INDIAN INSTITUTE OF INFORMATION TECHNOLOGY BHAGALPUR

Mechatronics Engineering (MEA)

B.Tech. Curricula and Syllabus

Semester -VII

Course Code	Course Name	L	T	P	C	Year	Semester	Semester Total Credit
HS401	Professional Ethics for Engineers	2	0	0	2	4	7	22
ME402	Robotics	3	0	0	3			
ME42X	Elective – III	3	1	0	4			
XX4XX	Open Elective	3	1	0	4			
HS45X	Foreign Language	0	0	2	2			
ME411	Robotics Lab	0	0	3	2			
ME491	Minor Project	0	0	0	4			
SAI-III	**Society Academia Industry Internship-III**	0	0	0	1			

Elective III

Semester	Area	Subject
VII	Mechatronics (Mechanical)	Mechanical Vibration, Computer Integrated Manufacturing
VII	Computation	Introduction to Data Science, Reinforcement Learning
VII	Mechatronics (Electrical)	Electro-mechanics and Magnetic Propulsion, Automobile Engineering

Open Elective

1. Quality Control.
2. Advanced Robotics.
3. Materials Characterizations Methods.
4. Physics of Manufacturing.

Syllabus:

Course Code	Course name	L	T	P	C	Year	Semester
HS401	Professional Ethics in Engineers	2	0	0	2	4th	7th
Course objective: To enable the students to create an awareness on Engineering Ethics and Human Values, to instil Moral and Social Values and Loyalty and to appreciate the rights of others.							
Topic	**Contents**						**No. of Lectures**
Module-I	HUMAN VALUES: Morals, Values and Ethics, Integrity, Work ethic, Service learning, Civic virtue, Respect for others, Living peacefully, Caring, Sharing, Honesty, Courage, Valuing time, Cooperation, Commitment, Empathy, Self-confidence, Character-Spirituality, Introduction to Yoga and meditation for professional excellence and Stress management.						**05**
Module-II	ENGINEERING ETHICS: Senses of Engineering ethics, Variety of moral issues, types of inquiry- Moral dilemmas, Moral Autonomy, Kohlberg's theory, Gilligan's theory, Consensus and Controversy, Models of professional roles, Theories of right action, Self-interest, Customs and Religion, Uses of Ethical theories.						**05**
Module-III	ENGINEERING AS SOCIAL EXPERIMENTATION: Engineering as Experimentation, Engineers as responsible experimenters, Code of ethics, A Balanced Outlook on Law						**04**
Module-IV	SAFETY, RERSPONSIBILITIES AND ETHICS: Safety and Risk, Assessment of Safety and risk, Risk Benefit Analysis and Reducing Risk, Respect for authority, Collective Bargaining, Confidentiality, Conflict of interest, Occupational crime, Professional Rights, Employee Rights, Intellectual Property Rights (IPR), Discrimination						**05**
Module-V	GLOBAL ISSUES: Multinational Corporations, Environmental Ethics, Computer ethics, Weapons Development, Engineers as managers, Consulting engineers, Engineers as Expert Witnesses and Advisors, Moral Leadership, Code of conduct, Corporate Social Responsibility						**05**
						Total	**24**
Text	1. Mike W Martin and Roland Schinzinger, *Ethics in Engineering*, Tata McGraw Hill, 2003. 2. Govindarajan M, Natarajan S, Senthil Kumar V S, *Engineering Ethics*, Prentice Hall of India, 2004.						

Course Code	Course name	L	T	P	C	Year	Semester
ME402	Robotics	3	0	0	3	4th	7th

Course objective:

1. To introduce the functional elements of Robotics.
2. To impart knowledge on the direct and inverse kinematics.
3. To introduce the manipulator differential motion and control.
4. To educate on various path planning techniques.
5. To introduce the dynamics and control of manipulators.

