M. Tech. Curricula and Syllabi (w.e.f. 2013-14)

- **Curriculum Structure**
    - **Applied Geosciences**
    - **Climate Science & Technology**
    - **Civil Engineering**
    - **Electronics & Communication Engineering**
    - **Power System Engineering**
    - **Materials Science and Engineering**
    - **Mechanical Systems Design**
    - **Thermal Science and Engineering**
    - **Structural Engineering (w.e.f. 2015-16)**
    - **Transportation Engineering (w.e.f. 2015-16)**

Curriculum for Joint M.Tech.-Ph.D. (Applied Geosciences)

Subject Name	Code	L-T-P	Credit	Contact Hour
SEMESTER - I				
Dynamics of Fluid in Earth System	ES6L101	3-1-0	4	4
Analytical & Measurement Techniques	ES6L102	3-1-0	4	4
Elective - I	ES6L1XX	3-0-0	3	3
Elective - II	ES6L1XX	3-0-0	3	3
Elective - III	ES6L1XX	3-0-0	3	3
Advanced Instrumentation Laboratory	ES6P102	0-0-3	2	3
Seminar - I	ES6S101	0-0-0	2	0
		Total :	**21**	**20**
SEMESTER - II				
Shallow Surface Geophysics	ES6L201	3-1-0	4	4
Mathematical & Computational Geosciences	ES6L202	3-1-0	4	4
Elective - IV	ES6L2XX	3-0-0	3	3
Elective - V	ES6L2XX	3-0-0	3	3
Elective - VI	ES6L2XX	3-0/1-0	3/4	3/4
Shallow Surface Geophysics Laboratory	ES6P201	0-0-3	2	3
Mathematical & Computational Geosciences Laboratory	ES6P202	0-0-3	2	3
Seminar - II	ES6S201	0-0-0	2	0
		Total :	**23/24**	**23/24**
SEMESTER - III				
Thesis Part - I	ES6D301	0-0-0	16	0
Research Review Paper - I	ES6D302	0-0-0	4	0
		Total :	**20**	**0**
SEMESTER – IV				
Thesis Part - II	ES6D403	0-0-0	16	0
Research Review Paper - II	ES6D404	0-0-0	4	0
		Total :	**20**	**0**

Total Credit: 84/85

List of Elective Subjects (Applied Geosciences)

Subject Name	Code	L-T-P	Credit	Contact Hour
Elective – I, II and III				
Remote Sensing & GIS Applications in Geosciences	ES6L103	2-0-2	3	4
Groundwater Modeling & Simulation	ES6L104	3-0-0	3	3
Neotectonics & Paleoseismology	ES6L105	3-0-0	3	3
Reservoir Characteristics & Sedimentology	ES6L106	3-0-0	3	3
Green Energy	ES6L107	3-0-0	3	3
Applied Rock Mechanics	ES6L108	3-0-0	3	3
Natural Gas Hydrates: Potential Energy & Environment	ES6L109	3-0-0	3	3
Carbon Capture & Sequestration	ES6L110	3-0-0	3	3
Applied Coal Petrography & Coal Bed Methane	ES6L111	3-0-0	3	3
Paleoceanography & Paleoclimatology	ES6L112	3-0-0	3	3
Advanced Glaciology	ES6L113	3-0-0	3	3
Hydrocarbon Basin Modeling	ES6L114	3-0-0	3	3
Ocean Resources & Technology	ES6L115	3-0-0	3	3
Advances in Polar Geoscience	ES6L116	3-0-0	3	3
Isotope Hydrology	ES6L117	3-0-0	3	3
Mineral Resources: Exploration & Management	ES6L118	3-0-0	3	3
Advanced Petrology	ES6L119	2-0-0	3	2
Applied Micropaleontology	ES6L120	2-0-0	3	2
Elective – IV, V and VI				
Borehole Geophysics	ES6L203	3-0-0	3	3
Geophysical Tomography	ES6L204	3-0-0	3	3
Airborne Geophysical Survey: Tools & Techniques	ES6L205	3-0-0	3	3
Deep Water Imaging	ES6L206	3-0-0	3	3
Seismology	ES6L207	3-0-0	3	3
Aqueous Environmental Geochemistry	ES6L208	2-0-0	3	2
Organic Environmental Geochemistry	ES6L209	2-0-0	3	2
Application of Petroleum Geochemistry in Exploration and Production	ES6L210	3-0-0	3	3
Environmental Geosciences	ES6L211	3-0-0	3	3
Mass & Heat Transfer in Solid Earth	ES6L212	3-0-0	3	3
Atmospheric Chemistry and Toxicology	ES6L213	3-0-0	3	3

Elective VI: Any subjects from other streams

Syllabus

Core Subjects:

Subject Code: ES6L101	Subject Name: Dynamics of Fluid in Earth System	L-T-P: 3-1-0	Credit: 4
Pre-requisite:			
Fundamentals of Geophysical Fluid Dynamics; Equations of motion in rotating frame; Potential vorticity conservation; Simplified equations for ocean and atmosphere; Instabilities and Waves; Large-Scale atmospheric circulation equatorial dynamics; Heat-induced tropical circulations; Mid-latitude circulation; Planetary waves and stratosphere; Ocean Dynamics: Ekman layers; Sverdrup transport; Western boundary currents; Large-scale ocean circulation; Response of ocean to a moving storm or hurricane; Oceanic mixed layer. Books: 1. Rai, S.N., Ramana, D.V. and Manglik, *A. Dynamics of Earth's Fluid System, Taylor and Francis.* 2. Durran, D.R., *Numerical Methods for Fluid Dynamics: With Applications to Geophysics* (Texts in Applied Mathematics), Springer 3. Shivendra Nath Rai , D.V. Ramana , A. Manglik, *Dynamics of Earth's Fluid System*, Taylor & Francis			

Subject Code: ES6L102	**Subject Name: Analytical & Measurement Techniques**	**L-T-P: 3-1-0**	**Credit: 4**
Pre-requisite:			

Concepts in analytical chemistry; Classical and rapid methods of analyses; Atomic absorption spectrometry; Inductively coupled plasma-atomic absorption spectrometry; X-ray fluorescence analysis; Energy dispersive X-ray spectrometry; X-ray diffraction analysis; micro beam and surface analysis techniques; Neutron activation analysis; Mass-spectrometry; General measurement system; Principles, measurement of meteorological parameters, wind speed, temperature, humidity and pressure etc; In-situ and remote measurements; SODAR; LIDAR; RADAR techniques; Aerosol measurement techniques, optical depth, size distribution, chemical composition; Trace gas measurement techniques.

Books:

1. Cornelis Klein & Barbara Dutrow, *Manual of Mineral Science*, Wiley.
2. Li-ling Ooi, *Principles of X-ray Crystallography*, Oxford University Press.
3. Vanhaecke, Frank and Degryse, Patrick: Isotopic Analysis: *Fundamentals and Applications Using ICP-MS*, CRC Press.
4. Pramod Kulkarni, Paul A. Baron, Klaus Willeke: *Aerosol Measurement: Principles, Techniques, and Applications*, Wiley.

Subject Code: ES6L201	**Subject Name: Shallow Surface Geophysics**	**L-T-P: 3-1-0**	**Credit: 4**
Pre-requisite:			
Various geophysical subsurface exploration techniques; Electrical survey and its application; Seismic survey and its application; Magnetic survey and its application; Gravity survey and its application; Limitations of different techniques; Applications in mineral, gas and groundwater exploration. Books: 1. Dobrin, M. B. And C. H. Savit, *Geophysical Prospecting*, McGraw-Hill. 2. Telford, W. M., L.P. Geldart, and R. E. Sheriff, *Applied Geophysics*, Cambridge University Press. 3. Kearey, P. And M. Brooks, and I. Hill, *An Introduction to Geophysical Exploration, Blackwell Science*.			

Subject Code: ES6L202	**Subject Name: Mathematical and Computational Geosciences**	**L-T-P: 3-1-0**	**Credit: 4**
Pre-requisite:			

Concept of a frequency distribution: Moments, skewness and kurtosis Probability; Various approaches of probability classical, frequency (statistical), subjective and axiomatic; Theorems on probability, conditional probability; Independence; Bayes Theorem; Random variable: discrete and continuous; Distribution function and their properties; Probability mass and density functions; Mathematical expectation; Moment generating function and its properties; Probability distributions: Bernoulli, binomial, negative binomial, Poisson and normal distributions; Theory of least squares and curve fitting; Correlation Simple; multiple and partial; Regression lines and regression coefficients; Multiple and partial regression; Test of Significance: Normal test, t-test, Chisquare and F-test, Principal component analysis, Multivariate analysis,

Fourier-Legendre transforms; FFT; Calculus of variations and Rayleigh Ritz method; Probability; covariance and correlation; Multivariate distributions and analysis; Principal component analysis of climate data.

MATLAB and its application in Geosciences

Books:

1. Trauth, M., *Matlab Recipes for Earth Sciences*, Springer
2. Zhao, C., and B. E. Hobbs, and A. Ord. *Fundamentals of Computational Geoscience: Numerical Methods and Algorithms*, Springer
3. Dawson, C., G. Margot, *Computational Challenges in the Geosciences*, Springer

ELECTIVES I, II & III

<table>
<tr><td>Subject Code: ES6L103</td><td>Subject Name: Remote Sensing & GIS application in Geosciences</td><td>L-T-P: 2-0-2</td><td>Credit: 3</td></tr>
<tr><td colspan="4">Pre-requisite:</td></tr>
<tr><td colspan="4">Introduction to various satellite and satellite data; Digital image processing and enhancement techniques; Optical/Thermal/Microwave/Acoustic Remote Sensing; Geoscientific data integration techniques in GIS; Application of Remote Sensing and GIS in Mineral/Oil Exploration; Targeting groundwater in hard and soft rock terrain; Application in engineering geology and natural disaster study; Digital elevation modelling and digital terrain modelling; Digitizing, editing and structuring of map data; GPS and navigation; DGPS application; GNSS.

Books
1. Xu, G., GPS Theory, Algorithms and Applications. Springer
2. F. S. Sabins, Remote Sensing: Principles and Interpretation:, Waveland Pr Inc.
3. Paul Bolstad, GIS Fundamentals: A First Text on Geographic Information Systems:, Eider Press.
4. Paul. R. Wolf, Bon. A. Dewitt: Elements of Photogrammetry with Applications in GIS:, McGraw-Hill Education (India) Pvt. Limited.
5. John R. Jensen, Introductory digital image processing: a remote sensing perspective, Prentice Hall, New Jersey.</td></tr>
</table>

Subject Code: ES6L104	Subject Name: Groundwater Modelling & Simulation	L-T-P: 3-0-0	Credit: 3
Pre-requisite:			
Data requirement; Aquifer configuration and hydraulic parameters; Subsurface groundwater flow equation; Conceptual modelling; Aquifer geometry; Model boundary; Model design; Model calibration; Simulation techniques; Solute transport modelling; Groundwater modelling examples from India. Books: 1. Damena, T, *Mathematical Modelling and Simulation on Groundwater Flow: The study of groundwater flow with computer aided mathematical methods*, LAP LAMBERT Academic Publishing. 2. Refsgaard, J.C., Kovar, K. Haarder, E. and Nygaard, E., *Calibration and Reliability in Groundwater Modelling: Credibility of Modelling (IAHS Proceedings & Reports)*, International Association of Hydrological Sciences. 3. Rushton, K.R., Groundwater Hydrology: *Conceptual and Computational Models*, Willey.			

Subject Code: ES6L105	**Subject Name: Neotectonics & Paleoseismology**	**L-T-P: 3-0-0**	**Credit: 3**
Pre-requisite:			

Plate tectonics in relation to Earthquake; Introduction to Neotectonics; Geomorphology of active faults and its impact; Determination of fault slip rates; Age and size of paleoearthquakes; Seismic hazard analyses using geological data; Neotectonic in relations with fluvial geomorphology, land slides; Modern technology to study neotectonism; Field techniques in paleoseismology; Dating techniques in paleoseismology; Assessment of paleoseismic hazard.

Books:

1. Kearey, P., K. A. Klepeis, and F. J. Vine. *Global Tectonics*, Wiley-Blackwell.
2. Khan, M.A., *Tectonics of the Nanga Purbat Syntaxis and the Western Himalaya (Geological Society Special Publication)*, Edited by McCalpin, J. P., Paleoseismology, Academic Press
3. Talwani, P., *Intraplate Earthquakes*, Cambridge University Press
4. Yeats, R., *Active Faults of the World*, Cambridge University Press.

Subject Code: ES6L106	**Subject Name: Reservoir Characteristics & Sedimentology**	**L-T-P: 3-0-0**	**Credit: 3**
Pre-requisite:			

Sediment transportation and hydraulics; Structures of mechanical origin; Bed configuration during sediment transport; Basin characterizations; Basin analysis; Facies models and diagnosis of carbonate rocks; microfacies and pore geometry of reservoir rocks.

Depositional environment and properties of sedimentrary rocks; Reservoir morphology and its characterizations; Reservoir heterogeneity; Reservoir sedimentology of Indian petroliferous basins.

Books:

1. Slatt, R.M., *Stratigraphic reservoir characterization for petroleum geologists, geophysicists, and engineers*: 2nd Edition: 6 (Developments in Petroleum Science, Elsevier Science.
2. Michael J. Economides, Kenneth G. Nolte: *Reservoir Stimulation*, Wiley.
3. Bernard Biju-Duval: *Sedimentary Geology: Sedimentary Basins, Depositional Environments, Petroleum Formation*, Editions Technip.
4. Maurice Tucker, *Sedimentary Petrology*, Wiley-Blackwell.

<table>
<tr><td>Subject Code: ES6L107</td><td>Subject Name: Green Energy</td><td>L-T-P: 3-0-0</td><td>Credit: 3</td></tr>
<tr><td colspan="4">Pre-requisite:</td></tr>
<tr><td colspan="4">Concept of green energy; Various sources of green energy; Principles and techniques of exploiting green energy from various sources; Advantages and disadvantages of various green energy techniques; Solar Thermal Energy; Solar Photovoltaics; Bioenergy; Hydroelectricity; Tidal Power; Wind Energy; Wave Energy; Geothermal Energy; Natural Resource Management.

Books:

1. Donald Steeby, Alternative Energy: Sources and Systems (Green Destination), Cengage Learning, Pro Building Trades.
2. Nelson and Vaughn, C., Introduction to Renewable Energy (Energy and the Environment), CRC Press.
3. John Byrne, Young-Doo Wang , Green Energy Economies: Transaction Publishers</td></tr>
</table>

Subject Code: ES6L108	Subject Name: Applied Rock Mechanics	L-T-P: 3-0-0	Credit: 3
Pre-requisite:			

Rock Mechanics and its applications; Rock rheology; Basic concepts of rock excavation and its utility; Open excavations: dams, reservoirs, canals, outfalls, trenching, cutting, ripping, highways.

Underground excavation: Tunnels, Caverns, Bunkers. Engineering rock properties and its applications and determination; In-situ stress measurement techniques: flat jack, hydro-fracturing, drilling and blasting practices; water-rock interaction - effect on physical properties, stress-distribution in and around openings, stabilization and strengthening of structures.

Soil/rock transportation and erosion, fluid migration through porous media and its effects on time dependent behaviour of rock; Rock dynamics; Rock mechanics aspects of reservoir performance; Fracture mechanics; Damage mechanics and naturally fractured reservoirs; Numerical and physical modelling for rock excavations; earth pressure theories; settlement analysis; liquefaction; rock mass rating for design and construction; health monitoring of various type of structures; rock engineering system.

Books:

1. Jaeger, J. and N. G. Cook, *R. Zimmerman. Fundamentals of Rock Mechanics. Wiley-Blackwell*.
2. Bell, F. G., *Engineering Geology*, Elsevier.
3. Waltham, T., *Foundations of Engineering Geology*, Spon Press.

Subject Code: ES6L109	Subject Name: Natural Gas Hydrates: Energy potential and Environment	L-T-P: 3-0-0	Credit: 3
Pre-requisite:			

Introduction to gas hydrates; Importance of gas hydrates; Various hydrate structures; Hydrate formation conditions; Clathrates; Origin of the methane in clathrates; Experimental techniques in determining the hydrate stability zone; Sample preparation; Predictive techniques; Case histories; Challenges in natural gas hydrate exploration; Environmental impact of gas hydrate; Clathrates of agents as climate change; Potential natural gas hydrates resources in India; Challenges in natural gas hydrate research.

Books:

1. Giavarini, Carlo and Hester, Keith, Gas Hydrates: *Immense Energy Potential and Environmental Challenges*, Springer
2. Thakur, N. K. and S. Rajput. *Exploration of Gas Hydrates*, Springer.
3. Sawhney, G.S., *Non-Conventional Energy Resources*, PHI Learning Private Limited.
4. Collett, T., A. Johnson, C. Knapp, R. Boswell, *Natural Gas Hydrates Energy Resource Potential and Associated Geologic Hazards, American Association of Petroleum Geologists*.

Subject Code: ES6L110	Subject Name: Carbon Capture & Sequestration	L-T-P: 3-0-0	Credit: 3
Pre-requisite:			

Carbon sources; Capture processes- Fuel Gas Separation; Oxy-Fuel Combustion; Pre-Combustion Capture; CO2 storage- Geologic Storage; Ocean Storage; Economics; Alternate approaches.

Books:

1. Smit, B., Reimer, J.R., Oldenburg, C.M., and Bourg, I.C., *Introduction to Carbon Capture and Sequestration (Berkeley Lectures on Energy)*, Imperial College Press
2. Steve Rackley, *Carbon Capture and Storage*, Butterworth-Heinemann.
3. Jennifer Wilcox, *Carbon Capture*, Springer.

Subject Code: ES6L111	Subject Name: Applied Coal Petrography & Coal Bed Methane	L-T-P: 3-0-0	Credit: 3
Pre-requisite:			
Coal depositional environments; Controls on coal quality; Coal occurrence; Maceral (kerogen) types; Liquid- vs. gas-prone kerogen; Effects of maceral type on gas sorption and diffusion; Coal bed gas origin; Thermal maturity of coal; Coal bed gas composition and heating value; Coal bed permeability; Estimation of coal tonnage and gas volume; Coal bed exploration models; Case studies. Books: 1. Seidle, J., *Fundamentals of Coalbed Methane Reservoir Engineering*, PennWell Corporation 2. D.W. van Krevelen, Coal, Third Edition: *Typology - Physics - Chemistry - Constitution (Coal Science & Technology)*, Elsevier Science 3. Isabel Suárez-Ruiz, John C. Crelling, *Applied Coal Petrology: The Role of Petrology in Coal Utilization*, Academic Press			

Subject Code: ES6L112	Subject Name: Paleoceanography and Paleoclimatology	L-T-P: 3-0-0	Credit: 3
Pre-requisite:			

Paleoceanographic changes in relation to earth system history including impact of the oceans on climate change; Evolution of oceans through the Cenozoic; Ocean gateways and their role in controlling global climates; Reconstructing Quaternary climatic and oceanographic history on shorter time scales using marine records; Mineral resources of the ocean including polymetallic nodules; Hydrocarbons beneath the sea floor; Marine gas hydrates and their economic potential

Different types paleoclimatic proxies; their applicability and limitations; Instrumental records; Historical written records; Tree rings; speleothem; Ice cores; Coral reefs: hundred thousands of years; Lake sediments; Deep ocean sediments; Sediments on land/shallow ocean.

Books:

1. Murray-Wallace, Colin V. and Woodroffe, Colin D., *Quaternary Sea-Level Changes: A Global Perspective*, Cambridge University Press
2. Bradley, R.S., Paleoclimatology; *Reconstructing climates of the Past*. Elesevier
3. Fairchild, Ian J. and Baker, Andy, *Speleothem Science: From Process to Past Environments*, Willey-Blackwell
4. Hillaire-Marcel, C. and de Vernal, Ann, *Proxies in Late Cenozoic Paleoceanography: 1 (Developments in Marine Geology)*, Elsevier Science
5. Kennth, J.P., *Marine Geology*, Prentice Hall

Subject Code: ES6L113	Subject Name: Advanced Glaciology	L-T-P: 3-0-0	Credit: 3
Pre-requisite:			

Glaciers-formation and movement; Glacier mass balance; Ice core analyses; Glacier dynamics; Glacier hydrology; Temperature conditions in glaciers; Remote sensing techniques in glaciology; Dynamic meteorology; Review of past changes in Earth's climate system with emphasis on the climate during the Quaternary period, Climate change causes; Techniques used to reconstruct paleoclimate records from ice cores.

Books:

1. Bennett, Matthew M. and Glasser, Neil F., *Glacial Geology: Ice Sheets and Landforms*, Willey
2. Jouzel, Jean, Lorius, Claude and Raynaud, Dominique, *The White Planet: The Evolution and Future of Our Frozen World*, Princeton University Press
3. Douglas Benn and David J A Evans , *Glaciers and Glaciation* , Routledge

Subject Code: ES6L114	**Subject Name: Hydrocarbon Basin Modelling**	**L-T-P: 3-0-0**	**Credit: 3**
Pre-requisite:			
Chemical composition and physical properties of petroleum crude; Origin of petroleum; Migration of oil and gas. Reservoir rocks classification and petrophysical properties; Hydrocarbon traps – definition and classification; structural, stratigraphic and combination traps. Plate tectonics and global distribution of hydrocarbon reserves. Petroliferous basins of India: classification and tectonic setup. Books: 1. A.G. Doré, J.H. Augustson, C. Hermanrud and D.J. Stewart, *Basin Modelling: Advances and Applications (Norwegian Petroleum Society Special Publications)*, Elsevier Science 2. Dietrich H. Welte, Brian Horsfield and Donald R. Baker *Petroleum and Basin Evolution: Insights from Petroleum Geochemistry, Geology and Basin Modeling*, Springer. 3. Thomas Hantschel , Armin I. Kauerauf, *Fundamentals of Basin and Petroleum Systems Modeling*, Springer			

Subject Code: ES6L115	Subject Name: Ocean Resources & Technology	L-T-P: 3-0-0	Credit: 3
Pre-requisite:			

Ocean boundaries; Fundamentals of marine geological principles; Geomorphology and structure of the Ocean floor; continental slope and shelf; Marine sediments: their formation, types, distribution and classification; Distribution of marine minerals along the Indian Coasts; Marine geo-physical technology; prospecting for oil-bearing strata; natural gas and oil traps; Marine mineral resources: Placer deposits hydrocarbon deposits and polymetallic nodules; Exploration and exploitation of natural minerals off the coast; Energy from oceans – Tides,Waves, Currents, Salinity and Thermal gradients with special reference to Indian coast; Energy converters for extraction of ocean energy - Design principles of wave power, tidal power and OTEC systems; Cost-benefit analysis autonomous underwater vehicle (AUV); ocean bottom features by swath bathymetry.

Books:

1. Kennth, J.P., *Marine Geology*, Prentice Hall
2. Hallwood, P., *Economics of the Oceans: Rights, Rents and Resources (Routledge Textbooks in Environmental and Agricultural Economics)*, Routledge
3. P.A. Floyd, *Ocean Basalt*, Springer

Subject Code: ES6L116	Subject Name: Advances in Polar Geosciences	L-T-P: 3-0-0	Credit: 3
Pre-requisite:			

Overview of Polar Geography and Climate; History of Indian Antarctic programme; Physical characteristics, weather and climate, ice coring in Antarctica for Paleo-environment studies, logistics of Antarctic Science, opportunities; Antarctic governance and protection of Antarctic environment, International linkages.

Ice characteristics and physical oceanography of polar seas; Sea ice: types, physical and mechanical properties, heat flux, temporal and spatial distribution; Melting and freezing processes; Forecasting models and remote sensing of ice/snow covered surfaces; Physical oceanography of currents and water masses; Deep and bottom water formation, fronts and eddies; Polynya processes and underwater acoustics.

Books:

1. Anderson, J.B., *Antarctic Marine Geology*, Cambridge University Press
2. Alessandro Capra and Reinhard Dietrich, *Geodetic and Geophysical Observations in Antarctica: An Overview in the IPY Perspective*
3. Walker O. Smith Jr., *Polar Oceanography: Chemistry, Biology, and Geology*, Academic Press.
4. John B. Anderson, *Antarctic Marine Geology*, Cambridge University Press.

Subject Code: ES6L117	**Subject Name: Isotope Hydrology**	**L-T-P: 3-0-0**	**Credit: 3**
Pre-requisite:			

Hydrological cycle and Water Balance; Stable water isotopes and isotopic fractionation; Rayleigh's Distillation Process; Spacio/temporal distributions of precipitation water isotopes; Application of Isotope hydrology; Global meteoric water line; Local meteoric water line; Radioactive isotopes in water; Research potential in Isotope Hydrology; Isotope fingerprinting of water and India.

Books:

1. M. S. Rao and Gopal Krishan, *Isotope Hydrology*, LAP LAMBERT Academic Publishing
2. Aggarwal, P., *Isotope Hydrology (Benchmark Papers in Hydrology), International Association of Hydrological Science*
3. Gat Joel R, *Isotope Hydrology*, World Scientific Publishing Company.
4. Ian D. Clark, Peter Fritz, *Environmental Isotopes in Hydrogeology*, CRC Press

Subject Code: ES6L118	**Subject Name: Mineral Resources: Exploration & Management**	**L-T-P: 3-0-0**	**Credit: 3**
Pre-requisite:			
Various mineral resources- occurrences; nature and characteristics; Geological exploration techniques; Geophysical exploration techniques; Geochemical exploration techniques; Sustainable mining practices; Environmental restoration; Impact of mineral resources on increasing population. Books: 1. Telford, W.M., L.P. Geldart, and R. E. Sheriff. *Applied Geophysics*, Cambridge University Press. 2. Charles J. Moon, Michael K. G. Whateley, Anthony M. Evans. *Introduction to Mineral Exploration*, Blackwell Publishing. 3. Marjoribanks, R., Geological Methods in Mineral Exploration and Mining, Springer			

<table>
<tr><td>Subject Code: ES6L119</td><td>Subject Name: Advanced Petrology</td><td>L-T-P: 2-0-2</td><td>Credit: 3</td></tr>
<tr><td colspan="4">Pre-requisite:</td></tr>
<tr><td colspan="4">Feldspars, Amphiboles and Sheet Silicates; Mid-Oceanic Ridge basalt and its chemical composition; Magma mixing and crustal contamination; Continental Basalt and its chemical composition; Volcanic eruption mechanism and processes; Phase petrology and its application to magmatic and metamorphic system; Geothermobarometry; Kinetics of rock forming process; Microstructures and chemical zonation.

Books:
1. Harvey Blatt, Robert Tracy and Brent Owens, Petrology: Igneous, Sedimentary, and Metamorphic, W. H. Freeman
2. John D. Winter, Principles of Igneous and Metamorphic Petrology, Prentice Hall
3. L. L. Perchuk, Progress in Metamorphic and Magmatic Petrology: A Memorial Volume in Honour of D. S. Korzhinskiy, Cambridge University Press</td></tr>
</table>

Subject Code: ES6L120	Subject Name: Applied Micropaleontology	L-T-P: 2-0-2	Credit: 3
Pre-requisite:			

Definition and scope of the subject; Relationship of micropaleontology with ocean sciences; Modern field and laboratory techniques in the study of microfossils; A brief account of the concepts and methods for the development of micropaleontological indicators useful in reconstruction of history of past; Environmental changes and biostratigraphic correlation.

Types of Microfossils; Calcareous Microfossils, Siliceous Microfossils, Phosphatic Microfossils, Organic Walled Microfossils; Application of Micropaleontology in petroleum exploration; Environmental significance of microfossils; Geochemical study of microfossil tests (stable isotopes; radiocarbon isotopes and elemental composition) and its application in paleoceanography and paleoclimatology and tracing history of marine pollution; Interpretaion of sea floor tectonism from micropaleontological evidence.

Books:

1. Haq, B.U. and Boersma, A, *Introduction to Marine Micropaleontology*, Elsevier Science
2. Martin, R.E., *Environmental Micropaleontology*: The Application of Microfossils to Environmental Geology (Topics in Geobiology), Springer
3. Jones, R.W., *Foraminifera and their Applications*, Cambridge University Press

ELECTIVES IV, V & VI			
Subject Code: ES6L203	**Subject Name: Borehole Geophysics**	**L-T-P: 3-0-0**	**Credit: 3**
Pre-requisite:			
Principles methods and applications; Subsurface Formation evaluation; Oil well technology; Drilling fluids; Logging techniques including neutron techniques; Image scanning methods; Data acquisition and interpretation; M-N plots; Estimation of physical parameters of rock formations; case studies. Books: 1. Labo, J. A *Practical Introduction to Borehole Geophysics*: *An Overview of Wireline Well Logging Principles for Geophysicists*. 2. Kobr, M. and S. Mares, and F. Paillet. *Geophysical Well Logging*. Springer. 3. Keys, W. S., *A Practical Guide to Borehole Geophysics in Environmental Investigations*. CRC Press.			

Subject Code: ES6L204	Subject Name: Geophysical Tomography	L-T-P: 3-0-0	Credit: 3
Pre-requisite:			
Theory and geometry of seismic waves; Seismic velocity of rocks; Characteristics of seismic events; Seismic sources and equipment; Seismic reflection and refraction field methods; CDP technique; Seismic noise; Velocity measurements; Marine seismic surveys; Data processing – convolution, correlation, filtering, velocity analysis, stacking and migration; Synthetic seismograms; Seismic interpretation. Fundamental concepts of inverse theory with application to Geophysics; Probability, inverses with discrete and continuous models; Inverse methods based on length; Generalized matrix inverses and maximum likelihood methods, non uniqueness, applications of vector spaces, resolving kernels, use of prior information, singular value decomposition, non-linear inverse problems, continuous inverse theory and tomography; Backus-Gilbert inverse problem; Applications of inverse theory to geophysics. Books: 1. Yilmaz, O., *Seismic Data Processin*g, Society of Exploration Geophysics (SEG). 2. Lo, T. and P. L. Inderwiesen, *Fundamentals of Seismic Tomography*, SEG. 3. Aster, R. C. and Borchers, B. and Thurber, C. H.,*Parameter Estimation and Inverse Problems*. Academic Press.			

Subject Code: ES6L205	Subject Name: Airborne Geophysical Survey: tools and techniques	L-T-P: 3-0-0	Credit: 3

Pre-requisite:

Introduction to Airborne geophysical survey; Types and techniques for airborne geophysical survey; Importance of Airborne geophysical survey; Principles, advantages and disadvantages; Qualitative and quantitative interpretation of various airborne survey data.

Books:

1. Stewart, P. G. and I. F. Jones, P. B. Hardy. *Solutions for Deep Water Imaging*. SPG, Geohorizons.
2. Blondel, P., *The Handbook of Sidescan Sonar*, Springer.
3. Aboelkhair, H. : *Application Of Airborne Geophysical Survey Data: In Geological Mapping, Mineral Exploration And Environmental Monitoring Of Bahariya Oases, Northern Western Desert, Egypt*. Vdm Verlag Dr. Müller.
4. Zhdanoy, M. S., *Geophysical Electromagnetic Theory and Methods (Methods in Geochemistry and Geophysics)*, Elsevier Science.
5. Michael Dentith, Stephen T. Mudge. *Geophysics for the Mineral Exploration Geoscientist*, Cambridge University Press.

Subject Code: ES6L206	**Subject Name: Deep water imaging**	**L-T-P: 3-0-0**	**Credit: 3**

Pre-requisite:

Introduction: Deep water-Indian and World Scenario; Deepwater depositional System; Deepwater challenges and strategy; Problems associated with seismic in deep water imaging; Marine Controlled Source Electromagnetic (MCSEM): Physics of MCSEM; EM boundary condition and attenuation; Numerical studies and case studies; Principles of marine magneto-telluric and case studies.

Books:

1. Aboelkhair, H. *Application of airborne geophysical survey data: in geological mapping, mineral exploration and environmental monitoring of bahariya oases, northern western desert, Egypt*. Vdm Verlag Dr. Müller.
2. Zhdanoy, M. S., *Geophysical Electromagnetic Theory and Methods (Methods in Geochemistry and Geophysics)*, Elsevier Science.
3. Stewart, P. G. and I. F. Jones, P. B. Hardy. *Solutions for Deep Water Imaging*. SPG, Geohorizons.
4. Blondel, P., *The Handbook of Sidescan Sonar*, Springer.
5. Biondo L. Biondi, 3D *Seismic Imaging (Investigations in Geophysics No. 14)*, Society of Exploration Geophysicists.

Subject Code: ES6L207	Subject Name: Seismology	L-T-P: 3-0-0	Credit: 3
Pre-requisite:			

Introduction to seismology; Elasticity; Stress-strain relationships; Equations of motion, seismic wave equations; Body waves and ray theory; Partitioning of energy; Attenuation, anisotropy and anelasticity; Travel times in layered media; Surface waves dispersion and free oscillations; Seismometry and Principles of Digital seismographs; Seismic observatory practices; Seismogram interpretation – Nomenclature of seismic phases; Body wave travel times in earth; Internal structure and composition of the earth; Earthquakes – Seismic sources, Directivity, Scaling laws, Magnitude scales, Location; Focal mechanisms; Moment tensors; Stress drop; Earthquake characteristics, effects and distribution; Seismotectonics; Earthquake prediction; Seismic hazard and risk; Waveform modelling and Inverse problems.

Books:

1. Shearer, Peter M., *Introduction to Seismology*, Cambridge University Press.
2. Aki, K. And P. G. Richards, *Quantitative Seismology*, University Science Books.
3. Lay, T. And T. Wallace, *Modern Global Seismology*, Academic Press
4. Tarantola, A. *Inverse Problem Theory and Methods for Model Parameter Estimation*, SIAM

Subject Code: ES6L208	Subject Name: Aqueous Environmental Geochemistry	L-T-P: 2-0-2	Credit: 3
Pre-requisite:			
Shallow earth interactions in emphasizing: Groundwater geochemistry; Elemental cycles linked to biological activity in the oceans; Geochemistry and global climate cycles; Geo-bioremediation and applied analytical techniques. Books 1. Peter Ryan, *Environmental and Low Temperature Geochemistry*, Wiley-Blackwell. 2. Charles R. Fitts, *Groundwater Science, Second Edition*, Academic Press. 3. C.A.J. Appelo, Dieke Postma, *Geochemistry, Groundwater and Pollution*, Second Edition, Taylor & Francis.			

<table>
<tr><td>Subject Code: ES6L209</td><td>Subject Name: Organic Environmental Geochemistry</td><td>L-T-P: 2-0-2</td><td>Credit: 3</td></tr>
<tr><td colspan="4">Pre-requisite:</td></tr>
<tr><td colspan="4">Introduction, production, preservation and degradation of organic matter in different environments; Determination of soil organic carbon concentrations; Chemical composition and different organic compound classes; Extraction and fractitation of Humic acid; Fulvic acid and Humin. Surface charge density; Electrostatic model; Metal adsorption; Redox potentials; Redox reactions; Photo-induced electron transfer reactions. Mobilization and immobilization of elements; Detoxification of pollutants.
1. Rene P. Schwarzenbach, Philip M. Gschwend, Dieter M. Imboden, Environmental Organic Chemistry, Wiley-Interscience.
2. Richard A. Larson , Eric J. Weber, Reaction Mechanisms in Environmental Organic Chemistry, CRC Press.
3. Richard A. Larson , Eric J. Weber, Reaction Mechanisms in Environmental Organic Chemistry, CRC Press.</td></tr>
</table>

Subject Code: ES6L210	Subject Name: Application of Petroleum Geochemistry in Exploration and Production	L-T-P: 3-0-0	Credit: 3
Pre-requisite:			

Petroleum source rock, oil, and natural gas evaluation using various organic and inorganic tools; Oil and gas generation, migration, and accumulation processes; Petroleum system analysis; Unconventional petroleum resources: shale gas and coal bed methane; Reservoir geochemistry applications such as indentification of productive and non-productive zones, predicting gas, oil, and water interfaces, reservoir conncetivity indentification, and predicting oil quality. Case studies.

Books

1. S.A. Tedesco, *Surface Geochemistry in Petroleum Exploration*, Springer.
2. Colin Barker, *Organic geochemistry in petroleum exploration*. AAPG Bookstore.
3. R. E. Chapman, *Petroleum Geology*, Elsevier Science.

Subject Code: ES6L211	Subject Name: Environmental Geosciences	L-T-P: 3-0-0	Credit: 3
Pre-requisite:			

Introduction to Natural hazards – earthquakes, tsunamis, volcanoes, landslides, avalanches, floods, cyclones, mine, fire and blow out; Causes, risk and mitigation of natural hazards; Mechanics of recent and historical earthquakes; Seismic risk and hazard; Earthquake prediction; Types of volcanism; Styles of eruption; Forecasting and mitigation of volcano hazard; Tsunami – causes and prediction; Prediction and prevention of landslides; Landslide zonation and risk assessment; Flood hazard and mitigation; geological hazards - vulnerability and risk assessment using GIS; Environmental hazards – Nuclear waste; Ground water pollution; Important case studies of natural hazards.

Books:

1. Gasparini, P., G. Manfredi, and J. Zschau. Earthquake Early Warning Systems, Springer.
2. Boris, L. and M. Nosov. Physics of Tsunamis, Springer
3. Edward A. Keller Environmental Geology, Prentice Hall

Subject Code: ES6L212	Subject Name: Mass & Heat Transfer in Solid Earth	L-T-P: 3-0-0	Credit: 3
Pre-requisite:			

Diffusive heat transfer; Measurement of surface heat flow. Heat sources and sinks: Radiogenic heating and release of latent heat during crystallisation of melts, shape of crustal isotherms; Transients, cooling of oceanic crust and mid-ocean ridges, contact metamorphism, intrusion of igneous bodies; Advective transfer; effect of uplift and erosion on the thermal structure of mountain belts; Natural and forced thermal convection of melt in the Earth's mantle and aqueous fluids in the Earth's crust.

Mass transfer in Earth's interior; Applications of mass transfer to magma generation and transport; Case studies-ocean ridges; trenches; continental rift systems; mantle plumes.

Books:

1. Fowler, C. M. R. The Solid Earth: *An Introduction to Global Geophysics*. Cambridge University Press.
2. Schubert, G., D. L. Turcotte, and P. Olson. *Mantle Convection in the Earth and Planets*, Cambridge University Press.
3. Turcotte, D. L. and G. Schubert. *Geodynamics*, Cambridge University Press.
4. Condie, K. C., *Mantle Plumes and Their Record in Earth History*, Cambridge University Press.

Subject Code: ES6L213	**Subject Name: Atmospheric Chemistry and Toxicology**	**L-T-P: 3-0-0**	**Credit: 3**
Pre-requisite:			

Introduction to toxicology of atmospheric organic matter and poly aromatic hydrocarbons (PAHs); Coal and petroleum emissions of PAHs and heavy metals; Atmospheric pollutants: photochemical smog, acid rain; Halocarbons and stratospheric ozone and Greenhouse gasses; Introduction to Global Climate: Past, Present and Future; Atmospheric chemistry; Atmospheric pollutants: environmental radioactive nuclides, their applications and hazardous issues

Books

1. John H. Seinfeld , Spyros N. Pandis, *Atmospheric Chemistry and Physics: From Air Pollution to Climate Change*, Wiley-Interscience.
2. Barbara J. Finlayson-Pitts , James N. Pitts Jr., *Chemistry of the Upper and Lower Atmosphere: Theory, Experiments, and Applications*, Academic Press.
3. Peter Fogg, James Sangster, *Chemicals in the Atmosphere: Solubility, Sources and Reactivity*, Wiley.

Laboratory Courses:

Subject Code: ES6P102	Name: Advance Instrumentation Lab.	L-T-P: 0-0-3	Credit: 2
Destructive and non-destructive methods of analysis of geological materials involving X- Ray Diffraction method, Energy Dispersive and Wavelength Dispersive X-ray Fluorescence, ICP-MS, Spectrophotometer, Flame Photometer and Ion Chromatograph. Basic principles, Sample preparation, Calibration of Equipment, Quality control mechanism; precession and accuracy of the instrument.			

Subject Code: ES6P201	Name: Shallow Surface Geophysics Lab.	L-T-P: 0-0-3	Credit: 2
Data acquisition using Resistivity meter: Vertical Electrical Sounding (VES); Electrical profiling; Processing of data; Interpretation of data; Resistivity array evaluation; Self potential survey; Relative meter; Data acquisition in seismic reflection and seismic refraction method; Processing and Interpretation of Seismic data.			

Subject Code: ES6L202	Name: Mathematical & Computational Geosciences Lab.	L-T-P: 0-0-3	Credit: 2
Test of significance; SPSS and other statistical software; FFT; Spectral analysis; Multivariate analysis of climate data; Programming in MATLAB.			

Curriculum for Joint M.Tech.-Ph.D. (Climate Science and Technology)

Subject Name	Code	L-T-P	Credit	Contact Hour
SEMESTER - I				
Physics of Atmosphere and Ocean	CL6L101	4-0-0	4	4
Dynamics of Atmosphere and Ocean	CL6L102	4-0-0	4	4
Earth and Its Interior	CL6L103	2-1-0	3	3
Elective - I	CL6L1XX	3-0-0	3	3
Elective - II	CL6L1XX	3-0-0	3	3
Elective - III	CL6L1XX	3-0-0	3	3
Weather Analysis and Forecasting Laboratory	CL6P101	0-0-3	2	3
Seminar - I	CL6S101		2	**0**
	Total :	**19-1-3**	**24**	**23**
SEMESTER - II				
Simulations of Atmospheric and Oceanic Processes	CL6L201	4-0-0	4	4
Planetary and Marine Boundary Layer	CL6L202	4-0-0	4	4
Elective - IV	CL6L2XX	3-0-0	3	3
Elective - V	CL6L2XX	3-0-0	3	3
Elective - VI	CL6L2XX	3-0-0	3	3
Remote Sensing and GIS Laboratory	CL6P201	0-0-3	2	3
Modelling and Visualization Laboratory	CL6P202	0-0-3	2	3
Seminar - II	CL6S201		2	0
	Total :	**17-0-6**	**23**	**23**
SEMESTER - III				
Thesis Part - I	CL6D301	0-0-0	16	0
Research Review Paper-I	CL6D302	0-0-0	4	0
		Total :	**20**	**0**
SEMESTER – IV				
Thesis Part - II	CL6D401	0-0-0	16	0
Research Review Paper-II	CL6D402	0-0-0	4	0
		Total :	**20**	**0**

Total Credit: 87

List of Elective Subjects (Climate Science and Technology)

Subject Name	Code	L-T-P	Credit	Contact Hour
Elective – I to III				
Advanced Computational Fluid Dynamics	CL6L111	3-0-0	3	3
Advanced Dynamic Meteorology	CL6L112	3-0-0	3	3
Advanced Dynamic Oceanography	CL6L113	3-0-0	3	3
Agro-meteorology	CL6L114	2-0-0	2	2
Aqueous Environmental Geochemistry	CL6L115	2-0-0	2	2
Assessing the Impact of Climate Change	CL6L116	2-0-0	2	2
Data Structure and Information Technology	CL6L117	3-0-0	3	3
Atmospheric Diffusion and Air Pollution	CL6L118	3-0-0	3	3
Ocean Colour and Applications	CL6L119	3-0-0	3	3
Climate Change and Sustainability	CL6L120	2-0-0	2	2
Climate Risk Assessment in Agriculture	CL6L121	2-0-0	2	2
Climate Variability & Global Warming	CL6L122	3-0-0	3	3
Instrumentation and Observation Systems	CL6L123	3-0-0	3	3
Mesoscale Meteorology	CL6L124	3-0-0	3	3
Science of Climate and Climate Change	CL6L125	3-0-0	3	3
Mountain Meteorology	CL6L126	3-0-0	3	3
Marine Resources & Technology	CL6L127	3-0-0	3	3
Satellite Oceanography and Meteorology	CL6L128	3-0-0	3	3
Elective – IV to VI				
Atmospheric Chemistry & Aerosol	CL6L211	3-0-0	3	3
Glaciology and Paleoclimate	CL6L212	3-0-0	3	3
Climate Change Impact and Adaptation	CL6L213	2-0-0	2	3
High Performance Computing in Earth System Science	CL6L214	3-0-0	3	3
Marine Biotechnology	CL6L215	2-0-0	2	2

Subject Name	Code	L-T-P	Credit	Contact Hour
Marine Pollution and Coastal Zone Management	CL6L216	3-0-0	3	2
Mathematical and Statistical Methods in Earth System Science	CL6L217	3-0-0	3	3
Mesoscale Atmospheric Modeling	CL6L218	3-0-0	3	3
Mitigation Climate Change Vulnerability	CL6L219	3-0-0	3	3
Modeling of Air-Sea Interactions	CL6L220	3-0-0	3	3
Modeling of Dynamic Processes of Ocean &Atmosphere	CL6L221	3-0-0	3	3
Modeling of Extreme Events	CL6L222	3-0-0	3	3
Modeling of the Climate	CL6L223	3-0-0	3	3
Neural Networks and Applications	CL6L224	3-0-0	3	3
Objective Analysis and Data Assimilation	CL6L225	3-0-0	3	3
Ocean Circulation and Wave Modeling	CL6L226	3-0-0	3	3
Ocean Resources & Technology	CL6L227	3-0-0	3	3
Ocean State Forecasting and Modeling	CL6L228	3-0-0	3	3
Parameterization of Physical Processes	CL6L229	3-0-0	3	3
Remote Sensing and GIS Applications	CL6L230	3-1-0	3	4
Satellite and Radar Meteorology	CL6L231	3-0-0	3	3
Tropical Meteorology	CL6L232	3-0-0	3	3
Weather Analysis and Forecasting	CL6L233	3-0-0	3	3

Syllabus

Core Subjects:

Subject Code:: CL6L101	Name: Physics of Atmosphere And Ocean	L-T-P: 4-0-0	Credit: 4
Pre-requisite(s):			

Thermodynamics of dry air, thermals; Thermodynamic of moist air: thermodynamic properties of water; Clausius-Clapeyron (C-C) equation, moist processes in the atmosphere, adiabatic; saturated and unsaturated accent, Thermodynamic diagrams, Moist convection, formation of cloud droplets, precipitation, thermodynamics of sea water, Processes at the sea surface, salinity, bulk temperature, measurement techniques of SST; heat flux and its global distribution, Sea surface hydrology, Polar Oceanography.

Text/Reference Books:

1. J M Wallace and Peter V Hobbs: *Atmospheric Science, Second Edition: An Introductory Survey*, International Geophysics
2. J R Holton and George J Hakim: *An Introduction to Dynamical Meteorology*, International Geophysics Series
3. Murry L. Salby:*Fundamental of Atmospheric Physics*, Academic Press
4. John A. Knauss. *Introduction to physical oceanography*
5. Lynne D. Talley:*Descriptive physical oceanography : an introduction*, Academic Press
6. John Ralph Apel:*Principles of Ocean Physics*
7. Reza Malek-Madani: *Physical Oceanography: A Mathematical Introduction with MATLAB,* Chapman and Hall

Subject Code: : CL6L102	Name: Dynamics of Atmosphere And Ocean	L-T-P: 4-0-0	Credit: 4

Pre-requisite(s):

Fundamentals of Geophysical Fluid Dynamics, Equations of motion in rotating frame; potential vorticity conservation, Simplified equations for ocean and atmosphere; Instabilities and Waves, Large-Scale Atmospheric Circulation Equatorial dynamics, heat-induced tropical circulations; Mid-latitude circulation; planetary waves and stratosphere; Ocean Dynamics: Ekman layers, Sverdrup transport, western boundary currents; Large-scale ocean circulation; Response of ocean to a moving storm or hurricane; oceanic mixed layer.

