equations for initial and boundary value problems, solution through Laplace transforms, numerical solution using Picard's iteration and higher order methods, partial derivatives, partial differential equations, analytical solution techniques.

#### **POW\* ZC234 Linear Algebra & Optimization 3**

Vector and matrix algebra, systems of linear algebraic equations and their solutions; eigenvalues, eigenvectors and diagonalization of matrices; Formulation of linear programming problems, Simplex method, Big-M method, two phase method, Sensitivity analysis, Revised and Dual Simplex Methods.

#### **POW\* ZC242 Engineering Measurements 3**

Performance characteristics of measuring instruments, measurement methods for mechanical, electrical, radiant, chemical, magnetic and thermal energy variables. Emphasis in this course shall be on the operation and use of instruments.

#### **POW\* ZC313 Power Generation 4**

Indian power scenario, sources of energy, working of thermal, nuclear, IC engine, gas turbine, hydro and renewable energy based power plants, power plant building and layout, economics of power generation, environmental impact assessment of power generation.

#### **POW\* ZC314 Prime Movers & Fluid Machines 4**

Theoretical analysis of energy and momentum transfer between fluid and rotor; principles of axial, mixed and radial flow compressors, turbines and pumps; design considerations; cascade aerodynamics and performance limitations; applications to power plant systems, laboratory exercises in testing reciprocating machines.

#### **POW\* ZC315 Transport Phenomena 4**

Fundamental concepts of fluid flow, concept of momentum transfer, Newton's law of viscosity, Continuity and Bernoulli's equation, concept of pressure drop and drag; Heat transfer: steady state and unsteady state heat conduction; analytical and empirical relations for forced and free convection heat transfer; heat exchanger analysis and design, heat transfer by radiation; Elements of mass transfer; one dimensional compressible flow; associated laboratory on condenser, boiler, economizer, super heater etc.

#### **POW\* ZC316 Power Electronics 4**

PNPN devices, power transistor characteristics, rating and specifications; triggering mechanism and commutation circuits; controlled power rectifiers, Inverters (DC to AC converters), choppers (DC to DC Converters); speed control of DC motors, speed control of AC motors; other industrial applications of thyristors and power transistors; voltage regulation and starting of electrical drives; logic modules for static converters; introduction to application of microprocessors for electrical drives.

### **POW\* ZC321 Technical Report Writing 3**

Elements of effective writing; art of condensation; business letter writing; memos; formal reports; technical proposals; conducting, and participating, meetings; agenda and minutes; strategies for writing technical descriptions, definitions, and classifications; oral presentation; use of graphic and audio-visual aids; editing.

### **POW\* ZC332 Energy Management 3**

System's view of energy in society involving societal goals, energy resources, the sub-systems for the generation. T&D, and utilization of energy carriers, energy economics and analysis, energy strategies, policies, policy instruments, policy agents and policy implementation. The "development-oriented end-use approach" to energy analysis, strategy design and policy formulation involving the disaggregation and scrutiny of demand beyond sectors into end-uses and basic needs. Energy management at the national, state, firm, city and village levels.

### **POW\* ZC342 Power Systems Engineering I 3**

Parameters of transmission lines, electrical and mechanical characteristics of transmission line, synchronous phase modifiers - overhead insulators - underground cables - distribution lines - substation practice -relevant portions of Indian Electricity Act.

### **POW\* ZC343 Microprocessors & Microcontrollers 3**

Introduction to microprocessors and microcontrollers. Architecture of 8086 microprocessors; Assembly directives, Assembly language programs with algorithms, Memory interfacing and timing diagrams; Architecture of 8-bit microcontrollers; Assembly language programming for microcontrollers; Interfacing I/O devices; System design examples.

### **POW\* ZC344 Instrumentation & Control 4**

Generalized measurement system and performance characteristics, Transducers - principles and applications, Signal conditioning circuits – bridges, amplifiers, data converters, filters; Process control – control schemes, controllers, multi-loop control configuration, Control valves; Programmable Logic Controllers, DCS and SCADA, Simulation, Case Studies.

### **POW\* ZC411 Environmental Pollution Control 3**

Environmental pollution: Solid, liquid and gaseous pollutants; removal of soluble and particulate pollutants from atmosphere, natural water systems and process systems; use of current literature for pollution control problems.

### **POW\* ZC413 Process Control 3**

Dynamic modeling and simulation of momentum, energy and mass transfer and reacting systems; analysis of the dynamic behaviour of lumped and distributed parameter systems; analysis and design of simple feedback and advanced control systems; design of control systems with multiple input and multiple output; introduction to computer control.

### **POW\* ZC421 Essentials of Project Management 3**

Programmes project management, project manager: role and responsibilities, project management and organization, project planning and scheduling, graphical techniques and PERT, CPM, price estimation and cost control; proposal, control valuation monitoring and trade off analysis in a project environment, pitfalls and future scenario.

### **POW\* ZC431 Maintenance & Safety 3**

Basic maintenance systems and practice; maintenance planning; estimating and budgeting; scheduling maintenance jobs; importance of safety; factors affecting safety; safety aspects of site and plant; hazards of commercial chemical reaction and operation; instrumentation for safe operation; safety education and training; personnel safety; disaster planning and measuring safety effectiveness; future trends in industrial safety; maintenance of components and equipment's; new dimensions in maintenance covering plant engineering, tribology, materials technology, terotechnology (life cycle costing) etc.; extensive case studies.

### **POW\* ZC434 Quality Control, Assurance & Reliability 4**

Basic concepts of probability and probability distributions, standard probability distribution, sampling and sampling distributions, confidence intervals, testing significance, statistical tolerance, various types of control charts, statistical process control techniques, value analysis, defect diagnosis and prevention, basic concepts of reliability, reliability design evaluation and control, methods of applying total quality management, production process. Practical assignments on statistical quality control using suitable statistical software tools such as R-software, MS Excel, SAS, Minitab or SPSS.

### **POW\* ZC441 Power Systems Engineering II 3**

Elementary principles of power system economics - Powers systems stability, equal area criterion and step by step method - protection, relays and relaying, protection of transmission lines, transformer and generators - High Voltage Protection - Symmetrical components, symmetrical and unsymmetrical faults.

### **POW\* ZC412 Power System Operation & Control 3**

### **POW\* ZC422 Power System Drawing and Design 3**

Course description for the above courses to be developed.

### **POW\* ZC452 Renewable Energy 3**

Introduction of renewable energy, advantages, potential, status of development, broad details of different renewable energy systems such as solar, wind, biomass, microhydel, geothermal etc.; Renewable energy development policy, Renewable energy industries, international co-operation, HRD and career growth opportunities, consultancy areas and future thrust areas in renewable energy development.

### **POW\* ZC471 Power Electronics & Drives 3**

Course description for the above course to be developed.

### **POW\* ZC481 Plant Layout & Design 4**

Factors affecting plant layout, Types of layout, procedure for plant layout, techniques and tools for planning layout, quantitative layout analysis, material handling equipment, improving and revising existing layout, evaluation of layout, plant location, evaluation of location, design of layout, computer applications in layout design.

### **PS\* ZC111 Probability and Statistics 3**

Probability spaces; conditional probability and independence; random variables and probability distributions; marginal and conditional distributions; independent random variables; mathematical expectation; mean and variance; binomial, Poisson and normal distributions; sum of independent random variables; law of large numbers; central limit theorem (without proof); sampling distribution and test for mean using normal ES\* ZGand student's t-distribution; test of hypothesis; correlation and linear regression.

### **PS\* ZC112 Human Anatomy and Physiology 3**

Structure and functions of the various systems of the human body; Homeostatic mechanisms; Progression of disease; Principles of drug action.

### **PS\* ZC113 General Mathematics - I 3**

Review of coordinate geometry, Theory of equations, Progression and series, permutations and combinations, Binomial theorem, Functions: Trigonometric (with identities), Transcendental. One Dimensional Calculus: Limit and continuity, Differentiation, Integration. Applications of derivatives and definite integration.

**PS\* ZC114 General Mathematics – II 3**

Polar coordinates, Function of several variables, Multiple integrals, Vector valued functions. Complex functions and their analyticity. First order and second order ordinary differential equations, Laplace transformations and its applications to ordinary differential equations.

**PS\* ZC212 Basic Statistical Process Control 3**

Course description to be developed.

**PS\* ZC213 Scale –Up of Pharmaceutical Operations 3**

Pilot plant design including process and product layout; Scale-up consideration in solid dosage forms including powder mixing, granulation, compaction, and coating; Scale-up considerations in non-sterile liquids and semi-solids including principles of similarity, dimensionless numbers method, inter-relationship between surface area and volume upon scale-up; Sterile drug product scale-up; Synthetic scale-up; Chromatographic scale-up; Scale-up of biotechnology derived products.

**PS\* ZC214 Utilities in Pharmaceutical Operations 3**

Course description to be developed.

**PS\* ZC221 Business Communication 3**

Managerial communication – national and international contexts, Interpersonal Communication, persuasive communication, communication technology, effective listening group communication, professional presentation.

**PS\* ZC222 Pharmaceutical Quality & GMP 4**

Regulatory perspective for drug product filing and approval, NDA, ANDA, sNDA and drug user fee act; Quality systems including concepts of TQM, ICH guidelines like Q1, Q3, Q6, Q7 and Q9; Quality control and validation including process validation, prospective and retrospective validation, analytical method validation; Good manufacturing practices in pharmaceutical industry; SUPAC guidelines; Quality audits.

**PS\* ZC223 Fundamentals of Biochemistry and Microbiology 4**

Prokaryotic and eukaryotic cells; Chemistry of biomolecules like carbohydrates, proteins & peptides, lipids, vitamins and nucleic acids; Enzymes – classification, mechanism of action, kinetics and regulation of activities; Growth of microorganisms including media requirements, growth curve, preserving and obtaining bacterial culture; Viruses; Sterilization techniques including principles, instruments and methods; Antiseptics, disinfectants and preservatives; Sterility testing, pyrogen testing, evaluation of antimicrobial drugs, Biosafety.

**PS\* ZC224 Novel Drug Delivery Systems 3**

Course description to be developed.

**PS\* ZC225 Environmental Studies 3**

Environment, human population, and industrialization; natural resources and the impact of man-made activities on them; structure and function of ecosystem, population ecology, biodiversity and its conservation, overview of natural resources, environmental pollution, social issues and the environment, and environmental impact assessment.

**PS\* ZC231 Physical & Inorganic Chemistry 3**

Atomic structure and chemical bonding including the concepts of hydrogenic atoms and VB theory; Thermodynamics and chemical kinetics; Electrochemistry including Nernst equation and its application, electrochemical series; Concepts in inorganic chemistry including electronegativity, measure of acid-base strength, Systematics

of acid base interactions, Hard soft acid base(HSAB) concept- relevance to diverse metal-ligand interactions, symbiosis; Main group elements (Periodicity); Introduction to co-ordination compounds including double salts, chelates and isomers, VB and CF theories, organometallic chemistry, bio-inorganic chemistry.

**PS\* ZC232 Chemistry of Synthetic Drugs 3**

Synthesis of Five-membered heterocyclic drugs; Six-membered heterocyclic drugs; Five-membered heterocyclic fused with benzene ring; Six-membered heterocyclic fused with benzene ring; Seven-membered heterocyclic fused with benzene ring; Heterocycles fused to two benzene rings; Heterocycles fused to other heterocyclic rings.

**PS\* ZC233 Pharmaceutical Packaging 3**

Course description to be developed.

**PS\* ZC234 Techniques in Pharmaceutical Analysis4**

Principles of titrimetric analysis including acid-base, redox and complexometric titrations; Modern analytical techniques used in drug product analysis – concepts, instrumentation, method of analysis and interpretation; UV-Visible spectroscopy, Spectro-fluorimetry, Infrared spectroscopy, NMR spectrometry, Mass spectroscopy, Chromatography including Paper, TLC, GC, HPLC and electrophoresis.

**PS\* ZC235 Linear Algebra & Optimization 3**

Vector and matrix algebra, systems of linear algebraic equations and their solutions; eigenvalues, eigenvectors and diagonalization of matrices; Formulation of linear programming problems, Simplex method, Big-M method, two phase method, Sensitivity analysis, Revised and Dual Simplex Methods.

**PS\* ZC241 Pharmaceutical Chemistry 3**

This course deals with study of important classes of organic compounds such as alcohols, ethers, esters, aldehydes etc and their reactions. The mechanisms for various reactions will also be dealt with to comprehensively cover the basics of chemical reactions. Some important five and six member heterocycles with their reactions will also be part of the course. This course also emphasizes the use of inorganic compounds in pharmacy.

**PS\* ZC244 Physical Pharmacy 3**

This course is designed to make the students conversant with the applications of physico-chemical principles to the study of the drug stability behaviour of drug powers and of other pharmaceutical systems; it includes the discussion of drug degradation, micromeritics, rheology and interactions of drugs.

**PS\* ZC311 Pharmaceutical Unit Operations – I 3**

Various pharmaceutical unit operations like Extraction, Distillation, Evaporation, Re-crystallization, Filtration and Drying; Equipment used; Factors affecting the process and the properties of the product obtained; Identification of the critical factors; Relevance to manufacturing of various pharmaceutical products.

**PS\* ZC312 Pharmaceutical Unit Operations – II 3**

Various pharmaceutical unit operations like Size reduction & Size Separation, Mixing, Granulation, Compression & Consolidation, Humidification & De-humidification and Materials of Construction; Equipment used; Factors affecting the process and the properties of the product obtained; Identification of the critical factors; Relevance to manufacturing of various pharmaceutical products.

**PS\* ZC313 Technical Report Writing 3**

Elements of effective writing; art of condensation; business letter writing; memos; formal reports; technical proposals; conducting, and participating, meetings; agenda and minutes; strategies for writing technical descriptions, definitions, and classifications; oral presentation; use of graphic and audio-visual aids; editing.

**PS\* ZC314 Pharmaceutical Jurisprudence in India 3**

Growth of modern pharmacy & pharmaceutical industry, brief overview of pharmacy act; Central Drugs Standard Control Organization (CDSCO): about the CDSCO, importance, functioning, and regulation; Drugs and Cosmetics Act; Various provisions of Schedule M; Branded and Generic medicines; Ministry of chemical and fertilizers: importance, functioning, and regulations; Indian Pharmacopoeia Commission: importance, functioning, and regulations; Provisions of Drug Price Control Order and National Pharmaceutical Pricing Authority; Narcotic and Psychotropic Substances Act; Medicinal and Toilet Preparations Act; Bonded and non-bonded laboratories; Drugs and Magic Remedies Act (Objectionable advertisements); The prevention of cruelty to animals act; Provision of Insecticide Act; Consumer protection Act.

