Department of Mechanical Engineering

Teaching Scheme and Syllabus of

M Tech (Regular) Programme

Effective July, 2014 onwards

Dr B R AMBEDKAR
NATIONAL INSTITUTE OF TECHNOLOGY JALANDHAR

Teaching Scheme for M Tech (Regular) in Mechanical Engineering

Course No.	Subject	Unit	Teaching Load			Credit
			L	T	P	
First Semester						
MAX-601	Computational Methods in Engineering	1	3	0	0	3
MEX-603	Mechanical Vibrations	1	3	0	0	3
MEX-605	Materials in Mechanical Design	1	3	0	0	3
MEX-	Elective-I	1	3	0	0	3
MEX-	Elective-II	1	3	0	0	3
MEX-	Elective-III	1	3	0	0	3
MEX-623	Mechanical Vibrations Laboratory		0	0	3	2
MEX-625	Experimental Methods and Analysis Laboratory		0	0	3	2
	Total	**6**	**18**	**0**	**6**	**22**
Second Semester						
MEX-602	Advanced Machine Design	1	3	0	0	3
MEX-606	Advanced Fluid Mechanics	1	3	0	0	3
MEX-608	Design and Optimization of thermal systems	1	3	0	0	3
MEX-	Elective-IV	1	3	0	0	3
MEX-	Elective-V	1	3	0	0	3
MEX-	Elective-VI	1	3	0	0	3
MEX-622	Simulation Techniques in Thermal Engineering Laboratory		0	0	3	2
MEX-624	Design of Mechanical System Laboratory		0	0	3	2
	Total	**6**	**18**	**0**	**6**	**22**
Third Semester						
MEX- 651	Seminar	1	0	0	6	3
MEX-700	Project work for M Tech Dissertation, Part-I	1	0	0	12	6
	Total	**2**	**0**	**0**	**18**	**9**
Fourth Semester						
MEX-700	Project work for M Tech Dissertation, Part-II	**1**	**0**	**0**	**24**	**12**
	Grand Total	***15***	***36***	***0***	***54***	***65***

List of Electives I, III & V (Thermal)

Sr. No.	Course Code	Course Title	L-T-P	Credit
	MEX-604	Advanced Thermodynamics	3-0-0	3
1	**MEX- 651**	Combustion Generated Pollution and Control	3-0-0	3
2	**MEX- 652**	Alternative Fuels for IC Engines	3-0-0	3
3	**MEX- 653**	Experimental Methods and Analysis	3-0-0	3
4	**MEX- 654**	Analysis of IC Engine Processes	3-0-0	3
5	**MEX- 655**	Computational Heat Transfer	3-0-0	3
6	**MEX- 656**	Applied Combustion	3-0-0	3
7	**MEX- 657**	Heat Exchangers	3-0-0	3
8	**MEX- 658**	Advanced Power Plant Cycles	3-0-0	3
9	**MEX- 659**	Refrigeration Systems and Components Design	3-0-0	3
10	**MEX- 660**	Gas Dynamics	3-0-0	3
11	**MEX- 661**	Computational Fluid Dynamics	3-0-0	3
12	**MEX-662**	Advanced IC Engines	3-0-0	3

List of Electives II, IV & VI (Design)

Sr. No.	Course Code	Course Title	L-T-P	Credit
1	**MEX- 631**	Robotics: Mechanics and Control	3-0-0	3
2	**MEX- 675**	Mechanics of Composite Materials	3-0-0	3
3	**MEX- 676**	Finite Element Methods	3-0-0	3
4	**ME- 677**	Machine Tool Design	3-0-0	3
5	**MEX- 678**	Modal Analysis of Mechanical Systems	3-0-0	3
6	**MEX- 679**	Vibration Control	3-0-0	3
7	**MEX- 681**	Viscoelasticity	3-0-0	3
8	**MEX- 682**	Theory of Elasticity and Plasticity	3-0-0	3
9	**MEX -684**	Theory of Plates and Shells	3-0-0	3
10	**ME X- 685**	Fracture Mechanics	3-0-0	3
11	**MEX- 687**	System Dynamics & Control	3-0-0	3
12	**MEX- 688**	Soft computing techniques	3-0-0	3
13	**MEX- 689**	Photovoltaic Cell and its Applications	3-0-0	3
14	**MEX- 690**	Methods of Analytical Dynamics	3-0-0	3
15	**MEX -691**	Nonlinear systems	3-0-0	3
16	**MEX- 692**	Modern Control Engineering	3-0-0	3
17	**MEX-693**	Basic Biomechanics	3-0-0	3

First Semester

MAX-601 Computational methods in Engineering (3 0 0 3)

In relation to mechanical engineering applications, such as, heat transfer, fluid mechanics, vibrations, dynamics and others, the following topics will be covered:

Partial differential equations – characteristics and classification of 2nd order PDEs. separation of variables special functions, Eigen function expansions, Fourier integrals and transforms, Laplace transforms, methods of characteristics, self-similarity.

Linear algebra: matrix theory, solution of linear system of algebraic and differential equations; round-off errors, pivoting and ill-conditioned matrices. Eigenvalues and eigenvectors. Unitary, hermitian and normal matrices.

Numerical Methods: Lagrange interpolation, splines, integration – trapezoid, Romberg, Gauss, adaptive quadrature. Explicity and implicity methods, multi-step methods, Runge-Kutta and predictor-corrector methods, boundary value problems, eigenvalue problems, systems of differential equations, stiffness. Accuracy, stability and convergence. Alternating direction implicity methods. Non-linear equations.

Books Recommended:

1. Ames W F, “Numerical Methods for Partial Differential Equations”, 3rd Edition, Academic Press, New York (1992).
2. Dahlquist G and Björck A, “Numerical Methods”, Prentice-Hall, NJ (1974).
3. Jain M K, Iyengar S R K. and Jain R K, “Numerical Methods for Scientific and Engineering Computations”, 4th Edition New Age International (P) Limited, Publishers, New Delhi (2003).
4. Shampine L F, “Numerical Solution of Ordinary Differential Equations”, Chapman and Hall, New York (1994).
5. Kreyszig, E., "Advanced Engineering Mathematics", 8th Ed, John Wiley, Singapore, 2002.

MEX-603 Mechanical Vibrations (3 0 0 3)

Introduction: Brief History of Vibration, importance of study of Vibration, fundamentals of vibration, classification of vibration. Modeling for vibration - Discrete and continuous vibratory systems.

Single Degree Freedom System: Free vibrations of translational system, torsional system, stability conditions; free vibration with viscous damping, Coulomb damping and Hysteretic damping.

Forced Vibration: Types of excitation, Response of undamped and damped system under – harmonic force, excitation of base, rotating unbalance. Forced response of system with Coulomb and hysteretic damping.

Two Degree Freedom System: Basic concepts, two degree freedom, discrete model for vibratory systems – examples, Equations of motion, Analysis of undamped vibratory systems,, coordinate coupling and principal coordinates, semi-definite system vibration. Forced vibration – frequency response curve and mode shape, stability analysis.

Multidegree Freedom System: Basic concept, modeling, Derivation of equation of motion using – Newton’s Second Law, Influence coefficient, Flexibility matrix approach and Lagrange’s equation. Eigen value problem and solution.

Natural Frequencies and Mode shapes: Various method for the prediction of natural frequencies and mode shapes – Dunkerley's formula, Raleigh's method, Holzer's method, Matrix Iteration method.

Continuous System: Analysis of transverse vibration of string, longitudinal vibration of bar, Torsional vibration of shaft, and Lateral vibration of beams.

Vibration Control: Need of vibration control – an introduction. Vibration isolation – Force transmitted to the foundation, methods of vibration isolation. Vibration absorbers – basic concept, classification, analysis of undamped and damped vibration absorbers.