Text/Reference Books:

1. Gill A: *Dynamics of Ocean and Atmosphere*, Academic Press
2. S. Pond and G L Pickard*: Introductory Dynamical Oceanography*, Butterworth-Heinemann
3. John A. Knauss. *Introduction to physical oceanography*,Waveland PrInc
4. Joseph Pedlosky. *Waves in the Ocean and Atmosphere: Introduction to Wave Dynamics*, Springer
5. Neumann and Pierson, *Introduction to principles of dynamic oceanography*

Subject Code:: CL6L103	Name: Earth and its Interior	L-T-P: 2-1-0	Credit:3
Pre-requisite(s):			

Earth and Planetary system; origin, size, shape, mass, density, rotational parameters; Internal structure and composition of the earth; characteristics and elemental abundance in different layers, Convection in earth's core and production of its magnetic field, Radioactivity and age of the Earth.Isostasy; elements of seismology; continents and continental processes; paleomagnetism, continental drift, plate tectonics. Weathering and erosion processes on the earth surface; earthquakes, volcanoes; basic concepts of gravity, magnetic and electrical prospecting for ores and ground water.

Text/Reference Books:

1. CesareEmiliani, Planet Earth*: Cosmology, Geology, and the Evolution of Life and Environment :* Cambridge University Press
2. James F. Luhr, *Earth;* Cambridge University Press
3. C.M. R. Fowler, *The Solid Earth: An introduction to Global Geophysics:* Cambridge University Press
4. W. Lowrie, *Fundamentals of Geophysics:* Cambridge University Press

Subject Code: : CL6L201	Name: Simulation of Atmospheric and Oceanic Processes	L-T-P: 4-0-0	Credit: 4
Pre-requisite(s):			

Governing equations for Atmospheric and Oceanic Processes: continuous equations, map projections, vertical coordinate system, wave oscillations in the atmosphere and Ocean, filtering approximations. Numerical methods: finite-difference methods, time and space differencing, stability analysis; spectral method, spherical harmonics, boundary conditions. Numerical models: Global models, regional models, mesoscale, coupled models. Principal of Coupling Air-Sea Interaction Processes, Parameterization of sub-grid scale physical processes: planetary boundary layer, moist microphysics physics, cumulus convection, radiation, air-sea interaction processes, and land surface processes. Data assimilation: Objective analysis schemes, continuous data assimilation techniques - 3D & 4D Variational assimilation; initialization. Predictability and Ensemble forecasting.

Text/Reference Books:

1. Kantha and Carol Anne Clayson, *Numerical Models of Oceans and Oceanic Processes*, Acdemic press
2. James C. McWilliams. *Fundamentals of Geophysical Fluid Dynamics*, Cambridge University Press.
3. Mark Z Jacobson. *Fundamentals of Atmospheric Modeling*, Cambridge University Press.

Subject Code:: CL6L202	Name: Planetary and Marine Boundary Layer	L-T-P: 4-0-0	Credit:4
Pre-requisite(s):			

Introduction: definitions and background, variables, wind and flow, turbulent transports; Taylor's hypothesis and observing techniques, boundary layer depth and structure Mathematical and conceptual tools: Turbulence and its spectrum; spectral gap; mean and turbulent parts; basic statistical methods; rules of averaging; turbulent kinetic energy; kinematic flux, eddy flux; stresses.

Governing equations for turbulent flow: methodology, basic equations, simplifications and approximations, equations for mean variables in a turbulent flow. Mixed layer theory: mixing and entropy; governing equations, model behaviour, surface fluxes and entrainment.

Cloud-topped boundary layers: moisture variables; radiative processes, observed structure; governing equations, entrainment. Trade wind boundary layer: mean structure and fluxes; moist convective processes; sub-cloud layer interactions; strato-cumulus to trade cumulus transitions.

Deep convection and Marine boundary layer: controls on deep convection; MABL modification by downdrafts; boundary layer recovery; boundary layer modeling and parameterizations.

Text/Reference Books:

1. Roland B. Stull . *An Introduction to Boundary Layer,* Springer
2. E. B. Kraus. *Atmosphere-Ocean Interaction,* Oxford University Press.
3. J. R. Garratt .*The Atmospheric Boundary Layer* , Cambridge University Press.
4. R.M. Stewart:*The Atmospheric Boundary Layer",* WMO-523.

Electives (I, II, III):

Subject Code:: CL6L111	**Name: Advanced Computational Fluid Dynamics**	**L-T-P: 3-0-0**	**Credit:3**
Pre-requisite(s):			

Governing Equation of Fluid Dynamics, Conservation Form, Simple C F D Techniques, Lax-Wendroff Technique, Mac Cormack's Techniques, Finite volume method, Application to Euler equations, upwind difference scheme, Viscous flow solutions, staggered grid, SIMPLE Algorithm, SOLA Algorithm, Boundary Element method and application to potential flows.

Text/Reference Books:

1. J.H. Ferziger and M. Peric, *Computational Methods for Fluid Dynamics.*Springer.
2. C. Hirsch, *Numerical Computation of Internal and External Flows. Vol. I and II.* John Wiley & Sons.

Subject Code:: CL6L112	Name: Advanced Dynamic Meteorology	L-T-P: 3-0-0	Credit:3
Pre-requisite(s):			

Quasi-geostrophic analysis, circulation and vorticity theorems, Ertel-Rossby invariants, Ertel's PV conservation theorem, Thomson's and Bjerknessbaroclinic circulation theorem, quasi-geostrophic turbulence; barotropic and baroclinic instabilities, symmetric instabilities; quasi-geostrophic motion in equatorial area, heat induced tropical circulations; Rossby waves, internal gravity waves, vertically propagating waves, Rossby adjustment theory; middle atmospheric dynamics, sudden stratospheric warming, QBO; general circulation of the atmosphere, dynamical oceanography.

Text/Reference Books:

1. J R Holton and Geroge J Hakim:*An introduction to Dynamical Meteorology,* International Geophysics Series.
2. George J.Haltiner and Frank L.Martin:*Dynamical and physical Meteorology,* International Geophysics Series
3. George J Haltiner and Roger T Williams: *Numerical Prediction and Dynamical Meteorology,* John Wiley & Sons
4. B.Haurwitz*, Dynamic Meteorology,* Mcgraw-Hill Book Co

Subject Code:: CL6L113	Name: Advanced Dynamic Oceanography	L-T-P: 3-0-0	Credit:3
Pre-requisite(s):			

Western boundary intensification, barotropic currents and baroclinic transport over topography. Meso-scale eddies and variability. Indian Ocean dipole circulation, Linear waves, wave spectra, wave propagation. Wave energy eqn. Breaking waves, reflection and dissipation, theory of tides, Tidal currents. Tidal processes in embayments and estuaries, Wind and buoyancy driven currents, Near-shore circulation, alongshore and rip currents, littoral drift, sediment transport, coastal ocean response to wind forcing, storm surges, coastal upwelling and fronts, Kelvin, Yanai, Rossby, inertia-gravitywaves.

Text/Reference Books:

1. Joseph Pedlosky. *Waves in the Ocean and Atmosphere: Introduction to Wave Dynamics*, Springer
2. D B Haidvogel, *A Beckmann. Numerical Ocean Circulation Modeling*, Imperial College Press
3. Gill A. *Dynamics of Ocean and Atmosphere,* Academic Press
4. Cavaleri L. et al. *Dynamics and Modelling of Ocean Waves,* Cambridge University Press

Subject Code: CL6L114	Name: Agro-meteorology	L-T-P: 2-0-0	Credit:2
Pre-requisite(s):			

Agricultural meteorology - its scope and aims; soil and water, plants and crop microclimate, Radiation and the surface energy balance - direct and diffuse components of solar short-wave radiation, estimation of global radiation on a horizontal surface, emission and reflection of radiation, energy in the visible spectrum - light; The energy balance and its components: the long-wave budget; surface radiation temperatures; total radiation budget and complete surface energy balance; Special aspects of radiation and temperature in agriculture.
Water and the hydrological cycle in agriculture - Moisture characteristics of soils; Determination of water loss from land surfaces: fundamentals of the evaporation process, existing methods to determine evaporation, energy balance estimation of evaporation, aerodynamic estimation of evaporation; "Combination" methods of Penman and others: development of the original Penman equation, evaporation formulae of Priestley-Taylor and Penman-Monteith; Special forms of precipitation: dew, snow; Soil moisture budgets - irrigation need.Weather hazards - Drought; Floods; Hail Storms:

Text/Reference Books:

1. *Guide to Agricultural Meteorological Practices:* WMO No.134, 1981.
2. *Lecture Notes for training Class IV Agricultural Meteorological personnel,* WMO No.593, 1982.
3. *Land use and agro system management under severe climatic conditions,* WMO No.633, 1986

Subject Code:: CL6L115	Name: Aqueous Environmental Geochemistry	L-T-P: 2-0-0	Credit:2
Pre-requisite(s):			

Shallow earth interactions emphasizing: groundwater geochemistry; elemental cycles linked to biological activity in the oceans; geochemistry and global climate cycles; geo-bioremediation; and applied analytical techniques.

Text/Reference Books:

1. Donald Langmuir, *Aqueous Environmental Geochemistry; Prentice Hall*
2. Peter Ryan, *Wiley-Blackwell, Environmental and Low Temperature Geochemistry*
3. Charles R. Fitts,*Groundwater Science,* Second Edition; Academic Press; 2 edition
4. Ian L. Pepper, Charles P. Gerba and Mark L. Brusseau, *Environmental and Pollution Science;* Academic Press.

Subject Code:: CL6L116	Name: Assessing the Impact of Climate Change	L-T-P: 2-0-0	Credit:2

Pre-requisite(s):

Climate change – historical perspectives; Carbon cyclone - the Global Carbon Cycle, the Ocean Carbon Cycle, the Terrestrial Carbon Cycle, Modeling the Carbon Cycle; Non-CO2 Greenhouse Gases and Aerosols; Greenhouse Effect: Temp, Radiation, & Energy, Climate Sensitivity; Linking Human Dimension to Climate Change; Econometric Models and GHG Emissions Scenarios; Climate Projections; Strategies to Slow & Stabilize Climate Change; Sequestrations of Atmospheric CO2; Impacts of Climate Change; Climate change & policy options.

Text/Reference Books:

1. *Climate Change 2014: Impacts, Adaptation, and Vulnerability,* IPCC
2. Kevin E Trenberth*: Climate System Modeling,* Cambridge University Press
3. Kendal McGuffie, *Ann Henderson-Sellers: A Climate Modeling Premier,* Wiley

Subject Code:: CL6L117	Name: Data Structure and Information Technology	L-T-P: 3-0-0	Credit:3
Pre-requisite(s):			

Definition of a programme, Programming methodology. Concepts of structured programming. Definition of operations on arrays, stacks, queues, lists, trees. Evaluation of arithmetic expressions using stacks. List representation. Recursive and non-recursive definitions of tree structures. Operations using recursive and non-recursive algorithms. Forests. Simple searching and sorting algorithms. Hashing techniques.

Text/Reference Books:

1. Richard F. Gilberg and Behrouz A. Forouzan, *Data Structures: A Pseudocode Approach with C, Cengage Learning;*
2. D. S. Malik, *Data Structures Using Java, Course Technology;*
3. Peter Brass, *Advanced Data Structures*,Cambridge University Press.

Subject Code:: CL6L118	Name: Atmospheric Diffusion and Air Pollution	L-T-P: 3-0-0	Credit:3
Pre-requisite(s):			

Various sources and types of pollutants in the atmospheric environment, Reynolds averaging, closure problem, atmospheric diffusion, types of boundary conditions for modeling dispersion. solution of diffusion equation for instantaneous and continuous sources; dispersion from a ground/ elevated sources; long and short range dispersion, removal mechanism; dry and wet deposition, chemical removal, atmospheric surface boundary layer, similarity theory. Wind rose, dispersion parameters and plume rise. Gaussian and box models, optical stack height. Case studies for the dispersion of pollutants.

Text/Reference Books:

1. John H. Seinfeld, Spyros N. Pandis *: Atmospheric Chemistry and Physics: From Air Pollution to Climate Change,* Wiley
2. S. Pal Arya: *Air Pollution Meteorology and Dispersion,* Oxford University
3. S Pal Arya*: Introduction to Micrometeorology*, Oxford University
4. William C Hinds: *Aerosol Technology: Properties, Behavior, and Measurement of Airborne Particles,* Wiley-Interscience

Subject Code:	Name: Ocean Colour and	L-T-P:	Credit:3
CL6L119	**Applications**	**3-0-0**	

Pre-requisite(s):

Physical basis of ocean color; Ocean color sensors; atmospheric corrections of ocean colordata; Bio-optical algorithms (empirical, semi-analytical, analytical), Validation of algorithmsApplications, Primary production, Climate research (carbon flux),Fisheries, Sedimenttransport, Water quality, space based technologies for ocean color monitoring.

Text/Reference Books:

1. G.A.Maul. *Introduction to Satellite Oceanography*, MartinusNijhoff
2. S Martin. *An Introduction to Ocean Remote Sensing*, Cambridge University Press
3. Ian S. Robinson. *Discovering The Ocean From Space* , Springer
4. A P Cracknell, *Dorderecht: D Reidel. Remote Sensing Applications in Marine Science and Technology*, Springer
5. GhassemAsrar. *Theory and Applications of Optical Remote Sensing*, Wiley Interscience

Subject Code:: CL6L120	Name: Climate Change and Sustainability	L-T-P: 2-0-0	Credit:2
Pre-requisite(s):			

Photosynthesis – radiation and its parameters, Solar radiation, Spectrum and effects; Energy balance at the level of a leaf and ecosystem, Crop production – canopy structure, radiation use efficiency, factors determining productivity; Sustainability – Ecosystem services, Millennium ecosystem assessment, Ecological foot print, Energy, Gaia, Climate Change and Sustainability -Natural Resources, Energy & Society at various space and time scale.

Text/Reference Books:

1. Climate Change 2014*: Impacts, Adaptation, and Vulnerability*, IPCC
2. Stephen Peak and Joe Smith, *Climate Change: From science to sustainability*, Oxford University Press
3. *Climate Change 2013: The Physical Science Basis*, IPCC

Subject Code:: CL6L121	Name: Climate Risk Assessment in Agriculture	L-T-P: 2-0-0	Credit:2
Pre-requisite(s):			

Climate Change; Agriculture; Agro-ecosystem; SustainabilityGlobal Agriculture; Environmental Pressures on Agriculture; Response of Agriculture to Rising CO2 and Climate Change;Sensitivity of Tropical Agriculture to Climate change; Social Vulnerability and Food Security; Economic Policy,Physiological Ecology and Niche Based Responses; Effect of global change in Agricultural Pests; Possible Impacts and Dynamics at Population, Species, Interactions and Community Level Food Webs.Crop production in Dry-land Region; Soil Organic Matters; Sequestering Soil Carbon; Food Security in Dry-land Areas; Climate Change and Crop production modeling

Text/Reference Books:

1. *IPCC (1995) Climate Change 1995: The Science of Climate Change*, CambridgeUniv Press, Cambridge, UK.
2. W Easterling, Aggarwal P, Batima P, Brander K, Erda L, Howden M, Kirilenko A, Morton J, Soussana J-F, Schmidhuber J, *Tubiello F (2007) in Climate Change 2007: Impacts, Adaptation and Vulnerability*, eds Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE, Cambridge Univ Press
3. Muchow, R.C. & Bellamy, J.A.1991.*Climatic risk in crop production: models and management for the semi-arid tropics and subtropics.*

Subject Code:: CL6L122	Name: Climate Variability & Global Warming	L-T-P: 3-0-0	Credit:3
Pre-requisite(s):			

Global distributions of temperature and precipitation, Koppen's classification of climates; climate variability as estimated from atmospheric observations. Impact of climate changes, simple energy balance climate models; atmospheric general circulation models, their design and use for climate studies, coupled ocean-atmosphere GCM. Global efforts in understanding and predicting climate change through WCRP(CLIVAR), IPCC, IGBP etc; Impact of paleo-climatic proxy data on climate modelling.

Text/Reference Books:

1. *Climate Change synthesis report (2007),* IPCC
2. *Climate Change 2014: Impacts, Adaptation and Vulnerability,* IPCC
3. *Climate Change 2013: The Physical Science Basis,* IPCC

Subject Code: : CL6L123	Name: Instrumentation and Observation Systems	L-T-P: 3-0-0	Credit:3

Pre-requisite(s):

General measurement system, principles, measurement of meteorological parameters, wind speed, temperature and humidity, pressure etc, in-situ and remote measurements, SODAR, LIDAR, RADAR techniques, aerosol measurement techniques, optical depth, size distribution, chemical composition, trace gas measurement techniques.
Image analysis, infrared and microwave techniques for measurement of temperature, humidity and cloud height, atmospheric sounders, limb sounding.

Text/Reference Books:

1. *Guide to Meteorological Instruments and Methods of Observation.* Sixth edition. WMO-No 8.
2. *Compendium of Lecture notes on Meteorological Instruments.* WMO-No 622.
3. F.Dobson, L.Hasses and R.Davis, *Air-Sea Interaction. Instruments and Methods,* Premium Press.
4. I.S.Robinson, Ellis Horward, *Satellite Oceanography – An Introduction to Oceanographers and Remote Sensing scientists..*

Subject Code:: CL6L124	Name: Mesoscale Meteorology	L-T-P: 3-0-0	Credit:3

Pre-requisite(s):

Circulation systems related to orography, valley winds, energy budgets, cloudiness, precipitation, evaporation, fog, lightening, snow avalanches and valley air pollution; general properties of mountain perturbations, adiabatic meso-scale perturbations in a straight atmospheric flow, adiabatic synoptic scale perturbations, dissipation of mechanical energy, mountain drag, modeling aspects of mountain waves, mountain generated momentum fluxes, theory of linear gravity waves, orographic gravity-wave drag, its parameterization and influence in general circulation models.

Text/Reference Books:

1. Roger A Pielke : *Mesoscale Meteorological Modelling*, Academic Press
2. B.W. Atkinson: *Mesoscale Atmospheric Circulation,* Academic Press
3. P S Ray: *Mesoscale Meteorology and Forecasts,* American Meteorological Society

Subject Code:: CL6L125	Name: Science of Climate and Climate Change	L-T-P: 3-0-0	Credit:3
Pre-requisite(s):			

Description of the climate system, natural greenhouse effect and the effect of trace gases and aerosols, feedbacks in the climate system, climate change in the past, ice ages, proxy records, abrupt climate change, Instrumental record of climate, climate variability on various time-scales, simple models of climate, General Circulation Models, natural and anthropogenic climate change: detection and attribution, impacts and mitigation of climate change.

Text/Reference Books:

1. *Climate Change synthesis report (2007)*, IPCC
2. *Climate Change 2014: Impacts, Adaptation and Vulnerability*, IPCC
3. *Climate Change 2013: The Physical Science Basis*, IPCC
4. Kevin E Trenberth: *Climate System Modeling*, Cambridge University Press
5. Kendal McGuffie, *Ann Henderson-Sellers: A Climate Modeling Premier*, Wiley

Subject Code:: CL6L126	Name: Mountain Meteorology	L-T-P: 3-0-0	Credit:3
Pre-requisite(s):			

Latitudinal, altitude and topographical effects of mountain on meteorological elements; Circulation systems related to orography, mountain and valley winds; Climatic characteristics of mountains, energy budgets, cloudiness, precipitation, evaporation, fog, lightening, snow avalanches and valley air pollution; some case studies, the equatorials mountains of New Guina, the Himalayas, sub- tropical desert mountains, the Rocky and the Alps. General properties of mountain perturbations, adiabatic meso-scale perturbations in a straight atmospheric flow, adiabatic synoptic scale perturbations, computation, of the dissipation of mechanical energy resulting from a mountain perturbation, modelling aspects of mountain waves, mountain generated momentum fluxes, theory of linear gravity waves, orographic gravity-wave drag, its parameterisation and influence in general circulation models.

Text/Reference Books:

1. C David Whiteman*: Mountain Meteorology: Fundamentals and Applications,* OUP USA
2. Fotini K. Chow, Stephan F.J. De Wekker and Bradley J. Snyder, *Mountain Weather Research and Forecasting: Recent Progress and Current Challenges;* Springer Atmospheric Sciences

Subject Code:: CL6L127	Name: Marine Resources & Technology	L-T-P: 3-0-0	Credit:3
Pre-requisite(s):			

Ocean boundaries; fundamentals of marine geological principles; Geomorphology and Ocean boundaries; fundamentals of marine geological principles; Geomorphology and structure of the Ocean floor, continental slope and shelf. Marine sediments: their formation; types; distribution and classification. Distribution of marine minerals along the Indian Coasts; Marine geo-physical technology; prospecting for oil-bearing strata; natural gas and oil traps. Marine mineral resources: Placer deposits hydrocarbon deposits and polymetallic nodules; Exploration and exploitation of natural minerals off the coast. Energy from oceans - Tides, Waves, Currents, Salinity and thermal gradients with special reference to Indian coast - Energy converters for extraction of ocean energy - Design principles of wave power, tidal power and OTEC systems -Cost-benefit analysis autonomous underwater vehicle (AUV); ocean bottom features by swath bathymetry.

Text/Reference Books:

1. A.P. Cracknell. *Remote Sensing Applications in Marine Science and Technology*, Springer
2. Joao, Cruz. *Ocean Wave Energy: Current Status and Future Perspectives*, Springer
3. Joseph Pedlosky. *Waves in the Ocean and Atmosphere: Introduction to Wave Dynamics*, Springer
4. Michel K. Ochi, Michael K. Ochi. *Ocean Waves: The Stochastic Approach*, Cambridge

Subject Code: CL6L128	Name: Satellite Oceanography and Meteorology	L-T-P: 3-0-0	Credit:3
Pre-requisite(s):			

Introduction to satellite remote sensing of the ocean; Propagation and sensing of EM waves and their interaction and scattering with the ocean's surface; Atmospheric absorption andscattering of microwave; visible and infrared radiation; Brief review of electromagnetic wave theory, antenna patterns and ocean surface processes; Detailed survey of major instruments for measuring Oceanographic and Atmospheric variables from space; Applications of visible, infrared, and microwave observations using objective, multi-spectral, and characteristic vector analysis; Emphasis on new methodologies, error assessments, sampling considerations and data interpretation. Basic principles of retrieval of Geophysical, Ocean and Atmospheric Variable from satellite platforms.

Text/Reference Books:

1. G.A.Maul. *Introduction to Satellite Oceanography*, Springer
2. Ian S. Robinson. *Discovering The Ocean From Space*, Springer
3. Kidder and Vonder Harr. *Satellite Meteorology: An Introduction*, Gulf Professional
4. John R Jensen. *Remote Sensing of the Environment: An Earth Resource Perspective*, Pearson Prentice Hall
5. R RKelkar. *Satellite Meteorology*, BS Publications

Electives (IV, V, VI):

Subject Code: : CL6L211	**Name: Atmospheric Chemistry & Aerosol**	**L-T-P: 3-0-0**	**Credit:3**
Pre-requisite(s):			

General Characteristics of the Atmosphere, Geochemical Cycles of Elements, Concepts in Atmospheric Chemistry, Gas Phase & Aqueous Phase Reactions, Chemistry of the Polluted Atmosphere, Photochemical Reactions and Smog, Monitoring Techniques, Organic Pollutants in the Atmosphere, Atmospheric Aerosols, Ozone Layer, Stratospheric and tropospheric chemistry, Montreal and Kyoto Protocols, Major Fire Emissions, Greenhouse Effect and Climate Change, Green Chemistry, Emission Inventories.

Text/Reference Books:

1. Barbara J. Finlayson-Pitts, James N. Pitts Jr..*Chemistry of the Upper and Lower Atmosphere : Theory, Experiments and Applications 1st Edition,* Academic Press
2. Wayne Richard P.*Chemistry Of Atmosphere 3 Rev ed Edition*, Oxford University Press
3. Kirill Ya. Kondratyev,Lev S. Ivlev, Vladimir F. Krapivin, Costas A. Varotsos. *Atmospheric Aerosol Properties, Formation, Process, Impacts*, Springer
4. Ernie R. Lewis, Stephen E. Schwartz. *Sea Salt Aerosol Production: Mechanisms, Methods, Measurements and Models - A Critical Review*, American Geophysical Union
5. J. H.Seinfield and S N Pandis- *Atmospheric Chemistry and Physics, From Air Pollution to Climate change,* Wiley

Subject Code::CL6L212	Name: Glaciology and Paleoclimate	L-T-P: 3-0-0	Credit:3
Pre-requisite(s):			

Introduction to Glacial Environments; Glacier Mass Balance; Supraglacial, Englacial, and Basal Hydrology; Glacier Dynamics I - Internal Deformation; Glacier Dynamics II - Basal Sliding; Glacier Dynamics III - the Role of Deformable Sediments; Glacier Surging; Ice Cores: Glaciological Aspects and the Climate Record, applications of remote sensing techniques for glacial change monitoring w.r.t climate change.

Text/Reference Books:

1. Thomas M Cronin: *Paleoclimates: Understanding Climate Change Past and Present*, Columbia University Press.
2. Raymod S Bradley: *Paleoclimatology, Volume 68, Second Edition: Reconstructing Climates of the Quaternary (International Geophysics),* Academic Press
3. K M Cuffey and W S B Paterson: *The physics of Glaciers,* Academic Press
4. C J Van der veen: *Fundamentals of Glacier Dynamics,* CRC Pres

Subject Code::CL6L213	Name: Climate Change Impact and Adaptation	L-T-P: 2-0-0	Credit:2
Pre-requisite(s):			

Climate change – historical perspectives; Carbon cyclone - the Global Carbon Cycle, the Ocean Carbon Cycle, the Terrestrial Carbon Cycle, Modeling the Carbon Cycle; Non-CO2 Greenhouse Gases and Aerosols; Greenhouse Effect: Temp, Radiation, & Energy, Climate Sensitivity; Linking Human Dimension to Climate Change; Econometric Models and GHG Emissions Scenarios; Climate Projections; Strategies to Slow & Stabilize Climate Change; Sequestrations of Atmospheric CO2; Impacts of Climate Change; Climate change & policy options.

Text/Reference Books:

1. *Climate Change synthesis report (2007),* IPCC
2. *Climate Change 2014: Impacts, Adaptation and Vulnerability*, IPCC
3. *Climate Change 2013: The Physical Science Basis,* IPCC
4. Kevin E Trenberth: *Climate System Modeling*, Cambridge University Press
5. Kendal McGuffie, *Ann Henderson-Sellers: A Climate Modeling Premier,* Wiley

Subject Code::CL6L214	Name: High Performance Computing in Earth System Science	L-T-P: 3-0-0	Credit:3

Pre-requisite(s):

Basic ideas on multitasking and massively parallel processing, different architectures, application of HPC in global and regional models, parallelism in weather and climate models, domain decomposition method, 1D, 2D and 3D parallelization of GCMs, MPI, PVM, SHMEM, message passing libraries, high performance compilers, load balancing, interprocessor communication, network communication, graphical user interface, data formats, local and wide area networking, data flow and data mining.

Text/Reference Books:

1. Lars PetterRøed. *Atmospheres and Oceans on Computers-Fundamentals*
2. Laurence T. Yang and MinyiGuo. *High-Performance Computing: Paradigm and Infrastructure*, Wiley
3. John Levesque and Gene Wagenbreth. High Performance Computing*: Programming and Applications*, Chapman and Hall.

Subject Code::CL6L215	Name: Marine Biotechnology	L-T-P: 2-0-0	Credit:2
Pre-requisite(s):			

Historical background, Overview of the present status of marine biotechnology, commercially important and potential species, micro-algae, macro-algae, aquaculture, algal production in real sector.

Marine natural products, valuable chemicals, bioactive compounds from micro-algae, marine biomedical and bioactive compounds from marine organisms, commercial bio-products from marine organisms, Marine biotechnology for economic development and environmental problem solving, Marine bio-film and bio-remediation, marine bio-sensor and transgenic marine organisms.

Text/Reference Books:

1. *OECD Report 2013: Organisation for Economic Co-operation and Development. Marine biotechnology: Enabling Solutions for Ocean Productivity and Sustainability*
2. *Milton Fingerman. Recent Advances in Marine Biotechnology: Biomaterials and Bioprocessing,* CRC press.

Subject Code:: CL6L216	Name: Marine Pollution and Coastal Zone Management	L-T-P: 3-0-0	Credit:3
Pre-requisite(s):			

Hydrodynamics of coastal zone, wave dynamics, coastal engineering, offshore backwater system, alongshore and waste water transport, sediment resuspension, offshore ocean dumping, impact of coastal ocean on living resources, petrochemical exploitation, wave power extraction, tidal energy, offshore thermal energy conversion, impact of salt water intrusion, sea level rise and impact on coastal zone, management of estuaries, sustainable development of the coastalzone, health related problems of coastal zone.

Text/Reference Books:

1. T Beatley, D Brower and A K Schwab: *An Introduction to Coastal Zone Management,* Island Press.
2. B C Sain, R Knechet and Gunnar kullenberg, *Integrated Coastal and Ocean Management: Concepts And Practices,* Island Press
3. R B Clark, *Marine Pollution,* Oxford University Press
4. M J Kennish, *Practical Handbook of Estuarine and Marine Pollution (CRC Marine Science),* CRC Press
5. Judith S Weis, Physiological, *Developmental and Behavioral Effects of Marine Pollution,* Springer

Subject Code:: CL6L217	Name: Mathematical and Statistical Methods in Earth System Science	L-T-P: 3-0-0	Credit:3

Pre-requisite(s):

Boundary value problems, meteorological fields in terms of orthogonal functions, normal modes, Fourier-Legendre transforms, FFT; Asymptotic expansions, method of multiple scales applied to atmospheric motions, Calculus of variations and Rayleigh-Ritz method; Probability, covariance and correlation, multivariate distributions and analysis, principal component analysis, singular value decomposition (SVD), Uncertainty analysis, Data assimilation techniques, error statistics, statistical softwares for satellite data analysis.
Empirical orthogonal functions, Fourier transforms, wavelet transforms, Neural networks, genetic algorithms, functions, matrices, fundamentals of signal theory, 1-D and n-D, discrete signals, 1-2 and 3-D computing/MATLAB/programming; Probability theory, least-square optimization, regression, non-linear; optimization. Highlighting information in the data: Interpolation; concept of frequency / wave number; Fourier transform and FFT 1-D and 2-D; spectra and power; spectral density (PSD); Filtering, 1-D and 2-D; applications of filtering, empirical orthogonal functions, Advanced techniques; random transforms, wavelets. Comparing different datasets: Auto and cross-correlation; relationship between correlation and PSD; cross spectra; applications; canonical correlation analysis.

Text/Reference Books:

1. Hans von Storch and Francis W. Zwier. *Statistical analysis in climate research*, *Cambridge* University Press
2. W. J. Emery, Richard E. Thomson. *Data Analysis Methods in Physical Oceanography*, Elsevier Science
3. Trauth, E. Sillmann, R. Gebbers, N. Marwan. *MATLAB® Recipes for Earth Sciences*, Springer
4. D S Wilks, *Statistical Methods in the Atmospheric Sciences,* Volume 100, Third Edition (International Geophysics), Academic Press

Subject Code:: CL6L218	Name: Mesoscale Atmospheric Modeling	L-T-P: 3-0-0	Credit:3

Pre-requisite(s):

Mesoscale processes; scaling; observations and analysis; wave fundamentals; Lee waves and windstorms; orographically forced flows; orographic precipitation; differential heating; gravity currents and convective initiation; isolated convective storms; tornadoes; MCS -squall lines; heavy rainfall; internal structure of cyclones; rain bands - observations and theory; Hydrostatic approximation and nonhydrostatic dynamics, basics of mesoscalemodeling; mesoscale data assimilation; details of some community mesoscale models (MM5 and WRF), mesoscale simulation of intense convective events.

Text/Reference Books:

1. Roger A Pielke : *Mesoscale Meteorological Modelling*, Academic Press
2. B.W. Atkinson: *Mesoscale Atmospheric Circulation*, Academic Press
3. P S Ray: *Mesoscale Meteorology and Forecasts*, American Meteorological Society

Subject Code:: CL6L219	Name: Mitigation Climate Change Vulnerability	L-T-P: 3-0-0	Credit:3
Pre-requisite(s):			

Market based system for reducing greenhouse gas emissions – preliminaries, basic economics of externalities; Determine the desired reduction in emissions/price of carbon - modeling costs, the important role of discounting, Important Role of Uncertainty; World policy experience - cap-and-trade policies, the international context, ethanol policy and the challenge of land use, electricity generation.

Text/Reference Books:

1. *Climate Change synthesis report (2007)*, IPCC
2. *Climate Change 2014: Impacts, Adaptation and Vulnerability*, IPCC
3. *Climate Change 2013: The Physical Science Basis*, IPCC
4. Kevin E Trenberth: *Climate System Modeling*, Cambridge University Press
5. Kendal McGuffie, Ann Henderson-Sellers: *A Climate Modeling Premier*, Wiley

Subject Code:: CL6L220	Name: Modeling of Air-Sea Interactions	L-T-P: 3-0-0	Credit:3
Pre-requisite(s):			

Atmospheric boundary layer: friction velocity and surface layer; log layer, methods of determining wind stress, surface wave effects on APBL fluxes; non-dimensional scaling. Heat fluxes: bulk aerodynamic formulas; Obukhov length scales; approximations, role of SSTs, precipitation and evaporation, methods of determining heat fluxes.

Forced upper ocean response: Ekman dynamics; projection of wind stress on baroclinic modes; near inertial responses; fronts, tropical and extra-tropical cyclones; wind forced equatorial Kelvin waves.

Introduction to weather and climate: momentum, continuity and thermodynamic energy equations; basic equations in isobaric coordinates; Balanced flow, inertial flow, cyclostrophic flow, thermal wind, vertical motion and surface pressure tendency; Circulation and vorticity, planetary boundary layer, atmospheric turbulence, Boussinesq approximations.

Introduction to Physical Oceanography; Properties of sea water and their distributions, measurements in the ocean, mixed layer and thermocline, governing equations, ocean circulation, wind driven currents, Ekmann flow, Sverdrup flow, geostrophic currents, coastal currents, air-sea interaction.

Text/Reference Books:

1. G. T. Csanady and Mary Gibson. *Air-Sea Interaction: Laws and Mechanisms, Cambridge* University Press
2. J M Wallace and Peter V Hobbs: *Atmospheric Science, Second Edition: An Introductory Survey,* International Geophysics
3. J. R. Garratt .*The Atmospheric Boundary Layer,* Cambridge University Press
4. Boris A. Kagan and M Hazain: *Ocean Atmosphere Interaction and Climate Modeling,* Cambridge University Press.

Subject Code::CL6L221	Name: Modeling of Dynamic Processes of Ocean & Atmosphere	L-T-P: 3-0-0	Credit:3

Pre-requisite(s):

Finite difference approximations, Discrete analogues of differential equations in meteorology, relaxation methods, advection equations, Time differencing schemes, stability analysis, shallow-water models and filtering, Integral invariants, enstrophy and energy conserving schemes, Matsuno, leap-frog schemes, geostrophic adjustment, spectral methods, semiimplicit formulation, Non-linear instability, vertical coordinates, vertical discretization, Limited area models, Ocean mixing and ocean wave modelling.

Text/Reference Books:

1. Kantha and Carol Anne Clayson. *Numerical Models of Oceans and Oceanic Processes*, Academic Press
2. James C. McWilliams. *Fundamentals of Geophysical Fluid Dynamics* , Cambridge University Press
3. Mark Z Jacobson. *Fundamentals of Atmospheric Modeling*, Cambridge University Press

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

Pre-requisite(s):

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:

1. Tim Vasquez: *Weather Analysis and Forecasting Handbook*, Weather Graphics Technology
2. David J Stensurd: *Parameterization Schemes: Keys to Understanding Numerical Weather Prediction Models*, Cambridge University Press
3. Christopher C Burt: *Extreme Weather: A Guide and Record Book*, W WNotron and Company.

Subject Code:: CL6L223	Name: Modeling of the Climate	L-T-P: 3-0-0	Credit:3
Pre-requisite(s):			

Hierarchy of climate models, one-dimensional climate models, computational methods in general circulation models (GCM), - finite difference and spectral method; radiation and climate, radiative convective models, parameterization of clouds, land-surface process and air-sea interaction; ocean-atmosphere coupled models, Ozone variations and climatic effect, Detection and attribution of anthropogenic forcing, climate feedback mechanisms.

Text/Reference Books:

1. Stephen Griffies , *Fundamentals of Ocean Climate Models,* Princeton University
2. Thomas Stocker, *Introduction to Climate Modelling,* Springer
3. Boris A. Kagan and M Hazin, *Ocean Atmosphere Interaction and Climate Modeling,* Cambridge University Press.
4. *Climate Change synthesis report (2007),* IPCC
5. *Climate Change 2014: Impacts, Adaptation and Vulnerability,* IPCC
6. *Climate Change 2013: The Physical Science Basis,* IPCC
7. Kevin E Trenberth, *Climate System Modeling,* Cambridge University Press
8. Kendal McGuffie, Ann Henderson-Sellers*: A Climate Modeling Premier,* Wiley.

Subject Code:: CL6L 224	Name: Neural Networks and Applications	L-T-P: 3-0-0	Credit:3

Pre-requisite(s):

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:

1. Vladimir M. Krasnopolsky, *The Application of Neural Networks in the Earth System Sciences: Neural Network Emulations for Complex Multidimensional Mappings:* Springer
2. James A. Freeman**,** *Neural Networks: Algorithms, Applications, and Programming Techniques (Computation and Neural Systems Series);* Addison-Wesley Pub.

Subject Code:: CL6L225	Name: Objective Analysis and Data Assimilation	L-T-P: 3-0-0	Credit:3

Pre-requisite(s):

The observing systems: present & future, subjective and objective analysis, function fitting, method of successive correction, Statistical Interpolation; Univariate and multivariate analysis, dynamic and normal-mode initialization, variational methods, variational and ensemble based assimilation, Kalman filtering, sensitivity analysis, estimation theory, 3D-/4DVAR shallow water model and its adjoint, radar data assimilation basics, oceanic data assimilation at mesoscale and assimilation of altimetry data.

Text/Reference Books:

1. Eugenia Kalna:. *Atmospheric modeling, data assimilation, and predictability*, Cambridge University Press
2. Roger Daley*: Atmospheric Data Analysis,* Cambridge University Press
3. Pierre P. Brasseur and Jacques C.J. Nihoul. *Data Assimilation: Tools for Modelling the Ocean in a Global Change Perspective,* Springer

Subject Code:: CL6L226	Name: Ocean Circulation and Wave Modeling	L-T-P: 3-0-0	Credit:3

Pre-requisite(s):

Physical description of wave evolution – Fundamental geophysical fluid dynamics, wave growth by wind theories, wave spectrum, effects of small scale disturbances and gustiness on wave growth, wave induced stress, drag of air flow over sea surface; Wave-wave interaction – general formalism, Wave dissipation by surface processes; Bottom friction and percolation – dissipation over sandy bottoms, parameterization of bottom stresses; Numerical modeling of ocean waves – model classes and generation, wave sensitivity studies, operational application and analysis; Extreme events - storm surges, tsunami and cyclones; governing equations of ocean circulations – geotropic flows, principles of vorticity dynamics, vortex theories to oceans, upwelling, baroclinic and barotropic instability with applications; theory of fronts and jets – gulf stream, equatorial dynamics and ocean currents; governing equations – large scale ocean circulation, numerical models, boundary layers, wind driven circulation in homogenous oceans, climate dynamics, global climate change, ENSO; Princeton Ocean Model and some of its applications.

Text/Reference Books:

1. Joseph Pedlosky, *Waves in the Ocean and Atmosphere: Introduction to Wave Dynamics*, Springer
2. Kantha and Clayson, *Numerical Models of Oceans and Oceanic Processes,* Academic Press
3. D B Haidvogel, A Beckmann. *Numerical Ocean Circulation Modeling,* Imperial College Press

Subject Code:: CL6L227	Name: Ocean Resources & Technology	L-T-P: 3-0-0	Credit:3

Pre-requisite(s):

Ocean boundaries; fundamentals of marine geological principles; Geomorphology and structure of the Ocean floor, continental slope and shelf.
Marine sediments: their formation; types; distribution and classification.
Distribution of marine minerals along the Indian Coasts; Marine geo-physical technology; prospecting for oil-bearing strata; natural gas and oil traps.
Marine mineral resources: Placer deposits hydrocarbon deposits and polymetallic nodules; Exploration and exploitation of natural minerals off the coast.
Energy from oceans - Tides, Waves, Currents, Salinity and thermal gradients with special reference to Indian coast - Energy converters for extraction of ocean energy - Design principles of wave power, tidal power and OTEC systems -Cost-benefit analysis autonomous underwater vehicle (AUV); ocean bottom features by swath bathymetry.

Text/Reference Books:

1. A.P. Cracknell, *Remote Sensing Applications in Marine Science and Technology*,Springer
2. Joao, Cruz, *Ocean Wave Energy: Current Status and Future Perspectives*, Springer
3. Joseph Pedlosky, *Waves in the Ocean and Atmosphere: Introduction to Wave Dynamics,* Springer
4. Michel K. Ochi, Michael K, Ochi. *Ocean Waves: The Stochastic Approach*,Cambridge University Press

Subject Code:: CL6L228	Name: Ocean State Forecasting and Modeling	L-T-P: 3-0-0	Credit:3

Pre-requisite(s):

Numerical techniques used in marine forecasting, forecasting of tides and currents in the North Indian Ocean, real time forecasting of storm surges in India and its neighborhood. Prediction of coastal upwelling, fronts and vertical thermal structure in the Bay of Bengal and the Arabian Sea, wave prediction in the North Indian Ocean, forecasting of salinity and flow structure in the Indian estuaries.

Text/Reference Books:

1. Schott and McCreary, *The monsoon circulation of the Indian Ocean.*
2. W. J. Emery, Richard E. Thomson. *Data Analysis Methods in Physical Oceanography*, Elsiver Science Publishing
3. Robert N. Miller, *Numerical Modeling of Ocean Circulation,* Cambridge University Press
4. Kantha L. H. & C. A. Clayson, *NumericalModels of Oceans and Oceanic Processes,* Academic Press.

Subject Code:: CL6L229	Name: Parameterization of Physical Processes	L-T-P: 3-0-0	Credit:3

Pre-requisite(s):

Parameterization of subgrid-scale processes, one-dimensional PBL model, Parameterization of subgrid orographic processes, gravity-wave (GW) drag, Parameterization of moist processes, clouds and convective processes in large-scale models, dry adiabatic adjustment; cloud microphysics in numerical models, radiative transfer, band and emissivity models, multi-level longwave and shortwave radiation computations, surface and atmosphere interaction, land surface parameterizations, surface hydrology modelling, vegetation cover.

Text/Reference Books:

1. David J Stensurd, *Parameterization Schemes: Keys to Understanding Numerical Weather Prediction Models*, Cambridge University Press
2. Kevin Hamilton, *Gravity Wave Processes: Their Parameterization in Global Climate Models (Nato ASI Subseries I: (closed))*, Springer

Subject Code:: CL6L230	Name: Remote Sensing and GIS	L-T-P: 3-1-0	Credit:3
Pre-requisite(s):			

Electromagnetic radiation, frequency and wavelength; nature of electromagnetic radiation, polarization, atmospheric windows and absorption bands; interaction with surface features, spectral reflectance, identification of surface elements based on spectral reflectance, spectral reflectance of vegetation. Types of sensors: multi-spectral, hyper-spectral, thermal IR and synthetic aperture radars; sensor design and selection; Image processing, digital image processing, radiometric and geometric corrections, atmospheric corrections, pixel resampling methods. Remote sensing of vegetation: leaf area index, soil line and vegetation, plant water and atmospheric water absorption bands. Applications in studying soil properties, rock and mineral identification, geomorphology, volcanology, fluvial processes, coastal processes and desertification.

Text/Reference Books:

1. George Joseph, *Fundamentals of Remote Sensing,* Universities Press
2. S. Kumar, *Basics of Remote Sensing and GIS,* Laxmi Publication
3. Paul Longley et al.*Geographic Information Systems and Science,* John Wiley & Sons

Subject Code:: CL6L231	Name: Satellite and Radar Meteorology	L-T-P: 3-0-0	Credit:3

Pre-requisite(s):

History of satellite and radar meteorology; Orbits and navigation, Orbit perturbations, Meteorological satellite orbits, Satellite positioning, tracking, and navigation, Space-time sampling, Launch vehicles and profiles; Elements of radiative transfer - Basic quantities, Blackbody radiation, Radiative transfer equation, Gaseous absorption, Scattering, Solar radiation and surface reflection; Meteorological satellite instrumentation - Operational polar-orbiting satellites, Operational geostationary satellites, Other satellite instruments, Satellite data archives; Radar - Radar basics, Conventional weather radar, Radar measurements of rainfall, Comparison with satellite rainfall products, NEXRAD system, Applications to hydrology; Image interpretation; Satellite -Visible infrared and water vapor imagery, Spectral properties, Image enhancement techniques, Geo-location and calibration; Doppler radar - Doppler wind measurements, reflectivity, Analysis of Doppler measurements, Atmospheric temperature and water vapor profiles, Winds, Clouds and aerosols, Precipitation; Integrated application topics - Hurricanes, Severe Storms, Agriculture Applications.

Text/Reference Books:

1. Kidder and Vonder Harr, *Satellite Meteorology:: An Introduction*, Academic Press
2. GhassemAsrar. *Theory and Applications of Optical Remote Sensing*,Wiley Blackwell
3. John R Jensen, *Remote Sensing of the Environment: An Earth Resource Perspective*, Academic Internet Publishers
4. R Kelkar, *Satellite Meteorology*, BS Publications.

Subject Code:: CL6L232	Name: Tropical Meteorology	L-T-P: 3-0-0	Credit:3

Pre-requisite(s):

Tropical weather systems: general circulation in the tropics, distribution of temperature, moisture, radiation, precipitation and evaporation in the tropics, convective systems. Inter tropical convergence zone, trade winds, theory and observation of tropical waves. Hydrological cycles and energy balance in the tropics; waves, hydrological cycles and energy balance in the tropics, heat induced tropical circulations.

