M.Tech. Programme
(Geotechnical Engineering)

School of Infrastructure
IIT Bhubaneswar

Geotechnical Engineering

School of Infrastructure

Curriculum for M. Tech. in Geotechnical Engineering

SEMESTER 1

Subject Code	Subject Name	L-T-P	Credit	Contact Hour
CE6L201	Applied Soil Mechanics	3-1-0	4	4
CE6L202	Computational Geomechanics	3-1-0	4	4
	Elective-I	3-0-0	3	3
	Elective-II	3-0-0/3-1-0	3/4	3/4
	Elective-III	3-1-0	4	4
CE6P201	Geotechnical Engineering Laboratory	0-0-3	2	3
CE6S001	Seminar I	0-0-3	2	3
Total		**15-3/4-3**	**22/23**	**24/25**

SEMESTER 2

Subject Code	Subject Name	L-T-P	Credit	Contact Hour
CE6L203	Foundation Analysis and Design	3-1-0	4	4
CE6L204	Soil Dynamics	3-1-0	4	4
	Elective-IV	3-0-0/3-1-0	3/4	3/4
	Elective-V	3-0-0	3	3
CE6P202	In-situ Testing of Soils Laboratory	0-0-3	2	3
CE6P203	Computational Geomechanics Laboratory	0-0-3	2	3
CE6S002	Seminar II	0-0-3	2	3
Total		**12-2-6**	**20/21**	**23/24**

SEMESTER 3

Subject Code	Subject Name	L-T-P	Credit	Contact Hour
CE6D001	Thesis : Part-I (CE)	0-0-0	16	0
CE6D002	Research Review Paper (CE)	0-0-3	04	3
Total		0-0-0	**20**	**3**

SEMESTER 4

Subject Code	Subject Name	L-T-P	Credit	Contact Hour
CE6D003	Thesis : Part-II (CE)	0-0-0	16	0
CE6D004	Research Review Paper (CE)	0-0-3	04	3
Total		0-0-0	**20**	**3**

Total Credit (Semester 1+Semester 2+Semester 3+Semester 4)	**82/84**

List of Core Subjects

Subject Code	Name	L-T-P	Credit
CE6L201	Applied Soil Mechanics	3-1-0	4
CE6L202	Computational Geomechanics	3-1-0	4
CE6L203	Foundation Analysis and Design	3-1-0	4
CE6L204	Soil Dynamics	3-1-0	4

List of Laboratory Courses

Subject Code	Name	L-T-P	Credit
CE6P201	Geotechnical Engineering Laboratory	0-0-3	2
CE6P202	In-situ Testing of Soils Laboratory	0-0-3	2
CE6P203	Computational Geomechanics Laboratory	0-0-3	2

List of Subjects as Electives (I to V)

Sl. No.	Subject Code	Name	L-T-P	Credit
1.	CE6L205	Theoretical Soil Mechanics	3-0-0	3
2.	CE6L206	Rock Mechanics	3-1-0	4
3.	CE6L207	Transportation Geotechnics	3-0-0	3
4.	CE6L208	Soil Structure Interaction	3-0-0	3
5.	CE6L209	Geotechnical Earthquake Engineering	3-1-0	4
6.	CE6L210	Geotechnical Risk and Reliability	3-0-0	3
7.	CE6L211	Ground Water Seepage and Earth Dams	3-1-0	4
8.	CE6L212	Ground Improvement	3-0-0	3
9.	CE6L213	Geosynthetic Engineering	3-0-0	3
10.	CE6L214	Dynamics of Soil and Foundations	3-0-0	3
11.	CE6L215	Foundations of Offshore Structures	3-1-0	4
12.	CE6L216	Geotechnics of Polluted Sites	3-0-0	3
13.	CE6L217	Geotechnics of Waste and Waste Containment	3-0-0	3
14.	CE6L218	Soil Exploration and In-situ Testing	3-1-0	4
15.	CE6L219	Unsaturated Soil Mechanics	3-0-0	3
16.	CE6L220	Optimization Methods	3-1-0	4
17.	MA6L001	Mathematical Methods	3-1-0	4
18.	MA6L002	Advanced Techniques in Operation Research	3-1-0	4
19.	ID6L001	Data Analytics	3-0-0	3

Sl. No.	Subject Code	Name	L-T-P	Credit
20.	CL6L224	Neural Networks and Applications	3-0-0	3
21.	CE6L454	Pavement Evaluation and Management	3-1-0	4
22.	CE6L110	Environmental Chemistry and Microbiology	3-1-0	4
23.	ML6L008	Materials Recycling and Waste Management	3-0-0	3
24.	CE6L306	Seismic Design of Structures	3-1-0	4
25.	CE6L309	Modern Construction Materials	3-0-0	3
26.	MA7L007	Soft Computing	3-1-0	4
27.	ID6L002	Design and Analysis of Experiments	3-0-0	3
28.	ME6L011	Finite Element Methods in Engineering	3-1-0	4
29.	ME6L006	Continuum Mechanics	3-1-0	4
30.	CE6L404	Analysis and Design of Pavements	3-1-0	4
31.	CL6L222	Modeling of Extreme Events	3-0-0	3
32.	CE6L515	GIS & Remote Sensing Applications in Civil Engineering	3-0-0	3
33.	CY7L025	Design and Application of Nanomaterials	3-0-0	3
34.	MA7L001	Numerical Solution of Ordinary and Partial Differential Equations	3-1-0	4

NB: Any other subjects of the same level floated by any other specialization of SIF or any other Schools can also be taken as an elective, as suggested by faculty advisor/PG Coordinators

Syllabi of Core, Elective and Laboratory Courses

Subject Code: CE6L201	Name: Applied Soil Mechanics Pre-requisites: nil	L-T-P: 3-1-0	Credits: 4

Soil formation; Soil structure; Clay mineralogy; Effective stress.
Shear Strength: Shear strength of cohesive and cohesionless soils; Stress paths in p-q space; Triaxial behavior, stress state and analysis of UCS, UU, CU, CD, and other special tests, stress paths in triaxial testing, porewater pressure parameters.
Slope Stability: Different methods of analysis, slope protection and stabilization.
Stresses in soil from surface loads: Boussinessqu, Westergard, Mindlin and Kelvin problems; Theory of arching in soils and its applications; Earth pressure theories; Anchored bulkheads; Braced excavations and open cuts; Sheet pile walls; Cofferdams; Diaphragm walls, Prestressed ground anchors.

Text/Reference Book:

- Bowles, J. E. (1996). Foundation Analysis and Design, McGraw-Hill, Singapore.
- Budhu, M. (2000) Soil Mechanics and Foundations, John Wiley & Sons Inc., New York, N.Y.
- Cernica, John N (1995) Geotechnical Engineering: Foundation Design, John Wiley & Sons, New York, N.Y.
- Clayton, C. R. I., Woods, R. I., Bond, A. J. and Milititsky, J. (2013). Earth Pressure and Earth-Retaining Structures, CRC Press, Boca Raton, Florida.
- Coduto, D. P. (2001). Foundation Design Principles and Practices, Prentice Hall, Upper Saddle River, New Jersey.
- Das, B. M. (2011). Principles of Foundation Engineering, PWS Publishing, Pacific Grove, California.
- Day, Robert W. (2005) Foundation Engineering Handbook, McGraw Hill, New York, N.Y.
- Fang, H. Y. (2004). Foundation Engineering Handbook, CBS Publishers and Distributors, New Delhi.
- FHWA (2009) Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes, Volumes I&II, US Department of Transport, Federal Highway Administration, Washington, DC, USA Publication No. FHWA-NHI-10-025
- Peck, R. B., Hanson, W. E. and Thornburn, T. H. (1974). Foundation Engineering, John Wiley and Sons, New York.
- Ranjan, G. and Rao, A. S. R. (2000). Basic and Applied Soil Mechanics, New Age International (P) Ltd., New Delhi.
- Shukla, S.K. (2012) Handbook of Geosynthetic Engineering, ICE Publishing, London, UK.
- Terzaghi, K., Peck, R. B. and Mesri, G. (1996). Soil Mechanics in Engineering Practice, John Wiley and Sons, New York.

