Curriculum and Syllabi

M.Tech Degree Programme

OFFSHORE STRUCTURES

(with effect from Academic Year 2006-2007)

Approved by DCC on 05/04/06 in its 28th meeting as item 28.2

DEPARTMENT OF CIVIL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY

CALICUTI

Department of Civil Engineering

NATIONAL INSTITUTE OF TECHNOLOGY CALICUT

Proposed Curriculum for M.Tech Programme in CIVIL ENGINEERING—OFFSHORE STRUCTURES (CEC)

S1

	Code	Title	L/T	P/S	Cr
1	CEC601	Wave Hydrodynamics	3		3
2	CEC602	Stochastic Processes in Structural Mechanics	3		3
3	CEC603	Design of Offshore Structures	3		3
4	CEC691	Computational Lab	1	2	2
5	CEC692	Offshore Engineering Lab	0	3	2
6		Elective	3		3
7		Elective	3		3
8		Elective	3		3

Total credits = 13 (Core)+9 or 6 (Electives)

S2

	Code	Title	L/T	P/S	Cr
1	CEC611	Offshore Structural Systems—Modelling and Behaviour	3		3
2	CEC612	Marine Foundations	3		3
3	CEC613	Stability of Structures	3		3
4	CEC693	Offshore Structures Design Studio	1	2	2
5	CEC697	Seminar	0	2	1
6		Elective	3		3
7		Elective	3		3
8		Elective	3		3

Total credits = 12 (Core)+9 or 6 (Electives)

S3

	Code	Title	L/T	P/S	Cr
1	CEC798	Project			8
2		Elective	3	0	3
3		Elective	3	0	3

Total credits = 8 (Core)+ 0 to 6 (Electives)

S4

	Code	Title	L/T	P/S	Cr
1	CEC799	Project			12

Total credits = 12 (Core)

Stipulations:

1. A minimum of 63 credits have to be earned for the award of M.Tech degree in this programme.
2. Students to register for six electives in three semesters together with two or three electives each in the first two semesters and a maximum of two in the third semester. Fourth semester is reserved for project work only.
3. Industrial Training (1 credit) during summer term is optional

List of Electives (CEC)

S1 or S3

CEC621	Ship Hydrodynamics
CEA601	Theory of Elasticity
CEA602	Structural Dynamics
CEA621	Structural Optimisation
CEA622	Modelling, Simulation and Computer Application
CEA624	Analytical Dynamics
CEA628	Multibody Dynamics and Applications
CEA630	Structural Health Monitoring
CEA631	Structural Reliability
CEB625	Geographic Information System and Applications
CEA701	Advanced Finite Element Analysis
CEA702	Advanced Theory of Shells
CEA703	Theory of Plasticity
* Any other subject offered in the Institute with approval from the Programme Coordinator/Faculty Advisor	

S2

CEC651	Advanced Wave Hydrodynamics
CEC652	Dynamics of Floating Bodies
CEA611	Finite Element Method
CEA612	Theory of Plates and Shells
CEA652	Random Vibrations
CEA653	Engineering Fracture Mechanics
CEA655	Design of Plated Structures and Shells
* Any other subject offered in the Institute with approval from the Programme Coordinator/Faculty Advisor	

CEC601 WAVE HYDRODYNAMICS

Pre-requisite :- Nil

L	T	P	Cr
3	0	0	3

Module 1 (8 hours)
Review of basic Fluid Mechanics – Fluid kinematics – Steady, Unsteady, Rotational and Irrotational flows - Stream lines and Equipotential lines, Velocity potential and Stream function - Conservation of mass - Continuity equation - Euler's equation of motion – Bernoulli's equation.

Module 2 (12 hours)
Introduction to Wave Mechanics – Wave generation by Wind - Small Amplitude Wave Theory ; Formulation and solution, Wave Celerity, Length and Period, Classification of waves based on relative depth, Orbital motions and Pressure - Standing waves - Wave trains and Wave energy - Wave reflection, Wave refraction and Wave diffraction - Breaking of waves.

Module 3 (10 hours)
Finite Amplitude Waves –Higher Order Wave Theories – Stokes Wave Theory, Cnoidal Wave Theory and Solitary Wave Theory - Wave interaction with Currents - Wave slamming and slapping - Sea as a Stationary Random Process - Wave Spectral density - Mathematical Spectrum models - Short term Wave statistics.

Module 4 (15 hours)
Wave Forces – Morison Equation; Wave force on a Circular Cylinder ; Vertical, Inclined and Oscillating - Wave Forces on Submarine Pipelines, Pipelines in proximity to seabed, Pipelines within the zone of wave influence – Froude Krylov theory - Diffraction theory; Close form solutions of Large fixed vertical cylinder - Wave forces on Sea walls and Breakwaters - Applications of Wave force regimes.

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References

1. Ippen, A. T., Estuary and Coastline Hydrodynamics, McGraw Hill, Inc.1982.
2. Dean, R.G., and Darlymple, R.A., Water Wave Mechanics for Engineers and Scientists, Prentice Hall, Inc. 1993.
3. Chakrabarti, S.K., Hydrodynamics of Offshore Structures, Springer Verlag, 1987.
4. Sarpkaya, T., and Isaacson, M., Mechanics of Wave Forces on Offshore Structures, Van Nostrand, 1981.
5. Kinsman, B., Wind Waves, Prentice Hall, Inc, 1965.
6. USACE, Shore Protection Manual, 2002.

CEC602 STOCHASTIC PROCESSES IN STRUCTURAL MECHANICS

Pre-requisite :- Nil

L	T	P	Cr
3	0	0	3

Module 1 (10 hours)

Basic Probability Concepts:- Sample space and events, probability measure, mathematics of probability.

Random variables: Probability distribution of a random variable, multiple random variables, main descriptors of a random variable – moments, expectation, covariance, correlation, conditional mean and variance. Functions of Random variables, expectation of a function of a random variable

Module 2 (9 hours)

Common Probabilistic Models:- Models from simple discrete random trails, models from random occurrences, models from limiting cases, other commonly used distributions, multivariate Models.

Derived probability distributions and distributions of functions.

Module 3 (13 hours)

Basic Theory of Stochastic Processes: Introduction, statistics of stochastic processes, stationary, ergodic and non stationary processes, auto and cross correlation and co variance function, stochastic calculus and mean square limit, conditions for continuity, differentiability, integrability of a random process, spectral decomposition of a random process, power spectral density function, narrow band and broad band random process, Wiener-Khintchine equation

Module 4 (13 hours)

Some important random processes: Normal processes, Poisson processes, Markov processes.

Properties of Random Processes: Level crossing peaks, fractional occupation time, envelopes, first-passage time, maximum value of a random process in a time interval.

Some models of random processes in nature: Earthquake, wind, atmosphere turbulence, random runways, road roughness, jet noise, ocean wave turbulence

References

1. Ang, A. H. S & Tang, W. H., Probability Concepts in Engineering Planning and Design, Vol. I Basic Principles, John Wiley & Sons, 1975.
2. J.R. Benjamin & C.A. Cornell., Probability, Statistics and Decision for Engineers, McGraw-Hill, 1970.
3. Papoulis, A., Probability, Random Variables and Stochastic Processes, McGraw Hill, 2002.
4. Nigam N. C., Introduction to Random Vibrations, MIT Press, Cambridge, USA, 1983.
5. Loren D Lutes & Shahram Sarkani., Stochastic Analysis of Structural and Mechanical Vibrations, Prentice Hall, NJ, 1997.
6. J Solnes, Stochastic Processes & Random Vibration, Theory and Practice, John Wiley, 1997

7. Lin, Y. K., Probabilistic Theory in Structural Dynamics, McGraw Hill, 1995.
8. Bendat & Piesol., Random Data Analysis and Measurement Procedure, John Wiley,1991.
9. Meirovitch, L., Elements of Vibration Analysis, McGraw Hill, 1986.
10. R.W Clough & J. Penzien,. Dynamics of Structures, McGraw Hill, 1993.

CEC603 DESIGN OF OFFSHORE STRUCTURES

Pre-requisite :- Nil

L	T	P	Cr
3	0	0	3

Module 1 (10 hours)

Types of offshore structures and conceptual development - Analytical models for jacket structures - Materials and their behaviour under static and dynamic loads - Statutory regulations - Allowable stresses - Various design methods and Code Provisions - Design specification of API, DNV, Lloyd's and other classification societies - Construction of jacket and gravity platforms

Module 2 (12 hours)

Operational loads - Environmental loads due to wind, wave, current and buoyancy - Morison's Equation - Maximum wave force on offshore structure - Concept of Return waves - Principles of Static and dynamic analyses of fixed platforms - Use of approximate methods - Design of structural elements.