Text/Reference Books:

1. G C Asnani, *Tropical Meteorology (Vol 1-3)*, Nebula Publishers
2. Wang, Bin, *The Asian Monsoon*, Spring
3. B. Petterson, *Weather analysis and forecasting: A Text book on Synoptic Meteorology*, McGraw-Hill
4. H.Riehl, *Tropical Meteorology*, McGraw-Hill
5. T.N. Krishnamurti, Stefanovaand Misra. *Tropical Meteorology: An Introduction* , Springer
6. S. Hastenrath, *Climate Dynamics of the tropics*, Springer
7. C.S. Ramage, *Monsoon meteorology Monograph*
8. Y.P.Rao, *Southwest monsoon Monograph*
9. H Riehl, *Climate and Weather in the Tropics*, Academic Press

Subject Code:: CL6L233	Name: Weather Analysis and Forecasting	L-T-P: 3-0-0	Credit:3

Pre-requisite(s):

Meteorological instruments, sensors, radiosonde, meteorological parameters, GTS, weather Subject Codes and decoding of weather observations, programming languages, Unix & shell programming, data formats, software tools for meteorological data, thermodynamic diagrams, weather charts, air masses and fronts, jet streams, mid-latitude and tropical disturbances; synoptic features during different seasons, meso-scale systems, monsoon climatology, 850 hPa& 200 hP, ψ and χ fields, mass & wind fields, cyclone development, synoptic forecasting.

Text/Reference Books:

1. Tim Vasquez, *Weather Analysis and Forecasting Handbook*, Weather Graphics Technology Publications
2. Jean Coiffier. *Fundamentals of Numerical weather prediction*, Cambridge University Press
3. Steven A. Ackerman, John A. Knox, *Meteorology*, Brooke/Cole Publications

Laboratory Courses

Subject Code:: CL6P101	Name: Weather Analysis and Forecasting Laboratory	L-T-P: 0-0-3	Credit:2
Pre-requisite(s):			

Weather Codes and Global Telecommunication System (GTS), Atmospheric Properties and Measurements, Instruments, Thermodynamic Diagrams, Station Data, Satellite and Radar Data Analysis and Interpretation, Stability Indices, Weather Chart Plotting, analysis and Interpretation (Synoptic, NWP), Wind Rose, Forecasting (Range of Forecasts, Alert and Warnings, Deterministic/Probabilistic).

Text/Reference Books:

1. Tim Vasquez, *Weather Analysis and Forecasting Handbook*, Weather Graphics Technology Publications
2. Jean Coiffier, *Fundamentals of Numerical weather prediction*, Cambridge University Press
3. Steven A. Ackerman, John A. Knox, *Meteorology*, Brooke/Cole Publications

Subject Code:: CL6P201	Name: Remote Sensing and GIS Laboratory	L-T-P: 0-0-3	Credit:2
Pre-requisite(s):			

Remote sensing satellites and various data products (paper product & Digital), False Color Composition & Natural Composition, Formulation of Interpretation Keys, on screen Visual image Interpretation.

Satellite digital data Formats, Geo-referencing of Digital Image. Image enhancement techniques, Image ratio and image classification. Land, Ocean and Atmosphere Remote Sensing Data Formats, Processing, Interpretation & Analysis.

GIS software, Creation of point, line and polygon in form of shape file/Geo-database, Geo-referencing of satellite data and digitized vector files using GIS software, Geo-Informatics (Pction of Geo-database, Integration of attribute data, Analysis using Map algebra, Map composition and finalization, Web-GIS.

Text/Reference Books:

1. BasudebBhatta,*Remote Sensing and GIS*,Oxford University Press
2. Manishika Jain, *GIS and Remote Sensing Techniques*, Himanshu Publications
3. QihaoWeng, *Remote Sensing and GIS Integration: Theories, Methods, and Applications*, McGraw-Hill Professional

Subject Code:: CL6P202	Name: Modeling and Visualization Laboratory	L-T-P: 0-0-3	Credit:2

Pre-requisite(s):

Unix/Linux Operating System, Programming (FORTRAN), Serial and Parallel Programming, MPI, Shell Scripting, Data analysis, Atmospheric and Ocean numerical Models (Global, Regional, Mesoscale, Couple model), Familiarization with multiple Data Formats, Familiarization with Post-Processing and Visualization Software (GrADs, Ferret, NCAR Graphics..etc).

Text/Reference Books:

1. K H Rosen, D A Host, R Klee and R R Rosinik: Unix, *The Complete Reference*, McGraw-Hil
2. W H Press, B P Flannery, S. A. Teukolsky and W. T. Vetterling, *Numerical Receipe in FORTRAN*, Cambridge University Press.

Curriculum for Joint M.Tech.-Ph.D. (Civil Engineering)

Subject Name	Code	L-T-P	Credit	Contact Hour
SEMESTER - I				
Foundation Analysis and Design	CE6L001	3-1-0	4	4
Urban Transportation System Planning	CE6L002	3-0-0	3	3
Elective-I		3-0-0	3	3
Elective-II		3-0-0	3	3
Elective-III		3-1-0	4	4
Advanced Transportation Engineering Laboratory	CE6P001	0-0-3	2	3
Seminar I	CE6S001	0-0-0	2	0
	Total	**15-2-3**	**21**	**20**
SEMESTER - II				
Traffic Flow Theory	CE6L003	3-0-0	3	3
Concrete Technology	CE6L004	3-1-0	4	4
Elective-IV		3-0-0	3	3
Elective-V		3-0-0	3	3
Elective-VI		3-1-0	4	4
Advanced Environmental and Water Resources Engineering Laboratory	CE6P002	0-0-3	2	3
Advanced Structural and Geotechnical Engineering Laboratory	CE6P003	0-0-3	2	3
Seminar II	CE6S002	0-0-0	2	0
	Total	**15-2-6**	**23**	**23**
SEMESTER - III				
Thesis : Part-I (CE)	CE6D001	0-0-0	16	0
Review Paper (CE)	CE6D002	0-0-0	04	0
	Total	0-0-0	**20**	**0**
SEMESTER – IV				
CE6D003	Thesis : Part-II CE)	0-0-0	16	0
CE6D004	Review Paper (CE)	0-0-0	04	0
	Total	0-0-0	**20**	**0**
		Total Credit:	**84**	

List of Elective Subjects (Civil Engineering)

Subject Name	Code	L-T-P	Credit	Contact Hour
Elective – I to III				
Pavement Materials	CE6L005	3-0-0	3	3
Construction Project Management	CE6L006	3-0-0	3	3
Modern Construction Materials	CE6L007	3-0-0	3	3
Hydraulics of Sediment Transport	CE6L008	3-0-0	3	3
Hydraulic Structure & Hydropower Engineering	CE6L009	3-0-0	3	3
Environmental Hydraulics	CE6L010	3-0-0	3	3
Environmental Management & Impact Assessment	CE6L011	3-0-0	3	3
Advanced Environmental Engineering	CE6L012	3-0-0	3	3
Water Supply and Sanitation Systems	CE6L013	3-0-0	3	3
Plate & Shell Structures	CE6L014	3-0-0	3	3
Advanced Structural Dynamics and Earthquake Engineering	CE6L015	3-0-0	3	3
Advanced Solid Mechanics	CE6L016	3-0-0	3	3
Mathematical Methods	MA6LXXX	3-1-0	4	4
Elective – IV to VI				
Advanced Transportation Systems Analysis	CE6L017	3-0-0	3	3
Analysis and Design of Pavements	CE6L018	3-0-0	3	3
Pavement Evaluation, Maintenance and Rehabilitation	CE6L019	3-0-0	3	3
Dynamics of Soil and Foundations	CE6L020	3-0-0	3	3
Soil-Structure Interaction	CE6L021	3-0-0	3	3
Ground Improvement	CE6L022	3-0-0	3	3
Computational Geomechanics	CE6L023	3-0-0	3	3
Geotechnical Earthquake Engineering	CE6L024	3-0-0	3	3
Geotechnical Risk and Reliability	CE6L025	3-0-0	3	3
Advanced Soil Mechanics	CE6L026	3-0-0	3	3
Free Surface Flows	CE6L027	3-0-0	3	3
Integrated Watershed Management	CE6L028	3-0-0	3	3
Advanced Water and Wastewater Engineering	CE6L029	3-0-0	3	3
Environmental Protection	CE6L030	3-0-0	3	3
Advanced Structural Analysis	CE6L031	3-0-0	3	3
Earthquake Analysis and Design of Structures	CE6L032	3-0-0	3	3
Theory of Elasticity & Plasticity	CE6L033	3-0-0	3	3
Advanced Techniques in Operation Research	MA6LXXX	3-1-0	4	4

Syllabus

Core Subjects

Subject Code: CE6L001	Subject Name: Foundation Analysis and Design	L-T-P: 3-1-0	Credit: 4
Pre-requisite(s): None			

Settlement and bearing capacity: shallow spread footings, mats, and deep foundations; Foundation models, contact pressure distribution for footings, rafts, piles; Retaining Structures; Soil-structure interaction studies; Case studies.

Text/Reference Books:

1. Das B. M. *Principles of Foundation Engineering*, Cengage Learning.
2. Budhu M. *Soil Mechanics and Foundations*, Wiley.
3. Coduto D. P. *Foundation design: Principles and Practices*, Prentice Hill.
4. Holts R. D. and Kovacs W. D. *An introduction Geotechnical Engineering*, Prentice Hall.
5. Das B. M. *Shallow Foundations: Bearing Capacity and Settlement*, CRC Press.
6. Tomilson M. J. *Foundation Design and Construction*, Pearson.
7. Poulos H. G. and Davis E. H. *Pile Foundation Analysis and Design*, Wiley.
8. Salgado R. *The Engineering of Foundations*, Tata McGraw-Hill.

Subject Code: CE6L002	Name: Urban Transportation System Planning	L-T-P: 3-0-0	Credit: 3
<u>**Prerequisite: None**</u>			

Fundamentals of transportation system planning, transportation system planning process, Characteristics of Travel and urban transportation system, Demand theory and supply theory of transportation system, Steps of urban travel demand forecasting- trip generation, trip distribution, modal split and trip assignment, basics of urban transportation network, tour/activity-based travel demand model, land use transport model, urban mass transportation, urban goods movement, parking in urban area.

Text/Reference Books:

1. Kadiyali L. R., *Traffic Engineering and Transport Planning*, Khanna.
2. Ortuzar J. D. and Williumsen L. G., *Modelling Transport, Technology and Engineering*.
3. Hutchinson B. G. *Principles of Urban Transport System Planning*, Scripta.

Subject Code: CE6L003	Name: Traffic Flow Theory	L-T-P: 3-0-0	Credit: 3
Prerequisite: None			
Driver behaviour, traffic information and control systems, traffic studies- volume, speed and delay studies, elements of traffic flow theory, PCU concept, characteristics of uninterrupted traffic, gap acceptance, queuing theory, shock wave, capacity and LOS of Uninterrupted facilities, characteristics of interrupted traffic, traffic characteristics at unsignalised intersections, queue discharge characteristics at signalised intersections, design of signalized intersections, capacity and LOS of signalized intersections, dilemma zone, actuated signal control, signal coordination.			

Text/Reference Books:

1. Mannering F. L., Kilareski W. P. and Washburn S. S., *Principles of Highway Engineering and Traffic Analysis*, John Wiley & Sons.
2. Drew D. R., *Traffic Flow Theory and Control*, McGraw-Hill.
3. May A. D., *Traffic Flow Fundamentals*, Prentice Hall.
4. Slinn M., Guest P. and Mathews P. *Traffic Engineering Design*, Elsevier.
5. Roess R. P., Prassas E. S. and McShane W. R. *Traffic Engineering*, Pearson.
6. Kadiyali L. R., *Traffic Engineering and Transport Planning*, Khanna.
7. Pignatro L. J., *Traffic Engineering-Theory and Practice*, Prentice Hall.
8. Khanna S. K., and Justo C. E. G. *Highway Engineering*, Nem Chand.
9. Khisty C. J. and Lall B. K., *Transportation Engineering*, Prentice Hall India.
10. Papacostas C. S. and Prevedouros P. D., *Transportation Engineering and Planning*, Pearson.

Subject Code: CE6L004	Name: Concrete Technology	L-T-P: 3-1-0	Credit: 4

Prerequisite: None

Fundamental of concrete - constituents, proportioning, mixing, transportation, placing and curing., Properties of fresh and hardened concrete., Quality control in concrete construction, Concrete mix design, Durability of concrete - alkali aggregate reaction, reinforcement corrosion, freezing and thawing, etc., Special concretes - high strength, low heat of hydration, high early strength, self-compacting, etc., Construction methods – shot-crete, roller compacted concrete, etc., Reinforcing materials - epoxy coated bars, fibre-reinforced plastics, Introduction to 'maintenance' of concrete structures - use of nondestructive testing, evaluation criteria.

Text/Reference Books:

1. Gambhir M. L. *Concrete Technology*, McGraw-Hill.
2. Neville A. M. and Brooks J. J. *Concrete Technology*, Pearson.
3. Neville A. M. *Properties of Concrete*, Pearson.
4. Ghose D. N. *Construction Materials*, McGraw-Hill.
5. Mehta P. K. and Montiero P. M. J. *Concrete Material, Microstructure and Properties*, McGraw-Hill.

Electives (I, II, III)

Subject Code: CE6L005	**Name: Pavement Materials**	**L-T-P: 3-0-0**	**Credit: 3**
Prerequisite: None			

Subgrade Soil: Classification, desirable properties, determination of soil strength characteristics, resilient modulus, Road aggregates: classification, properties of aggregates, design of aggregate gradation, Bituminous road binders: bitumen, emulsions, cut backs and modified binders, Rheology of bituminous binders, modified binders, Hot mix, Warm mix and Cold mix Bituminous constructions, Mix design: Marshall method and Superpave procedure, Visco-elastic and fatigue properties of bituminous mixtures, Requirements of paving concrete, design of mixes for recycling of bituminous and concrete pavement surfaces.

Text/Reference Books:

1. Papagiannakis A. T. and Masad E. A. *Pavement Design and Materials*, Wiley.
2. Read J. and Whiteoak D. *The Shell Bitumen Handbook*, Thomas Telford.
3. Anderson R. M. *MS-26 Asphalt Binder Handbook*, Asphalt Institute.
4. Mallick R. B. and El-Korchi T. *Pavement Engineering: Principles and Practice*, CRC Press.

Subject Code: CE6L006	Name: Construction Project Management	L-T-P: 3-0-0	Credit: 3

Prerequisite: None

Principles of Project Management, Project Planning, Introduction to scheduling -work/project break down structures, Bar-charts; Principles of application of CPM and PERT; Precedence Method; Updating; Time - cost tradeoffs, Resource constrained scheduling; Resource levelling Project control; Performance Measurement, Earned value; Multiple Construction Projects; Other network techniques; Project Management Software Packages.

Text/Reference Books:

1. Jha N. K. *Construction Project Management*, Pearson.
2. Williams T. *Construction Management*, Pearson.
3. Chitkara K. *Construction Project Management Techniques and Practice*, McGraw-Hill.
4. Peurifoy, Schexnayder and Shapira. *Construction Planning, equipments and Methods*, McGraw-Hill.

Subject Code: CE6L007	Name: Modern Construction Materials	L-T-P: 3-0-0	Credit: 3

Prerequisite: None

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:

1. Varghese P. C. *Building Materials*, Prentice.
2. Callister W. D. *Materials Science and Engineering: An introduction*, Wiley.
3. Raghavan V. *Materials Science and Engineering*, Prentice.
4. Higgins R. A. *Properties of Engineering Materials*, Industrial Press.
5. Domone P. and Illston J. *Construction materials: Their nature and behaviour*, Spon Press.
6. Young J. F., Mindess S., Gray R. J. and Bentur A. *The Science and Technology of Civil Engineering Materials*, Prentice.
7. Ashby M. F. and Jones D. R. H. *Engineering Materials 1:An introduction to their properties & applications*, Butterworth Heinemann.
8. Schaffer J. P., Saxena A., Antolovich S. D., Sanders T. H. and Warner S. B. *The Science and Design of Engineering Materials*, Irwin.
9. Mehta P. K. and Monteiro P. J. M. *Concrete: Microstructure, properties and materials*, McGraw-Hill.
10. Neville A. M. *Properties of concrete*, Pearson.

Subject Code: CE6L008	Name: Hydraulics of Sediment Transport	L-T-P: 3-0-0	Credit: 3
Prerequisite: None			

Sediment properties; Initiation of motion; Bed Load; Bed Forms; Effective bed roughness; Armouring; Suspended Load; Total Load; Transport of Sediment due to unsteady flow; Meandering of rivers; Braided river; Local scour at different structures; Sediment sampling; Mathematical models of sediment transport.

Text/Reference Books:

1. Yang C. T. *Sediment Transport: Theory and Practice*, Krieger.
2. Graf W. H. *Hydraulics of Sediment Transport*, Water Resources Publications.
3. Fredsoe J. and Diegaard R. *Mechanics of Coastal Sediment Transport*, World Scientific.
4. Garde R. J. *History of Fluvial Hydraulics*, New Age.

Subject Code: CE6L009	Name: Hydraulic Structure & Hydropower Engineering	L-T-P: 3-0-0	Credit: 3
Prerequisite: None			

Advanced topics in design and construction of Gravity, earth and Rockfill dams, Dynamic analysis of gravity dams under earthquake loading through computer package. Spillways and energy dissipators, Gates, Sluices, galleries, Contraction joints, Seepage control measures, Principles of foundation treatment. Transients in water conductor systems. Design of hydropower installation components intake structures, water conductor systems, tunnels, surge-tanks, penstocks, valves and anchor-blocks. Types of powerhouse Underground, Semi-Underground. Turbines and their foundations. Introduction to structural and geotechnical aspects of powerhouse design, CAD applications. Similitude and Models.

Text/Reference Books:

1. Subramanya K. *Flow in open channels*, McGraw-Hill.
2. Garg S. K. *Irrigation Engineering and Hydraulic Structures*, Khanna.
3. Subramanya K. *Fluid Mechanics and Hydraulic Machines*, McGraw-Hill.
4. Daugherty R. L. *Hydraulic Turbines*, HardPress

Subject Code: CE6L010	Name: Environmental Hydraulics	L-T-P: 3-0-0	Credit: 3
Prerequisite: None			

Basic concepts in friction and flow in pipes, Flow formulation, turbulent and viscous flow, Hardy-Cross, Tong O Conner and other methods of analysis of pipe networks, Basic concepts in open channel hydraulics, Energy and momentum equations, critical flow, channel control and transitions, uniform flow, gradually varied flow, flow profiles and their computation, unsteady flow, hydraulic jumps, Design of drainage systems, Ground water hydraulics, estimation of aquifer parameters, confined and unconfined aquifers, steady and unsteady flow into wells, Dupuit approximations, single and multi-well system, well losses, recharging, well developments etc., movement of pollutants in ground water and wastewater treatment plants hydraulics.

Text/Reference Books:

1. Chow V. T. *Flow through open channel*, McGraw-Hill.
2. RangaRaju K. G. *Flow through Open Channels*, McGraw-Hill.
3. Garde R. J. and RangaRaju K. G. *Mechanics of sediment transportation and alluvial stream problems*, New Age.
4. Bhave P. R. *Analysis of Flow in Water Distribution Network*, Technomic.
5. Todd D. K. *Groundwater Hydrology*, Wiley.
6. Bear J. *Hydraulics of Groundwater*, Dover.
7. Raghunath H. M. *Groundwater & Well Hydraulics*, Wiley.

Subject Code: CE6L011	Name: Environmental Management & Impact Assessment	L-T-P: 3-0-0	Credit: 3
Prerequisite: None			

Environmental management, problems and strategies; Review of political, ecological and remedial actions; Future strategies; multidisciplinary environmental strategies, the human, planning, descision-making and management dimensions. Environment Risk assessment, Pollution prevention and Waste minimization; sustainable development (SD), Life cycle assessment. Environmental impact assessment (EIA), definitions and concepts, Screening and scoping criteria; Rapid and comprehensive EIA, Legislative and environmental clearance procedures in India and other countries, Siting criteria; CRZ; Public participation; Resettlement and rehabilitation. Practical applications of EIA; EIA methodologies; Baseline data collection; Prediction and assessment of impacts on physical, biological and socio-economic environment; Environmental management plan; Post project monitoring, initial environmental examination (IEE), environmental impact statement (EIS), environmental appraisal, environmental audit (EA); Environmental impact factors and areas of consideration, measurement of environmental impact, organisation, scope and methodologies of EIA, case studies stressing physical aspects of environment. Evolution of EIA; EIA at project; Regional and policy levels; Strategic EIA; EIA process;

Text/Reference Books:

1. Canter L. *Environmental Impact Assessment*, McGraw-Hill.
2. Kiely G. *Environmental Engineering*, McGraw-Hill.
3. Rau G. J. and Wooten C. D. *Environmental Impact Analysis Handbook*, McGraw-Hill.
4. Dhameja S. K. *Environmental Engineering and Management*, S. K. Kataria & Sons.
5. World Bank, 'Environmental Assessment Source Book', Environment Dept., Washington D.C., 1991
6. Welford R. *Corporate Environmental Management*, Earthscan.
7. Sayre D. *Inside ISO 14000: Competitive Advantage of Environmental Management*, St. Louis Press.
8. Rosencranz A., Divan S. and Noble M. L. *Environmental Law and Policy in India: Cases, Materials and Statutes*, Tripathi Pvt.
9. Asolekar S. R. and Gopichandran R. *Preventive Environmental Management - An Indian Perspective*, Foundation Books Pvt.

Subject Code: CE6L012	Name: Advanced Environmental Engineering	L-T-P: 3-0-0	Credit: 3

Prerequisite: None

The air pollution system: Gases and particulate; Atmospheric sources, sinks, transport; Effects of health and environment; Criterial pollutants, ambient and source standards. Characterization of aerosols, size distributions. Gaseous Pollutants, Control systems. Air quality management, dispersion modeling. Industrial and Vehicular sources of air pollution; Behaviour of pollutants in atmosphere; Emission factors, regulations, control strategies and policies; Monitoring of air pollutants, Particulate and Gaseous Pollutant Control, Control technologies for removal of SO2, NOx, VOC, Control technologies for motor vehicles.

Solid waste management: Sources, Composition and Properties of Municipal Solid Waste, Engineering principles; Generation, Onsite handling, storage and processing including segregation; Collection, Transfer and transport; Processing technique and equipment; Recovery of resources; Conversion products and energy; Composting; Recycling; Incineration and pyrolysis; Disposal of solid waste including sanitary landfill, planning, siting, design, closure and post-closure monitoring; Regional/Integrated solid waste management related issues.

Biomedical waste: Regulatory framework, categorization; generation, collection, transport, treatment and disposal.

Hazardous Waste Fundamentals, Definition, Classification, Generation, Regulatory process, Current Management Practices, Treatment and Disposal Methods, Physicochemical processes, Biological processes, Stabilization and solidification; Thermal methods; Land disposal, Remediation of Contaminated Sites.

Text/Reference Books:

1. Peavy H. S., Rowe D. R. and Tchobanoglous G. *Environmental Engineering*, McGraw-Hill.
2. Nevers N. D. *Air Pollution Control Engineering*, McGraw-Hill.
3. Tchobanoglous G., Theisen H. and Vigil S. A. *Integrated Solid Waste Management: Principles and Management Issues*, McGraw-Hill.
4. LaGrega M. D., Buckingham P. L. and Evans J. C. *Hazardous Waste Management*, McGraw-Hill.
5. Martin E. J. and Johnson J. H. *Hazardous Waste Management Engineering*, van Nostrand-Reinhold.
6. Wentz C. A. *Hazardous Waste Management*, McGraw-Hill.
7. Buonicore A. J. and Davis W. T. *Air Pollution Engineering Manual*, van Nostrand-Reinhold.
8. Flagan R. C. and Seinfeld J. H. *Fundamentals of Air Pollution Engineering*, Prentice Hall.

Subject Code: CE6L013	Name: Water Supply and Sanitation Systems	L-T-P: 3-0-0	Credit: 3

Prerequisite: None

Planning of urban and metropolitan water supply project and its implementation, Water demand forecasting and management, Sources, Water-lifting arrangements, Aqueducts, Hydraulics of conduits, structural requirement for aqueducts. Appurterenances and valves, water pipes, Storage tanks Network design, Design of water distribution system, hydraulic analysis, distribution system components, building plumbing systems. Municipal wastewater collection; Systems of sanitation and systems for water carriage sewage; Estimation of wastewater flows and variation in waste water flow; Design of urban sanitary and storm water sewers, structural requirements of sewer under various conditions, corrosion protection in sewers, design of surface and subsurface drainage, roadways and airport drainage, design of water and wastewater pumping systems, building sanitation. Regulations & Acts, Agencies involved, General sanitation of schools, Hospitals, Bathing places and houses etc. Considerations for layout of treatment plants; Hydraulics and Design of water and Water treatment plants.

Text/Reference Books:

1. Bhave P. R. *Optimal Design Of Water Distribution Networks*, Narosa.
2. Bhave P. R. and Gupta R. *Analysis of Water Distribution Networks*, Narosa.
3. Central Public Health and Environmental Engineering Organization. *Manual on Water Supply and Treatment*, Ministry of Urban Development.
4. Central Public Health and Environmental Engineering Organization. *Manual on Sewerage and Sewage Treatment*, Ministry of Urban Development.
5. McGhee T. J. *Water Supply and Sewerage*, McGraw-Hill.
6. Metcalf and Eddy. *Wastewater Engineering- Treatment and Reuse*, McGraw-Hill.
7. Peavy H. S., Rowe D. R. and Tchobanoglous G. *Environmental Engineering*, McGraw-Hill.
8. Quasim S. R., Motley E. M. and Zhu G. *Water Works Engineering- Planning, Design and Operation*, Prentice.
9. Streeter V. L. and Wylie E. D. *Fluid Transients*, McGraw-Hill.

Subject Code: CE6L014	Name: Plate and Shell Structures	L-T-P: 3-0-0	Credit: 3
Prerequisite: None			
Pure bending of plates; Symmetric bending of circular plates; Small deflection of laterally loaded plates; Rectangular plates with various edge conditions; Continuous rectangular plates; Plates of various shapes; Shells as space enclosure, geometry, classification, principal and Gauss curvature; General theory of thin elastic shells; Shallow and high rise shells; Circular long and short cylindrical shells, beam-arch approximation for long shells; Shells of double curvature, surfaces of revolution and translation; Circular, elliptic and hyperbolic paraboloids, conoids and funicular shells - membrane and approximate bending theories; Closed form and numerical methods of analysis of synclastic and anticlastic shells. **Text/Reference Books:** 1. Timoshenko S. *Theory of Plates and Shells*, McGraw-Hill. 2. Reddy J. N. *Theory and Analysis of Elastic Plates and Shells*, Taylor & Francis. 3. Ugural A. C. *Stresses in plates and shells*, McGraw-Hill.			

Subject Code: CE6L015	Name: Advanced Structural Dynamics and Earthquake Engineering	L-T-P: 3-0-0	Credit: 3
Prerequisite: None			

Single-degree-freedom systems: undamped and damped free vibration; Response to harmonic and periodic excitations; Response to non-periodic excitations; Numerical evaluation of dynamic response; Generalized single-degree-freedom systems. Elements of analytical dynamics: The principle of virtual work; Principle of D Alembert; Hamiltons principle; Lagrange's equation.Multi-degree-freedom systems: Equation of motion; undamped free vibration; Intepretation of modal orthogonality; Decomposition of response in terms of modal co-ordinates; Modal analysis; Response to external excitations; Rayleigh s quotient and its properties; Systems with proportional damping; Systems with arbitrary viscous damping. Distributed parameter systems: axial and bending vibration of beams; orthogonality of modes; Response to external excitations; Rayleigh s quotient; Approximate methods. Earthquake response of linear systems: Earthquake excitations; Equations of motion; Response spectrum concept; Response spectrum characteristics; Design response spectrum; Modal analysis; Displacement response; Element forces; Modal response contribution; Response history analysis; Response spectrum analysis. Introduction to Random Vibration; Stationary and non-stationery random processes; Ergodic random processes. Narrow band and wide band random processes; Properties of Autocorrelation and Power spectral density functions; Response to arbitrary excitation by Fourier transform method.

Text/Reference Books:

1. Paz M. *Structural Dynamics*, CBS Publisher.
2. Clough R. W. and Penzien J. *Dynamics of Structures*, McGraw-Hill.
3. Chopra A. K. *Dynamics of Structures*, Pearson.

Subject Code: CE6L016	Name: Advanced Solid Mechanics	L-T-P: 3-0-0	Credit: 3
Prerequisite: None			

Introduction to elasticity theory; Simple 2D/3D problems and their solutions;Plane stress and plane strain problems, Pure bending of beams with unsymmetrical section; Shear Center; Thermal stresses; Torsion of noncircular members; Curved Beams; Beams on elastic foundation; Plasticity; failure theories; Energy methods; Thermal stresses; Introduction to viscoplasticity and viscoplasticity; Coupled axial force and bending moment problems; coupled torsion and bending moment problems.

Text/Reference Books:

1. Srinath L. S. *Advanced Mechanics of Solids*, McGraw-Hill.
2. Timoshenko S. *Strength of Materials*, CBS Publisher.
3. Bruhns O. T. *Advanced Mechanics of Solids*, Springer.

Electives (IV, V, VI)

Subject Code: CE6L017	Name: Advanced Transportation Systems Analysis	L-T-P: 3-0-0	Credit: 3
Prerequisite: None			

Behavioural aspect of transportation planning: Basics of travel behaviour analysis, stated and revealed preference data, binary logit, multinomial logit, nested logit model, maximum likelihood technique, travel behaviour survey, case study analysis/discussion on travel behaviour analysis-destination choice, mode choice, route choice etc. demand-supply interaction in an urban transport system, urban transportation network analysis, shortest path analysis, formulation of traffic assignment problem, solving traffic assignment problems, equilibrium traffic assignment with link interactions, traffic assignment under travel behaviour, Basics of dynamic traffic assignment.

Text/Reference Books:

1. Manheim M. L. *Fundamentals Of Transportation Systems Analysis*, MIT Press.
2. Louviere J. J., Hensher D. A. and Swait J. D. *Stated Choice Methods*, Cambridge University Press.
3. Akiva M. B. *Discrete Choice Analysis: Theory and Analysis to Travel Demand*, MIT Press.
4. Sheffi Y. *Urban Transportation Networks*, Prentice-Hall.
5. Cascetta E. *Transportation Systems Engineering: Theory and Methods*, Kluwer Academic.

Subject Code: CE6L018	Name: Analysis and Design of Pavements	L-T-P: 3-0-0	Credit: 3
Prerequisite: None			

Types of Pavements, Pavement Composition, Philosophy of design of flexible 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 and rigid pavements using different methods, comparison of different pavement design approaches, design of overlays and drainage system.

Text/Reference Books:

1. Huang Y. H. *Pavement Analysis and Design*, Pearson.
2. Yoder E. J. and Witczak M. W. *Principles of Pavement Design*, Wiley.
3. Mallick R. B. and El-Korchi T. *Pavement Engineering: Principles and Practice*, CRC Press.

*The examination for this course may be considered for open book system.

Subject Code: CE6L019	Name: Pavement Evaluation, Maintenance and Rehabilitation	L-T-P: 3-0-0	Credit: 3
Prerequisite: None			
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. **Text/Reference Books:** 1. Huang Y. H. *Pavement Analysis and Design*, Pearson. 2. Mallick R. B. and El-Korchi T. *Pavement Engineering: Principles and Practice*, CRC Press. 3. Pearson D. *Deterioration and Maintenance of Pavements*, Instituion of Civil Engineers. 4. Haas R., Hudson W. R. and Zaniewski J. P. *Modern pavement management*, Krieger.			

Subject Code: CE6L020	Name: Dynamics of Soil and Foundations	L-T-P: 3-0-0	Credit: 3
Prerequisite: None			

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:

1. Saran S. *Soil Dynamics and Machine Foundations*, Galgotia.
2. Das B. M. and Ramana G. V. *Principles of Soil Dynamics*, CL-Engineering.
3. Richart F. E., Woods R. D. and Hall J. R. *Vibrations of soils and foundations*, Prentice.
4. Kramer S. L. *Geotechnical Earthquake Engineering*, Prentice.

Subject Code: CE6L021	Name: Soil-Structure Interaction	L-T-P: 3-0-0	Credit: 3
Prerequisite: None			

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:

1. Selvadurai A. P. S. *Elastic analysis of soil foundation interaction*, Elsevier Science.
2. Davis R. O. and Selvadurai A. P. S. *Plasticity and Geomechanics*, Cambridge University Press.
3. Davis R. O. and Selvadurai A. P. S. *Elasticity and Geomechanics*, Cambridge University Press.
4. Poulos H. G. and Davis E. H. *Pile Foundation Analysis and Design*, Wiley
5. Bull J. W. *Soil structure interaction: numerical analysis and modelling*, Spon.

Subject Code: CE6L022	Name: Ground Improvement	L-T-P: 3-0-0	Credit: 3
Prerequisite: None			

Introduction, ground improvements schemes for cohesive soil sites (preloading, staged construction, accelerated consolidation with prefabricated drains, granular columns, lime columns, electro-osmosis, compaction piles, deep mixing, and vibro-replacement), ground improvement schemes for cohesionless soil sites (deep dynamic compaction, vibro-compaction, blast densification, grouting, and jet grouting), mechanically stabilized earthwork, soil nailing, ground anchors, light weight fill, and monitoring and quality control in ground improvement projects.

Text/Reference Books:

1. Raju P. P. *Ground Improvement Techniques*, Laxmi Publications.
2. Moseley M. P. and Kirsch K. *Ground Improvement*, Spon Press.
3. Das B. M. *Principles of Foundation Engineering*, Cengage Learning.
4. Indraratna B. and Chu J. J. *Ground Improvement: Case Histories*, Elsevier.
5. Raison C. A. *Ground and Soil Improvement*, Thomas Telford.
6. Koerner R. M. *Designing with Geosynthetics*, Pearson.

Subject Code: CE6L023	Name: Computational Geomechanics	L-T-P: 3-0-0	Credit: 3
<u>Prerequisite: None</u>			

Numerical modeling, constitutive modeling of soils and rock, continuum and discrete element modeling. Concept of stress and strain, principle 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:

1. Desai C. S. and Christian J. T. *Numerical Methods in Geotechnical Engineering*, McGraw-Hill.
2. Davis R. O. and Selvadurai A. P. S. *Plasticity and Geomechanics*, Cambridge University Press.
3. Potts D. M. and Zdravkovic L. *Finite Element Analysis in Geotechnical Engineering: Theory and Application*, Thomas Telford.
4. Christian J. T. *Numerical Methods in Geotechnical Engineering*, McGraw-Hill.
5. Zienkiewicz O. C., Chan A. H. C., Pastor M. and Schrefler B. A. *Computational Geomechanics with Special Reference to Earthquake Engineering*, Wiley.

Subject Code: CE6L024	Name: Geotechnical Earthquake Engineering	L-T-P: 3-0-0	Credit: 3
Prerequisite: None			

Introduction, engineering seismology, plate tectonics, earthquake 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:

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

Subject Code: CE6L025	Name: Geotechnical Risk and Reliability	L-T-P: 3-0-0	Credit: 3
<u>Prerequisite: None</u>			

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, reliability methods, first order second moment (FOSM) method, Hasofer-Lind approach, Response Surface Method, Monte Carlo simulations.

Text/Reference Books:

1. Haldar A. and Mahadevan S. *Probability, Reliability, and Statistical Methods in Engineering Design*, John Wiley.
2. Baecher G. and Christian J. *Reliability and Statistics in Geotechnical Engineering*, John Wiley.
3. Ang A. H. S. and Tang W. H. *Probability Concepts in Engineering Planning and Design: Basic Principles (Vol. I)*, John Wiley.
4. Ang A. H. S. and Tang W. H. *Probability Concepts in Engineering Planning and Design: Decision, Risk, and Reliability (Vol. II)*, John Wiley.
5. Ang A. H. S. and Tang W. H. *Probability Concepts In Engineering: Emphasis On Applications In Civil & Environmental Engineering*, Wiley.
6. Melchers R. E. *Structural Reliability Analysis and Prediction*, John Wiley.
7. Nowak A. S. and Collins K. R. *Reliability of Structures*, CRC Press.
8. Vanmarcke E. *Random Fields: Analysis and Synthesis*, MIT Press.

Subject Code: CE6L026	Name: Advanced Soil Mechanics	L-T-P: 3-0-0	Credit: 3
Prerequisite: None			

Introduction: Origin of soil and its types, mineralogy and structure of clay minerals, Consolidation: Steady State flow, 2D and 3D seepage, transient flow; Compressibility and rate of consolidation, one, two, and three dimensional consolidation theories; Sand drains; 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; Soil Stabilization: Classification of stabilizing agents and stabilization processes. Strength improvement characteristic of soft and sensitive clays, Marine clay and waste material.

Text/Reference Books:

1. Das B. M. *Advanced Soil Mechanics*, Taylor and Francis.
2. Scott R. F. *Principles of Soil Mechanics*, Addison & Wesley.
3. Davis R. O. and Selvadurai A. P. S. *Elasticity and Geomechanics*, Cambridge University Press.
4. Mitchell J. K. *Fundamentals of Soil Behaviour*, Wiley.
5. Wood D. M. *Soil Behaviour and Critical State Soil Mechanics*, University of Glasgow.
6. Schofield A. N. and Wroth C. P. *Critical State Soil Mechanics*, McGraw-Hill.

Subject Code: CE6L027	Name: Free Surface Flows	L-T-P: 3-0-0	Credit: 3
Prerequisite: None			

Energy and momentum of flow; critical flow; channel control and transitions; discharge measurement methods; uniform flow and flow resistance; composite roughness and compound channels; gradually varied flow; classifications and computations of free surface profiles; spatially varied flow; supercritical flows and oblique flows; rapidly varied flow; hydraulic jump; continuity and dynamic equations of unsteady flow; wave propagation and surge; method of characteristics; dam-break problem; flow in channel bends; buoyant and submerged jets.

Text/Reference Books:

1. Subramanya K. *Flow in open channels*, McGraw-Hill.
2. Chanson H. *Hydraulics of Open Channel Flow*, Butterworth Heinemann.
3. Chow V. T. *Open Channel Hydraulics*, McGraw-Hill.
4. French R. *Open Channel Hydraulics*, Water Resources Publications.
5. Sturm. *Open Channel Hydraulics*, McGraw-Hill.

Subject Code: CE6L028	Name: Integrated Watershed Management	L-T-P: 3-0-0	Credit: 3
Prerequisite: None			

Introduction to integrated approach for the management of watersheds; preparation of land drainage schemes; types and design of surface drainage as well as subsurface drainage in coastal and interior basins; controlling of soil erosion and soil salinity; types and design of water conservation and water harvesting structures for different types of catchments; estimation of design storm and design flood for spillways and other outlet structures; flood routing through channels and reservoirs; flood control through single purpose and multipurpose reservoir operation; types and design of flood forecasting and protection systems; flood damage case studies.

Text/Reference Books:

1. Subramanya K. *Engineering Hydrology*, McGraw-Hill.
2. Garg S. K. *Irrigation Engineering and Hydraulic Structures*, Khanna.
3. Chow V. T., Maidment D. R. and Mays L. W. *Applied Hydrology*, McGraw-Hill.
4. Heathcote I. W. *Integrated Watershed Management*, Wiley.

Subject Code: CE6L029	Name: Advanced Water and Wastewater Engineering	L-T-P: 3-0-0	Credit: 3
Prerequisite: None			

Conventional water and waste water treatment methods, their capabilities and limitations, Need for advanced treatment of water and waste water, Advanced water treatment- Iron and manganese removal, colour and odour removal, activated carbon treatment, carbonate balance for corrosion control, ion exchange, electro-dialysis, reverse osmosis and modern methods and flouride management, Advanced waste water treatment- Nutrient control in effluents, Nitrogen and phosphorus removal methods including biological methods, Methods for the removal of heavy metals, oil and refractory organics, Micro-screening, ultra-filtration, centrifugation and other advanced physical methods- aerobic digestion, anaerobic filtration, rotating biological contractor, novel methods of aeration etc., Combined physico-chemical and biological processes, Activated carbon treatment, chlorination of waste water, Pure oxygen systems, Filtration for high quality effluents, Multistage treatment systems, Land treatment and other resources recovery systems. Decentralised wastewater treatment systems; Reliability and cost effectiveness of wastewater systems. Natural treatment systems- floating aquatic plant treatment systems, constructed wetlands. Industrial Wastewater management and reuse, removal of industry specific pollutants including nitrate, sulphate, phosphorous, pathogens, color, odor, TDS, COD and residual BOD, Specific issues in management of industrial wastewater including petrochemical, Text Books:ile, food processing, pharmaceutical, fertilizer, pesticides etc.

Text/Reference Books:

1. Peavy H. S., Rowe D. R. and Tchobanoglous G. *Environmental Engineering*, McGraw-Hill.
2. Nemerow N. L. and Dasgupta A. *Industrial and Hazardous Waste Treatment*, Van Nostarnd Reinhold.
3. Arceivala S. J. and Asolekar S. R. *Wastewater Treatment for Pollution Control and Reuse*, McGraw-Hill.
4. Metcalf and Eddy. *Wastewater Engineering- Treatment and Reuse*, McGraw Hill.
5. Eckenfelder W. W. *Industrial Water Pollution Control*, McGraw-Hill.
6. Nemerow N. L. *Zero Pollution for Industry: Waste Minimization through Industrial Complexes*, John Wiley.
7. Cites R. W., Middlebrooks E. J. and Reed S. C. *Natural wastewater Treatment Systems*, CRC Taylor and Francis.

Subject Code: CE6L030	Name: Environmental Protection	L-T-P: 3-0-0	Credit: 3
Prerequisite: None			

Noise pollution and its control, measuring equipment, Indoor air Pollution and control, Ventilation systems, health and comfort ventilation, natural ventilation and its measurement. Fire protection and equipment, Energy conservation in buildings, Green Building, LEED and TERI-GRIHA requirement, Water supply system for various type of buildings, appurtenances, fixtures, water supply systems. Drainage systems and Solid waste disposal in buildings, Thermal environment in a building and its control, Importance of safety measures in buildings, Various types of safety measures. Water supply preparedness and protection, emergency water supply strategy, rural and urban emergencies. Assessment of damage. Emergency water supply schemes – sources, quality, treatment, storage and distribution, operation and maintenance. Sanitation – human waste and health, strategy for excreta disposal in emergencies, techniques for excreta disposal, disposal of wastewater, management of refuse. Health aspects of water supply and sanitation, disposal of wastewater in rural and urban areas, integrated approach to health and sanitation. Transmission of diseases through air, water and food. Insect vector and rodent control. Excreta treatment and management in rural and urban slums, low cost options. Software related to environmental health and hygiene. National Acts & Rules for Environmental Protection.

Text/Reference Books:

1. Goel P. K. and Sharma K. P. *Environmental guidelines and standards in India*, Techno Science.
2. Singh G. *Environmental law in India*, Macmillan.
3. Thakur K. *Environmental protection law and policy in India*, Deep publishers.
4. BIS. *Functional Requirements of Buildings (other than Industrial Buildings)*, BIS.
5. Manas V. T. *National Plumbing code*, McGraw-Hill.
6. Panchadhari A. K. *Water Supply and Sanitary Installations–Design, Construction and Maintenance*, New Age.
7. Alexander D. *Principles of emergency planning and management*, Oxford University Press.
8. Hallow G. and Bullock J. *Introduction to Emergency Management*, Elsevier.

Subject Code: CE6L031	Name: Advanced Structural Analysis	L-T-P: 3-0-0	Credit: 3
Prerequisite: None			
Basics of structural analysis: static & dynamic loading, linear & nonlinearstructural behaviour, geometric & material nonlinearity, hysteretic behaviour;Classical linear analysis of frames and trusses: displacement method, slopedeflection equations & matrix displacement method, effect of foundationsettlement and temperature; Geometric nonlinear analysis of frames and trusses: displacement method, nonlinear slope-deflection equations & nonlinear behaviour,linearized iterative matrix displacement method, geometric stiffness matrix,tangent stiffness matrix, P- Ä effect, buckling of frames, tension structures;Material nonlinear analysis of frames: basics of plasticity, distributed plasticity& lumped plasticity, incremental nonlinear analysis. **Text/Reference Books:** 1. Thandavamoorthy T. S. *Structural Analysis*, Oxford University Press. 2. Wang C. K. *Intermediate Structural Analysis*, McGraw-Hill. 3. Hibbeler R. C. *Structural Analysis*, Pearson.			

Subject Code: CE6L032	Name: Earthquake Analysis and Design of Structures	L-T-P: 3-0-0	Credit: 3

Prerequisite: None

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:

1. Duggal S. K. *Earthquake Resistant Design of Structures*, Oxford University Press.
2. Chopra A. K. *Dynamics of Structures*, Pearson.
3. Paulay T. and Priestley M. J. N. *Seismic Design of Reinforced Concrete and Masonry Buildings*, Wiley.
4. Bolt B. A. *Earthquakes*, Freeman.
5. Kramer S. L. *Geotechnical Earthquake Engineering*, Pearson.
6. Dutta S. C. and Mukhopadhyay P. S. *Improving Earthquake and Cyclone Resistance of Structures*, TERI.

Subject Code: CE6L033	Name: Theory of Elasticity & Plasticity	L-T-P: 3-0-0	Credit: 3

Prerequisite: None

Three dimensional stress and strain analysis, stress-strain transformation, stress invariants; equilibrium and compatibility equations, boundary conditions; Two dimensional problems in Cartesian, polar and curvilinear co-ordinates, bending of a beam, thick cylinder under pressure, complex variable, harmonic and bi-harmonic functions; Torsion of rectangular bars including hollow sections, bending problems; Energy principles, variational methods and numerical methods.Plasticity :Basic concepts and yield criteria; Equations of plasticity, elasto-plastic analysis of torsion and bending problems, torsion of a bar of oval section (Sokoloskey's method), problems of spherical and axial symmetry, slip lines and plastic flow, strain hardening and FEM applications.

Text/Reference Books:

1. Timoshenko S. P. and Goodier J. N. *Theory of Elasticity*, McGraw-Hill.
2. Kachanov L. M. *Fundamentals of the Theory of Plasticity*, Dover Publications.
3. Chakrabarty J. *Theory of Plasticity*, Butterworth-Heinemann.
4. Starovoitov E. and Naghiyev F. B. O. *Foundations of the Theory of Elasticity, Plasticity, and Viscoelasticity*, Apple Academic Press.