Contents		No. of Lectures
Module 1		
Introduction	Mathematical Modeling of Robots, Robots as Mechanical Devices, Common Kinematic Arrangements of Manipulators, Rigid Motions and Homogeneous Transformations	**9**
Module 2		
Kinematics	Kinematic Chains, Forward Kinematics: The Denavit- Hartenberg, Convention, Inverse Kinematics, Angular Velocity: The Fixed Axis Case, Skew Symmetric Matrices, Angular Velocity: The General Case, Addition of Angular Velocities, Linear Velocity of a Point Attached to a Moving Frame, Derivation of the Jacobian, Singularities	**9**
Module 3		
Dynamics of Robot Manipulators	The Euler-Lagrange Equations, General Expressions for Kinetic and Potential Energy, Equations of Motion, Some Common Configurations, Properties of Robot Dynamic Equations, Newton-Euler Formulation	**9**
Module 4		
Control of Robot Manipulator	PD control, Nonlinear Control, Stability, Lyapunov's Direct Method, Adaptive Control	**12**
Module 5		
Path-Planning	Configuration space, potential fields	**5**
	Total	**44**

Course Code	Course name	L	T	P	C	Year	Semester
ME42X	**Mechanical Vibrations**	3	1	0	4	4th	7th

Course objective:

1. To understand the one and multi-degree-of-freedom systems.
2. To find the natural frequency and modes of vibration.
3. To understand the use of vibration in practical problems and avoid the excessive vibration.

Contents	No. of Lectures
Module 1	
Introduction: Overview of the course, practical applications and research trends, Harmonic and periodic motions, vibration terminology **Single-DOF Free Vibrations**: Vibration model, Equation of motion-Natural Frequency, Energy method, Rayleigh method, Principle of virtual work, Damping models.	**8**
Module 2	
Single-DOF Free Vibrations: Viscously damped free vibration, Special cases: oscillatory, non-oscillatory and critically damped motions. Logarithmic decrement, Experimental determination of damping coefficient. **Single-DOF Forced Vibrations:** Forced harmonic vibration, Magnification factor, Rotor unbalance, Transmissibility, Vibration Isolation, Equivalent viscous damping, Sharpness of resonance.	**8**
Module 3	
Two-DOF Free Vibrations: Generalized and Principal coordinates, derivation of equations of motion, Lagrange's equation, Coordinate coupling, Forced Harmonic vibration **Vibration Absorber**: Tuned absorber, determination of mass ratio, Tuned and damped absorber, unturned viscous damper. **Multi-DOF:** Derivation of equations of motion, influence coefficient method, Properties of vibrating systems: flexibility and stiffness matrices, reciprocity theorem, Modal analysis : undamped, Modal analysis: damped.	**10**
Module 4	
Calculation of natural frequencies: Rayleigh method, Stodala method, Matrix iteration method, Holzer method and Dunkerley's method **Torsional vibration**: Simple systems with one or two rotor masses, Multi-DOF systems-transfer matrix method, Geared system, Branched system	**8**
Module 5	
Continuous systems : closed form solutions: Vibration of strings, Longitudinal and torsional vibration of rods, Transverse vibration of beams: equations of motion and boundary conditions, Transverse vibration of beams: natural frequencies and mode shapes Continuous systems : Approximate form solutions: Rayleigh's energy method, Rayleigh-Ritz method, Assumed modes and Galerkin's method	**8**
Total	**42**

Text	1. L. Meirovitch, "Elements of Vibration Analysis", McGraw Hill, Second edition, 1986. 2. S. S. Rao, "Mechanical Vibrations", 5th Ed., Prentice Hall International, 2011.
Reference	1. L. Meirovitch, "Principles & Techniques of Vibrations", Prentice Hall International (PHIPE), New Jersey, 1997. 2. W. T. Thomson, Theory of Vibration with Applications, CBS Publ., 1990.

Course Code	Course name	L	T	P	C	Year	Semester
ME42X	**Computer Integrated Manufacturing**	3	1	0	4	4th	7th

Course objective:

1. Students will employ engineering and scientific concepts in the solution of engineering design problems.
2. Students will develop problem-solving skills and apply their knowledge of research and design to create solutions to various challenges.

Contents	No. of Lectures
Module : 1	
Introduction to CAD and CAM, Manufacturing Planning and control, CIM concepts, Computerised elements of CIM system, Types of manufacturing, Manufacturing models, Manufacturing Control	**10**
Module : 2	
Review of automation and control technologies. Material Handling technologies. Data Communication technologies. Automatic Data Acquisition technologies. Database Management technologies.	**10**
Module : 3	
Group Technology & Cellular Manufacturing Systems, Flexible Manufacturing Systems, Production flow Analysis, Transfer lines, Machine cell design and layout, Automated Assembly Systems. Quality Control Systems. Computer-Aided Process Planning. Concurrent Engineering. Production Planning and Control Systems.	**10**
Module : 4	

Levels of Automation, Lean and Agile Manufacturing.Web-based manufacturing.	**8**
Total	**38**