Module 3 (15 hours)

Introduction to tubular joints - Possible modes of failure - Eccentric connections and offset connections - Cylindrical and rectangular structural members – In plane and multi plane connections - Parameters of in-plane tubular joints - Kuang's formulae - Elastic stress distribution - Punching shear Stress - Overlapping braces - Stress concentration - Chord collapse and ring stiffener spacing - Stiffened tubes - External hydrostatic pressure - Fatigue of tubular joints - Fatigue behaviour - S-N curves - Palmgren-Miner cumulative damage rule - Design of tubular joints as per API Code

Module 4 (8 hours)

Corrosion - Corrosion mechanism - Types of corrosion - Offshore structure corrosion zones – Biological corrosion - Preventive measures of Corrosion - Principles of cathode protection systems - Sacrificial anode method and impressed current method – Online corrosion monitoring - Corrosion fatigue.

References

1. Dawson, T. H., Offshore Structural Engineering, Prentice Hall, 1983.
2. API RP 2A., Planning, Designing and Constructing Fixed Offshore Platforms, API.
3. McClelland, B & Reifel, M. D., Planning & Design of fixed Offshore Platforms, Van Nostrand, 1986.
4. Graff, W. J., Introduction to Offshore Structures, Gulf Publ. Co.1981.
5. Reddy, D. V & Arockiasamy, M., Offshore Structures Vol.1 & 2, Kreiger Publ. Co.1991.
6. Morgan, N., Marine Technology Reference Book, Butterworths, 1990.
7. B.C Gerwick, Jr. Construction of Marine and Offshore Structures, CRC Press, Florida, 2000.

CEC691 COMPUTATIONAL LAB

Pre-requisite: -Nil

L	T	P	Cr
1	0	2	2

Introduction to Engineering Software - Introduction to O/S–storage and time optimisation - General purpose packages in Civil Engineering – Program Implementation-

Course Requirement:

Students are expected to know at least one high-level language. They will be imparted instructions for using available computer systems. Each student will be assigned a term project in his/her area of interest and shall develop an application program.

References

1. Rajaraman, A., Object oriented applications in engineering design, Narosa, India, 2003.
2. Heileman, G.L., Data structure, algorithms and object-oriented programming, McGraw Hill, New York, 1996.
3. Antia, H.M., Numerical Methods for Scientists and Engineers, Tata McGraw Hill.
4. Chapra, S.C., and Canale, R.P., Numerical Methods for Engineers, Tata McGraw Hill.

CEC692 OFFSHORE ENGINEERING LAB

Prerequisite:– Nil

L	T	P	Cr
0	0	3	2

Measurement of regular and random waves - Calibration of instruments for the measurement of waves - Measurement of reflectivity and transmissivity - Wave force measurements on cylinders - Wave-current-structure interaction studies - Analysis of experimental results.

Use of various transducers & pickups for static and dynamic measurements in ocean structures - Non-destructive testing - Data transmission and analysis using DACs.

CEC611 OFFSHORE STRUCTURAL SYSTEMS— MODELLING AND BEHAVIOUR

Prerequisite: Structural Dynamics

L	T	P	Cr
3	0	0	3

Module 1 (9 hours)

Structures in the offshore environment **-** Description of typical offshore structures - Fixed - Compliant- Floating - Solid fluid interaction parameters - Spring factor - Added mass and damping - Influence of viscosity and free surface effect on the added mass and damping - Environmental forces - Buoyancy and gravity - Dynamic characteristics and water depth capability of offshore structures - Dynamic amplification factor.

Module 2 (14 hours)

Response of offshore structures - Modelling of offshore structures – single and multi degree freedom systems – effect of foundations - Coupled motions - Frequency domain analysis - Time domain analysis - Newmark β method - Wilson θ method - Response analysis of jacket structures - Response analysis of complaint structures – non linear response and stability characteristics

Module 3 (12 hours)

Freely moving structures - Stability of submerged and floating structures - Stability at small and large angles - Motion of structure in response to excitation - Diffraction and radiation problems - Added mass – Damping - Wave exciting force - Strip theory - Mooring line forces - Motion analysis of floating vessels.

Module 4 (10 hours)

Motion analysis in random waves - Low frequency oscillation - High frequency oscillation - Wave drift forces - Springing forces - Non-linear sum forces - Damping at low and high frequencies - Dynamic positioning.

References

1. Wilson, J. F., Dynamics of Offshore Structures, John Wiley, 2002.
2. Clauss, G, Lehmann, E & Ostergaard, C., Offshore structures - Vols 1 & 2**,** Springer-Verlag, 1992.
3. Chakraborti, S. K., Non Linear methods in Offshore Engineering, Elsevier Science Publ, .2002.
4. Hooft, J. P., Advanced Dynamics of Marine Vehicles, John Wiley, 1982.
5. Chakraborti, S. K, Hydrodynamics of Offshore Structures, Springer-Verlag, 1987.
6. Bhattacharya. R., Dynamics of Marine Vehicles, John Wiley, 1978.
7. Patel, M.H., Compliant Offshore Structures, Butterworth Heinemann Ltd., Oxford, 1991.

CEC612 MARINE FOUNDATIONS

Prerequisite: - Nil

L	T	P	Cr
3	0	0	3

Module 1 (15 hours)

Introduction to Marine Geotechnical Engineering: Scope of marine geotechnical engineering - Marine and submarine soils - Classification of marine soils - Relative distribution of marine soils in the different marine regions - General characteristics of marine deposits in some specific locations and in the Indian sub-continent.

Sedimentological characteristics of marine soils: Structure of marine soils - Cementation bonding - Morphology and genesis of marine and submarine sediments - Post-depositional changes - Effect of calcium carbonate in marine deposits.

Engineering behaviour of marine soils: Fine and coarse-grained deposits - Strength and deformation behaviour of fine - and coarse-grained marine deposits - Effect of cementation - Strength and deformation behaviour under static and cyclic loading

Module 2 (10 hours)

Offshore Soil Investigation: General characteristics of offshore soil exploration - Sampling using free corer, gravity corer, tethered systems and manned submersibles - Deep penetration sampling using wire line techniques - In-situ determination of strength of submarine soils - Penetrometer, piezocone, vane and pressure meter techniques - General reconnaissance procedure for installation of fixed structures (gravity and piled type), floating structures, sea bed anchors and submarine pipelines.

Module 3 (10 hours)

Foundations for Gravity Structures: Types of gravity structures - Installation techniques - Movement of gravity structures - Settlement of soil beneath gravity structures - Stress distribution beneath gravity structures - Stability of gravity structures under static and cyclic loads

Foundations for jacket type structures: Types - Installation techniques - Design considerations - Axial and lateral load capacity of piles - Lateral load deformation behaviour of piles - Calculation of bearing capacity of piles - Design of piles subjected to lateral loads - Reese-Matlock method & p-y curves method.

Module 4 (10 hours)

Foundations for jack up platforms: Types of jack up platforms - Piles and mat supported - Spud cans - Different types - Techniques for installation and removal of jack up - Stability of jack up platforms - Determination of penetration of supports - Stability under lateral loads - Stability under static and cyclic load effects.

Sea bed anchors, submarine pipe lines: General introduction to sea bed anchors, moorings, submarine pipe line etc. - general design considerations (brief outline only) - geotechnical aspects in the design and installation of sea bed anchors, moorings, submarine pipelines etc.

References

1. Chaney, F. Marine geotechnology and nearshore/offshore structures, ASTM, STP-, 1986.
2. Chaney, R. C & Demars, K. R., Strength Testing of Marine Sediments - Laboratory and In-situ Measurements, ASTM, STP -883, 1985.
3. George, P & Wood, D., Offshore Soil Mechanics, Cambridge University Press.

4. Le Tirant, Sea Bed Reconnaissance and Offshore Soil Mechanics for the Installation of Petroleum Structures, Gulf Publ. Co., 1979.
5. Poulos, H. G & Davis, E. H., Pile Foundation Analysis and Design, John Wiley, 1980.
6. Numerical Methods in offshore Piling, Proc. Conf. Inst. of Civil Engineers, London, 1980.