Vibration Measurement: Response of vibratory system, vibration measurement scheme, transducers, vibration pickups – seismic instrument, accelerometer. Frequency measurement - Fullarton tachometer, Frahm tachometer and stroboscope.

Books Recommended

1. Rao S S, "Mechanical Vibrations", Pearson Education, Delhi (2004).
2. Roger A A, "Fundamentals of Vibrations", Amerind Publisher Company Private Limited, New Delhi (1999).
3. Srinivas P, "Mechanical Vibration Analysis", Tata McGraw Hill Company Limited, New Delhi (1990).
4. Mallik A K, "Principles of Vibrations Control", Affiliated East West Press Private Limited, New Delhi (2000).
5. Daniel J Inman, "Engineering Vibration", Prentice Hall, New Jersey (2001).

MEX-605 Materials in Mechanical Design (3 0 0 3)

Materials in design, evolution of engineering materials, Design tools and materials data, Function, material, shape and process. Review of properties of Engineering materials and nomenclature of materials.

Material Selection: Introduction, displaying material properties, material property charts Basics concerning material selection, selection strategy, property limits and material indices, selection procedure and structural index. Material selection –case studies

Selection of Materials and Shape: Shape factor, efficiency of standard sections, materials for shape factors, material indices, microscopic or micro-structural shape factor and co-selecting material and shape. Shape case studies.

Multiple constraints and compound objectives selection by successive application of property limits and indices, methods of weight factors, methods using fuzz logic, systematic methods for multiple constraints, compared objectives, exchange constrains and value functions. Case studies.
Materials processing design: Processes and their influence attributes, systematic process selection, screening process selection diagrams, Ranking – process cost, supporting information. Case studies related to processing design.
Data Sources: Data needs for design, data structures, ways of checking and estimating data. Case studies on data sources. Materials aesthetics and industrial design, aesthetics and industrial design economic versus performance. Case Studies.

Books Recommended

1. Ashby M, "Materials Selection in Mechanical Design", Third Edition, Elsevier, Indian Edition, (2005)
2. Ashby M and Johnson K, "Materials & Design, 2nd Edition- The Art & Science of Material Selection in Product Design", Butterworth-Heinemann (2009)
3. Farag M M, "Materials & Process selection for Engineering Design", 2nd Edition, CRC Press (2007)
4. Popov E P, "Engineering Mechanics of Solids", SI Version 2nd Edition, Prentice Hall of India, New Delhi (2003).
5.

MEX- 623 Mechanical Vibrations Laboratory (0 0 3 2)

1. Study of vibration equipments: Accelerometer, vibration analyzer, Oscilloscope, Hammers
2. Measurement of Deflection of cantilever beam using accelerometer
3. Measurement of damping of Al beam
4. Measurement of damping of cast iron using model analysis software
5. Measurement of damping of Fiber reinforced Composite lamina
6. Measurement of damping of Fiber reinforced composite plates
7. Experimental evaluation of multi degree freedom system

Second Semester

MEX-602 Advanced Machine Design (3 0 0 3)

Introduction to Advanced Machine Design, Materials and processes for machine elements, Review of static strength failure analysis and theories of failure, Fracture and fatigue, High cycle and low cycle fatigue, Design of Machine element against fatigue. Problems on fatigue design of shafts and gears, rolling contact bearings (surface fatigue design failure). Stiffness based design. Design to prevent buckling and instability. Introduction to dynamic design of machine equipment and its implementation.

Books Recommended

1. Norton L R, "Machine Design an Integrated Approach", Ist Indian Reprint, Pearson Education Asia (2001).
2. Sharma P C and Aggrawal D K, "A text book on Machine Design", 9th Edition, S K Kataria and sons (2000).
3. Shigley J E and Mischke C R, "Mechanical Engineering Design" Tata Mcgraw Hill, New Delhi, (2003).
4. Richard W Hertzberg, "Deformation and fracture mechanics of engineering materials", John Wiley and sons, Inc Newyork, (1996).
5. Burr H and John B Cheatham, "Mechanical Analysis and Design", PHI Private Limited, New Delhi (2001).

MEX-606 Advanced Fluid Mechanics (3 0 0 3)

Review of basic laws of fluid flow in integral and differential form, kinematics, Ideal fluid flow. Newtonian fluid flow and applications, Creeping flow, Boundary layer theory, Transition and turbulence turbulent boundary layer Fundamentals of compressible flows Modelling and dimensional analysis.

Books Recommended

1. Douglas J F. Gasionckw, and Swaffield JP “Fluid Mechanics” 3rd edition Addision Wesley Longman, Inc Pitman, 1999.
2. Pao H F Richard “Fluid Mechanics” John Wiley and Sons. 1995
3. Kumar DS “Fluid Mechanics and Fluid Power Engineering” 6th edition SK Kataria and Sons, Delhi. 1998.
4. Streeter V L and Wylie E B “Fluid Mechanics” McGraw Hill International.
5. Bansal R K “ A text book of Fluid mechanics and Hydraulic Machines” 8th edition, Laxmi Publications (P) Ltd. New Delhi, 2002.
6. Mohanty A K, “Fluid Mechanics”, 2nd Edition Prentice Hall of India Private Limited, New Delhi, 2002.

MEX-608 Design and Optimization of thermal systems (3 0 0 3)

Introduction to Design and Analysis, and Project Initiation, Review of Fluid Mechanics, Thermodynamics & Heat transfer, System identification and description & component design: Heat exchangers, Prime movers, System Design and Optimization Techniques and Economic Evaluation, Engineering economics

Books Recommended

1. Stoecker, W., Design of Thermal Systems, McGraw-Hill
2. Burmeister, L.C., Elements of Thermal-Fluid System Design, 1998,Prentice Hall
3. Jaluria, Y., Design and Optimisation of Thermal Systems, 2007,McGraw-Hill,
4. Janna, W.S., Design of Fluid Thermal Systems, 1993,PWS-Kent Publishing, 1993.

MEX-624 Design of Mechanical System Laboratory (0 0 3 2)

1. Design of Gear box for Lathe machine
2. Design a Mechanical shaker
3. Nonlinear analysis of beam using FEM
4. Design a overhead traveling crane for dynamic response
5. Modeling for micromechanical damping for composite materials

List of Electives (Thermal)

MEX-604 Advanced Thermodynamics (3 0 0 3)

Recapitulation of fundamentals. The two laws of thermodynamics–Caratheodory's formulation, analysis of typical simple closed systems, analysis of open systems–exergy analysis. Multi-component systems–concepts of fugacity, chemical potential. General conditions for thermodynamic equilibrium–instability of thermodynamic equilibrium and phase transition. Thermodynamics of reactive mixtures. Elements of irreversible thermodynamics.

Recommended books

1. Cengel & Boles, " Thermodynamics-An Engineering approach".5th Ed, Tata McGraw Hill
2. Winterbone, Desmond E, " Advanced Thermodynamics for engineers",1997,Elsevier
3. Annamalai, Puri, Ishwar.K. " Advanced Thermodynamics Engineering"2002,CRC Press.
4. Nag,P.K., " Engineering Thermodynamics",4th ed., Tata Mcgraw Hill

MEX-651 Combustion Generated Pollution and Control (3 0 0 3)

Generation and nature of pollutants from various combustion sources, their effects on health and the environment. Emission indices. Thermo-chemistry of pollutant formation, stoichiometry, chemical thermodynamics, kinetics. Pollutants from I.C. engines, power plants, domestic and other sources. Meteorology and dispersion of pollutants, instruments for pollutant measurement and monitoring. Legislation and emission standards.

1. Edward f. Obert, Internal Combustion Engine and air pollution, Intent Education publishers.
2. John B.Heywood, Internal Combuston Engine Fundamentals, Mc Graw Hill Book, 1988.
3. Crouse William, Automotive Emission Control, Gragg Division/Mc Graw Hill, 1980.
4. Ernst S.Starkman, Combustion Generated air pollution, Plenum Press.
5. George Springer and Donald J.Patterson, Engine Emissions, Pollutant formation and measurement, Plenum press.
6. Obert.E F, IC Engines and air pollution, Intent Education publishers.