**PS\* ZC318 Fundamentals of Transport Processes 4**

Concept of momentum transfer, Newton's law of viscosity, Continuity and Bernoulli's equation, Concept of pressure drop and drag, Introduction to conduction, convection (free and forced) and radiation including Fourier's law of heat conduction, Newton's law of cooling, Stefan Boltzmann and Kirchhoff's laws, concept of resistance and lumped capacitance; Boundary layer theory (momentum, thermal and mass), Heat transfer correlations; Phase change heat transfer, Diffusion fundamentals including Fick's law, Interphase mass transfer, Concept of mass transfer coefficient, Momentum, heat and mass transfer analogies, Introduction to transport equations.

**PS\* ZC321 Chemical Process Calculations 3**

Properties of gases, liquids and solids; material and energy balances; elementary process analysis involving phase equilibria and chemical reactions; recycling and unsteady state processes; combustion calculations and typical industrial applications.

**PS\* ZC322 Pharmaceutical Quality by Design 3**

Course description to be developed.

**PS\* ZC323 Sterile Pharmaceutical Products 3**

Sterile products characteristics; Sterile dispersed systems; Sterile manufacturing process; Freeze drying of sterile products; QA & QC of sterile drug products; Process validation & equipment qualification in sterile product manufacturing; Packaging of sterile drug products.

**PS\* ZC324 Name Reactions in Chemical Synthesis 3**

Stereochemistry in drug action; Rearrangement reactions and their applications to drug synthesis; Name reactions and examples in drug synthesis.

**PS\* ZC331 Pharmaceutical Formulations- I 3**

Various liquid dosage forms and semi-solid dosage of drugs manufactured in pharmaceutical industries; Excipients used and their role in liquid dosage forms and semi-solid dosage forms; Manufacturing methods and equipment used in manufacturing liquid and semi-solid dosage forms; Various

quality control tests performed; Selection of suitable liquid and semi-solid dosage form for a given drug.

**PS\* ZC332 Pharmaceutical Formulations – II 4**

Various solid dosage forms and aerosols manufactured in pharmaceutical industries; Excipients used and their role in solid dosage forms and aerosols; Manufacturing methods and equipment used in manufacturing solid dosage forms and aerosols; Various quality control tests performed; Selection of suitable solid dosage form for a given drug.

**PS\* ZC341 Drug Discovery and Action 4**

Drugs discovery process; Different regulatory requirements in the process of drug discovery; Effect of drugs on living organisms and application to therapeutics; Mechanism of action; physiological and biochemical effects (pharmacodynamics); Absorption, distribution, metabolism and excretion (pharmacokinetics); Adverse effects and interactions.

**PS\* ZC342 Medicinal Chemistry 3**

This course deals with the study of important classes of drugs. Various aspects like structure, properties, therapeutic and pharmaceutical importance and the uses of drug molecules both of natural and synthetic origin will be covered. Study of physico-chemical properties, mechanism of action, S.A.R. and metabolism of drugs dealt will also be emphasized. Special emphasis will be given on Important topics such as Anti hypertensive drugs, Drugs affecting sugar metabolism, Antimalarial drugs, Anticancer agents, Antiviral agents etc.

**PS\* ZC343 Professional Ethics 3**

Ethics, nature and purpose; ethical theories; ethics in business and management; ethics in engineering, global ethical issues.

**PS\* ZC344 Natural Drugs 3**

The course imparts a knowledge of the crude drugs of natural origin used in pharmaceutical and medical practice. Study will include the different systems of classifications of crude drugs; cell contents; general principles of cultivation, collection, drying, storage and commerce of natural products of current medical and pharmaceutical importance; their morphological and microscopical study: use and knowledge of common substitutes and adulterants.

**PS\* ZC361 Environmental Pollution Control 3**

Air and water pollutants; sampling and analysis; control methods for air & water pollutants; modeling of different control techniques; advanced wastewater treatment processes; solid waste management, noise pollution; case studies.

**PS\* ZC414 Biopharmaceutics 3**

Biopharmaceutics and Biopharmaceutical aspects of drug delivery covering absorptions, distribution, metabolism and elimination (ADME) characters of drugs. Compartment model, pharmacokinetics of drugs and their applications, bioavailability, bioequivalence and their studies, drug-drug interactions and other related matters.

**PS\* ZC229T Project 5**

Apply the knowledge of chemical technology operations in the manufacture of API or formulation technology operations in the manufacture of pharmaceutical drug product and assess the quality of the same; the student's actual day-to-day task involvement would constitute the central thread of the learning process. The evaluation will recognize this aspect by demanding day-to-day engagement and productivity of the student.

**PS\* ZC499T Capstone Project 15**

Real-life problems related to the manufacture and quality control of active pharmaceutical ingredients and pharmaceutical drug products, as per applicable regulatory guidelines; Jointly mentored by the industry experts and faculty; Presentation of the progress and results in appropriate forms; Periodic review of the progress of the project.

**QM ZC441 Human Resource Management 4**

Introduction, manpower planning, career and succession planning, procurement of personnel, performance appraisal, job satisfaction and morale, job rotation, employee communication, audit and control, management training and development, wage and salary administration, welfare administration, trade unions and collective bargaining, industrial dispute and worker participation in management.

**QM ZC472 Precision Engineering 3**

Concept of accuracy, accuracy of numerical control systems, tolerances and fits, acceptance tests for machine tools, static stiffness and its influence on machining accuracy, inaccuracies due to thermal effects, influence of forced vibrations on accuracy, dimensional wear of cutting tools and its influences on accuracy, clamping and setting errors, location principles and errors due to location, surface roughness and microfinishing processes, dimensioning and dimensional chains, methods of improving accuracy and surface finish, thread and gear measuring instruments, coordinate measuring machines, introduction to computer aided tolerancing.

**QM ZG514 Leadership & Managing Change 4**

Individuals as leaders, team leadership and organizational leadership. Introduction to managing change, management of change: organizational structure, culture, recruitment, performance management, human resource development, reward management, employee relations and involvement, downsizing, and evaluating and promoting.

**QM ZG515 Quantitative Methods 4**

Basic concepts in Operations Research; Analytical & Mathematical Modeling Techniques; Model Building; Inventory Control, queuing theory; Linear Programming; Transportation and assignment problems, simulation, index numbers, decision theory, etc.

**QM ZG524 Quality Management Systems 5**

Quality system & quality management, evolution of quality post world war II era i.e. Quality control, quality assurance, total quality control & total quality management; ISO 9000 series of standards, formation of ISO (1947), background & development of ISO 9000. ISO 9000 family of standards, selection & use of appropriate model of ISO 9000. Requirements of ISO 9001; System demonstration & documentation, how to organize formal quality assurance system, pyramid of quality system documentation structure, two tier, three tier & four tier documentation, preparation of quality manual & quality procedures, quality records; Implementing documented quality system, how to proceed, how to implement change, obtaining top management commitment, assessing current company position, developing the implementation plan, initiating people (employees) to own the system, system development; System audit & review, objective of system audit, types of quality audit, product Vs system audit, internal quality audit, management review; System certification, benefits of third party certification, choice of certification body, route to certification, surveillance & renewal; Other quality system standards, relating ISO 9000 with QS 9000 and ISO 14000.

**QM ZG523 Project Management 4**

Concepts and techniques of project formulation, evaluation and implementation; Project planning and scheduling; Risk management; Time-cost trade off; Resource leveling and allocation; Project monitoring and control; Contract management.

**QM ZG526 Operations Management 5**

Operations strategy; process view vs. functional view in operations; factors in product and process design and selection; facility configuration; demand planning and forecasting; capacity planning; aggregate planning; planning service operations; productivity of operations; inventory planning and independent demand systems; materials requirements planning; quality management; uncertainty and variability; project management; current developments in operations management.

**QM ZG528 Reliability Engineering 5**

Basic Reliability Models, Reliability of Systems, Design for Reliability and Maintainability, Maintainability, availability and reliability; Data Collection and Empirical Methods, Reliability Testing, Identifying Failure and Repair Distributions, Reliability Estimation and Application.

**QM ZG531 Statistical Quality Control 5**

Sources of Variation: Common and Assignable Causes, Descriptive Statistics, Statistical Process Control Methods, Control Charts for Variables, Control Charts for Attributes, C-Charts, Process Capability, Acceptance Sampling, Operating characteristic curve, Statistical Quality Control in Services.

**QM ZG532 Total Quality Management 4**

TQM principles and practices; leadership; customer satisfaction; employee involvement; continuous process improvement; supplier partnership; performance measures; statistical process control; ISO 9000; benchmarking; quality function deployment; concurrent engineering; experimental design; Taguchi's quality engineering; product liability

**QM ZG533 Manufacturing Planning & Control 5**

Planning and control of manufacturing operations; material flow planning; product and process planning; demand forecasting and forecasting models; facility location; plant layout planning and design; machine cells; capacity planning; designing work methods; material handling; line balancing; aggregate planning; inventory models and systems for independent demand; materials requirements planning; elements of monitoring and production control; current developments in operations management.

**QM ZG535 Decision Analysis 4**

Introduction to quantitative techniques and statistics, Decision making, intelligence design and choice phases, basic theory of decision making under uncertainty; decision trees, qualification of judgments and preferences, Bayes theorem, the structuring of complex decisions, and multi-attribute utility theory. Statistical estimation and forecasting.

**QM ZG536 Design of Experiments 4**

Course description to be developed.

**QM ZG539 Six Sigma 4**

History of Six Sigma, Implementing Six Sigma, Becoming a Customer and Market-Driven Enterprise, Customer Expectations and Needs, Linking Six Sigma Projects to Strategies, Attributes of Good Metrics, Using resources wisely, Project Management Using the DMAIC and DMADV Models, The Define Phase, The Measure Phase, Measurement System Analysis, Analyzing Data: Value Streams and Dealing with Variations, Designing Experiments, The Improve Phase, The Control Phase.

**QM ZG541 Product Design 5**

Introduction to creative design; user research and requirements analysis, product specifications, Computer Aided Design; standardization, variety reduction, preferred numbers and other techniques; modular design; design economics, cost analysis, cost reduction and value analysis techniques, design for production; human factors in design: anthropometric, ergonomic, psychological, physiological considerations in design decision making; legal factors, engineering ethics and society.



**QM ZG611Strategic Management & Business****Policy 4**

Strategic management elements; internal, external, external environment. assessment of corporate strengths, weaknesses and opportunities; planning and deployment of capital assets; profit planning and control functions problems, pressures, responsibilities, limits of the chief executive; evaluation of one's own business undertaking; formulating objectives, strategies, policies and programmes for improving company's present situation; personnel strength and implementation of the policies and programmes, development, implementation, evaluation and control of strategies, strategic management of MNCs, management style and behavior, corporate style, behavior and culture.

**QM ZG621 Supply Chain Management 4**

Customer driven strategies in production and distribution systems; Integrated production and distribution networks; SCM in the context of JIT and MRP-II; Distribution Resource Planning; Management of dealer networks; Total Control & Product innovation across the supply chain; Incoming logistics and supplier relationships; Value addition analysis; Metrics for management of supply chain performance; Mathematical models and computer assisted decision support for SCM; Mathematical programming for SCM.

**QM ZG661Software Quality Management 4**

Software quality challenges and expectations; quality dilemma; software life cycle and link to quality; quality gates, formal reviews, system requirement reviews, preliminary design reviews, critical design reviews, test reviews; engineering reviews, walkthroughs, inspections, internal reviews; quality gate categories; technical environment and quality; planning for software quality, quality requirements for planning, quality needs, elements of quality planning, quality assessments during planning, software quality organization requirements; quality evaluation of software development process, process quality attributes, measuring software process quality; software process metrics; quality gate integrity; software product quality, standards and conventions, metrics; quality hierarchy, factors; quality assessment; quality evaluation techniques, reviews, walkthroughs, audit, inspections, analytical evaluation techniques; quality systems.

**QM ZG663Concurrent Engineering 5**

Introduction of concurrent engineering and need, concurrent engineering tools, advances in design and manufacturing engineering, design for manufacture, design for assembly, rapid prototyping, simulation, concurrent approaches to design, manufacturing and other aspects of engineering.

**QM ZG628T Dissertation 16**

A student registered in this course must take a topic in an area of professional interest drawn from the on the job work requirement which is simultaneously of direct relevance to the degree pursued by the student as well as to the employing / collaborating organization of the student and submit a comprehensive report at the end of the semester working under the overall supervision and guidance of a professional expert who will be deemed as the supervisor for evaluation of all components of the dissertation. Normally the Mentor of the student would be the Dissertation supervisor and in case Mentor is not approved as the supervisor, Mentor may play the role of additional supervisor. The final grades for dissertation are Non-letter grades namely Excellent, Good, Fair and Poor, which do not go into CGPA computation.

**SE\* ZC111Probability and Statistics 3**

Probability spaces; conditional probability and independence; random variables and probability distributions; marginal and conditional distributions; independent random variables; mathematical expectation; mean and variance; binomial, Poisson and normal distributions; sum of independent random variables; law of large numbers; central limit theorem (without proof); sampling distribution and test for mean using normal ES\* ZGand student's t-distribution; test of hypothesis; correlation and linear regression.

**SE\* ZC163Computer Programming 4**

Basic Computing Steps and Flow Charting (Assignment, Sequencing, Conditionals, Iteration). Programming Constructs – Expressions, Statements, Conditionals, Iterators/Loops, Functions/ Procedures; Data Types – Primitive Types, Tuples, Choices (Unions or Enumerations), Lists/Arrays, Pointers and Dynamically Allocated Data. Input output and Files. Laboratory Component: Programming Exercises involving development and testing of iterative and procedural programs using bounded and unbounded iterations, function composition, random access lists, sequential access lists, dynamically allocated lists, and file access.

**SE\* ZC222Discrete Structures for Computer Science3**

Sets and relations; graphs and digraphs; trees, lists and their uses; partially ordered sets and lattices; Boolean algebras and Boolean expressions; semigroups and machines; codes and applications.

**SE\* ZC234Linear Algebra & Optimization 3**

Vector and matrix algebra, systems of linear algebraic equations and their solutions; eigenvalues, eigenvectors and diagonalization of matrices; Formulation of linear programming problems, Simplex method, Big-M method, two phase method, Sensitivity analysis, Revised and Dual Simplex Methods.

**SE\* ZC241Principles of Management 3**

Fundamental concepts of management - planning; organizing; staffing; directing and controlling; production, financial, personnel, legal and marketing functions; accounting and budgeting, balance sheets.

**SE\* ZC263Digital Electronics and Microprocessors4**

Binary logic gates; logic circuits; Boolean algebra and K-map simplification; number systems and codes; arithmetic logic units; flipflops; registers and counters; introduction to microprocessors; architecture; instruction set and programming; memory and I/O interfacing examples of system design.