CEC613 STABILITY OF STRUCTURES

L	T	P	Cr
3	0	0	3

Prerequisite: -Nil

Module 1 (11 hours)

Introduction:- Concept of stability – Static, Dynamic and Energy criterion of stability
Beam Columns - Differential Equation of Equilibrium of Beam-Columns – Concentrated Loads – Continuous Uniformly Distributed Lateral Loads – Different End Conditions – The Effect of Initial Curvature on Deflections – Interaction formula.

Module 2 (13 hours)

Elastic Buckling of Bars – Review of Euler Column Theory for Four Different End Conditions – Evaluation of Critical Loads of Column Using Determinant – Approximate Methods of Evaluation of critical Loads of Columns – Energy Method – Rayleigh Ritz Method – Finite Difference Method – Newmark's Deflection Comparison Method - Buckling of Bars with Changes in Cross Section Using the Approximate Methods Such as Successive Approximations – The Effect of Shearing Force on the Critical Load – Buckling of Built up Columns – Various Empirical Formulae for Column Design.

Module 3 (11 hours)

Stability of Rigid Bars having Linear or Rotational Springs - Stability of System of Rigid Bars Using Equilibrium and Principle of Stationary Potential Energy
Buckling of Frames:- Portal, Rectangular and L-shaped Frames under Non-sway Conditions - Beams Subjected to Compressive Loads by Matrix Approach and Stability Functions

Module 4 (10 hours)

Pure Torsion of Thin walled Bars of Open Cross-section – Torsional Buckling – Determination for Warping displacement for a Thin Walled Channel Section – Examples of Section with Thin Elements in which there is no Warping.
Lateral Buckling of Beams in Pure Bending – Lateral Buckling of Simply Supported I-beams.
Introduction to stability of Plates and Shells: Buckling of plates, buckling of shells.

References

1. Timoshenko, S.P., and Gere, J.M., Theory of Elastic Stability, McGraw Hill, Singapore, 1963.
2. Chajes, A., Principles of Structural Stability Theory, Prentice Hall Inc., Englewood Cliffs, New Jersey, 1974.
3. Brush, D.O., and Almorth, B.O., Buckling of Bars, Plates and Shells, McGraw Hill, 1975.
4. Kumar, A., Stability of Structures, Allied Publishers Limited, 1998.
5. Iyengar, N.G.R., Structural Stability of Columns and Plates, East West Press, 1986.
6. Simitses, G.J., Introduction to the elastic stability of structures, Prentice Hall Inc., New Jersey, 1976.

CEC693 OFFSHORE STRUCTURES DESIGN STUDIO

Pre requisite: Design of Offshore Structures

L	T	P	Cr
1	0	2	2

Module 1 (15 hours)
Design Principles of Jacket platform tower, Jack up legs - Design of decking - Design of supporting legs - Design of braces - Design of deck legs, Deck framings, Plating etc. - Design of platform derricks, Masts, Helipads etc. - Seismic analysis of Offshore Platforms - Offshore Platform Pile Foundations - Pile capacity -Soil-pile Interaction - Pile design as per API recommendations.

Module 2 (8 hours)
Design of Concrete Gravity Platforms - Ingredient materials and Protective Measures - Design of Side walls, Design of Decking - Design of Raft Foundation

Module 3 (10 hours)
Design of offshore pipelines - Design considerations - Structural aspects - Static and dynamic analyses - Approximate methods - Structural and positional stability - Pipeline-soil interaction - Pipe laying methods like lay barge, bottom tow, floating, reel-ship & RAT methods - Trenching of pipelines

Module 4 (12 hours)
Design of Compliant towers - Articulated towers - Guyed towers - Cylindrical Buoys - Single point Moored Buoy systems - Statics of mooring lines without and with elasticity - Dynamics of mooring lines - Design of mooring cables

Note: Each student shall design and submit designs and drawings of an offshore structure as a term project.

References

1. Dawson, T. H., Offshore Structural Engineering, Prentice Hall, 1983.
2. --American Petroleum Institute, API RP-2A, Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms.
3. McClelland, B & Reifel, M. D., Planning & Design of fixed Offshore Platforms, Van Nostrand, 1986.
4. Graff, W. J., Introduction to Offshore Structures, Gulf Publ. Co.1981
5. Reddy, D. V and Arockiasamy, M., Offshore Structures Vol. 1& 2, Kreiger Publ. Co.1991.
6. Morgan, N., Marine Technology Reference Book, Butterworths, 1990.

CEC697 SEMINAR

L	T	P	Cr
0	0	2	1

Prerequisite: -Nil

Each Student shall prepare a Paper and present a Seminar on any topic related to the branch of specialisation under the guidance of a staff member. The student shall submit typed copy of the paper to the Department. Grades will be awarded on the basis of contents of the paper and the presentation.

CEC621 SHIP HYDRODYNAMICS

Prerequisite: - Nil

L	T	P	Cr
3	0	0	3

Module 1 (10 hours)

Sea environment - Waves on the sea surface - Statistical description of waves - Wind-Current - Hull forms of different types of ships and boats - Numerical techniques for ship calculations - Weight estimation, centre of gravity, effect of shifting weights - Fluid pressure, centre of pressure - Effects of ship on waves- Frequency of wave encounter - Smith correction - Forward speed - Response of ship to wave excitation.

Module 2 (12 hours)

Ship distortion in still water - Hydrostatic fluid actions - Stability of ships - Transverse and longitudinal stability - Metacentre - Metacentric height - Stability at small angles - heel, trim and angle of roll - Free surface effects - Inclining experiment - Stability at large angles - cross curves of stability - dynamic stability levers - Wind heeling moment, maximum allowable KG - Stability of grounded vessels - Submarine stability - Stability criterion for various types of crafts.

Module 3 (15 hours)

Hydrodynamic forces - Strip theory - Diffraction theory - Transient Loading - Slamming - Second order forces - Mean wave drift forces and moments - Slow drift forces in irregular waves - Slowly varying oscillation due to wind - Sum frequency effects - Ship response to regular seaway - uncoupled and coupled motions - Ship response to irregular seaway.

Module 4 (8 hours)

Motion stabilisation - Roll stabilisation - Pitch stabilisation - Effectiveness of motion stabilisation.

References

1. Bishop and Price, Hydroelasticity of ships, Cambridge University Press, Cambridge, 1979.
2. Faltinsen, Sea loads on ships and offshore structures, Cambridge University Press-Cambridge, 1993.
3. Bhattacharya, R., Dynamics of marine vehicles, A Wiley Interscience Publication-John Wiley, 1978.
4. Comstock, Principles of Naval Architecture, New York: Society of Naval Architects and Marine Engineers, 1967.

CEA601 THEORY OF ELASTICITY

L	T	P	Cr
3	0	0	3

Prerequisite: - Nil

Module 1 (12 hours)

Introduction to the mathematical theory of elasticity**:** Elasticity, stress, strain, Hooke's law, two-dimensional idealisations, plane stress and plane strain problems, equations of equilibrium, strain-displacement relations, constitutive relations, compatibility conditions, displacement and traction boundary conditions.

Two-dimensional problems in rectangular coordinates: Stress function, solution by polynomials, Saint Vénant's principle, bending of a cantilever, determination of displacements.

Module 2 (12 hours)

Two-dimensional problems in polar coordinates: General equations, problems of axisymmetric stress distribution, pure bending of curved bars, effect of circular hole on stress distribution in plates, concentrated force at a point on a straight boundary.

Introduction to Cartesian Tensors: Transformation laws of cartesian tensors, special tensors and tensor operations, the Kronecker's delta, the permutation tensor, the e-δ identity, symmetry and skew-symmetry, contraction, derivatives and the comma notation, Gauss' theorem, the base vectors and some special vector operations, eigenvalue problem of a symmetric second order tensor, equations of elasticity using index notation.

Module 3 (12 hours)

Stress and strain problems in three dimensions: Principal stresses, principal strains, three-dimensional problems.

Energy Theorems and Variational Principles of Elasticity: Strain energy and complementary energy, Clapeyron's theorem, virtual work and potential energy principles, principle of complementary potential energy, Betti's reciprocal theorem, principle of linear superposition, uniqueness of elasticity solution.

Module 4 (9 hours)

Torsion of straight bars: Elliptic and equilateral triangular cross-section, membrane analogy, narrow rectangular cross-section, torsion of rectangular bars, torsion of rolled profile sections, hollow shafts and thin tubes.