MEX-652 Alternative Fuels for IC Engines (3 0 0 3)

Hydrocarbon fuels: Crude petroleum oil and its refining, products of refining, availability of hydrocarbon fuels and their impact on environment.

Gasoline: Chemical composition, combustion characteristics of gasoline, Effect of various engine parameters on the combustion of gasoline; Knocking, Octane number, Effect of sulphur, ash forming additives, oxygenates, olefins, aromatics, benzene content.

Diesel: Chemical composition, combustion characteristics of diesel, Engine parameters affecting the combustion of diesel ; Cetane number, sulphur content, density, volatility, distillation characteristics.

Ethanol and Methanol: Benefits of using ethanol, methanol as fuel, their method of production, properties of ethanol, methanol, methods of using ethanol, methanol in diesel engines: Fumigation, solutions, Spark injection, dual injection, ignition improvers, surface ignition, low heat rejection.

Biodiesel: Definition, advantages of biodiesels, methods of producing biodiesels; blending, cracking, Transesterification, super critical methanol Transesterification, properties of biodiesels, emission characteristics of biodiesels.

Gaseous Fuels: LPG, LNG and CNG Composition, combustion characteristics, dispensing methods, emission studies. Hydrogen, its combustion characteristics, flashback control

technique, safety aspects and system development. Biogas, producer gas, their method of preparation, their use as an engine fuel.

1. Biodiesel, Basics And Beyond New Society Pub 2006
2. McGowan, Thomas Biomass and Alternate Fuel Systems: An Engineering and Economic Guide Wiley-AIChE 2009
3. Processing and Testing of Biodiesel Fuels Serials Publications 2009

MEX-653 Experimental Methods and Analysis (3 0 0 3)

Statistics: Distributions, estimators, confidence levels, sample size, test of hypothesis, goodness-of-fit test Chauvenet's criteria; Regression analysis, co-relations. Uncertainty analysis. Design of experiments. Instruments: Specifications. Static and dynamic characteristics. Instruments for measuring distance, profile, pressure, temperature, velocity, flow rate, level, speed, force, torque, noise, chemical analyses. Estimation of systematic errors. Signal conditioning, data acquisition and analysis. Transducers, A-D & D-A converters, interfacing with computers and PLCs.
Control theory fundamentals: Steady state and transient response, Stability analysis Routh and Nyquist criteria, Root locus method. Sequence and programmable logic controllers. Hydraulic, pneumatic and electrical systems. Laboratory: Calibration. Experiments related to heat transfer, fluid mechanics, thermodynamics and gas dynamics.
Project on experiment design including drawings, wiring diagrams, selection of instruments and computer interfacing. Use of various controllers and actuators. Data management and presentation.

Books Recommended

1. Dally J E and Rilley W P, "Experimental Stress Analysis", 3rd Edition, McGraw Hill, New Delhi (1991).
2. Dove R C and Adams P H, "Experimental Stress Analysis and Motion Measurement", McGraw Hill, New York (1978).
3. Holister C S, "Experimental Stress Analysis", 5th Edition, Cambridge University Press (1987).
4. Dally J E and Rilley W P, "Introduction to Photomechanics", Prentice Hall Inc, NJ (1981).
5. Mubeen A, "Experimental Stress Analysis", 1st Edition Dhanpat Rai and Sons, New Delhi (1997).

MEX-654 Analysis of IC Engine Processes (3 0 0 3)

Introduction to basic I.C. engine processes, air standard and fuel-air cycles, computation of fuel-air and exhaust gas properties. Real cycles and their comparison with standard cycles. Thermodynamic analysis and modeling of salient I.C. engine processes. Modeling engine emissions. Cycle simulation of the I.C. engine.

Books Recommended

1. Heywood J B, "Internal Combustion Engine Fundamentals", McGraw Hill, Publication, New Delhi (1988).
2. Taylor C F, "The Internal Combustion in Theory land Practice", Volume I and II, MIT Press, Cambridge, Mass (1968).
3. PulkRabek W W, "Engineering Fundamentals of Internal Combustion Engine", Pearson Education, New Delhi (2003).
4. Stone R, "Introduction to Internal Combustion Engines", 2nd Edition, Macmillan (1993).
5. Milton B E, "Thermodynamics, Combustion and Engines", Champman and Hall (1995).

MEX-655 Computational Heat Transfer (3 0 0 3)

Introduction. 1-, 2- and 3-D conduction for steady state and transient conditions. Boundary conditions, implementation and solution methods. Convection in incompressible flows; stream function vorticity and primitive variables formulations, staggered grid, SIMPLE and SIMPLER pressure-velocity coupling methods, boundary conditions and implementation issues. External and internal flow simulations. Numerical
methods for radiation–enclosures with gray gas, Hottel zone method. Combined convection and radiation. Applications of Monte-Carlo method. Special topics.

Books Recommended

1. S V Patankar Numerical Heat Transfer and Fluid Flow McGraw Hill, NY, (2005).
2. John C. Tannehill, Dale Arden Anderson, Richard H. Pletcher Computational Fluid Mechanics And Heat Transfer, Taylor and Francis, Second Edition.
3. P.S Ghoshdastidar Computer Simulation Of Flow And Heat Transfer by., Tata Mcgraw Hill, 1998
4. H. K. Versteeg, W. Malalasekera An Introduction To Computational Fluid Dynamics: The Finite Volume Method, (2nd Edition), Prentice Hall.

MEX-656 Applied Combustion (3 0 0 3)

Review of combustion fundamentals. Gas-fired furnace combustion. Oil-fired furnace combustion. Gas turbine spray combustion. Combustion of solids. Industrial applications involving combustion. Burner design, testing and control. Emissions. Combustion safety.

Books Recommended

1. Kenneth Kuan-yun Kuo, Principals of Combustion, John Wiley and Sons, NY (2005).
2. Stephen R. Turns, An Introduction to Combustion: Concepts and Applications, 2nd Edition, Mc-Graw Hill, (2005).
3. Norbert Peters, Turbulent Combustion, Cambridge University Press, First Ed. (2000).

MEX-657 Heat Exchangers (3 0 0 3)

Applications. Basic design methodologies – LMTD and effectiveness-NTU methods. Overall heat transfer coefficient, fouling. Correlations for heat transfer coefficient and friction factor. Classification and types of heat exchangers and construction details. Design and rating of double pipe heat exchangers, compact heat exchangers, plate and heat pipe type, condensers, cooling towers. Heat exchanger standards and testing, Heat transfer enhancement and efficient surfaces. Use of commercial software packages for design and analysis, optimization.

Books Recommended

1.Kays and London, “Compact Heat Exchangers”, McGraw Hill.
2. Hesselgreaves, “Compact Heat Exchangers Selection, Design & Operation”, Pergamon.
3.Shah, R.K. & Sekulic D.P, “Fundamentals of Heat Exchanger Design”, John Wiley & Sons.
4.Kakac & Liu, “ Heat Exchangers-Selection, Rating and Thermal Design”, 2nd ed.,CRC Press

MEX-658 Advanced Power Plant Cycles (3 0 0 3)

Review of various ideal cycles–Rankine and Brayton–and fuel-air cycles. Thermodynamics optimization of design parameters. Real cycle effects–internal and external irreversibilitites, pressure drops, heat loss, condenser air leakage, fouling of heat transfer surfaces, combustion losses–and their impact on the thermodynamic cycle. Optimization of real and double reheat

cycles. Analysis of off-design performance. Combined cycles–ideal and real cycles–thermodynamic analysis. Design of alternate schemes for combined cycles– single, dual and triple pressure cycles, and their optimization. Retrofit of ageing power plants. Parametric analysis–effects of gas and steam cycle variables. Binary vapour and Kalina cycles. Thermochemical and H2-O2 cycles. Cycles for nuclear power plants (PWR, BWR, PHWR, FBR). All simulations will
involve extensive use of numerical techniques as part of laboratory work.