Text	1. M. P. Groover, "Automation production systems, and computer-integrated manufacturing", second edition, Prentice-Hall of India, New Delhi, 2001. 2. P. Radhakrishnan, S. Subramanyan and V.Raju, "CAD/CAM/CIM", 2nd Edition, New Age International (P) Ltd, New Delhi, 2000.
Reference	1. S. K. Vajpayee, " Principles of computer-integrated manufacturing", Prentice-Hall of India, New Delhi, 2005

Course Code	**Course name**	**L**	**T**	**P**	**C**	**Year**	**Semester**
ME42X	**Introduction to Data Science**	3	1	0	4	4th	7th

Course Objective: The goal of this course is to provide students with an introduction to the mathematical and algorithmic foundations of data science, including machine learning, high-dimensional geometry, and analysis of large networks. The goal of this course to improve decision making power to the students through the analysis of data.

Topic	**Contents**	**No. of Lectures**
Module 1	Introduction to Data Science: Big Data and Data Science hype, Datafication, Current landscape of perspectives- Skill sets needed.	**5**
Module 2	Statistical Inference, Exploratory Data Analysis and the Data Science Process,	**7**
Module 3	Three Basic Machine Learning Algorithms- Linear Regression, K-Nearest Neighbors (k-NN), K-means. One More Machine Learning Algorithm and Usage in Applications.	**10**
Module 4	Feature Generation and Feature Selection (Extracting Meaning From Data), Recommendation Systems: Building a User-Facing Data Product,	**10**
Module 5	Mining Social-Network Graphs, Data Visualization, Data Science and Ethical Issues.	**10**
	Total	**42**

Text Books	1. Cathy O'Neil and Rachel Schutt. Doing Data Science, Straight Talk From The Frontline.O'Reilly. 2014. 1. John D. Kelleher, Brendan Tierney, Data Science, MIT Press, 2018.
Reference Books	1.Jure Leskovek, Anand Rajaraman and Jeffrey Ullman. Mining of Massive Datasets, Cambridge University Press, 2014. 2.Avrim Blum, John Hopcroft and Ravindran Kannan. Foundations of Data Science, Cambridge University Press, 2019.

	3.Mohammed J. Zaki and Wagner Miera Jr. Data Mining and Analysis: Fundamental Conceptsand Algorithms, Cambridge University Press, 2014. 4.Jiawei Han, Micheline Kamber and Jian Pei. Data Mining: Concepts and Techniques, Morgan Kaufmann. 2011.

Course Code	Course name	L	T	P	C	Year	Semester
ME42X	**Reinforcement Learning**	3	1	0	4	4th	7th

Course Objective: To introduce the students with basics of reinforcement learning reinforcement learning algorithms, dynamic programming and its usage in RL and state of the art applications in RL

Topic	Contents	No. of Lectures
Module 1	**Introduction to Reinforcement Learning Problem:** Reinforcement Learning, Elements of Reinforcement Learning, Limitations and Scope, An Extended Example: Tic-Tac-Toe, History of Reinforcement Learning **Multi-arm Bandits:** An n-Armed Bandit Problem, Action-Value Methods, Incremental Implementation, Tracking a Nonstationary Problem, Optimistic Initial Values, Upper-Confidence-Bound Action Selection, Gradient Bandits, Associative Search (Contextual Bandits).	**8**
Module 2	**Finite Markov Decision Processes:** The Agent–Environment Interface, Goals and Rewards, Returns, Unified Notation for Episodic and Continuing Tasks, The Markov Property, Markov Decision Processes, Value Functions, Optimal Value Functions, Optimality and Approximation. **Dynamic Programming:** Policy Evaluation, Policy Improvement, Policy Iteration, Value Iteration,	**8**
Module 3	**Dynamic Programming:** Asynchronous Dynamic Programming, Generalized Policy Iteration, Efficiency of Dynamic Programming. **Monte Carlo Methods:** Monte Carlo Prediction, Monte Carlo Estimation of Action Values, Monte Carlo Control, Monte Carlo Control without Exploring Starts, Off-policy Prediction via Importance Sampling, Incremental Implementation, Off-Policy Monte Carlo Control, Importance Sampling on Truncated Returns.	**8**
Module 4	**Temporal-Difference Learning:** TD Prediction, Advantages of TD Prediction Methods, Optimality of TD(0), Sarsa: On-Policy TD Control, Q-Learning: Off-Policy TD Control, Games.' **Policy Approximation:** Actor–Critic Methods, Eligibility Traces for Actor–Critic Methods, R-Learning and the Average-Reward Setting,	**9**
Module 5	**Policy Approximation:** Vanilla policy gradient method, REINFORCE and TROP algorithms. **State of the art applications of RL:** Latest practical application of RL: Atari, Go, robotic applications and NLP.	**8**
	Total	**41**