Subject Code: CE6L202	Name: Computational Geomechanics Pre-requisites: nil	L-T-P: 3-1-0	Credit: 4

Numerical modelling, constitutive modelling of soils and rock, continuum and discrete element modelling; Concept of stress and strain, principal stresses and strains; Octahedral stresses and strains, finite element discretization of a continuum, geomechanics problems of plane strain and axisymmetric problem; Failure criteria for soils, associated and non-associated flow rule; Finite elements for non-linear material problems in soil mechanics computational procedures; Finite difference approach; Simulation of soil-structure interaction problems; application in consolidation, bearing capacity and slope stability problems using numerical approaches.

Text/Reference books

- Chandrakant S. Desai and J.T. Christian Numerical Methods in Geotechnical Engineering, McGraw-Hill Publishers.
- Plasticity and Geomechanics by R. O. Davis, A. P. S. Selvadurai, Cambridge University Press
- Finite Element Analysis in Geotechnical Engineering: Theory and Application Author: David M. Potts and Lidija Zdravkovic (January 1, 2001)
- John T. Christian, Numerical Methods in Geotechnical Engineering, McGraw-Hill Publishers.
- Computational Geomechanics with Special Reference to Earthquake Engineering by O. C. Zienkiewicz, A. H. C. Chan, M. Pastor, and B. A. Schrefler (Hardcover - May 11, 1999), Publisher: Wiley.
- Potts and Zdravkonics (1999) Finite element analysis in geotechnical engineering: Part-I Theory & part-II Applications, Thomas Telford Publishers.

Subject Code: CE6L203	Name: Foundation Analysis and Design Pre-requisites: nil	L-T-P: 3-1-0	Credit: 4

Settlement and bearing capacity: shallow spread footings, mat or raft foundations, deep foundations; Analysis of Elastic settlement; Soil Plasticity; Special cases of shallow foundation; Contact pressure distribution for footings, rafts, piles; Retaining Structures: special cases; Drilled shafts; Pile Foundations; Laterally loaded piles; Well foundation; Introduction to Foundations of offshore structures.

Text/Reference Books

- Das, B. M. Principles of Foundation Engineering, Cengage Learning.
- Budhu, M., Soil mechanics and foundations, Wiley Publishers, New Delhi.
- Coduto, D.P., Foundation design: Principles and Practices, Prentice Hill Publishers.
- Holts R.D. and Kovacs, W.D. An introduction Geotechnical Engineering, Prentice Hall.

- Das, B.M. Shallow Foundations: Bearing Capacity and Settlement, CRC Press.
- Tomilson, M.J. Foundation Design and Construction, Pearson Publishers.
- Poulos, H.G. and Davis E.H. Pile Foundation Analysis and Design.
- Salgado, R. The engineering of foundations. Tata Mc.Graw Hill Edu. Pvt. Ltd. New Delhi. 2011.

Subject Code: CE6L204	**Name: Soil Dynamics** Pre-requisites: nil	**L-T-P: 3-1-0**	**Credits: 4**

Introduction (Dynamic properties of geomaterials, design criteria related to applied loads and material properties, vibration tolerances); Vibration of elementary systems; Transient vibrations; Analysis of earthquake and blast loadings; Liquefaction of soils; Laboratory and field evaluation of soil properties as per IS Codes; Analysis and design of foundations for hammers, reciprocating engines and turbogenerators; Vibration isolation and damping; Propagation of elastic waves in soils; Waves in layered and saturated soils; Theories for vibration of foundations on elastic media; Design procedures for dynamically loaded foundations and constructional features; Interaction of soils and foundations under dynamic loadings.

Text/Reference books:

- Braja Das, G.V. Ramana, Principles of Soil Dynamics, Cengage Learning, USA.
- Prasad Bharat Bhushan, Fundamentals of Soil Dynamics and Earthquake Engineering, PHI Publisher, New Delhi.
- Milutin Srbulov, Practical Soil Dynamics: Case Studies in Earthquake and Geotechnical Engineering, Springer link Publishers.

Subject Code: CE6L205	**Name: Theoretical Soil Mechanics** Pre-requisites: nil	**L-T-P: 3-0-0**	**Credit: 3**

Introduction: Origin of soil and its types, mineralogy and structure of clay minerals; dilatancy angle; Compressibility and rate of consolidation, one, two, and three dimensional consolidation theories; Mohr's circles; Critical state soil mechanics: Critical State Line, Hvorslev Surface, Yield Surfaces: Modified Cam-clay and Original Cam-clay; Elastic and plastic analysis of soil; Constitutive relationships of soil; failure theories; Limit analysis-Upper bound theorems, lower bound theorems, limit equilibrium methods.

Text/Reference books

- Das, B M Advanced Soil Mechanics, Taylor and Francis
- Scott, R F Principles of Soil Mechanics, Addison & Wesley.
- Davis R.O. and Selvadurai, A.P.S., Elasticity and Geomechanics, Cambridge University Press, New York.
- Mitchell, James K, Fundamentals of Soil Behaviour, John Wiley and Sons.
- Wood, D.M. Soil Behaviour and Critical State Soil Mechanics, University of Glasgow.
- Schofield, A. N.; Wroth, C. P., Critical State Soil Mechanics, McGraw-Hill.

Subject Code: CE6L206	Name: Rock Mechanics Pre-requisites: nil	L-T-P: 3-1-0	Credit: 4

Geological survey and exploration; Physical properties and classification of intact rock and rock masses, rock exploration, engineering properties of rock, stresses in rock near underground openings; Static Elastic constants of rock ; Rock Testing: Laboratory and Field tests; Discontinuities in Rock Masses: Discontinuity orientation, Effect of discontinuities on strength of rock; Strength Behaviour: Compression, Tension and Shear, Stress-Strain relationships, Rheological behavior; Strength/Failure Criterion: Coulomb, Mohr, Griffith theory of brittle strength and other strength criteria; In-situ determination of engineering properties of rock mass, in-situ stresses; Rock slope stability, bolting, blasting, grouting and rock foundation design; Rock slopes, Rock foundations; Bearing Capacity of Rocks; Drilling and blasting of rocks; Grouting; Underground openings, Tutorials on rock slope stability using ROCSCIENCE.

Text/Reference books:

- Verma, B. P., "Rock Mechanics for Engineers" Khanna Publishers.
- Singh, B. and Goel, R. K. "Rock Mass Classification Systems – A Practical Approach in Civil Engineering "Elsevier Publisher.
- Hoek, E. and Brown, E. T. "Underground Excavations ", Span Press.
- Hoek, E. and Bray, J D., "Rock Slope Engineering ", Span Press.
- Brown, E.T., "Rock Characterisation, Testing and Monitoring", Pergamon Press, London, U.K.
- Farmer, W. Engineering Behavior of Rocks, Chapman and Hall Ltd.
- Goodman, R. E. Introduction to Rock Mechanics.
- Sheorey, P.R. Empirical Rock Failure Criteria, Balkema, Rotterdam, 1997.

Subject Code: CE6L207	Name: Transportation Geotechnics Pre-requisites: nil	L-T-P: 3-1-0	Credit: 4

Subgrade Soil: Classification, desirable properties, determination of soil strength characteristics; Road aggregates: classification, properties of aggregates, design of aggregate gradation; Cyclic response of soils, resilient and plastic behaviour of soils and aggregates, Effects of traffic loads, natural forces, and material quality.
Current design practices; Principles and theoretical concepts of rigid and flexible pavements for highways and airfields; Pavement evaluation and performance; Utilization of recycled materials for sustainable pavements; Life cycle cost analysis.
Highway embankments; Design and construction of embankments; Stage construction; Introduction to reinforced earth design and construction.