Books Recommended

1. Wiesman J and Eckart R, "Modern Power Plant Engineering", Prentice Hall,New Delhi (1985).
2. Nag P K, "Power Plant Engineering", Tata McGraw Hill,New Delhi (1998).
3. Kostyuk.A and Frolov V, "Steam and Gas Turbines", Mir Publishers, Moscow (1988).
4. Aschner F S, "Planning Fundamentals of Thermal Power Plants", John Wiley (1978).
5. Eastop T D and McConkey, "Applied Thermodynamics", Longman Scientific and Technical (1986).

MEX-659 Refrigeration Systems and Components Design (3 0 0 3)

Introduction to various components. Thermal design of reciprocating, centrifugal and screw compressors. Capacity control methods. Thermal design of different evaporators–DX, flooded, etc. Thermal design of condensers–water-cooled and air-cooled. Sizing of capillary. Selection of expansion valves and other refrigerant control devices. Components balancing. Testing and charging methods. Design of absorber and generator of vapor absorption systems. Design of cold storages, mobile refrigeration, refrigerators, commercial appliances.

Books Recommended

1. Arora C P, "Refrigeration and Air Conditioning", 19th Edition, Tata McGraw Hill, Delhi (1985).
2. Pradad M, "Refrigeration and Air Conditioning", 2nd Edition, New Age International Private Limited, Delhi (2002).
3. Dossat, R J, "Principles of Refrigeration", 4th Edition, Pearson Education (Singapore), India, (2002).
4. Mcquiston F G, Parker J D and Spilter J D, "Heating, Ventilating, and Air Conditioning", 5th Edition, John Wiley and Sons Inc, New York (2001).
5. Jordan and Prister, "Refrigeration and Air Conditioning", Prentice Hall of India (1998).

MEX-660 Gas Dynamics (3 0 0 3)

Recapitulation of fundamentals, introduction to numerical analysis of compressible flow. Oblique shocks, compression and expansion waves, Prandtl Meyer expansion. Interaction of shock waves and shock-boundary layer interaction. Flow with friction and heat transfer. Introduction to 1-D transient and 2-D compressible flow. Method of characteristics. Applications in measurement of subsonic and supersonic flows, wind tunnels, medical, aircraft and rocket propulsion. Introduction to hypersonic, high temperature flows and astro gas dynamics. fans. Surge, stall. Hydraulic turbines and pumps.

Books Recommended

1. Shepherd D G, "An Introduction to Gas Turbine", Von Nastrand, New York (1949).
2. Stodola A, "Steam and Gas Turbines", McGraw Hill Book Company, (1970).
3. Shapiro A M, "Dynamics and Thermodynamics of Compressible Fluids", Ronald's Press, New York (1953).

4. Benson R W, “Advanced Engineering Thermodynamics”, Pergamon Press, London (1975).
5. Cohen H, Rogers G F C and Saravanamuttoo H I H, “Gas Turbine Theory”, Orient Longman Limited, New Delhi (1996).

MEX- 661 Computational Fluid Dynamics [3 0 0 3]

Review of basic fluid mechanics and the governing Navier-Stokes equations, Techniques for solution of PDEs – finite difference method, finite element method and finite volume method, Finite volume (FV) method in one-dimension, Differencing schemes, Steady and unsteady calculations, Boundary conditions, FV discretizationin two and three dimensions, Simple algorithm and flow field calculations, variants of SIMPLE, Turbulence and turbulence modeling, illustrative flow computations, Commercial softwares FLUENT and CFX – grid generation, flow prediction and post-processing.

Books Recommended:

1. S V Patankar, *Numerical Heat Transfer and Fluid Flow*, McGraw Hill, NY, (2005).
2. John Anderson, "*Computational Fluid Dynamics*", McGraw-Hill Publication, First edition (February 1, 1995).
3. W M Kays and M E Crawford, *Convective Heat and Mass Transfer*, Mc-Graw Hill, New York (1993)
4. F M White, *Viscous Fluid Flow* by, Mc-Graw Hill, New York, 2nd Ed. (1991).
5. Robert Siegel and John Howell, *Thermal radiation Heat Transfer*, 4th Edition, Taylor and Francis NY, (2002)

MEX- 662 ADVANCED I.C. ENGINE TECHNOLOGIES [3 0 0 3]

CYCLE ANALYSIS

Otto, diesel, dual, Stirling and Brayton cycles, comparison of air standard, fuel air and actual cycles, simple problems on the above topics.

COMBUSTION IN SI ENGINES

Thermodynamic analysis of SI engine Combustion: Burned and unburned mixture states. Analysis of cylinder pressure data, Combustion process characterization, Flame structure and speed; flame structure, laminar burning speeds, flame propagation relations, Cyclic variations in combustion, partial burning and misfire: definitions, causes of cycle – by – cycle and cylinder to cylinder variations, partial burning, misfire and engine stability. Spark Ignition: Ignition fundamentals, conventional ignition systems, alternative ignition systems, alternative ignition approaches, Abnormal Combustion: knock and surface ignition, knock fundamentals, fuel factors.

COMBUSTION IN CI ENGINES

Types of diesel combustion systems: Direct injection systems, indirect injection systems, comparison of different combustion systems, Analysis of cylinder pressure data; combustion efficiency, DI engines, IDI engines, Fuel spray behaviour: Fuel injection, overall spray structure, atomization, spray penetration, droplet size distribution and spray evaporation, Ignition delay: definitions and discussion, fuel ignition quality, auto ignition fundamentals, physical properties affecting delay, effect of fuel properties.

COMBUSTION MODELLING

Basic concepts of engine simulation, governing equations, simulation of various engine processes for SI and CI engines. Adiabatic flame temperature, Heat release calculations. Thermodynamic and Fluid mechanic based models.

SPECIAL TYPES OF ENGINES
Introduction to working of stratified charged engines, Wankel engine, variable compression engine, Surface ignition engines, free piston engines, Current engines and future trends (e.g. Convergence of SI and CI engine technology, Control developments, fuel quality), Effect of air cleaners and silencers on engine performance.

RECENT TRENDS
Homogeneous Charge Compression Ignition Engine, Lean Burn Engine, Stratified Charge Engine, Surface Ignition Engine , Four Valve and Overhead cam Engines, Electronic Engine Management, Common Rail Direct Injection Diesel Engine, Gasoline Direct Injection Engine, Data Acquisition System –pressure pick up, charge amplifier PC for Combustion and Heat release analysis in Engines.

ELECTRONIC ENGINE MANAGEMENT
Computer control of SI & CI engines for better performance and low emissions, closed loop control of engine parameters of fuel injection and ignition

TEXTS:
1. Heinz Heisler, 'Advanced Engine Technology," SAE International Publications,USA,1998
2. Ganesan V. "Internal Combustion Engines" , Third Edition, Tata Mcgraw-Hill ,2007
3. Tom Denton. "Automobile Electrical and Electronic Systems", Elsevier, 2004
REFERENCES:
1. John B Heywood," Internal Combustion Engine Fundamentals", Tata McGraw-Hill, 1988
2. Richard Stone. "Introduction to Internal Combustion Engine", Society of Automotive Engineers Inc 1999
3. Hua Zhao, Nicos Ladommatos. "Engine combustion instrumentation and diagnostics", Society of Automotive Engineers, 2001
4. Robert Bosch GmbH. "Bosch Automotive Electrics and Automotive Electronics: Systems and Components, Networking and Hybrid Drive", Springer View

List of Elective (Design)

MEX- 631 Robotics: Mechanics and Control (3 0 0 3)

Introduction to Robotics:

Kinematics and Dynamics of Robotic linkages (open ended type manipulators):
Frames, Transformations: Translation and rotation, Denavit-Hartenberg parameters,
Forward and Inverse Kinematics, Jacobian,
Dynamics: Equations of motion, Newton-Euler formulation

Sensors and actuators:
Strain gauge, resistive potentiometers, Tactile and force sensors, tachometers, LVDT, Piezo electric accelerometer, Hall effect sensors, Optical Encoders, Pneumatic and Hydraulic actuators, servo valves, DC motor, stepper motor, drives

Control of Manipulators:
Feedback control of II order Linear systems, Joint control, Trajectory control, Controllers, PID control

Recommended Books

1. John J. Craig, Introduction to Robotics: Mechanics and Control, Addison-Wesley, 2005.
2. Tsuneo Yoshikawa, Foundations of Robotics, MIT Press, 1990.