Text Books	1.RS Sutton Reinforcement Learning: An Introduction – Stanford University.. 2.Hands-On Reinforcement Learning with Python: Master Reinforcement and Deep Reinforcement Learning Using OpenAI Gym and TensorFlow.
Reference Books	1. Richard S. Sutton and Andrew G. BartoReinforcement Learning: An Introduction (Introduction (Adaptive Computation and Machine Learning series) Kindle Edition.

Course Code	Course name	L	T	P	C	Year	Semester
ME401	**Electro mechanics and magnetic propulsion**	3	1	0	4	4^{th}	7^{th}

Course objective:

The objective of the course is to provide fundamental knowledge in electro mechanics.

Contents	No. of Lectures
Module : 1	
Introduction to electromagnetics: Maxwell's Equations, Magnetic Circuits and Induction, Principles of electromechanical energy conversion;	**6**
Module : 2	
Introduction to Rotating Machines: Types of electrical machines, generalized theory of electrical machines, Reference frame theory, space vector formulation;	**8**
Module : 3	
Unbalanced Magnetic Pull: definition, cause, effect and remedies, different winding scheme to reduce unbalanced magnetic pull; Magnetic Bearings: introduction, principles of magnetic suspension, mathematical modeling, hardware components which includes power amplifiers, sensors, actuators, controllers.	**8**
Module : 4	
Self-bearing machine: Basic principles, different methods of producing controllable force, introduction to self-bearing machine and control techniques.	**6**
Module : 5	
Solution of Laplace's and Poisson's equation, coupled circuit equation and field equation; Coupled rotordynamics combining electrical dynamics and mechanical dynamics: Coupled dynamics of electrical machines, dynamics and control of rotors on magnetic bearings; System fault analysis using electromechanical devices; Magnetostriction.	**8**

Total	**36**
Text	1. S. J. Chapman, "Electric Machinery Fundamentals", McGraw Hills, Fifth Edition, 2011. 2. Gerhard Schweitzer and Eric Maslen, "Magnetic Bearings: Theory, Design and Application to Rotating Machinery", Springer, 2009.
Reference	1. Juha Pyrhonen, Tapani Jokinen and Valeria Hrabovcova, "Design of Rotating Electrical Machines", Wiley, 2nd Edition, October 2013. 2. A. Chiba, T. Fukao, M. Oshima, M. Takemoto and D. Dorrell, "Magnetic Bearings and Bearingless Drives", Elsevier, 2005.

Course Code	**Course name**	**L**	**T**	**P**	**C**	**Year**	**Semester**
ME401	**AUTOMOBILE ENGINEERING**	3	1	0	4	4^{th}	7^{th}

Course objective:

1. To understand the basic concept and component of automobile.
2. To understand the power generation system in automobile.
3. To understand the automobile structure and suspension system.
4. To understand the emissions and pollution control on automobile.

Contents	**No. of Lectures**
Module 1	
Introduction: Introduction, Basic concepts of Automobile Engineering and general configuration of an automobile, Power and Torque characteristics. Rolling, air and gradient resistance. Tractive effort. Gear Box. Gear ratio determination. **Transmission System:** Requirements. Clutches. Torque converters. Over Drive and free wheel, Universal joint.	**7**
Module 2	
Differential Gear Mechanism of Rear Axle. Automatic transmission, Steering and Front Axle. Castor Angle, wheel camber & Toe-in, Toe-out etc.. Steering geometry. Ackerman mechanism, Under steer and Over steer. **Braking system:** General requirements, Road, tyre adhesion, weight transfer, Braking ratio. Mechanical brakes, Hydraulic brakes. Vacuum and air brakes. Thermal aspects. **Chasis and Suspension System:** Loads on the frame, Strength and stiffness, Independent front & rear suspension, Perpendicular arm type, Parallel arm type, Dead axle suspension system, Live axis suspension system, Air suspension & shock absorbers.	**7**