**SE\* ZC312Technical Report Writing 3**

Elements of effective writing; art of condensation; business letter writing; memos; formal reports; technical proposals; conducting, and participating, meetings; agenda and minutes; strategies for writing technical descriptions, definitions, and classifications; oral presentation; use of graphic and audio-visual aids; editing.

**SE\* ZC313 Object Oriented Programming & Design4**

Object oriented concepts and design, abstraction, architecture and design patterns, GUI programming and frameworks, design of object oriented solutions using UML, design for concurrency, implementation of solutions using object oriented languages like C++ or Java; Language level mapping and realization of object oriented constructs, realization and performance issues versus abstraction and usability.

**SE\* ZC333 Systems Programming 4**

Batch processing; Systems programs; operating characteristics and limitations; parallel processing of I/O and interrupt handling, multiprogramming; multiprocessing systems; design of system modules and interfaces with focus

on contemporary open source operating system-specific programming; laboratory experiments or programming assignments involving Unix/Linux System-specific Programming including shell-scripting via online laboratory facility.

#### **SE\* ZC337 Database Systems & Applications 4**

Introduction to Database Management Systems; File organization; Data Independence in databases; Data Models; Query processing systems; Database Design techniques; Concepts of security and integrity in databases; Distributed Databases; Applications using DBMS, database programming experiments involving use of SQL, database creation etc. via online laboratory facility.

#### **SE\* ZC344 Software Engineering 4**

Software engineering concepts and methodology; formal requirements specification; estimation; software project planning; detailed design; techniques of design; productivity; documentation; programming languages styles, code review; tool, integration and validation; software quality assurance; software maintenance; metrics, automated tools in software engineering.

#### **SE\* ZC353 Computer Organization & Architecture 4**

Overview of logic design; Instruction set architecture; Assembly language programming; Pipelining; Computer Arithmetic; Control unit; Memory hierarchy; Virtual memory; Input and output systems; Interrupts and exception handling; Implementation issues; Case studies; This course covers the fundamentals of computer organization and architecture from a programmer's perspective.

#### **SE\* ZC363 Data Structures & Algorithms 4**

Introduction to software design principles, modularity, abstract data types, data structures and algorithms; Analysis of algorithms; Linear data structures – stacks, arrays, lists, queues and linked representations; Pre-fix, in-fix and post-fix expressions; Recursion; Set operations; Hashing and hash functions; Binary and other trees, traversal algorithms, Huffman codes; Search trees, priority queues, heaps and balanced trees; Sorting techniques; Graphs and digraphs; Algorithmic design techniques; Data structures for external storage, multi-way search and B-trees; Implementation techniques for different data structures including trees, graphs and search structures; Performance evaluation of data structures and algorithms; Implementation issues in large data structures.

#### **SE\* ZC364 Operating Systems 4**

Introduction to operating systems; Various approaches to design of operating systems; Overview of hardware support for operating systems; Process management: process synchronization and mutual exclusion, inter process communication, process scheduling; CPU scheduling approaches; Memory management: paging, segmentation, virtual memory, page replacement algorithms; File systems: design and implementation of file systems; input/output systems; device controllers and device drivers; Security and protection; Case studies on design and implementation of operating system modules, select laboratory experiments related to creating different elements of operating system and/or implementation of select scheduling, memory management and I/O related algorithms/schemes, using system calls for creating file system specific command, creating simple file system etc. via online laboratory facility.

#### **SE\* ZC373 Compiler Design 4**

Introduction to Programming Languages and Compilers, Programming Language Features, Front End of a Compiler, Back End of a Compiler, Special aspects of compilers and runtime.

#### **SE\* ZC420 Data Visualization 3**

Information overload and issues in decision making. Design of visual encoding schemes to improve comprehension of

data and their use in decision making; presentation and visualization of data for effective communication. elementary graphics programming, charts, graphs, animations, user interactivity, hierarchical layouts, and techniques for visualization of high dimensional data & discovered patterns.

#### **SE\* ZC425 Data Mining 3**

Data Mining – introduction, fundamental concepts; motivation and applications; role of data warehousing in data mining; challenges and issues in data mining; Knowledge Discovery in Databases (KDD); role of data mining in KDD; algorithms for data mining; tasks like decision-tree construction, finding association rules, sequencing, classification, and clustering; applications of neural networks and machine learning for tasks of classification and clustering.

#### **SE\* ZC444 Artificial Intelligence 3**

The object of this course is to give an introduction to the problems and techniques of A.I. along with the applications of A.I. techniques to the fields like natural language understanding, image processing, game theory and problem solving. The course also aims at understanding its implementation using LISP and PROLOG languages.

#### **SE\* ZC465 Machine Learning 4**

Introduction to Machine Learning, Various kinds of learning, Supervised Learning, Unsupervised Learning, Model Selection; Bayesian Learning, MAP Hypothesis, MDL Principle, Bias Variance Decomposition, Bayes Optimal Classifier, Naive Bayes Classifier; Linear Models for Regression, Linear Models for Classification; Non-Linear models, Decision trees; Instance Based Learning, KNN Algorithm, CBR Learning; Support Vector Machines, VC Dimension; Neural Networks, Perceptron Learning, Back Propagation Algorithm; Introduction to Genetic Algorithms.

#### **SE\* ZC467 Computer Networks 4**

Introduction: components of a modern computer network, packet switched network and its metrics, layered architecture of protocols and historical perspective; Application Layer: principles, examples: Web and HTTP, Email, DNS, Peer-to-Peer applications, socket programming; Transport Layer: Services, the concept of connection less, connection oriented and reliable transport, TCP congestion control; Network Layer: addressing mechanism in networks, router architecture, intra and inter-AS routing protocols, multicast and broadcast; Link Layer: error detection and correction, medium access, MAC addressing, Ethernet, switches, Point to point protocol and link virtualization; Physical Layer: signals, medium, and transmission methods, QoS: forward error correction, scheduling and policing mechanism in the networks.

#### **SE\* ZC472 Computer Graphics 3**

Generation of dots, lines, arcs and polygons; color graphics, shades and levels; image transformation, windowing and clipping; 2-D and 3-D graphics; data structures, algorithms and optimization methods; case studies using GKS, CORE, etc; graphic languages and compilers.

#### **SE\* ZG512 Object Oriented Analysis & Design 4**

Object orientation concepts, theories and principles; fundamental concepts of the object model: classes, objects, methods and messages, encapsulation and inheritance, interface and implementation, reuse and extension of classes, inheritance and polymorphism; process of object-oriented requirements specification, analysis and design; notations for object-oriented analysis and design; case studies and applications using some object oriented programming languages.

**SE\* ZG514 Introduction to DevOps 4**

Continual Service - continuous integration and continuous delivery; Scaling: automating infrastructure and infrastructure-as-code; DevOps and Cloud: platform-as-a service and DevOps, use of virtual machines and containers for deployment, Micro-services; application lifecycle management: deployment pipeline and application deployment, continuous deployment pipeline; stack management - life cycle of stack and events, resource and event monitoring, auto healing; Security: security of deployment pipeline, policy-as-code.

**SE\* ZG515 Data Warehousing 5**

Introduction, evolution of data warehousing; decision support systems; goals, benefit, and challenges of data warehousing; architecture; data warehouse information flows; software and hardware requirements; approaches to data warehouse design; creating and maintaining a data warehouse; Online Analytical Processing (OLAP) and multi-dimensional data, multi-dimensional modeling; view materialization; data marts; data warehouse metadata; data mining.

**SE\* ZG516 Embedded Systems Design 4**

Design issues involved in embedded systems and system-on-chip technologies, Programming languages and processor architectures used for embedded systems, Standard Embedded System Development tools and hands-on experience involving these tools, understanding design constraints such as – power, memory, size constraints in system design and tradeoffs. Introduction to other specialized embedded design techniques – such as hardware, software co-design, design of accelerated and distributed embedded systems, fault tolerant design etc.

**SE\* ZG518 Database Design & Applications 5**

DBMS architecture; Data models: Network model, Hierarchical model and Relational model; Database design & optimization; Query processing & Query optimization; Transaction Processing; Concurrency control; Recovery; Security & protection; Introduction to Object Oriented data model & Multimedia Databases.

**SE\* ZG519 Data Structures & Algorithms Design 5**

Introduction to Abstract Data Types, Data structures and Algorithms; Analysis of Algorithms – Time and Space Complexity, Complexity Notation & Solving Recurrence Relations.; Divide-and-Conquer as a Design Technique; Recursion – Design of Recursive Functions / Procedures, Tail Recursion, Conversion of Recursive Functions to Iterative Form. Linear data structures – Lists, Access Restricted Lists (Stacks and Queues) – Implementation using Arrays and Linked Lists; Searching and Order Queries. Sorting – Sorting Algorithms (Online vs. Offline, In-memory vs. External, In-space vs. Out-of-space, QuickSort and Randomization). Unordered Collections: Hashtables (Separate Chaining vs. Open Addressing, Probing, Rehashing). Binary Trees – Tree Traversals. Partially Ordered Collections: Search Trees and Height Balanced Search Trees, Heaps and Priority Queues. Algorithm Design: Greedy Algorithms and Dynamic Programming. Graphs and Graph Algorithms: Representation schemes, Problems on Directed Graphs (Reachability and Strong Connectivity, Traversals, Transitive Closure. Directed Acyclic Graphs - Topological Sorting), Problems on Weighted Graphs (Shortest Paths. Spanning Trees). Introduction to Complexity Classes (P and NP) and NP-completeness. NP-Hard problems. Designing Algorithms for Hard Problems – Back tracking, Branch-and-Bound, and Approximation Algorithms.

**SE\* ZG522 Big Data Systems 5**

What is big data - are existing systems sufficient?; Data Warehouse v/s Data Lakes; Hadoop – Components; Storage - Relational DBs/ NoSQL dbs / HDFS / HBase / Object Data stores - S3; Serialization; Interfaces - Hive/ Pig; Stream Processing; Spark; Mahout.

**SE\* ZG527 Cloud Computing 5**

Concurrency and distributed computing, message passing over the network, connectivity and failure models, local vs remote connectivity, distributed resource modeling, distributed data models; replication & consistency; virtualization; CPU virtualization, memory and storage virtualization, virtualized networks, computing over WAN and Internet; computing on the cloud, computing models, service models and service contracts, programming on the cloud; Cloud infrastructure, LAN vs Wan issue, resource scaling and resource provisions, performance models, scalability, performance measurement and enhancement techniques; cloud applications and infrastructure services.

**SE\* ZG528 Cyber Physical Systems 4**

This course provides an overview of Cyber-Physical Systems, with respect to its components and characteristics. As an example of a Cyber-Physical System, this course explains the various aspects of IoT systems, and helps students understand the IoT system components, its protocol stack and design methodologies. The course also enables students to get familiar with the Raspberry Pi platform, via simple examples/applications. At the end of this course, students will be able to explain the various facets of Cyber-Physical Systems, with focus on IoT and demonstrate simple IoT applications.

**SE\* ZG533 Service Oriented Computing 4**

Introduction to Web Services: Distributed computing using software component technologies like DCOM and EJBs-overview about Service Oriented Architecture- RPC and Document centric SOAP enabled web Services-Describing information using XML -SAX and DOM based XML parsers-XSLT-XPath. SOAP Protocol for web services- Describing Web Services using WSDL-Publishing and Finding web services using UDDI Registry-UDDI SOAP APIs-Inquiry APIs-Publisher APIs. Web Services security –Need for secured web service-confidentiality of web service invocation using XML encryption and its advantages over SSL security - Integrity of soap message using xml digital signing-Maintaining confidentiality and integration together for soap messages -Authentication mechanisms for Web service client – Security Assertion Markup Language- Incorporating saml assertions for web service client authentication- IP layer security for web service- Need for work flow of web services- Usage of Business Process Execution Language for describing workflow of web services-Rest web service, its protocol and usage-Usage of Ajax in invoking Rest web service-Role played by web services in cloud computing.

**SE\* ZG544 Agile Software Processes 4**

Course description to be developed.

**SE\* ZG547 Usability Engineering 5**

Usability-driven approach to Information Design; software usability bridge& its critical components; Iterative & evaluation of a two-level approach of UCID (User-Centered Information Design); five key principles of UCID; getting UCID into organization ; Benefits of implementing UCID; key features of UCID;UCID process & analysis; traditional processes for information development & their limitations; Managing UCID; role of usability engineers; preparing the usability plan; implementing a metrics program in typical UCID projects; key contributors; goal setting for software usability & information quality; critical design goals; designing the information architecture ;designing the specifications & prototypes; evaluating prototypes; two-level design activities; designing software labels; designing effective messages; designing online support elements & printed support elements; achieving information design goals; online search & navigation; evaluating information; two-level evaluation; approach achieving information design goals for improved software usability; testing information & validating; quality indicators; retrievability; implementation techniques & issues; Application of Usability Engineering in typical live projects to

validate improved software usability .

**SE\* ZG548 Advanced Data Mining 4**

Topics beyond conventional record data mining. Mining complex data structures. Tree/graph mining, sequence mining, web/text data mining, stream data mining, spatiotemporal data mining, mining multi-variate time series data, high-dimensional data clustering, and mining social networking sites. Mining data from multiple relations (Multi-relational Data Mining). Privacy preserving Data Mining. Distributed computing solutions for data intensive data mining.

**SE\* ZG552 Software Testing Methodologies 4**

Concepts and principles of software testing and quality assurance; software testing tools; functional, structural, integration and system testing techniques; software testing process and its management; evaluation of test effectiveness; testing specialized systems and applications; automated software testing; case studies.

**SE\* ZG566 Secure Software Engineering 5**

Best practices for designing secure systems, software engineering principles for designing secure systems, criteria for designing secure systems; analysis of system properties and verification of program correctness; use of formal methods and verification for security; tools for verification of security properties; techniques for software protection (such as code obfuscation, tamper-proofing and watermarking) and their limitations; analysis of software based attacks (and defenses), timing attacks and leakage of information, and type safety.

**SE\* ZG568 Applied Machine Learning 4**

Need for machine learning. Prediction and classification methods. Use cases in application domains. Interpretation of results. Limitations of various techniques. End to end Machine learning - data collection, data preparation, model selection.

**SE\* ZG569 Blockchain Technologies & Systems 4**

Highly successful decentralized blockchain-based systems, such as Bitcoin, have immense potential to revolutionize financial, information, and other infrastructures. This course aims to provide a broad overview of the essential concepts involved in blockchain technology in order to lay down the foundation necessary for developing applications. This course also covers the technical aspects of consistency and consensus in distributed algorithms, public distributed ledgers, public-key cryptography and cryptographic properties, cryptocurrencies, and smart contracts. The course aims to develop expertise among students to build these systems, interact with them, and to design and build secure distributed applications.

**SE\* ZG583 Scalable Services 5**

Software principles related to scalability. Architectures for Scaling. Microservices - design, service discovery, load balancing, API management. Deployment - container configurations and orchestrations, automated deployments of microservices, integration with CI/CD pipelines. Performance: Scaling and load balancing with containers and microservices, Ensuring QoS and SLAs.