3. Saeed B. Niku, Introduction to Robotics: Analysis, Systems, Applications, Pearson Education Inc., 2001
4. Spong M. W., and Vidyasagar M., Robot Dynamics and Control, John Wiley & Sons, 1989.
5. Murray R. M., et al, A Mathematical Introduction to Robotic Manipulation, CRC Press, 1994.
6. Waldron K. J., and Kinzel G. L., Kinematics, Dynamics and Design of Machinery, John Wiley & Sons, 2004.
7. Eronini Umez-Eronini, System Dynamics & Control, Brooks/ Cole Publishing Company, 1999.
8. Amalendu Mukherjee, Ranjit Karmakar and Arun Kumar Samantaray, Bond Graph in Modeling, Simulation and Fault Identification, I. K. International Publishing House Pvt.

MEX-675 Mechanics of Composite Materials (3 0 0 3)

Introduction: Definition of composite, load transfer mechanism, classification of composites, advantages and applications of composites, fibers, matrix materials and their properties. Basic concepts of solid mechanics – general state of stress, equilibrium equations, tensors – constitutive equations, plane stress, plane strain and strain energy concept.

Micromechanics of Composites: 3-D constitutive equations: Generalized Hooke's Law – orthotropic, transversely isotropic and isotropic materials. Engineering constants, stiffness and compliance matrix, stress and strain transformation, transformed stiffness and compliance matrix. Lamina stress-strain relations in principal and global coordinates. Thermal Stress.

Micromechanics of Composites**:** Basic concepts, fiber packing geometry, micromechanical methods for prediction of properties of fiber-reinforced composites – Longitudinal, transverse and shear moduli, Poisson's ratios, tensile and compressive strength.

Composite Laminates: Basic concepts of classical lamination theory (CLT) – laminate stress. Laminate stiffness – A-B-D matrix, and their implications.

Failure Theories: Application of theories of failure to fiber – reinforced composites, failure mechanisms, maximum stress, maximum strain, Tsai-Hill theory, Tsai-Wu theory of failure. Comparison of failure criteria.

Dynamic behavior: Linear viscoelastic behavior, creep and relaxation, differential equations and spring dashpot models. Complex modulus, elastic-viscoelasitc correspondence principle, longitudinal, flexural vibrations of composite beams and transverse vibrations of laminations, analysis of damping in composites.

Books Recommended

1. Broutman L J and Krock R H "Modern Composite Materials", Addison Wesley Publishing Company, 1967.
2. Jones R M "Mechanics of Composite Materials", Scripta Book Company, 1975.
3. Herkovic C T "Mechanics of Fibres Composites", University of Virginia, John Wiley and Sons, Inc, 1998.
4. Tsai Stephen W "Introduction to Composite Materials", Technomic Publishing Company Inc., 1980.
5. Gibson R F, "Principles of Composites Materials Mechanics", McGraw Hill International Edition, New York, 1994.
6. Hyer M W, "Stress analysis of Fiber-Reinforced Composites Materials", WCB McGraw Hill, Boston, 1997.

7. Halpin J C, “Primer on Composite Materials Analysis”, Technomic Publishing Company Inc, Lanchester, 1992.

MEX-676 Finite Element Methods (3 0 0 3)

Fundamentals of the Finite Element Method, discritization of the domain, one-two and three dimensional elements and interpolation functions, local and global coordinates, properties of interpolation functions, compatibility and completeness requirements, Assembly and boundary conditions; Formulation for FEM solutions.
Application to solid mechanics, vibrations, plates and shell problems.

Books Recommended

1. Desai and Abel, “Introduction to Finite Element Method”, East West, CBS Delhi (1987).
2. Zienkiewicz O C, “Finite Element Method”, McGraw Hill (1989).
3. Krishnamurthy C J, “Finite Element Method – Analysis Theory and Programming”, Tata McGraw Hill (1994).
4. Bathe k J, “Finite Element Procedures”, Prentice Hall of India Private Limited, New Delhi, (1996).
5. Belegundu Ashok D and Chandrupatla T, “Introduction to Finite Element Method”, PHI Private Limited, New Delhi (2003).

MEX-677 Machine Tool Design (3 0 0 3)

Design requirements of machine tools, A design approach for machine tools, identification and quantification of objectives and constraints in machine tool design. Estimation of power requirements and selection of motor for metal cutting machine tool spindles. Design of gearbox, spindle and guideways. Principles of design of structural components, namely, head stock, tail stock, carriage, table, knee, column and over arms to achieve desired static and fatigue strength, stiffness, dynamic characteristics and other requirements. Exercises on the design of machine tools using existing CAD software packages.

Introduction to computer integrated manufacturing systems and CNC machine tools. Design/selection of linear motion systems, ball, screws, CNC feedback devices, controllers, feed drives and servomotors for CNC machine tools. Recent developments in CNC and other machine tools.

Books Recommended:

1. Devris W R, “Analysis of Material Removal Processes”, Springer – Verlag, 1992.
2. N Acherkan , “Machine Tool Design” , Volume- 1-4, MIR Publishers, Moscow, 1969
3. Mishra P K, “Non Conventional Machining”, Narosa Publishing House, New Delhi, 1977 Edition.
4. Panday P C, Shan H S, “Modern Machining Processes”, Tata McGraw Hill Publishing Company Limited, New Delhi, 1980 Edition.
5. Schey A, John, “Introduction to Manufacturing Processes”, McGraw Hill Book Company, New York, 1987.
6. Jain R K, “Production Technology”, Khanna Publishers Delhi, 1995.
7. HMT Bangalore, “Production Technology”, Tata McGraw Hill, New Delhi, 1980.

MEX-678 Modal Analysis of Mechanical Systems (3 0 0 3)

Overview: Applications of Modal Testing, Philosophy of Modal Testing, Summary of Theory, Summary of Measurement Methods, Summary of Modal Analysis Processes, Review of test procedures, and levels, Terminology and Notation.

Theoretical Basis: Single-Degree-of Freedom (SDOF) system theory, Presentation and properties of FRF Data for SDOF system, Undamped Multi-Degree-of Freedom (MDOF) system, MDOF systems with proportional damping, MDOF systems with structural (hysteretic) damping – General case, MDOF systems with viscous damping – general case, Modal Analysis of Rotating Structures, Complex Modes, Characteristics and presentation of MDOF FRF Data.
Non-sinusoidal Vibration and FRF properties.

Response Function Measurement Techniques: Basic measurement system, Structure Preparation, Excitation of the Structure, Transducers and amplifiers, Analyzers, Digital signal processing, use of different excitation signals, calibration, mass cancellation, rotational FRF measurement, measurements on non-linear structures, multi-point excitation methods, measuring FRFs and ODSs using the scanning LDV.

Modal Parameter Extraction Methods: Preliminary checks of FRF data, SDOF modal analysis, methods, MDOF modal analysis in the frequency domain (SISO), global modal analysis in the time domain, modal analysis of non-linear structures, concluding comments.