Text/Reference books

- Papagiannakis A. T. and Masad, E. A. Pavement Design and Materials
- Shell Bitumen, The Shell Bitumen Handbook
- Asphalt Institute, MS-26 Asphalt Binder Handbook
- Rajib B. Mallick, Tahar El-Korchi, Pavement Engineering: Principles and

Practice.

- Chakraborty P. and Das, A. Principles of Transportation Engg., PHI Publication, 1st Edition 2005.
- Rao, G.V. Principles of Transportation and Highway Engineering, Tata Mc. Graw Hill, 1st Ed. 1995.

Subject Code: CE6L208	**Name: Soil Structure Interaction** Pre-requisites: nil	**L-T-P: 3-0-0**	**Credit: 3**

Introduction to soil foundation interaction problems, soil behaviour, foundation behaviour, interface behaviour, concept of subgrade modulus, effects/parameters influencing subgrade modulus soil foundation interaction analysis, Winkler, elastic continuum, two parameter elastic model, Elastic Plastic behaviour, time dependent behaviour, elastic analysis of single pile, theoretical solutions for settlement and load distributions, analysis of pile group, interaction analysis, Load deflection prediction for laterally loaded piles, other applications.

Text/Reference books

- Selvadurai, A.P.S.," Elastic analysis of soil foundation interaction. Elsevier Science Ltd.
- Plasticity and Geomechanics by R. O. Davis, A. P. S. Selvadurai, Cambridge University Press
- Davis R.O. and Selvadurai, A.P.S. Elasticity and Geomechanics, Cambridge University Press, New York.
- Poulos, H.G. and Davis E.H. Pile Foundation Analysis and Design.
- Soil structure interaction: numerical analysis and modelling / edited by John W. Bull. London; New York: E & FN Spon, 1994.

Subject Code: CE6L209	**Name: Geotechnical Earthquake Engineering** Pre-requisites: nil	**L-T-P: 3-1-0**	**Credit: 4**

Introduction, engineering seismology, plate tectonics, earthquake sources, ground motions and magnitude, ground motion characteristics, effect of local soil conditions on ground motion, dynamic behaviour of soils, analysis of seismic site response. Liquefaction analysis of soil, laboratory and in-situ testing for seismic loading, analysis and design of slopes, embankments, foundations and earth retaining structures for seismic loading, computer-aided analysis.

Text/Reference books

- Kramer, S.L., Geotechnical Earthquake Engineering, Pearson Education.
- Day, R.W., Geotechnical Earthquake Engineering Handbook, McGraw Hill.

Subject Code: CE6L210	**Name: Geotechnical Risk and Reliability** Pre-requisites: nil	**L-T-P: 3-0-0**	**Credit: 3**

Introduction to probabilistic geotechnical engineering, variability measures, random variables, probability mass and density functions, moments of distribution, modelling of uncertainty, engineering judgment, spatial variability of soil, autocovariance functions, functions of random fields, levels of reliability, loads and resistances (LRFD methods), reliability methods, first order second moment (FOSM) method, Hasofer-Lind approach, Response Surface Method, Monte Carlo simulations.

Text/Reference Books:

- Haldar A. and Mahadevan, S. Probability, Reliability, and Statistical Methods in Engineering Design, John Wiley and Sons.
- Baecher G. and Christian, J. Reliability and Statistics in Geotechnical Engineering, John Wiely and Sons, Inc.
- Hua-Sing Ang A. and Tang, W.H. Probability Concepts in Engineering Planning and Design: Basic Principles (Vol. I), John Wiely and Sons, Inc.
- Melchers, R. E. Structural Reliability Analysis and Prediction, John Wiley and Sons.
- Nowak A.S and Collins, K.R. Reliability of Structures
- Erik V., Random Fields: Analysis and Synthesis, The MIT Press, Cambridge, Massachusetts.

Subject Code: CE6L211	**Name: Ground Water Seepage and Earth Dams** Pre-requisites: nil	**L-T-P: 3-1-0**	**Credit: 4**

Water and soil properties; Darcy's Law, coefficient of permeability and intrinsic permeability, transmissibility; Flow of water through soils; Seepage and drainage: hydraulic conductivity and flow nets, advanced flow nets, use of flow nets for design, filters; Seepage Analysis: phreatic line in earth dams and its location by various methods, problem of seepage control in earth dams-control of seepage through embankment, adverse effects of seepage, methods of seepage control, impervious core and its design, design of transition filters, rock toe, horizontal drainage, chimney drains, control of seepage through foundations-various options, upstream impervious blanket, analysis for blanket length, relief wells, related problems; Applications of Dupiut theory of unconfined flow; confined flow; Unconfined flow through earth structures on homogeneous foundations of great depth; Unconfined flow through homogeneous earth structures of finite depth; Seepage from canals and ditches; Seepage toward wells

Text/Reference Books:

- Cedergren, H.R., Seepage, Drainage, and Flow Nets, 3rd Edition, John Wiley & Sons, Inc., New York 1989
- Michael Duncan J. and Stephen G. Wright, Soil Strength and Slope Stability, John Wiley & Sons, Inc., New Jersey 2005
- Rushton K. R. and S. C. Redshaw, Seepage and groundwater flow, numerical analysis by analog and digital methods, Wiley, New York, 1979.
- Harr, M.E. Ground Water and Seepage, McGraw-Hill, 1962.

Subject Code: CE6L212	Name: Ground Improvement Pre-requisites: nil	L-T-P: 3-0-0	Credit: 3

Introduction; necessity of ground improvement; methods of ground improvement for cohesive soils and cohesionless soils; Selection of suitable ground improvement technique.
Preloading, accelerated consolidation using sand drains and prefabricated vertical drains, stone columns, vibro-flotation, dynamic compaction, blast densification, grouting, Heating and Freezing, soil stabilization: lime, fly ash, cement, asphalt; electro-osmosis, Dewatering and electrokinetic stabilization, micropiles, deep soil mixing, soil nailing, ground anchors, Microbial ground improvement, nanotechnology in ground improvement, monitoring and quality control issues in ground improvement projects.

Text/Reference books

- Puroshothama Raju, P. Ground Improvement Techniques, Laxmi Publications, New Delhi.
- Moseley M.P. and Kirsch, K.Ground Improvement, Spon Press, Taylor and Francis Group.
- Das, B. M. Principles of Foundation Engineering, Cengage Learning.
- Buddhima Indraratna and Jian J Chu, Ground Improvement: Case Histories, Elsevier.
- Chris A. Raison, Ground and Soil Improvement, Thomas telford, UK.

Subject Code: CE6L213	Name: Geosynthetic Engineering Pre-requisites: nil	L-T-P: 3-0-0	Credit: 3

Introduction to Geosynthetics; Basic description of geosynthetics; Types and functions of geosynthetics; Engineering properties of geosynthetics and their evaluation; Testing of geosynthetic materials; Design methodologies with geosynthetics; Geotechnical applications: bearing capacity, settlement, stability analysis, retaining walls, embankments; Geoenvironmental applications: covers and liners of landfills; Hydraulic applications: liners for ponds, canals, reservoirs; Transportation applications: separator, drainage and filtering in road pavement, strength improvement in base, sub-base and subgrade layers; Mining, agriculture and aquaculture applications: containment, filtration; Case studies.