References

1. Timoshenko, S.P. and Goodier, J.N., Theory of Elasticity, Mc Graw Hill, Singapore, 1982.
2. Leipholz, H., Theory of Elasticity, Noordhoff International Publishing, Layden,1974.
3. Sokolnikoff, I.S., Mathematical Theory of Elasticity, Tata Mc Graw Hill, India,1974.
4. Xu, Z., Applied Elasticity, Wiley Eastern Ltd, India, 1992.
5. Srinath, L.S., Advanced Mechanics of Solids, Second Edition, Tata McGraw Hill, India, 2003.
6. Ameen, M., Computational Elasticity—Theory of Elasticity, Finite and Boundary Element Methods, Narosa Publishing House, 2004.

CEA602 STRUCTURAL DYNAMICS

Prerequisite: - Nil

L	T	P	Cr
3	0	0	3

Module 1 (12 hours)

Over view:- Basic features of dynamic loading and response – models for dynamic analysis – lumped mass, generalized displacements and finite element models Formulation of equation of motion – Direct equilibration, principle of virtual displacement and Hamilton's principle.

Degrees of freedom – Translational and rotational systems - mass moment of inertia

Generalized single degree of freedom systems- rigid body assemblage determination of characteristic properties.

Free vibration of single degree of freedom system:- Solution of equation of motion, undraped free vibration - Damped free vibration, critically damped, under damped and over damped systems, Negative damping.

Module 2 (12 hours)

Single degree of freedom system – Response:- Response to harmonic loading, Undamped system- damped system, Response to periodic loading -Fourier series expansion of the loading- response to Fourier series loading Exponential form of Fourier series loading and response- Complex frequency transfer functions

Response to impulsive loads :- Suddenly applied load, sine wave impulse, rectangular impulse, triangular impulse, spike loading, approximate analysis

Response to general dynamic loading:- Duhamel integral for undamped system – unit impulse response function – numerical evaluation, response of damped system- numerical evaluation, Numerical analysis in the frequency domain, fast Fourier transform analysis.

Module 3 (12 hours)

Multi degree of freedom system:- Two degree of freedom system – equation of motion, characteristic equation, frequencies and mode shapes, coordinate coupling and choice of degree of freedom, orthogonality of modes, natural coordinates, superposition of natural modes , response of two degree of freedom system to initial excitation, beat phenomenon, response to harmonic excitation

Multi- degree of freedom system – analysis of multi- degree of freedom system- mode superposition analysis.

Distributed Parameter System: Partial differential equation of motion - Axial vibration of prismatic bars - Elementary case of flexural vibration of beams - Beam flexure including axial force effects.

Module 4 (9 hours)

Practical Vibration Analysis:- Determination of frequency by Rayliegh's method, beam flexure – selection of shape- improved Rayleigh's method.

Framed structures – Shear building concept and models for dynamic analysis, discrete parameter system by Rayleigh's method , improvement of frequency, Stodola method for discrete parameter system, reduction of second and higher modes- Stodola method for continuous parameter system.

References

1. Clough,R.W. and Penzien, J., Dynamics of structures, McGraw Hill, 1993.
2. Chopra, A.K., Dynamics of structures – Theory and Application to Earthquake Engineering, Prentice Hall of India, 1996.
3. --IS 1893 – Criteria for Earthquake Resistant Design of Structures, 2002.
4. --SP 22: Explanatory Handbook on Codes for Earthquake Engineering.
5. Meirovitch L., Elements of Vibration Analysis, Mc.Graw Hill, 1986.
6. Thomson W.T., Theory of Vibration with Applications, Pearson Education Inc., 1998.
7. Craig, Jr. R.R., Structural Dynamics, John Wiley, 1981.
8. Hurty, W.C. and Rubinstein M.F., Dynamics of Structures, Prentice Hall, 1964.

CEA621 STRUCTURAL OPTIMISATION

L	T	P	Cr
3	0	0	3

Pre-requisite: - Nil

Module 1 (12 hours)

Introduction: Problem formulation with examples.
Single Variable Unconstrained Optimisation Techniques: Optimality Criteria.
Bracketing methods: Unrestricted search, Exhaustive search.
Region Elimination methods: Interval Halving methods, Dichotomous search, Fibonacci method, Golden section method.
Interpolation methods: Quadratic Interpolation method, Cubic Interpolation method.
Gradient Based methods: Newton-Raphson method, Secant method, Bisection method.

Module 2 (12 hours)

Multi Variable Unconstrained Optimisation Techniques: Optimality Criteria. Unidirectional Search.

Direct Search methods: Random search, Grid search, Univariate method, Hooke's and Jeeves' pattern search method, Powell's conjugate direction method, Simplex method.
Gradient based methods: Cauchy's (Steepest descent) method, Conjugate gradient (Fletcher-Reeves) method, Newton's method, Variable metric (DFP)method, BFGS method.

Module 3 (11 hours)

Constrained Optimisation Techniques: Classical methods: Direct substitution method, Constrained variation method, method of Lagrange multipliers, Kuhn-Tucker conditions.
Linear programming problem: Standard form, Simplex method.
Indirect methods: Elimination of constraints, Transformation techniques, and Penalty function method.
Direct methods: Zoutendijk's method of feasible direction, Rosen's gradient Projection method.

Module 4 (10 hours)

Specialised Optimisation techniques: Dynamic programming, Geometric programming, Genetic Algorithms.

References

1. Rao S. S., Engineering Optimisation – Theory and Practice, New Age International, 1998.
2. Deb, K., Optimisation for Engineering Design – Algorithms and examples, Prentice Hall, 1995
3. Kirsch U., Optimum Structural Design, McGraw Hill, 1981.
4. Arora J S. Introduction to Optimum Design, McGraw Hill, 1989.
5. Rajeev S and Krishnamoorthy C. S., Discrete Optimisation of Structures using Genetic Algorithms, Journal of Structural Engineering, Vol. 118, No. 5, 1992, 1223-1250.

CEA622 MODELLING, SIMULATION AND COMPUTER APPLICATION

L	T	P	Cr
3	0	0	3

Prerequisite: -Nil.

Module 1 (11 hours)

Numerical Solution of Nonlinear Equations

Fixed point iteration – Newton-Raphson method – Broyden's method

Functional Approximations: - Choice of norm and model – linear least squares – nonlinear least squares – discrete Fourier transform – fast Fourier transform – FFT in two or more dimensions – inversion of Laplace transform – Chebyshev approximations.

Module 2 (12 hours)

Finite Difference Method: - Elliptic equations – Laplace equation – solution techniques – boundary conditions – the control volume approach.

Parabolic equations – the heat conduction equation – explicit method – simple implicit method – parabolic equation in two spatial dimensions.

Module 3 (10 hours)

Algebraic Eigenvalue Problem: - Eigenvalue problem for a real symmetric matrix – inverse iteration – QL algorithm for a symmetric tridiagonal matrix – reduction of a general matrix to Hessenberg form – Lanczos method – QR algorithm for a real Hessenberg matrix – errors.

Integral Equations: - Fredholm equations of the second kind – expansion methods – eigenvalue problem – Fredholm equations of the first kind – Volterra equations of the second kind – Volterra equations of the first kind.

Module 4 (12 hours)

Simulation and Monte Carlo Methods:

Random number generation – congruential generators – statistical tests of pseudorandom numbers.

Random variate generation – inverse transform method – composition method – acceptance-rejection method.

Simulation of random vectors - inverse transform method – multivariate transform method – multinormal distribution.

Simulation of stochastic fields – one-dimensional and multidimensional fields.

References

1. Antia, H.M., Numerical Methods for Scientists and Engineers, Tata McGraw Hill, 1991.
2. Chapra, S.C., and Canale, R.P., Numerical Methods for Engineers, Tata McGraw Hill, 2000.
3. Rubinstein, R.Y., Simulation and the Monte Carlo Method, John Wiley, 1982.
4. Press, W.H., et al., Numerical Recipes in C, Cambridge University Press, 1998.

CEA624 ANALYTICAL DYNAMICS

Pre- requisite: - Nil

L	T	P	Cr
3	0	0	3

Module 1 (12 hours)

Fundamentals of Newtonian Mechanics: Newton's laws, impulse and momentum, angular momentum, work and energy, systems of particles.
Fundamentals of Analytical Mechanics**:** Degrees of freedom, generalised coordinates, systems with constraints, stationary value of a definite integral, 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, Hamilton's equations.

Module 2 (9 hours)

Motion Relative to Rotating Reference Frames: Transformation of coordinates, rotating coordinate systems, moving references.

Module 3 (12 hours)

Rigid Body Dynamics: Kinematics of a rigid body, linear and angular momentum of a rigid body, translation theorem for angular momentum, kinetic energy of a rigid body, Euler's equations of motion, Euler's angles, moment-free inertially symmetric body, general case of moment-free body, symmetric top, equations of motion referred to arbitrary system of axes.