Derivation of Mathematical Models: Modal models, refinement of modal models, display of modal model, response model, spatial models, mobility skeletons and system models.

Applications: Comparison of and correlation of experiment and prediction, adjustment or updating of models, coupled and modified structure analysis, response prediction and force determination, test planning.

1. He and fu “Modal Analysis” Elsevier Science & Technology 2001.
2. J M M Silva & N M M Maia “Modal Analysis and Testing” Kluwer Academic Publishers Group 1999.
3. G Conciauro, M Guglielmi, R Sorrentino “Advanced Modal Analysis” John Wiley & Sons 2000.

MEX-679 Vibration Control (3 0 0 3)

Factors affecting level of vibration, vibration reduction at the source, vibration control by structural design, selection of materials, vibration control by artificial damping, viscoelastic laminate, and material damping, vibration absorbers and auxiliary mass dampers, optimum, tunings and damping application of absorbers, Theory of vibration and shock isolation.

Books Recommended

1. Rao S S, “Mechanical Vibrations”, Pearson Education, Delhi (2004).
2. Roger A A, “Fundamentals of Vibrations”, Amerind Publisher Company Private Limited, New Delhi (1999).
3. Srinivas P, “Mechanical Vibration Analysis”, Tata McGraw Hill Company Limited, New Delhi (1990).
4. Mallik A K, “Principles of Vibrations Control”, Affiliated East West Press Private Limited, New Delhi (2000).
5. Lazan B J , “Damping of materials and members in structural mechanics” Pergamon Press 1968.

MEX-681 Viscoelasticity ` (3 0 0 3)

Introduction to stress and strain tensor, Mechanical models of time dependant behavior, operator type of stress-strain relations. Boltz man's supper position principle. Integral form of stress-strain relations. General theory of viscoelasticity, Modeling of viscoelastic materials. Behavior under complex stress system. Application to model plastics and composite materials.

Recommended Books

1. W Flugge, "Viscoelasticity" Blaisdell Publishing Company, 1967
2. J D Ferry, "Viscoelastic properties of Polymers" John Wiley & Sons 1970
3. R. M. Christensen, "Theory of Viscoelasticity" Dover Pubns 2003

MEX-682 Theory of Elasticity and Plasticity (3 0 0 3)

State of stress and stress transformation laws, principal stresses. Equilibrium equations, compatibility equations, Plane stress and plane strain problems in Cartesian and polar coordinates. Torsion of non circular cross sections.

Mechanical behavior of materials in plastic range, Foundation of theory of plasticity, Axisymmetric problems, Limit analysis theorem, plane strain and slip line theory. Application to mechanical working of materials.

Recommended Books

1. Martin H. Sadd, " Elasticity: Theory, Applications, and Numerics" Academic Pr 2009
2. Weimin Han, B. Dayanand Reddy, "Plasticity: Mathematical Theory and Numerical Analysis" Springer Verlag 1999
3. Alexander Mendelson, "Plasticity: Theory and Applications" Krieger Pub Co 1983

MEX-684 Theory of Plates and Shells (3 0 0 3

Small deflections of transversely loaded plates. Plates equations, boundary conditions. Rectangular and circular plates with different support conditions. General equations of elastic shells in invariant form. Membrane theory, Moment theory. Rotationally symmetric shells. Shallow shell theory. Examples.

Recommended Books

1. J.N. Reddy, "Theory And Analysis of Elastic Plates And Shells" Taylor & Francis 2006.
2. T Krauthammer, E Ventsel, " Thin Plates and Shells: Theory, Analysis, and Applications" Marcel Dekker Inc 2001.
3. S Timoshenko, "Theory of Plates and Shells" McGraw-Hill College 1959.

MEX-685 Fracture Mechanics (3 0 0 3)

Linear elastic fracture mechanics – Energy approach and stress intensity factor approach. General yielding fracture mechanics. Concept of crack opening displacement and J integral fracture criteria. Evaluation of fracture mechanics parameters. Fracture safe designing of structures and machine components. Service failure analysis.

Recommended Books

1. Richard W. Hertzberg Deformation and Fracture Mechanics of Engineering Materials John Wiley & Sons Inc 1995
2. S. D. Antolovich, “Fundamentals of Fracture Mechanics” Academic Pr 2009
3. A Saxena “Non-Linear Fracture Mechanics for Engineers” CRC Press 2009

MEX- 687 System Dynamics & Control (3 0 0 3)

Introduction to Physical System Dynamics
Modeling of Physical System Dynamics: A Unified Approach:
Physical systems, Introduction to Bond graphs, Ports, Bonds and Power;
Elements of Bond graphs, 1-port elements – resistor R, Stiffness C, and Inertia I, Source of Effort Se and Flow Sf; 2-port elements – Transformer TF and Gyrator GY, with modulation, Junction elements 1 and 0;
Causality: Causality for basic 1-port and multi-ports.
Derivation of System equations from Bond graphs in first order state space form.
Bond graph modeling of multi-energy systems:
Mechanical Systems, Translation and rotation (about a fixed axis), Electrical Systems, Electromechanical Systems, Fluid systems,
Transducer models – cylinder, rack and pinion, electromechanical transducers - motors, pumps – positive displacement and centrifugal pump, gear trains, etc.
Analysis of linear systems:
Free and forced response for first and second order systems, Undamped and damped oscillator, Derivation of Signal flow graphs from Bond graphs, Derivation of Transfer functions, Bode plots
State variable analysis:
State transition matrix, Characteristic equation, Eigen values and Eigen vectors, Their impact on system response, Similarity transformations and their properties, Controllability and Observability, Canonical forms: Controllable, Observable, Diagonal
Stability Criteria:
Routh-Hurwitz criterion, Liapunov stability criteria.
Controllers:
39
Pole-placement method, Proportional Integral and Derivative feedback
Simulation and case studies:
Computer simulation of Dynamic Systems using Bond graphs

Recommended Books

1. Karnopp, Margolis, Rosenberg, System Dynamics: Modeling and Simulation of Mechatronic Systems, Fourth Edition, Wiley (Higher education), 2005.
2. Karnopp, Margolis & Rosenberg, System Dynamics: A Unified Approach, Wiley , 1990.
3. Amalendu Mukherjee & R. Karmakar, Modeling & Simulation of Engineering Systems through Bond Graphs, Narosa, 2000.
4. Amalendu Mukherjee, Ranjit Karmakar and Arun Kumar Samantaray, Bond Graph in Modeling, Simulation and Fault Identification, I. K. International Publishing House Pvt. Ltd, 2006.
5. Eronini Umez-Eronini, System Dynamics & Control, Brooks/ Cole Publishing Company, 1999.
6. B. C. Kuo, Feedback Control Systems, Prentice Hall.
7. K. Ogata, Modern Control Engineering, Prentice Hall.
8. Bernard Friedland, Control Systems Design, McGraw-Hill.