**SE\* ZG585 Cross Platform Application Development 4**

Cross-platform applications development involves creation of software applications that are compatible with multiple platforms or software environments. This can be achieved through various development frameworks like Ionic, React Native, Adobe PhoneGap, Xamarin etc. This course aims to equip students with the expertise to design and develop web and mobile based applications that can operate in varied environments and platforms. Additionally, it also aims to develop the understanding of the role and importance of API management in such applications. The course involves hands-on exposure to full stack development of cross-

platform applications using some of the existing development frameworks.

**SE\* ZG586 Edge Computing 5**

This course will explore frameworks and applications in Edge Computing. The topics covered will include edge architecture, edge to edge and edge to cloud communication, Sensor networks and related protocols, Distributed caching, Reliability, availability and energy efficiency in edge computing, Pipeline, Performance issues like latency and Data flow for Big data analytics, Semantic Web of Things and Application level security.

**SE\* ZG587 Open Source Software Engineering 4**

This course aims to develop an understanding about open source software, its life cycle, its history and the benefits that it has provided to the world's technology infrastructure over the past few decades. It also aims to teach the students about ways to contribute to open source projects productively, learn and engage themselves in effective collaboration and gain benefits from it. The course will also discuss about different licensing models that are available, with a view to develop expertise to choose the best one for your project/organization. Hands-on on hosting and development of open source software on distributed code hosting platforms like GitHub etc., will also be carried out.

**SE\* ZG589 Middleware Technologies 4**

Evolution of Middleware Technologies: Transaction Processing, Remote Procedure Calls, Message-Oriented-Middleware, Object Request Brokers, Web services and REST; Forms of Middleware: Enterprise Middleware, Web Middleware, and Cloud / Services Middleware; Middleware Elements: communication protocols, middleware protocols, data representation, server process control, naming and directory services, security, system management; Select case studies such as MS .NET, J2EE. Service Oriented Architecture: Loosely Coupled Systems, Business processes, Tiers, Architectural Choices; Resiliency in Middleware: resiliency techniques, hardware failures, communication failures, software failures; Performance and scalability in Middleware; Security in Middleware; Implementation Aspects: business process implementation, enterprise integration, web and database middleware (e.g. NoSQL middleware) change management. Case studies of Enterprise application architecture (EAI) - Eg. Tibco, Websphere.

**SE\* ZG622 Software Project Management 4**

Managing a software development project, concepts, objects of a project, environment of a software project, system development life cycle, tools, review process; documentation in software program management, procedures, diagramming techniques, management; Planning and monitoring a software project, project planning, management tools, software project definitions, project management packages, project control; software project definition, classification, project sizes and methodologies, feasibility, requirements and start-up; programmer productivity; software planning, control tools, accelerated design; prototyping and role in software project management; software production and software project management; software system installation, managing testing requirements, test plans, alpha and beta systems; emerging directions in project management.

**SE\* ZG626 Hardware Software Co-Design 5**

FPGA and ASIC based design, Low-Power Techniques in RT Embedded Systems On-chip networking. Hardware Software partitioning and scheduling, Co-simulation, synthesis and verifications, Architecture mapping, HW-SW Interfaces and Re-configurable computing.

**SE\* ZG651 Software Architectures 5**

Systems engineering and software architectures; Hatley-Pirbhai architectural template; architecture flow diagrams; requirements engineering and software architecture; architectural design processes; design post-processing; real-

time architectures; architectural design patterns; software architecture and maintenance management; object oriented architectures; client-server architectures; forward engineering for object oriented and client-server architectures; emerging software architectures.

#### **SE\* ZG661 Software Quality Management 4**

Software quality challenges and expectations; quality dilemma; software life cycle and link to quality; quality gates, formal reviews, system requirement reviews, preliminary design reviews, critical design reviews, test reviews; engineering reviews, walkthroughs, inspections, internal reviews; quality gate categories; technical environment and quality; planning for software quality, quality requirements for planning, quality needs, elements of quality planning, quality assessments during planning, software quality organization requirements; quality evaluation of software development process, process quality attributes, measuring software process quality; software process metrics; quality gate integrity; software product quality, standards and conventions, metrics; quality hierarchy, factors; quality assessment; quality evaluation techniques, reviews, walkthroughs, audit, inspections, analytical evaluation techniques; quality systems.

#### **SE\* ZG681 Cyber Security 4**

Cyber Security principles; Security architectures; Security threats, attacks and vulnerabilities; CIA Triad, Cyber Security Policies, Models and Mechanisms; Types of Cyber Attacks; Security Risk Management; Malware; Ransomware; Implementing Cyber Security Solutions

#### **SE\* ZG685 Software Product Management 5**

Identifying customer needs. Defining value proposition. Specifying and validating MVP. Building products through agile and scrum. Metrics, measurement and improvements. Software product lifecycle management; analytical evaluation techniques; quality systems.

#### **SS\* ZC111 Probability and Statistics 3**

Probability spaces; conditional probability and independence; random variables and probability distributions; marginal and conditional distributions; independent random variables; mathematical expectation; mean and variance; binomial, Poisson and normal distributions; sum of independent random variables; law of large numbers; central limit theorem (without proof); sampling distribution and test for mean using normal ES\* ZG and student's t-distribution; test of hypothesis; correlation and linear regression.

#### **SS\* ZC163 Computer Programming 4**

Basic Computing Steps and Flow Charting (Assignment, Sequencing, Conditionals, Iteration). Programming Constructs – Expressions, Statements, Conditionals, Iterators/Loops, Functions/ Procedures; Data Types – Primitive Types, Tuples, Choices (Unions or Enumerations), Lists/Arrays, Pointers and Dynamically Allocated Data. Input output and Files. Laboratory Component: Programming Exercises involving development and testing of iterative and procedural programs using bounded and unbounded iterations, function composition, random access lists, sequential access lists, dynamically allocated lists, and file access.

#### **SS\* ZC222 Discrete Structures for Computer Science 3**

Sets and relations; graphs and digraphs; trees, lists and their uses; partially ordered sets and lattices; Boolean algebras and Boolean expressions; semigroups and machines; codes and applications.

#### **SS\* ZC234 Linear Algebra & Optimization 3**

Vector and matrix algebra, systems of linear algebraic equations and their solutions; eigenvalues, eigenvectors and diagonalization of matrices; Formulation of linear programming problems, Simplex method, Big-M method, two

phase method, Sensitivity analysis, Revised and Dual Simplex Methods.

#### **SS\* ZC241 Principles of Management 3**

Fundamental concepts of management - planning; organizing; staffing; directing and controlling; production, financial, personnel, legal and marketing functions; accounting and budgeting, balance sheets.

#### **SS\* ZC263 Digital Electronics and Microprocessors 4**

Binary logic gates; logic circuits; Boolean algebra and K-map simplification; number systems and codes; arithmetic logic units; flipflops; registers and counters; introduction to microprocessors; architecture; instruction set and programming; memory and I/O interfacing examples of system design.

#### **SS\* ZC312 Technical Report Writing 3**

Elements of effective writing; art of condensation; business letter writing; memos; formal reports; technical proposals; conducting, and participating, meetings; agenda and minutes; strategies for writing technical descriptions, definitions, and classifications; oral presentation; use of graphic and audio-visual aids; editing.

#### **SS\* ZC313 Object Oriented Programming & Design 4**

Object oriented concepts and design, abstraction, architecture and design patterns, GUI programming and frameworks, design of object oriented solutions using UML, design for concurrency, implementation of solutions using object oriented languages like C++ or Java; Language level mapping and realization of object oriented constructs, realization and performance issues versus abstraction and usability.

#### **SS\* ZC327 Systems Programming 4**

Batch processing; Systems programs; operating characteristics and limitations; parallel processing of I/O and interrupt handling, multiprogramming; multiprocessing systems; design of system modules and interfaces with focus on contemporary open source operating system-specific programming; laboratory experiments or programming assignments involving Unix/Linux System-specific Programming including shell-scripting via online laboratory facility.

#### **SS\* ZC328 Software Testing 3**

Brief description of importance of software, Life cycle model and process, Basic software testing, all definitions, Types of testing and techniques (CFG, CDG etc.), Black Box & white box Testing Methodologies, Finite State Machine Model, State based Testing, Static Testing and analysis, Test cases, Test Data Generation, Test selection, Minimizations and Prioritization, Test adequacy criteria, Software Testing on Web Engineering, Object based Software Testing, Architecture of Testing tool, Software Test Effort Estimation, Testing behavior and process model, Qualitative analysis, Quality factors in software testing, Selection of testing tools.

#### **SS\* ZC337 Database Systems & Applications 4**

Introduction to Database Management Systems; File organization; Data Independence in databases; Data Models; Query processing systems; Database Design techniques; Concepts of security and integrity in databases; Distributed Databases; Applications using DBMS, database programming experiments involving use of SQL, database creation etc. via online laboratory facility.

**SS\* ZC343 Software Engineering 4**

Software engineering concepts and methodology; formal requirements specification; estimation; software project planning; detailed design; techniques of design; productivity; documentation; programming languages styles, code review; tool, integration and validation; software quality assurance; software maintenance; metrics, automated tools in software engineering.

**SS\* ZC353 Computer Organization & Architecture4**

Overview of logic design; Instruction set architecture; Assembly language programming; Pipelining; Computer Arithmetic; Control unit; Memory hierarchy; Virtual memory; Input and output systems; Interrupts and exception handling; Implementation issues; Case studies; This course covers the fundamentals of computer organization and architecture from a programmer's perspective.

**SS\* ZC363 Data Structures & Algorithms 4**

Introduction to software design principles, modularity, abstract data types, data structures and algorithms; Analysis of algorithms; Linear data structures – stacks, arrays, lists, queues and linked representations; Pre-fix, in-fix and post-fix expressions; Recursion; Set operations; Hashing and hash functions; Binary and other trees, traversal algorithms, Huffman codes; Search trees, priority queues, heaps and balanced trees; Sorting techniques; Graphs and digraphs; Algorithmic design techniques; Data structures for external storage, multi-way search and B-trees; Implementation techniques for different data structures including trees, graphs and search structures; Performance evaluation of data structures and algorithms; Implementation issues in large data structures.

**SS\* ZC364 Operating Systems 4**

Introduction to operating systems; Various approaches to design of operating systems; Overview of hardware support for operating systems; Process management: process synchronization and mutual exclusion, inter process communication, process scheduling; CPU scheduling approaches; Memory management: paging, segmentation, virtual memory, page replacement algorithms; File systems: design and implementation of file systems; input/output systems; device controllers and device drivers; Security and protection; Case studies on design and implementation of operating system modules, select laboratory experiments related to creating different elements of operating system and/or implementation of select scheduling, memory management and I/O related algorithms/schemes, using system calls for creating file system specific command, creating simple file system etc. via online laboratory facility.

**SS\* ZC373 Compiler Design 4**

Introduction to Programming Languages and Compilers, Programming Language Features, Front End of a Compiler, Back End of a Compiler, Special aspects of compilers and runtime.

**SS\* ZC416 Mathematical Foundations for Data Science4**

Vector and matrix algebra, systems of linear algebraic equations and their solutions; Eigenvalues, eigenvectors and diagonalization of matrices, Sets and relations; Graphs and digraphs; Trees, lists and their uses; Partially ordered sets and lattices.

**SS\* ZC425 Data Mining 3**

Data Mining – introduction, fundamental concepts; motivation and applications; role of data warehousing in data mining; challenges and issues in data mining; Knowledge Discovery in Databases (KDD); role of data mining in KDD; algorithms for data mining; tasks like decision-tree construction, finding association rules, sequencing, classification, and clustering; applications of neural networks and machine learning for tasks of classification and clustering.

**SS\* ZC427 Software for Embedded Systems 4**

Design methodologies for embedded software, Real time operating systems fundamentals, Embedded Linux and other commercially available real time systems, fundamental of device drivers development, Introduction to Android

**SS\* ZC444 Artificial Intelligence 3**

The object of this course is to give an introduction to the problems and techniques of A.I. along with the applications of A.I. techniques to the fields like natural language understanding, image processing, game theory and problem solving. The course also aims at understanding its implementation using LISP and PROLOG languages.

**SS\* ZC446 Data Storage Technologiesand Networks3**

Storage Media and Technologies – Magnetic, Optical and Semiconductor media, techniques for read/write operations, issues and limitations. Usage and Access – Positioning in the memory hierarchy, Hardware and Software Design for access, Performance issues. Large Storages – Hard Disks, Networked Attached Storage, Scalability issues, Networking issues. Storage Architecture. - Storage Partitioning, Storage System Design, Caching, Legacy Systems. Storage Area Networks – Hardware and Software Components, Storage Clusters/Grids. Storage QoS – Performance, Reliability, and Security issues.

**SS\* ZC462 Network Programming 3**

Overview of computer networks; inter-process communication; network programming; socket interface; client-server computing model: design issues, concurrency in server and clients; external data representation; remote procedure calls; network file systems; distributed systems design.

**SS\* ZC463 Cryptography 3**

Objectives of cryptography; ciphers – block and stream; mathematical foundations – modular arithmetic, finite fields, discrete logarithm, primality algorithms; RSA; digital signatures; interactive proofs; zero-knowledge proofs; probabilistic algorithms; pseudo-randomness.

**SS\* ZC467Computer Networks 4**

Introduction: components of a modern computer network, packet switched network and its metrics, layered architecture of protocols and historical perspective; Application Layer: principles, examples: Web and HTTP, Email, DNS, Peer-to-Peer applications, socket programming; Transport Layer: Services, the concept of connection less, connection oriented and reliable transport, TCP congestion control; Network Layer: addressing mechanism in networks, router architecture, intra and inter-AS routing protocols, multicast and broadcast; Link Layer: error detection and correction, medium access, MAC addressing, Ethernet, switches, Point to point protocol and link virtualization; Physical Layer: signals, medium, and transmission methods, QoS: forward error correction, scheduling and policing mechanism in the networks.

**SS\* ZG512 Embedded Systems Design 4**

Design issues involved in embedded systems and system-on-chip technologies, Programming languages and processor architectures used for embedded systems, Standard Embedded System Development tools and hands-on experience involving these tools, understanding design constraints such as – power, memory, size constraints in system design and tradeoffs. Introduction to other specialized embedded design techniques – such as hardware, software co-design, design of accelerated and distributed embedded systems, fault tolerant design etc.

**SS\* ZG513 Network Security 4**

This course examines issues related to network and information security. Topics include security concepts, security attacks and risks, security architectures, security policy management, security mechanisms, cryptography algorithms, security standards, security system interoperation

and case studies of the current major security systems.