Curriculum for Joint M.Tech.-Ph.D.
(Electronics & Communication Engineering)

Subject Name	Code	L-T-P	Credit	Contact Hour
SEMESTER - I				
Advanced Communication Engineering	EC6L001	3-1-0	4	4
Image and Video Processing	EC6L002	3-1-0	4	4
Elective I		3-0-0/3-1-0	3/4	3/4
Elective II		3-0-0	3	3
Elective III		3-0-0	3	3
Advanced Communication and Radiating System Laboratory	EC6P001	0-0-3	2	3
Design and Simulation Laboratory	EC6P002	0-0-3	2	3
Seminar-I	EC6S001	0-0-3	2	3
		Total :	**23 / 24**	**26/27**
SEMESTER - II				
Information Theory and Coding	EC6L003	3-1-0	4	4
Advanced Digital Signal Processing	EC6L004	3-1-0	4	4
Elective IV		3-0-0/3-1-0	3/4	3/4
Elective V		3-0-0	3	3
Elective VI		3-0-0	3	3
Advanced Digital Signal Processing Laboratory	EC6P003	0-0-3	2	3
Seminar-II	EC6S002	0-0-3	2	3
		Total :	**21 / 22**	**23/24**
SEMESTER - III				
Thesis Part I	EE6D001	0-0-0	16	0
Research Review Paper I	EE6D002	0-0-0	4	0
		Total :	**20**	**0**
SEMESTER – IV				
Thesis Part II	EC6D003	0-0-0	16	0
Research Review Paper II	EC6D004	0-0-0	4	0
		Total :	**20**	**0**

Total Credit: 84 / 86

List of Elective Subjects (Electronics & Communication Engineering)

Subject Name	Code	L-T-P	Credit	Contact Hour
Elective – I to III				
Computational Intelligence	CS6L001	3-0-0	3	3
Statistical Signal Processing	EC6L005	3-0-0	3	3
Design and Analysis of Algorithms	EC6L006	3-0-0	3	3
VLSI Signal processing	EC6L007	3-0-0	3	3
Adaptive and Robust Control	EC6L008	3-0-0	3	3
EMI and EMC Techniques	EC6L009	3-0-0	3	3
Communication Network	EC6L010	3-0-0	3	3
Remote Sensing Systems	EC6L011	3-0-0	3	3
Optical Communication	EC6L012	3-0-0	3	3
Antenna Theory	EC6L013	3-0-0	3	3
Mathematical Methods	MA6LXXX	3-1-0	4	4
Low Power VLSI Circuit & System	EC6L029	3-0-0	3	3
Elective – IV to VI				
Photonic Network	EC6L014	3-0-0	3	3
Biomedical Signal Processing	EC6L015	3-0-0	3	3
Computational Electromagnetics	EC6L016	3-0-0	3	3
Semiconductor Device Modeling	EC6L017	3-0-0	3	3
Satellite Communication	EC6L018	3-0-0	3	3
Fiber Optic Sensors	EC6L019	3-0-0	3	3
Wireless and Mobile Communication	EC6L020	3-0-0	3	3
Microwave Design and Measurement	EC6L021	3-0-0	3	3
Modern Radar System	EC6L022	3-0-0	3	3
Adaptive Signal Processing	EC6L023	3-0-0	3	3
Array Signal Processing	EC6L024	3-0-0	3	3
Multimedia Network	EC6L025	3-0-0	3	3
Computer Networks	EC6L026	3-0-0	3	3
Networks and Systems Security	CS6L002	3-0-0	3	3
Advanced Techniques in Operation Research	MA7L022	3-1-0	4	4

Syllabus

Core Subjects:

Subject Code: EC6L001	Name: Advanced Communication Engineering	L-T-P: 3-1-0	Credit: 4

Noise in amplitude modulation, frequency modulation, pulse code, delta modulation, BPSK and FSK;
Information theory and coding; Optimum reception of digital signals, Performance analysis of digital communication systems;
Multi carrier communications, Multi-channel communications and Multi-user communications;
Introduction to software defined radios, Spectrum sensing, Dynamic spectrum access and management, Distributed learning; Introduction to sensor networks, Deployment and configuration, Protocols routing and application;

Prerequisite: None

Text/References:

1. H. Taub, D.L. Schilling and G. Saha, *"Principles of communication"*, 3rd Edition, Tata McGraw Hill Publishers, 2008.
2. B.P. Lathi, Zhi Ding, *"Modern Digital and Analog Communication Systems"*, 4th Edition, Oxford University Press, 2009.
3. Masoud Salehi, John G. Proakis, *"Fundamentals of Communication Systems"*, 1st Edition, Prearson Education, 2006.
4. Holger Kerl, Andreas Willing, *"Protocols and Architecture for Wireless Sensor Network"*, John Willey and Sons, 2007.
5. Cauligi S Raghavendra, Krishna M Sivalingam, Taieb Znati, *"Wireless Sensor Network"*, Springer, 2006.
6. Hüseyin Arslan, *"Cognitive Radio, Software Defined Radio and Adaptive Wireless Systems"*, Springer, 2007.
7. Kwang-Cheng Chen, Ramjee Prasad, *"Cognitive Radio Networks"*, John Wiley & Sons, 2009.

Subject Code: EC6L002	Name: Image and Video Processing	L-T-P: 3-1-0	Credit: 4

Introduction to digital image processing, intensity transformation, spatial filtering, frequency domain filtering, point and line detection, edge detection, Hough Transform, image restoration, color processing, thresholding, image segmentation, affine transformation, image transforms, multi-resolution image analysis, shape and texture representation and description, introduction to object recognition, image compression, JPEG, introduction to digital video, video compression standards, motion estimation.

Prerequisite: None

Texts/References:

1. *Digital Image processing, Gonzalez and Woods*, 3rd edition, Pearson and Prentice Hall, 2009
2. W.K. Pratt: *Digital image processing*, 4th edition, Wiley India, 2007.
3. K.R. Castleman: *Digital image processing*, 2nd edition, Pearson, 2012.
4. A.K. Jain: *Fundamentals of digital image processing*, Prentice Hall, 1989.

Subject Code: EC6L003	Name: Information Theory and Coding	L-T-P: 3-1-0	Credit: 4

Introduction: entropy and mutual information theory: joint entropy, conditional entropy, relationship between entropy and mutual information, chain rules for entropy, relative entropy, mutual information, jensen's inequality fano's inequality.
An introduction to codes: coding: kraft inequality, optimal codes, bounds on optimal code length, kraft inequality for uniquely decodable codes, shannon and huffman codes, shannon, fano, elias codes, block codes, linear block codes, cyclic codes
Efficient encoding, information sources; average code word length; huffman encoding; noiseless coding: the noiseless coding theorem
Channel capacity: discrete memoryless channels and capacity, examples of channel capacity, symmetric channels, properties of channel capacity, channel coding theorem
Theory and practice of error-control coding: trellis diagram and the viterbi algorithm, convolution coding in mobile communications and modern graph-based codes (turbo-codes and ldpc codes), the main coding theory problem.

Prerequisites: None

Text Books:

1. T. M. Cover and J. A. Thomas, *Elements of Information Theory*, 2nd ed. Wiley-Interscience, 2006. ISBN-13: 978-0471241959.
2. S. Lin and D. J. Costello, *Error Control Coding*, 2nd ed. Pearson Prentice Hall, 2004, ISBN-13: 978-0130426727.

Reference Books:

1. R. G. Gallager, *Information Theory and Reliable Communication*. Wiley, 1968, ISBN-13: 978-0471290483
2. I Csiszar and J. Korner, *Information Theory: Coding Theorems for Discrete Memoryless Sys-tems*. Akademiai Kiado, December 1981, ISBN-13: 978-9630574402.
3. T. S. Han, *Information-Spectrum Methods in Information Theory*. Springer, 2002, ISBN-13: 978-3642078125.
4. Andre Neubauer, Jurgen Freedenberg, Volker Kuhn, *"Coding theory Algorithm, Architectures and Applications*",Willey India Editions, ISBN: 978-81-265-3432-6, 2007
5. Ranjan Bose, *"Information theory, Coding and Cryptography",* TMH publication, ISBN: 978-0-07-0669017, 2008
6. Roman, Steven, *"Introduction to Coding and Information Theory",* Springer, ISBN 978-0-387-94704-4 Journal readings

Subject Code: EC6L004	Name: Advanced Digital Signal Processing	L-T-P: 3-1-0	Credit: 4

Multi-rate digital signal processing: decimation, interpolation, sampling rate conversion, digital filter banks, two-channel quadrature mirror filter bank, M-channel QMF bank.

Linear prediction and optimum linear filters: forward and backward linear prediction, normal equations, AR lattice and ARMA lattice-ladder filters, Wiener filters

Power spectrum estimation: nonparametric and parametric methods, filter bank methods, Eigen analysis algorithms

Time-frequency analysis: uncertainty principle, Short-time Fourier transform, Wigner distribution, Kernel design, Gabor wavelets, multi-resolution analysis

Prerequisite: None

Texts/Reference Books:

1. *Digital Signal Processing: Principles, Algorithms and Applications, Proakis and Manolakis*, 4th edition, Pearson, 2012
2. *Time-frequency analysis*, Cohen, Prentice-Hall, 1995
3. *Advanced digital signal processing*, Vaseghi, 4th edition, Wiley, 2008
4. *Multi-rate systems and filter banks*, Vaidyanathan, Pearson, 1992

Electives (I, II, III):

Subject Code: CS6L001	Name: Computational Intelligence	L-T-P: 3-0-0	Credit: 3

Soft Computing: Artificial Neural Network: Artificial neuron, single layer and multilayer architecture, nonlinear function like sigmoid function, back propagation learning algorithm. Functional link artificial neural network, trigonometric, Chebyshev and Legendre polynomial. Readial basis function neural network, its learning algorithm, recurrent neural network and its learning algorithm.

Fuzzy Logic: Types of fuzzy logic, membership functions, fuzzification and defuzzification, rule-based fuzzy inference engine, Type-1 and Type-2 fuzzy logic, typical applications.
Evolutionary Computing and Swarm Intelligence: Derivative based and derivative free optimization, multivariable and multiconstraint optimization. Genetic algorithm and its variants, Differential evolution and its variants, particle swarm optimization and its variants, Cat swarm optimization, bacterial foraging optimization, Artificial immune system, multiobjective optimization like NSGA-II.

Prerequisite: None

Texts/References:

1. S. Haykin, *'Neural Networks and Learning Machines'*, Prentice Hall, 2009.
2. Y.H. Pao, *'Adaptive pattern recognition and neural networks'*, Addison-Wesley, 1989.
3. Jang, J.S.R., Sun, C.T. and Mizutani, E., *'Neuro-fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence'*, Prentice Hall, 2009.
4. Hagan, M., *'Neural Network Design'*, Nelson Candad, 2008.
5. K.A.D. Jong, *'Evolutionary Computation – A Unified Approach'*, PHI Learning, 2009.

(Research publications that will be suggested during the course.)

Subject Code: EC6L005	Name: Statistical Signal Processing	L-T-P: 3-0-0	Credit: 3

Review of Probability and Stochastic Process

Estimation Theory: Minimum-variance unbiased estimator (MVUE), Cramer-Rao Lower bound, Best Linear Unbiased Estimator, Maximum likelihood Estimator, General Bayesian Estimator

Detection Theory: Neyman Pearson Theorem, Receiver Operating Characteristics, Matched Filters, Composite Hypothesis Testing

Nonparametric Spectral Estimation: Estimation of power spectrum of stationary random signal using periodogram-various methods, Joint signal analysis and estimation of cross power spectrum

Linear Signal Model: Synthesis of coloring filter and Analysis of whitening filter, Rational power spectra (AR, MA, ARMA), Relationship between filter parameters and autocorrelation sequences, Lattice-Ladder filter realization

Parametric Spectral Estimation: Order selection criterion of AR model , Minimum-variance, Maximum entropy and Maximum likelihood spectrum estimation Harmonic models and frequency estimation techniques Harmonic Decomposition, MUSIC algorithm, ESPRIT algorithm

Linear Optimum Filter: Optimum FIR Filter, PCA of optimum linear estimator and its frequency domain interpretation, Forward and Backward Linear prediction and optimum reflection coefficients Optimum causal and non-causal IIR Filters, Deconvolution and Signal restoration Algorithms and Structure of Optimum Linear Filters Levinson Recursion for optimum estimate, Order-recursive algorithms for optimum FIR filters and its lattice structures.

Prerequisite: None

Texts Books:

1. Steven Kay, *Fundamentals of Statistical Signal Processing*, Vol I: EstimationTheory, Vol II: Detection Theory, Prentice Hall, 1993/1998.

Reference Books:

1. Harry L. Van Trees, *Detection, Estimation, and Modulation Theory*, Part I, Wiley-Inter science, 2001
2. Monson H. Hayes, *Statistical Digital Signal Processing and Modeling*, John Wiley, 1996.

Subject Code: EC6L006	Name: Design and Analysis of Algorithms	L-T-P: 3-0-0	Credit: 3

Introduction: Order notations, induction, floor and ceiling functions, pigeon-hole principle, recurrence relations; Algorithm design techniques: Greedy algorithms, divide-and-conquer algorithms, dynamic programming, amortization, optimal algorithms; Algorithms on arrays: Selection and median-finding, counting, radix and bucket sorts, string matching (Rabin-Karp and Knuth-Morris-Pratt algorithms); Geometric algorithms: Convex hulls, sweep paradigm, Voronoidiagrams; Algorithms on graphs: Traversal, topological sort, minimum spanning trees, shortest path, network flow; NP-completeness: Classes P and NP, reduction, NP-completeness, examples of NP-complete problems; Approximation algorithms: PTAS and FPTAS, examples; Randomized algorithms: Monte Carlo and Las Vegas algorithms, examples.

Prerequisite: None

Texts/References:

1. T. H.Cormen, C. E.Lieserson, R. L.Rivest and C. Stein, *"Introduction to Algorithms"*, 3rd Ed., PHI, 2010.
2. J. Kleinberg and É. Tardos, *"Algorithm Design"*, Pearson, 2012.
3. M. T. Goodrich and R.Tamassia, "Algorithm Design: Foundations, Analysis, and Internet Examples", Second Edition, Wiley, 2006.
4. R.Motwani and P. Raghavan, *"Randomized* Algorithms", MHE, 2010.
5. V.V. Vazirani, *"Approximation Algorithms",* Springer, 2010.

Subject Code: EC6L007	Name: VLSI Signal processing	L-T-P: 3-0-0	Credit: 3

Generic transceiver architectures in current wireless communications systems: various wireless LAN standards and digital broadcast standards - DVB-T/S; Analog RF front-end modules of a communication receiver: LNA, filter, RF VGA, Mixer, IF Amplifier, VCO, Oscillators and Frequency Synthesizer; Digital IF Extension and AGC: ADCs and DACs at IF-level and AGC; Digital Baseband Modules: OFDM signal processing – Timing and Frequency Synchronization, FFT/IFFT, Adaptive Equalizer, Mapper/Demapper, Channel EnSubject Coder/DeSubject Coders, Viterbi, Reed-Solomon, Turbo Subject Codes; Non-idealities in RF front-end: Non-linearities, Imperfect gain, DC- offset, Oscillator phase noise, I/Q mismatch. Digital Compensation techniques for front-end imperfections; Power Amplifier design issues in OFDM transmitter; Image/Video compression: core/compute-intensive algorithms – DCT/IDCT, motion estimation and compensation; candidate VLSI structures.

Prerequisite: None

Texts/References:

1. B. Leung, *"VLSI for Wireless Communication",* Springer, 2011.
2. B. Razavi, *"RF Microelectronics",* Pearson Education, 2011.
3. R.J. Plassche, *"CMOS Integrated Analog-to-Digital and Digital-to-Analog Converters*", Springer, 2005.
4. F. Horlin and A. *Bourdoux*, "Digital Compensation for Analog Front-Ends: A New Approach to Wireless Transceiver Design", John Wiley & Sons, 2008.
5. K. K. Parhi, *"VLSI Digital Signal Processing Systems: Design and Implementation",* Wiley India, 2007.
6. *J.E. Franca, Y. Tsividis, "Design of Analog-Digital VLSI Circuits for Telecommunication and Signal Processing",* Prentice Hall, 1993.

Subject Code: EC6L008	Name: Adaptive and Robust Control	L-T-P: 3-0-0	Credit: 3

Introduction; Models for dynamic systems: State-space models, Input-output models, Parametric models; Stability: Input-output stability, Lyapunov stability, Stability of LTI feedback systems; Online parameter estimation: Adaptive laws with normalization, Adaptive laws with projection, Hybrid adaptive laws; Parametric identifiers and adaptive observers; Model reference adaptive control (MRAC): Simple direct MRAC schemes, MRAC for SISO plants, Direct MRAC with unnormalized and normalized adaptive laws, Indirect MRAC; Adaptive pole placement control (APPC): Simple APPC schemes, PPC for known parameters, Indirect APPC schemes; Robust adaptive laws: Plant uncertainties and robust control, Instability in adaptive systems; Some robust adaptive laws; Robust adaptive control schemes: Robust identifiers and adaptive observers, Robust MRAC, Performance improvement of MRAC, Robust APPC schemes

Prerequisites: None

Texts/References:

1. P. A. Ioannou and J. Sun, *'Robust Adaptive Control'*, Prentice Hall, Upper Saddle River, NJ, 1996
2. S. Sastry and M. Bodson, *'Adaptive Control'*, Prentice-Hall, 1989
3. K. J. Astrom and B. Wittenmark, *'Adaptive Control'*, 2nd Edition, Addison-Wesley, 1995
4. K. S. Narendra and A. M. Annaswamy, *'Stable Adaptive Systems'*, Prentice-Hall, 1989
5. I.D. Landau, R. Lozano, and M. M'Saad, *'Adaptive Control'*, Springer Verlag, London, 1998.

Subject Code: EC6L009	Name: EMI and EMC Techniques	L-T-P: 3-0-0	Credit: 3

Basic Concepts: Definition of EMI and EMC, Classification of EMI/EMC, Sources of EMI, EMI coupling modes, ESD Phenomena and effects, Transient phenomena and suppression, EMC requirements for electronic systems, Non-ideal Behaviors of Components

EMI Measurements: Basic principles of EMI measurements, EMI measuring instruments

EMI Control Methods: Conducted and radiated emissions and susceptibility, Crosstalk and shielding, Grounding, Bonding, Filtering, EMI gasket, Isolation transformer, opto isolator.

EMC Standard And Regulations: National and Intentional standardizing organizations, Frequency assignment, Spectrum conversation.

EMC Design And Interconnection Techniques: Cable routing and connection, Component selection and mounting, PCB design (Trace routing, Impedance control, decoupling, Zoning and grounding)

EMC analysis and detection techniques: Using tools for signal integrity analysis, Study eye diagrams for communication systems

Prerequisites: None

Text Books:

1. Clayton R.Paul, *Introduction to Electromagnetic compatibility*, Wiley & Sons, 1992.

Reference Books:

1. Kenneth L. Kaiser, *Electromagnetic Compatibility Handbook*, CRC Press, 1st edition, 2004.
2. Mark I. Montrose, *Printed Circuit Board Design Techniques for EMC Compliance: A Handbook for Designers (IEEE Press Series on Electronics Technology)*, Wiley-IEEE Press, 2nd edition, 2000.

Subject Code: EC6L010	Name: Communication Network	L-T-P: 3-0-0	Credit: 3

Transmission Fundamentals, Protocols and the TCP/IP Suite. An Overview/History of Wireless Systems, Tele traffic Engineering, Radio Propagation and Propagation Path Loss Models, An Overview of Digital Communication and Transmission, Fundamentals of Cellular Communications, Multiple Access Techniques, Speech Coding and Channel Coding, Modulation Schemes, Antennas Diversity and Link Analysis, Spread Spectrum SS and CDMA Systems, Mobility Management in Wireless Networks, Security in Wireless Systems, Mobile Network and Transport Layer, Wide Area Wireless Networks WANs ,GSM Evolution, Wide Area Wireless Networks , CDMA One Evolution, Planning and Design of Wide Area Wireless Networks, Wireless Personal Area Network Bluetooth, Wireless Local Area Networks , Fourth Generation Systems and New Wireless Technologies,

Prerequisite: None

Texts/References:

1. William Stallings *"Wireless Communications and Networks*", Prentice Hall, second edition, 2005
2. Vijay Garg, Morgan Kaufmann *"Wireless Communications & Networking"*, June 2007
3. Theodore Rappaport, *"Wireless Communications: Principles and Practice"*, Prentice Hall, Second Edition.

Subject Code: EC6L011	Name: Remote Sensing Systems	L-T-P: 3-0-0	Credit: 3

Electromagnetics basis: Electromagnetic waves, Polarization, Spectra and Fourier transform, Doppler effect, Angular distribution of radiation, Thermal radiation, diffraction

Interactions of electromagnetic radiation: Propagation through homogeneous materials, Reflection and emission from real materials, Propagation through the atmosphere Molecular absorption and scattering, Radiative transfer equation

Electro optical remote sensing system: Spectral Imagery, VIR imaging systems, Thermal infrared imagers

Passive Microwave Systems: Antenna Theory, Microwave Radiometry

Ranging Systems: Laser profiling, Radar altimetry

Scattering Systems: Lidar, Microwave Scatterometry, Synthetic Aperture Radar

Data Processing: Image Processing, Classification and Segmentation

Applications of Remote Sensing Systems

Prerequisite: None

Text Books:

1. W. G. Rees, *Physical Principles of Remote Sensing*, Cambridge University Press; 3rd edition, 2013.

Reference Books:

1. *Remote Sensing from Air And Space* by R. C. Olsen, SPIE Press, 2007.
2. James B. Campbell, Randolph H. Wynne, *Introduction to Remote Sensing*, 5th Edition, The Guilford Press, 2011.

Subject Code: EC6L012	Name: Optical Communication	L-T-P: 3-0-0	Credit: 3

Introduction: overview of optical fiber communications, optical spectral bands, fundamental of data communication concepts, network information rate.

Optical fibers: introduction to the optical fibres: evolution of optical fibres, itu-t standards g652, g655, optical fibres cables, measurements on optical links: the otdr principles

Optical sources: light-emitting diodes, power–current characteristics, led spectrum, semiconductor lasers, optical gain, feedback and laser threshold, laser structures. Distributed feedback lasers, coupled-cavity semiconductor lasers, tunable semiconductor lasers, laser characteristics, reliability considerations.

Optical detection: photo detectors, optical receivers, detector responsivity, rise time and bandwidth, common photo detectors, *p–i–n* photodiodes, avalanche photodiodes, receiver design, receiver noise, coherent receiver, noise mechanisms, receiver sensitivity, bit-error rate, minimum received power, quantum limit of photo detection, intensity noise, timing jitter, receiver performance.

Digital: point-to-point links, power penalties, error control, intensity modulation, coherent modulation, wavelength multiplexing (wdm) techniques, components for wdm, optical amplifier and optical filters for wdm links.

Optical networks: network concept, network topology, sonet/sdh, components for optical networks: characteristics and evolution trends- oadm (optical add and drop multiplexers)- oxc (optical cross connecters)- wavelength converters (w-c)

Prerequisite: None

Text Books:

1. G. P. Agrawal, *Fiber-Optic Communication Systems*, Third Ed., John Wiley & Sons, Inc., 2002
2. G. Keiser, *Optical Fiber Communications*, McGraw-Hill, 2000

Reference Books:

1. J. Senior, *Optical Fiber Communications. Principle and Practice*, Prentice Hall,
2. J.P. Laude, *DWDM Fundamentals, Components and Applications*, Ed. Artech House, 2002.
3. R. Ramaswami *Optical Networks. A Practical Perpective*, Morgan Kaufmann Publishers, Inc. ITU-T Recommendations
4. R. L. Freeman, *Fiber-Optic Systems for Telecommunications*, John Wiley & Sons, Inc., 2002
5. Eugene Hecht , *Optics*, 4th Edition, (Addison-Wesley)
6. Djafar K. Mynbaev and Lowell L. Scheiner, *Fiber-Optic Communications Technology*, (Prentice-Hall)
7. Joseph C. Palais , *Fiber Optic Communications*, 4th Edition, (Prentice Hall)
8. Selvarajan and Kar, *"Optical Fiber Communications",* Tata McGraw-Hill Education, 2003.

Subject Code: EC6L013	Name: Antenna Theory	L-T-P: 3-0-0	Credit: 3

Introduction, Definitions, EM radiation, Friis and Radar Equations
Basic antenna elements (Dipole, Monopole, Loop)
Antenna arrays (Linear and End-fire arrays) and Pattern synthesis
Complex Wire Antennas (Helical, Spiral, LPDA, Turnstile)
Aperture antennas
Broadband and Ultra-wideband Antennas
Antennas in Communication Link Budgets
Introduction to Computational Methods (including Integral Equations, Method of Moments)
Novel Antenna Concepts and Emerging Trends (e.g. Metamaterial Antennas, Fractal Antennas, Reconfigurable Antennas, Nanoantennas)

Prerequisite: None

Text Books:

1. C.A. Balanis, *Antenna Theory Analysis and Design*, 3rd edition, John Whiley & Sons, 2005.

Reference Books:

1. *Antenna Theory and Design*, revised Ed., by Robert S. Elliott, Willey-Interstice & IEEE Press, 2003.
2. *Antenna Theory and Design*, 2nd Ed., by Warren L. Stutzman, and Gary A. Thiele, John Wiley, 1997.
3. *Microwave Antenna Theory and Design*, by Samuel Silver, M.I.T. Radiation Laboratory Series.

Subject Code: MA6LXXX	Name: Mathematical Methods	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.

Prerequisite: None

Text books:

1. B.S. Grawel, *Numerical Methods*
2. M.K. Jain, S.R.K. Iyengar and R.K. Jain, *Numerical Methods-problem and solutions*, Wiley Eastern Limited, 2001.
3. S. Ross, *Introduction to Probability Models*, Wiley India
4. A.M. Gun, M.K. Gupta and B.S. Gupta, *Fundamentals of Statistics*

Reference Books:

1. A.J. Hayter, *Probability and Statistics*, Duxbury, 2002
2. J.B. Scarborough, *Numerical mathematical analysis*, oxford & IBH Publishing Co.Pvt.,2000
3. R.W. Hamming, *Numerical Methods for Scientist and Engineers*, McGraw Hill, 1998
4. J.H. Mathews and K.D. Fink, *Numerical Methods using MATLAB*, Pearson Education, 2004.

Subject Code: EC6L029	Name: Low Power VLSI Circuits & Systems	L-T-P: 3-0-0	Credit: 3

Basics of MOS circuits: MOS transistor structure and device modelling; MOS inverters; MOS combinational circuits – Different logic families. Sources of power dissipation in CMOS circuits: Static power dissipation; Diode leakage current, sub-threshold leakage current, gate and other tunnel currents; Dynamic power dissipation; Short circuit power; Switching power; Gliching power, Supply voltage scaling approaches: Technology level, Logic level, Architecture level, Algorithm level, Dynamic voltage scaling, Power Management; Switched Capacitance Minimization Approaches: Hardware Software Trade-off, Bus Encoding, Two's compliment vs Sign magnitude, Architectural optimization, Clock gating, Logic styles; Leakage power minimization approaches: Variable-threshold voltage CMOS (VTCMOS) approach, Multi-threshold voltage CMOS (MTCMOS) approach, Dual-Vt assignment approach, Transistor stacking; Special Topics: Adiabatic switching circuits, Battery-aware synthesis, Variation tolerant design.

Prerequisite: None

Text/Reference Books:

1. Kiat-Seng Yeo and Kaushik Roy, *Low-voltage, Low-power VLSI sub-systems*, Mc Graw Hill, 2005.
2. Sung-Mo Kang, Y Leblebici, *CMOS Digital Integrated Circuits: Analysis and Design*, Tata Mc Graw Hill, 2003.
3. Neil H. E. Weste and K. Eshraghian, *Principles of CMOS VLSI Design*, Addison Wesley (Indian reprint).
4. A. Bellamour and M. I. Elmasri, *Low-power VLSI CMOS Circuit Design*, Kluwer Academic Press, 1995.
5. Kaushik Roy and Sharat C. Prasad, *Low-power CMOS VLSI Design*, Wiley-Interscience, 2000.

Electives (IV, V, VI):

Subject Code: EC6L014	Name: Photonic Network	L-T-P: 3-0-0	Credit: 3

Introduction to photonics networks, bandwidth management, internet growth, topology, osi reference model, photonic system technologies and issues, tdm and wdm multiplexing and demultiplexing. Routing. Wavelength blocking and conversion.

Photonic network topologies and architectures, modulation and demodulation techniques, modulation related effects & nonlinear optical effects, photonic components, signal amplification and regeneration, link budget, network technologies and issues

Photonic network components: multiplexer/demultiplexer, switches/routers, cross connectors-converter.

Network protocols: ip, g-ethernet, sdh/sonet, fddi, atm, etc

System performance and management, dispersion management, ber & sources of noise, power budgets; optical switching & routing, network safety, regulations & standards, current issues of photonic systems.

Prerequisite: Optical Communication

Text / Reference Books:

1. Giancarlo Prati *"Photonic Networks: Advances in Optical Communications"* Springer Verlag, 1997
2. R Ramaswami and K.N.Sivarajan, "*Optical networks: A practical perspective 2nd ed"*, Morgan Kaufman, ISBN 1-55860-655-6
3. U Black, "*Optical Networks: Third Generation Transport Systems"*, Prentice Hall
4. Roberto Sabella, Paolo Lugli, *"High speed optical communications",* Kluwer, IEEE Journals

Subject Code: EC6L015	Name: Bio-Medical Signal Processing	L-T-P: 3-0-0	Credit: 3

EEG and ECG signals: Genesis, monitoring, measurement and uses. Time and frequency domain analysis of signals: Morphological studies, correlation, spectral analysis. Linear prediction technique: AR model and its implementation, inverse filter. Homomorphic processing: generalized superposition, complex cepstrum, minimum phase component. Nonlinear dynamics and chaos: fractal dimension, correlation dimension, Lyapunovexponent. Artifacts: Types, detection and minimization. Applications to biomedical signals.

Prerequisite: None

Texts/References:

1. E. N. Bruce, *'Biomedical Signal Processing And Signal Modeling'*, Wiley, 2009
2. R. M. Rangayyam, *'Biomedical Signal Analysis – A Case-Study Approach'*, Wiley, 2009.

Subject Code: EC6L016	Name: Computational Electromagnetics	L-T-P: 3-0-0	Credit: 3

Applications of electromagnetics in the 21st century. Numerical Methods: ODE solvers, Euler, Runge-Kutta. Review of Basic Electromagnetics: Electrostatics, Magnetostatics, Wave Equations. Numerical Techniques: Method of Moements, Finite Difference Method, Finite Element method, Charge Simulation Method, Monte carlo method. Time Varying Electromagnetic Fiels: Eddy currents & skin depth, introduction to wavelets, families of wavelets. Microwaves, Optics, Micromagnetics, Bio-electromagnetics. Tutorials and demonstration on PC, programming assignments.

Prerequisite: None

Text/ Reference Books:

1. *Numerical Techniques in Electromagnetic*, 2nd edition, M.N.O. sadiku, CRC Press.
2. Weber, E., *Electromagnetic Fields*, Dover 1951
3. Silvester, P. P. and Ferrari, R. L., *Finite Elements for Electrical Engineers*, Cambridge University Press 1996.
4. *Numerical Methods in Engineering with Python*, *Jaan Kiusalaas*, Cambridge.
5. Selected journal papers

Subject Code: EC6L017	Name: Semiconductor Device Modeling	L-T-P: 3-0-0	Credit: 3

Review of semiconductor physics: Quantum foundation, Carrier scattering, high field effects; P- N junction diode modeling: Static model, Large signal model and SPICE models; BJT modeling: Ebers - Moll, Static, large-signal, small- signal models. Gummel - Poon model. Temperature and area effects. Power BJT model, SPICE models, Limitations of GP model; Advanced Bipolar models: VBIC, HICUM and MEXTARM;MOS Transistors: LEVEL 1, LEVEL 2 ,LEVEL 3, BSIM, HISIMVEKV Models, Threshold voltage modeling, Punchthrough, Carrier velocity modeling, Short channel effects, Channel-length modulation, Barrier lowering, Hot carrier effects, Mobility modeling, Model parameters; Analytical and Numerical modeling of BJT and MOS transistors; Types of models for Heterojunction Bipolar Transistors, Compact modeling concepts, Modeling of HBTs, HBT noise models, Measurement and parameter extraction.

Pre-requisite: None

Text Books:

1. G. Massobrio, P. Antognetti, *Semiconductor Device Modeling with SPICE, 2nd edition*, McGraw-Hill, New York,1993.
2. M Rudolph, *Introduction to Modeling HBTs*, Artech House, Boston, 2006.

Reference Books:

1. S M Sze, K K Ng, *Physics of Semiconductor Devices*, 3rd edition, John Wiley, New Jersey, 2007.

   G. A. Armstrong, C.K.Maiti, *Technology Computer Aided Design for Si, SiGe and GaAs Integrated Circuits ,IET Series*, London, 2007.

Subject Code: EC6L018	Name: Satellite Communication	L-T-P: 3-0-0	Credit: 3

Introduction, general overview, types of satellite communications systems, historical developments

Link budgets: antennas, propagation, noise, c_0/n_0, c/n calculation, transmitters, propagation and rain, receivers, lnas, figure of merit, total system performance.

Orbital mechanics: basic equations, special orbits, geometry and movement , constellations, real world effects

Rf and licensing issues : spectrum allocations, modulation, multiplexing, multiple access

Current and future trends

Spectrum sharing, additional noise issues, interference and coordination, telemetry and tracking, power limitations, reliability

Prerequisites: None

Text/Reference Books:

1. *Principles of Communications Satellites*, by G. Gordon and W. Morgan
2. Don I Dalgleish *"An Introduction to Satellite Communications"*: IET Publisher
3. Dennis Roddy, *"Satellite Communication,"* ,Tata McGraw-Hill Education

Subject Code: EC6L019	Name: Fibre Optic Sensors	L-T-P: 3-0-0	Credit: 3

Optical fiber sensors and devices: overview of fibre optic sensors – advantages over conventional sensors, broadband classification, light sources, spatial light modulator, detection process in the fourier domain, system performance parameter

Introduction: intensity modulated optical fibre sensors, intensity modulation through light interruption shutter, multimode fibre optic sensors – reflective fibre optic sensors, evanescent wave fibre sensors, microbend optical fibre sensors, fibre optic refractometers, intensity modulated fibre optic thermometers, distributed sensing with fibre optics.

interferometric optical fibre sensors: introduction, basic principles of interferometric optical fibre sensors, components and applications of interferometric sensors.

Fibre optic sensor multiplexing: introduction, general topological configuration, and incoherent and coherent detection.

signal processing in monomode fibre optic sensor systems: introduction, transduction mechanisms, optical signal processing, electronic processing, industrial applications of fiber optic sensors, fiber optic smart structures and their applications.

Prerequisite: None

Text/Reference Books:

1. *Optical Fiber Communications* – Gerd Keiser, 4th Ed. McGraw Hill.
2. *Fundamentals of Fibre Optics in Telecommunication and Sensor Systems* – Bishnu P PAL Wiley Eastern Ltd. (1994).
3. David A. Krohn, *"Fiber Optic Sensors: Fundamentals and Applications*, Isa, 2000
4. Andreas Othonos, Kyriacos Kalli *"Fiber Bragg gratings: fundamentals and applications in telecommunications and sensing",* Artech House, 1999,
5. Francis T.S. Yu, Shizhuo Yin *"Fiber Optic Sensors",* Second Edition CRC Press, CRC Press, 2002
6. IEEE Sensors Journal

Subject Code: EC6L020	Name: Wireless and Mobile Communications	L-T-P: 3-0-0	Credit: 3

Review of Digital Communication: Block diagram of digital communication, Modulation Schemes (BPSK, M-PSK, M-QAM, M-FSK), Pulse Shaping, Bandwidth efficiency, MAP-Receivers, AWGN Channel and Performance analysis.

Wireless Channels: Fading Wireless Channel Modeling , Rayleigh/Ricean Fading Channels ,BER Performance in Fading Channels , Diversity modeling for Wireless Communications, BER Performance Improvement with diversity, RMS Delay Spread , Doppler Fading, Jakes Model, Jakes Spectrum , Impact of Doppler Fading, Types of Diversity – Frequency, Time, Space;

Cellular Communications: Introduction to Cellular Communications, Frequency reuse, Multiple Access Technologies, Cellular Processes - Call Setup, Handover, Introduction to CDMA ,Walsh codes, PN Sequences , Multipath diversity, RAKE Receiver, MIMO/OFDM: Introduction to MIMO, MIMO Channel Capacity, SVD and Eigenmodes of the MIMO Channel, MIMO Spatial Multiplexing – BLAST, MIMO Diversity – Alamouti, OSTBC, Introduction to OFDM , Multicarrier Modulation and Cyclic Prefix, OFDM Issues.

Wireless Standards: GSM, GPRS, WCDMA, LTE, WiMAX.

Prerequisite: None

Texts/References:

1. *Fundamentals of Wireless Communications, David Tse and Pramod Viswanath*, • Cambridge University Press, 2005.
2. *Wireless Communications,* Andrea Goldsmith, Cambridge University Press, 2005.
3. *Wireless Communications*: Principles and Practice, Theodore Rappaport, Prentice Hall, Second Edition.

Subject Code: EC6L021	Name: Microwave Design and Measurement	L-T-P: 3-0-0	Credit: 3

This course will be an introduction to microwave circuit design and analysis techniques, with particular emphasis on applications for modern microwave communication and sensing systems. Also, it will cover fundamental measurement techniques for device and circuit characterization at microwave frequencies The specific content of the course may be as follows:

Review of electromagnetics: Maxwell's equations, plane wave solutions.

Types of transmission lines and their properties: coaxial lines, rectangular waveguides, Microstrip.

Network analysis: scattering matrix, transmission matrix formulations.

Matching networks: lumped element designs and limitations, single and double-stub tuned designs, Quarter-wavelength transformers, multisection matching transformers.

Active microwave circuit design: characteristics of microwave transistors, mixers and detectors, Oscillators.

Amplifier design: LNA and Power amplifiers, gain and stability, design for noise figure. Single-stage amplifier design.

Noise in microwave circuits: dynamic range and noise sources, equivalent noise temperature, system noise figure considerations.

Prerequisites: None.

Text Books:

1. David M. Pozar, *Microwave Engineering*, 3rd. ed., John Wiley & Sons, 2005.

Reference Books:

1. Guillermo Gonzalez, *Microwave Transistor Amplifiers*, 2nd. ed., Prentice-Hall, 1997.
2. Thomas H. Lee, *Planar Microwave Engineering*: *A Practical Guide to Theory, Measurement, and Circuit*s, 1st Edition, Cambridge University Press, 2004.

Subject Code: EC6L022	Name: Modern Radar System	L-T-P: 3-0-0	Credit: 3

Introduction, Radar Basics, Radar Equation including its search and track forms, Displays, Receivers, Transmitters, Radar Antennas including Reflectors and Phased Array Antennas, Radar Cross Section, Statistical Models for Noise and Target RCS, General Characteristics of Clutter and Clutter Modelling, Clutter Reduction Techniques of Doppler and MTI, Pulse compression, Radar Measurements, Radar Tracking, Radar Detection and Target Classification, Constant False Alarm Rate Detectors, DPCA and STAP, Types of Radar and Emerging Trends.

Prerequisite: None

Text Books:

1. *M.A. Richards et al, Principles* of Modern Radar, Basic Principles Vol. 1, 1st edition, SciTech 2010

Reference Books:

1. Skolnik, *Introduction to Radar Systems*, 3rd edition, Tata McGraw Hill.
2. Hamish Meikle, *Modern Radar Systems*, 2nd Edition, ARTECH House, INC.

Subject Code: EC6L023	Name: Adaptive Signal Processing	L-T-P: 3-0-0	Credit: 3

Introduction to adaptive filters, optimal estimation, linear estimation: normal equation, orthogonality principle, linear models. Constrained linear estimation: minimum variance unbiased estimation, steepest descent algorithms, stochastic gradient algorithms: LMS algorithm, normalized LMS algorithm, RLS algorithm. Steady-state performance of adaptive filters, transient performance of adaptive filters, block adaptive filters, the least-squares criterion, recursive least-squares, lattice filters

Prerequisite: None

Texts/Reference Books:

1. *Fundamentals of adaptive filtering*, A. H. Sayed, Wiley, 2003
2. *Adaptive filter theory*, Simon Haykin, Fourth edition, Pearson, 2012
3. *Adaptive Signal Processing*, Widrow and Stearns, Pearson, 2007

Subject Code: EC6L024	Name: Array Signal Processing	L-T-P: 3-0-0	Credit: 3

Introduction: Array Processing and Applications

Arrays and Spatial Filters: Uniform Linear Array, Array Steering, Array Performance, Linear Aperture

Synthesis of Linear Arrays and Apertures: Spectral Weighting, Array Polynomials, Minimum Beamwidth, Null Steering, Spatially Non-uniform Linear Arrays, Broadband Arrays

Planar Arrays and Apertures: Rectangular Arrays, Circular Arrays, Circular Apertures, Non-planar Arrays

Characterization of Space-time Processes: Snapshot Models, Space-time Random Process

Optimum Waveform Estimation: Optimum Beamformers, MVDR and MPDR Beamformers, LCMV and LCMP Beamformers, Eigenspace Beamformer, Beamspace Beamformer, Broadband Beamformer

Adaptive Beamformers: Parametric Estimation, RLS, LMS, Gradient Algorithms

Parameter Estimation and Direction of Arrival Estimation: Cramer-Rao Bounds, Maximum Likelihood Estimation, Capon methods, Subspace methods - MUSIC, Minimum-Norm and ESPRIT techniques.

Prerequisites: None

Text Books:

1. Harry L. Van Trees, *Optimum Array Processing (Part IV of Detection, Estimation, and Modulation Theory)*, Wiley-Interscience, 2002.

Reference Books:

1. Dan E. Dugeon and Don H. Johnson. (1993). *Array Signal Processing: Concepts and Techniques*. Prentice Hall.
2. Petre Stoica and Randolph L. Moses. (2005, 1997) *Spectral Analysis of Signals*. Prentice Hall.

Subject Code: EC6L025	Name: Multimedia Network	L-T-P: 3-0-0	Credit: 3

Introduction: multimedia information representation – text, images, audio, video, digital coding techniques and standards, audio coding, image coding, video coding

Multimedia compression and resiliency, codecs, adaptive coding, error handling techniques, multimedia network services and applications

Wireless broadband, broadcast tv and video streaming, qos, media transport protocols, session initiation protocol (sip), real-time streaming protocol (rtsp), real-time transport protocol (rtp), session description protocol (sdp), media transport - security issues/techniques and compression

Firewalls, nats, ipsec and secure rtp, header compression, next-generation multimedia network architecture standards: multiservice switching forum architecture.

Prerequisite: Communication Network

Text/Reference Books:

1. Perkins, *RTP: Audio and Video for the Internet*, Addison-Wesley, 2003
2. Hwang, *Multimedia Networking: From Theory to Practice*, Cambridge
3. Fred Halsall, *Multimedia Communications Applications, Networks, Protocols and Standards*, Addison Wesley, 2001
4. K.R. Rao and Z.S. Bojkovic, *Packet Video Communications over ATM Networks*, Prentice Hall, 2000,
5. *Mobile Communications*, John B. Anderson, Series Editor
6. Chwan-Hwa Wu and J.D. Irwin *"Emerging Multimedia Computer Communication Technologies,"* Prentice Hall, 1998
7. IEEE Journals

Subject Code: EC6L026	Name: Computer Networks	L-T-P: 3-0-0	Credit: 3

Overview of OSI reference model. Topology design, Media Access Control Level, Services, Problems and protocols, Practical local area network design and implementation. IEEE LAN Standards, Logical Link Control protocols, HDLC, ALOHA, SLOTTED ALOHA, FDDI, Client Server model and related softwares.

Network Layer level services, problems and protocols. WAN, MAN, interconnection networks related softwares, TCP/IP, Novel NetWare, Routers, Bridges and Gateways their Practical implementation aspects. X.25, Internet and related softwares NETSCAPE and MOSAIC.

Transport layer, services, problems and their protocol.

Brief functioning of upper layers, E-mail and other application.

Prerequisites: None

Texts/ Reference Books:

1. *Data Communications and Networking*, Fourth Edition by Behrouza A. Forouzan, Tata McGraw-Hill Education.
2. *Computer Networks*, A.S.Tanenbaum,4th Edition,Pearson education.

Subject Code: CS6L002	Name: Networks and Systems Security	L-T-P: 3-0-0	Credit: 3

Introduction: computer security concepts , the osi security architecture, security attacks, security services, security mechanisms, a model for network security

Basic cryptography: historical background, transposition/substitution, caesar cipher, introduction to symmetric crypto primitives, asymmetric crypto primitives, and hash functions, block ciphers, message authentication, symmetric-key encryption, public-key encryption, digital signatures.

Secret key cryptography applications, data encryption standard (des), encrypting large messages (ecb, cbc, ofb, cfb, ctr), multiple encryption des (ede)

Public key cryptography applications, theory: euclidean algorithm, euler theorem, fermat theorem, multiplicative and additive inverse, rsa, selection of public and private keys. Authentication: security handshake pitfalls, online vs. Offline password guessing, reflection attacks, per-session keys and authentication tickets, key distribution centers and certificate authorities.

Real-time communication security: introduction to tcp/ip protocol stack, implementation layers for security protocols and implications,

Network security applications: key distribution and user authentication , symmetric key distribution using symmetric encryption, key distribution using asymmetric encryption, certificates, public-key infrastructure, federated identity management, transport-level security, web security considerations, secure socket layer and transport layer security, transport layer security, https, secure shell (ssh), wireless network security, ieee 802.11 wireless lan overview, ieee 802.11i wireless lan security, wireless application protocol overview, wireless transport layer security, wap end-to-end security,

Electronic mail security: distribution lists, establishing keys, privacy, source authentication, message integrity, non-repudiation, proof of submission, proof of delivery, message flow confidentiality, anonymity, pretty good privacy (pgp),

Firewalls and web security: packet filters, application level gateways, encrypted tunnels, cookies, web security problems

Prerequisite: None

Text Books:

1. William Stallings, "*Network Security Essentials Applications and Standards*" (5th Edition), Prentice Hall
2. Kaufman, Perlman and Speciner, "*Network Security: Private Communication in a Public World*" (2nd Edition) Prentice Hall, Publication Date: May 2, 2002.

Reference Books:

1. W. Richard Stevens, *"TCP/IP Illustrated, Vol. 1: The Protocols"* (Addison-Wesley Professional Computing Series) 1993, Edition: US ed.
2. ERIC Cole, *"Network Security Bible"*, Willey
3. Joseph Migga Kizza *"Computer Network Security"*

Subject Code:	Name: Advanced Techniques in Operation Research	L-T-P: 3-0-0	Credit: 3

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 probabilitistic 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 Book:

1. S.S. Rao, *Engineering Optimization Theory and Practices*, John Wiley and Sons, 2009

Reference Books:

1. M. Ehrgott, *Multi-criteria Optimization*, Springer 2006
2. K.M, Miettien, *Non-linear multi-objective optimization*, Kluwers International Series, 2004
3. K. Deb, *Multi-Objective Optimization using Evolutionary Algorithms*, John Wiley & Sons, 2001.