MEX -688 Soft computing techniques (3 0 0 3)

Simple Calculations with MATLAB, Writing Scripts and Functions, Plotting Simple Functions, Loops and Conditional Statements, Root Finding, Interpolation and Extrapolation, Matrices, Numerical Integration
Solving Differential Equations: Some Basics of ODE Integration, Linear PDE, Nonlinear PDE Simulations and Random Numbers
Optimization Methods: Linear Programming, Dynamic Programming, Network Analysis
SIMULINK: Introduction to SIMULINK Engineering and Scientific Computations Using SIMULINK, Engineering and Scientific Computations Using SIMULINK

Books recommended

1. S.R. Otto and J.P. Denier, An Introduction to Programming and Numerical Methods in MATLAB. Springer-Verlag London Limited 2005
2. Steven T. Karris , Numerical Analysis Using MATLAB® and Spreadsheets Orchard Publications 2005
3. Sergey E. Lyshevski, Engineering and Scientific Computations Using MATLAB,
Pave1 Solin Partial Differential Equations and the Finite Element Method, John Wiley & Sons, Inc., Publication

MEX-689 Photovoltaic cell and its application (3 0 0 3)

Solar Radiation
Introduction, Measurement of Solar Radiation on Earth's Surface, Sun–Earth Angles, Solar Radiation on a Horizontal Surface, Solar Radiation on an Inclined Surface,
Solar Cell Materials and Their Characteristics,
Introduction, Doping, Fermi Level, p-n Junction, p-n Junction Characteristics, Photovoltaic Effect, Photovoltaic Material, Basic Parameters of Solar Cells, Effect of Cell Temperature on Cell Efficiency, Current Research on Materials and Devices, Silicon Processing
PV Array Analysis
Introduction, Photovoltaic (PV) Module and Array, Theory and Construction, Series and Parallel , Combinations, Balance of PV Array, Partial Shading of Solar Cell and Module, Maximum Power Point Tracker (MPPT), International Status of PV Power Generation,
Role of Batteries and Their Uses
Introduction, Fundamental Principles, Electro-chemical Action, Physical Construction, Discharge Characteristics, Charging Characteristics, Selection of PV Battery, Batteries Commonly Used for PV, Applications, Battery Installation, Operation and Maintenance, Battery Protection and Regulating Circuits ,Battery Simulation and Sizing,Battery Lifetime in a PV System, Charging State of PV-powered Storage Batteries, General Terms
Thermal Modelling of Hybrid Photovoltaic/Thermal (PV/T) Systems
Introduction, PV/T Air Collectors, Hybrid Air Collector, Double-pass PV/T Solar Air Collector, Thermal Modelling of PV/T Air Collector, Covered by Glass-to-Tedlar Type PV Module, Thermal Modelling of PV/T Air Collector, Covered by Glass-to-Glass Type PV Module, Testing of the Solar Air Collector, PV/T Solar Water Heater, PV/T Solar Distillation System, Active PV/T Distillation System,
PV/T Solar Dryers,Statistical Analysis
Energy and Exergy Analysis 257
Energy Analysis, Energy Matrices,Embodied Energy, Embodied Energy of PV Module (Glass-to-Glass)
Balance of System (BOS), Analysis of Embodied Energy and EPBT of PV/T Solar Systems, Energy Pay-back Periods of Roof-mounted Photovoltaic Cells, Exergy Analysis, Importance of Exergy, Exergy of a Process, Exergetic Analysis of Flat-plate Collector, Exergetic Analysis of PV/T Systems

Economic Analysis
Introduction, Cost Analysis, Cash Flow, Cost Comparisons with Equal Duration, Cost Comparisons with Unequal Duration, Analytical Expression for Payout Time, Net Present Value, Benefit-Cost Analysis, Internal Rate of Return, Effect of Depreciation, Cost Comparisons of Solar Dryers with Duration

Case Studies of PV/T Systems
Introduction, Different types of case study Grid-connected Building Integrated, Photovoltaic System (BIPV) , PV-integrated Water-pumping Application, Simulation of an Existing BIPV System for Indian Climatic Conditions etc.

MEX-690 Methods of Analytical Dynamics (3 0 0 3)

Fundamentals of Newtonian Mechanics: Historical survey of Mechanics, Newton's Laws, Impulse and Momentum, Moment of a Force and Angular Momentum, Work and Energy, Energy Diagrams, Systems of Particles, The Two-Body Central Force Problem, The Inverse Square Law, Orbits of Planets and Satellites, Scattering by a Repulsive Central Force;

Fundamentals of Analytical Mechanics: Degree of Freedom. Generalized Coordinates, System with Constraints, The Stationary Value of a Function, The Stationary Value of a Definite Integral, The Principle of Virtual Work, D'Alembert's Principle, Hamilton's Principle, Lagrange's Equations of Motion, Lagrange's Equations for Impulsive Forces, Conservation Laws, Routh's Method for the Ignoration of Coordinates, Rayleigh's Dissipation Function, Hamiltion's Equations;

Motion Relative to Rotating Reference Frames: Transformation of Coordinates, Rotating Coordinates Systems, Expressions for the Motion in Terms of Moving Reference Frames, Motion Relative to the Rotating earth, Motion of a Free Particle Relative to the Earth, Foucault's Pendulum;

Rigid Body Dynamics: Kinematics of a Rigid Body, The Linear and Angular Momentum of a Rigid Body, Translation Theorem for the angular Momentum, The Kinetic Energy of a Rigid Body, Principle Axes, Moment-Free Inertially Symmetric Body, General Case of a Moment-Free Body, Motion of a Symmetric Top, The Lagrangian Equation of Quasi-Coordinates, The Equations of Motion Referred to an Arbitrary System of Axes, The Rolling of a Coin;

Behaviour of Dynamical Systems. Geometrical Theory: Fundamental Concepts, Motion of Single-Degrees-of Freedom Autonomous Systems about Equilibrium Points, Conservative Systems. Motion in the Large, The Index of Poincaré, Limit Cycles of Poincaré;

Stability of Multi-Degree-of-Freedom Autonomous Systems: General Linear Systems, Linear Autonomous Systems, Stability of Linear Autonomous Systems. Rourh-Hurwitz Criterion, The Variational Equations, Theorem on the First-Approximation Stability, Variation from Canonical Systems. Constant Coefficients, The Liapunov Direct Method, Geometrical Interpretation of the Liapunov Direct Method, Stability of Canonical Systems, Stability in the Presence of Gyroscopic and Dissipative Forces, Construction of Liapunov Function for Linear Autonomous Systems;

Nonautonomous Systems: Linear Systems with Periodic Coefficients. Floquet's Theory, Stability of Variational Equations with Periodic Coefficients, Orbital Stability, Variuation from Canonical Systems, Periodic Coefficients, Second-Order Systems with Periodic Coefficients, Hill's Infinite determinant, Mathieu's Equation, The Liapunov Direct Method;

Analytical Solution by Perturbation Techniques: The Fundamental Perturbation Technique, Secular Terms, Lindstedt's Methods, The Krylov-Bogoliubov-Mutroposlsky (KBM) Method, A Perturbation Technique Based on Hill's Determinations, Periodic Solutions of Nonautonomous Systems. Duffing's Equation, The Method of Averaging;

Transformation Theory. The Hamilton-Jacobi Equations: The Principle of Least Action, Constant Transformations, Further Extensions of the Concept of Contact Transformations, Integral Invariants, The Langrange and Poisson Brackets, Infinitesimal Contact Transformations, The Hamilton-Jacobi Equation, Separable Systems, Action and Angule Variables, Peturbation Theory.

Books Recommended

1. Leonard Meirovitch, “Methods of Analytical Dynamics”, First South Asian Edition, Dover Publications Inc., 2007.
2. H. Goldstein, Classical Mechanics, Pearson, 2011.
3. Francis B. Hildebrand, *Methods of Applied Mathematics*, 2nd Edition, Dover Publications Inc., 2002.