Module 3	
Electrical System: Types of starting motors, generator & regulators, lighting system, Ignition system, Horn, Battery etc. **Fuel Supply System**: Diesel & Petrol vehicle system such as Fuel Injection Pump, Injector & Fuel Pump, Carburetor etc. MPFI.	**7**
Module 4	
Emission standards and pollution control : Indian standards for automotive vehicles-Bharat I and II, Euro-I and Euro-II norms, fuel quality standards, environmental management systems for automotive vehicles, catalytic converters, fuel additives and modern trends in automotive engine efficiency and emission control. **Maintenance system:** Preventive maintenance, break down maintenance and over hauling.	**7**
Total	**28**
Text/ Reference	1. Kripal Singh, "Automobile Engineering, Vol.1 & Vol.2.", Standard publisher and distributer 2. K. K. Jain and R. B. Asthana, "Automobile Engineering", 1st Ed., Tata Mcgraw Hill, 2017.

Open electives

Course Code	Course name	L	T	P	C	Year	Semester
XXXXX	**Quality Control**	3	1	0	4	4th	7th

Course objective:

1. To understand the philosophy and basic concepts of quality improvement in industry or organization.
2. To understand the quality control in specified limit.
3. To understand the principle of acceptance of sample.
4. To understand the defect diagnosis process of the samples.

Contents	No. of Lectures
Module 1	
Introduction: Introduction, Concept and evaluation of quality control. Measurement & Metrology, precision vs accuracy. Process capability, standardization& Interchange ability. **Inspection and Gauges:** Inspection methods. Types of Gauges. Limits Fits and Tolerances. Non-Destructive Testing& Evaluation.	**8**
Module 2	
Control charts for SQC: Statistical Quality Control (SQC). Control charts for variables suchas X, R charts and control charts for attributes such as p-chart, c-chart. Construction & use of the control charts, Process capability. **Acceptance Sampling for SQC:** Introduction, Principle of acceptance sampling. Producer's and consumer's risk. Sampling plans - single, double & sequential. Sampling by attributes and variables	**8**

Module 3	
Reliability: Introduction to reliability, bath-tub curve. Life expectancy. Reliability based design. Series & Parallel System. **Defect Diagnosis and prevention**: Basic causes of failure, curve/control of failure. MTBF. Maintainability, Condition monitoring and diagnostic techniques.	**8**
Module 4	
Value Engineering: Elements of value analysis, Techniques **TQM:** Basic Concept, Quality control , Quality Assurance and Quality Management and Total Quality Management. Implementation of TQM . ISO 9000 and its series, Zero defect. . Taguchi method, Six Sigma concepts.	**8**
Module 5	
Other Factors in Quality : Human Factors such as attitude and errors. Material-Quality, Qualitycircles, Quality in sales & service.	**8**
Total	**40**

Text	1. D. C. Montgomery, "Introduction to Statistical Quality Control", 6th Ed., John Wiley & Sons, Inc, 2009. 2. I. Kaoru, "Introduction to Quality Control", springer, 1989

Course Code	**Course name**	**L**	**T**	**P**	**C**	**Year**	**Semester**
XXXXX	**Advanced Robotics**	3	1	0	4	4^{th}	7^{th}

Course objective:

1. To understand the philosophy and basic concepts of quality improvement in industry or organization.
2. To understand the quality control in specified limit.
3. To understand the principle of acceptance of sample.
4. To understand the defect diagnosis process of the samples.

Contents	**No. of Lectures**
Module 1	
CONTROL SYSTEMS AND COMPONENTS: Basic Control Systems Concepts and Models,Controllers, Control System Analysis, Robot Activation and Feedback Components,Power Transmission Systems, Robot Joint Control Design. **ROBOT END EFFECTORS:** Types, Mechanical Grippers and Other types, Tools as End Effectors, The Robot/End Effector Interface, Considerations in Gripper Selection and Design	**8**
Module 2	
MACHINE VISION: Introduction, The Sensing and Digitizing function, Image processing and Analysis,Trainig and Vision Systems, Robotic Applications.	**8**

Module 3	
ROBOT PROGRAMMING: Programming methods, Robot program as a path in space,Motion Interpolation, WAIT,SGNAL,DELAY Commands, Branching	**8**
Module 4	
ROBOT LANGUAGES : The Textual Robot languages, Generations of Robot programming languages, Robot language Structures, Constants, Variables, and other data Objects, Motion Commands, program Control and Subroutines	**10**
Module 5	
ROBOT APPLICATIONS IN MANUFCATURING: Material Transfer And Machine Loading / Unloading, An Approach for Implementing Robotics FUTURE APPLICATIONS: Characteristics of Future Robot Tasks, Future manufacturing Applications, Hazardous and Inaccessible Nonmanufacturing Environments	**8**
Total	**42**
Text	**1.** Mikell P. Groover , Mitchell Weiss , Roger N. Nagel , Nicholas G. Odrey Industrial Robotics: Technology, Programming, and Applications , 1stedition, McGraw-Hill International Edition, 1986 2. K.S.Fu, R.C Gonzalez, C.S.G.Lee , ROBOTICS , Control, Sensing , Vision and Intelligence , 1stedition, McGraw-Hill International Edition, 1987