#### **SS\* ZG514 Object Oriented Analysis & Design 4**

Object orientation concepts, theories and principles; fundamental concepts of the object model: classes, objects, methods and messages, encapsulation and inheritance, interface and implementation, reuse and extension of classes, inheritance and polymorphism; process of object-oriented requirements specification, analysis and design; notations for object-oriented analysis and design; case studies and applications using some object oriented programming languages.

#### **SS\* ZG515 Data Warehousing 5**

Introduction, evolution of data warehousing; decision support systems; goals, benefit, and challenges of data warehousing; architecture; data warehouse information flows; software and hardware requirements; approaches to data warehouse design; creating and maintaining a data warehouse; Online Analytical Processing (OLAP) and multi-dimensional data, multi-dimensional modeling; view materialization; data marts; data warehouse metadata; data mining.

#### **SS\* ZG516 Computer Organization and Software Systems 5**

Programmer model of CPU; Basic concept of buses and interrupts; Memory subsystem organization; I/O organization; Concept of assembler, linker & loader; Types of operating systems; Concept of process; OS functions: Process scheduling, Memory management, I/O management and related issues.

#### **SS\* ZG518 Database Design & Applications 5**

DBMS architecture; Data models: Network model, Hierarchical model and Relational model; Database design & optimization; Query processing & Query optimization; Transaction Processing; Concurrency control; Recovery; Security & protection; Introduction to Object Oriented data model & Multimedia Databases.

#### **SS\* ZG519 Data Structures & Algorithms Design 5**

Introduction to Abstract Data Types, Data structures and Algorithms; Analysis of Algorithms – Time and Space Complexity, Complexity Notation, Solving Recurrence Relations.; Divide-and-Conquer as a Design Technique; Recursion – Design of Recursive Functions / Procedures, Tail Recursion, Conversion of Recursive Functions to Iterative Form. Linear data structures – Lists, Access Restricted Lists (Stacks and Queues) – Implementation using Arrays and Linked Lists; Searching and Order Queries. Sorting – Sorting Algorithms (Online vs. Offline, In-memory vs. External, In-space vs. Out-of-space, QuickSort and Randomization). Unordered Collections: Hashtables (Separate Chaining vs. Open Addressing, Probing, Rehashing). Binary Trees – Tree Traversals. Partially Ordered Collections: Search Trees and Height Balanced Search Trees, Heaps and Priority Queues. Algorithm Design: Greedy Algorithms and Dynamic Programming. Graphs and Graph Algorithms: Representation schemes, Problems on Directed Graphs (Reachability and Strong Connectivity, Traversals, Transitive Closure. Directed Acyclic Graphs - Topological Sorting), Problems on Weighted Graphs (Shortest Paths. Spanning Trees). Introduction to Complexity Classes (P and NP) and NP-completeness. NP-Hard problems. Designing Algorithms for Hard Problems – Back tracking, Branch-and-Bound, and Approximation Algorithms.

#### **SS\* ZG520 Wireless and Mobile Communication 5**

Signal propagation in a mobile environment, modulation, coding, equalization; first generation generation systems; multiple access techniques like FDMA, TDMA, CDMA, spread spectrum systems; second & third generation systems, UMTS, IMT-2000; Wireless LAN, Wireless ATM and Mobile IP; emerging trends in Wireless & Mobile Communication.

#### **SS\* ZG522 Design and Operation of Data Centres 5**

Data Center Design: Principles (Scalability, Reliability, and Elasticity), Components - Computing Infrastructure (Processing, Storage, and Networking) and Physical Infrastructure (Power, Cooling, and Physical Security); Servers – Server Hardening, Server Optimization, Server Deployment and Consolidation, Converged and Hyper-Converged Infrastructure. Application monitoring and maintenance. Networking for data centers – device hardening, bandwidth aggregation, traffic management, redundancy, network isolation, deployment of internal security and peripheral security; Contingency Planning & Disaster Recovery: Backup, recovery, and redundancy/replication technologies and approaches. Data Center Architecture: Private, Public, and Hybrid models; Distributed Data Centers; Introduction to Software Defined Data Centers. Costing and Pricing– Costing and Cost Optimization, Pricing and Economics of Data Center Operation.

#### **SS\* ZG525 Advanced Computer Networks 5**

Topics in advanced networking – Quality of Service in IP networks, IPv6, Wireless and Mobile Networks, Carrier Technologies (Frame Relay, FDDI, ISDN, ATM), Peer-to-Peer Networks and Overlays, Routing and QoS Issues in Optical Networks.

#### **SS\* ZG526 Distributed Computing 5**

The course focuses on the fundamental principles and models underlying all aspects of distributed computing. It addresses the principles underlying the theory, algorithms and system aspects of distributed computing. The course covers topics such as Logical and Vector clocks, Global state and Snapshot recording algorithms, Basic distributed algorithms, Message Ordering and termination detection, Distributed Mutual Exclusion & Deadlock detection, Consensus and Agreement Algorithms, Peer-to-Peer computing and Overlay graphs, Cluster Computing & Grid Computing, and Internet of Things.

#### **SS\* ZG527 Cloud Computing 5**

Concurrency and distributed computing, message passing over the network, connectivity and failure models, local vs remote connectivity, distributed resource modeling, distributed data models; replication & consistency; virtualization; CPU virtualization, memory and storage virtualization, virtualized networks, computing over WAN and Internet; computing on the cloud, computing models, service models and service contracts, programming on the cloud; Cloud infrastructure, LAN vs Wan issue, resource scaling and resource provisions, performance models, scalability, performance measurement and enhancement techniques; cloud applications and infrastructure services.

#### **SS\* ZG528 Cyber Physical Systems 4**

This course provides an overview of Cyber-Physical Systems, with respect to its components and characteristics. As an example of a Cyber-Physical System, this course explains the various aspects of IoT systems, and helps students understand the IoT system components, its protocol stack and design methodologies. The course also enables students to get familiar with the Raspberry Pi platform, via simple examples/applications. At the end of this course, students will be able to explain the various facets of Cyber-Physical Systems, with focus on IoT and demonstrate simple IoT applications.

#### **SS\* ZG529 Deep Learning 4**

Common Architectural Principles of Deep Networks; Building Blocks of Deep Networks; Convolutional Neural Networks (CNNs); Recurrent Neural Networks; Recursive Neural Networks; Building Deep Networks with ND4J; Applications to Sequence Data, Anomaly Detection; Tuning Deep Networks; Vectorization.

#### **SS\* ZG530 Natural Language Processing 3**

Language modelling with N-gram, spelling correction, Neural

networks and neural language models, Parts-of-Speech tagging, Syntactic parsing, Language semantics, Computational symantics.

#### **SS\* ZG536 Advanced Statistical Techniques for Analytics** 4

This course will cover the statistical techniques which are very important in Data analytics. It covers the models related to descriptive statistics, inferential statistics, predictive analytics and applied multivariate analytics. And also this course introduces the important tools used in Data Analytics in Particular R language.

#### **SS\* ZG537 Information Retrieval** 4

Organization, representation, and access to information; categorization, indexing, and content analysis; data structures for unstructured data; design and maintenance of such data structures, indexing and indexes, retrieval and classification schemes; use of codes, formats, and standards; analysis, construction and evaluation of search and navigation techniques; search engines and how they relate to the above. Multimedia data and their representation and search.

#### **SS\* ZG547Usability Engineering** 5

Usability-driven approach to Information Design; software usability bridge& its critical components; Iterative & evaluation of a two-level approach of UCID (User-Centered Information Design); five key principles of UCID; getting UCID into organization ; Benefits of implementing UCID; key features of UCID;UCID process & analysis; traditional processes for information development & their limitations; Managing UCID; role of usability engineers; preparing the usability plan; implementing a metrics program in typical UCID projects; key contributors; goal setting for software usability & information quality; critical design goals; designing the information architecture ;designing the specifications & prototypes; evaluating prototypes; two-level design activities; designing software labels; designing effective messages; designing online support elements & printed support elements; achieving information design goals; online search & navigation; evaluating information; two-level evaluation; approach achieving information design goals for improved software usability; testing information & validating; quality indicators; retrievability; implementation techniques & issues; Application of Usability Engineering in typical live projects to validate improved software usability .

#### **SS\* ZG548 Advanced Data Mining** 4

Topics beyond conventional record data mining. Mining complex data structures. Tree/graph mining, sequence mining, web/text data mining, stream data mining, spatiotemporal data mining, mining multi-variate time series data, high-dimensional data clustering, and mining social networking sites. Mining data from multiple relations (Multi-relational Data Mining). Privacy preserving Data Mining. Distributed computing solutions for data intensive data mining.

#### **SS\* ZG553Real Time Systems** 5

Real time software, Real time operating systems-scheduling, virtual memory issues and file systems, real time data bases, fault tolerance and exception handling techniques, reliability evaluation, data structures and algorithms for real time/embedded systems, programming languages, compilers and run time environment for real time/embedded systems, real time system design, real time communication and security, real time constraints and multi-processing and distributed systems.

#### **SS\* ZG554 Distributed Data Systems** 5

Distributed File Systems - File System Models; Replication and Synchronization - Caching; Failure & Recovery; File System Security. Distributed Databases - Distributed Data Sources and Updates; Database Connectivity; Concurrency Control and Distribution mechanism; Distributed indexing

schemes. Database security. Data on the Web - Web as a distributed data repository. Data Collection and Use Crawlers, Search Engines, and Indexing Schemes. Information Retrieval Techniques. Data Exchange - Hierarchical Data Models, XML, and query languages. Semi-structured / Unstructured data -querying and synchronization. Pervasive Data - Data distribution and access for non-computing devices, small computing devices, embedded computing devices and sensory devices.

#### **SS\* ZG556 Stream Processing and Analytics** 5

Real Time , Streaming Data & Sources, Real time streaming system architecture , Characteristics of a Real Time Architecture and Processing ; Configuration and Coordination Systems: Distributed State and Issues, Coordination and Configuration using Apache ZooKeeper; Data Flow Management : Distributed Data Flows , Various Data Delivery and Processing Requirements, N+1 Problem, Apache Kafka (High-Throughput Distributed Messaging); Processing Stream Data with Storm; Overview of Data Storage – Requirements: Need for long-term storage for a real time processing framework, In-memory Storage, No-Sql Storage Systems, Choosing a right storage solution; Visualizing Data :Requirements, Principles and tools; Bounds of Random variables, Poisson Processors, Maintaining Simple Statistics from Data Streams, Sliding Windows and computing statistics over sliding windows, Data Synopsis (Sampling, Histograms, Wavelets, DFT), Exact Aggregation, Timed Counting and Summation, Multi Resolution Time Series Aggregation, Stochastic Optimization; Statistical Approximation to Streaming Data: Probabilities and Distributions, Sampling Procedures for Streaming Data, Approximating Streaming Data with Sketching, Registers and Hash Functions, Working with Sets, The Bloom Filter, Distinct Value Sketches, The Count-Min Sketch; Clustering techniques for Streaming Data; Classification methods : Decision Tree (VFDT); Evaluating stream processing algorithms; Case Studies in Designing solutions to streaming data

#### **SS\* ZG562 Software Engineering and Management**5

Current concepts, methods, techniques, and tools of the software engineering process; software process models; process definition and assessment; software measurement and metrics; project planning, estimation and control; requirements analysis and specification, design methods; quality assurance and testing; configuration management; process improvement; case studies and project work.

#### **SS\* ZG566 Secure Software Engineering** 5

Best practices for designing secure systems, software engineering principles for designing secure systems, criteria for designing secure systems; analysis of system properties and verification of program correctness; use of formal methods and verification for security; tools for verification of security properties; techniques for software protection (such as code obfuscation, tamper-proofing and watermarking) and their limitations; analysis of software based attacks (and defenses), timing attacks and leakage of information, and type safety.

#### **SS\* ZG567 AI and ML Techniques in Cyber Security**5

Introduction to Cyber-Security; Supervised Learning for Misuse/Signature Detection; Machine Learning for Anomaly Detection; Malware detection and classification; Network Intrusion detection and classification; Detection and categorization of domain names; Profiling Network Traffic; Adversarial Machine Learning for Malware detection



**SS\* ZG568 Applied Machine Learning 4**

Need for machine learning. Prediction and classification methods. Use cases in application domains. Interpretation of results. Limitations of various techniques. End to end Machine learning - data collection, data preparation, model selection.

**SS\* ZG569 Blockchain Technologies & Systems 4**

Highly successful decentralized blockchain-based systems, such as Bitcoin, have immense potential to revolutionize financial, information, and other infrastructures. This course aims to provide a broad overview of the essential concepts involved in blockchain technology in order to lay down the foundation necessary for developing applications. This course also covers the technical aspects of consistency and consensus in distributed algorithms, public distributed ledgers, public-key cryptography and cryptographic properties, cryptocurrencies, and smart contracts. The course aims to develop expertise among students to build these systems, interact with them, and to design and build secure distributed applications.

**SS\* ZG570 Cloud, IoT and Enterprise Security 5**

Enterprise Security Overview, Security Architectures, Security as a Process, Securing the Network, Systems, Enterprise Data, Internet of Things, Security Requirements in IoT and Current Vulnerabilities, Security Architecture in the Internet of Things, Device Security and Node Authentication, Data Security Schemes for IoT and Social IoT Concerns, Cloud Computing Fundamentals, Cloud Computing Software Security Fundamentals, Cloud Computing Risk Issues, Cloud Computing Security Challenges, Cloud Computing Security Architecture

**SS\* ZG574 Embedded Network Security 4**

Introduction to networked embedded systems, network security fundamentals, internet communication and security protocols, techniques for embedded network security, wireless communication in embedded network security, wireless and cellular network security, WSN and adhoc network security, embedded device attestation techniques, handling attacks from compromised systems, security issues in IoT devices and networks.

**SS\* ZG575 Ethical Hacking 3**

Techniques and tools for ethical hacking and countermeasures; exploit approaches – social engineering, scanning, footprinting, enumeration, sniffers, buffer overflows, web-hacking including cross scripting, SQL injection, privilege escalation, root kits, search engine hijack, covert channel, binary auditing, services specific hacking like DNS, Email, Web servers, Proxy; techniques of bypassing security mechanisms and hardening systems and networks for countermeasures of security analysis, monitoring and analysis tools including network traffic and system logs.

**SS\* ZG576 Identity and Access Management Technologies 4**

Course description to be developed.

**SS\* ZG577 Metaheuristics for Optimization 4**

Metaheuristics refers to class of approximation algorithms which can solve hard optimization problems within an acceptable time limit. This course covers principles behind such algorithms and application to real world problems. The algorithms covered in the courses include simulated annealing, evolutionary algorithms, ant colony method, and particle swarms.