Module 4 (12 hours)

Behaviour of Dynamical Systems: Motion of single degree of freedom autonomous systems about equilibrium points, limit cycle, stability of linear multi-degree of freedom autonomous systems, Routh-Hurwitz criterion, Liapunov direct method, geometric interpretation, construction of Liapunov function.

Introduction to Advanced Topics: Introduction to the following topics: non-autonomous systems, perturbation techniques, transformation theory, Hamilton-Jacobi equation.

References

1. Meirovitch, L., Methods of Analytical Dynamics, McGraw-Hill, 1970.
2. Goldstein, H., Poole, C., and Safko, J., Classical Mechanics, Third edition, Pearson Education Inc., 2002.
3. Torok, J.S., Analytical Mechanics with an Introduction to Dynamical Systems, John Wiley, New York, 2000.
4. Baruh, H., Analytical Dynamics, McGraw-Hill, New York, 1999.
5. Greenwood, D.T., Classical Dynamics, Prentice-Hall, Englewood Cliffs, New Jersey, 1979.
6. Shames, I.H., Engineering Mechanics: Dynamics, Fourth Edition, Prentice-Hall of India, 1996.

CEA628 MULTIBODY DYNAMICS AND APPLICATIONS

L	T	P	Cr
3	0	0	3

Prerequisite: - Nil

Module 1 (9 hours)

Kinematics of Rigid Bodies: Angular velocity and acceleration, derivatives of a vector in multiple reference frames, addition rule for angular velocity, relative motion of two points fixed on a rigid body, motion of a point that is moving on a rigid body, Coriolis acceleration, orientation of a rigid body, Euler Angles.

Momentum and Kinetic Energy of Rigid Bodies: Angular momentum, kinetic energy.

Module 2 (12 hours)

Inertia Tensor and its Properties: Formal definition of inertia quantities, parallel axis theorem, rotation transformation, principal axes and principal moments of inertia.

Newtonian Dynamics: Moment-of-momentum equations for general motion of rigid bodies, Euler equations of motion, rotating mass imbalance, gyroscopic effects.

Lagrangian Dynamics and Virtual Work: Generalised forces and the principle of virtual work, Lagrange's equations of motion, linearisation of equations of motion about equilibrium points.

Module 3 (12 hours)

Introduction to Multibody System Dynamics: Systems of interconnected rigid bodies, equations of motion for systems of rigid bodies, kinematics for general multibody systems, modelling of forces in multibody systems, equations of motion, handling of constraints in multibody systems dynamics, linearisation and vibration analysis of multibody systems, dynamics of multibody systems with terminal flexible links, dynamic analysis of multiple flexible-body systems, Lagrange's equations of motion with constraints.

Module 4 (12 hours)

Computational Methods: Comparison of the different dynamic formulations for the determination of the equations of motion, investigation of their applicability to computer simulation of the dynamic behaviour of the mechanical systems, computer simulation using MATLAB, treatment of holonomic and nonholonomic constraints through various elimination and augmentation methods, extraction of data from equations of motion, computational issues.

References

7. T. R. Kane and D. A. Levinson, Dynamics: Theory and Application, 1996.
8. J.H. Ginsberg, Advanced Engineering Dynamics, Second edition, 1999.
9. A.A. Shabana, Dynamics of Multibody Systems, Cambridge Press, 2nd Ed., 1998.
10. R. Huston, Multibody Dynamics, Butterworth-Heinemann, 1990;
11. F.M.L. Amirouche, Computational Methods in Multibody Dynamics, Prentice Hall 1991.
12. Meirovitch, L., Methods of Analytical Dynamics, McGraw-Hill, 1970.

13. Torok, J.S., Analytical Mechanics with an Introduction to Dynamical Systems, John Wiley, New York, 2000.
14. Baruh, H., Analytical Dynamics, McGraw-Hill, New York, 1999.
15. Greenwood, D.T., Classical Dynamics, Prentice-Hall, Englewood Cliffs, New Jersey, 1979.

CEA630 STRUCTURAL HEALTH MONITORING

Prerequisite: - Nil

L	T	P	Cr
3	0	0	3

Module 1 (9 hours)

Review of Structural Modelling and Finite Element Models: Modelling for damage and collapse behaviour of structures, finite element modelling, theoretical prediction of structural failures.

Module 2 (12 hours)

Review of Signals, Systems and Data Acquisition Systems: Frequency and time domain representation of systems, Fourier/Laplace transforms, modelling from frequency response measurements, D/A and A/D converters, programming methods for data acquisition systems.

Sensors for Health Monitoring Systems: Acoustic emission sensors, ultrasonic sensors, piezoceramic sensors and actuators, fibre optic sensors and laser shearography techniques, imaging techniques.

Module 3 (12 hours)

Health Monitoring/Diagnostic Techniques: Vibration signature analysis, modal analysis, neural network-based classification techniques.

Integrated Health Monitoring Systems: Intelligent Health Monitoring Techniques, Neural network classification techniques, extraction of features from measurements, training and simulation techniques, connectionist algorithms for anomaly detection, multiple damage detection, and case studies.

Module 4 (12 hours)

Information Technology for Health Monitoring: Information gathering, signal analysis, information storage, archival, retrieval, security; wireless communication, telemetry, real time remote monitoring, network protocols, data analysis and interpretation.

Project Based Health Monitoring Techniques: Health monitoring techniques based on case studies, practical aspects of testing large bridges for structural assessment, optimal placement of sensors, structural integrity of aging multistorey buildings, condition monitoring of other types of structures.

References

1. Armer, G.S.T (Editor), Monitoring and assessment of structures, Spon, London, 2001.
2. Wu, Z.S. (Editor), Structured health monitoring and intelligent infrastructure, Volumes 1 and 2, Balkema, 2003.
3. Harris, C.M., Shock vibration handbook, McGraw-Hill, 2000.
4. Philip, W., Industrial sensors and applications for condition monitoring, MEP, 1994.
5. Rao, J.S., Vibratory condition monitoring of machines, Narosa Publishing House, India, 2000.

CEA631 STRUCTURAL RELIABILITY

Pre-requisite :- Nil

L	T	P	Cr
3	0	0	3

Module 1 (9 hours)

Concepts of structural safety

Basic Statistics: Introduction, data reduction.

Probability theory: Introduction, random events, random variables, functions of random variables, moments and expectation, common probability distributions.

Module 2 (10 hours)

Resistance distributions and parameters: Introduction, Statistics of properties of concrete, steel and other building materials, statistics of dimensional variations, characterization of variables, allowable stresses based on specified reliability.

Probabilistic analysis of loads: gravity loads, wind loads.

Module 3 (13 hours)

Basic structural reliability: Introduction, computation of structural reliability.

Level 2 Reliability methods: Introduction, basic variables and failure surface, first order second moment methods (FOSM).

Reliability based design: Introduction, determination of partial safety factors, development of reliability based design criteria, optimal safety factors.

Module 4 (13 hours)

Monte Carlo study of structural safety: General, Monte Carlo method, applications.

Reliability of Structural system: Introduction, system reliability, modelling of structural systems, bounds of system reliability, reliability analysis of frames.

References

1. R. Ranganathan., Reliability Analysis and Design of Structures, Tata McGraw Hill, 1990.
2. Ang, A. H. S & Tang, W. H., Probability Concepts in Engineering Planning and Design, Vol. I Basic Principles, John Wiley & Sons, 1975.
3. Ang, A. H. S & Tang, W. H., Probability Concepts in Engineering Planning and Design, Vol. II Decision, Risks and Reliability, John Wiley & Sons, 1984.
4. Benjamin, J.R & Cornell, C.A., Probability, Statistics and Decision for Engineers, McGraw-Hill, 1982.
5. H. O. Madsen, S. Krenk & N. C. Lind, Methods of Structural Safety, Prentice-Hall, 1986.
6. R. E. Melchers. Structural Reliability - Analysis and prediction, Ellis Horwood Ltd, 1987.

CEB625 GEOGRAPHIC INFORMATION SYSTEMS AND APPLICATIONS

L	T	P	Cr
3	0	0	3

Prerequisite:- Nil

Module 1 (11 hours)

Introduction:- Definitions of GIS – Components of GIS – Geographic data presentation: maps – mapping process – coordinate systems – transformations – map projection – geo referencing - data acquisition.