Curriculum for Joint M.Tech.-Ph.D. (Power System Engineering)

Subject Name	Code	L-T-P	Credit	Contact Hour
SEMESTER - I				
Power System Analysis and Operation	EE6L001	4-0-0	4	4
Electric Power Quality	EE6L002	3-0-0	3	3
Elective I		3-0-0	3	3
Elective II		3-0-0	3	3
Elective III		3-0/1-0	3 / 4	3/4
Power System Lab - I	EE6P001	0-0-3	2	3
Energy Systems Lab	EE6P002	0-0-3	2	3
Seminar - I	EE6S001	0-0-3	2	3
		Total :	**22 / 23**	**25/26**
SEMESTER - II				
Power System Dynamics & Control	EE6L003	4-0-0	4	4
Power System Protection	EE6L004	4-0-0	4	4
HVDC and Flexible AC Transmission Systems	EE6L005	3-0-0	3	3
Elective IV		3-0/1-0	3 / 4	3/4
Elective V		3-0/1-0	3 / 4	3/4
Power System Lab - II	EE6P003	0-0-3	2	3
Seminar - II	EE6S002	0-0-3	2	3
		Total :	**21 / 23**	**23/25**
SEMESTER - III				
Thesis Part I	EE6D001		16	0
Research Review Paper I	EE6D002		4	0
		Total :	**20**	**0**
SEMESTER – IV				
Thesis Part II	EE6D003		16	0
Research Review Paper II	EE6D004		4	0
		Total :	**20**	**0**

Total Credit: 83 / 86

List of Elective Subjects (Power System Engineering)

Subject Name	Code	L-T-P	Credit	Contact Hour
Elective – I to III				
Renewable and Distributed Energy Sources	EE6L006	3-0-0	3	3
Industrial Instrumentation	EE6L007	3-0-0	3	3
Energy, Ecology and Environment	EE6L008	3-0-0	3	3
High Voltage Engineering	EE6L009	3-0-0	3	3
Advanced Power Electronics	EE6L010	3-0-0	3	3
Energy Storage Systems	EE6L011	3-0-0	3	3
EHV/UHV Power Transmission Engineering	EE6L012	3-0-0	3	3
Computational Intelligence	CS6L001	3-0-0	3	3
Statistical Signal Processing	EC6L005	3-0-0	3	3
Mathematical Methods	MA6LXXX	3-1-0	4	4
Elective – IV to V				
Grid Integration of Renewable Energy Systems	EE6L013	3-0-0	3	3
Smart Grid Technology	EE6L014	3-0-0	3	3
Advanced High Voltage Engg.	EE6L015	3-0-0	3	3
Advanced Control	EE6L016	3-0-0	3	3
Distribution System Engineering	EE6L017	3-0-0	3	3
Networks and Systems Security	CS6L002	3-0-0	3	3
Advanced Digital Signal Processing	EC6L004	3-1-0	4	4
Pattern Recognition	EC6L027	3-0-0	3	3
Computational Electromagnetics	EC6L016	3-0-0	3	3
Advanced Techniques in Operations Research	MA7L022	3-1-0	4	4

Syllabus

Core Subjects:

Subject Code: EE6L001	Name: Power System Analysis and Operation	L-T-P: 4-0-0	Credits: 4

Load Flow Studies in power systems, Network model formulation, Bus-Admittance Matrix, Gauss-Siedel, Newton Raphson and decoupled load flow studies, Line Flow and Losses, Load flow with power electronics control, AC-DC analysis.

State estimation: static and dynamic.

Optimal system operation: Optimal operation of generators on bus bar, optimal unit commitment, optimal generation scheduling, Unit commitment and Scheduling of Hydro thermal systems, Power system security: System state classification, security analysis, contingency analysis, sensitivity factors.

State estimation of power system: LSQ, static state estimation and tracking state estimation of power systems, computational considerations, Reliability considerations in power system operation.

Load forecasting : forecasting methodology, time series and Kalman filter based approach, long term load forecasting.

Introduction to power system restructuring, deregulation and market operations.

Texts/References:

1. D P Kothari, I J Nagrath *'Modern Power System Analysis'*, Tata McGraw-Hill Education, 2011.
2. Hadi Sadat *'Power system analysis'*, Tata Mcgraw Hill Education, 2002.
3. Grainmger and Stevenson *'Modern Power system Analysis'*, Tata McGraw-Hill Education, 1994.
4. Loi Lei Lai, *'Power System Restructuring and Deregulation: Trading, Performance and Information Technology'*, John Wiley & Sons, 2001.

Subject Code: EE6L002	Name: Power Quality	L-T-P: 3-0-0	Credits: 3

Brief review of various power quality (PQ) problems: Source of generation and their impacts on equipment and systems, need of monitoring, international power quality standards.

Passive Filters: Control of harmonics using passive L-C filters, tuned and de-tuned filters, their design criterion and implementation.

Active Power Filters: Power factor improvement, reactive power compensation, mitigation of harmonics and voltage sag compensation using active power filters. Study of various active power filters viz., static shunt compensators (STATCOM), dynamic voltage restorer (DVR), unified power quality conditioner (UPQC), etc. Suitability of type of active filters for mitigation of various power quality problems, Design of active power filters, various topologies and control schemes.

Texts/References:

1. Arindam Ghosh and Gerard Ledwich *'Power Quality Enhancement Using Custom Power Devices (Power Electronics and Power Systems)'*, Springer; 2002.
2. Surya Santoso, H. Wayne Beaty, Roger C. Dugan, and Mark F. McGranaghan, *'Electrical Power Systems Quality'*, McGraw-Hill Professional, 2002.
3. Math H. Bollen *'Understanding Power Quality Problems: Voltage Sags and Interruptions'*, Wiley-IEEE Press, 1999.
4. Narain G. Hingorani and Laszlo Gyugy *'Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems'*, Wiley-IEEE Press, 1999.

Subject Code: EE6L003	Name: Power System Dynamics & Control	L-T-P: 4-0-0	Credits: 4

Basic Ideas of Modeling of Synchronous machines, excitation systems and Governors-Steady state, Dynamic and Transient stability. State space formulation of single and multi-machine models with control equipments. Damping effects of FACTS devices.

Sub-synchronous Resonance: Modal Analysis, Torsional Oscillations, induction generator effect, Torsional interaction effect, countermeasure.

Application of numerical techniques to multi-machine dynamic and transient stability studies.

Generation/Frequency Characteristics and load frequency characteristics, tie-line bias control, Automatic Generation Control, Alert and emergency system operation control. Control of reactive power flow: AVR, OLTC Transformers, FACTS, Static var compensators, system loss minimization, Emergency control, Reliability and security, Protective relaying.

Texts/References:

1. Yao-Nan Yu *'Electric Power System Dynamics'*, Academic Press, 1983.
2. Olle I. Elgerd *'Electric Energy Systems Theory: An Introduction'*, Tata McGraw Hill, 2001.
3. K. R. Padiyar *'Power System Dynamics: Stability and Control'*, B P B Publications, 2002.

Subject Code: EE6L004	Name: Power System Protection	L-T-P: 4-0-0	Credits: 4

Generation, propagation and interaction of electrical transients in electric power systems. Analysis of single and multiple transients including three phase and switching transients. Mathematical modeling of transmission lines and other power equipment in the presence of surge phenomena. Evolution in Protection systems, Characteristic of protective relays, Basic elements of Digital protection, signal conditioning and conversion, Fourier analysis and least square based techniques, Differential equation based techniques for transmission line applications, Fundamentals of travelling wave based techniques, Digital differential protection of transformers and transmission systems. Intelligent protection using ANN and Fuzzy systems, Application of advanced DSP in numerical relaying.

Texts/References:

1. A T Johns and S Kalman *'Digital Protection for Power Systems'*, IET, 1997.
2. A G Phadke and J. Thorp *'Computer Relaying for Power Systems'*, Wiley, 2009.
3. Allen Greenwood *'Electrical Transient in Power Systems'*, McGraw Hill, 1990.

Subject Code: EE6L005	Name: HVDC and Flexible AC Transmission Systems	L-T-P: 3-0-0	Credits: 3

HVDC transmission- introduction- comparison of ac and HVDC- HVDC transmission analysis of HVDC converters - pulse number- analysis with and without overlap- converter bridge characteristics- converter and HVDC system control- principles of DC link control- starting and stopping of DC link, power control- harmonics & filters– introduction- generation of harmonics- types of ac filters. power flow analysis in AC/DC systems - general modeling of dc links, solutions of AC-DC power flow- flexible ac transmission systems(FACTS)- concept of FACTS - flow of power in an ac system- dynamic stability consideration- basic types of FACTS controllers- static shunt compensators - SVC & STATCOM - objectives of shunt compensation- methods of controllable var generation- switching converter type var generators-basic operating principle and control approaches- static series compensators – GCSC, TSSC, TCSC & SSSC - objectives of series compensator, variable impedance type series compensators:- basic operating control schemes- power angle characteristics- control range and VA rating- external control- combined compensators.

Texts/References:

1. K.R. Padiyar, *'HVDC Power Transmission System'*, New Age Intl. Co, 2002.
2. N.G *Hingorani, and L. Gyugyi* 'Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems', IEEE Press Book, Standard Publishers and Distributors, Delhi, 2001.
3. R. Streeram Kumar, *'Lecture Notes on Flexible AC Transmission Systems (FACTS)'*, Institution of Engineers (India), Calicut Local Centre, 2003.
4. K.S. Sureshkumar, and S. Ashok, *'FACTS Controllers & Applications*', E-book edition, Nalanda Digital Library, NIT Calicut, 2003.
5. T. J. E Miller, *'Reactive Power Control in Electric Systems'*, John Wiley & Sons, 2010.

Elective (I to III)

Subject Code: EE6L006	Name: Renewable and Distributed Energy Sources	L-T-P: 3-0-0	Credits: 3

Brief idea on renewable and distributed sources, their usefulness and advantages.

Wind Energy: Estimates of wind energy potential, wind maps, instrumentation for wind velocity measurements, aerodynamic and mechanical aspects of wind machine design, conversion to electrical energy, aspects of location of wind farms.

Solar Energy: Present and new technological developments in photovoltaic, estimation of solar irradiance, components of solar energy systems, solar-thermal system applications to power generation, heating.

Hydel Power: Water power estimates, use of hydrographs, hydraulic turbine, characteristics and part load performance, design of wheels, draft tubes and penstocks, plant layouts.

Brief idea of other sources viz., tidal, geothermal, gas-based, etc.

Requirements of hybrid/combined use of different renewable and distributed sources, need of energy storage.

Texts/References:

1. Math J. Bollen, Fainan Hassan *'Integration of Distributed Generation in the Power System'*, IEEE Press, 2011.
2. Loi Lei Lai and Tze Fun Chan *'Distributed Generation: Induction and Permanent Magnet Generators'*, Wiley-IEEE Press, 2007.
3. Studies' Craig Anderson and Rudolf I. Howard *'Wind and Hydropower Integration: Concepts, Considerations and Case'*, Nova Publisher, 2012.
4. Amanda E. Niemi and Cory M. Fincher *'Hydropower from Small and Low-Head Hydro Technologies'*, Nova Publisher, 2011.
5. D. Yogi Goswami, Frank Kreith and Jan F. Kreider *'Principles of Solar Engineering'*, Taylor & Francis 2000.
6. G. N. Tiwari *'Solar Energy Technology'*, Nova Science Publishers, 2005.

Subject Code: EE6L007	Name: Industrial Instrumentation	L-T-P: 3-0-0	Credits: 3

Static and dynamic characteristics of sensors, Resistive, Inductive and Capacitive sensors and signal conditioning circuits. Temperature, pressure, flow and level measurement techniques. pH and conductivity sensors. Piezo-electric and ultrasonic sensors and its application in process and biomedical Instrumentation. Measurement of viscosity, humidity and thermal conductivity. Optical Instrumentation: devices, intensity modulation and interferometric technique. Nucleonic gauges: Sources and Detectors and its application. Interfacing Sensors and actuators using LabVIEW programs. Instrumentation system Design.

Texts/References:

1. K. Krishnaswamy, S Vijayachitra, *'Industrial Instrumentation'* New Age International, 2005.
2. William C Dunn, William Dunn *'Fundamentals of Industrial Instrumentation and Process Control'* McGraw-Hill, 2005.
3. Al Sutko, Adolph A. Sutko, Jerry Faulk *'Industrial Instrumentation'* Cengage Learning, 2009.

Subject Code: EE6L008	Name: Energy, Ecology and Environment	L-T-P: 3-0-0	Credits: 3

Environment definition, Environmental Segments, Concepts of Ecosystem: Fundamentals of Ecology and Ecosystem, Components of ecosystem, Food chain, Food web, Trophic level, Energy flow. Introduction, types, characteristic features, structure and function of the following ecosystem: Forest, Grassland, Desert and Aquatic ecosystem. Effects of human activities on environment: Agriculture, Housing, Industry, Mining and Transportation activities, Basics of Environmental Impact Assessment & Sustainable Development.

Water Resources - Availability and Quality aspects. Mineral Resources, Soil, Material cycles-Carbon, Nitrogen and Sulphur Cycles. Energy - Different types of energy, Conventional and Non-Conventional Sources - Hydro Electric, Fossil Fuel based, Nuclear, Solar, Biomass and Geothermal energy and Bio-gas.
Gas Hydrates, Hydrogen as an alternative future source of Energy.

Definition causes effects and control measures of: Air Pollution, Water pollution, Land pollution, Noise pollution. Climate Change and Global warming: Effects, Acid Rain, Ozone Layer depletion, Photochemical Smog, Solid waste management, Waste water treatment.

Ambient air quality standards, Water quality parameters and standards; Turbidity, pH, Suspended solids, hardness, residual chlorine, sulfates, phosphates, iron and manganese, DO, BOD, COD.

Texts/References:

1. James Girard *'Principles Of Environmental Chemistry'*, Jones & Bartlett Learning, 2005
2. Benny Joseph *'Environmental Studies'*, Tata McgrawHill, 2005.
3. A K De *'Environmental Chemistry'* New Age International Publishers, 2005.
4. D.D. Mishra, S.S. Dara *'A Textbook of Environmental Chemistry and Pollution Control (With Energy, Ecology, Ethics and Society)'*, S. Chand and Co, 2004.
5. Samir K. Banerjee *'Environmental Chemistry'* Prentice Hall of India, 2009.
6. P. Venugoplan Rao *'Principles of Environmental Science and Engineering'* Prentice Hall of India, 2006.
7. D.L. Manjunath *'Environmental Studies'* Pearson Education, 2006.

Subject Code: EE6L009	Name: High Voltage Engineering	L-T-P: 3-0-0	Credits: 3

Generation of High Voltages and Currents: Generation of High Direct Current Voltages, Generation of High alternating voltages, Generation of Impulse Voltages, Generation of Impulse currents, Tripping and control of impulse generators.

Measurement of High Voltages and Currents: Measurement of High Direct Current voltages, Measurement of High Voltages alternating and impulse, Measurement of High Currents-direct, alternating and Impulse, Oscilloscope for impulse voltage and current measurements.

Break Down in Solid Dielectrics: Intrinsic breakdown, electromechanical breakdown, thermal breakdown, breakdown of solid dielectrics in practice, Breakdown in composite dielectrics, solid dielectrics used in practice.

Break Down in Gaseous and Liquid Dielectrics: Gases as insulating media, collision process, Ionization process, Townsend's criteria of breakdown in gases, Paschen's law. Liquid as Insulator, pure and commercial liquids, breakdown in pure and commercial liquids.

High Voltage Testing of Electrical Apparatus: Testing of Insulators and bushings, Testing of Isolators and circuit breakers, Testing of cables, Testing of Transformers, Testing of Surge Arresters, Radio Interference measurements.

Texts/References:

1. E. Kuffel, and W. S. Zaengl, J. Kuffel *'High Voltage Engineering: Fundamentals'*, CBS Publishers, 2005.
2. .Ravindra Arora, Wolfgang Mosch, *'High Voltage and Electrical Insulation Engineering'* John Wiley & Sons, 2011.
3. L L Alston *'High Voltage Technology'*, Oxford University Press, 2011.
4. Dieter Kind, Kurt Feser, and Y. Narayana *Rao 'High-Voltage Test Techniques'* Newnes, 2001.
5. W. Peek, and F. W. Peek *"Dielectric Phenomena in High Voltage Engineering"*, Rough Draft Printing, 2008.
6. Research publications that will be suggested during the course.

Subject Code: EE6L010	Name: Advanced Power Electronics	L-T-P: 3-0-0	Credits: 3

Advanced Switch Mode Power Converters: Cuk dc-dc converter, Full bridge dc-dc converter, Half-bridge converter Forward converter, Flyback converter, Push-pull converter,
Resonant Converters: Introduction, classification of resonant converters, series and parallel resonant inverters, load resonant converters, resonant switch converters, zero voltage and zero current switching resonant converters
Multilevel Inverters: Concept, types of multilevel inverters, diode-clamped, flying-capacitor, and cascaded multilevel inverters, applications, comparison
FACTS: Principles of shunt and series compensation, compensators: TCR, TCS, SVC, TSSC, TCSC, UFC, comparison
Matrix converters: Basic principles and analysis, applications

Texts/References:

1. Muhammad H. Rashid, *"Power Electronics: Circuits, Device and Applications"*, 2nd Ed. 1993, Prentice-Hall, Inc.
2. Ned Mohan, T M Undeland, W PRobbins, *"Power Electronics: Converters, Application and Desig*n", John Wiley, 3rd Edition, 2003
3. A M Trzynadlowski, *"Introduction to Modern Power Electronics"* John Wiley, 1998.

Subject Code: EE6L011	Name: Energy Storage Systems	L-T-P: 3-0-0	Credits: 3

Energy and economic growth and the environment, implications of the Kyoto Protocol, and structural change in the electricity supply industry, Fundamental concept of batteries, battery performance, charging and discharging of a battery, storage density, energy density, and safety issues. Particularly, we will cover classical batteries, such as (i) Lead-Acid (ii) Nickel-Cadmium, (iii) Zinc Manganese dioxide, and modern batteries: (i) Zinc-Air (ii) Nickel Hydride, (iii) Lithium Battery. Thermo-electricity, Super-capacitor technology, Fuel cell, Use of power electronic converters in energy storage

Texts/References:

1. Huggins, Robert *'Energy Storage'*, Springer, 2010.
2. Ter-Gazarian *'Energy Storage for Power Systems'*, Institution of Engineering and Technology, 1994.

Subject Code: EE6L012	Name: EHV/UHV Power Transmission Engineering	L-T-P: 3-0-0	Credits: 3

Electrical power transmission by HVAC and HVDC, overhead transmission lines, bundled conductors, mechanical vibration of conductors, surface voltage gradient on conductors, corona and associated power loss, radio-noise and audio-noise and their measurement, fields under transmission lines, overhead line insulators, insulator performance in polluted environment, EHV cable transmission – underground cables and GIL, high voltage substations – AIS and GIS, grounding of towers and substations, over voltages in power systems, temporary, lightning and switching over voltages, design of line insulation for power frequency voltage, lightning and switching over voltages, insulation co-ordination.

Texts/References:

1. Begamudre, R.D., *Extra High Voltage AC Transmission Engineering*, Wiley Eastern Limited, 1990.
2. *Transmission line Reference Book 345 kV & above*, Electrical Power Research Institute, (EPRI), USA, 1982.

Subject Code: CS6L001	Name: Computational Intelligence	L-T-P: 3-0-0	Credits: 3

Soft Computing: Artificial Neural Network: Artificial neuron, single layer and multilayer architecture, nonlinear function like sigmoid function, back propagation learning algorithm. Functional link artificial neural network, trigonometric, Chebyshev and Legendre polynomial. Readial basis function neural network, its learning algorithm, recurrent neural network and its learning algorithm.

Fuzzy Logic: Types of fuzzy logic, membership functions, fuzzification and defuzzification, rule-based fuzzy inference engine, Type-1 and Type-2 fuzzy logic, typical applications.

Evolutionary Computing and Swarm Intelligence: Derivative based and derivative free optimization, multivariable and multiconstraint optimization. Genetic algorithm and its variants, Differential evolution and its variants, particle swarm optimization and its variants, Cat swarm optimization, bacterial foraging optimization, Artificial immune system, multiobjective optimization like NSGA-II.

Texts/References:

1. S. Haykin, *'Neural Networks and Learning Machines'*, Prentice Hall, 2009.
2. Y.H. Pao, *'Adaptive pattern recognition and neural networks'*, Addison-Wesley, 1989.
3. Jang, J.S.R., Sun, C.T. and Mizutani, E., *'Neuro-fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence*', Prentice Hall, 2009.

Subject Code: EC6L005	Name: Statistical Signal Processing	L-T-P: 3-0-0	Credits: 3

Review of Probability and Stochastic Process
Estimation Theory: Minimum-variance unbiased estimator (MVUE), Cramer-Rao Lower bound, Best Linear Unbiased Estimator, Maximum likelihood Estimator, General Bayesian Estimator
Detection Theory: Neyman Pearson Theorem, Receiver Operating Characteristics, Matched Filters, Composite Hypothesis Testing
Nonparametric Spectral Estimation: Estimation of power spectrum of stationary random signal using periodogram-various methods, Joint signal analysis and estimation of cross power spectrum
Linear Signal Model: Synthesis of coloring filter and Analysis of whitening filter, Rational power spectra (AR, MA, ARMA), Relationship between filter parameters and autocorrelation sequences, Lattice-Ladder filter realization
Parametric Spectral Estimation: Order selection criterion of AR model , Minimum-variance, Maximum entropy and Maximum likelihood spectrum estimation Harmonic models and frequency estimation techniques Harmonic Decomposition, MUSIC algorithm, ESPRIT algorithm
Linear Optimum Filter: Optimum FIR Filter, PCA of optimum linear estimator and its frequency domain interpretation, Forward and Backward Linear prediction and optimum reflection coefficients Optimum causal and non-causal IIR Filters, Deconvolution and Signal restoration Algorithms and Structure of Optimum Linear Filters Levinson Recursion for optimum estimate, Order-recursive algorithms for optimum FIR filters and its lattice structures.

Texts Books:

1. Steven Kay, *Fundamentals of Statistical Signal Processing, Vol I: EstimationTheory, Vol II: Detection Theory*, Prentice Hall, 1993/1998.

Reference Books:

1. Harry L. Van Trees, *Detection, Estimation, and Modulation Theory, Part I*, Wiley-Inter science, 2001
2. Monson H. Hayes, *Statistical Digital Signal Processing and Modeling*, John Wiley, 1996.

Subject Code: MA6LXXX	Name: Mathematical Methods	L-T-P: 3-1-0	Credits: 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 algebraic and transcendental equations: Secant and Newton-Raphson methods, Numerical solutions of systems of linear equations: Gauss elimination, LU decomposition, Gauss-Jacobi and Gauss-Seidel methods. Interpolation: Newton's forward and backward interpolation formulae for equal intervals, Lagrange's and Newton's divided difference formulae for unequal intervals, Differentiation and integration methods, Power method for eigenvalues and eigenvectors. 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 wave equation, 1-D heat equation.

Texts/References:

1. B. S. Grewel, *'Numerical Methods'* Khanna Publishers, 2012.
2. K. K. Jain, and S.R.K. Iyengar and R.K. Jain, *'Numerical Methods-problem and solutions'*, Wiley Eastern Limited, 2001.
3. S. M. Ross, *'Introduction to Probability Models'*, Academic Press, 2004.
4. A. M. Gun, M.K. Gupta, and B.S. Gupta, *'Fundamentals of Statistics'*, World Press Private Ltd, 2005.
5. A. J. Hayter, *'Probability and Statistics for Engineers and Scientists'*, Duxbury Resource Center, 2012
6. J. B. Scarborough, *'Numerical mathematical analysis'*, Oxford & IBH Publishing Co.Pvt., 2000.
7. R. W. Hamming, *'Numerical Methods for Scientist and Engineers'*, McGraw Hill, 1998
8. J. H. Mathews and K. D. Fink, *'Numerical Methods using MATLAB'*, Pearson Education, 2004

Elective (IV to V)

Subject Code: EE6L013	Name: Grid Integration of Renewable Energy Systems	L-T-P: 3-0-0	Credits: 3

Control of frequency and voltage of distributed generation in Stand-alone and Grid-connected mode, use of energy storage and power electronics interfaces for the connection to grid and loads. Design and optimization of size of renewable sources and storages.
Concept of microgrid, operation of microgrid in grid-connected as well as isolated mode, power quality problems and fault-ride through capability of microgrid.
Integration of large capacity renewable sources to grid: Operation and control, present trends, challenges, future technological needs viz., advanced characteristics of renewable energy generating units and plants, improved flexibility in conventional generation, transmission technology.

Texts/References:

1. Math J. Bollen, Fainan Hassan *'Integration of Distributed Generation in the Power System'*, IEEE Press, 2011.
2. S. Heier and R. Waddington *'Grid Intergration of Wind Energy Conversion Systems'*, Wiley, 2006.
3. Loi Lei Lai and Tze Fun Chan *'Distributed Generation: Induction and Permanent Magnet Generators'*, Wiley-IEEE Press, 2007.

Subject Code: EE6L014	Name: Smart Grid Technology	L-T-P: 3-0-0	Credits: 3

Review of basic elements of electrical power systems, desirable traits of a modern grid, principal characteristics of the smart grid, key technology areas.
Smart grid communication: Two way digital communication paradigm, network architectures, IP-based systems, Power line communications, advanced metering infrastructure.
Renewable Generation: Renewable Resources: Wind and Solar, Microgrid Architecture, Tackling Intermittency, Distributed Storage and Reserves.
Wide Area Measurement: Sensor Networks, Phasor Measurement Units, Communications Infrastructure, Fault Detection and Self-Healing Systems, Application and Challenges.
Security and Privacy: Cyber Security Challenges in Smart Grid, Defense Mechanism, Privacy Challenges.

Texts/References:

1. James Momoh *'Smart Grid: Fundamentals of Design and Analysis'* Wiley-IEEE Press, 2012.
2. Philllip F. Schewe *'The Grid: A Journey through the Heart of our Electrified World'* Joseph Henry Press, 2006.

Subject Code: EE6L015	Name: Advanced High Voltage Engg.	L-T-P: 3-0-0	Credits: 3

Electrostatic applications: Electrostatic separation, electro-static coating of materials, electro-static precipitation, electro-static copying.

Plasma-based applications: Ion Beam accelerators, Ion nitriding for surface hardening of materials, Ion thrusters for space applications. Nuclear Electro-magnetic Pulse simulation.

Pulsed Power Engineering: Capacitive and inductive energy storage, pulse forming lines, switches for pulsed power. High voltage sources for Cathode ray oscilloscopes and electron microscopes

Non Thermal Atmospheric Pressure Plasma: Non-thermal plasma stabilization at high pressure, Townsend and spark breakdown mechanisms, corona discharge, pulse corona discharge, dielectric barrier discharge, spark discharge, atmospheric pressure glows, microplasmas, plasma discharge in water.

Texts/References:

1. David A. Lloyd *'Electrostatic Precipitator Handbook'*, Institute Of Physics Publishing, 1988.
2. M. Haddad and D. Warne *'Advances in High Voltage Engineering'* IET, 2009.
3. John Ernest Harry *'Introduction to Plasma Technology'* Wiley-vch Verlag Gmbh, 2010.
4. J. Reece Roth, J. Reece Roth, and Roth J. Reece *'Industrial Plasma Engineering – Volume-2'* Taylor & Francis Group, 2001.
5. Bernie M. Penetrante, *'Non-Thermal Plasma Techniques for Pollution Control: Part B: Electron Beam and Electrical Discharge Processing'* Springer, 2012.
6. Research publications that will be suggested during the course.

Subject Code: EE6L016	Name: Advanced Control	L-T-P: 3-0-0	Credits: 3

State-space representation; Different canonical forms: Controller canonical form, Observer canonical form, Diagonal canonical form, Jordan canonical form, Controllable canonical form, Observable canonical form; Decomposition of transfer functions into different canonical forms; Controllability and Observability; Stabilizability and Detectability; State feedback control; Full and reduced order observers: observer based state feedback control, Separation principle; Optimal control: Linear Quadratic control, Linear Quadratic Gaussian control, Loop transfer recovery control; Internal stability, Well-posedness; Concept of uncertainties and robustness: Structured uncertainties, Unstructured uncertainties, Sensitivity, Complementary Sensitivity and their significance for robustness study, Robust stability of $M-\Delta$ structure; H_∞ control: Two block frame work, Four block frame work, mu-synthesis; Approximate linearization; Feedback linearization: Input to state exact linearization, input to output exact linearization; Sliding mode control.

Texts/References:

1. R. C. Dorf and R. H. Bishop *'Modern Control Systems'*, Pearson Education, Inc, 2008.
2. R. T Stefani *'Design of Feedback Control Systems'*, Oxford University Press, 2002.
3. S. Skogestad and I. Postlethwaite *'Multivariable Feedback Control'*, John Wiley, 2005.

Subject Code: EE6L017	Name: Distribution System Engineering	L-T-P: 3-0-0	Credits: 3

Distribution system planning: Short term planning, Long term planning, Dynamic planning, Sub-transmission and substation design, Sub-transmission networks configurations, Substation bus schemes, Distribution substations ratings, Service areas calculations, Substation application curves.

Distributed Generation: Standards, DG potential, Definitions and terminologies; current status and future trends, Technical and economic impacts, Definitions and terminologies; current status and future trends, Technical and economic impacts. DG Technologies, DG from renewable energy sources, DG from non-renewable energy sources, Distributed generation applications, Operating Modes, Base load; peaking; peak shaving and emergency power, Isolated, momentary parallel and grid connection

Primary and secondary system design considerations, Primary circuit configurations, Primary feeder loading, secondary networks design, Economic design of secondaries, Unbalance loads and voltage considerations, Distribution system performance and operation, Distribution automation and control, Voltage drop calculation for distribution networks, Power loss Calculation, Application of capacitors to distribution systems, Application of voltage regulators to distribution systems.

Texts/References:

1. Anthony J. Pansini *“Electrical Distribution Engineering”*, CRC Press.
2. H Lee Willis, *“Distributed Power Generation Planning and Evaluation”*, CRC Press.
3. James A Momoh, *“Electric Power Distribution Automation Protection And Control”* CRC Press
4. James J. Burke *“Power distribution engineering: fundamentals and applications”*, CRC Press.
5. T. Gonen, “*Electric Power Distribution System Engineering”*, McGraw-Hill, 1986.

Subject Code: CS6L002	Name: Networks and Systems Security	L-T-P: 3-0-0	Credits: 3

Introduction: computer security concepts, the osi security architecture, security attacks, security services, security mechanisms, a model for network security.
Basic cryptography: historical background, transposition/substitution, caesar cipher, introduction to symmetric crypto primitives, asymmetric crypto primitives, and hash functions, block ciphers, message authentication, symmetric-key encryption, public-key encryption, digital signatures.
Secret key cryptography applications, data encryption standard (des), encrypting large messages (ecb, cbc, ofb, cfb, ctr), multiple encryption des (ede)
Public key cryptography applications, theory: euclidean algorithm, euler theorem, fermat theorem, multiplicative and additive inverse, rsa, selection of public and private keys. Authentication: security handshake pitfalls, online vs. Offline password guessing, reflection attacks, per-session keys and authentication tickets, key distribution centers and certificate authorities.
Real-time communication security: introduction to tcp/ip protocol stack, implementation layers for security protocols and implications,
Network security applications: key distribution and user authentication , symmetric key distribution using symmetric encryption, key distribution using asymmetric encryption, certificates, public-key infrastructure, federated identity management, transport-level security, web security considerations, secure socket layer and transport layer security, transport layer security, https, secure shell (ssh), wireless network security, ieee 802.11 wireless lan overview, ieee 802.11i wireless lan security, wireless application protocol overview, wireless transport layer security, wap end-to-end security,
Electronic mail security: distribution lists, establishing keys, privacy, source authentication, message integrity, non-repudiation, proof of submission, proof of delivery, message flow confidentiality, anonymity, pretty good privacy (pgp),
Firewalls and web security: packet filters, application level gateways, encrypted tunnels, cookies, web security problems

Text/ Reference Books:

1. William Stallings, "*Network Security Essentials Applications and Standards*" (5th Edition), Prentice Hall
2. Kaufman, Perlman and Speciner, "*Network Security: Private Communication in a Public World*" (2nd Edition) Prentice Hall, Publication Date: May 2, 2002.
3. W. Richard Stevens, *"TCP/IP Illustrated, Vol. 1: The Protocols"* (Addison-Wesley Professional Computing Series) 1993, Edition: US ed.
4. ERIC Cole, *"Network Security Bible*, Willey
5. Joseph Migga Kizza *"Computer Network Security*"

Subject Code: EC6L004	Name: Advanced Digital Signal Processing	L-T-P: 3-1-0	Credits: 4

Power spectrum analysis, filter banks, multirate digital signal processing, higher order statistics, 1D & 2D DFT, properties and applications, short time Fourier transform, spectrograms, discrete cosine transform, discrete Wavelet transform, S-transform

Adaptive filters: Least mean square (LMS) algorithm and its variants, Recursive least square algorithm and its variants, block adaptive filtering; transform domain filtering, adaptive filters as estimator, classifier, forecaster, and equalizer.

Application of adaptive signal processing to telecommunication, instrumentation, power system & control and biomedical engineering.

Texts/References:

1. P. Stoica, and R. Moses, *'Spectral Analysis of Signals`,* Prentice Hall, 2008.
2. J. G. Proakis, and D. G. Manolakis, *'Digital Signal Processing'*, Pearson, 2009.
3. S. Mallat, *'A wavelet tour of signal processing: the sparse way'*, Academic Press, 2010.
4. S.O. Haykin, *'Adaptive filter theory'*, Prentice Hall, 2001.
5. G.Strang, and T. Nguyen, *'Wavelets and filter banks'*, Wellesley-Cambridge Press, 1996.
6. Research publications that will be suggested during the course.

Subject Code: EC6L027	Name: Pattern Recognition	L-T-P: 3-0-0	Credits: 3

Introduction to pattern recognition

Bayesian decision theory : Classifiers, Discriminant functions, Decision surface, Normal density and discriminant functions

Parameter estimation methods: Maximum-Likelihood estimation, gaussian mixture models, Expectation-maximization method, Bayesian estimation

Hidden Markov models: Discrete hidden Markov models, Continuous density hidden Markov models

Dimensionality reduction methods: Fisher discriminant analysis, Principal component analysis

Non-parametric techniques for density estimation: Parzen-window method, K-Nearest Neighbour method

Linear discriminant function based classifiers: Perceptron , Support vector machines

Non-metric methods for pattern classification: Non-numeric data or nominal data Decision trees

Unsupervised learning and clustering: Criterion functions for clustering Algorithms for clustering: K-means, Hierarchical and other methods, Cluster validation.

Texts/References:

1. R.O.Duda, P.E.Hart and D.G.Stork, *Pattern Classification*, John Wiley, 2001
2. S.Theodoridis and K.Koutroumbas, *Pattern Recognition*, 4th Ed., Academic Press, 2009
3. C.M.Bishop, *Pattern Recognition and Machine Learning*, Springer, 2006

Subject Code: EC6L016	Name: Computational Electromagnetics	L-T-P: 3-0-0	Credits: 3

Applications of electromagnetics in the 21st century. Numerical Methods: ODE solvers, Euler, Runge-Kutta. Review of Basic Electromagnetics: Electrostatics, Magnetostatics, Wave Equations. Numerical Techniques: Method of Moements, Finite Difference Method, Finite Element method, Charge Simulation Method, Monte carlo method. Time Varying Electromagnetic Fiels: Eddy currents & skin depth, introduction to wavelets, families of wavelets. Microwaves, Optics, Micromagnetics, Bio-electromagnetics. Tutorials and demonstration on PC, programming assignments.

Text/ Reference Books:

1. *Numerical Techniques in Electromagnetic*, 2nd edition, M.N.O. sadiku, CRC Press.
2. Weber, E., *Electromagnetic Fields*, Dover 1951
3. Silvester, P. P. and Ferrari, R. L., *Finite Elements for Electrical Engineers*, Cambridge University Press 1996.
4. *Numerical Methods in Engineering with Python*, Jaan Kiusalaas, Cambridge.
5. Selected journal papers

Subject Code:	Name: Advanced Techniques in Operations Research	L-T-P: 3-1-0	Credits: 4

Non--Linear Programming Problems: One variable unconstrained optimization, multivariable unconstrained optimisation, Karush-Kuhn-Tucker (KKT) conditions for constrained optimization, quadratic programming, separable programming, convex and non-convex programming, teepest 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.

Texts/References:

1. S.S. Rao, *'Engineering Optimization Theory and Practices'*, John Wiley and Sons, 2009
2. M. Ehrgott, *'Multi-criteria Optimization'*, Springer 2006
3. K.M, Miettien, *'Non-linear multi-objective optimization'*, Kluwers International Series, 2004
4. K. Deb, *'Multi-objective evolutionary optimization for product design and manufacturing'*, Springer, 2011.

Laboratory

Subject Code: EE6P001	Name: Power System Lab -I	L-T-P: 0-0-3	Credits: 2
Synchronous Machine, Induction Generator, 3 φ-3 windings Transformer, Determination of Phase Sequence and Symmetrical Components, Overcurrent Relay and Undervoltage Relay, Percentage biased Differential Relay protecting a Transformer, Directional Relay and Digital distance relay, High Voltage ac power frequency test transformer, Impulse Voltage Generator, Condition Monitoring of Distribution Transformer.			

Subject Code: EE6P002	Name: Energy Systems Lab	L-T-P: 0-0-3	Credits: 2
Experiments on characteristics and control aspects of various renewable energy systems such as wind energy conversion system, photovoltaic systems, wave energy systems and hybrid systems etc. will be performed. Both isolated and grid-connected systems will be used in the experiments.			

Subject Code: EE6P003	Name: Power System Lab -II	L-T-P: 0-0-3	Credits: 2
Simulation experiments on Modeling of Transmission Lines, Load Flow Analysis, Fault Analysis, Transient and Small Signal Stability Analysis: Single-Machine Infinite Bus System, Transient Stability Analysis of Multimachine Power Systems, Electromagnetic Transients in Power Systems, Load – Frequency Dynamics of Single –Area and Two Area Power Systems, Economic Dispatch in Power Systems.			

Curriculum for Joint M.Tech.-Ph.D. (Materials Science and Engineering)

Subject Name	Code	L-T-P	Credit	Contact Hour
SEMESTER - I				
Advanced Thermodynamics and Kinetics	ML6L001	3-1-0	4	4
Materials Processing	ML6L002	3-1-0	4	4
Materials Characterization	ML6L003	3-1-0	4	4
Elective I	ML6L0XX	3-0-0	3	3
Elective II	ML6L0XX	3-0-0	3	3
Materials Characterization Laboratory	ML6P001	0-0-6	4	6
Seminar - I	ML6S001		2	0
		Total :	**24**	**24**
SEMESTER - II				
Modeling and Simulation of Materials	ML6L004	3-1-0	4	4
Phase Transformation in Materials	ML6L005	3-0-0	3	3
Elective III	ML6L0XX	3-0-0	3	3
Elective IV	ML6L0XX	3-0-0	3	3
Elective V	MLS60XX	3-0-0	3	3
Modeling and Simulation Laboratory	ML6P002	0-1-3	4	4
Seminar – II	ML6S002		2	0
		Total :	**22**	**20**
SEMESTER - III				
Project (Part – I)	ML6D001	0-0-0	16	0
Research Review Paper	ML6D002	0-0-0	4	0
		Total :	**20**	**0**
SEMESTER – IV				
Project (Part – II)	ML6D003	0-0-0	16	0
Research Review Paper	ML6D004	0-0-0	4	0
		Total :	**20**	**0**
		Total Credit:	**86**	

List of Elective Subjects (Materials Science and Engineering)

Subject Name	Code	L-T-P	Credit	Contact Hour
Elective – I to V				
Advances in Materials Science	ML6L006	3-0-0	3	3
Structure of Materials and X-ray Diffraction	ML6L007	3-0-0	3	3
Materials Recycling and Waste Management	ML6L008	3-0-0	3	3
Advanced Physical Metallurgy	ML6L009	3-0-0	3	3
Materials Design	ML6L010	3-0-0	3	3
Ceramic Materials	ML6L011	3-0-0	3	3
Biomaterials Processing and Applications	ML6L012	3-0-0	3	3
Surface Engineering	ML6L013	3-0-0	3	3
Powder Materials and Processing	ML6L014	3-0-0	3	3
Heat Treatment of Materials	ML6L015	3-0-0	3	3
Extractive Metallurgy	ML6L016	3-0-0	3	3
Mineral Beneficiation	ML6L017	3-0-0	3	3
Principles of Materials Engineering	ML6L018	3-0-0	3	3
Mechanical Behavior of Materials	ML6L019	3-0-0	3	3
Transport Phenomena	ML6L020	3-0-0	3	3
Corrosion Science and Engineering	ML6L021	3-0-0	3	3
Diffusion in Solids	ML6L022	3-0-0	3	3
Advanced Joining Processes	ML6L023	3-0-0	3	3
Granular Materials	ML6L024	3-0-0	3	3
Advanced Composites	ML6L025	3-0-0	3	3

Syllabus

Core Courses:

Subject Code: ML6L001	Name: Advanced Thermodynamics and Kinetics	L-T-P: 3-1-0	Credit: 4
Pre-requisite(s): None			

Thermodynamics: First law, Second law, Entropy, Heat engine, Cyclic process, Entropy criteria for equilibrium, Combination of 1st and 2nd laws; Maxwell's Relation, Gibb's-Helmholtz equation, Thermal expansivity and compressibility; Third law: Hess law, Kirchhoff's law; Phase Equilibria: Clausius–Clapeyron equation, solid-liquid/vapor-condensed phase equilibria, Fugacity; Solution Thermodynamics: Raoult's law, Henry law, Gibb's–Duhem equation, Configurational entropy, Regular solution, Excess function, Thermodynamics of point defects; Free energy: Evaluation of phase diagram, Gibb's phase rule, Lever rule; Thermodynamics of Metallurgical Reaction: Ellingham diagram, Predominance area diagram;
Kinetics: Laws of kinetics, Theory of reaction rates, Grain growth kinetics, Precipitate nucleation and growth kinetics, Concept and modelling of diffusion controlled growth.

Texts / Reference Books:

1. David R. Gaskell, *Introduction to thermodynamics of materials*
2. C.H.P. Lupis, *Chemical thermodynamics of materials*
3. G.S. Upadhyaya and R.K.Dube, *Problems in metallurgical thermodynamics and kinetics*

Subject Code: ML6L002	Name: Materials Processing	L-T-P: 3-1-0	Credit: 4
Pre-requisite(s): None			

Solidification processing: Plane front solidification, cellular solidification, cellular-dendritic transition, Theories of regular and irregular eutectic growth, Rheocasting, Thixocasting, casting of composites; Powder processing: preparation of metallic, ceramic and composite powders; Sintering and full density processing; Metal forming processes: Deformation theories, Applications in rolling, forging, extrusion, machining; Processing of new materials: nanomaterials and biomaterial; Joining of materials: Fundamentals of liquid and solid state joining, friction stir welding, joining of similar and dissimilar materials; Processing of minerals, particulate materials; characterization of particles; crushing, grinding and classification; minerals separation using gravity techniques, electrical and magnetic methods, froth flotation, de-watering using thickening, filtration and drying operations; effluent processing and tailings disposal; Processing of ceramics: Crystal Systems, Amorphous Systems - Glass, Phase Equilibria, Sintering of ceramics, Microstructure of Ceramics, Mechanical Properties, Thermal Properties, Optical Properties, Electrical and Magnetic Properties, Chemical Properties Traditional Ceramic Raw Materials, Non-Traditional and Special Ceramic Raw Materials, Glass ceramics, Bio implants, Advanced ceramics; Material processing from solid waste from metal industry and thermal power plants.

Texts / Reference Books:

1. Porter, Easterling and Sherif, *Phase Transformation in metals and alloys*
2. Randall M. German, *Powder Metallurgy & Particulate Materials Processing*
3. WD Kingery, HK Bowen, DR Uhlmann, *Introduction to ceramics*
4. B.A. Wills and T. Napier-Munn, *Wills' Mineral Processing Technology*
5. E.G. Kelly and D.J. Spottiswood, *Introduction to Mineral Processing*

Subject Code: ML6L003	Name: Materials Characterization	L-T-P: 3-1-0	Credit: 4
Pre-requisite(s): None			

Importance of characterization studies in materials science – applications in industry and research; Review of materials science fundamentals; Mechanical waves and Ultrasonic testing; Principles of image formation and optical aberrations; Sample preparation techniques for optical and scanning electron microscopy; Optical metallographic - phase contrast, Nomarski contrast techniques; Scanning electron microscopy: beam-sample interaction, Interaction volume concept, WDS, EDS, EPMA techniques and their application; X-ray diffraction – application in macro-texture, crystal structure and residual stress determination; Atomic absorption spectroscopy; Optical emission spectroscopy; X-ray fluorescence spectroscopy; Electron energy loss spectroscopy; Gas chromatography – application in dissolved gas analysis; Differential scanning calorimetry; Thermo gravimetric analysis; Surface analysis methods: AES, XPS; Transmission electron microscopy: sample preparation, bright field and dark field imaging, Kikuchi line formation and selected area diffraction analysis; Orientation imaging microscopy: sample preparation, application in micro-texture, phase, residual stress and grain size determination; Mass spectrometry.

Texts / Reference Books:

1. J. Goldstein, D.E. Newbury, D.C. Joy, C.E.Lyman,P.Echlin,E. Lifshin, L. Sawyer, J.R. M L Sawyer, J R Michael, *Scanning Electron Microscopy and X-ray Microanalysis*.
2. ASM Handbooks Online
3. David B. Williams, C.Barry Carter, *Transmission Electron Microscopy: A Textbook for Materials Science (4 Vol. Set).*
4. G. Hohne, W.F. Hemminger, H. –j Flammersheim, *Differential Scanning Calorimetry.*
5. O. Engler, V. Randle, *Introduction to Texture Analysis: Macrotexture, Microtexture, and Orientation Mapping*.
6. B.D. Cullity, C.R. Stock, *Elements of X-Ray Diffraction*

Subject Code: ML6L004	Name: Modeling and Simulation of Materials	L-T-P: 3-1-0	Credit: 4
Pre-requisite(s): None			

Basics of modeling and simulations, Empirical and phenomenological modeling, Population balance models, Kinetic models, Stochastic models, Matrix models, Discrete size discrete time models, Discrete size continuous time models, Continuous size continuous time models, Modeling of flotation networks and simulation of complex flotation circuits, Material balance over complex minerals flow sheets, Physical modeling, Mathematical modeling; Data modeling as a new type of modeling, Reverse Monte-Carlo Analysis (RMCA): Reconstruction of 3-D atomic ensemble from diffraction data, Discrete Element Modeling (DEM), Finite Element Method (FEM) and its application in materials science, Ab-initio simulations, Phase-field modelling.

Texts / Reference Books:

1. K. Janssens, G. Frans, D. Rabbe, B. Nestler, E. Kozeschnik, M, Miodownik, *Computational Materials Engineering- An Introduction to Microstructure Evolution*.
2. K. KesavaRao, Prabhu R. Nott, *An Introduction to Granular Flow*.
3. Dominik Marx, JürgHutter, *Ab Initio Molecular Dynamics: Basic Theory and Advanced Methods.*

Subject Code: ML6L005	Name: Phase Transformation in Materials	L-T-P: 3-0-0	Credit: 3
Pre-requisite(s): None			

Diffusion and thermodynamics of surfaces and interfaces, Irreversible thermodynamics, Kinetics of phase transformations, Salient features of solid-solid and solid-liquid phase transformations, Ingot, Continuous cast and fusion weld microstructure, Defects during solidification, Diffusional transformations in steel, Precipitation phenomena in age hardened alloys, Order-disorder transformation, Martensitic transformations.