**SS\* ZG578 Mobile Networks 4**

This course covers networking topics, including in-depth study of networking protocols and system designs, with specific focus on mobile and wireless scenarios and applications. The main objective of this course is to introduce a wide range of current and next-generation wireless

networking protocols and technologies. The course focuses on the most widely used mobile and wireless network standards including cellular (LTE), Wi-Fi, Bluetooth, etc. During the course, students will learn the specific mechanisms of different network architectures and tools used to analyze network performance. Given wireless and mobile networking is a very dynamic and constantly changing area, the course will cover emerging research advances in the areas of 5G, Internet-of-Things, LTE-direct, and other work from recent conferences in the field.

**SS\* ZG579 Real Time Scheduling 4**

Real time scheduling algorithms, Resource constraints and allocation, Real time scheduling for multi-processing and distributed systems, Real time operating systems

**SS\* ZG580 Software Defined Networks 5**

The course covers genesis of Software Defined Networks (SDN), characteristics and operation of SDN, SDN Devices and controller, Protocols such as overflow, Controller and application models, Middleboxes and network function virtualization in SDNs, SDN in the data center, Applications of SDN.

**SS\* ZG584 Data Management for IoT 5**

Data in IoT, IoT analytics, data acquisition and preparation for IoT, data exploration for IoT, Big data management for IoT, applied predictive analytics, IoT analytics over the cloud, IoT data analytics case studies.

**SS\* ZG585 Cross Platform Application Development 4**

Cross-platform applications development involves creation of software applications that are compatible with multiple platforms or software environments. This can be achieved through various development frameworks like Ionic, React Native, Adobe PhoneGap, Xamarin etc. This course aims to equip students with the expertise to design and develop web and mobile based applications that can operate in varied environments and platforms. Additionally, it also aims to develop the understanding of the role and importance of API management in such applications. The course involves hands-on exposure to full stack development of cross-platform applications using some of the existing development frameworks.

**SS\* ZG586 Edge Computing 5**

This course will explore frameworks and applications in Edge Computing. The topics covered will include edge architecture, edge to edge and edge to cloud communication, Sensor networks and related protocols, Distributed caching, Reliability, availability and energy efficiency in edge computing, Pipeline, Performance issues like latency and Data flow for Big data analytics, Semantic Web of Things and Application level security.

**SS\* ZG588 Cyber Crimes, Forensics and Incident Handling 4**

Introduction to Computer Forensics: collection, preservation, analysis, preparation and presentation of computer based evidence for the purposes of criminal law enforcement or civil litigation. Structure of Storage Media: Study of different file systems (FAT12, FAT16, FAT32, NTFS, EXT2/EXT3, etc.). Study of digital forensic techniques: Disk forensics, Network forensics and Device forensics. Understanding Computer Crime, Data Acquisition, Forensic Analysis (Internet History files, Email files and major operating system files for different OS's). Study of Steganography: information hiding and retrieval. Live versus Dead forensics. Use of Forensic Tools for file system analysis, registry analysis, network analysis, etc., Introduction to computer crimes in India and abroad, Overview of cloud forensics.

**SS\* ZG589 Middleware Technologies 4**

Evolution of Middleware Technologies: Transaction Processing, Remote Procedure Calls, Message-Oriented-Middleware, Object Request Brokers, Web services and REST; Forms of Middleware: Enterprise Middleware, Web Middleware, and Cloud / Services Middleware; Middleware Elements: communication protocols, middleware protocols, data representation, server process control, naming and directory services, security, system management; Select case studies such as MS .NET, J2EE. Service Oriented Architecture: Loosely Coupled Systems, Business processes, Tiers, Architectural Choices; Resiliency in Middleware: resiliency techniques, hardware failures, communication failures, software failures; Performance and scalability in Middleware; Security in Middleware; Implementation Aspects: business process implementation, enterprise integration, web and database middleware (e.g. NoSQL middleware) change management. Case studies of Enterprise application architecture (EAI) - Eg. Tibco, Websphere.

**SS\* ZG626 Hardware Software Co-Design 5**

FPGA and ASIC based design, Low-Power Techniques in RT Embedded Systems On-chip networking. Hardware Software partitioning and scheduling, Co-simulation, synthesis and verifications, Architecture mapping, HW-SW Interfaces and Re-configurable computing.

**SS\* ZG653 Software Architectures 5**

Systems engineering and software architectures; Hatley-Pirbhai architectural template; architecture flow diagrams; requirements engineering and software architecture; architectural design processes; design post-processing; real-time architectures; architectural design patterns; software architecture and maintenance management; object oriented architectures; client-server architectures; forward engineering for object oriented and client-server architectures; emerging software architectures.

**SS\* ZG656 Networked Embedded Applications 4**

Networked embedded systems, Clock synchronization, Protocol mechanisms protocol performance, CAN Bus architecture, USB Architecture, Embedded Internet, distributed computing, Use of Java in building networked systems, Reliability & Fault Tolerance etc. Mission-critical distributed real-time applications, e.g., military, air traffic control; Prototyping benchmark applications, e.g. simulated air traffic visualization, radar display; Networking: TCP/IP, distributed objects; Embedded system programming and middleware: I/O, analog / digital conversion, DSP, runtime monitoring of CPU, processes, network equipment; Modeling distributed real-time systems; Quality of service maintenance.

**SS\* ZG681 Cyber Security 4**

Cyber Security principles; Security architectures; Security threats, attacks and vulnerabilities; CIA Triad, Cyber Security Policies, Models and Mechanisms; Types of Cyber Attacks; Security Risk Management; Malware; Ransomware; Implementing Cyber Security Solutions

**SS\* ZG682 Embedded Middleware Design 5**

System Middleware, hardware abstraction Middleware, distributed computing middleware, with a focus on architectural principles, overview of required functions of emerging middleware and how middleware is designed to support these function, middleware for mobile computing, middleware for embedded systems, and middleware for sensor networks.

**SS\* ZG683 Fault Tolerant Embedded System 4**

Design techniques for reliable, fault-tolerant, fail-safe and fail-soft systems, Fault diagnosis and fault avoidance methods, Fault Tolerant Networks, Experimental and Commercial fault-tolerant embedded systems

**SS\* ZG684 Parallel Embedded Architectures 4**

Instruction level parallelism, Typical RISC Pipeline Design, Superscalar Architectures, Data Parallel Architecture, Thread & Process Level Parallel Architectures, Multi-Threaded Architectures.

**SSTM\* ZG511 Sanitation Technology 5**

This course aims to give the participants a review of the fundamentals as well as the latest technological developments applied in the field of sanitation. Urban Drainage and Sewerage, Carbon, nitrogen and phosphorus removal & recovery; sludge treatment, Site evaluation; toilets; onsite sanitation systems; emptying and transport; established and transferring technologies for dewatering, stabilization, pathogen inactivation and nutrient management, urban low cost drainage, Innovation processes, Intro & Exercise technology selection tool / decision support system; discuss outcomes

**SSTM\* ZG512 Sanitation and Public Health 5**

This course will have four modules – Introduction to Sanitation, Sanitation system and services, Public Health and Analysis of sanitation flow. Background on urban sanitation, Material flow analysis, Monitoring frameworks, Shit Flow Diagrams, Human Health Hazards and Waste, Review and Assessment of Transmission Routes, Review and Assessment of Transmission Routes, Disease Cycles – Lifecycles & Vectors, Control Measures, Risk Evaluation Tools, Urban development trends, demography, Urban sanitation planning & programming

**SSTM\* ZG513 Sanitation Governance, Behavioral Change and Advocacy 5**

This particular course will have two modules – Sanitation Governance and Behaviour change & Advocacy. Water & sanitation governance: definitions, debates, controversies, Power relations among actors in the local and global levels: Gender, class & race relations and power asymmetries, Practices of coordination & decision, making around contested water distribution, Case studies on regulatory frameworks around the world – how is sanitation managed: where, how and why, Everyday sanitation from different perspectives. Behaviour with reference to Societal and cultural aspects, Types: Knowledge, motivations and reactions, Reinforcements: Norms and behaviour Settings

**SSTM\* ZG514 Sanitation Financing & Project Management 5**

This course will have two modules – Sanitation Financing and Project Management. Introduction to financial viability, CAPEX, OPEX, business models and PPP of sanitation project, Calculating CAPEX and OPEX of a sanitation project and developing a business model, Local authority/municipal budgeting and public/government financing, Key aspects of project management including stakeholders' relationship, people management, risk management, budget management, reporting, Objective Oriented Project Planning.

**SSTM\* ZG515 Emergency Sanitation & Leadership 5**

This course will have two modules – Emergency Sanitation and Leadership. The evolution of humanitarian aid: historical events and the humanitarian system as it stands today. Overview of the international legal framework (Refugee law, International Humanitarian Law-IHL, International Disaster Relief Law-IDRL), code of conduct and guiding principles of humanitarian action. Standards applied by relief agencies and global cluster, Sphere, WASH cluster. Disaster cycle, risk reduction/ response/ recovery/ development, emergency response phases. Overview of relief organizations, their mandates, their commitments and priorities in emergencies.

**SSTM\* ZG516 Environmental Sampling and Analytical Methods 5**

Principles of sample collection and data analysis / interpretation, Gravimetric methods, titrimetric methods, electrochemical methods, Spectrometric methods of analysis, Chromatographic methods of analysis, Sampling techniques for air and water pollution, Biological methods of analysis, Interpretation of data in environmental monitoring

**SSTM\* ZG521 Environmental Chemistry 5**

Fundamentals of Physical Chemistry, Water Chemistry, Water pollution, Green Chemistry, Fundamentals of Analytical Chemistry, Atmospheric Chemistry and air pollution, Energy and climate change, Toxic compounds, Metals, soils, sediments and waste disposal, Case studies

**SSTM\* ZG522 Environmental Biotechnology 5**

Principles, concepts and applications of Biotechnology to the management of environmental problems, Microbial technologies for waste management, Bioremediation of toxicants, Microbial systems for detoxification, Microbial technologies for waste management, Biochemical kinetics and engineering, Concept of rDNA technology, Regulation and ethics

**SSTM\* ZG523 Biological Treatment Principles and Design of Waste Water Systems 4**

Fundamentals of biological treatment, Biochemistry and kinetics of biochemical processes like oxidation, nitrification & denitrification, Dephosphatization, Acedogenesis and methogenesis, Aerobic and anaerobic treatment processes, Basic description of equipment and design methodologies, Design of reactors and configurations; Case studies for industrial and wastewater treatment.

**SSTM\* ZG524 Environmental Statistics 4**

Introduction to probability and Statistics, Probability concepts and probability distributions, Fundamentals of data analysis, Uncertainty in Measurement, Precision and accuracy, Reproducibility/repeatability, Types of errors, Error propagation, Confidence intervals, Hypothesis testing for equality of mean and standard deviation: t-test, chi-square test and F-test, Errors in hypothesis testing, Experiment design and analysis of variances, Autocorrelation, cross-correlation and sensitivity analysis in data sets, Linear least-squares regression. Precision of parameter estimates, Coefficient of determination; Interpreting statistical results, documentation and recommendations, Theory of attributes, Time series analysis, Case studies

**SSTM\* ZG525 Environmental Systems Modelling4**

Introduction to air quality models, Atmospheric stability and turbulence, Gaussian dispersion models, single source and multisource models, Transport and fate of pollutant in aquatic systems, Introduction to modeling of river, lake and estuarine hydrodynamics, Stratification and eutrophication of water bodies, Dissolved oxygen model for water streams, Computational methods in environmental modeling and simulation, Transport and fate of pollutants in soils and ground water, Applications of public domain models and software; Case studies.

**SSTM\* ZG526 Solid Waste Management 4**

Introduction to solid waste management: Sources and classification, Composition and Properties of Solid Waste and emerging e-waste, Onsite handling, storage and processing including segregation, Collection of solid waste, Transfer and transport, Recycling, Incineration pyrolysis and composting, Processing technique and equipment, Recovery of resources, conversion products, and energy, Biomedical and hazardous waste, Electronic waste, Regulatory framework, categorization, generation, collection, transport, treatment and disposal, Leachate collection and treatment, Bioleaching and bioremediation; Case studies.

**SSTM\* ZG527 Environmental Management Systems5**

Introduction to air & water pollutants & solid wastes; sampling & analysis techniques; impact of these on environment; national & international regulations; ISO series; conventional & non-conventional energy resources; life cycle analysis; environmental audit; sustainable developments; case studies.

**SSTM\* ZG528 Environmental Risk and Impact Assessment 4**

Introduction to Environmental Impact Assessment (EIA), Environmental assessment framework, Impact assessment methodologies; Air and water quality Impact analysis (AQIA / WQIA), Energy and noise impact analysis (EnIA / NIA), Vegetation, wild life and socio-impact analysis, Environment risk assessment, Environmental Impact statement.

**SSTM\* ZG628T Dissertation 16**

A student registered in this course must take a topic in an area of professional interest drawn from the on the job work requirement which is simultaneously of direct relevance to the degree pursued by the student as well as to the employing / collaborating organization of the student and submit a comprehensive report at the end of the semester working under the overall supervision and guidance of a professional expert who will be deemed as the supervisor for evaluation of all components of the dissertation. Normally the Mentor of the student would be the Dissertation supervisor and in case Mentor is not approved as the supervisor, Mentor may play the role of additional supervisor. The final grades for dissertation are Non-letter grades namely Excellent, Good, Fair and Poor, which do not go into CGPA computation.

**ST\* ZG511 Matrix Methods in CivilEngineering 5**

Matrix techniques; basic equations of solid mechanics; variational methods; finite difference and finite element methods; applications to structural mechanics, soil and rock mechanics, fluid mechanics, and hydraulic structures.

**ST\* ZG513 Advanced Computational Techniques 4**

Interpolation, Polynomial Interpolation, Lagrange, Newton's Interpolation, Numerical integration, Wilson  $\theta$  Method, Newmark's Method, Gauss and Hermitian Quadrature, Quadrature rules for multiple integrals, Large system of linear simultaneous equations, Direct and iterative algorithms based on Gauss elimination, Gauss Seidel method and symmetric banded equations, storage schemes – skyline, band solver, frontal solver, Cholesky decomposition, Non-linear system of equations, Eigen value problems, Forward iteration, Inverse iteration, Jacobi, Given's method, Transformation of generalized Eigen value problem to standard form, Vector iteration method, Initial and boundary value problems, Solution of first and second order differential equations using Euler, modified Euler, and Runge-Kutta methods, Finite difference operators.

**ST\* ZG514 Structural Optimization 4**

Introduction, Engineering Optimization Problems, Optimal problem formulation, Single-variable optimization algorithms, Bracketing methods, Region Elimination methods, Gradient-based methods, Multivariable optimization algorithms, Evolutionary optimization methods, Simplex Search method, Hooke-Jeeves pattern search method, Powell's conjugate direction method, Cauchy's method, Newton's method, Conjugate Gradient method, Constrained Optimization algorithms, Kuhun-Tucker conditions, Transformation methods, Direct search for constrained minimization, Feasible Direction Method, Specialized algorithms, Integer Programming, Geometric Programming, Nontraditional optimization Algorithms, Genetic algorithms, Simulated Annealing, Structural Optimization, Methods of optimal design of structural elements, minimum weight design of truss members, optimum reinforced design of R.C. C. Slabs and beams, Optimization to the design of structures such as multi-storey buildings, water tank, shell roofs, folded plates.