Text/Reference books

- Sanjay Kumar Shukla and Jian-Hua Yin, Fundamentals of Geosynthetic Engineering, CRC Press.
- Moseley M.P. and Kirsch, K. Ground Improvement, Spon Press, Taylor and Francis Group.
- Robert M. Koerner., Designing with Geosynthetics, Pearson Prentice Hall.
- Rao G. V. and Rao, G. V. S. Text Book on Engineering with Geotextiles, Tata McGraw Hill.
- Jewell, R.A. (1996) Soil reinforcement with geotextiles, CIRIA & Thomas Telford,

London, U.K.
- John, N.W.M. (1987) Geotextiles, Blackie & Son Ltd., London, UK.
- Jones, C.J.F.P. (2010) Earth Reinforcement and Soil Structures, Thomas Telford, London, U.K.
- Mandal, J.N and Divshikar, D.G. (2000) A guide to geotextile testing, New Age International Ltd., New Delhi.
- Saran, Swami (2006) Reinforced Soil and its Engineering Applications, I.K. International, New Delhi.
- Shukla, S.K. (2012) Handbook of Geosynthetic Engineering, 2nd Edition, ICE Publishing, London, U.K.
- Federal Highway Administration Guidelines for Mechanically Stabilised Earth Walls and Reinforced Soil Slopes, Design and Construction Guidelines, Report No. FHWA-NHI-00-0043, Washington, D.C. 2001

Subject Code: CE6L214	**Name: Dynamics of Soil and Foundations** Pre-requisites: nil	**L-T-P: 3-0-0**	**Credit: 3**

Introduction, vibration theories, analysis of free and forced vibrations using spring dashpot model, single degree of freedom system, multi-degrees of freedom system, application of single and multi-degree of freedom systems, wave propagation in elastic media, laboratory and field evaluation of dynamic soil properties, seismic bearing capacity of shallow foundations, pile foundation under dynamic load, seismic earth pressures, seismic slope stability.

Text/Reference books:
- Swami Saran, Soil Dynamics and Machine Foundations, Galgotia Publications.
- Braja M. Das and G. V. Ramana, Principles of Soil Dynamics, Publisher: CL-Engineering.
- Richart, F.E., Woods, R.D., and Hall, J.R., Vibrations of soils and foundations, Prentice Hall, 1970.
- Steven L. Kramer, Geotechnical Earthquake Engineering, 1996, Prentice Hall.

Subject Code: CE6L215	**Name: Foundations of Offshore Structures** Pre-requisites: nil	**L-T-P: 3-1-0**	**Credit: 4**

Basic Soil Mechanics: Basic soil properties, correlation between engineering parameters, geotechnical investigation, bore log.
Offshore site investigations, properties of marine soils; Soil behaviour under cyclic loading, design storm loading; Gravity structures; Dynamic response and cyclic displacements; Pile foundations for offshore structures, axial lateral and cyclic loads, types of foundation anchorage; Jack-up platforms; Rig foundations.
Pile foundation: Jacket main piles, skirt piles, driven piles, drilled and grouted piles, steel and concrete piles, axial capacity, point bearing and skin friction, factor of safety, lateral load on piles, p-y, t-z and q-z curves, pile group effect, scour around piles,

seabed subsidence and design of piles against seabed movement, negative skin friction, cyclic degradation, main pile to jacket connections, skirt pile to jacket connections, API RP 2A provisions.
Pile Installation: Minimum pile wall thickness, pile handling stresses, static and dynamic stresses, pile stickup, stresses during stickup, wave and current loads, hammer selection, pile driving stresses, wave equation analysis, pile driving fatigue, API RP 2A guidelines.
Pile Testing: Working load test, ultimate load test, pile monitoring during driving, pile integrity testing, high strain dynamic testing, rebound method.

Text/Reference books:

- S.K. Chakrabarti, Handbook of Offshore Engineering, Elsevier, 2005.
- Tomlinson, M. J. and Spon F.N. Pile Design and Construction, 1994.
- Bowles, J. E., Foundation analysis and design, McGraw-Hill, 1988
- Gerwick, B.C., Construction of Marine and Offshore Structures, CRC press

Subject Code: CE6L216	**Name: Geotechnics of Polluted Sites** Pre-requisites: nil	**L-T-P: 3-0-0**	**Credit: 3**

Basic concepts related to soil pollution; Sources of pollution: industrial areas, agricultural, municipal, nuclear; types of contaminants; Role of physical and chemical properties of soil in contamination; Factors effecting retention and transport of contaminants; Soil sampling collection and characterization: sampling of contaminated soil, site investigation and monitoring parameters, exploratory site investigation, methods of analysis/identification, sample handling, preservation, transportation and storage; Non-destructive techniques of site characterization: electrical and thermal properties, GPR; Soil and ground water remediation: conceptual approach to soil and ground water remediation, risk assessment, methodologies and selection of treatment models; Soil remediation: excavation, soil washing, stabilization/solidification; Soil vapor extraction, electrokinetic remediation, thermal desorption, vitrification; Bioremediation, phytoremediation, soil fracturing; Groundwater Remediation: selection of technique, pump and treat, in-situ flushing; Groundwater Remediation: permeable reactive barriers, in-situ air sparging, monitored natural attenuation, bioremediation; Green and sustainable remediation; Case studies on polluted sites and issues related to environment.

Text/Reference books

1. Sharma, H.D., and Reddy, K.R., Geoenvironmental Engineering: Site Remediation, Waste Containment, and Emerging Waste Management Technologies, John Wiley & Sons, Inc., Hoboken, New Jersey, 2004, 992p. (ISBN: 0-471-21599-6).
2. Reddy, K.R., and Cameselle, C. Editors, Electrochemical Remediation Technologies for Polluted Soils, Sediments and Groundwater, John Wiley & Sons, Inc., Hoboken, New Jersey, 2009, 760p. (ISBN: 0-470-38343-7).
3. Reddy, K.R., and Adams, J.A., Sustainable Remediation of Contaminated Sites, Momentum Press, New York, December 2014 (ISBN: 9781606505205).

4. Rowe R.K.," Geotechnical and Geoenvironmental Engineering Handbook" Kluwer Academic Publications, London, 2000.

Subject Code: CE6L217	**Name: Geotechnics of Waste and Waste Containment** Pre-requisites: nil	**L-T-P: 3-0-0**	**Credits: 3**

Sources and types of wastes; Environmental and engineering properties of wastes; New and developing government policies; Beneficial re-use of wastes; Fundamentals of waste-soil interaction; Containment systems and basic principles; Lining and capping systems; Leachate and gas collection systems; Compacted soil liners; Admixed soil liners; Geosynthetic clay liners; Geomembranes; Drainage layers; Geosynthetic composites; Seepage flow; Contaminant transport; Landfill settlement; Landfill slope stability; Conventional caps, ET caps; Ground water monitoring; Landfill gas; Post-closure monitoring; Bioreactor landfills; Landfill mining; End-use of closed landfills; Impoundments; Integrated waste management and alternative landfills.

Text/Reference books:

- Sharma H.D. and Reddy K.R., Geo-environmental Engineering: Site Remediation, Waste Containment, and Emerging Waste Management Technologies, John Wiley, New Jersey, 2004.
- Yong, R.N. Geoenvironmental Engineering: Contaminated Ground: Fate of Pollutions and Remediation, Thomson Telford, 2000.
- Reddy L.N. and Inyang, H.I. Geoenvironmental Engineering: Principles and Applications, Marcel Dek, 2000.
- Raju, V.S., Datta, M., Seshadri, V., and Agarwal, V.K. (1996) (Eds.), "Ash Ponds and Ash Disposal Systems", Narosa Publishers, Delhi, 424 pages.
- Datta, M. (1997) (Ed.), "Waste Disposal in Engineered Landfills", Narosa Publishers, Delhi, 231 pages.
- Datta, M., Parida, B.P., Guha, B.K. and Sreekrishnan, T., (1999) (Eds.), "Industrial Solid Waste Management and Landfilling Practice", Narosa Publishers, Delhi, 204 pages.
- David E. Daniel, Geotechnical Practice for Waste Disposal, Published by Chapman & Hall, London, 1993.
- Bagchi, A., "Design of landfills and integrated solid waste management" John Wiley & Sons, Inc., USA, 2004.
- Qian, X., R. M. Koerner, and D. H. Gray. Geotechnical Aspects of Landfill Design and Construction. New Jersey: Prentice Hall, Upper Saddle River, 2002.