Module 2 (12 hours)

Geographic Data Representation, Storage, Quality and Standards:- Storage - Digital representation of data – Data structures and database management systems – Raster data representation – Vector data representation – Concepts and definitions of data quality – Components of data quality – Assessment of data quality – Managing data errors – Geographic data standards.

Module 3 (12 hours)

GIS Data Processing, Analysis and Modelling:- Raster based GIS data processing – Vector based GIS data processing – Queries – Spatial analysis – Descriptive statistics – Spatial autocorrelation – Quadrant counts and nearest neighbour analysis – Network analysis – Surface modelling – DTM.

Module 4 (10 hours)

GIS Applications:- (in one of the following areas)
Applications of GIS in Environment monitoring – Natural hazard management – Natural resources management urban planning – utility management – Land information – Business development

References

1. Lo, C.P. & Yeung A.K.W., Concepts and Techniques of Geographic Information Systems, Prentice Hall of India, New Delhi, 2002.
2. Reddy, A.M., Remote Sensing and Geographical Information Systems, B.S.Publications, Hyderabad, 2001.
3. Burrough, P.A., Principles of Geographical Information Systems, Oxford Publication, 1998.
4. Clarke, K., Getting Started with Geographic Information Systems, Prentice Hall, New Jersy, 2001.
5. DeMers, M.N., Fundamentals of Geographic Information Systems, John Wiley & Sons, New York, 2000.
6. Geo Information Systems – Applications of GIS and Related Spatial Information Technologies, ASTER Publication Co., Chestern (England), 1992

7. Jeffrey, S. & John E., Geographical Information System – An Introduction, Prentice-Hall, 1990
8. Marble, D.F., Galkhs HW & Pequest, Basic Readings in Geographic Information Systems, Sped System Ltd., New York, 1984.

CEA701 ADVANCED FINITE ELEMENT ANALYSIS

Prerequisite: A basic course on Finite Element Analysis

L	T	P	Cr
3	0	0	3

Module 1 (12 hours)

Plate Bending: Plate behaviour, Kirchhoff and Mindlin plate elements, boundary conditions.

Shells: Shells of revolution, general shells, three- and four-noded shell elements, curved isoparametric elements.

Module 2 (9 hours)

Error, Error Estimation and Convergence: Sources of error, ill-conditioning, condition number, diagonal decay test, discretisation error, multimesh extrapolation, mesh revision methods, gradient recovery and smoothing, a-posteriori error estimate, adaptive meshing.

Constraints**,** Penalty Forms, Locking and Constraint Counting: Explicit constraints, transformation equations, Lagrange multipliers, penalty functions, implicit penalty constraints and locking, constraint counting, modelling incompressible solids.

Module 3 (12 hours)

Finite Elements in Structural Dynamics and Vibrations: Dynamic equations, mass and damping matrices, consistent and lumped mass, natural frequencies and modes, reduction of the number of degrees of freedom, modal analysis, Ritz vectors, harmonic response, direct integration methods, explicit and implicit methods, stability and accuracy, analysis by response spectra.

Modelling Considerations and Software Use: Physical behaviour versus element behaviour, element shapes and interconnections, test cases and pilot studies, material properties, loads and reactions, connections, boundary conditions, substructures, common mistakes, checking the model, critique of computed results.

Module 4 (12 hours)

Introduction to Nonlinear Problems: Nonlinear problems and some solution methods, geometric and material nonlinearity, problems of gaps and contacts, geometric nonlinearity, modelling considerations.

Stress Stiffening and Buckling: Stress stiffness matrices for beam, bar and plate elements, a general formulation for $[k_\sigma]$, bifurcation buckling, remarks on $[k_\sigma]$, its use, and on buckling and buckling analysis.

Reference:

1. Cook, R.D., et al, Concepts and Applications of Finite Element Analysis, Fourth Edition, John Wiley & Sons Inc., Singapore, 2003.
2. Desai, C.S., and Kundu, T., Introductory Finite Element Method, CRC Press, London, 2001
3. Bathe, K.J., Finite Element Procedures, Prentice Hall of India, 1996.
4. Zienkiewicz, O.C., and Taylor, R.L., The Finite Element Method, Vols. I and II, Mc Graw Hill, 1991.

CEA702 ADVANCED THEORY OF SHELLS

Prerequisite**:** A course on Theory of Elasticity

L	T	P	Cr
3	0	0	3

Module 1 (9 hours)

General Properties of Stress Systems in Shells: Stress resultants, membrane forces, membrane forces in arbitrary directions, rectangular coordinates, oblique coordinates and skew forces, transformation of moments.

Module 2 (12 hours)

Direct Stresses in Shells of Revolution: General differential equations, equilibrium of shell element, axisymmetric loads, spherical dome, pressure vessel, pointed shells, toroidal shells, conical shells, shells of constant strength.

Loads without axial symmetry, spherical shell, distributed load, edge load, concentrated forces, couples.

Solution for shells of arbitrary shape, solution by an auxiliary variable, solution by numerical integration, shell formed as a one-sheet hyperboloid.

Deformation, strains and displacements, inextensional deformation, differential equation, finite solution for spherical shell, solution for arbitrary shape of meridian, toroidal shell, strain energy.

Module 3 (12 hours)

Direct Stresses in Cylindrical Shells: Statically determinate problems, general theory, tubes and pipes, barrel vault, deformation, differential equations, Fourier solution for circular cylinder, statically indeterminate structures.

Polygonal domes, folded plate structures.

Direct Stresses in Shells of Arbitrary Shape: Conditions of equilibrium, elliptic problems, paraboloid of revolution, triangular shell, elliptic paraboloid, solution by relaxation method, hyperbolic problems.

Membrane forces in affine shells, general theory, applications, deformation.

Module 4 (12 hours)

Bending of Circular Cylindrical Shells: Differential equations, equilibrium, deformation, differential equations for the displacements.

Solution of the inhomogeneous problem, loads applied to the edges x = constant, loads applied to the edges phi = constant, exact solution, barrel vaults, simplified theory, examples.

Cylindrical tanks and related problems, anisotropic shells, folded plate structures.

Bending stresses in shells of revolution.

References

1. Flügge, W., Stresses in Shells, Springer-Verlag, 1960.
2. Novozhilov, V.,V., Thin Shell Theory, Noordhoff, Groningen 1964.
3. Gould, P. L., Analysis of Shells and Plates, Springer-Verlag, New York 1988.
4. A.C. Ugural, *Stresses in Plates and Shells*, Second Edition, McGraw Hill, Singapore, 1999.

CEA703 THEORY OF PLASTICITY

L	T	P	Cr
3	0	0	3

Pre-requisite: A course on Theory of Elasticity

Module 1 (12 hours)

Preliminaries: Basic equations of theory of elasticity:- Index notation, equations of equilibrium, constitutive relations for isotropic bodies, strain-displacement relations, compatibility, displacement and traction boundary conditions, admissibility of displacement and stress fields, plane stress and plane strain problems.

Framework of Plastic Constitutive Relations:- Plastic behaviour in simple tension, generalisation of results in simple tension, yield surfaces, uniqueness and stability postulates, convexity of yield surface and normality rule, limit surfaces**.**

Module 2 (13 hours)

Initial Yield Surfaces for Polycrystalline Metals:- Summary of general form of plastic constitutive equations, hydrostatic stress states and plastic volume change in metals, shear stress on a plane, the von Mises initial yield condition, the Tresca initial yield condition, consequences of isotropy.

Plastic Behaviour under Plane Stress Conditions:- Initial and subsequent yield surfaces in tension-torsion, the isotropic hardening model, the kinematic hardening model, yield surfaces made of two or more yield functions, piecewise linear yield surfaces, elastic perfectly plastic materials.

Module 3 (11 hours)

Plastic Behaviour of Bar Structures:- Behaviour of a three bar truss, behaviour of a beam in pure bending, simply supported beam subjected to a central point load, fixed beams of an elastic perfectly plastic material, combined bending and axial force.

The Theorems of Limit Analysis: Introduction, theorems of limit analysis, alternative statement of the limit theorems, the specific dissipation function.

Module 4 (9 hours)

Limit Analysis in Plane Stress and Plane Strain:- Discontinuities in stress and velocity fields, the Tresca yield condition in plane stress and plane strain, symmetrical internal and external notches in a rectangular bar, the punch problem in plane strain, remarks on friction.

Limit Analysis as a Programming Problem:- Restatement of limit theorems, application to trusses and beams, use of finite elements in programming problem, incremental methods of determining limit load.