**ST\* ZG521 Topics in Structural Engineering 5**

Introduction to structural optimization, application to simple structures such as trusses, and simple frames; Theory of plates and its applications in Civil Engineering; folded plate design; theory and design of shell structures specifically with application in structures covering large area.

**ST\* ZG522 Structural Health Assessment and Rehabilitation 4**

Introduction, Overview of present repair, retrofitting, and strengthening practices, Distress identification, Repair management, Causes of deterioration and durability aspects, Holistic models of Deterioration of RCC, Durability Aspects, Intrinsic and Extrinsic causes and stages of Distress, Condition Survey and Non-destructive Evaluation, Classes of Damages and Repair Classification, Structural Analysis and Design, Reserve Strength, Evaluation of Building Configuration, Repair materials and their selection, Rehabilitation and Retrofitting Methods, Analysis and Design of Externally FRP and ECC Strengthened Structures, Retrofitting using External Unbonded Post-tensioning and Near Surface Mounted FRP Rebars, Durability Based Design of FRP Reinforced/Strengthened Bridge Girders, Case Study Problems.

**ST\* ZG523 Advanced Concrete Technology 4**

Components of Concrete, chemical properties of cement & cementitious paste, properties of aggregates; chemistry of admixtures: mineral, chemical; effect of concrete composition on properties of fresh concrete and hardened concrete; Durability of concrete and its relation with concrete composition; Techniques for non-destructive evaluations (NDE) of concrete; Concrete mix design; Special concrete, Concrete with alkali activated binder.

**ST\* ZG524 Advanced Concrete Structural Design 5**

Design of indeterminate beams and frames; Design of beam-column joints, Design of flat slabs, Analysis of slab using yield-line theory; Design of circular slabs; Design of beams curved in plan, Design of Folded plates and cylindrical shells, Design of Water Tanks.

**ST\* ZG532 Advanced Soil Mechanics 4**

Modern concept of soil structure and its application in explaining its behaviour; effects of seepage on equilibrium of ideal soil; mechanics of drainage; theories of elastic subgrade reaction; theories of semi-infinite elastic soils; vibration problems.

**ST\* ZG533 Advanced Composite Materials for Structures 4**

Introduction and History of FRP, Overview of Composite materials, Physical and Mechanical Properties and Test methods, Design of RC Structures reinforced with FRP Bars, Flexural Strengthening of RC Beams, Shear Strengthening of Beams, Flexural Strengthening of Slabs, Strengthening of Axially and Eccentrically Loaded Columns, Seismic Retrofit of Columns.

**ST\* ZG551 Dynamics of structures 4**

Free and forced Vibration Analysis of SDOF system, Response to general dynamic loadings, Numerical evaluation of dynamic response, Effect of damping; Free and forced vibration of undamped and damped multi degree of freedom systems; Modeling for multi degree of freedom systems; Equation of motions, Evaluation of natural frequencies and mode shapes, orthogonality conditions, Modal analysis and modal combination rules, Numerical evaluation of dynamic response for multi degree of freedom, time history analysis; support excited vibration, analysis of non-linear systems, Free and forced vibration analysis of continuous systems, Random vibrations, Stochastic response; Vibration isolation, vibration absorber and tuned mass damper; Evaluation of wind, blast, wave loading and other dynamic forces on structure; Modeling and dynamic analysis of buildings, bridges, water tank, liquid storage tanks, stack like structure, machine foundations etc.

**ST\* ZG552 Advanced Structural Mechanics and Stability 4**

Analysis of stress and strain in three-dimension domain, deviatoric stress and strain; stress and strain invariants, compatibility conditions, equilibrium equations; stress-strain relations for anisotropic, orthotropic and isotropic elastic materials; yield criterion; plastic potential and flow rules. Problems on plane stress and plain strain conditions, Airy stress function; Axi-symmetric problems; torsion of prismatic bars, circular and non-circular sections; thin-walled sections, membrane and sand-heap analogies, concept of stability of structures and examples of instability. Stability of structures with one and two degree of freedom, buckling of columns; beam-columns and simple frames, lateral torsion buckling of beams; and introduction to postbuckling of plates.

**ST\* ZG553 Theory of Plates and Shells 4**

Analysis procedure and the basic theory of plates and shells; Different kinds of plates such as rectangular, circular, and elliptical; Different kinds of shell structures such as shell of revolution: spherical shells, cylindrical shells and special shell structures; Principles and applications of bending of plates, membrane theory, bending of shells, and stability of plates and shells; Kirchhoff theory, Reissner-Mindlin-Naghadi type theories, rectangular plates-solution by double Fourier series, membrane theory of shells, and case study on plates and shells using numerical tools.

**ST\* ZG554 Advanced Structural Design 4**

Practical design problems on analysis and design of multistoried and industrial buildings, chimney, retaining wall, water tank, towers, etc using both the steel and concrete materials. Modeling of structures subjected to various load (DL, LL, WL, EQ etc.) combinations, structural analysis, design, and detailing of specific advanced concrete and steel structures.

**ST\* ZG610 Computer Aided Analysis and Design in Civil Engineering 5**

Computer languages; CAD, graphics; database management system; knowledge base expert system; development of preprocessor and post processor with graphic interface; analysis and design, optimization techniques, genetic algorithms, software development for analysis and design, interfacing.

**ST\* ZG612 Advanced Steel Structures 4**

Steel properties; high strength steels, structural behaviour, analysis and design; loads and environmental effects; load and resistant factor design (LRFD); column and beams; connections; member under combined loads; bracing requirements; composite members; plastic analysis and design; tall steel buildings, detailing in steel structures.

**ST\* ZG613 Advanced Concrete Structures 4**

Materials; high strength concrete, flexure analysis and design; shear and diagonal tension; bond and anchorage; serviceability; torsion; columns; joints; indeterminate beams and frames; yield line analysis; strip method for slabs; composite construction; footing and foundations; concrete building system; concrete tall buildings, detailing in concrete structures.

**ST\* ZG614 Prestressed Concrete Structures 4**

Effect of prestressing; source of prestress, prestressing steel; concrete for construction; elastic flexure analysis, flexural strength; partial prestressing; flexural design based on concrete stress limits; tension profile; flexural design based on load balancing; losses due to prestress; shear diagonal tension and web reinforcement; bond stress, transfer and development length, anchorage zone design, deflections.

**ST\* ZG615 Earthquake Engineering 4**

Single and multi-degree freedom system; seismic risk, causes and effects of earthquakes; seismicity, determination of site characteristics; design earthquakes; earthquake

resistant design philosophy; seismic response; earthquake resistant design of structures; detailing for earthquake resistance in concrete and steel structures.

**ST\* ZG616 Bridge Engineering 4**

Purpose of bridge; classification of bridges; characteristics of each bridge; loads stresses and combinations; design of RC bridges; design of non-composite and composite bridges; prestressed bridge; continuous spans, box girders, long span bridges; substructure design for bridges.

**ST\* ZG617 Advanced Structural Analysis 4**

Flexibility Method; stiffness method; beam curved in plan; two dimensional and three dimensional analysis of structures; shear deformations, shear wall analysis; interactive software development for analysis of structures.

**ST\* ZG618 Design of Multi-Storey Structures 4**

Loads and stresses; building frames; framing systems, bracing of multistorey building frames; diaphragms; shear walls and cover; tube structure, approximate analysis and preliminary design; frame analysis; design loading, wind effects and response, earthquake response of structures.

**ST\* ZG619 Finite element analysis 5**

Fundamentals of Finite Element Method (FEM); basic formulations of FEM; assembly of elements, solution techniques; 2D and 3D problems; review of the isoparametric elements; thin and thick plate elements; introduction to shell formulations; use of newly developed elements; mixed finite element method; material and geometric nonlinear problems; application of FEM to civil engineering problems, programming FEM.

**ST\* ZG620 Advanced Foundation Engineering 4**

Types of foundations, capacity and settlement of foundations, soil properties, design considerations, discrete method for analysis, design of shallow and deep foundations, failure in foundations, remedial measures, case studies of foundations.

**ST\* ZG621 Fluid Dynamics 5**

Mechanics of turbulent flow; semi-empirical expressions; statistical concepts; stability theory; flow of non-Newtonian fluids; stationary and moving shock waves; Prandtl-Mayer expressions; two and three dimensional subsonic and supersonic flow; methods of characteristics; small perturbation theory and similarity rules.

**ST\* ZG622 Soil-Structure-Interaction 4**

Importance of soil-structure interaction, basic theories, types of interaction problems, numerical modelling, experimental and field investigations, prediction of failure mechanism, economic considerations.

**ST\* ZG623 Ground Improvement Techniques 4**

Requirements for ground improvement, various techniques of improvement, water table lowering, ground freezing, electro-osmosis, compaction, tamping, use of explosives, vibratory probes, thermal treatment, addition of lime, cement and bitumen, gravel and sand columns, preloading techniques, reinforced earth, soil replacement techniques.

**ST\* ZG631 Selected Topics in Soil Mechanics and Geotechnical Engineering 4**

Formation of soil & soil deposits, subsurface exploration, collapsible soils identification treatment & design consideration, review of casting expansion models in soil, treatment of weak soil, numerical modelling, fracture propagation & fracture energy, fluid infiltrated materials, modern trends.

**ST\* ZG641 Theory of Elasticity and Plasticity 5**

Basic equations of theory of elasticity; elementary elasticity problems in two and three dimensions; theories of plastic flow; problems in plastic flow of ideally plastic and strain hardening materials; theory of metal forming processes.

**TA ZC163 Computer Programming 4**

Basic Computing Steps and Flow Charting (Assignment, Sequencing, Conditionals, Iteration). Programming Constructs – Expressions, Statements, Conditionals, Iterators/Loops, Functions/ Procedures; Data Types – Primitive Types, Tuples, Choices (Unions or Enumerations), Lists/Arrays, Pointers and Dynamically Allocated Data. Input output and Files. Laboratory Component: Programming Exercises involving development and testing of iterative and procedural programs using bounded and unbounded iterations, function composition, random access lists, sequential access lists, dynamically allocated lists, and file access.

**TA ZC164 Computer Programming 4**

Basic Computing Steps and Flow Charting (Assignment, Sequencing, Conditionals, Iteration). Programming Constructs – Expressions, Statements, Conditionals, Iterators/Loops, Functions/Procedures; Data Types – Primitive Types, Tuples, Choices (Unions or Enumerations), Lists/Arrays, Pointers and Dynamically Allocated Data. Input output and Files. Laboratory Component: Programming Exercises involving development and testing of iterative and procedural programs using bounded and unbounded iterations, function composition, random access lists, sequential access lists, dynamically allocated lists, and file access.

**TA ZC142 Computer Programming 3**

Elementary computer organization; introduction to Number Systems; Representation of integers, real numbers and characters on computers; concept of range and accuracy; Arithmetic Overflow; Algorithms and algorithm development; structured program development through step wise refinement. Introduction to C language; Functions; Recursion; Data structure & algorithms; File management & file handling; Problem solving using C.

**TA ZC233 Engineering Measurements 4**

Performance characteristics of measuring instruments, measurement methods for mechanical, electrical, radiant, chemical, magnetic and thermal energy variables. Emphasis in this course shall be on the operation and use of instruments.

**TA ZC312 Technical Report Writing 3**

Elements of effective writing; art of condensation; business letter writing; memos; formal reports; technical proposals; conducting, and participating, meetings; agenda and minutes; strategies for writing technical descriptions, definitions, and classifications; oral presentation; use of graphic and audio-visual aids; editing.

**TE\* ZG511 Soil Mechanics for Highway Engineering 4**

Origin and classification of soils; physicochemical properties, index properties of soil, IS classification of soils and their applications in roads, airfields and embankments, Stresses within a soil, effective stress principle, Soil - water systems - capillarity, flow, Darcy's law, permeability, and tests for its determination, Stresses due to applied load, Stress analysis for embankments and pavements, Compressibility and consolidation characteristics, over consolidation ratio, determination of coefficients of consolidation and secondary compression (creep), consolidation under construction loading, Shear Strength and Mohr Coulomb strength criterion, direct and triaxial shear tests, drained, consolidated undrained and undrained tests, strength of loose and dense sands, NC and OC soils, dilation, pore pressures, Skempton's coefficients. Compaction characteristics, water content – dry unit weight relationships, OMC, maximum dry unit weight, field compaction, quality control, etc. Analysis and design of highway embankment, Characterization of ground, site investigations, methods of drilling, sampling, in situ test - SPT, CPT, plate load and dynamic tests, in-situ permeability and groundwater level, etc., Earth Pressure Theories, Selection and design of earth retaining structures.

#### **TE\* ZG512 Soil Exploration and Field Techniques 4**

Necessity and Importance of soil exploration, Method of sub surface exploration Test pits, Trenches, Wash boring, Percussion drilling, Rotary drilling, Factors affecting the selection of a suitable method of boring. Extent of boring, Factors controlling spacing and depth of bore holes, Spacing and depth of various Civil engineering structures. Indirect method of exploration, Seismic method, Electrical resistivity, Resistivity sounding and profiling, Different method of stabilization of the bore holes, their relative merits and demerits. Different method of ground water observation: Time lag in observation, sampling of ground water. Source of disturbance and their influence. Type of sampler, Principle of design of sampler, Representative and undisturbed sampling in various types of soils. Surface sampling, Amount of sampling, Boring and sampling record, Preservation and shipment of sample, preparation of bore log. Penetration tests, Standard penetration tests, Dynamic cone penetration tests with and without bentonite slurry, Static cone penetration tests, Pressure meter, Dilatometer, factors affecting the penetration tests. Various corrections in the test results. Interpretation of test result for design and determination of modulus of deformation. Small size penetrometers, Plate load test, Field CBR, Dynamic cone penetrometer for CBR evaluation. Various corrections, empirical correlations and interpretation of test result for design in transportation engineering.

#### **TE\* ZG513 Reinforced Soil Structures for Transportation Engineering 4**

Introduction and need for geosynthetics, Types, functions, properties and testing of geosynthetics, Strength analysis of reinforced soil, different types of soil retaining structure, Design codes for reinforced soil retaining walls, External and internal stability of reinforced soil retaining walls, Bearing capacity of footings resting on reinforced soil, Geo-synthetics in flexible pavements, geosynthetics application and design for Separation, Filtration, drainage, erosion control, barrier in highway engineering, Reinforced slope, Design and Construction of Geosynthetic Reinforced Embankments on Soft Subsoils, Other methods of reinforcement like soil nailing, rock bolting, stone columns etc., Practical case studies of reinforced soil structures, Applications of Geocell, PVD, Jute Geotextile and Coir Geotextile in transportation engineering, case studies.