Subject Code: CE6L218	**Name: Soil Exploration and In-situ Testing** Pre-requisites: nil	**L-T-P: 3-1-0**	**Credits: 4**

Introduction: Planning of Geotechnical exploration, methods of boring, types of samples & sampling, field tests, Geophysical exploration; standard penetration test, plate load test, cyclic plate load test, static and dynamic cone penetration test,

pressure meter tests, dilatometer tests, in-situ permeability tests; Pile load tests; Presentation and processing of soil exploration data and its interpretation.
Types of field measurements; Principles of instrumentation; Settlement gauges, Piezometers, earth pressure cells and inclinometers; Planning of instrumentation; Vibration measurements.
Shallow foundations: Bearing capacity and settlement calculations from in-situ tests, empirical correlations.
Deep foundations: estimation of point load and side friction for in-situ tests, empirical correlations for single pile and pile groups, settlement calculations from empirical correlations.
Advanced topics on in-situ soil testing: SSAW, MSAW, GPR

Text/Reference Books:

- Das, B. M. Principles of Foundation Engineering, Thomson Brooks/Cole
- Bowles, J. E. Foundation Analysis and Design, McGraw-Hill Book.
- Kurien, N.P. Design of Foundation Systems: Principles & Practices, Narosa, New Delhi 1992.
- Ranjan G. and Rao, A.S.R. Basic and Applied Soil Mechanics, New Age international Publishers.
- Winterkorn H. F. and Fang, H Y. Foundation Engineering Hand Book, Galgotia Book source.
- John Dunnicliff, Geotechnical Instrumentation for Monitoring Field Performance, Wiley-Interscience Publishers, 1993.
- Coduto and Donald (2011). Geotechnical Engineering Principles and Practices. New Jersey: Pearson Higher Education.

Subject Code: CE6L219	**Name: Unsaturated Soil Mechanics** Pre-requisites: nil	**L-T-P: 3-0-0**	**Credits: 3**

Introduction to unsaturated soil problems; Phase properties and relations; Effective stress concepts for unsaturated soils; Measurement of unsaturated soil properties; Flow of water in unsaturated soils; Steady state and transient flows; Soil water characteristic curve; Hydraulic conductivity-suction relations; Infiltration; Evaporation and drainage and applications to soil covers and earth dams; Mechanical behaviour of unsaturated soils; Pore pressure parameters; Volume change constitutive relations under drained and undrained loading.

Text/References Books:

- Lu N. and Likos, W. J. Unsaturated Soil Mechanics, John Wiley & Sons, Inc., 2004
- Fredlund, D. G. Rahardjo, H. and Fredlund, M. D. Unsaturated Soil Mechanics in Engineering Practice.

Subject Code: CE6L220	**Name: Optimization Methods** Pre-requisites: nil	**L-T-P: 3-0-0**	**Credits: 3**

Basics of engineering analysis and design; Need for optimal design; formulation of optimal design problems; basic difficulties associated with solution of optimal problems; Classical optimization methods; Necessary and sufficient optimality criteria for unconstrained and constrained problems; Kuhn-Tucker conditions; Global optimality and convex analysis; Linear optimal problems; Simplex method; Introduction to Karmarkar's algorithm; Numerical methods for nonlinear unconstrained and constrained problems, sensitivity analysis; Linear post optimal analysis, sensitivity analysis of discrete and distributed systems; Introduction to variational methods of sensitivity analysis, shape sensitivity; Introduction to integer programming, dynamic programming, stochastic programming and geometric programming, Introduction to genetic algorithm and simulated annealing.

Text/References Books:

- Deb. K., Optimization for engineering design: Algorithms and examples, PHI Pvt Ltd., 1998.
- Arora., J.S. Introduction to optimum design, McGraw Hill International edition, 1989.
- Hafta, R.T. and Gurdal. Z., Elements of structural optimization, Kluwer academic publishers, third revised and expanded edition, 1996.

Subject Code: MA6L001	**Name: Mathematical Methods** Prerequisite: Nil	**L-T-P: 3-1-0**	**Credit: 4**

Probability and Statistics : Random variables (rv) and their properties, some standard discrete and continuous rv, Expectation, Variance, moments, moment generating functions, functions of a rv, their distribution and moments, joint, marginal and conditional distribution and independence of rvs, Hypothesis testing.
Numerical solutions of systems of linear equations: Gauss elimination, LU decomposition, Gauss-Jacobi and Gauss-Seidel methods.
Numerical methods of ODE and PDE: Runge-Kutta and finite difference methods for ODE, Finite difference methods for solving 2-D Laplace's equation, Poisson's equation, 1-D heat equation : Bender Schmidt, Crank Nicholson method and Du Fort Frankel methods, 1-D wave equation using Explicit method. Consistency and stability analysis.

Text/Reference Books:

- Grawel, B.S. Numerical Methods
- Jain, M.K., Iyengar, S.R.K. and Jain, R.K. Numerical Methods-problem and solutions, Wiley Eastern Limited, 2001.
- Ross, S. Introduction to Probability Models, Wiley India
- Gun, A.M., Gupta, M.K. and Gupta, B.S. Fundamentals of Statistics
- Hayter, A.J., Probability and Statistics, Duxbury, 2002
- Scarborough, J.B., Numerical mathematical analysis, Oxford & IBH Publishing Co. Pvt., 2000
- Hamming, R.W., Numerical Methods for Scientist and Engineers, McGraw Hill, 1998.

- Mathews, J.H. and Fink, K.D. Numerical Methods using MATLAB, Pearson Education, 2004.

Subject Code: MA6L002	Name: Advanced Techniques in Operation Research Prerequisite: Nil	L-T-P: 3-1-0	Credit: 4

One variable unconstrained optimization, multivariable unconstrained optimisation, Karush-Kuhn-Tucker (KKT) conditions for constrained optimization, quadratic programming, separable programming, convex and non convex programming, steepest and Quasi-Newton method.
Dynamic Programming: Characteristics of dynamic problems, deterministic dynamic programming and probabilistic dynamic programming, Network analysis, Shortest path
problems, minimum spanning tree problem, maximum flow problem, minimum cost flow problem, network simplex, interior point methods, stochastic programming, Nonlinear goal programming applications, Geometric Programming.
Multi-objective Optimization Problems: Linear and non linear programming problems,
Weighting and Epsilon method, P-norm methods, Gradient Projection Method, STEM method, Convex Optimization.

Text/Reference Books:

- Rao, S.S., Engineering Optimization Theory and Practices, John Wiley and Sons, 2009
- Ehrgott, M. Multi-criteria Optimization, Springer 2006
- Miettien, K.M, Non-linear multi-objective optimization, Kluwers International Series, 2004.
- Deb, K., Multi-Objective Optimization using Evolutionary Algorithms, John Wiley & Sons, 2001.

Subject Code: ID6L001	Name: Data Analytics Prerequisite: nil	L-T-P: 3-0-0	Credit: 3

Introduction: Sources, modes of availability, inaccuracies, and uses of data. Data Objects and Attributes: Descriptive Statistics; Visualization; and Data Similarity and Dissimilarity.
Pre-processing of Data: Cleaning for Missing and Noisy Data; Data Reduction – Discrete Wavelet Transform, Principal Component Analysis, Partial Least Square Method, Attribute Subset Selection; and Data Transformation and Discretization.
Inferential Statistics: Probability Density Functions; Inferential Statistics through Hypothesis Tests
Business Analytics: Predictive Analysis (Regression and Correlation, Logistic Regression, In-Sample and Out-of-Sample Predictions), Prescriptive Analytics (Optimization and Simulation with Multiple Objectives);
Mining Frequent Patterns: Concepts of Support and Confidence; Frequent Itemset Mining Methods; Pattern Evaluation.