References

1 Martin, J.B., Plasticity: Fundamentals and General Results, MIT Press, London, 1988.

2 Kachanov, L.M., Fundamentals of the Theory of Plasticity, Mir Publishers, Moscow. 1981.

3 Chakrabarty, J, Theory of Plasticity, McGraw Hill, New York, 1998.
4 Hill, R., Mathematical Theory of Plasticity, Oxford University Press, 1981.
5 Chen, W.F., and Han, D.J., Plasticity for Structural Engineers, Springer Verlag, 1988.

CEC651 ADVANCED WAVE HYDRODYNAMICS

Prerequisite: Wave Hydrodynamics

L	T	P	Cr
3	0	0	3

Module 1 (9 hours)

Random waves: Review of basic statistical concepts, Random processes, Probability distributions such as Gaussian distribution and Rayleigh distribution; Auto correlation and Cross correlation; Applications.

Module 2 (12 hours)

Spectral properties of ocean waves: Alternate spectral representations - Transformations of wave spectra to proposed frequency spectra - Estimation of short term wave statistics based on wind data and wave data.

Module 3 (12 hours)

Estimation of extreme waves: Collection of data - Plotting formulae - Extreme value probability distributions - Methods of parameter estimation - Confidence intervals - Design wave selection.

Module 4 (12 hours)

Random wave forces: Morison equation with arbitrary wave spectrum and with narrow band wave spectrum - Estimation of force coefficients - Effects of wave non-linearity - Random forces on large bodies - Long term force distribution.

Introduction to analysis of multidirectional waves.

References

1. Sarpkaya, T. & Isaacson, M., Mechanics of Wave Forces on Offshore Structures, Van Nostrand.
2. Bendat, J. S. & Piersol, A. G., Random Data: Analysis and Measurement Procedures, John Wiley & Sons.
3. Kinsman, B., Wind Waves, Prentice Hall, Inc.
4. Goda, Y., Random Seas and Design of Maritime Structures, John Wiley and Sons.
5. Davenport., An Introduction to the Theory of Random Signals and Noise, McGrawHill, Inc.
6. Newland, D. E., Introduction to Random Vibrations and Spectral Analysis, Longman.
7. Chakrabarti, S.K., Hydrodynamics of Offshore Structures, Springer Verlag.
8. Chakrabarti, S. K., Nonlinear Methods in Offshore Engineering, Elsevier Science Pub.

CEC652 DYNAMICS OF FLOATING BODIES

Prerequisite: Structural Dynamics

L	T	P	Cr
3	0	0	3

Module 1 (13 hours)
Floating body dynamics – diffraction and radiation by large bodies – linearised equations of motion for a constrained floating body – simple harmonic motion – exciting and restoring forces – added mass and radiation damping – numerical solutions – drift forces – transient motion of floating bodies.

Module 2 (13 hours)
Behaviour of systems with time dependent characteristics- Undamped free motions of a system with time dependent spring characteristics – Damped free motions of a system with time dependent spring characteristics – Forced motions of a system with time dependent spring characteristics – Behaviour of systems with time dependent damping characteristics- Non linear dynamics and instability of floating structures.

Module 3 (10 hours)
Response analysis of floating structures – semi submersible, tension leg platforms – tower tanker systems – Floating production systems – multi body structures.

Module 4 (9 hours)
Station keeping– mooring systems – Thruster forces – Springing forces – Wave drift oscillation – Dynamic positioning.

References

1. Chiang C. M, Applied Dynamics of Ocean Surface Waves, John Wiley & Sons.
2. Chakraborti, S. K., Non Linear methods in Offshore Engineering, Elsevier Science.
3. Hooft, J. P., Advanced Dynamics of Marine Vehicles, John Wiley.
4. Chakraborti, S. K, Hydrodynamics of Offshore Structures, Springer-Verlag.
5. Bhattacharya. R., Dynamics of Marine Vehicles, John Wiley.
6. Faltinsen, Sea loads on ships and offshore structures- Cambridge University Press- Cambridge.
7. Minoo H Patel, Compliant Offshore Structures, Butterworth Heinemann Ltd., Oxford.
8. Thompson and Stewart, Non linear dynamics and chaos, John Wiley.

CEA611 FINITE ELEMENT METHOD

Prerequisite :- Nil

L	T	P	Cr
3	0	0	3

Module 1 (10 hours)

Introduction:- The Finite Element Method – The element characteristic matrix – Element assembly and solution for unknowns – Summary of finite element history.
Basic equations of elasticity – Strain-displacement relations – Theory of stress and deformation – Stress-strain-temperature relations.

The Direct Stiffness Method: - Structure stiffness equations – Properties of [K] – Solution of unknowns – Element stiffness equations – Assembly of elements – Node numbering to exploit matrix Sparsity – Displacement boundary conditions – Gauss elimination solution of equations – Conservation of computer storage – Computational efficiency – Stress computation – Support reactions – Summary of the finite element procedure.

Module 2 (12 hours)

Stationary Principles, Rayleigh-Ritz Method and Interpolation: - Principle of stationary potential energy – Problems having many d.o.f – Potential energy of an elastic body – The Rayleigh-Ritz method – Piecewise polynomial field – Finite element form of Rayleigh-Ritz method – Finite element formulations derived from a functional – Interpolation – Shape functions for C^0 and C^1 elements – Lagrangian and Hermitian interpolation functions for one dimensional elements – Lagrangian interpolation functions for two and three dimensional elements

Introduction to Weighted Residual Method: **-**Some weighted residual methods – Galerkin finite element method – Integration by parts – Axially loaded bar – Beam – Plane elasticity.

Module 3 (12 hours)

Displacement-based Elements for Structural Mechanics:- Formulas for element stiffness matrix and load vector – overview of element stiffness matrices – Consistent element nodal load vector – Equilibrium and compatibility in the solution – Convergence requirements – Patch test – Stress calculation – Other formulation methods.

Straight-sided Triangles and Tetrahedra:- Natural coordinates for lines, triangles and tetrahedra – Interpolation fields for plane triangles – linear and quadratic triangle – quadratic tetrahedron.

The Isoparametric Formulation:- Introduction – An isoparametric bar element – Plane bilinear element – Summary of Gauss quadrature – Quadratic plane elements – Direct construction of shape functions for transition elements – Hexahedral (solid) isoparametric elements – Triangular isoparametric elements – Consistent element nodal loads – Validity of isoparametric elements – Appropriate order of quadrature – element and mesh instabilities – Remarks on stress computation

Module 4 (11 hours)

Coordinate Transformation:- Transformation of vectors – transformation of stress, strain and material properties – Transformation of stiffness matrices – Transformation of Flexibility to Stiffness – Inclined support – Joining dissimilar elements to one another – Rigid links – Rigid elements.

Topics in Structural Mechanics: - D.o.f. within elements – Condensation – Condensation and recovery algorithm – Substructuring – Structural symmetry.

References

1. Cook, R.D., et al, Concepts and Applications of Finite Element Analysis, John Wiley, 2001.
2. Desai, C.S., Elementary Finite Element Method, Prentice Hall of India, 1998.
3. Chandrupatla, T.R., and Belegundu, A.D., Introduction to Finite Elements in Engineering, Prentice Hall of India, 1998.
4. Bathe, K.J., Finite Element Procedures, Prentice Hall of India, 1996.
5. Gallaghar, R.H., Finite Element Analysis: Fundamentals, Prentice Hall Inc, 1986.
6. Rajasekaran, S., Finite Element Analysis in Engineering Design, Wheeler Pub, 1998.
7. Krishnamoorthy, C.S., Finite Element Analysis – Theory and Programming, Tata Mc Graw Hill, 1996.
8. Zienkiewicz, O.C., and Taylor, R.L., The Finite Element Method, Vol. I and II, Mc Graw Hill, 1991.

CEA612 THEORY OF PLATES AND SHELLS

L	T	P	Cr
3	0	0	3

Prerequisite: - Theory of Elasticity

Module 1 (8 hours)

Introduction:- Assumptions in the theory of thin plates – Pure bending of Plates – Relations between bending moments and curvature - Particular cases of pure bending of rectangular plates, Cylindrical bending - immovable simply supported edges - Synclastic bending and Anticlastic bending – Strain energy in pure bending of plates in Cartesian and polar co-ordinates – Limitations.

Module 2 (8 hours)

Laterally Loaded Circular Plates:- Differential equation of equilibrium – Uniformly loaded circular plates with simply supported and fixed boundary conditions – Annular plate with uniform moment and shear force along the boundaries.