#### **TE\* ZG514 Advanced Concrete Technology in Transportation Engineering 4**

Cements including blended cements, chemical and physical processes of hydration; concrete admixtures: pulverized fuel ash, ground granulated blast furnace slag, silica fume; effects on properties of concretes, mortars and grouts; methods of test; applications; mixer blends and blended cement; admixtures: Review of types and classification; chemical composition; origin and manufacture; actions and interactions; usage; effects on properties of concretes, mortars and grouts; methods of test; applications; Aggregates: Review of types; elementary mineralogy and petrology; aggregate prospecting; quarrying and gravel-winning practice; production of artificial aggregates; sampling and testing; effects on properties of concretes, mortars and grouts; Fresh concrete: Rheology of concentrated suspensions, pastes, mortars and concretes; workability, segregation and bleeding. Theory and principles governing the correct placing and compaction of concrete; Setting and hardening concrete: Plastic settlement and plastic shrinkage; exothermic characteristics; early age thermal movements; strength development; maturity, accelerated curing; assessment of safe stripping times; hot and cold weather concreting; Properties of hardened concrete: Strength; deformation under load; elasticity; creep; drying shrinkage and other volume changes. Thermal properties; Durability of concrete and concrete construction: Durability concept; pore structure and transport processes; reinforcement corrosion; fire resistance; frost damage;

sulphate attack; alkali silica reaction; delayed ettringite formation; methods of providing durable concrete; short-term tests to assess long-term behaviour; Mix design: Review of methods and philosophies; mix design for special purposes; Special concretes: Lightweight concrete: autoclaved aerated concrete, no-fines concrete, lightweight aggregate concrete and foamed concrete. High strength concrete; refractory concrete; high density and radiation-shielding concrete; polymer concrete; fibre-reinforced concrete; mortars; renders; recycled concrete; Special processes and technology for particular types of structure: Sprayed concrete; underwater concrete; grouts, grouting and grouted concrete; mass concrete; slipform construction; pumped concrete; concrete for liquid retaining structures; vacuum process; concrete coatings and surface treatments; Ready-mixed concrete; Precast concrete; Concrete for roads and industrial floors

#### **TE\* ZG515 GIS Applications in Transportation Engineering 4**

Remote sensing: Physics of remote sensing, Ideal remote sensing system, Remote sensing satellites and their data products, Sensors and orbital characteristics, Spectral reflectance curves, resolution and multi concept, FCC, Interpretation of remote sensing images. Digital image processing: Satellite image – characteristics and formats, Image histogram, Introduction to image rectification, Image enhancement, Land use and land cover classification system. Geographic information system (GIS): Basic concept of geographic data, GIS and its components, Data acquisition, Raster and vector formats, Topography and data models, Spatial modelling, Data output, GIS applications. Global positioning system (GPS): Introduction, Satellite navigation system, GPS- space segment, Control segment, User segment, GPS satellite signals, Receivers; Static, Kinematic and Differential GPS. Applications in Transportation Engineering: Intelligent Transport System, Urban Transport Planning, Accident Studies, Transport System Management, Road Network Planning, Collecting Road Inventory

#### **TE\* ZG516 CAD Laboratory in Transportation Engineering 4**

Basic AUTOCAD commands, exercises on earth work computations, cross sections of highways, exercises on packages like MX Roads to compute earth work, geometric design of highways, Exercises on HDM 4 package

#### **TE\* ZG517 Road Safety and Audit 4**

Characteristics of accidents, accidents vs. crash, land use and road environment for safety, Multidisciplinary approach to planning for traffic safety and injury control; pre-crash and post-crash models; role of vehicle, roadway traffic, driver, and environment on road safety, crash and injuries.; accident analysis, conflict points at intersections, pedestrian safety, road safety improvement strategies; Road safety audit and analysis: Stages, aim and objectives, principles, process, roles and responsibility, Specific parameters, design standards, various stages of road safety audit, Road safety audit for rural roads, Checklists, Structuring of report. Steps in treatment of crash locations, diagnosing crash problem and solutions, accident report form, storing of data, using and interpreting crash data, identifying and prioritizing hazardous locations, condition and collision diagrams; Vulnerable road users: crashes related to pedestrian and bicyclists, their safety, provision for disabled; Crash reconstruction: understanding basic physics, calculation of speed for various skid, friction, drag, and acceleration scenarios; Engineering Measures: Speed humps and bumps, speed tables and cushions; Community awareness and education; Enforcement- Non-physical measures- physical measures; Road Safety Audit Case study.

#### **TE\* ZG518 Pavement Analysis and Design 4**

Types of pavements, flexible, rigid and semi-rigid; components of pavement structure; stresses and strains in flexible and rigid pavements: layered systems, visco-elastic

solutions; stresses and deflections in rigid pavements; computer programmes for analysis of stresses and deflections in rigid pavements; traffic loadings, load equivalency factors, traffic projections and analysis; material characterization as input to pavement design; flexible pavement design using IRC, AASHTO, MEPDG methods; Rigid pavement design using IRC, AASHTO, MEPDG, ACI and PCA methods; design of overlays; Considerations in pavement drainage design.

#### **TE\* ZG519 Pavement Evaluation Field Project 4**

Structural condition, Functional Condition and Safety evaluation of pavements, Flexible and Rigid Pavement Rating and establishment of Pavement Condition Index, Case study, involving a failed pavement structure, to investigate the condition and suggest remedial measures, Use of HDM 4 software for establishing the best alternative remedy for the chosen case study.

#### **TE\* ZG520 Infrastructure Planning and Management 4**

The goals and perspectives of planning; forecasting and design of alternatives; plan testing: economic, financial and environmental evaluation; the challenges of managing infrastructure; Information management and decision support system; Concepts of total quality management; Economics: life-cycle analysis and maintenance, Rehabilitation and Reconstruction (M.R & R) programming; Infrastructure management system (IMS) development and implementation; Rural Infrastructure Planning.

#### **TE\* ZG521 Environmental Impact Assessment 4**

Environment and global problems; Framing Environmental issues; effects of infrastructure development on environment; prediction and assessment of environmental impacts of infrastructure projects: technical and procedural aspects, guidelines and legal aspects of environmental protection, impacts on air, water, soil and noise environment, valuation, strategic assessment, mathematical modeling for environmental processes; social impact assessment (SIA), dislocation/disruption impact of Infrastructure projects; Life Cycle Assessments (LCA) and risk analysis methodologies; mitigation of environmental impacts; case studies; environmental management plan (EMP), national and international certification and guidelines including ISO.

#### **TE\* ZG523 Transportation Systems Planning and Management 4**

System and environment; sequential transportation systems planning: trip generation, trip distribution, modal split and traffic assignment. Transportation Systems Management (TSM) actions: traffic management techniques for improving vehicular flow, preferential treatment for high occupancy modes, demand management technique for reduced traffic demand, staggered hours, vehicle restrictions; planning for pedestrians, parking planning; Methods of accident data collection and analysis.

#### **TE\* ZG524 Urban Mass Transit Planning, Operations and Management 4**

Modes of public transportation and application of each to urban travel needs; Comparison of transit modes and selection of technology and transit service; Estimating demand in transit planning studies and functional design of transit routes; Terminal design; Management and operation of transit systems, Model for operational management; Fleet and crew management; Terminal management; Fiscal management.

#### **TE\* ZG528 Selection of Construction Equipment and Modeling 4**

Selection and application of construction and earth moving equipment; Productivity analysis of equipment operations; mathematical models for construction operations; Quality issues in construction process modeling.

#### **TE\* ZG534 Pavement Material Characterization 5**

Soil properties for highway engineers: Origin, properties of soils, tests on soils, Aggregates: origin, classification, requirements, properties, importance of aggregate gradation; bituminous materials: origin, preparation, properties and tests, criterion for selection of different viscosity grades of bitumen, modified binders and bituminous emulsions, Bituminous mixture design: Marshall method of mixture design, SUPERPAVE procedure of mixture design; mechanical properties of bituminous mixtures: resilient modulus, dynamic modulus, visco-elastic and fatigue characteristics. Warm mix asphalt, micro-surfacing, slurry seal, dense bituminous Macadam and bituminous concrete Cement concrete pavement materials: requirements and design of concrete mixture for rigid pavement, IRC and IS specifications and tests, joints, filler and sealant materials.

#### **TE\* ZG535 Highway Geometric Design 4**

Highway functional classification; route layout and selection, design controls and criteria: turning paths, driver performance, traffic characteristics; highway capacity; access control; safety; environment; Elements of design: sight distance, horizontal alignment, transition curves, super elevation and side friction; vertical alignment: - grades, crest and sag curves; highway cross-sectional elements and their design; at-grade Inter-sections – sight distance consideration and principles of design, channelization, mini roundabouts, layout of roundabouts, inter-changes: major and minor interchanges, entrance and exit ramps, acceleration and deceleration lanes, bicycle and pedestrian facility design; parking layout and design; terminal layout and design, geometric design for express ways.

#### **TE\* ZG536 Traffic Engineering and Safety 4**

Road users and their characteristics; traffic studies- volume, speed, origin-destination (O-D) and delay studies; analysis and interpretations of traffic studies; traffic forecasting; capacity and level of service analysis; traffic characteristics at un-signalized and signalized intersections; design of signalized intersections, capacity and LOS of signalized intersections, actuated signal control, signal coordination; traffic controls: signs, markings, street furniture; traffic regulations; parking studies; nature of traffic problems and their solutions; traffic safety: accidents- data collection and analysis; causes and prevention.

#### **TE\* ZG537 Transportation Economics and Finance 4**

Need for economic evaluation; concept of total transport cost; fixed and variable costs, elasticity of demand, marginal costs; value of travel time, accident costs; methods of economic evaluation; taxation in road transport, user charges: fees and tolls; highway legislation; investment policies and pricing, issues in financing and subsidy policy, public private partnership (PPP) options in transport sector: BOT, BOOT, BOLT; feasibility studies, identification and sharing of risks in PPP projects, operation and management agreements.

#### **TE\* ZG539 Introduction to Discrete Choice Theory 4**

Introduction, element of choice process, individual preferences, behavioral choice rule, utility based choice theory; data collection techniques, stated preference (SP) survey, revealed preference (RP) survey, paradigms of choice data; discrete choice models, property of discrete choice models, Multinomial logit model; overview and structure, Nested logit model formulation; discriminant analysis, Naive Bayes classification, classification trees, classification using nearest neighbors; application of fuzzy logic and artificial neural network in discrete choice modeling.

#### **TE\* ZG543 Traffic Flow Theory 4**

Traffic flow elements: speed, volume and density and their relationships; time-space diagrams, controlled access concept, freeway concept, system performances, measures of effectiveness; mathematical modeling; probabilistic & stochastic models of traffic flow process, discrete and continuous modeling: headways, gaps and gap acceptance; macroscopic models; car-following model; queuing models; fundamentals & development of queuing processes; traffic simulation; intelligent transportation systems (ITS).

**TE\* ZG545 Airport Planning and Design 4**

Air Transport-structure and organization; forecasting air travel demand: trend forecasts and analytical methods; air freight demand; airport system; characteristics of the aircraft; airport planning: site selection, layout plan, orientation and length of runway; airport capacity and configuration; geometric design of runway, taxiway and aprons; passenger terminal function, passenger and baggage flow, design concepts, analysis of flow through terminals, parking configurations and apron facilities; air cargo facilities-flow through cargo terminals, airport lighting; airport drainage; pavement design; airport access problem; environmental impact of airports.

**TE\* ZG546 Highway Construction Practices 4**

Road planning and reconnaissance; right of way selection; fixing of alignment; road construction techniques: construction staking, clearing and grubbing of the road construction area; subgrade construction: excavation and filling, compaction, preparation of sub grade, quality control tests as per MORTH specifications; granular subbase and base course construction: gravel courses, WBM, WMM, stabilized soil subbases, use of geo-textiles and geo-grids; construction of bituminous layers; concrete pavement construction; field quality control ; road making machinery.

**TE\* ZG547 Pavement Failures, Evaluation and Rehabilitation4**

Pavement deterioration, distress and different types of failures, pavement surface condition deterioration such as slipperiness, unevenness, rutting, cracking; pot holes, etc., causes, effects, methods of measurement and treatment, use of modern equipment for pavement surface condition measurements, Analysis of data, interpretation. Structural deterioration of pavements: causes, effects, methods of treatment. Structural evaluation of flexible pavements by rebound deflection method, analysis of data, design of overlay, use of FWD and other methods for evaluation of flexible and rigid pavements and their application. Evaluation of new pavement materials, model studies, pavement testing under controlled conditions, accelerated testing and evaluation methods, Test track studies. Instrumentation for pavement testing.

**TE\* ZG548 Pavement Management Systems 4**

Components of pavement management systems, pavement maintenance measures; pavement performance evaluation: general concepts, serviceability, pavement distress survey systems, performance evaluation and data collection using different equipment; evaluation of pavement distress modeling and safety; pavement performance prediction: concepts, modeling techniques, structural condition deterioration models, mechanistic and empirical models, HDM-IV models, comparison of different deterioration models, functional and structural condition deterioration models; ranking and optimization methodologies: Recent developments, economic optimization of pavement maintenance and rehabilitation.

**TE\* ZG549 Rural Road Technology 4**

Network planning, accessibility and mobility; road alignment and survey; geometric design: cross-sectional elements, sight distance, horizontal and vertical alignments; road materials and use of marginal materials; pavement design, drainage, culverts and small bridges; construction and specifications; quality control in construction; pavement failures; maintenance; preparation of detailed project report (DPR); community participation in planning, design, construction and management.

**TE\* ZG616 Bridge Engineering 4**

Purpose of bridge; classification of bridges; characteristics of each bridge; loads stresses and combinations; design of RC bridges; design of non-composite and composite bridges; prestressed bridge; continuous spans, box girders, long span bridges; substructure design for bridges.

**TE\* ZG619 Finite element analysis 5**

Fundamentals of Finite Element Method (FEM); basic formulations of FEM; assembly of elements, solution techniques; 2D and 3D problems; review of the isoparametric elements; thin and thick plate elements; introduction to shell formulations; use of newly developed elements; mixed finite element method; material and geometric nonlinear problems; application of FEM to civil engineering problems, programming FEM.

**TE\* ZG623 Ground Improvement Techniques 4**

Requirements for ground improvement, various techniques of improvement, lowering the water table, ground freezing, electro-osmosis, compaction, tamping, use of explosives, vibratory probes, thermal treatment, addition of lime, cement and bitumen, gravel and sand columns, preloading techniques, reinforced earth, soil replacement techniques, Modern methods of ground improvement with rubber tires, construction wastes, bio-cementation.