Course Code	Course name	L	T	P	C	Year	Semester
XXXXX	Material Characterization Methods	3	1	0	4	4^{th}	7^{th}

Course objective:

1. Introduce basic techniques for materials characterization.
2. Introduce the working principles and instrumentation of main techniques.
3. Introduce the interpretation of the characterization technique outputs.
4. Observe operations of characterization equipment.

Topics	Contents	No. of Lectures
Module : 1		
Elements of Crystallography, Principles of X-ray diffraction, X-ray equipment and data analysis; associated techniques in X-ray spectroscopy, Fundamentals of elemental analysis.		**10**
Module : 2		

Optical/Electron Microscopy Techniques, Specimen preparation techniques for optical and electron microscopy in metallurgy. Elements of phase identification, grain size determination, inclusion analysis, Image analysis, etc.	**10**
Module : 3	
Electron diffraction, SEM, Failure analysis and fractography, EDAX / EPMA, data analysis. Neutron Scattering Techniques: Diffraction, inelastic scattering and reflectometry.	**10**
Module : 4	
Thermal Analysis: Principles and applications of thermal analysis; DTA, DSC, TGA, TMA, DMA, etc.	**8**
Module : 5	
Mechanical Property characterization, Principles and chartacterisation techniques related to Tensile, compressive, hardness, fatigue and fracture toughness properties. Deformation; Superplasticity	**10**
Total	**48**

Text	1. "Materials characterization",Vol. 10, ASM hand book,1997. 2. B. D. Cullitey, "Elements of X-ray diffraction", Addison-Wesely, 1968.
Reference	1. ASTM handbook, vol. 3, 1997. 2. R. F. Speyer, "Thermal Analysis of Materials", Marcel Decker, 1994

Course Code	Course name	L	T	P	C	Year	Semester
XXXXX	Physics of Manufacturing Processes	3	1	0	4	4th	7th

Course objective:

1. This course gives an introduction to production methods and manufacturing technologies used in engineering.
2. The focus is given on the understanding of physical phenomena underlying the processes, the relation between materials/manufacturing processes.

Topics	Contents	No. of Lectures
Module : 1		

Stress and strain behavior of materials, plastic and tangent modulus, work hardening, plastic instability in tensile test, empirical stress-strain equations, effect of pressure, strain-rate and temperature.	**8**
Module : 2	
Analysis of stress tensor, eigenvalues, decomposition into deviatoric and hydrostatic components, octahedral stresses, analysis of strain and strain rates, stress equilibrium and virtual work, objective stress rates.	**8**
Module : 3	
Plasticity: the criteria of yielding, isotropic and anisotropic hardening, rules of plastic flow, Levy-Mises and PrandtlReussequations,anisotropic flow rule, Hill's 1948 and 1979 yield criteria for anisotropic yielding.	**8**
Module : 4	
Upper bound theorem and its application in deformation processes like rolling, wire drawing, extrusion, forging. Lower bound theorem with a few applications. Slab method and its application in deformation process like symmetric/asymmetric rolling, forging, wire drawing and extrusion.	**8**
Module : 5	
Elastoplastic sheet bending. Analysis of autofrettage. Theory of slip line field and its application in metal forming. Heat transfer analysisin deformation processes with examples from rolling and friction stir welding/processing. Workability and dynamic materials model.	**8**
	Total **40**
Text	1. J. Chakrabarty, "Theory of plasticity", Elsevier Butterworth-Heinemann Company, Singapore, 2006. 2. B. L. Juneja, "Fundamentals of metal forming processes", New Age International, New Delhi, 2007.
Reference	1. P. M. Dixit and U. S. Dixit, "Modelling of Metal Forming and Machining Processes: By Finite Element and Soft Computing Methods", Springer, London, 2008. 2. W. F. Hosford and R. M. Caddell, "Metal forming: mechanics and metallurgy", Cambridge University Press, London, 2011.