MEX-691 Nonlinear Systems (3 0 0 3)

Introduction: Nonlinear Models and Nonlinear Phenomena, Examples Pendulum Equation, Tunnel- Diode Circuit, Mass-Spring System, Negative-Resistance Oscillator, Artificial Neutral Network, Adaptive Control, Common Nonlinearities;
Second-Order Systems: Qualitative Behaviour of linear Systems, Multiple Equilibria, Qualitative Behaviour Near Equilibrium Points, Limits Cycles, Numerical Construction of Phase Portraits, Existence of Periodic Orbits, Bifurcation;
Fundamental Properties: Existence and Uniqueness, Continuous Dependence on Initial Conditions and Parameters, Differentiability of Solutions and Sensitivity Equations, Comparison Principle;
Lyapunov Stability: Autonomous Systems, The Invariance Principle, Linear Systems and Linearization, Comparison Functions, Nonautonomous Systems, Linear Time-Varying Systems, and Linearization, Converse Theorems, Boundedness and Ultimate Boundedness, Input-to-State Stability;
Input-Output Stability: L Stability, L Stability of State Models, L_2 Gain, Feedback Systems: The Small-Gain Theorem;
Passivity: Memory less Functions, State Models, Positive Real Transfer Functions, L_2 and Lyapunov Stability, Feedback Systems: Passivity Theorems;
Feedback Control: Control Problems, Stabilization via Linearization, Integral Control, Integral Control via Linearization, Gain Scheduling;
Feedback Linearization: Motivation, Input-Output Linearization, Full-State Linearization, State Feedback Control;

Nonlinear Design Tools: Sliding Mode Control, Lyapunov Redesign, Backstepping, Passivity-Based Control, High-Gain Observers.
Books Recommended

1. Hassan K. Khalil, Nonlinear Systems, Second Edition, Prentice Hall Inc., 2002.
2. Ali H. Nayfeh, The Method of Normal Forms, Wiley, 2011.
3. Ali H. Nayfeh, Introduction to Perturbation Techniques, Wiley-VCH Verlag GmbH.
4. D. T. Mook, Ali H. Nayfeh, Nonlinear oscillations, Wiley-VCH Verlag GmbH.
5. Leonard Meirovitch, Methods of Analytical Dynamics, First South Asian Edition, Dover Publications Inc., 2007.

MEX-692 Modern Control Engineering (3 0 0 3)

Introduction to Control Systems. Historical perspective leading to modern control engineering;
Mathematical Modeling of Dynamic Systems: Mechanical, Electrical, Fluid, Thermal Systems, etc. State variable models;
Dynamic response: Transient and Steady-State Response Analyses
Characteristics and performance of feedback control systems:
Stability in the frequency and time domains: Lyapunov stability;
Control systems analysis and design: Root-locus method, frequency-response method;
Control systems analysis and design in state space: Controllability and Observability, Pole placement using feedback, the separation principle and estimator design, PID Controllers
Digital control systems: Sampled-data systems, stability analysis, compensation, implementation of digital controllers;
Case studies: Computer simulation of dynamic systems.

Books Recommended

1. G. F. Franklin, J. D. Powell, A. Emami-Naeini, Feedback Control of Dynamic Systems, Pearson Education Inc., 2002.
2. R. C. Dorf, R. H. Bishop, Modern Control Systems, Addison-Wesley Longman Inc. 1998.
3. B. C. Kuo, Feedback Control Systems, Prentice Hall.
4. K. Ogata, Modern Control Engineering, Prentice Hall.
5. Eronini Umez-Eronini, System Dynamics & Control, Brooks/ Cole Publishing Company, 1999.
6. N. S. Nise, Control Systems Engineering, John Wiley & Sons (Asia) Pte. Ltd., Singapore, 2004.
7. Bernard Friedland, Control Systems Design, McGraw-Hill.
8. Graham C Goodwin, Stefan F Graebe, Mario E Salgado, Control System Design, Pearson Education Inc., 2001.
9. Karnopp, Margolis, Rosenberg, System Dynamics: Modeling and Simulation of Mechatronic Systems, Fourth Edition, Wiley (Higher education), 2005.
10. Amalendu Mukherjee, Ranjit Karmakar and Arun Kumar Samantaray, Bond Graph in Modeling, Simulation and Fault Identification, I. K. International Publishing House Pvt. Ltd, 2006.
11. NPTEL lectures on modern control engineering

MEX-693 Basic Biomechanics (3 0 0 3)

Introduction to Biomechanics. Historical sketch and scope; Mechanics in Physiology; Contributions of Biomechanics to Mechanics?

Segmental movement and vibrations; Generalized Coordinates, Lagrange's Equations, Normal Modes of Vibration, Decoupling of Equations of Motion, Muscle Forces, Segmental Movement and Vibrations, Systems with Damping and Fluid Dynamic Loads, Sufficient Conditions for Decoupling Equations of System with Damping.

Constitutive equations: Application to solids and fluids in biomechanics; Stress, Strain, Strain Rate, Constitutive Equations, The Nonviscous Fluid, The Newtonian Viscous Fluid, The Hookean Elastic Solid, The Effect of Temperature, Materials with More Complex Mechanical Behavior, Viscoelasticity, Response of a Viscoelastic Body to Harmonic Excitation, Use of Viscoelastic Models, Methods of Testing, Mathematical Development of Constitutive Equations

Description of internal deformation and forces; Use of Curvilinear Coordinates, Description of lnternal Forces, Work and Strain Energy, Calculation of Stresses from the Strain Energy Function, Complementary Energy Function, Rotation and Strain.

External Flow: Fluid dynamic forces acting on moving bodies; Flow Around an Airfoil, Flow Around Bluff Bodies, Steady-State Aeroelastic Problems, Transient Fluid Dynamic Forces Due to Unsteady Motion, Flutter, Kutta-Joukowski Theorem, The Creation of Circulation Around a Wing, Circulation and Vorticity in the Wake, Vortex System Associated with a Finite Wing in Nonstationary Motion, Thin Wing in Steady Flow, Lift Distribution on a Finite Wing, Drag.

Flying and swimming; Comparing Birds and Insects with Aircraft, Forward Flight of Birds and Insects, Hovering and Other Modes of Motion, Aquatic Animal Propulsion, Stokeslet and Dipole in a Viscous Fluid, Motion of Sphere, Cylinder, and Flagella in Viscous Fluid, Resistive-Force Theory of Flagellar Propulsion, Theories of Fish Swimming, Energy Cost of Locomotion, Cell Movement.

Skeletal muscle; The Functional Arrangement of Muscles, The Structure of Skeletal Muscle, The Sliding Element Theory of Muscle Action, Single Twitch and Wave Summation, Contraction of Skeletal Muscle Bundles, Hill's Equation for Tetanized Muscle ,Hill's Three-Element Model, Hypotheses of Cross-Bridge Theory, Evidences in Support of the Cross-Bridge Hypotheses, Mathematical Development of the Cross-Bridge Theory, Constitutive Equation of the Muscle as a Three-Dimensional Continuum,

Heart Muscle; The Difference Between Myocardial and Skeletal Muscle Cells, Use of the Papillary or Trabecular Muscles as Testing Specimens, Use of the Whole Ventricle to Determine Material Properties of the Heart Muscle,Properties of Unstimulated Heart Muscle, Force, Length, Velocity of Shortening, and Calcium Concentration Relationship for the Cardiac Muscle, The Behavior of Active Myocardium According to Hill's Equation and its Modification, Pinto's Method, Micromechanical Derivation of the Constitutive Law for the Passive Myocardium

Smooth Muscles; Types of Smooth Muscles, The Contractile Machinery, Rhythmic Contraction of Smooth Muscle, The Property of a Resting Smooth Muscle: Ureter, Active Contraction of Ureteral Segments, Resting Smooth Muscle: Taenia Coli, Other Smooth Muscle Organs.

Bone and Cartilage; Bone as a Living Organ, Blood Circulation in Bone, Elasticity and Strength of Bone, Viscoelastic Properties of Bone, Functional Adaptation of Bone, Cartilage, Viscoelastic Properties of Articular Cartilage, The Lubrication Quality of Articular Cartilage Surfaces, Constitutive Equations of Cartilage According to a Triphasic Theory, Tendons and Ligaments.

Books Recommended

1. Y. C. Fung, Biomechanics: Motion, Flow, Stress, and Growth, Springer, 1990.
2. Y. C. Fung, Biomechanics: Mechanical Properties of Living Tissues, 2nd Edition, Springer, 1993.
3. A. Freivalds, Biomechanics of the upper limbs: Mechanics, Modeling, and Musculoskeletal Injuries, CRC Press, 2004.
4. Fundamentals of Biomechanics, Duane Knudson, , 2nd Edition, Springer, 2007.