Classification: Decision Trees – Attribute Selection Measures and Tree Pruning; Bayesian and Rule-based Classification; Model Evaluation and Selection; Cross-Validation; Classification Accuracy; Bayesian Belief Networks; Classification by Back propagation; and Support Vector Machine.
Clustering: Partitioning Methods – k-means Hierarchical Methods and Hierarchical Clustering Using Feature Trees; Probabilistic Hierarchical Clustering; Introduction to Density-, Grid-, and Fuzzy and Probabilistic Model-based Clustering Methods; and Evaluation of Clustering Methods.
Machine Learning: Introduction and Concepts: Ridge Regression; Lasso Regression; and k-Nearest Neighbours, Regression and Classification.
Supervised Learning with Regression and Classification Techniques: Bias-Variance Dichotomy, Linear and Quadratic Discriminant Analysis, Classification and Regression Trees, Ensemble Methods: Random Forest, Neural Networks, Deep Learning.

Text/Reference Books:

- Han, J., M. Kamber, and J. Pei, Data Mining: Concepts and Techniques, Elsevier, Amsterdam. Textbook. Year of Publication 2012
- James, G., D. Witten, T. Hastie, and R. Tibshirani, An Introduction to Statistical learning with Application to R, Springer, New York. Year of Publication 2013
- Jank, W., Business Analytics for Managers, Springer, New York. Year of Publication 2011
- Williams, G., Data mining with Rattle and R: The Art of Excavating Data for Knowledge Discovery, Springer, New York. Year of Publication 2011
- Witten, I. H., E. Frank, and M. A. Hall, Data Mining: Practical Machine Learning Tools and Techniques, Morgan Kaufmann. Year of Publication 2011
- Wolfgang, J., Business Analytics for Managers, Springer. Year of Publication 2011
- Montgomery, D. C., and G. C. Runger, Applied Statistics and Probability for Engineers. John Wiley & Sons. Year of Publication 2010
- Samueli G., N. R. Patel, and P. C. Bruce, Data Mining for Business. Intelligence, John Wiley & Sons, New York. Year of Publication 2010
- Hastie, T., R. T. Jerome, and H. Friedman, The Elements of Statistical Learning: Data Mining, Inference and Prediction, Springer. Year of Publication 2009
- Bishop C., Pattern Recognition and Machine Learning, Springer. Year of Publication 2007
- Tan, P., M. Steinbach, and V. Kumar, Introduction to Data Mining, Addison-Wesley. Year of Publication 2005

Subject Code: CL6L224	**Name: Neural Networks and Applications** Prerequisite: Nil	**L-T-P: 3-0-0**	**Credit: 3**

Neurons and neural networks, basic models of artificial neural networks: simple layer perception, feed forward multilayer perceptron, Hopfield networks, competitive learning networks, applications of neural networks for matrix algebra problems, adaptive filtering and adaptive pattern recognition, dynamic system identification, dynamic system modeling using recurrent neural networks,

approximation/optimization problems, VLSI implementation of neural networks.

Text/Reference Books:

- Valdimir M Krasnopolsky, The application of neural networks in the earth system sciences: Neural network emulations for complex multidimensional mapping, Springer.
- James A. Freeman, Neural networks: Algorithms, applications, and programming techniques (Computation and neural systems series); Addison-Wesley Pub.

Subject Code: CE6L454	**Name: Pavement Evaluation and Management** Prerequisite: Nil	**L-T-P: 3-1-0**	**Credit: 4**

Types of pavements, Distresses in flexible and rigid pavements , Techniques for functional and structural evaluation of pavements, pavement rehabilitation techniques, overlay design procedures, recycling of flexible and rigid pavements, Maintenance of paved and unpaved roads, Pavement management systems, Introduction to HDM-4

Text/Reference Books:

- Y. H. Huang, Pavement Analysis and Design, Second ed., Pearson Education
- Rajib B. Mallick,Tahar El-Korchi, Pavement Engineering: Principles and Practice, Second Edition, CRC Press
- Derek Pearson, Deterioration and Maintenance of Pavements, ICE Publishing
- Ralph Haas, W. Ronald Hudson, John P. Zaniewski, Modern pavement management Modern Pavement Management, Krieger Pub Co
- Croney, D. and P. Croney, The design and performance of road pavements, McGraw-Hill Book Company, London, UK.

Subject Code: CE6L110	**Name: Environmental Chemistry and Microbiology** Prerequisite: Nil	**L-T-P: 3-1-0**	**Credit: 4**

Environmental chemistry-basic concepts from general chemistry, Chemical equations, chemical reactions, calculation from chemical reactions, solutions, activity and activity coefficients, Chemical Equilibria and Kinetics Fundamentals, Acid-Base equilibria fundamentals, equilibrium diagrams, Acidity, Alkalinity, Buffers and Buffer Intensity, Chemical equilibrium calculations, pC-pH diagram, Langelier index, Solubility diagram, Oxidation and Reduction equilibria.

Water and wastewater quality parameters and their analysis, Basic concepts of quantitative analytical chemistry, instrumental methods of analysis.

Types of microorganisms found in the environment, Metabolic classification of organisms, Enzyme and enzyme kinetics, indicator organisms, coliforms - fecal coliforms - E.coli, Streptococcus fecalis differentiation of coliforms - significance - MPN index, M.F. technique, standards, Microbiological Parameter Analysis, Measurements and Isolation of Microorganism, Different Cultures, Media and

Techniques of Staining and Enumeration of microorganism, Staining and detection of microbes, Methods of enumerating microbes, Multiple tube fermentation technique, Membrane filter technique.

Text/Reference Books:

- Sawyer, C.N. and McCarty, P.L., and Parkin, G.F. Chemistry for Environmental Engineers, 4th Edition, McGraw Hill, New Delhi, 1994.
- Benefield, Judkins and Weand Process Chemistry for Water and Wastewater Treatment, Prentice Hall
- Maier R. M., Pepper I. L., and Gerba C. P., Environmental Microbiology, Second Edition, Elsevier- AP, 2009.
- Pelczar, Jr, M.J., Chan, E.C.S., Krieg, R.N., and Pelczar M. F, Microbiology, 5thEdn., Tata McGraw-Hill Publishing Company Limited, New Delhi, 1996.
- Rittman B, McCarty P L McCarty P, Environmental Biotechnology: Principles and Applications, 2nd Edition, McGraw-Hill, 2000

Subject Code: ML6L008	**Name: Materials Recycling and Waste Management** Prerequisite: Nil	**L-T-P: 3-0-0**	**Credit: 3**

Recycling of different classes of materials, Solid Waste Regulations, Waste generation, Waste characterization, Physical properties of Waste, Waste separation and processing, Composting, Landfills, Incineration.

Texts / Reference Books:

- T. Randall Curlee, Sujit Das, William Andrew; 1 edition, Materials recycling and waste management.

Subject Code: CE6L306	**Name: Seismic Design of Structures** Prerequisite: Nil	**L-T-P: 3-1-0**	**Credit: 4**

Characteristics of earthquakes; Earthquake response of structures; Concept of earthquake resistant design; Response of SDOF and MDOF systems to random excitations. Code provisions of design of buildings; Design for Liquefaction; Non-engineered construction; Special topics: bridges, dams, strengthening of existing buildings.