Texts / Reference Books:

1. D. A. Porter and K. E. Easterling, *Thermodynamics of solids, R. A. Swalin, Phase transformations in metals and alloys*.
2. P. G. Shewmon, *Diffusion in solids*.
3. R. E. Reed-Hill, *Physical metallurgy principles*.
4. R. w. Cahn and P Haasen, *Physical Metallurgy (4th Ed.)*
5. M. P. Allen, D. J. Tildesley, *Computer Simulation of Liquids*.
6. J. M. Haile, *Molecular Dynamics Simulation: Elementary Method.*

Laboratory Courses:

Subject Code: ML6P001	**Name: Materials Characterization Laboratory**	**L-T-P: 0-0-6**	**Credit: 4**
Pre-requisite(s): None			

Optical microscopy: micro-etching techniques for ferrous and non-ferrous alloys, dark/bright field imaging, differential interference contrast technique, phase contrast technique; Scanning electron microscopy: sample preparation techniques, secondary electron and backscattered electron imaging, point, line and area mapping, X-ray mapping; Transmission electron microscopy: sample preparation, bright/dark field imaging, weak beam technique; X-ray Diffraction: crystallite size calculation, residual stress calculation; Optical emission spectroscopy: calibration using primary standards and measurement; Differential Scanning Calorimetry: sample preparation, determination of thermodynamic parameters, measurements on precipitation hardened Al alloys.

Texts / Reference Books:

1. J. Goldstein, D.E. Newbury, D.C. Joy, C.E.Lyman,P.Echlin,E. Lifshin, L. Sawyer, J.R. Michael, *Scanning Electron Microscopy and X-ray Microanalysis*.
2. ASM Handbooks Online
3. David B. Williams, C.Barry Carter, *Transmission Electron Microscopy: A Textbook for Materials Science (4 Vol. Set).*
4. G. Hohne, W.F. Hemminger, H. –j Flammersheim, *Differential Scanning Calorimetry*.
5. O. Engler, V. Randle *Introduction to Texture Analysis: Macrotexture, Microtexture, and Orientation Mapping*.
6. B.D. Cullity, C.R. Stock, *Elements of X-Ray Diffraction.*

Subject Code: ML6P002	Name: Modeling and Simulation Laboratory	L-T-P: 0-1-3	Credit: 3

Pre-requisite(s): None

General introduction and programming protocols, Discrete element modeling, Contact rule for soft particles, Molecular dynamics simulation: hard and soft core potentials, Lenard-Jones potentials, Equation of motion, Conservation laws, Euler method, Runga-Kutta method, Predictor corrector method, Verlet algorithm; Monte-Carlo methods, Reverse Monte-Carlo analysis and reconstruction of the atomic ensemble from the diffraction data, Optimization techniques such as Genetic Algorithm (GA) and Simulated Annealing (SA).

Texts / Reference Books:

1. K. Janssens, G. Frans, D. Rabbe, B. Nestler, E. Kozeschnik, M. Miodownik *Computational Materials Engineering – An Introduction to Microstructure Evolution.*
2. M. P. Allen, D. J. Tildesley, *Computer Simulation of Liquids*.
3. J. M. Haile, *Molecular Dynamics Simulation: Elementary Methods*.
4. K. KesavaRao, Prabhu R. Nott, *An Introduction to Granular Flow*, K. KesavaRao.
5. Dominik Marx, JürgHutter, *Ab Initio Molecular Dynamics: Basic Theory and Advanced Methods.*

List of Elective Courses (I to V)

Subject Code: ML6L006	Name: Advances in Materials Science	L-T-P: 3-0-0	Credit: 3
Pre-requisite(s): None			

Fundamentals of structure in crystalline solids, Imperfections in materials, Characterization Techniques, Phase Diagrams (Fe-C, Al-Si, Pb-Sn, Al-Cu etc.), Phase transformations in metals, Solidification in metals and alloys, Diffusion in solids, Mechanical working of metals, Strengthening mechanisms in metals, Mechanical properties of materials, Failure in materials, Non-destructive testing of materials, Composite materials, Corrosion of materials, Electrical properties of materials, Magnetic properties of materials, Thermal properties of materials, Optical properties of materials, Recycling of materials.

Texts / Reference Books:

1. William D. Callister, *Jr. Materials Science and Engineering*
2. V. Raghavan, Materials Science and Engineering: A First Course

Subject Code: ML6L007	Name: Structure of Materials and X-ray Diffraction.	L-T-P: 3-0-0	Credit: 3
Pre-requisite(s): None			

Production and detection of X-rays; Crystallography: lattice, motif, unit cells and crystal structures, symmetry elements, point groups, space groups, defects; Diffraction: Wave theory and electromagnetic waves, single crystal diffraction method and applications, powder diffraction method and applications, indexing of powder diffraction patterns, Bragg's law and Laue equation, reciprocal space and its application; Fourier transforms: analysis of diffraction patterns, structure factor and pair distribution function; Determination of crystal structures from symmetry and geometry; Rietveld method and precise crystal structures; Qualitative and quantitative phase identification.

Texts / Reference Books:

1. B. E. Warren, *X-Ray Diffraction*.
2. B. D. Cullity, S.R. Stock, *Elements of X-ray diffraction*.
3. Buerger, Martin J, *Elementary Crystallography: An Introduction to the Fundamental Geometrical Features of Crystals*.
4. F. C. Phillips, *An Introduction to Crystallography*.
5. Norman ,F. M., and Kathleen Lonsdale, *International Tables for X-Ray Crystallography. Vol. 1*
6. *International Tables for Crystallography/ Volumes A(2006) / A1(2011) / B(2010) / C(2006)/ D(2006) / E(2010) / F(2012) / G(2006).*

Subject Code: ML6L008	Name: Material Recycling and Waste Management.	L-T-P: 3-0-0	Credit: 3
Pre-requisite(s): None			
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:** 1. T. Randall Curlee, Sujit Das, William Andrew; 1 edition, *Materials recycling and waste management.*			

Subject Code: ML6L009	Name: Advanced Physical Metallurgy	L-T-P: 3-0-0	Credit: 3
Pre-requisite(s): None			

Microstructure & Properties: solidification and solidification structures, interfaces, crystallographic texture, residual stress, structure-property relations. Plasticity and work-hardening: fundamentals, stress-strain behavior, fracture, creep & deformation mechanisms. Recovery, recrystallization, grain growth. Phase transformation: thermodynamic basics, nucleation and growth, spinodal decomposition, martensitic transformations.

Texts / Reference Books:

1. R. E. Smallman PhD and A.H.W. Ngan, *Physical Metallurgy and Advanced Materials, Seventh* Edition.

Subject Code: ML6L010	Name: Materials Design	L-T-P: 3-0-0	Credit: 3
Pre-requisite(s): None			

Physical properties of materials – review; Property measurement techniques and limitations; Ashby diagrams – interpretations; Materials selection for: stiffness-limited design, strength limited design, fracture-limited design; Creep behavior of materials: design of materials for high temperature; Materials processing: classification and choice for design; Phase prediction using first-principles and CALPHAD approach; Structure-property relationship using molecular dynamics simulation; Processing – microstructure correlation using finite element and phase field simulation methods.

Texts / Reference Books:

1. M. Ashby, H. Shercliff & D. Cebon, *Materials Engineering, Science, Processing and Design*.
2. Sidney Yip, *Handbook of Materials Modeling (Vol. 1 & 2).*
3. *ASM Handbooks Vol. 22A.*

Subject Code: ML6L011	Name: Ceramic Materials	L-T-P: 3-0-0	Credit: 3
Pre-requisite(s): None			

Introduction, Ceramic Materials: structure, microscructure and polymorphism, synthesis of ceramics, ceramic forming processes, silicate and non-silicate ceramics, structural, functional (electronic, optical) and bio-ceramics, nano-ceramics, Properties and Applications of Ceramics: refractory materials, properties of refractories, fracture of refractories, corrosion of refractories, different refractory lines, alumina-silica brick, magnesia refractories, silica brick, doloma refractories, carbonaceous refractories, spinel-containing refractories, glass tank blocks, ceramic wool preparation and properties, carbide and nitride based refractories, refractory coatings, refractory castables, unshaped refractory products, surface chemistry as a tool for the development of advanced refractory castables, thermo-mechanical considerations for refractory linings, refractory applications in refineries and circulating fluid bed reactors, heating wall refractories, damage and causes of failure, testing of refractory materials, refractory lining design and manufacture.

Texts / Reference Books:

1. W. D. Kingery, H. K. Bowen, Donald R. Uhlmann, *Introduction to Ceramics*, 2nd Edition.

Subject Code: ML6L012	Name: Biomaterials Processing and Applications	L-T-P: 3-0-0	Credit: 3
Pre-requisite(s): None			

Surface chemistry and physics of selected metals, polymers, and ceramics, surface characterization methodology, modification of biomaterials' surfaces, biosensors and microarrays, bulk properties of implants, acute and chronic responses to implanted biomaterials, drug delivery and tissue engineering; Property requirement of biomaterials; Concept of biocompatibility; Cell-material interactions and foreign body response; Assessment of biocompatibility of biomaterials, important biometallic alloys; Ti-based, stainless steels, Co-Cr-Mo alloys; Bio-inert, bio-active and bio-resorbable ceramics; Processing and properties of different bio-ceramic materials with emphasize on hydroxyapatite; Synthesis of biocompatible coatings on structural implant materials; Microstructure and properties of glass ceramics; Biodegradable polymers; Design concept of developing new materials for bio-implant applications.

Texts / Reference Books:

1. *Teoh Swee Hin Engineering Materials For Biomedical Applications (Biomaterials Engineering and Processing Series*

Subject Code: ML6L013	Name: Surface Engineering	L-T-P: 3-0-0	Credit: 3
Pre-requisite(s): None			

Introduction to surface, Thermodynamics of surface, Surface dependent properties-physical, chemical and mechanical; Surface dependent degradation and their characteristics, Analysis of surface initiated degradation; Approaches and classifications of surface engineering techniques; Introduction to surface cleaning techniques by physical, mechanical and chemical routes; Surface modifications techniques-conventional surface modification methods applicable to steel, cast iron, and non-ferrous metals/alloys- shot peening, sand blasting, flame, induction hardening, solid state diffusion assisted surface modifications; Emerging surface modification techniques- chemical route (electroless deposition, sol-gel coating), electro-chemical routes (electro-deposition, electro-phoretic deposition); Chemical conversion coatings - hot dipping, thermal spraying; Surface painting- basic paint technology, polymeric binders, pigments and extenders, additives, essential concepts of paint formulation and paint properties, paint preparation (pigment dispersion), surface preparation and paint application techniques applied for film preparation and their properties; Surfaces in vacuum- ultra-high vacuum techniques and processes; Thin film technologies-development of metallic and ceramic thin film by physical routes (thermal evaporation, sputtering and ion implantation) and chemical route (chemical vapor deposition); Directed energy beam assisted surface engineering techniques (ion, electron beam and laser assisted surface engineering techniques), Economics and designing of surface engineering processes; Characterisation of surfaces, effect of substrate surface structure on the over-layer properties, theoretical and experimental evaluation of surface energies, solid-liquid and solid-gas interfaces, damage of the surfaces by corrosion and wear.

Texts / Reference Books:

1. M. Ashby, H. Shercliff& D. Cebon, *Materials Engineering, Science, Processing and Design*.
2. ,D. SrinivasaRao, Shrikant V. Joshi , *Daya Publishing House (2010)* .
3. W. Gissler, H.A. Jehn, Springer, *Advanced Techniques for Surface Engineering*.
4. Research Papers.

Subject Code: ML6L014	Name: Powder Materials and Processing	L-T-P: 3-0-0	Credit: 3
Pre-requisite(s): None			

Introduction: development of powder metallurgy, scope of powder metallurgy, characterization of metal powders, physical properties-particle size and shape determination, technological properties-apparent density, flow rate etc. and chemical properties, particle interaction and control; Powder manufacturing: powder mixing and blending, dry and colloidal processing, reduction, electrolysis, and atomization processes, shaping techniques such as compacting, injection molding; Compaction and sintering: die compaction and other consolidation techniques, sintering, sintering with liquid phase; Powder metallurgy products: bearing, filters, friction parts, hard metals, refractory metals, contact materials, magnetic materials, structural parts, and dispersion strengthened materials.

Texts / Reference Books:

1. Glaus G. Goetzel, *TREATISE ON POWDER METALLURGY in three volumes*
2. *Volume 1: Technology of Metal Powders and Their Products*
3. *Volume II: Applied and Physical Powder Metallurgy*
4. *Volume III: Classified and Annotated Bibliography*

Subject Code: ML6L015	Name: Heat Treatment of Materials	L-T-P: 3-0-0	Credit: 3
Pre-requisite(s): None			
Heat Treatment -IT and CCT diagrams in steels, quench hardening and tempering of martensite, hardenability of steels, surface hardening processes, tool steels and their heat treatments, heat treatment of aluminium alloys, magnesium alloys, Ni-base super alloys and Ti alloys, Thermo-mechanical treatments; Hardenability, thermo-chemical and thermo-mechanical and thermo cycling treatments; Failure analysis of heat treated products. **Texts / Reference Books:** 1. Gregory J. Bonami, *Heat Treatment: Theory, Techniques, and Applications (Materials Science and Technologies).*			

Subject Code: ML6L016	Name: Extractive metallurgy	L-T-P: 3-0-0	Credit: 3
Pre-requisite(s): None			

Thermodynamics and kinetics of metallurgical reactions, heat transfer and fluid flow, Methods of extraction and refining of metals – pyrometallurgy, hydrometallurgy and electrometallurgy; Extraction of non-ferrous metals such as – U, Th, Cu, Zn, Au, Ag, Al, Pb, etc; Extractive metallurgy of rare earths; Iron making, blast furnace, blast furnace slag, various zones in blast furnace, controlling of various elements like P, Si, Mn, S, in hot metal, alternative routes of iron making processes *i.e.* solid state reduction, steel making principles, furnaces, modern steel making process, control of various elements in steel by refining the hot metal, slag property, stainless steel making, Ferro-alloy; Green extraction processes; Current research developments in extraction processes.

Texts / Reference Books:

1. A. Ghosh, H. S. Ray, *New Age International, Principles of Extractive Metallurgy*.
2. H.S Ray, R Shridhar, K.P Abraham , *East-West Private Ltd, Extraction of Non-Ferrous Metals*.
3. A. Ghosh, A. Chatterjee, *PHI Learning Ltd., Iron making and Steel Making; Theory and Practice.*

Subject Code: ML6L017	Name: Mineral Beneficiation	L-T-P: 3-0-0	Credit: 3
Pre-requisite(s): None			

Principles of mineral beneficiation, Mineralogy, Colloids and material chemistry Sampling methodology, Working principles and equipment design for: primary crushers, secondary crushers, grinding, froth flotation, magnetic separation, electrical separation, Electro and Hydro-Metallurgy processes, Bio-mineral processing, Discrete element method simulations.

Texts / Reference Books:

1. **A**. Ghosh, H. S. Ray, *New Age International, Principles of Extractive Metallurgy*.
2. H.S Ray, R Shridhar, K.P Abraham , *East-West Private Ltd, Extraction of Non-Ferrous Metals.*
3. Barry A. Wills, Elsevier and Butterwoth – Heineman, *Wills' Mineral Processing Technology, Seventh Edition: An Introduction to the Practical Aspects of Ore Treatment and Mineral Recovery.*

Subject Code: ML6L018	Name: Principles of Materials Engineering	L-T-P: 3-0-0	Credit: 3
Pre-requisite(s): None			

Introduction: Solid Engineering Materials- their classification and characteristic properties. Structure of solids: crystal systems/lattices, crystal structure, crystallographic planes and directions, interstitial sites, crystalline metals, ceramics, semiconductors and polymers. Microstructures and metallography; Amorphous or glassy state; Solidification of pure metal: homogeneous and heterogeneous nucleation processes, cooling curve, concept of supercooling, microstructure of pure metals. Defects in solids: point, line, planar and volume defects. Fundamentals of plastic deformation of metals, deformation by slip and twin, plastic deformation in polycrystalline metals, concept of cold working, preferred orientation; Annealing: recovery, recrystallization and grain growth; hot working; Properties of materials: Definition, units and common tests conducted to evaluate important engineering properties like physical, mechanical, chemical, electrical, magnetic, semi/super-conducting, optical, and thermal properties in engineering materials; Concept of formation of alloys: Types of alloys, solid solutions, factors affecting solid solubility, order-disorder transformation; Binary phase diagrams: isomorphous, eutectic, peritectic, eutectoid and peritectoid systems, effect of non-equilibrium cooling: coring and homogenization; Iron-cementite phase diagram: Construction and interpretation of Fe-Fe_3C and Fe-Graphite diagrams. Microstructure, and properties of different alloys in steel and cast iron, types of cast iron, their microstructures and typical uses; Heat treatment: T-T-T and C-C-T diagrams, concept of heat treatments of steel: annealing, normalizing, hardening and tempering; microstructural effects brought about by these processes and their influence on mechanical properties. Effect of common alloying elements in steel, concept of hardenability, factors affecting it; Common alloy steels, stainless steel, tool steel, high speed steel, high strength low alloy steel, micro-alloyed steel, specifications of steels; Physical metallurgy of common non-ferrous alloys: Cu-,Al- and Ni- based alloys. Microstructures and heat treatment of common alloys of these systems; Engineering ceramics and polymers: Structure, properties and application of common engineering ceramics and polymers.

Texts / Reference Books:

1. William D. Callister, *Jr. Materials Science and Engineering,* Wiley India (P) Ltd.
2. V.Raghavan, Materials Science and Engineering: *A First Course 5th Ed, Prentice Hall of India*, New Delhi (2000).
3. Sidney H. Avner, *Introduction to Physical Metallurgy*, Tata McGraw-Hill.
4. Butterworth-Heinemann, Michael Ashby, Hugh Shercliff and David Cebon, *Materials Engineering, Science, Processing and Design*

Subject Code: ML6L019	Name: Mechanical Behaviour of Materials	L-T-P: 3-0-0	Credit: 3
Pre-requisite(s): None			

Elasticity basics: Stress and strain tensors, tensor transformations, Mohr's circle representation of stress and strain, constitutive equations. Origin of stresses in thin films: thermo-elastic mismatch between film and substrate, lattice mismatch in hetero-epitaxial films, recrystallization, phase transformation, incorporation of atoms and chemical reactions. Application of the above for designing structures with low stresses. Experimental techniques for measuring stresses/strains in thin films: Substrate curvature; Stoney's equation, methods for curvature measurement and X-ray diffraction. Measurement of mechanical properties of thin films - nanoindentation, bulge test, 4-point bend test, and micro-tensile test. Models for high stresses, strain-hardening rates and Bauschinger effect in thin films, influence of grain size, film thickness and interfaces.

Texts / Reference Books:

1. Marc André Meyers, Krishan Kumar Chawla, Cambridge, *Mechanical Behavior of Materials*

Subject Code: ML6L020	Name: Transport Phenomena	L-T-P: 3-0-0	Credit: 3

Pre-requisite(s): None

Heat, mass and momentum balance, laminar, turbulent flow, concept of boundary layer, friction factor, heat and mass transfer coefficients and dimensionless correlations; Process modeling: governing equations, boundary conditions, and some case studies of some important metallurgical system: packed and fluidized bed, moving boundary problems with melting, solidifications and reactions, solid-gas reactions. Modeling of electrochemical processes. Numerical methods applied in transport modeling: control volume method for solving partial differential equations. Numerical solutions of some metallurgical processes: extraction processes, iron making, steel making gas stirred ladle, filling ladle, fusion welding, cored wire injection, soaking pits, continuous casting etc.

Texts / Reference Books:

1. R. Byron Bird, Warren E. Stewart, Edwin N. Lightfoot. *Wiley International edition, Transport Phenomena.*
2. D. R. Poirier, G. H. Geiger, Wiley, *Transport Phenomena in Materials Processing*.
3. Julian Szekely, Academic Press, *University of Michigan, Fluid flow phenomena in metals processing.*

Subject Code: ML6L021	Name: Corrosion Science and Engineering	L-T-P: 3-0-0	Credit: 3
Pre-requisite(s): None			

Importance of corrosion, corrosion rates evaluation, thermodynamics of corrosion; Electrochemical mechanisms: Electrode potentials and corrosion tendency, polarization, mixed potential theory, Evan's corrosion diagrams, potential-pH diagrams; Different forms of corrosion including microscopic and macroscopic forms. High temperature corrosion: Oxidation laws, selective oxidation, internal oxidation and catastrophic oxidation. Corrosion testing: design principles of corrosion evaluation of materials, accelerated corrosion tests, common experimental techniques for corrosion rate measurements including electrochemical methods. Different forms of corrosion and their control *viz.,* uniform corrosion, galvanic corrosion, selective leaching, crevice corrosion, fill form corrosion, pitting corrosion, inter-granular corrosion, erosion corrosion, fretting damage, stress corrosion cracking, corrosion fatigue, hydrogen embrittlement and microbes induced corrosion. Elementary treatment of corrosion testing procedures, inhibitors and corrosion of steels. Corrosion protection methods -studies on electroplating, cathodic and anodic protection, protecting coatings, coatings for prevention of high temperature oxidation etc. Some case studies of real life corrosion.

Texts / Reference Books:

1. M.G. Fontana, McGraw Hill, Singapore, 1987, *Corrosion Engineering*.
2. Edward Arnold, London, 1983.A.S. Khanna, *Introduction to Oxidation of Metals*.
3. Zaki Ahmed, Butterworth-Heinemann Publication, *Principles of Corrosion Engineering and Corrosion Control.*

Subject Code: ML6L022	Name: Diffusion in Solids	L-T-P: 3-0-0	Credit: 3

Pre-requisite(s): None

Introduction; review of basic concepts, Ficks laws; measurement of diffusion coefficients; formation of defects, movement of defects, random walk; fundamental thermodynamic relations; atomistic of diffusion, mechanism, effect of pressure, temperature and various driving forces on diffusion, uphill diffusion, Kirkendall effect, Darken's analysis; grain boundary and surface diffusion; diffusion along moving boundaries; applications, theories of creep and design of creep resistant alloys, prediction of creep life; diffusion theory of sintering, carburizing, nitriding and metalizing; tracer diffusivity, vacancy wind effect; ternary and multicomponent diffusion.

Texts / Reference Books:

1. Paul G. Shewmon, Paul G. Shewmon

Subject Code: ML6L023	Name: Advanced Joining Processes	L-T-P: 3-0-0	Credit: 3

Pre-requisite(s): None

Welding standards and codes; Friction welding: process technology, effect of intermetallic and low melting phase formation; Diffusion bonding: mechanism of bond formation; Ultrasonic welding: thermo-mechanical process modeling, mechanism of bond formation; Friction stir welding and friction stir spot welding: thermo-mechanical and microstructure evolution modeling, multi-scale modeling scope, friction stir tool design; Dis-similar metal welding; Lead-free solders in electronic packaging technology: microstructure and mechanical properties.

Texts / Reference Books:

1. ASM Handbooks Vol. 6A.
2. Eds. R.S. Mishra, M.W. Mahoney, ASM, *Friction stir welding and processing*.
3. AWS codes and standards.

Subject Code: ML6L024	Name: Granular Materials	L-T-P: 3-0-0	Credit: 3
Pre-requisite(s): None			

Granular materials: the fourth state of matter, industrial importance, granular statics and flow, antiparticle forces, discrete and continuum models, balance laws, fluid–particle interaction, yield conditions, shear stress, yield surfaces, flow rules, equation for plane flow, theory for steady and plane flow, effect of wall roughness, exit condition, smooth wall and radial gravity problem for compressible flow, constitutive equations involving a yield condition for slow three-dimensional flow, constitutive equations that do not involve a yield condition, introduction to rapid flow: theory for rapid flow of smooth, inelastic particles, model for inelastic collisions, thermodynamic description of rapid granular flows, kinetic theory for a granular gas of smooth inelastic particles.

Texts / Reference Books:

1. K. KesavaRao and Prabhu R Nott, *An introduction to granular flows*

Subject Code: ML6L025	Name: Advanced Composites	L-T-P: 3-0-0	Credit: 3
Pre-requisite(s): None			

Synthesis of composites, reinforcements, matrices; Metal Matrix Composites (MMCs), Ceramic Matrix Composites (CMCs), Special High Temperature High performance Carbon-Carbon composites; Processing issues in Metal Matrix Composites and Ceramic Matrix Composites, Solidification, Particulate technology, Sol gel, Chemical Vapour Deposition (CVD) and Physical Vapour Deposition (PVD) routes of manufacturing composites; Physico-chemical aspects of interfaces in composites; Nan composites.

Texts / Reference Books:

1. Krishan Kumar Chawla, *Composite Materials: Science and Engineering*.
2. Krishan Kumar Chawla, *Ceramic Matrix Composites*.

Curriculum for Joint M.Tech.-Ph.D. (Mechanical Systems Design)

Subject Name	Code	L-T-P	Credit	Contact Hour
SEMESTER - I				
Vibrations	ME 6L001	3-1-0	4	4
Advanced Solid Mechanics	ME 6L002	3-1-0	4	4
Elective I	-	3-0/1-0	3/4	3/4
Elective II	-	3-0-0	3	3
Elective III	-	3-0-0	3	3
Mechanical Systems Simulation Lab I	ME 6P001	0-0-3	2	3
Experimental Techniques for Mechanical Engineers	ME 6P002	0-0-3	2	3
Seminar I	ME 6S001	0-0-3	2	0
	Total :	**15-2/3-9**	**23/24**	**23/24**
SEMESTER - II				
Dynamics and Control of Mechanical Systems	ME 6L051	3-1-0	4	4
Applied Elasticity	ME 6L052	3-1-0	4	4
Elective IV	-	3-0/1-0	3/4	3/4
Elective V	-	3-0-0	3	3
Elective VI	-	3-0-0	3	3
Mechanical Systems Simulation Lab II	ME 6P003	0-0-3	2	3
Seminar II	ME 6S002	0-0-3	2	0
	Total :	**15-2/3-6**	**21/22**	**20/21**
SEMESTER - III				
Thesis - Part I	ME 6D001	0-0-0	16	0
Research Review Paper - I	ME 6D002	0-0-0	4	0
		Total :	**20**	**0**
SEMESTER – IV				
Thesis - Part II	ME 6D003	0-0-0	16	0
Research Review Paper - II	ME 6D004	0-0-0	4	0
		Total :	**20**	**0**

Total Credit: 84/86

List of Elective Subjects (Mechanical Systems Design)

Subject Name	Code	L-T-P	Credit	Contact Hour
Elective – I, II and III				
Mathematical Methods I	MA 60XX	3-0-0	3	3
Fatigue, Creep & Fracture	ME 6L003	3-0-0	3	3
Modern Control Theory	ME 6L004	3-1-0	4	4
Tribology	ME 6L005	3-1-0	4	4
Continuum Mechanics	ME 6L006	3-1-0	4	4
Engineering Design Optimization	ME 6L007	3-0-0	3	3
Sensing and Actuation	ME 6L008	3-0-0	3	3
Engineering Measurements	ME 6L009	3-1-0	4	4
Operations Management	ME 6L010	3-0-0	3	3
Finite Element Methods in Engineering	ME 6L011	3-1-0	4	4
Acoustics	ME 6L012	3-1-0	4	4
Robotics and Automation	ME 6L013	3-1-0	4	4
Advanced Fluid Dynamics	ME 6L101	3-1-0	4	4
Elective – IV, V and VI				
Mathematical Methods II	MA60XX	3-0-0	3	3
Industrial Noise Control	ME 6L053	3-0-0	3	3
Acoustics of Ducts and Mufflers	ME 6L054	3-1-0	4	4
Random Vibration Theory	ME 6L055	3-0-0	3	3
Experimental Stress Analysis	ME 6L056	3-0-0	3	3
Theory of Composite Materials	ME 6L057	3-1-0	4	4
Experimental Modal Analysis	ME 6L058	3-0-0	3	3
Vibration of Structures	ME 6L059	3-0-0	3	3
Artificial Intelligence & Neuro-Fuzzy Theory	ME 6L060	3-1-0	4	4
Applied Ergonomics	ME 6L061	3-0-0	3	3
MEMS& Microsystems Technology	ME 6L062	3-0-0	3	3
Advanced Heat Transfer	ME 6L151	3-1-0	4	4

Syllabus

Core Subject:

Vibrations (ME 6L001) **Pre-Requisites: None**	**CORE** **L – T – P – C** **3 – 1 – 0 – 4**

Fundamental concepts in vibration and modeling: Introduction to modeling and analysis
Introduction to mechanical vibration
Free vibration of single degree of freedom systems: Undamped vibration; Simple harmonic motion; Damped vibration; Modeling: Energy and Newton's methods; Measurement of vibrational components; Design Consideration; Stability
Forced harmonic excitation of single degree of freedom systems: Undamped vibration; Damped vibration; Base excitation; Rotating unbalance; Coulomb damping
Vibration of single degree of freedom systems under general forcing conditions: Impulsive inputs; Arbitrary non-periodic inputs; Arbitrary periodic inputs; Stability
Vibration of multi degree of freedom systems: Modeling, Free undamped vibration; Eigenvalue problem; Modal analysis; Free damped vibration; Forced vibration Dynamic vibration absorbers; Isolators for shock and harmonic loading.

Recommended Books:

1. *Theory of Vibrations with Applications* - William T. Thomson and Marie Dillon Dahleh (Pearson Education)
2. *Mechanical Vibration* - William J. Palm (Wiley)
3. *Principles of Vibration* – B. H. Tongue (Oxford University Press)
4. *Fundamentals of Vibrations* - Leonard Meirovitch (Mcgraw-Hill)
5. *Mechanical Vibrations*: Theory and Applications - S. Graham Kelly (CL-Engineering)
6. *Mechanical Vibration* – S. S. Rao (Prentice Hall)
7. *Advanced Theory of Vibration* - J. S. Rao (New Age International)
8. *Structural Dynamics*: *Vibrations and Systems* – Madhujit Mukhopadhyay (ANE Books)
9. *Vibration Testing: Theory and Practice* - Kenneth G. McConnell and Paulo S. Varoto (Wiley)
10. *Vibration problems in engineering*- Stephen Timoshenko (Oxford)

Advanced Solid Mechanics (ME 6L002) Pre-Requisites: None	CORE L – T – P – C 3 – 1 – 0 – 4

Analysis of stress and strain, Stress-strain relations for linearly elastic solids, Theories of failure or yield criteria and introduction to ideally plastic solids, Applications of energy methods, Bending of straight beams, Shear centre for thin-wall beam sections, Curved beams, Thick and thin wall cylinders, Elastic and inelastic stability of columns, Torsion, Analysis of plates, Stress concentration, Basic concepts of fatigue, creep and fracture.

Recommended Reference Books:

1. *Advanced Mechanics of Materials* – A. P. Boresi and R. J. Schmidt (Wiley)
2. *Advanced Mechanics of Solids* – L. S. Srinath (Tata McGraw-Hill)
3. *Fracture Mechanics: Fundamentals and Application* – T. L. Anderson (Taylor & Francis Group)
4. *Advanced Mechanics of Materials* – R. Solecki (Oxford University Press)
5. *Strength of Materials and Structures* – J. Case, L. Chilver and Carl T. F. Ross (Butterworth-Heinemann)
6. *Advanced Mechanics of Solids* – Bruhns Otto T. (Springer)
7. *Advanced Mechanics of Materials* – R. D. Cook, W. C. Young (Prentice Hall)
8. *Elements of Fracture Mechanics* – Prashant Kumar (Tata Mcgraw Hill)
9. *Fundamentals of Fracture Mechanics* – TribikramKundu (CRC Press)

Dynamics and Control of Mechanical Systems (ME 6L051) **Pre-Requisites: None**	**CORE** **L – T – P – C** **3 – 1 – 0 – 4**

Revisit to the history of development of mechanics from Galileo to Newton. Kinematics of rigid bodies - coordinate transformation, angular velocity vector, description of velocity and acceleration in relatively moving frames. Euler angles, Review of methods of momentum and angular momentum of system of particles, inertia tensor of rigid body. Dynamics of rigid bodies - Euler's equation, application to motion of symmetric tops and gyroscopes and problems of system of bodies.Kinetic energy of a rigid body, virtual displacement and classification of constraints. D' Alembert's principle. Introduction to generalized coordinates, derivation of Lagrange's equation from D' Alembert's principle.Small oscillations, matrix formulation, Eigen value problem and numerical solutions. Introduction to MAPLE® and MATLAB®, computer generation and solution of equations of motion. Introduction to complex analytic functions, Laplace and Fourier transform. Transfer function and block diagrams, tiMEnd frequency domain system behavior. Root-locus, Bode and Nyquist plots; stability and sensitivity; PID controllers, Phase lag and Phase lead compensation. Analysis of Control systems in state space, pole placement, computer simulation through MATLAB - SIMULINK®.

Recommended Reference Books:

1. *Methods of Analytical Dynamics* - Leonard Meirovitch – Dover.
2. *Classical Dynamics* - Donald T. Greenwood – Dover.
3. *Advanced Dynamics* - Donald T. Greenwood – Cambridge University Press.
4. *Analytical Mechanics* - Herbert Goldstein - Addison Wesley.
5. *Engineering Mechanics:* Dynamics – I. H. Shames, Prentice-Hall of India.
6. *Dynamics: Theory and Applications* - T.R. Kane, David A. Levinson - McGraw-Hill.
7. *System Dynamics* - Katsuhiko Ogata - Pearson Education India.
8. *Modern Control Theory* - William L. Brogan - Prentice Hall.
9. *Modern Control Engineering* - Katsuhiko Ogata - Prentice Hall.
10. *Control Systems Engineering* - Norman S. Nise – Wiley.
11. *Control System Design:* An Introduction to State-Space Methods – B. Friedland – Dover.
12. *Feedback and Control for Everyone* - P. Albertos Pérez, Pedro Albertos – Springer.
13. *Automatic Control Systems* - Benjamin C. Kuo, FaridGolnaraghi – Wiley.
14. *A Mathematical Introduction to Control Theory* - ShlomoEngelberg - World Scientific Publishing Company.
15. *Computational Methods in Multibody Dynamics* - Farid M. L. Amirouche - Prentice Hall.
16. *MATLAB® for Control Engineers* - Katsuhiko Ogata - Prentice Hall.
17. *Dynamical Systems with Applications using Maple®* - Stephen Lynch - Birkhäuser Boston.

Applied Elasticity (ME 6L052) Pre-Requisites: None	CORE L – T – P – C 3 – 1 – 0 – 4
Concepts of states of stress and strain. Analysis of three dimensional stresses and strains, equations of equilibrium, generalized Hookes law, Plane elastic problems in cartesian and polar coordinates, axisymmetric problems, torsion, solutions of problems using elasticity theory, anisotropic elasticity, thermoelasticity, contact problems, energy and variational principles and elastic stability. **Recommended Books:** 1. *Theory of Elasticity*- S. Timoshenko and J.N. Goodier (McGraw Hill) 2. *Elasticity in engineering mechanics*- Arthur Peter Boresi, Ken Pin Chong (Wiley)	

Detailed Plans for the Core Courses

ME 6L001:Vibrations

Unit 0: Fundamental concepts in vibration and modeling **Hours = 5**

Unit 1: Introduction to modeling and analysis **Hours = 5**

Unit 2: Introduction to mechanical vibration **Hours = 5**

Unit 3: Free vibration of single degree of freedom systems: Undamped vibration; Simple harmonic motion; Damped vibration; Modeling: Energy and Newton's methods. **Hours = 8**

Unit 4: Measurement of vibrational components; Design Consideration; Stability **Hours = 8**

Unit 5: Forced harmonic excitation of single degree of freedom systems: Undamped vibration; Damped vibration; Base excitation; Rotating unbalance; Coulomb damping **Hours=8**

Unit 6: Vibration of single degree of freedom systems under general forcing conditions: Impulsive inputs; Arbitrary nonperiodic inputs; Arbitrary periodic inputs; Stability **Hours = 8**

Unit 7: Vibration of multi degree of freedom systems: Modeling, Free undamped vibration; Eigenvalue problem; Modal analysis; Free damped vibration; Forced vibration Dynamic vibration absorbers; Isolators for shock and harmonic loading. **Hours = 8**

Total Hours = 55

ME 6L002: Advanced Solid Mechanics

Unit 0: Analysis of stress and strain. **Hours = 5**
Unit 1: Stress-strain relations for linearly elastic solids. **Hours = 4**
Unit 2: Theories of failure/yield criteria and introduction to ideally plastic solids. **Hours = 4**
Unit 3: Applications of energy methods. **Hours = 5**
Unit 4: Bending of straight beams. **Hours = 5**
Unit 5: Shear centre for thin-wall beam sections. **Hours = 4**
Unit 6: Curved beams. **Hours = 5**
Unit 7: Thick and thin wall cylinders. **Hours = 4**
Unit 8: Elastic and inelastic stability of columns. **Hours = 5**
Unit 9: Torsion. **Hours = 4**
Unit 10: Analysis of plates. **Hours = 5**
Unit 11: Stress concentration, Basic concepts of fatigue, creep and fracture. **Hours = 5**

Total Hours = 55

ME 6L051: Dynamics and Control of Mechanical Systems

Unit 0: Revisit to the history of development of mechanics from Galileo to Newton. Kinematics of rigid bodies - coordinate transformation, angular velocity vector, description of velocity and acceleration in relatively moving frames.

Hours = 8

Unit 1: Euler angles, Review of methods of momentum and angular momentum of system of particles, inertia tensor of rigid body. Dynamics of rigid bodies - Euler's equation, application to motion of symmetric tops and gyroscopes and problems of system of bodies.

Hours = 8

Unit 2: Kinetic energy of a rigid body, virtual displacement and classification of constraints. D' Alembert's principle.

Hours = 4

Unit 3: Introduction to generalized coordinates, derivation of Lagrange's equation from D' Alembert's principle.

Hours = 4

Unit 4: Small oscillations, matrix formulation, eigenvalue problem and numerical solutions.

Hours = 4

Unit 5: Introduction to MAPLE and MATLAB, computer generation and solution of equations of motion.

Hours = 4

Unit 6: Introduction to complex analytic functions, Laplace and Fourier transform.

Hours = 4

Unit 7: Transfer function and block diagrams, tiMEnd frequency domain system behavior.

Hours = 5

Unit 8: Root-locus, Bode and Nyquist plots; stability and sensitivity; PID controllers, Phase lag and Phase lead compensation.

Hours = 8

Unit 9: Analysis of Control systems in state space, pole placement, computer simulation through MATLAB SIMULINK;

Hours = 6

Total Hours = 55

ME 6L052: Applied Elasticity

Unit 1	Introduction: Concepts of states of stress and strain	**Hours =04**
Unit 2	Analysis of three dimensional stresses and strains, Equations of equilibrium and Generalized Hookes law.	**Hours = 20**
Unit 3	Plane elastic problems in cartesian and polar coordinates, axisymmetric problems, torsion and solutions of problems using elasticity theory	**Hours = 20**
Unit 4	Anisotropic elasticity, thermo-elasticity, contact problems, energy and variational principles and elastic stability	**Hours = 11**

Total Hours = 55

Syllabus

1st Semester (Electives-I, Electives-II & Elective-III):

<table>
<tr><td>MA60XX</td><td>Mathematical Methods I</td><td></td></tr>
<tr><td colspan="2">Fatigue, Creep & Fracture (ME 6L003)
Pre-Requisites: None</td><td>ELECTIVE
L – T – P – C
3 – 0 – 0 – 3</td></tr>
<tr><td colspan="3">Analysis of stresses and strains in three dimensions: Principal stresses and strains. Stress / Strain Invariants, Octahedral stresses, Theories of Failure, Various yield criteria.
Repeated stresses and fatigue in metals: Fatigue tests, endurance limit. Fatigue under combined loadings. Fatigue design theory: Goodman, Gerber and Soderberg criteria. Factors influencing fatigue behavior of metals: Frequency, temperature, size, form, surface conditions, residual stress, etc. Influence of stress concentration, Notch sensitivity. Various mechanical and metallurgical methods used for improving fatigue strength of metals. Effect of corrosion, Corrosion fatigue and fretting. Cumulative fatigue damage and life estimation of components.
Fracture mechanics: Basic modes of fracture. Griffith theory of brittle fracture and Orwon's modifications. Linear Elastic fracture mechanics: Stress field ahead of crack-tip, Stress Intensity factors, Critical SIF, Fracture toughness testing and evaluation of KIC. Elasto-plastic fracture mechanics: Plane stress and plane strain plastic zone sizes. J-Integral method. SERR computations and evaluation of structural integrity.
Creep behavior of metals: Creep–stress-time-temperature relations, creep testing methods. Mechanics of creep, creep in tension, bending and torsion. Strain-hardening effects on creep. Creep buckling, members subjected to combined stresses and creep.

<u>Recommended Books:</u>
1. Engineering Fracture Mechanics – S. A. Meguid (Springer)
2. Elementary Engineering Fracture Mechanics – David Broek (Springer)
3. Fracture Mechanics – C. T. Sun and Z. H. Jin (Elsevier)
4. Elements of Fracture Mechanics – Prashant Kumar (Tata Mcgraw Hill)
5. Fundamentals of Fracture Mechanics – TribikramKundu (CRC Press)
6. Mechanical Metallurgy – George E. Dieter (McGraw-Hill)
7. Mechanical Behaviour of Materials – Norman E. Dowling (Prentice Hall)
8. Metal Fatigue in Engineering – R. I. Stephens and H. O. (Willey)
9. Creep of Engg. Materials – I. Finnie and W. R. Heller (Mc Graw Hill Book Co.)</td></tr>
</table>

Modern Control Theory (ME 6L004) Pre-Requisites: None	ELECTIVE L – T – P – C 3 – 1 – 0 – 4

Overview of Classical Control Theory: System Modeling; Transfer Function; Stability;Transient and Steady-State Responses; Frequency Response; Graphical Methods; PID Control; Lead-Log Control; System Identification

Digital Control Theory: Sampling; Discrete-Time Modeling; Zero-Order Hold Circuit; Pulse Transfer Function; Response Analysis; Position and Velocity Algorithms; Direct Design of Digital Control Algorithm

State-Space Control Theory: State-Space Modeling; State-Space Representation; Transfer Function; Stability; Controllability and Observability; Regulator Design; Observer Design; Compensator Design by the Separation Principle

Optimal Control Theory: Linear Quadratic Regulator; Random Processes; Kalman Filters: Optimal Observers; Linear Quadratic Gaussian Control: The Separation Theorem

Recommended Books:

1. *Modern Control Engineering*, Katsuhiko Ogata, PHI Learning, 2010.
2. *Discrete-Time Control Systems*, Katsuhiko Ogata, PHI Learning, 2011
3. *Automatic Control Systems*. FaridGolnaraghi, Benjamin C. Kuo, Wiley, 2007.
4. *Frequency-Domain Analysis and Design of Distributed Control Systems (eBook)*, Yu-Ping Tian, Wiley, 2012.

Tribology (ME 6L005) Pre-Requisites: None	ELECTIVE L – T – P – C 3 – 1 – 0 – 4

Introduction: Economic aspects, lubrication of bearings, friction control and wear prevention. Properties and testing of lubricants. Mechanics of fluid flow - Reynolds equation and its limitations.
Idealized bearings : Infinitely long plane pivoted shoe and fixed shoe sliders, Infinitely long journal bearings, Infinitely short (narrow) bearings, Lightly loaded infinitely long journal bearing (Petroffs' solution).
Finite bearings: Approximate analytical solution, Numerical solution and Electrical analogy method.
Hydrostatic oil bearing: Thrust and journal bearings, Squeeze film bearings,
Gas-lubricated bearings: Hydrodynamic bearings, Hydrostatic bearings, Porous bearings, Elasto-hydrodynamic lubrication, Fluid inertia and turbulence and hydrodynamic instability, Friction and wear of metals.

Recommended Books:

1. *Tribology* – Hutchings (Asterix)
2. *Tribology: Lubrication, Friction and Wear* - I. V. Kragelsky and V. V. Alisin (John Wiley & Sons)
3. *Fundamentals of Tribology* - R. Gohar and H. Rahnejat (World Scientific Publishing Co.pvt Ltd)
4. *A Tribology Casebook* -J. D. Summers-smith (John Wiley & Sons)
5. *Tribology of Interface Layers* - HooshangHeshmat (CRC Press)
6. *Principles of Tribology* - Shizhu Wen and Ping Huang(John Wiley & Sons)

Continuum Mechanics (ME 6L006) **Pre-Requisites: None**	**ELECTIVE** **L – T – P – C** **3 – 1 – 0 – 4**

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

Recommended Books:

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

Engineering Design Optimization (ME 6L007) Pre-Requisites: None	ELECTIVE L – T – P – C 3 – 0 – 0 – 3

Basic concepts: Unconstrained and constrained problems. The Kuln-Tucker conditions; Function of one variable; Polynomial approximations, Golden section method. Finding the bounds on the solution, a general strategy for minimizing functions of one variable; Unconstrained functions of n variables : Zero-order, first-order and second order methods, convergence criteria; constrained functions of n variables: linear programming, Sequential unconstrained minimization techniques, Direct methods; Approximation techniques; Duality; General design applications.

Recommended Books:

1. *Optimization for Engineering Design*: Algorithms and Examples- Deb Kalyanmoy (PHI)
2. *Introduction to Engineering Design Optimization*- ChinyereOkechiOnwubiko (Prentice Hall)
3. *Engineering Optimization*: Theory and Practice- S. S. Rao (Wiley)
4. *Optimization Concepts and Applications in Engineering*-Ashok D. Belegundu and Tirupathi R. Chandrupatla(Cambridge Univ)
5. *Engineering Optimization*: methods and applications- A. Ravindran , K. M. Ragsdell, G. V. Reklaitis (Wiley)

Sensing and Actuation (ME 6L008) Pre-Requisites: None	ELECTIVE L – T – P – C 3 – 0 – 0 – 3

Sensing Principle: Introduction to Sensing Static and Dynamics Characteristics of Sensors; Motion and Dimensional Sensors; Force, Torque, and Power Sensors; Pressure and Sound Sensors; Fluid Flow Sensors; Temperature Sensors.

Electrical Actuators: Introduction to Electro-Magnetic Principle; Classification of Electrical Actuators; DC Motors and Modeling; DC Motor Drivers; AC Motors and Modeling; AC Motor Drivers; Stepper Motors and Modeling; Stepper Motor Drivers.

Hydraulic and Pneumatic Actuators: Description of Fluid Behavior; Hydraulic Actuator and System; Pneumatic Actuator and System

Sensors and Actuators Design

Recommended Books:

1. *Theory and Design for Mechanical Measurements* - Richard S. Figliola, Donald E. Beasley (John Wiley & Sons)

Engineering Measurements (ME 6L009) Pre-Requisites: None	ELECTIVE L – T – P – C 3 – 1 – 0 – 4

Principles of Measurement: Static characteristics and accuracy in the steady state, Generalized model, Measurement errors and error reduction techniques, Dynamic characteristics, Loading effects and noise, Transfer function, TiMEnd frequency responses, Dynamic errors and compensation, Random signals and effects of noise and interference, Noise sources and reduction methods, Economics of measurement systems: Reliability, Selection of measurement systems, Operating cost; Measurement System Design: Sensing elements: resistive, capacitive, inductive, electromagnetic and other sensing elements, Signal conditioning and processing elements: deflection bridges, amplifiers, AC carrier systems, current transmitters, oscillators and resonators, A/D conversion, sampling, quantization and encoding, Data Acquisition, Multiplexing, Data acquisition system, digital signal analysis; Specialized Measurement Systems: Principles of flow, optical and ultrasonic measurement systems, Heat transfer effects and particle size analysis.