Module 3 (17 hours)

Laterally Loaded Rectangular Plates: - Differential equation of plates – Boundary conditions – Navier solution for simply supported plates subjected to uniformly distributed load and point load – Levy's method of solution for plates having two opposite edges simply supported with various symmetrical boundary conditions along the other two edges loaded with u. d. l. – Simply supported plates with moments distributed along the edges - Approximate Methods.

Effect of transverse shear deformation - plates of variable thickness – Anisotropic plates- thick plates- orthotropic plates and grids - Large Deflection theory .

Module 4 (12 hours)

Deformation of Shells without Bending:- Definitions and notation, shells in the form of a surface of revolution, displacements, unsymmetrical loading, spherical shell supported at isolated points, membrane theory of cylindrical shells, the use of stress function in calculating membrane forces of shells.

General Theory of Cylindrical Shells:- A circular cylindrical shell loaded symmetrically with respect to its axis, symmetrical deformation, pressure vessels, cylindrical tanks, thermal stresses, inextensional deformation, general case of deformation, cylindrical shells with supported edges, approximate investigation of the bending of cylindrical shells, the use of a strain and stress function, stress analysis of cylindrical roof shells.

References

1. S.P Timoshenko and S.W Krieger, Theory of Plates and Shells, McGraw Hill, 1989.
2. R. Szilard, Theory and Analysis of Plates – Classical Numerical Methods', Prentice Hall inc, 1974.
3. P.L Gould, Analysis of Shells and Plates, Springer-Verlag, New York, 1988.

4. H. Leipholz, *Theory of Elasticity*, Noordhoff International Publishers, Leyden, 1974.
5. A.C. Ugural, *Stresses in Plates and Shells*, Second Edition, McGraw Hill, Singapore, 1999.

CEA652 RANDOM VIBRATIONS

Pre-requisite**: Stochastic Processes in Structural Mechanics**

L	T	P	Cr
3	0	0	3

Module 1 (9 hours)

Basic Theory of Stochastic Processes (A review): Introduction, statistics of stochastic processes, ergodic processes, some properties of the correlation functions, spectral analysis, Wiener-Khintchine equation

Module 2 (13 hours)

Stochastic Response of Linear SDOF Systems: Deterministic dynamics, evaluation of impulse response function and frequency response function, impulse response function and frequency response function as Fourier Transform pairs, stochastic dynamics, response to stationary excitation, time domain analysis, frequency domain analysis, level crossing, peak, first passage time and other characteristics of the response of SDOF Systems

Module 3 (12 hours)

Linear systems with multiple inputs and outputs: Linear MDOF Systems, uncoupled modes of MDOF systems, stochastic response of linear MDOF Systems – time domain and frequency analysis.
Stochastic response of linear continuous system.

Module 4 (11 hours)

Response of non-linear systems to random excitation: Approach to problems, Fokker-Plank equation, statistical linearization, perturbation and Markov Vector Methods.
Fatigue damage of structure due to random loads.

References

1. Nigam N. C., Introduction to Random Vibrations, MIT Press, Cambridge, USA, 1983.
2. Loren D Lutes & Shahram Sarkani., Stochastic Analysis of Structural and Mechanical Vibrations, Prentice Hall, NJ, 1997.
3. J Solnes, Stochastic Processes & Random Vibration, Theory and Practice, John Wiley,1997
4. Lin, Y. K., Probabilistic Theory in Structural Dynamics, McGraw Hill, 1972.
5. Bendat & Piesol., Random Data Analysis and Measurement Procedure, John Wiley, 1991.
6. Meirovitch, L., Elements of Vibration Analysis, McGraw Hill, 1986.
7. Papoulis, A., Probability, Random Variables and Stochastic Processes, McGraw Hill, 1991.
8. Clough, R.W., and Penzien, J., Dynamics of Structures, McGraw Hill, 1993.

CEA653 ENGINEERING FRACTURE MECHANICS

Prerequisite: A course on **Theory of Elasticity**

L	T	P	Cr
3	0	0	3

Module (11 hours)

Introduction:- Significance of fracture mechanics, Griffith energy balance approach, Irwin's modification to the Griffith theory, Stress intensity approach, Crack tip plasticity, Fracture toughness, sub-critical crack growth, Influence of material behaviour, I, II & III modes, Mixed mode problems.

Linear Elastic Fracture Mechanics (LEFM):- Elastic stress field approach, Mode I elastic stress field equations, Expressions for stresses and strains in the crack tip region, Finite specimen width, Superposition of stress intensity factors (SIF), SIF solutions for well known problems such as centre cracked plate, single edge notched plate and embedded elliptical cracks.

Module 2 (12 hours)

Crack Tip Plasticity:- Irwin plastic zone size, Dugdale approach, Shape of plastic zone, State of stress in the crack tip region, Influence of stress state on fracture behaviour.

Energy Balance approach:- Griffith energy balance approach, Relations for practical use, Determination of SIF from compliance, Slow stable crack growth and R-curve concept, Description of crack resistance.

LEFM Testing:- Plane strain and plane stress fracture toughness testing, Determination of R-curves, Effects of yield strength and specimen thickness on fracture toughness, Practical use of fracture toughness and R-curve data.

Module 3 (10 hours)

Elastic Plastic Fracture Mechanics (EPFM):- Development of EPFM, J-integral, Crack opening displacement (COD) approach, COD design curve, Relation between J and COD, Tearing modulus concept, Standard J_{Ic} test and COD test.

Fatigue Crack Growth:- Description of fatigue crack growth using stress intensity factor, Effects of stress ratio and crack tip plasticity – crack closure, Prediction of fatigue crack growth under constant amplitude and variable amplitude loading, Fatigue crack growth from notches – the short crack problem.

Module 4 (10 hours)

Sustained Load Fracture:- Time-to-failure (TTF) tests, Crack growth rate testing, Experimental problems, Method of predicting failure of a structural component, Practical significance of sustained load fracture testing.

Practical Problems:- Through cracks emanating from holes, Corner cracks at holes, Cracks approaching holes, fracture toughness of weldments, Service failure analysis, applications in pressure vessels, pipelines and stiffened sheet structures.

Text Book: Ewalds, H.L. & Wanhill, R.J.H., Fracture Mechanics – Edward Arnold Edition

References

1. Broek, D. Elementary Engineering Fracture Mechanics, Sijthoff & Noordhoff Int. Pub., 1988.
2. Broek, D. The Practical Use of Fracture Mechanics, Kluwer Academic Pub., 1990.
3. Hellan, D. Introduction to Fracture Mechanics, McGraw Hill Book Company, 1985.
4. Kumar, P. Elements of Fracture Mechanics, Wheeler Publishing, 1998.
5. Simha, K.R.Y. Fracture Mechanics for Modern Engineering Design, University Press, 1996.

CEA655 DESIGN OF PLATED STRUCTURES AND SHELLS

L	T	P	Cr
3	0	0	3

Prerequisite: -Nil

Module 1 (12 hours)

Cylindrical bending of plates – laterally loaded circular plates – artificial systems of equilibrium – uniformly loaded core with simple and fixed boundary conditions.

Laterally loaded rectangular plate – differential equations – boundary conditions – Navier solution for simply supported plates subjected to uniform and point loads – Levy's method

Module 2 (12 hours)

Approximate methods of solution of plates – Rayleigh-Ritz method – Galerkin's method – finite difference method
Orthotropic plates – stiffened plates – stability of plates – design of plated structures.

Module 3 (12 hours)

Stressed skin surfaces – types – cylindrical shells thin shells – membrane theory – bending theory – theories due to Finster-Welder and Schorer – shells of revolution – membrane theory – paraboloid of revolution – analysis using polynomial stress function – hyperbolic paraboloids – rectangular hyperbolic paraboloid.

Module 4 (9 hours)

Stiffened cylindrical shells – design curves for pressure hull buckling of cylindrical shells

References

1. S.P Timoshenko and S.W Krieger, Theory of Plates and Shells, McGraw Hill, 1989.
2. R. Szilard, Theory and Analysis of Plates – Classical Numerical Methods', Prentice Hall inc, 1974.
3. P.L Gould, Analysis of Shells and Plates, Springer-Verlag, New York, 1988.
4. H. Leipholz, *Theory of Elasticity*, Noordhoff International Publishers, Leyden, 1974.
5. A.C. Ugural, *Stresses in Plates and Shells*, Second Edition, McGraw Hill, Singapore, 1999.
6. W. Flugge, Stresses in Shells, Stringer- Verlag
7. Ramaswamy, G.S, Design and Construction of Concrete Shell Roofs, Tata McGraw Hill.