Text/Reference Books:

- Duggal, S.K., Earthquake Resistant Design of Structures, Oxford University Press
- Chopra, A.K., Dynamics of Structures: Theory and Applications to Earthquake Engineering, Prentice Hall/Pearson Education
- Paulay, T. and Priestley, M.J.N., Seismic Design of Reinforced Concrete and Masonry Buildings, Wiley International Publication
- Bolt, B.A., Earthquakes, W.H. Freeman
- Kramer, S.L., Geotechnical Earthquake Engineering, Pearson

Subject Code: CE6L309	Name: Modern Construction Materials Prerequisite: Nil	L-T-P: 3-0-0	Credit: 3

Basics (Introduction to the course, Science, Engineering and Technology of Materials); Microstructure (Atomic Bonding, Structure of solids, Movement of atoms, Development of microstructure); Material behaviour (Surface properties, Response to stress, Failure theories, Fracture mechanics, Rheology, Thermal properties); Structural Materials (Review of Construction Materials and Criteria for Selection, Wood and Wood Products, Polymers, Fibre Reinforced Polymers, Metals, Bituminous Materials, Concrete, Glass); : Non-structural materials, accessories and finishes (Review of Non-structural Materials and Criteria for Selection, Waterproofing materials, Polymer Floor Finishes, Paints, Tiles, Acoustic Treatment, Dry walls, Anchors); Environmental Concerns, Social Perception of Construction Materials.

Text/Reference Books:

- Varghese, P.C., Building Materials, Prentice-Hall India
- Callister, W.D., Materials Science and Engineering: An introduction, John Wiley
- Raghavan, V., Materials Science and Engineering, Prentice Hall
- Higgins, R.A., Properties of Engineering Materials, Industrial Press
- Construction materials: Their nature and behaviour, Eds. J.M. Illston and P.L.J. Domone, Spon Press
- Young, J.F., Mindess, S., Gray, R.J. and Bentur, A., The Science and Technology of Civil Engineering Materials, Prentice Hall
- Neville, A.M., Properties of concrete, Pearson

Subject Code: MA7L007	Name: Soft Computing Prerequisite: Nil	L-T-P: 3-1-0	Credit: 4

Introduction to Soft Computing, Components of Soft Computing, Importance of Soft Computing, Fuzzy Set Theory - Definition, Different types of fuzzy set Membership Functions, Fuzzy Set theoretic operations, Fuzzy Rules and Fuzzy Reasoning, Fuzzy Inference Systems, GA, Simulated Annealing, Particle swarm optimization, Neural Networks- Supervised Learning, Unsupervised Learning, Hybrid Systems - Neuro Fuzzy Modeling, Fuzzy c-means, Applications in Image Processing, Neuro-fuzzy control, Data Mining.
Implementation of the problems using MATLAB.

Text/Reference Books:

- Jang J.S.R. , Sun C.T. and Mizutani E. Neuro Fuzzy and Soft Computing , Amazon
- Haykin. An Introduction to Neural Networks
- Klir and Yuan, Fuzzy Sets and Fuzzy Logic
- Goldberg. Genetic Algorithms
- Kennedy J., Eberhart R.C. and Shi Y. Particle Swarm Intelligence, Morgan Kaufman Publisher
- Maurice Clerce. Particle swaram Optimization, ISTE

- Olsson A. E. Particle swarm Optimization

Subject Code: ID6L002	Name: Design and Analysis of Experiments Prerequisite: Nil	L-T-P: 3-0-0	Credit: 3

Introduction to Designed Experiments: Strategy of experimentation, Typical applications, Basic principles and guidelines for designing experiments
Basic statistical concepts: Descriptive Statistics, Sampling and Sampling Distributions, Tests of Hypotheses.
Single factor experiments with Fixed Effects: ANOVA, Model Adequacy Tests, Orthogonal Contrasts
Experiments with Blocking Factors: Randomised Complete and Incomplete Block Designs, Latin Squares Design
Factorial Experiments: 22,, 32, and 2k Designs, Blocking and Confounding, and Fractional Factorial Designs
Linear Regression Models: Estimation of Parameters, Tests of Hypothesis, Regression Model Diagnostics
Response Surface Design: Method of Steepest Ascent, Second-Order Response Surface, Experimental Designs, Computer Models, Mixture Experiments, Evolutionary Operations
Advanced Design of Experiments: Random Effects Models, Analysis of Covariance, Non-Normal Response, and Taguchi Methods.

Text/Reference Books:

- Design and Analysis of Experiments, D. C. Montgomery, John Wiley & Sons, Wiley Student Edition, International Student Version, 7th Edition, 2009
- Experimental Design: From User Studies to Psychophysics, D. W. Cunningham and C. Wallraven, CRC Press, 2011
- Design of Experiments: An Introduction Based on Linear Models, M. Morris, Chapman & Hall/CRC Texts in Statistical Science, First Edition, 2010
- Experiments: Planning, Analysis, and Optimization C. F. J. Wu and M. S. Hamada, Wiley Series in Probability and Statistics, Wiley, 2009
- Statistics for Experimenters: Design, Innovation, and Discovery, G. E. P. Box, J. S. Hunter, and W. G. Hunter, Wiley, 2nd Edition, 2005
- Practical Guide to Designed Experiments: A Unified Approach, P. D. Funkenbusch, CRC Press, 2004
- Statistical Design and Analysis of Experiments, with Applications to Engineering and Science, R. L. Mason, R. F. Gunst, and J. L. Hess, Wiley Interscience, Second Edition, 2003
- Design and Analysis of Experiments A. M. Dean and D. Voss, Springer Texts in Statistics, Second Edition, 2001
- The Theory of the Design of Experiments, D. R. Cox and N. Reid, Chapman and Hall/CRC, 2000
- Statistical Design and Analysis of Experiments, P. W. M. John, (Classics in Applied Mathematics No 22), Society for Industrial and Applied Mathematics, 1999.

Subject Code: ME6L011	Name: Finite Element Methods in Engineering Prerequisite: Nil	L-T-P: 3-1-0	Credit: 4

Integral Formulations and Variational Methods, Second-Order boundary value problems; Bending of Beams; FE Error Analysis; Eigen value and Time-Dependent Problems; Numerical Integration and Computer Implementation, Single-Variable Problems; Interpolation Functions, Numerical Integration and Modeling; Plane Elasticity; Flows of Viscous Incompressible Fluids; Bending of Elastic Plates; Computer Implementation, Analysis of Three-Dimensional and Nonlinear Problems.

Text/Reference Books:

- An Introduction to the Finite Element Method – J. N. Reddy (McGraw Hill)
- An Introduction to Nonlinear Finite Element Method – J. N. Reddy (Oxford)
- Concepts and Applications of Finite Element Analysis – R D Cook (Willey)
- The Finite Element Method: Its Basis & Fundamental – O C Zienkiewicz (Elsevier)
- The Finite Element Method in Engineering – Rao (Elsevier)
- Finite Element Methods for Engineers – U. S. Dixit (Cengage)
- Introduction to Finite Elements in Engineering – T. R. Chandrupatla (PHI)

Subject Code: ME6L006	Name: Continuum Mechanics Prerequisite: Nil	L-T-P: 3-1-0	Credit: 4

Mathematical Foundations, Analysis of Stress, Deformation and Strain, Motion and Flow, Fundamental Laws of Continuum Mechanics, Linear Elasticity, Fluids, Plasticity and Viscoelasticity

Text/Reference Books:

- An Introduction to Continuum Mechanics – J. N. Reddy (Cambridge University Press)
- Introduction to Continuum Mechanics for Engineers: Revised Edition Revised Edition - Ray M. Bowen (Dover Publications)
- An Introduction to Continuum Mechanics - Morton E. Gurtin (Academic Press)
- Continuum Mechanics: Elasticity, Plasticity, Visoelasticity- Ellis H. Dill (CRC Press)
- Continuum Mechanics: Concise Theory and Problems 2nd Edition - P. Chadwick, Peter Chadwick, Physics (Dover Publications)
- Continuum Mechanics - Franco M. Capaldi (Cambridge University Press)

Subject Code: CE6L404	Name: Analysis and Design of Pavements Prerequisite: Nil	L-T-P: 3-1-0	Credit: 4

Types of Pavements, Pavement Composition, Philosophy of design of flexible, composite and rigid pavements, analysis of pavements using different analytical methods, selection of pavement design input parameters, traffic loading and volume, material characterization, drainage, failure criteria, reliability, design of flexible,

composite and rigid pavements using different methods (IRC, AASHTO, Austroads etc), comparison of different pavement design approaches, design of overlays.