Recommended Books:

1. *Theory and Design for Mechanical Measurements* - Richard S. Figliola, Donald E. Beasley (John Wiley & Sons)
2. *Mechanical Measurements* - Thomas G. Beckwith, Roy D. Marangoni, John H. Lienhard, V (Pearson)
3. *Instrumentation: Measurement and Analysis* - B.C. Nakra **and** K.K. Chaudhry (Tata Mcgraw-hill Education Private Ltd.)

Operations Management (ME 6L010) **Pre-Requisites: None**	**ELECTIVE** **L – T – P – C** **3 – 0 – 0 – 3**

Productivity, Competitiveness, Operations strategy, Production system, Facility Location, Facility layout, product and services, Process planning, Process Capability, Statistical Process control, Quality control tools, Acceptance Sampling Plans and selection, Taguchi Techniques, Product Reliability, ISO 9000, ISO 14000, Inventory control, Project Management, Decision Analysis, Work measurement, Resource Planning.

Recommended Books:

1. *Operations management* -Russel& Taylor (Wiley India)
2. *Operations management* - Krajewski, Ritzman, Malhotra (Pearson Prenctice Hall)
3. *Operations management* - Heizer, Render (Pearson Education)
4. *Operations Management* – Stevenson (McGraw Hill)
5. *Operations Management* - Chase and Aquilano (Tata McGraw Hill)

Finite Elements Methods in Engineering (ME 6L011) Pre-Requisites: None	ELECTIVE L – T – P – C 3 – 1 – 0 – 4

Introduction. Integral Formulations and Variational Methods.

FE Analysis of One-dimensional problems. Second-Ordesr boundary value problems; Bending of Beams; FE Error Analysis; Eigenvalue and Time-Dependent Problems; Numerical Integration and Computer Implementation.

FE Analysis of Two-Dimensional Problems. Single-Variable Problems; Interpolation Functions, Numerical Integration and Modeling; Plane Elasticity; Flows of Viscous Incompressible Fluids; Bending of Elastic Plates; Computer Implementation.

FE Analysis of Three-Dimensional and Nonlinear Problems.

<u>Recommended Reference Books:</u>

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

Acoustics (ME 6L012) **Pre-Requisites: None**	**ELECTIVE** **L – T – P – C** **3 – 1 – 0 – 4**

Fundamentals of vibration, vibrations of continuous systems (strings, rods, beams and membranes), one dimensional wave equation, initial values and boundary conditions, acoustic wave equation, concept of impedance, sound radiation from simple sources, near field and far field, directivity of sources, sound waves in pipes standing waves and travelling waves, resonances, wave guides, lumped parameter modeling of acoustic systems, transmission of sound through partitions, dynamics of microphones and speakers, room acoustics, sound in enclosures (cylinders).

Recommended Books:

1. *Fundamentals of Acoustics* - Lawrence E. Kinsler, Austin R. Frey, Alan B. Coppens, James V. Sanders, Wiley, 1999.
2. *Fundamentals of Physical Acoustics* - David T. Blackstock, Wiley; 4th edition (December 30, 1999)
3. *Sound and Structural Vibration* - Frank J. Fahy, Elsevier India Pvt. Ltd, New Delhi, 2010.
4. *Sound And Structural Vibration*: Radiation, Transmission And Response - Frank J. Fahy, Paolo Gardonio, Academic Press, 2007 .
5. *Handbook of Acoustics* - Malcolm J. Crocker, Wiley-Interscience, 1998.

Robotics and Automation (ME 6L013) **Pre-Requisites: None**	**CORE** **L – T – P – C** **3 – 1 – 0 – 4**

Introduction to robots, Internal and external sensors, actuators: hydraulic, pneumatic and electric actuators, programming of robots.
Homogeneous transformations, D-H parameter notation, direct & inverse kinematics of manipulators: examples of kinematics of some common manipulator configurations.
Jacobian, dynamics of manipulators: L-E formulation, N-E formulation, trajectory planning.

Automation, types of automation, analysis of automated assembly systems, line balancing problems, analysis of automated material handling systems, automated storage and retrieval systems

Recommended Books:

1. *Robotics: Fundamental concepts and analysis*, A. Ghosal, Oxford university press
2. *Industrial Robotics* / Groover M P /Pearson Edu.
3. *Robotics and Control* / Mittal R K &Nagrath I J / TMH.
4. *Robotics: Control, sensing, vision and intelligence*, Fu, K., Gonzalez, R. and Lee, C. S. G McGraw Hill.
5. *Robotic Engineering* / Richard D. Klafter,
6. *Introduction to Robotics* / John J Craig / Pearson Edu. Prentice Hall
7. *Robot Dynamics & Control* – Mark W. Spong and M. Vidyasagar / John Wiley & Sons (ASIA) Pte Ltd.
8. *Automation, Production systems and Computer Intigrated Manufacturing* – M P Groover, Prentice Hall India.

Advanced Fluid Dynamics (ME 6L101) **Pre-Requisites: None**	**ELECTIVE** **L – T – P – C** **3 – 1 – 0 – 4**

Introduction to Tensors & Tensors Equations. Concept of continuum and definition of a fluid. Body and surface forces, stress tensor, Scalar and vector fields, Eulerian and Lagrangian description of flow. Motion of fluid element - translation, rotation and vorticity; strain rate tensor, continuity equation, stream function and velocity potential. Potential Flows. Transport theorems, constitutive equations, derivation of Navier Stokes equations for compressible flow. Exact solutions of Navier Stokes equations : plane Poiseuille flow and Couette flow, Hagen-Poiseuille flow, flow between two concentric rotating cylinders, Stoke's first and second problem, Hiemenz flow, flow near a rotating disk, flow in convergent- divergent channels. Slow viscous flow: Stokes and Oseen's approximation, theory of hydrodynamic lubrication. Boundary layer: derivation, exact solutions, Blasius, Falkner Skan, series solution and numerical solutions. Approximate methods. Momentum integral method. Two dimensional and axi-symmetric jets. Description of turbulent flow, velocity correlations, Reynold's stresses, Prandtl's Mixing Length Theory, Karman's velocity defect law, universal velocity distribution.

Recommended Reference Books:

1. *Incompressible Flow 3ed* - R. L. Panton – Wiley
2. *Viscous Fluid Flow 3ed* - F. M. White - McGraw-Hill
3. *Boundary Layer Theory 8 Ed* - H. Schlichting& K. Gersten – Springer
4. *An Introduction to Fluid Dynamics* – G. K. Batchelor – Cambridge University Press
5. *Turbulent Flows* – S. B. Pope – Cambridge
6. *Vectors, Tensors and the Basic Equations of Fluid Mechanics* – Rutherford Aris - Dover
7. *Fluid Mechanics with Multimedia DVD, 4ed* - Pijush K. Kundu, Ira M. Cohen – AP / Elsevier
8. *Fundamentals of Fluid Mechanics 6ed* - Bruce R. Munson, Donald F. Young, Theodore H. Okiishi, Wade W. Huebsch - Wiley
9. *Fundamental Mechanics of Fluids 3ed – I.* G. Currie – Marcel DekerInc
10. *Fluid Mechanics* – R. A. Granger – Dover
11. *Introduction to Fluid Mechanics 8ed* – R. W. Fox, A. T. McDonald & P. J. Pritchard - Wiley
12. *Partial Differential Equations for Scientists & Engineers* – Stanley J. Farrow – Dover
13. *Momentum Transfer in Boundary Layers* – T. Cebeciand P. Bradshaw – McGraw-Hill
14. *Turbulence, An Introduction for Scientists and Engineers* – P. A. Davidson – Oxford
15. *The Structure of Turbulent Shear Flows* – A. A. Townsend
16. *An Album of Fluid Motion* – Milton Van Dyke
17. *Multimedia Fluid Mechanics DVD-ROM 2ed* – G. M. Homsey
18. *A Gallery of Fluid Motion* – M. Samimy, K. S. Breuer, L. G. Leal, P. H. Steen
19. *Advanced Engineering Mathematics 10ed* – E. Kreyzig – Wiley
20. *Differential Equations 3ed* – Shepley L. Ross – Wiley

2nd Semester (Electives-IV, Elective-V& Elective-VI):

MA60XX	Mathematical Methods II	
Industrial Noise Control (ME 6L053) **Pre-Requisites: None**		**ELECTIVE** **L – T – P – C** **3 – 0 – 0 – 3**

Nature of air borne and structure-borne sound; source path receiver concept; various mechanisms of the generation of radiation of sound; propagation of sound; noise reduction by sound absorption or dissipation, isolation and damping of structure borne sound; general methods of noise control; applications to specific machines; principles of flow acoustics and application thereof to I.C. engines, fans and compressors.

Recommended Books:

1. *Noise Control: From Concept to Application* - Colin Hansen, CRC Press, 2005.
2. *Noise and Vibration Control Engineering: Principles and Applications* - Leo L. Beranek, István L. Vér, Wiley-Interscience, 1992.
3. *Handbook of Acoustic*s, Malcolm J. Crocker, Wiley-Interscience, 1998.
4. *Industrial Noise Control: Fundamentals and Applications* - L. H. Bell, D. H. Bell, CRC Press, 1993.
5. *Industrial noise and vibration control* - J. David Irwin, Edward R. Graf, Prentice-Hall, 1979.

Acoustics of Ducts and Mufflers (ME 6L054) Pre-Requisites: None	ELECTIVE L – T – P – C 3 – 1 – 0 – 4

Acoustics of moving media; duct acoustics; analysis and synthesis of one dimensional acoustic filters; the rational synthesis of one dimensional acoustic filters; the exhaust process of reciprocating I.C. engines; analysis of exhaust mufflers, finite wave analysis of exhaust systems, aeroacoustic characterization of engine sources; design of exhaust mufflers.

Recommended Books:

1. *Acoustics of Ducts and Mufflers With Application to Exhaust and Ventilation System Design* - M. L. Munjal, Wiley-Interscience, 1987.
2. *Fundamentals of Acoustics* - Lawrence E. Kinsler, Austin R. Frey, Alan B. Coppens, James V. Sanders, Wiley, 1999.
3. *Sound And Structural Vibration: Radiation, Transmission And Response* - Frank J. Fahy, Paolo Gardonio, Academic Press, 2007 .
4. *Industrial noise and vibration control* - J. David Irwin, Edward R. Graf, Prentice-Hall, 1979.
5. *Industrial Noise Control: Fundamentals and Applications* - L. H. Bell, D. H. Bell, CRC Press, 1993.

Random Vibration Theory (ME 6L055) Pre-Requisites: None	ELECTIVE L – T – P – C 3 – 0 – 0 – 3

Introduction to random processes, probability distributions and associated concept, linear time invariant systems excited by stationery random process. Failure due to random vibration vector random process and response of MIO systems to vector random excitations, theory of Kalman Filter. Chapman-Kolmogorov-Smoluchowskiequaion, Fokker-Plank equation and it's solution for simple systems, the method of Ito, cumulant-neglect closure of Ito's equations, soMEimulation studies of systems excited by random signals.

Recommended Books:

1. *Stochastic Processes and Random Vibrations: Theory and Practice* - JúlíusSólnes, Wiley, 1997.
2. *Random Vibrations: Theory and Practice* - Paul H. Wirsching, Thomas L Paez, Keith Ortiz, Dover Publications, 2006.
3. *Fundamentals of Vibrations* - Leonard Meirovitch, Waveland Press Inc., 2010.
4. *Analytical methods in vibrations* - Leonard Meirovitch, Macmillan, 1967.
5. *Vibration theory and applications* - William Tyrrell Thomson, Prentice-Hall, 1965.
6. *Shock and vibration handbook* - Cyril M. Harris, Charles E. Crede, McGraw-Hill, 1976.

Experimental Stress Analysis (ME 6L056) Pre-Requisites: None	ELECTIVE L – T – P – C 3 – 0 – 0 – 3

Basic elasticity theory. Strain Measurement Methods: Various types of strain gauges, Electrical Resistance strain gauges, semiconductor strain gauges, strain gauge circuits, transducer applications, recording instruments for static and dynamic applications. Photoelasticity: Theory of photoelasticity, Analysis techniques, Three dimensional photoelasticity, Reflection Palanscope and application. Brittle coating methods of strain indication. Moire Method of strain analysis. Grid method of strain analysis. Computer interfacing and on-line monitoring of strain and stress fields.

Recommended Books:

1. *Modern Experimental Stress Analysis: Completing The Solution Of Partially Specified Problems* - James F. Doyle (Willey)
2. *Experimental Stress Analysis* - James W. Dally, William F. Riley (College House Enterprises)
3. *Experimental Stress Analysis* - U C Jindal (Pearson)
4. *Advanced strength and applied stress analysis*- Richard Gordon Budynas (McGraw Hill)

Theory of Composite Materials (ME 6L057) Pre-Requisites: None	ELECTIVE L – T – P – C 3 – 1 – 0 – 4

Basic concepts of three dimensional stresses and strains, Introduction to composite materials, Processes and characteristics, Macromechanical and micromechanical behavior of a lamina, Macromechanical and micromechanical behavior of a laminate, Hygrothermal effects, Bending, buckling and vibration of laminated plates, shells and panels, Experimental methods for characterization and testing of composite materials.

Recommended Books:

1. *Mechanics of Composite Materials* – R. M. Jones (Taylor & Francis)
2. *Engineering Mechanics of Composite Materials* – I. M. Daniel and O. Ishai (Oxford University Press)
3. *Practical Analysis of Composite laminates* – J. N. Reddy and A. Miravete (CRC Press)
4. *Mechanics of laminated plates and shells* – J. N. Reddy (CRC Press)
5. *Introduction to Composite Materials Design*- Ever J. Barbero(CRC Press)
6. *Composite Materials: Science and Engineering* - Krishan K. Chawla (Springer)
7. *Mechanics of composite Materials and Structures* – MadhujitMukopadhyay (Oriental Swan)

Experimental Modal Analysis (ME 6L058) Pre-Requisites: None	ELECTIVE L – T – P – C 3 – 0 – 0 – 3

Overview of vibration, Modal testing, Experimental Modal theory, Excitation techniques (Shaker and Hammer) Transducer and calibration, Digital signal processing for experimental modal analysis Modal parameter extraction, Validation of extracted modal parameters, Model updating, Structural Dynamic modification, Practical discussion and case studies.

Recommended Books:

1. *Modal Testing, Theory, Practice, and Application* - D.J. Ewins(Mechanical Engineering Research Studies: Engineering Dynamics Series)
2. *Theoretical and Experimental Modal Analysis* - Maia N M M(Mechanical Engineering Research Studies. Engineering Control Series, 9)
3. Modal Analysis - Zhi-Fang Fu , Jimin He (Butterworth-Heinemann, publisher)

Vibration of Structures (ME 6L059) Pre-Requisites: None	ELECTIVE L – T – P – C 3 – 0 – 0 – 3

Introduction; Boundary value and eigenvalue problems; Self-adjoint and non-self-adjoint systems; Vibration of rods, shafts and strings; Bending vibration of bars; Two-dimensional problems; Variational Characterization of the eigenvalues; The response problem; discretization of continuous systems; Rayleigh-Ritz method, Assumed modes method, Method of weighted residuals; System response by approximate methods; Vibration of a system with time dependent boundary conditions; Transform method solution of continuous systems; The finite element method; Substructure synthesis.

Recommended Books:

1. *Mechanical and Structural Vibrations* - Demeter G. Fertis (Wiley-Interscience)
2. *Mechanical and Structural Vibrations*: Theory and Applications -Jerry H. Ginsberg (John Wiley & Sons)

Artificial Intelligence & Neuro-Fuzzy Theory (ME 6L060) **Pre-Requisites: None**	**ELECTIVE** **L – T – P – C** **3 – 1 – 0 – 4**

Machine Intelligence Technologies: Neural Networks ; Introduction to Neural Networks; Perception Learning Rule; Hebbian Learning; Widrow-Hoff Learning; Backpropagation; Associative Learning; Competitive Networks; Grossberg Networks and Adaptive Resonance Theory; Hopfield Networks
Fuzzy Set Theory: Introduction to Fuzzy Set with Properties; Fuzzy Relations; Fuzzy Arithmetic; Fuzzy Logic; Applications and Fuzzy Control
Genetic Algorithm: Introduction to Genetic Algorithm; GA Operations; Standard Method; Rank Method; Rank Space Method
Simulated Annealing: Introduction to Annealing Process; Simulated Annealing Optimization
Particle Swarm Optimization: Introduction to Swarm Behavior; Particle Swarm Optimization
Artificial Intelligence: Introduction to Artificial Intelligence; Semantic Nets and Description Matching ;Generate and Test, Means-Ends Analysis, and Problem Reduction; Nets, Basic Search, and Optimal Search; Trees and Adversarial Search; Rules and Rule Chaining; Planning

Recommended Books:

1. *Artificial Intelligence: A Modern Approach by Stuart Russell*, Peter Norvig (Prentice Hall)
2. *Probabilistic Robotics (Intelligent Robotics & Autonomous Agents Series)* - Sebastian Thrun (MIT Press)

Applied Ergonomics (ME 6L061) Pre-Requisites: None	ELECTIVE L – T – P – C 3 – 0 – 0 – 3

Introduction to the concept of system design in product design, Analysis of MMEystem design, How to assess the interface design, Design methodology, Body dimensions and its application in design, Dimensional optimization for the population and use of percentile, The musculo-skeletal system and joint motion study, Human body follows the principle of lever, Basic model on calculation of biomechanical stresses on our body. Effect of stresses imposed on body. Design from the view point of biomechanics, Work posture analysis, Static and Dynamic work, The visual, auditory and thermal environment and their impact on design. Design for the physically challenged. Controls and display Psycho physiological aspects of design. Research techniques in Ergonomic data generation, interpretation and application of statistical methods. Case analysis. Mini Project work involving Ergonomic design research for product system.

Recommended Books:

1. *Introduction to Work Study: International Labour Office Geneva*; Universal Book Corporation
2. *The practice and Management of industrial ergonomics*- David Alexander- Prentice Hall
3. *Work Design and Industrial Ergonomics*- Konz S and S Johnson

MEMS & Microsystems Technology (ME 6L062) Pre-Requisites: None	ELECTIVE L – T – P – C 3 – 0 – 0 – 3

Introduction to MEMS & MST. Scaling Laws and demand in miniaturization. Working principles of Micro Sensors, Actuators and applications in real systems. Microsystems mechanisms & precision using flexures, design considerations, modeling and innovations. Materials selection, Micro Fabrication. Microfluidics, Chemical Sensors, Biomedical & Bio-MEMS, and Lab-on-a-chip. System Integration and Packaging.

Recommended Books:

1. Tai-Ran Hsu, *"MEMS & MICROSYSTEMS Design and Manufacture*", Tata McGraw Hill Education Pvt. Ltd.
2. Marc Madou, *"Fundamentals of Microfabrication: The Science of Miniaturization"*, Vol. I, II, & III, CRC Press. 2012
3. Stephen D. Senturia, *"Microsystems Design",* Springer, 2006.

Advanced Heat Transfer (ME 6L151) Pre-Requisites: None	ELECTIVE L – T – P – C 3 – 1 – 0 – 4

Review of Conduction Heat Transfer, Multi-dimensional Conduction, Unsteady Conduction Heat Transfer, A review of viscous flow, the continuity and Navier-Stokes equation, boundary layer equation, laminar boundary layer over a flat plate, Energy equation, derivation of energy equation, energy equation in non dimensional form, derivation of thermal boundary layer equation, heat transfer in a parallel flow over a flat surface, analogy between momentum and heat transfer in turbulent flow, forced convection in internal flows, concept of entrance length and fully developed flow, heat transfer in high speed flow; Governing equation, Scaling laws, free convection in laminar flow over a vertical plate, empirical co-relation in external free convection flows, inclined plates, long horizontal cylinder, spheres, free convection in enclosures, and cavities, concentric cylinders, concentric spheres, combined free and forced convection, Basic design methodologies – LMTD and effectiveness-NTU methods. Overall heat transfer coefficient, fouling. Correlations for heat transfer coefficient and friction factor, Heat transfer in boiling, forced convection boiling, Condensation heat transfer, theory of film condensation, drop wise condensation, heat pipes, heat transfer in freezing and melting; Mechanism and fundamental concepts, definition of concentration, mass fluxes and mole fluxes, Ficks law of diffusion, temperature and pressure dependence of mass diffusivity, diffusion in a multi component system, theory of diffusion in gases and liquids, mass transfer coefficient, simultaneous heat and mass transfer.

Recommended Books:

1. *Fundamentals of Heat and Mass Transfer* – Incropera& Dewitt – Wiley
2. *Heat and Mass Transfer* – Cengel&Ghajar – McGraw Hill
3. *Heat Transfer* : A Basic Approach – M. N. Ozisik - McGraw Hill
4. *Heat Transfer* –Mills &Ganeshan – Pearson
5. *Heat Transfer* – J. P. Holman - McGraw Hill
6. *Convective Heat Transfer* – A. Bejan – Wiley
7. *Computation of Conduction and Duct Flow Heat Transfer* – S. V. Patankar – CRC Press
8. *Process Heat Transfer* – D. Q. Kern - McGraw Hill

Curriculum for Joint M.Tech.-Ph.D. (Thermal Science and Engineering)

Subject Name	Code	L-T-P	Credit	Contact Hour
SEMESTER - I				
Advanced Fluid Dynamics	ME6L101	3-1-0	4	4
Computational Methods in Thermal & Fluid Engineering	ME6L102	3-1-0	4	4
Elective I	-	3-0-0	3	3
Elective II	-	3-0-0	3	3
Elective III	-	3-0/1-0	3/4	3/4
Mechanical Systems Simulation Lab - I	ME 6P001	0-0-3	2	3
Advanced Thermo-Fluids Lab	ME6P102	0-0-3	2	3
Seminar I	ME6S101	0-0-3	2	0
	Total :	**15-2/3-9**	**23/24**	**23/24**
SEMESTER - II				
Advanced Heat Transfer	ME6L151	3-1-0	4	4
Compressible Flows	ME6L152	3-1-0	4	4
Elective IV	-	3-0-0	3	3
Elective V	-	3-0-0	3	3
Elective VI	-	3-0/1-0	3/4	3/4
Thermo-Fluids Systems Simulation Lab	ME6P103	0-0-3	2	3
Seminar II	ME6S102	0-0-3	2	0
	Total :	**15-2/3-6**	**21/22**	**20/21**
SEMESTER - III				
Thesis - Part I	ME6D101	0-0-0	16	0
Research review paper - I	ME6D102	0-0-0	4	0
		Total :	**20**	**0**
SEMESTER – IV				
Thesis - Part II	ME6D103	0-0-0	16	0
Research review paper - II	ME6D104	0-0-0	4	0
		Total :	**20**	**0**

Total Credit: 84/86

List of Elective Subjects (Thermal Science and Engineering)

Subject Name	Code	L-T-P	Credit	Contact Hour
Elective – I, II and III				
Mathematical Methods I	MA6L1XX	3-0-0	3	3
Conduction and Radiation Heat Transfer	ME6L104	3-0-0	3	3
Advanced Thermodynamics	ME6L105	3-0-0	3	3
Air-Conditioning and Ventilation	ME6L107	3-0-0	3	3
Combustion & Emissions	ME6L108	3-0-0	3	3
Gas Turbine & Jet Propulsion	ME6L110	3-0-0	3	3
Internal Combustion Engine and Combustion Modelling	ME6L111	3-0-0	3	3
Two Phase Flow Heat Transfer	ME6L112	3-0-0	3	3
Engineering Measurements	ME6L009	3-1-0	4	4
Finite Elements Methods in Engineering	ME6L011	3-1-0	4	4
Elective – IV, V and VI				
Convective Heat and Mass Transfer	ME6L153	3-0-0	3	3
Conduction and Change of Phase Heat Transfer	ME6L154	3-0-0	3	3
Turbulence	ME6L155	3-1-0	4	4
Refrigeration Systems	ME6L156	3-0-0	3	3
Transport Phenomenon in Material Processing	ME6L157	3-0-0	3	3
Boiling and Condensation	ME6L158	3-0-0	3	3
Heat and Mass Transfer in Biological Systems	ME6L159	3-0-0	3	3
Microfluidics	ME6L160	3-0-0	3	3
Experimental Fluid Mechanics	ME6L161	3-1-0	4	4
Nuclear Power, Generation & Safety	ME6L162	3-0-0	3	3
High Performance Computing in Thermo-Fluids Applications	ME6L163	3-0-0	3	3
Numerical Methods in Radiative Heat Transfer	ME6L164	3-0-0	3	3
Principles of Turbo Machinery	ME6L165	3-0-0	3	3
Geophysical Fluid Dynamics	ME6L166	3-0-0	3	3
Dynamics and Control of Mechanical Systems	ME6L051	3-1-0	4	4

Syllabus

Core Subjects:

Subject Code: ME6L101 **Prerequisites: None**	**Name: Advanced Fluid Dynamics**	**L – T – P : 3 – 1 – 0**	**Credits: 4**

Introduction to Tensors & Tensors Equations. Concept of continuum and definition of a fluid. Body and surface forces, stress tensor, scalar and vector fields. Eulerian and Lagrangian description of flow.Motion of fluid element - translation, dilation, strain, rotation and vorticity. Strain rate & rotation rate tensors. Continuity equation, stream function and velocity potential. Transport theorems, constitutive equations, Derivation of Navier-Stokes equations for compressible flow, Newtonian Fluid & Constant Property Incompressible Navier-Stokes equation. Exact solutions of Navier Stokes equations. Slow viscous flow: Stokes and Oseen's approximation. Theory of hydrodynamic lubrication. Boundary layers: Exact, Approximate & Numerical solutions. Free Shear Flows – Jets & Wakes. Introduction to Turbulent Flow – Reynolds Stress, Turbulent Viscosity Hypothesis.

Recommended Books:

1. *Incompressible Flow 3ed* - R. L. Panton – Wiley
2. *Viscous Fluid Flow 3ed* - F. M. White - McGraw-Hill
3. *Boundary Layer Theory 8 Ed* - H. Schlichting& K. Gersten – Springer
4. *An Introduction to Fluid Dynamics* – G. K. Batchelor – Cambridge University Press
5. *Turbulent Flows* – S. B. Pope – Cambridge
6. *Vectors, Tensors and the Basic Equations of Fluid Mechanics* – Rutherford Aris - Dover
7. *Fluid Mechanics with Multimedia DVD, 4ed* - Pijush K. Kundu, Ira M. Cohen – AP / Elsevier
8. *Fundamentals of Fluid Mechanics 6ed* - Bruce R. Munson, Donald F. Young, Theodore H. Okiishi, Wade W. Huebsch - Wiley
9. *Turbulence, An Introduction for Scientists and Engineers* – P. A. Davidson – Oxford
10. *The Structure of Turbulent Shear Flows* – A. A. Townsend

Subject Code: ME6L102 Prerequisites: None	Name: Computational Methods in Thermal & Fluid Engineering	L – T – P : 3 – 1 – 0	Credits: 4

A brief overview of the basic conservation equations for fluid flow and heat transfer, classification of partial differential equations and pertinent physical behaviour, parabolic, elliptic and hyperbolic equations, role of characteristics. Common methods of discretization: an overview of finite difference, finite element and finite volume methods. Numerical solution of parabolic partial differential equations using finite-difference and finite-volume methods: explicit and implicit schemes, consistency, stability and convergence. Numerical solution of systems of linear algebraic equations: general concepts of elimination and iterative methods, Gaussian elimination, LU decomposition, tri-diagonal matrix algorithm, Jacobi and Gauss-Seidel iterations, necessary and sufficient conditions for convergence of iterative schemes.The finite volume method of discretization for diffusion problems: one-dimensional steady diffusion problems, specification of interface diffusivity, source-term linearization. Discretization of transient one-dimensional diffusion problems. Discretization for multi-dimensional diffusion problems. Solution of discretized equations using point and line iterations, strongly implicit methods and pre-conditioned conjugate gradient methods.
Convection-diffusion problems: Central difference, upwind, exponential, hybrid and power-law schemes, concept of false diffusion.Numerical solution of the Navier-Stokes system for incompressible flows: stream-function vorticity and artificial compressibility methods, requirement of a staggered grid. SIMPLE, SIMPLEC and SIMPLER algorithms.Special topics: phase-change problems, interface/free-surface tracking methods.

Recommended Books:

1. *Numerical Heat Transfer and Fluid Flow1ed*, 2004 - Suhas V. Patankar, - Taylor and Francis
2. *Introduction to Computational Fluid Dynamics*: The Finite Volume Method 2ed, 2008 - H. K. Versteeg and W. Malalasekera – Pearson
3. *Computational Fluid Dynamics1ed*, 1995 - D. A. Anderson Jr - McGraw-Hill
4. *Computational Fluid Mechanics and Heat Transfer* - John C. Tannehill, Dale A. Anderson and Richrad H. Pletcher - Taylor and Francis Group, 1997
5. *Introduction to Computational Fluid Dynamics 2005* - Anil W. Date, Cambridge University Press
6. *Computational Fluid Flow and Heat Transfer2ed, 2009* - K. Muralidhar and T. Sundararajan - Narosa
7. *Numerical Solution of Partial Differential Equations: Finite Difference Methods3ed*, 1986 - G. D. Smith - Oxford University Press

Subject Code: ME6L151 Prerequisites: None	Name: Advanced Heat Transfer	L – T – P : 3 – 1 – 0	Credits: 4

Introduction to Heat Transfer

Review of Conduction Heat Transfer, Multi-dimensional Conduction, Unsteady Conduction Heat Transfer, A review of viscous flow, the continuity and Navier-Stokes equation, boundary layer equation, laminar boundary layer over a flat plate, Energy equation, derivation of energy equation, energy equation in non-dimensional form, derivation of thermal boundary layer equation, heat transfer in a parallel flow over a flat surface, analogy between momentum and heat transfer in turbulent flow, forced convection in internal flows, concept of entrance length and fully developed flow, heat transfer in high speed flow; Governing equation, Scaling laws, free convection in laminar flow over a vertical plate, empirical co-relation in external free convection flows, inclined plates, long horizontal cylinder, spheres, free convection in enclosures, and cavities, concentric cylinders, concentric spheres, combined free and forced convection, Basic design methodologies – LMTD and effectiveness-NTU methods. Overall heat transfer coefficient, fouling. Correlations for heat transfer coefficient and friction factor, Heat transfer in boiling, forced convection boiling, Condensation heat transfer, theory of film condensation, drop wise condensation, heat pipes, heat transfer in freezing and melting; Mechanism and fundamental concepts, definition of concentration, mass fluxes and mole fluxes, Ficks law of diffusion, temperature and pressure dependence of mass diffusivity, diffusion in a multi component system, theory of diffusion in gases and liquids, mass transfer coefficient, simultaneous heat and mass transfer.

Recommended Books:

1. *Fundamentals of Heat and Mass Transfer* – Incropera& Dewitt – Wiley
2. *Heat and Mass Transfer* – Cengel&Ghajar – McGraw Hill
3. *Heat Transfer : A Basic Approach* – M. N. Ozisik - McGraw Hill
4. *Heat Transfer* –Mills &Ganeshan – Pearson
5. *Heat Transfer* – J. P. Holman - McGraw Hill
6. *Convective Heat Transfer* – A. Bejan – Wiley
7. *Computation of Conduction and Duct Flow Heat Transfer* – S. V. Patankar – CRC Press
8. *Process Heat Transfer* – D. Q. Kern - McGraw Hill

Subject Code: ME6L152 Prerequisites: None	Compressible Flows	L – T – P : 3 –1 – 0	Credits: 4

Fundamental Aspects of Compressible Flow: Introduction, Isentropic flow in a stream tube, speed of sound, Mach waves; One dimensional Isentropic Flow; Normal Shock Waves; Oblique Shock Waves; Prandtl-Meyer Expansion; Flow over bodies involving shock and expansion waves; Variable Area Flow, operating characteristics of nozzles, convergent-divergent supersonic diffusers; Adiabatic Flow in a Duct with Friction : Flow in a constant area duct, friction factor variations, the Fanno line; Flow with Heat addition or Removal.

Review of Eigen Vectors & Eigen Values, Linearization of PDEs, Perturbation; Introduction to Instability & Transition of Fluid Flows; Linear Stabiltiy& Normal Modes as Perturbations; KH Instability; Stability of Parallel Flows, Orr-Sommerfield Equation; Blasius Boundary Layer – Secondary Instability & Bypass Transition.

<u>Recommended Books:</u>

1. *Modern Compressible Flow with Historical Perspective 3 rd* – John D. Anderson – McGraw-Hill
2. *The Dynamics & Thermodynamics of Compressible Fluid Flow (Vol 1 &Vol 2)* – Asher H. Shapiro
3. *Incompressible Flow 3ed* - R. L. Panton – Wiley
4. *Viscous Fluid Flow 3ed* - F. M. White - McGraw-Hill
5. *Boundary Layer Theory 8 Ed* - H. Schlichting& K. Gersten – Springer
6. *Gas Dynamics 3 Ed* – James John & Theo Keith – Pearson
7. *Elements of Gas Dynamics* - Liepmann and Roshko
8. *Gas Dynamics for Engineers* – P. Balachandran - PHI
9. *Fundamentals of Compressible Fluid Dynamics* – P. Balachandran – PHI

Syllabi of Elective Courses

1st Semester (Electives-I, Electives-II & Elective-III):

Subject Code: MA6L1XX **Prerequisites: None**	**Mathematical Methods I**	**L – T – P : 3 – 0 – 0**	**Credits: 3**
Subject Code: ME6L009 **Prerequisites: None**	**Engineering Measurements**	**L – T – P : 3 –1 – 0**	**Credits: 4**

Principles of Measurement: Static characteristics and accuracy in the steady state, Generalized model, Measurement errors and error reduction techniques, Dynamic characteristics, Loading effects and noise, Transfer function, Time and frequency responses, Dynamic errors and compensation, Random signals and effects of noise and interference, Noise sources and reduction methods, Economics of measurement systems: Reliability, Selection of measurement systems, Operating cost; Measurement System Design: Sensing elements: resistive, capacitive, inductive, electromagnetic and other sensing elements, Signal conditioning and processing elements: deflection bridges, amplifiers, AC carrier systems, current transmitters, oscillators and resonators, A/D conversion, sampling, quantization and encoding, Data Acquisition, Multiplexing, Data acquisition system, digital signal analysis; Specialized Measurement Systems: Principles of flow, optical and ultrasonic measurement systems, Heat transfer effects and particle size analysis.

Recommended Books:

1. *Engineering measurements: methods and intrinsic errors*, T. A. Polak, Caroline Pande, Professional Engineering, 1999
2. *Engineering measurements*, Benjamin Austin Barry, Wiley, 1964
3. *Measurement Science for Engineers*, Paul Regtien, F. van der Heijden, M. J. Korsten, W.Otthius, Kogan Page Science, 2004.

Subject Code: ME6L011 Prerequisites: None	Finite Elements Methods in Engineering	L – T – P : 3 – 1 – 0	Credits: 4

Integral Formulations and Variational Methods, Second-Order boundary value problems; Bending of Beams; FE Error Analysis; Eigenvalue 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.

Recommended Books:

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

Subject Code: ME6L104 Prerequisites: None	Conduction and Radiation Heat Transfer	L – T – P : 3 –0 – 0	Credits: 3

Derivation of heat conduction equation. Analytical solutions. Eigen value problems. Solution of heat conduction equation by Laplace transform, Fourier transform and separation of variables techniques. Contact resistance. Transient heat conduction, conduction with moving boundary, solidification and melting. Problems with periodic boundary conditions.Fundamentals of thermal radiation; integral equation for radiative exchange; view factors. Radiative exchange between surfaces: black surfaces, gray, diffuse, partially specular surfaces. Radiative properties of participating media: introduction to gas properties, wide band models, total emissivity, particle properties. Radiative transfer through participating media: gray, plane-parallel slab; approximate methods; non-gray media.

Recommended Books:

1. *Conduction Heat Transfer*, D. Poulikakos, Prentice Hall, 1994.
2. *Heat Conduction*, S. Kakac and Y. Yener, Taylor and Francis, 1994.
3. *Analytical methods in Conduction Heat Transfer*, G.E.Myers, McGraw Hill, 1971.
4. *Conduction Heat Transfer*, V.S. Arpaci, Addison Wesley, 1996 (Abridged edition Ginn press 1998)
5. *Heat Transfer*, A.J.Chapman, Macmillan, 1984.
6. *Thermal Radiation Heat Transfer,* R. Siegel and J.R.Howell, Taylor & Francis, 2002.
7. *Radiation Heat Transfer,* E.M.Sparrow and R.D.Cess, Wadsworth, 1966.
8. *Radiative Transfer,* H.C.Hottel and A.F.Saroffim, McGraw hill, 1967.
9. *Radiative Heat Transfer*, M.F.Modest, McGraw Hill, 2003.

Subject Code: ME6L105 Prerequisites: None	Advanced Thermodynamics	L – T – P : 3 –0 – 0	Credits: 3

Review of basic thermodynamics: Laws of thermodynamics, entropy, entropy balance for closed and open systems. Exergy: Concept of reversible work & irreversibility; Second law efficiency; Exergy change of a system: closed & open systems, exergy transfer by heat, work and mass, exergy destruction, exergy balance in closed & open systems; Exergy analysis of industrial systems – power systems and refrigeration systems. Cycle analysis and optimization: Regenerative reheat Rankine cycle and Brayton cycle, combined cycle power plants, multi-stage refrigeration systems. Thermodynamic optimization of irreversible systems: Finite time thermodynamics principles, optimization studies of various thermal systems, Minimization of entropy generation principle. Properties of Gas Mixtures: Equation of state and properties of ideal gas mixtures; Change in entropy on mixing; Partial molal properties for non-ideal gas mixtures. Thermodynamics of Reactive System: Conditions of equilibrium of a multiphase - multicomponent system; Second law applied to a reactive system; Condition for reaction equilibrium. Statistical-mechanical evaluation of thermodynamic properties of gases, liquids, and solids, Elementary kinetic theory of gases and evaluation of transport properties. Non-Equilibrium Thermodynamics of small scale systems.

<u>Recommended Books:</u>

1. A. Bejan, *Advanced Engineering Thermodynamics*, 3rd edition, John Wiley and sons, 2006.
2. F.W.Sears and G. L. Salinger, *Thermodynamics, Kinetic Theory and Statistical Thermodynamics,* Narosa Publishing House, New Delhi, 3rd edition, 1998.
3. M.J.Moran and H.N.Shapiro, *Fundamentals Of Engineering Thermodynamics*, John Wiley and Sons.
4. M. W. Zemansky and R. H. Dittman, *Heat and Thermodynamics*, McGraw Hill International Editions, 7th edition, 2007.
5. I. K. Puri and K. Annamalai, *Advanced Engineering Thermodynamics*, CRC Press, 2001.

Subject Code: ME6L107 Prerequisites: None	Air-Conditioning and Ventilation	L – T – P : 3 –0 – 0	Credits: 3

Psychrometry, simple psychometrics processes, use of psychometrics chart. Comfort and industrial air conditioning. Air filtration. Principles of ventilation. Physiological factors. Comfort index. Air conditioning systems: Spray systems, chilled water and DE Coils, absorption and adsorption systems. Humidifiers. Air conveying: fans, ducts and air diffusion equipment. Estimation of air conditioning load, determination of supply state. Design and constructional details of Unitary air conditioning equipment. Noise level and acoustic control. Automatic controls in air conditioning.

Recommended Books:

1. *ASHRAE Handbook - Fundamentals, American Society of Heating, Refrigerating and Air - Conditioning Engineers Inc*., Atlanta, USA, 2009.
2. Threlkeld, J.L., *Thermal Environmental Engineering*, Prentice Hall, New Jersey, 1962.
3. Croome, D.J. and Roberts, B.M., *Air conditioning and ventilation of buildings*, Pergamon.
4. Stoecker, W.F., and Jones, J.W., *Refrigeration and Air Conditioning*, 2nd Edition, Tata McGraw Hill, New Delhi 1982.
5. Arora, C.P., *Refrigeration and Air Conditioning*, Tata-McGraw-Hill, New Delhi, 2003.

Subject Code: ME6L108 Prerequisites: None	Combustion & Emissions	L – T – P : 3 –0 – 0	Credits: 3

Principles of Combustion, combustion chemistry. Thermodynamics of reactive systems. Reaction kinetics. Theory of premixed laminar and turbulent flames. Concepts of ignition and quenching, Burner systems. Gaseous diffusion flame, atomization of liquid fuel, stability and propagation of flames, droplet and spray combustion. Coal combustion: fixed bed combustion, pulverized coal and fluidized bed combustion. Mechanism and kinetics of coal combustion. Volatile and char combustion. Flames related to industrial applications. Combustion generated pollutants: various sources, modelling of emissions, industrial furnace emissions.

Recommended Books:

1. J.B. Heywood, *Internal Combustion Engine Fundamentals*, McGraw Hill International Editions, 1989.
2. B. P. Pundir, *Engine Emissions: Pollutant Formation and Advances in Control Technology*, Narosa Publishing House, New Delhi, 2007.
3. *Handbook of Air Pollution from Internal Combustion Engines: Pollutant Formation and Control*, Ed. EranSher, Academic Press, 1998.

Subject Code: ME6L110 Prerequisites: None	Gas Turbine & Jet Propulsion	L – T – P : 3 –0 – 0	Credits: 3

Thermodynamic cycle analysis of gas turbines; open and closed cycles, Axial flow turbines; blade diagrams and design of blading, performance characteristics, Centrifugal and axial flow compressors, blowers and fans.Theory and design of impellers and blading, Matching of turbines and compressors, Fuels and combustion, effect of combustion chamber design and exhaust on performance, Basic principles and methods of heat recovery, Thermodynamic cycle analysis and efficiencies of propulsive devices. Thrust equation, classification and comparison of ram jets, turbojets, pulse jets and rockets. Performance of turbo-prop, turbo-jet and turbofan engines, Augmentation of thrust.

Recommended Books:

1. *Gas Turbines & Jet Propulsion*, M.J. Sable M.S. Ramgir, Technical Publications, 2006
2. *Gas Turbines*, V Ganesan,Tata McGraw-Hill Education,(2003)
3. *Aircraft Propulsion and Gas Turbine Engines*, Ahmed F. El-Sayed, CRC Press, 2008.

Subject Code: ME6L111 Prerequisites: None	Internal Combustion Engine and Combustion Modelling	L – T – P : 3 –0 – 0	Credits: 3

Air standard and fuel–air cycle analysis of Otto, Diesel and limited pressure cycles, Effect of design and operating parameters on cycle efficiency, Modified fuel-air cycle considering heat losses and valve timing, Modern fuel injection system of IC engines, Fuels and combustion in SI engines, knocking and fuel rating, Energy balance, volumetric efficiency, Measurement, Testing and performance of IC engines, Combustion chamber designs for spark-ignition and compression-ignition engines. Cooling of engine and governing of engine, Ignition system: conventional and electronic, Supercharging, Variable compression ratio engine, Wankel rotary combustion engine, Exhaust emissions, its measurement and control, Fault diagnosis of SI Engines, Modeling of IC Engine Combustion.

Recommended Books:

1. *Internal combustion engines*, Ganesan, Tata McGraw-Hill Education,(2008).
2. *Engineering fundamentals of the internal combustion engine*, Willard W. Pulkrabek, Pearson Prentice Hall, (2004).
3. *Introduction to Modeling and Control of Internal Combustion Engine Systems*, LinoGuzzella, Christopher Onde, Springer, 2010.

Subject Code: ME6L112 Prerequisites: None	Two Phase FlowHeat Transfer	L – T – P : 3 –0 – 0	Credits: 3

Formulation and Solution to Phase Change Problem, Two Phase Flow Fundamentals, Review of one-dimensional conservation equations in single phase flows; Governing equations for homogeneous, separated and drift-flux models; Flow pattern maps for horizontal and vertical systems; Simplified treatment of stratified, bubbly, slug and annular flows. Modelling of Two-Phase Flow, Pressure Drop in Two-Phase Flow, Brief Discussion on Critical Flow and Unsteady Flow.

Description and Classification of Boiling, Pool Boiling Curve, Nucleation and Dynamics of Single Bubbles, Heat Transfer Mechanisms in Nucleate Boiling, Nucleate Boiling Correlations, Hydrodynamic of Pool Boiling Process, Pool Boiling Crisis, Film Boiling Fundamentals, Flow Boiling, Forced-Flow Boiling Regimes, Flow Boiling Curves, Nucleate Boiling in Flow, Sub-cooled Nucleate Flow Boiling, Saturated Nucleate Flow Boiling, Flow Boiling Correlations, Flow Boiling Crisis. Condensation- Film and dropwise condensation.

Recommended Books:

1) S. MostafaGhiaasiaan, *"Two-Phase Flow, Boiling And Condensation in Conventional and Miniature Systems"*, Cambridge University Press, 2008
2) L. S. Tong and Y. S. Tang, *"Boiling Heat Transfer and Two-Phase Flow"*, Taylor and Francis, 1997
3) J. B. Collier, and J. R. Thome, *"Convective boiling and condensation, Oxford Science Publications"*, 1994.

2^{nd} Semester (Electives-IV & Elective-V):

<table>
<tr><td>MA6LXXX</td><td>Mathematical Methods II</td><td></td><td></td></tr>
<tr><td>Subject Code: ME S6L051
Prerequisites: None</td><td>Name: Dynamics and Control of Mechanical Systems</td><td>L – T – P : 3 – 1 – 0</td><td>Credits: 4</td></tr>
<tr><td colspan="4">Revisit to the history of development of mechanics from Galileo to Newton. Kinematics of rigid bodies - coordinate transformation, angular velocity vector, description of velocity and acceleration in relatively moving frames. Euler angles, Review of methods of momentum and angular momentum of system of particles, inertia tensor of rigid body. Dynamics of rigid bodies - Euler's equation, application to motion of symmetric tops and gyroscopes and problems of system of bodies.Kinetic energy of a rigid body, virtual displacement and classification of constraints. D′ Alembert′s principle. Introduction to generalized coordinates, derivation of Lagrange's equation from D′ Alembert′s principle.Small oscillations, matrix formulation, Eigen value problem and numerical solutions. Introduction to MAPLE® and MATLAB®, computer generation and solution of equations of motion. Introduction to complex analytic functions, Laplace and Fourier transform. Transfer function and block diagrams, time and frequency domain system behavior. Root-locus, Bode and Nyquist plots; stability and sensitivity; PID controllers, Phase lag and Phase lead compensation. Analysis of Control systems in state space, pole placement, computer simulation through MATLAB - SIMULINK®.