Text/Reference Books:

1. Y. H. Huang, Pavement Analysis and Design, Pearson Education.
2. E.J. Yoder and M. W. Witczak, Principles of Pavement Design, McGrawPub.
3. Rajib B. Mallick, Tahar El-Korchi, Pavement Engineering: Principles and Practice, Second Edition, CRC Press
4. Animesh Das, Analysis of Pavement Structures, CRC Press
5. Nick Thom, Principles of Pavement Engineering, ICE Publishing

Subject Code: CL6L222	**Name: Modeling of Extreme Events** Prerequisite: Nil	**L-T-P: 3-0-0**	**Credit: 3**

Overview of hazards: Tropical cyclones; Storm surges; Tsunamis, Sea Level Rise, Volcanos. Cloud bursts; Drought, Flood, Tornadoes, Earth quake, Land Slide, Heat and Cold Waves, Man-made and industrial disasters. Observation, Modelling/Simulation and Warning systems for natural and man-made hazards, Risk and Vulnerability assessment (Physical, Economic, Societal), Mitigation strategies and Management. Assessment of these events in a Global Warming Scenario.

Text/Reference Books:

- Tim Vasquez: Weather Analysis and Forecasting Handbook, Weather Graphics Technology.
- David J Stensurd: Parameter schemes: keys to understanding numerical weather prediction models, Cambridge University Press.
- Christopher C Burt: Extreme Weather: A Guide and Record Book, W WNotron and Company

Subject Code: CE6L515	**Name: GIS & Remote Sensing Applications in Civil Engineering** Prerequisite: Nil	**L-T-P: 3-0-0**	**Credit: 3**

Remote sensing; Energy source; Spectral signatures; Remote sensing satellites and sensors; Radar image interpretation; Digital image processing; Image classification; Principal component transformation; Applications in watershed management, flood management, groundwater quality, reservoir sedimentation, irrigation management. Geographic information systems (GIS); Raster and vector data; GIS for Surface-Water Hydrology; Digital elevation models; Hydrographic vector data; Arc-hydro model; GIS for groundwater modeling; GIS for flood plain management; HEC-RAS and HEC-GeoRAS; Case studies.

Text/Reference Books:

- Lillesand, T., Kiefer, R. W., and Chipman, J., Remote Sensing and Image Interpretation, Seventh Edition, John Wiley & Sons, New York, 2015.
- Burrough, P. A., and McDonnell, R. A., Principles of Geographical Information Systems, Second Edition,Oxford University Press, Oxford, 1998.

- Richards, J. A., Remote Sensing Digital Image Analysis: An Introduction, Fifth Edition, Springer-Verlag Berlin Heidelberg, 2013.
- Johnson, L. E., Geographic Information Systems in Water Resources Engineering, CRC Press, Boca Raton, 2008.

Subject Code: CY7L025	**Name: Design and Application of Nanomaterials** Prerequisite: Nil	**L-T-P: 3-0-0**	**Credit: 3**

Introduction: Inorganic Materials Chemistry and Nanochemistry; Basics Nanomaterials Synthesis Methods: Bottom-up vs. Top-down Methods; Nanoclusters and Nanowires; Metal, Metal Oxide, semiconductor nanoparticles, quantum confinement, fluorescent properties, and Carbon Nanotubes. Inorganic Materials synthesis by Templating and Self-Assembly; 2-D Nanopatterns and Self-assembled Monolayers on Inorganic Substrates; Mesostructured and Mesoporous Materials; Inorganic-Organic and Inorganic-Polymer Nanocomposite Materials; Opals and Photonic Materials; Layer by layer self-assembly and core-shell Inorganic Nanomaterials; Biomimetics: Bioinspired Synthesis of Inorganic Nanobiomaterials; Catalysis and Photocatalysis (Environmental remediation); Solar Cells and Nanoelectronics/ Nanophotonics Applications Studying and working with matter on an ultra-small scale. Delivery of anti-cancer drugs.New ethical, health and safety or social issues.

Text/Reference Books:

- Hornyak L. G.; Tibbals H. F.; Dutta J. and Moore J. J. Introduction to Nanoscience and Nanotechnology, CRC Press.
- Arsenault A. and Ozin G. A. Nanochemistry: A Chemical Approach to Nanomaterials, RSC.
- Klabunde K. J. Nanoscale Materials in Chemistry, Wiley Interscience.
- Vollmer M. and Kreibig U. Optical Properties of Metal Clusters, Springer.

Subject Code: MA7L001	**Name: Numerical Solution of Ordinary and Partial Differential Equations** Prerequisite: Nil	**L-T-P: 3-1-0**	**Credit: 4**

Errors: Round-off error, Truncation error, Absolute error, Relative error, Percentage error; Ordinary Differential equations (ODE): Solutions of Initial Value Problems by Taylor Series, Euler, Improved Euler, Modified Euler, Runge-Kutta methods for First and second order differential equations, Multistep methods (Milne and Adams Bashforth). Consistency, stability and convergence aspects of the methods of IVP. Boundary Value Problems: Shooting and finite difference methods. Partial Differential Equations (PDE): Classification of PDEs, Finite difference approximations to partial derivatives, Numerical solutions of Elliptic, Parabolic and Hyperbolic partial differential equations. Solutions of Laplace equation by Leibmann's iteration procedure, Poisson equation, Explicit, Crank-Nickolson, Du Fort Frankel methods for Parabolic PDE. Explicit formula for Hyperbolic PDE and Consistency, stability and convergence aspects of these methods.

Text/Reference Books:

- Smith G. D. Numerical Solutions to Partial Differential Equations, Oxford University Press
- Jain M.K., and Iyengar S.R.K. Numerical methods for scientific and engineering
- Lapidus L. and Pinder G. F. Numerical Solution of Partial Differential Equations in Science and Engineering, John Wiley
- Jain M.K. Numerical Solutions of Differential Equations
- Smith, Numerical solutions of partial Differential Equations (Finite difference methods) computation

Subject Code: CE6P201	**Name: Geotechnical Engineering Laboratory**	**L-T-P: 0-0-3**	**Credit: 2**

Consolidation, Pocket penetrometer, Static and Cyclic triaxial testing, Model studies using centrifuge.
Geosynthetics testing: Specific gravity, Mass per unit area, Thickness, Permeability: in-plane and cross plane, Cone drop test, Tensile strength, Impact tests, CBR Puncture tests, Friction behavior, Pullout tests
Rock testing: Compressive strength, Indirect tensile strength test by Brazilian testing, Point load strength index testing, Sonic velocity: P-and S-waves, Schmidt rebound hammer test, Slake durability index.

Subject Code: CE6P202	**Name: In-situ Testing of Soils Laboratory**	**L-T-P: 0-0-3**	**Credit: 2**

GPR, Shear wave velocity of soils, Packer test for in-situ permeability, In-situ/field density test, Drilling techniques, In-situ testing (SPT, cone penetration test, pressuremetre test), Resistivity testing.

Subject Code: CE6P203	**Name: Computational Geomechanics Laboratory**	**L-T-P: 0-0-3**	**Credit: 2**

Static and dynamic analysis of foundations; Analysis of retaining walls and slopes; Finite element modelling of geotechnical structures; Seismic ground response analysis; Usage of software's for geotechnical structure analysis.