<u>Recommended Books:</u>
1. Methods of Analytical Dynamics - Leonard Meirovitch – Dover.
2. Classical Dynamics - Donald T. Greenwood – Dover.
3. Advanced Dynamics - Donald T. Greenwood – Cambridge University Press.
4. Analytical Mechanics - Herbert Goldstein - Addison Wesley.
5. Engineering Mechanics: Dynamics – I. H. Shames, Prentice-Hall of India.
6. Dynamics: Theory and Applications - T.R. Kane, David A. Levinson - McGraw-Hill.
7. System Dynamics - Katsuhiko Ogata - Pearson Education India.
8. Modern Control Theory - William L. Brogan - Prentice Hall.
9. Modern Control Engineering - Katsuhiko Ogata - Prentice Hall.
10. Control Systems Engineering - Norman S. Nise – Wiley.
11. Control System Design: An Introduction to State-Space Methods – B. Friedland – Dover.
12. Feedback and Control for Everyone - P. Albertos Pérez, Pedro Alertos – Springer.
13. Automatic Control Systems - Benjamin C. Kuo, FaridGolnaraghi – Wiley.
14. A Mathematical Introduction to Control Theory - ShlomoEngelberg - World Scientific Publishing Company.
15. Computational Methods in MultibodyDynamics -Farid M. L. Amirouche - Prentice Hall.
16. MATLAB® for Control Engineers - Katsuhiko Ogata - Prentice Hall.
17. Dynamical Systems with Applications using Maple® - Stephen Lynch - Birkhäuser Boston.</td></tr>
</table>

Subject Code: ME6L153 Prerequisites: None	Convective Heat and Mass Transfer	L – T – P : 3 –0 – 0	Credits: 3

Forced Convective Heat Transfer: Introduction to heat transfer by convection, a review of viscous flow, conservation of mass and momentum – the continuity and Navier-Stokes equation, boundary layer equation, laminar boundary layer over a flat plate, boundary layer separation, energy equation, derivation of energy equation, energy equation in non-dimensional form, derivation of thermal boundary layer equation, heat transfer in a parallel flow over a flat surface, analogy between momentum and heat transfer in turbulent flow, heat transfer in parallel flow and cross flow over a cylinder, heat transfer in parallel flow over a sphere, heat transfer for impinging jets, forced convection in internal flows, concept of entrance length and fully developed flow, heat transfer in high speed flow;
Natural Convection Heat Transfer: Governing equation and similarity considerations, free convection in laminar flow over a vertical plate, empirical co-relation in external free convection flows, inclined plates, long horizontal cylinder, spheres, free convection in enclosures, and cavities, concentric cylinders, concentric spheres, combined free and forced convection.Heat Transfer with Phase Change: Heat transfer in boiling, modes of boiling, regimes of pool boiling, pool boiling correlation, critical heat flux in nucleate pool boiling, forced convection boiling, modes ofcondensation, theory of film condensation, laminar and turbulent film condensation on a vertical plate, film condensation inside and outside horizontal tubes, drop wise condensation, heat pipes, theory of heat pipes,design limitations, heat transfer in freezing and melting;Mass Transfer: Mechanism and fundamental concepts, definition of concentration, mass fluxes and molefluxes, Ficks law of diffusion, temperature and pressure dependence of mass diffusivity, diffusion in a multi component system, theory of diffusion in gases and liquids, mass transfer coefficient, conservation of species for a control volume – species continuity equation, equimolar counter diffusion, simultaneous heat and mass transfer.

Recommended Books:

1. Kays W M and Crawford M E, "*Convective Heat and Mass Transfer*", McGraw Hill Int Edition, 3rd edition, 1993.
2. Spalding D B, "*Introduction to Convective Mass Transfer*", McGraw Hill, 1963.
3. Bird R. B., Stewart W. E. and Lightfoot E. N., " *Transport Phenomena* ", John Wiley and sons, Inc., 1960.
4. Schlichting H., "*Boundary Layer Theory* ", Sixth edition, McGraw Hill , 1968.

Subject Code: ME6L154 Prerequisites: None	Conduction and Change of Phase Heat Transfer	L – T – P : 3 –0 – 0	Credits: 3

Solutions of steady and transient heat conduction problems with various boundary conditions. Approximate methods: application of numerical techniques. Moving boundaries: problems in freezing and melting. Condensation heat transfer. Boiling: mechanisms and heat transfer correlations. Thermal modeling of engineering systems: thermal contact resistance; heat and mass transfer in material processing; heat transfer in biomedical systems.

Recommended Books:

1. *Liquid Vapor Phase Change Phenomena* by Van P. Carey (Taylor & Francis).
2. *One Dimensional Two-Phase Flow* G. B. Wallis (McGraw Hill).
3. *Heat Pipe Science and Technology* by Amir Faghri (Taylor and Francis).
4. *Convective Boiling And Condensation* by Collier John (Oxford Engineering Science)
5. *Two-phase Flow and Heat Transfer* - P. B. Whalley (Oxford Engineering Science)
6. *Heat Transfer Characteristics in Boiling and Condensation* by Karl Stephan (Springer)
7. *Heat Pipe Technology and Applications* by J. P. Peterson (John Wiley & Sons)
8. *Heat Transfer* - A practical approach by Yunus Cengel (Tata McGraw Hill)
9. *Heat Transfer* - Incropera and Dewitt (John Wiley and Sons)

Subject Code: ME6L155 Prerequisites: None	Turbulence	L – T – P : 3 –1 – 0	Credits: 4

Review of Tensor Equations, Stochastic Processes, Probability & Averaging; Reynolds averaging, Reynolds Stresses, RANS equations, Turbulent Viscosity Hypothesis; Free-Shear Flows – Round Jet, Similarity, Turbulent kinetic energy and kinetic energy of mean flow-convection, production and dissipation of turbulence, re-distribution, turbulent diffusion; Other Self-Similar Flows – Homogenous Shear, Wind Tunnel Turbulence, Mixing Layer; Statistical Description of Turbulence - stationary and non-stationary turbulence, homogeneous and non-homogeneous turbulence, nonlinearity, two-point correlations, structure functions, turbulence scales, energy cascade, vortex stretching, velocity spectra & energy spectrum; Wall bounded flows – Channel flow, Boundary Layer, Near wall velocity & turbulence quantities profile , Equations for Reynolds stresses & TKE balance; Introduction to Turbulence Modeling – Mixing Length Model & k-**ε** model.

Recommended Books:

1. *Turbulent Flows*, S. B. Pope, Cambridge University Press, (2003).
2. *Turbulence:* An Introduction for Scientists and Engineers: An Introduction, P. A. Davidson, Oxford university press, (2005).
3. *Turbulence:* The Legacy of A. N. Kolmogorov, Uriel Frisch, Andrei Nikolaevich Kolmogorov, Cambridge Univ. Press, 2004.

Subject Code: ME6L156 Prerequisites: None	Refrigeration Systems	L – T – P : 3 –0 – 0	Credits: 3

Reverse Carnot cycle and standard vapour compression refrigeration cycle- analysis, comparison and Ewings construction. Compressor – reciprocating, centrifugal, rotary, screw type. Volumetric efficiency and performance of single stage refrigeration system, its limitations. Multistage multi evaporator and Cascade systems. Properties of refrigerants: primary, secondary and mixtures, piping design and lubricants. Absorption refrigeration systems: LiBr-water and aqua-ammonia systems, calculations by h-x diagram. Electrolux system and solar energy applications. Steam jet refrigeration, vortex tube, thermoelectric refrigeration and Gas Cycle refrigeration. Air liquefaction cycles. Condenser and evaporators, overall heat transfer coefficient, classification, design and performance. Expansion valves: capillary tube, AEV, TEV and float value; performance and balance point. System balancing of condensing unit and evaporator.

Recommended Books:

1. *Refrigeration and Air Conditioning*, C. P. Arora, Tata McGraw-Hill Education, (2000).
2. *Refrigeration & Air Conditioning Technology*, William C. Whitman, William M. Johnson, John A. Tomczyk, Thomson publication, (2005).
3. *Refrigeration Systems and Applications*, Ibrahim Dincer, Mehmet Kanoglu, Wiley publication, 2003.

Subject Code: ME6L157 Prerequisites: None	Transport Phenomenon in Material Processing	L – T – P : 3 –0 – 0	Credits: 3

Transport Phenomena Fundamentals: Definitions and Concepts, Field Theory and Field Operations, Transport Processes and Transport Laws;Physical Laws and Governing Equations:Frame of Reference and Coordinate System, Kinematics of fluids and model philosophy, Differential and Integral Formulation and Procedures, Property Balance and Equation of Change, Equation of Continuity, Momentum Equations, Initial/Boundary Conditions, Application Examples, Convection-Diffusion Equation and Examples, Energy Equation and Examples;Transient Heat Transfer:Lumped Capacitance Method, Semi-infinite System, Example;Solidification of Metal Castings:Introduction, Analysis and Modeling of Metal Castings, Solidification in Sand Mold, Analysis and Modeling of Metal Melting, Melt Efficiency, Stefan-Neumann Problem, Drag Induced Melt Removal;Fluid Flow and Heat Transfer in a Porous Medium:Introduction, Macroscopic Model for a Porous Medium, Darcy's Equation and Permeability, Fluid Flow and Heat Transport Governing Equations in a Porous Medium; Rheology of Non-Newtonian Fluids:Material Functions, Constitutive Equations, Linear Viscoelastic Fluids.

Recommended Books:

1. *Transport Phenomena* by R. B. Bird, W. E. Stewart and E. N. Lightfoot, Wiley (2nd Edition).
2. *Transport Phenomena* by W. J. Beek, K. M. K. Muttzall and J. W. Van Heuven, Wiley (2nd Edition).
3. *Fundamentals of Fluid Mechanics* by Bruce R. Munson, Donald F. Young and Theodore H. Okiishi, Wiley (5th Edition)
4. *Heat Conduction* by M. N. Ozisik, Academic Press.

Subject Code: ME6L158	Boiling and Condensation	L – T – P : 3 –0 – 0	Credits: 3

Pool boiling: Nukiyama Experiment, theory of vapour bubble formation, Mechanism of CHF, various models and correlations. Flow Boiling, Homogeneous, and hetrogeneous models, Boiling enhancement techniques. Heat Pipes. Design of boilers, Film and dropwise condensation. Nusselt's analysis of laminar film condensaion on vertical flat plate, single horizontal tube and vertical array of tubes. Laminar-wavy and turbulent film condensation. Film condensation inside horizontal tubes, condensation enhancement techniques, design of condensers, special topics: Computer simulation of boiling.

Recommended Books:

1. *Boiling, condensation, and gas-liquid flow*, P. B. Whalley, Clarendon Press, (1987).
2. *Convective Boiling and Condensation*, John G. Collier, John R. Thome, Oxford Science Publications.

Subject Code: ME6L159 Prerequisites: None	Heat and Mass Transfer in Biological Systems	L – T – P : 3 –0 – 0	Credits: 3

Introduction to Biological Systems: Human body – Physiological aspects – Biothermofluidics: Renal System, Blood Circulation and Lungs – Heat Transfer and Temperature Distribution in the Human body – Mass, energy, and flow transport in biosystems and biotechnology – Biothermology: Major Challenges.

Thermal control: Cell – Cellular energy production – Energetics of Cell Growth and Division – Energetics of Body Metabolism – Body Temperature – Temperature Regulation – Pathologic Variations in Body Temperature.

Heat transfer modeling: A Bioheat Equation – The PennesBioheat Equation – Wulff Continuum Model – The Klinger Continuum Model – The Continuum Model by Chen and Holmes (1980) – Counter-current Heat Transfer: The Mitchel and Myers model – Model of Keller and Seiler – Weinbaum-Jiji Bioheat Transfer Models – Rhythms and Hemodynamic Parameters – porous medium approach to tissue and blood flow through capillaries.

Mass transfer modeling: mass diffusion in tissues – porous medium approach to bio mass transfer – lungs – Respiratory System – Alveolar Gas Transport – Lung Diffusing Capacity – Modeling Alveolar Gas Transport – Microscopic – macroscopic – unification – introduction to nephrology.

Applications: Extreme temperatures – Biothermal Cooling – freezing and thawing – Cryosurgery – Biothermal Heating – Radiofrequency thermotherapy – Thermal injury – modeling – lasers and tissue heating – Cell Surgery – Modeling of specific human body functions – measurement of thermophysical properties – transient bioheat equation modelling laser surgery in eye.

Recommended Books:

1. *Biomedical applications of heat and mass transfer*, R. C. Seagrave, Iowa State University Press,(1971).

Subject Code: ME6L160 Prerequisites: None	Microfluidics	L – T – P : 3 –0 – 0	Credits: 3

Introduction: Fundamentals of kinetic theory-molecular models, micro and macroscopic properties, binary collisions, distribution functions, Boltzmann equation and Maxwellian distribution functions, continuum hypothesis and deviations from the same, scaling laws for micro-domains, Microscale gas flows: Wall slip effects and accommodation coefficients, flow and heat transfer analysis of microscaleCouette flows, Pressure driven gas micro-flows with wall slip effects, heat transfer in micro-Poiseuille flows, effects of compressibility, introductory concepts on gas flows in transitional and free molecular regimes, some representative applications of micro-scale gas flows in accelerometers, micro-propulsion and micro-nozzles, Microscale liquid flows: Pressure driven liquid microflow, apparent slip effects, physics of near-wall microscale liquid flows, capillary flows, electro-kinetically driven liquid micro-flows and electric double layer (EDL) effects, concepts of electroosmosis, electrophoresis and dielectro-phoresis, analysis of hydro-dynamically and thermally fully developed electro-osmotic flows, ac electro-osmosis, an introduction to fluid dynamics over nano scales (nanofluidics), concepts of nano-fluids and their augmented transport characteristics, An introduction to bio-microfluidics and some illustrative applications (drug delivery, DNA hybridization, leuokocyte rolling etc.), An introduction to special computational modelling of micro-flows: MD and DSMC methods.

Recommended Books:

1. *Fundamentals and Applications of Microfluidics*, Nam-Trung Nguyen, Steven T. Wereley, Artech House (2002).
2. *Theoretical Microfluidics*, HenrikBruus, Oxford University Press, (2008).
3. Nguyen, N. T., Werely, S. T., *Fundamentals and applications of Microfluidics*, Artech house Inc., 2002.
4. Bruus, H., *Theoretical Microfluidics*, Oxford University Press Inc., 2008.
5. Madou, M. J., *Fundamentals of Microfabrication*, CRC press, 2002.
6. Tabeling, P., *Introduction to microfluidics*, Oxford University Press Inc., 2005.
7. Kirby, B.J., *Micro- and Nanoscale Fluid Mechanics: Transport in Microfluidic Devices*, Cambridge University Press, 2010.
8. Colin, S., *Microfluidics*, John Wiley & Sons, 2009.

Subject Code: ME6L161 Prerequisites: None	Experimental Fluid Mechanics	L – T – P : 3 –1 – 0	Credits: 4

Introduction to experimental data collection and analysis, in particular as they pertain to fluid flows. Covers computer-based experimental control, analog and digital data acquisition, discrete sampling theory, digital signal processing, uncertainty analysis. Also covers: LabView& Simulink, Analog Transducers, Hot-wire/Hot-Film & Cold-Wire/Cold-Film Anemomentry, Acoustic and Laser Doppler velocimetry, Full-field (2-D) quantitative imaging techniques like PIV& PLIF; Particle based techniques – PTV & PDPA, Optical Density Based Techniques – Schlieren, Shadograph.

Recommended Books:

1. *Measurement in Fluid Mechanics*, Stavros Tavoularis, Cambridge Univ. Press, (2005).
2. *Recent Developments in Theoretical and Experimental Fluid Mechanics: Compressible and Incompressible Flows,* U. Müller, K. G. Roesner, B. Schmidt, Springer London,(2011).

Subject Code: ME6L162 Prerequisites: None	Nuclear Power, Generation & Safety	L – T – P : 3 –0 – 0	Credits: 3

Basic concepts of reactor physics, radioactivity, Neutron Scattering, Thermal & fast reactors, Nuclear cross sections, Neutron flux & reaction rates, Moderator criteria, Reactor core design, Conversion & breeding. Types of reactors, Characteristics of boiling water, pressurized water, pressurized heavy water, gas cooled and liquid metal cooled reactors. Future trends in reactor design and operation. Thermal-hydraulics of reactors, Heavy water management, Containment system for nuclear reactor, Reactor safety radiation shields, Waste management, Indian nuclear power programme.

Recommended Books:

1. Lamarsh, J.R. and Baratta, A.J., "*Introduction to Nuclear Engineering*", 3rd Edition, Prentice Hall, 2001.
2. Duderstadt, J.J. and Hamilton, L.J., "*Nuclear Reactor Analysis*", John Wiley and Sons, 1976.
3. Glasstone, S. and Sesonske, A, "*Nuclear Reactor Engineering Vol-1: Reactor Design Basics*", 4th Edition, Elsevier, 1996.
4. Glasstone, S. and Sesonske, A, "*Nuclear Reactor Engineering Vol-2: Reactor System Engineering*", 4th Edition, Elsevier, 1996.

Subject Code: ME6L163 Prerequisites: None	High Performance Computing in Thermo-Fluids Applications	L – T – P : 3 –0 – 0	Credits: 3

Parallel computing for HPC:Historical perspective and introduction to High Performance Computing, Massively parallel computing using MPI and OpenMP, Different architectures and parallel programming models, Domain decomposition method, Message passing libraries, Communication between processors, Solution of hyperbolic and elliptic model problems using MPI, HPC Benchmarking & Performance analysis.
Construction of high accuracy & high efficiency methods for HPC:Spectral methods, Compact schemes and spectral optimization, Dispersion relation preservation property (DRP) and analysis of DRP methods, Conjugate gradient methods, Numerical filters.
Grid generation methodologies for HPC applications in complex flows:Generalized coordinate transformation and grid generation methods, Chimera grid and role of interpolation error.
Some examples of HPC formulations for complex fluid flow: Bypass Transition, KH Instability, Seperated flows past bluff bodies, Decaying Isotropic Turbulence in a periodic box

Recommended Books:

1. *High accuracy computing methods: fluid flows and wave phenomena*, Tapan K. Sengupta, Cambridge Univ. Press, USA, (2013).
2. *Computational Fluid Dynamics (Vol. 1-3)*, Klaus A. Hoffmann and Steve T. Chiang, Engineering Education System; 4th edition (2000).
3. *Vectors, Tensors and the Basic Equations of Fluid Mechanics*, Rutherford Aris, Dover Publications (1990).

Subject Code: ME6L164 Prerequisites: None	Numerical Methods in Radiative Heat Transfer	L – T – P : 3 –0 – 0	Credits: 3

Fundamentals of thermal radiation; Radiative transfer without participating media; Radiative transfer with participating media; Governing equations in radiative transfer analysis with participating media; Methods for solving radiative transfer problems - analytic method, Monte Carlo method, zonal method, flux method, P-N approximation, discrete ordinate method, finite element method, discrete transfer method, finite volume method, collapsed dimension method. Application of numerical methods for solving conjugate radiation, conduction and/or convection problems in 1-D and 2-D Cartesian and axi-symmetric geometry.

<u>Recommended Books:</u>

1. *Thermal Radiation Heat Transfer*, R. Siegel and J.R.Howell, Taylor & Francis, 2002.
2. *Radiation Heat Transfer*, E.M.Sparrow and R.D.Cess, Wadsworth, 1966.
3. *Radiative Transfer*, H.C.Hottel and A.F.Saroffim, McGraw hill, 1967.
4. *Radiative Heat Transfer*, M.F.Modest, McGraw Hill, 2003.

Subject Code: ME6L165 Prerequisites: None	Principles of Turbo Machinery	L – T – P : 3 –0 – 0	Credits: 3

Classification Specific work, Representation of specific work in T-S and H-S diagrams, Internal and external losses, Euler's equation of turbo-machinery, Ideal and actual velocity triangles, Slip and its estimation, Impulse and reaction type machines, Degree of reaction, Effect of outlet blade angle on blade shape, Model laws, specific speed and shape number, Special features of hydro, steam and gas turbines, Performance characteristics of turbo machines, Cavitation, Surge and Stall, Thin aerofoil theory Cascade mechanics.

Recommended Books:

1. Fluid Dynamics and Heat Transfer of Turbo machinery by B. Lakshminarayana, John Wiley, N.Y.
2. *Principles of Turbomachinery in Air-Breathing Engines*, Erian A. Baskharone, Cambridge University Press.

Subject Code: ME6L166 Prerequisites: None	Geophysical Fluid Dynamics	L – T – P : 3 –0 – 0	Credits: 3

Introduction to geophysical fluid dynamics – rotation & stratification. Coriolis force. Equations of fluid motion (bulk flow & budgets, governing equations). Diffusion & transport process in oceans & atmosphere. Geostrophic flows &vorticity Dynamics. Ekman layer, barotropic waves & instability. Stratification & its effects, internal waves. Turbulence in stratified fluids. Introduction to stratified rotating flows – Quasi-Geostrophic dynamics, instabilities & geostrophic turbulence.

Recommended Books:

1. *Atmosphere-Ocean Dynamics*, Adrian Gill, Academic Press, (1982).
2. *Atmospheric and Oceanic Fluid Dynamics*, GeoffreyVallis, Cambridge University Press, (2006).
3. *An Introduction to Dynamical Meteorology*, James Holton, 4th Ed., Academic Press, (2004).
4. *Geophysical Fluid Dynamics*, Joseph Pedlosky,SpringerVerlag.
5. *Lectures on Geophysical Fluid Dynamics,* Rick Salmon, Oxford University Press.
6. *Introduction to Circulating Atmospheres,* Ian James, Cambridge University Press, (1994).
7. *Waves in Fluids, James Lighthill*, Cambridge University Press, (1978).

Curriculum for M.Tech (Structural Engineering)

Subject Name	Code	L-T-P	Credit	Contact Hour
SEMESTER - I				
Dynamics of Structures	CE6L301	3-1-0	4	4
Advanced Structural Analysis	CE6L302	3-1-0	4	4
Elective-I		3-1-0/ 3-0-0	4/3	4/3
Elective-II		3-1-0/ 3-0-0	4/3	4/3
Elective-III		3-1-0	4	4
Advanced Structural Laboratory	CE6P301	0-0-3	2	3
Seminar I	CE6S001	0-0-0	2	-
	Total :	**15-1-3**	**24-22**	**23-21**
SEMESTER - II				
Advanced Solid Mechanics	CE6L303	3-1-0	4	4
Advanced Concrete Technology	CE6L304	3-0-0	3	3
Elective - IV		3-1-0/ 3-0-0	4/3	4/3
Elective - V		3-1-0	4	4
Computational Laboratory	CE6P302	0-0-3	2	3
Design of Special Structures	CE6P303	0-0-6	4	3
Seminar II	CE6S002	0-0-0	2	0
	Total :	**15-1-6**	**23-22**	**21-20**
SEMESTER - III				
Thesis : Part-I (CE)	CE6D001	0-0-0	16	-
Review Paper (CE)	CE6D002	0-0-0	04	-
	Total :	0-0-0	**20**	**-**
SEMESTER – IV				
Thesis : Part-II (CE)	CE6D003	0-0-0	16	
Review Paper (CE)	CE6D004	0-0-0	04	
	Total :	0-0-0	**20**	

Total Credit : 87-82

List of Elective Subjects (Structural Engineering)

Subject Name	Code	L-T-P	Credit	Contact Hour
Elective – I to V				
Theory of Plates & Shells	CE6L305	3-1-0	4	4
Seismic Design of Structures	CE6L306	3-1-0	4	4
Bridge Engineering	CE6L307	3-0-0	3	3
Infrastructure Maintenance and Rehabilitation	CE6L308	3-0-0	3	3
Modern Construction Materials	CE6L309	3-0-0	3	3
Advanced construction Techniques	CE6L310	3-0-0	3	3
Construction Project Management	CE6L311	3-0-0	3	3
Advanced Design of RC Structures	CE6L312	3-1-0	4	4
Mathematical Methods	MA6L001	3-1-0	4	4
Advanced Techniques in Operation Research	MA6L002	3-1-0	4	4

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

Subject Code: CE6L301	Name: Dynamics of Structures	L-T-P: 3-1-0	Credit: 4

Prerequisite: None

Single-degree-freedom systems: undamped and damped free vibration; Response to harmonic and periodic excitations; Response to non-periodic excitations; Numerical evaluation of dynamic response; Generalized single-degree-freedom systems. Elements of analytical dynamics: The principle of virtual work; Principle of D Alembert; Hamiltons principle; Lagrange's equation. Multi-degree-freedom systems: Equation of motion; undamped free vibration; Interpretation of modal orthogonality; Decomposition of response in terms of modal co-ordinates; Modal analysis; Response to external excitations; Rayleigh s quotient and its properties; Systems with proportional damping; Systems with arbitrary viscous damping. Distributed parameter systems: axial and bending vibration of beams; orthogonality of modes; Response to external excitations; Rayleigh s quotient; Approximate methods. Earthquake response of linear systems: Earthquake excitations; Equations of motion; Response spectrum concept; Response spectrum characteristics; Design response spectrum; Modal analysis; Displacement response; Element forces; Modal response contribution; Response history analysis; Response spectrum analysis. Introduction to Random Vibration; Stationary and non-stationery random processes; Ergodic random processes. Narrow band and wide band random processes; Properties of Autocorrelation and Power spectral density functions; Response to arbitrary excitation by Fourier transform method.

Books:

1. Chopra, A.K., Dynamics of Structures: *Theory and Applications to Earthquake Engineering*, Prentice Hall/Pearson Education
2. Clough, R.W. and Penzien, J., *Dynamics of structures*, McGraw Hill, Inc., New York
3. Craig, R.R., Structural Dynamics: *An Introduction to Computer Methods*, Wiley New York
4. Meriovitch, L., *Elements of vibration analysis*, McGraw-Hill
5. Rao, S.S., *Mechanical Vibrations*, Pearson
6. Thomson, W.T., *Theory of Vibration with Application*, CRC Press
7. Newland, D.E., *An Introduction to Random Vibrations*, Spectral and Wavelet Analysis, Courier Dover Publications

Subject Code: CE6L302	Name: Advanced Structural Analysis	L-T-P: 3-1-0	Credit: 4

Prerequisite: None

Basics of structural analysis: static & dynamic loading, linear & nonlinear structural behaviour, geometric & material nonlinearity, hysteretic behaviour; Classical linear analysis of frames and trusses: displacement method, slope deflection equations & matrix displacement method, effect of foundation settlement and temperature; Geometric nonlinear analysis of frames and trusses: displacement method, nonlinear slope-deflection equations & nonlinear behaviour, linearized iterative matrix displacement method, geometric stiffness matrix, tangent stiffness matrix, P-Δ effect, buckling of frames, tension structures; Material nonlinear analysis of frames: basics of plasticity, distributed plasticity & lumped plasticity, incremental nonlinear analysis.

Books:

1. Thandavamoorthy, T.S., *Structural Analysis*, Oxford University Press
2. Weaver, W. and Gere, J.M., *Matrix Analysis of Framed Structures*, CBS Publisher
3. Wang, C.K., *Intermediate Structural Analysis*, McGraw Hill
4. Kanchi, M.B., *Matrix Methods of Structural Analysis*, Wiley Eastern Limited
5. Hibbeler, R.C., *Structural Analysis*, Pearson

Subject Code: CE6P301	Name: Advanced Structural Laboratory	L-T-P: 0-0-3	Credit: 2
Prerequisite: None Vibration analysis of SDOF system, Modal study, Natural Period determination using free and forced vibration, Stress-strain behaviour of MS steel and high strength steel bars. 1g shake table test.			

Subject Code: CE6L303	Name: Advanced Solid Mechanics	L-T-P: 3-1-0	Credit:4

Prerequisite: None

Introduction to elasticity theory; Stress analysis: forces and moments, theory of stress, principal stresses and stress invariants, compatibility equations, equilibrium equations; Strain: deformation and velocity gradients, Lagrangian and Eulerian description and finite strain, small deformation theory, principal strains and strain invariants, compatibility conditions; Fundamental physical principles: conservation of mass, linear momentum, angular momentum, and energy, second law of thermodynamics; Constitutive theory: St. Venant's principal, linear elasticity and generalized Hook's law, Stokesian and Newtonian fluids, Navier-Stokes equations, Bernoulli equation, linear viscoelasticity, yield criteria; Applications: Airy stress function, two-dimensional elastostatics problems, torsion.

Books:

1. Srinath, L.S., *Advanced Mechanics of Solids*, Tata McGraw Hill
2. Timoshenko, S., *Strength of Materials*, CBS
3. Bruhns, O.T., *Advanced Mechanics of Solids*, Springer
4. Timoshenko, S., and Goodier, J.N., *Theory of Elasticity*, Tata McGraw Hill
5. Chakrabarty, J. *Theory of Plasticity* , Butterworth-Heinemann

Subject Code: CE6L304	Name: Advanced Concrete Technology	L-T-P: 3-0-0	Credit:3

Prerequisite: None

Fundamental of concrete - constituents, proportioning, mixing, transportation, placing and curing., Properties of fresh and hardened concrete., Quality control in concrete construction, Concrete mix design, Durability of concrete - alkali aggregate reaction, reinforcement corrosion, freezing and thawing, etc., Special concretes - high strength, low heat of hydration, high early strength, self-compacting, etc., Construction methods – shot-crete, roller compacted concrete, etc., Reinforcing materials - epoxy coated bars, fibre-reinforced plastics, Introduction to 'maintenance' of concrete structures - use of non-destructive testing, evaluation criteria.

Books:

1. Gambhir, M,L., *Concrete Technology*, Tata Mcgraw Hill
2. Neville, A.M. and Brooks, J.J., *Concrete Technology*, Neville, ELBS/Longman
3. Neville, A.M., *Properties of Concrete*, ELBS/Longman
4. Ghose, D.N., *Construction Materials*, Tata Mcgraw Hill
5. Mehta, P.K. and Montiero, P.M.J., *Concrete Material, Microstructure and Properties*, Tata Mcgraw Hill

Subject Code: CE6P302	Name: Computational Laboratory	L-T-P: 0-0-3	Credit: 2
Prerequisite: None Finite element modelling of structures, Seismic analysis of structures, Pushover analysis, seismic ground response analysis.			

Subject Code: CE6P303	Name: Design of Special Structures	L-T-P: 0-0-6	Credit: 4

Prerequisite: Advanced Design of RC Structure

Design of overhead, underground, ground supported water tanks, dams; Design of industrial structures; Design of bunkers and silos; Design of special RC elements: Design of slender columns, RC walls, ordinary and shear walls, Corbels, Deep beams, RCC chimney; Design of simple cylindrical shell roof by beam theory.

Books:

1. Fintel, M., *Handbook of Concrete Engineering*, CBS Publishers Delhi
2. Naeim, F., *Handbook on Seismic Analysis and Design of Structures*, Kluwer Academic Publisher
3. IS 4326, *Earthquake Resistant Design and Construction of Buildings - Code of Practice*, Bureau of Indian Standard; New Delhi
4. Jain, S.K. and Jaiswal, O.R., *Guidelines for Seismic Design of Liquid Storage Tanks*, NICEE, IIT Kanpur

Subject Code: CE6L305	Name: Theory of Plates & Shells	L-T-P: 3-1-0	Credit: 4

Prerequisite: None

Pure bending of plates; Symmetric bending of circular plates; Small deflection of laterally loaded plates; Rectangular plates with various edge conditions; Continuous rectangular plates; Plates of various shapes; Shells as space enclosure, geometry, classification, principal and Gauss curvature; General theory of thin elastic shells; Shallow and high rise shells; Circular long and short cylindrical shells, beam-arch approximation for long shells; Shells of double curvature, surfaces of revolution and translation; Circular, elliptic and hyperbolic paraboloids, conoids and funicular shells - membrane and approximate bending theories; Closed form and numerical methods of analysis of synclastic and anticlastic shells.

Books:

1. Timoshenko, S.L., *Theory of Plates and Shells*, McGraw Hill
2. Reddy, J.N., *Theory and Analysis of Elastic Plates and Shells*, Taylor & Francis
3. Ugural, A.C., *Stresses in plates and shells*, WCB/McGraw Hill
4. Ventsel, E. and Krauthammer, T., *Thin Plates and Shells: Theory: Analysis, and Applications*, CRC Press

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

Prerequisite: None

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.

Books:

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

Subject Code: CE6L307	Name: Bridge Engineering	L-T-P: 3-0-0	Credit: 3

Pre-requisite(s): None

Introduction, historical review, engineering and aesthetic requirements in bridge design, introduction to bridge codes of practice, economic evaluation of bridge projects, site investigation and planning, hydraulic calculations for bridges, bridge foundations-open, pile, well and caisson, Piers, abutments and approach structures, superstructures-analysis and design of right, skew and curved slabs, Girder bridges-Types, load distribution, design, orthotropic plate analysis of bridge decks, introduction to long span bridges- cantilever, arch, cable stayed and suspension bridges.

Books:

1. Victor, D.J., *Essentials of bridge engineering*, Oxford & IBH Publishing
2. Ponnuswamy, S., *Bridge Engineering*, Tata Mcgraw Hill
3. Jagadeesh, T.R. and Jayaram, *M.A., Design of Bridge Structures*, Phi Learning
4. Bindra, S.P., *Principles and Practice of Bridge Engineering*, Dhanpat Rai Publications

Subject Code: CE6L308	Name: Infrastructure Maintenance and Rehabilitation	L-T-P: 3-0-0	Credit: 3

Pre-requisite(s): None

Quality assurance for concrete construction as built concrete properties strength, permeability, thermal properties and cracking. Influence on servicebility and durability:–Effects due to climate, temperature, chemicals, wear and erosion, Design and construction errors, corrosion mechanism, Effects of cover thickness and cracking, methods of corrosion protection, corrosion inhibitors, corrosion resistant steels, coatings, cathodic protection; Maintenance and repair strategies:– Definitions: Maintenance, repair and rehabilitation, Facets of Maintenance importance of Maintenance, Preventive measures on various aspects Inspection, Assessment procedure for evaluating a damaged structure, causes of deterioration , testing techniques; Materials:-Materials for Repair – Special Mortar and Concretes, Concrete Chemicals, Special Cements and High Grade Concrete, Expansive Cement, Polymer Concrete, Sulphur Infiltrated Concrete, Ferro Cement, Fiber Reinforced Concrete, and Admixtures of latest origin. Techniques for Repair-Surface Repair – Material Selection – Surface Preparation - Rust Eliminators and Polymers Coating For Rebar During Repair – Repair Of Cracks In Concrete and Masonry-Methods of Repair - Epoxy Injection, Mortar Repair For Cracks - Guniting and Shotcreting - Waterproofing Of Concrete Roofs; Strengthening Measures - Flexural Strengthening, Beam Shear Capacity Strengthening, Column Strengthening, Shoring, Under Pinning and Jacketing. Demolition of Buildings – Introduction, Planning, Precautions and protective measures in demolition work, Sequence of operations, demolition of structural elements.

Books:

1. Campbell-Allen, D. and Roper, H., *Concrete Structures, Materials, Maintenance and Repair*, Longman Scientific and Technical, UK
2. Allen, R.T and Edwards, S.C, *Repair of Concrete Structures*, Blakie and Sons, UK
3. Santhakumar A.R., *Concrete Technology*, Oxford University Press
4. Dayaratnam, P. and Rao, R., *Maintenance and Durability of Concrete Structures*, University Press, India
5. CPWD, *Handbook on Repairs and Rehabilitation of RCC Buildings*.

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

Prerequisite: None

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.

Books:

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

Subject Code: CE6L310	Name: Advanced construction Techniques	L-T-P: 3-0-0	Credit: 3

Prerequisite: None

Sub Structure Construction -Box jacking, Pipe Jacking, Under Water Construction of diaphragm walls and Basement, Tunnelling Techniques, Piling Techniques, Driving Well and Caisson Sinking, Cofferdam, Cable Anchoring and Grouting, Driving Diaphragm Walls, Sheet Piles-Laying Operations For Built Up Offshore System-Shoring For Deep Cutting-Large Reservoir Construction with membranes and Earth system-well points-Dewatering and stand by Plant equipment for underground open excavation ; Super Structure Construction- Vacuum dewatering of concrete flooring-Concrete paving technology, Techniques of construction for continuous concreting operation in Tall buildings of various shapes and Varying sections, Launching Techniques-Suspended formwork-erection techniques of tall structures, Large span structures-Launching techniques for heavy decks- in-situ pre-stressing in high rise structures, aerial transporting ,handling, erecting light weight components on tall structures-erection of lattice towers and rigging of transmission line structures; Construction Sequences- in cooling towers, Silos Chimney, Sky scrapers, bow string bridges, cable stayed bridges; Launching and pushing of box decks, support structure for heavy Equipment and conveyor and machinery in heavy industries, erection of articulated structures, braced domes and space decks; Repair Construction: Mud Jacking Grout through Slab Foundation, Micro Piling for Strengthening Floor and Shallow Profile, Pipeline Laying, Protecting Sheet Piles, Sub Grade Water Proofing, Underpinning Advanced Techniques and Sequence in Demolition and Dismantling.

Books:

1. Brown, R., *Practical foundation engineering hand book*, McGraw Hill Publications
2. Powers, J.P., Corwin, A.B., Schmall, P.C. and Kaeck, W.E., *Construction Dewatering: New Methods and Applications*, John Wiley and Sons
3. Irvine, J., *Advanced Construction Techniques*, California Rocketry
4. *National Building Code of India*, Part-IV and VII – 2006
5. Mohan, R. and Jaisingh. M.P., *Advances in Building Materials and Construction*, CBRI Roorkee
6. *Hand Book on concrete Mixes based on Indian standards*, SP-23 (S&T)

Subject Code: CE6L311	Name: Construction Project Management	L-T-P: 3-0-0	Credit: 3

Prerequisite: None

Principles of Project Management, Project Planning, Introduction to scheduling - work/project break down structures, Bar-charts; Principles of application of CPM and PERT; Precedence Method; Updating; Time - cost trade-offs, Resource constrained scheduling; Resource leveling Project control; Performance Measurement, Earned value; Multiple Construction Projects; Other network techniques; Project Management Software Packages.

Books:

1. Jha, N.K., *Construction Project Management*, Pearson Education India
2. Williams, T., *Construction Management*, Pearson Education India
3. Chitkara, K., *Construction Project Management Techniques And Practice*, Tata McGraw Hill
4. Purifoy, R., Schexnayder, C.J., Shapira, A. and Schmitt, R., *Construction Planning, equipment and Methods*, McGraw Hill, Tokyo, Japan

Subject Code: CE6L312	Name: Advanced Design of RC Structure	L-T-P: 3-1-0	Credit: 4

Prerequisite: None

Design of overhead, underground, ground supported water tanks, dams; Design of industrial structures; Design of bunkers and silos, Airy's theory, Janssen's theory; Design of special RC elements: Design of slender columns, RC walls, ordinary and shear walls, Corbels, Deep beams, RCC chimney; Introduction to shell and folded plate roofs, their forms and structural behaviour. Design of simple cylindrical shell roof by beam theory, Yield line analysis of slabs by virtual work, Yield line analysis by equilibrium methods.

Books:

1. Varghese , P.C., *Advanced Reinforced Concrete Design*, PHI Learning
2. Naeim, F., *Handbook on Seismic Analysis and Design of Structures*, Kluwer Academic Publisher
3. IS 4326, *Earthquake Resistant Design and Construction of Buildings - Code of Practice*, Bureau of Indian Standard; New Delhi
4. Jain, S.K. and Jaiswal, O.R., *Guidelines for Seismic Design of Liquid Storage Tanks*, NICEE, IIT Kanpur
5. Fintel, M., *Handbook of Concrete Engineering*, CBS Publishers Delhi

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

Prerequisite: None

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.

Books:

1. Grawel, B.S. *Numerical Methods*, Khanna Publishers
2. Jain, M.K., Iyengar, S.R.K. and Jain, R.K. *Numerical Methods-problem and solutions*, Wiley Eastern Limited
3. Ross, S. *Introduction to Probability Models*, Wiley India
4. Gun, A.M., Gupta, M.K. and Gupta, B.S., *Fundamentals of Statistics*
5. Hayter, A.J., *Probability and Statistics*, Duxbury
6. Scarborough, J.B., *Numerical mathematical analysis*, Oxford & IBH Publishing Co.Pvt.
7. Hamming, R.W., *Numerical Methods for Scientist and Engineers*, McGraw Hill
8. Mathews, J.H. and Fink, K.D., *Numerical Methods using MATLAB*, Pearson Education.

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

Prerequisite: None

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 probabilitistic 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.

Books:

1. Rao, S.S., *Engineering Optimization Theory and Practices*, John Wiley and Sons
2. Ehrgott, M., *Multi-criteria Optimization*, Springer
3. Miettien, K.M., *Non-linear multi-objective optimization*, Kluwers International Series
4. Deb, K., *Multi-Objective Optimization using Evolutionary Algorithms*, John Wiley & Sons

Curriculum for M.Tech (Transportation Engineering)

Subject Name	Code	L-T-P	Credit	Contact Hour
SEMESTER - I				
Urban Transportation Planning	CE6L401	3-1-0	4	4
Pavement Material Characterization	CE6L403	3-1-0	4	4
Elective-I	XXXXXX	3-1-0	4	4
Elective -II	XXXXXX	3-1-0/ 3-0-0	4/3	4/3
Elective-III	XXXXXX	3-0-0	3	3
Pavement Materials Laboratory	CE6P401	0-0-3	2	3
Seminar I	CE6S001	0-0-0	2	0
	Total :	**15-3-3**	**22-23**	**22-23**
SEMESTER - II				
Fundamentals of Traffic Flow Theory	CE6L402	3-1-0	4	4
Analysis and Design of Pavements	CE 6L404	3-1-0	4	4
Elective-IV	XXXXXX	3-1-0	4	4
Elective-V	XXXXXX	3-1-0/ 3-0-0	4/3	4/3
Traffic Engineering Studies	CE6P402	0-0-3	2	2
Transportation Systems Planning Studio	CE6P404	0-0-3	2	3
Seminar II	CE6S002	0-0-0	2	0
	Total :	**12-3-6**	**21-22**	**19-20**
SEMESTER - III				
Thesis : Part-I	CE6D001	0-0-0	16	0
Review Paper	CE6D002	0-0-0	04	0
	Total :	0-0-0	**20**	**0**
SEMESTER – IV				
Thesis : Part-II	CE6D003	0-0-0	16	0
Review Paper	CE6D004	0-0-0	04	0
	Total :	0-0-0	**20**	**0**

Total Credit : 83/85

List of Elective Subjects (Transportation Engineering)

Subject Name	Code	L-T-P	Credit	Contact Hour
Elective – I to V				
Mathematical Methods-I	MA6L001	3-1-0	4	
Advanced Techniques in Operation Research	MA6L002	3-1-0	4	
Design of Transportation Facilities and Safety	CE6L451	3-1-0	4	
Economic Evaluation of Transportation System	CE6L452	3-0-0	3	
Analysis of Transportation Systems	CE6L453	3-0-0	3	
Pavement Evaluation and Management	CE6L454	3-1-0	4	
Airport Planning and Design	CE6L455	3-0-0	3	
Public Transportation System	CE6L456	3-0-0	3	

NB: Any other subjects of same level floated by any other specialisations of School of Infrastructure and/or any other Schools can also be taken as an elective, as suggested by faculty

COMPULSORY SUBJECTS			
Subject Code: CE6L403	**Subject Name:** Pavement Material Characterization	**L-T-P: 3-1-0**	**Credit: 04**
Pre-requisite(s): None			

Subgrade Soil: Classification, desirable properties, determination of soil strength characteristics, resilient modulus, Road aggregates: classification, properties of aggregates, design of aggregate gradation, Bituminous road binders: bitumen, emulsions, cut backs and modified binders, Rheology of bituminous binders, modified binders, Hot mix, Warm mix and Cold mix Bituminous constructions, Mix design: Marshall method and Superpave procedure, Visco-elastic and fatigue properties of bituminous mixtures, Requirements of paving concrete, design of mixes for recycling of bituminous and concrete pavement surfaces.

Reference Books:

1. A. T. Papagiannakis and E. A. *Masad, Pavement Design and Materials,* Wiley Publications
2. J. Read and D. Whiteoak, *The Shell Bitumen Handbook,* 5th edition, Thomas Telford Ltd
3. Asphalt Institute, *Asphalt Binder Handbook, Manual Series No. 2 (MS-26).* Asphalt Institute. Lexington, KY
4. Asphalt Institute. *Mix Design Methods for Asphalt, Manual Series No. 2 (MS-02).* Asphalt Institute. Lexington, KY
5. Rajib B. Mallick, Tahar El-Korchi *Pavement Engineering: Principles and Practice,* Second Edition, CRC Press
6. Roberts, F.L.; Kandhal, P.S.; Brown, E.R.; Lee, D.Y. and Kennedy, T.W. *Hot Mix Asphalt Materials, Mixture Design, and Construction.* National Asphalt Pavement Association Education Foundation. Lanham, MD

Subject Code: CE6L401	Subject Name: Urban Transportation Planning	L-T-P: 3-1-0	Credit: 04
Pre-requisite(s): None			

Fundamentals of transportation system planning, transportation system planning process, Characteristics of Travel and urban transportation system, Demand theory and supply theory of transportation system, Steps of urban travel demand forecasting- trip generation, trip distribution, modal split and trip assignment, basics of urban transportation network, basics of tour-based or activity-based travel demand model, land use transport model, urban mass transportation, urban goods movement, Basics of activity-based model

Reference Books:

1. L.R. Kadiyali, *Traffic Engineering and Transport Planning*
2. Williumsen and Ortuzar, *Modelling Transport*
3. Kanafani, Transp. *Demand Analysis.*
4. B.G. Hutchinson, *Principles of Urban Transport System Planning*
5. Marvin L. Manheim, *Fundamentals of Transportation Systems Analysis,* Volume 1
6. *Travel Demand Software for example TRANSCA,* CUBE

Subject Code: **CE6L402**	**Subject Name:** Fundamentals of Traffic Flow Theory	**L-T-P: 3-1-0**	**Credit: 04**
Pre-requisite(s): None			

Driver behaviour, traffic information and control systems, traffic studies- volume, speed and delay studies, elements of traffic flow theory, PCU concept, characteristics of uninterrupted traffic, mathematical theories of traffic flow (Poisson arrivals, binomial and negative binomial distributions), headway distributions, gap acceptance, critical gap estimation, queuing theory, shock wave, capacity and LOS of Uninterrupted facilities, characteristics of interrupted traffic, traffic characteristics at unsignalised intersections, queue discharge characteristics at signalised intersections, dilemma zone.

Reference Books:

1. Fred. L. Mannering, Walter P. Kilareski and Scott S. Washburn, *Principles of Highway Engineering and Traffic Analysis,* John Wiley & Sons.
2. D. R. Drew, *Traffic Flow Theory and Control,* MaGraw-Hill Book Company.
3. A. D. May*, Traffic Flow Fundamentals,* Prentice Hall.
4. Mike Slinn, Peter Guest and Paul Mathews, (2012). *Traffic Engineering design*, Taylor & Francis.
5. Roess and McShane, Roger P. Roess, Elena S. Prassas, William R. McShane, *Traffic Engineering*, Pearson.
6. L. R. Kadiyali, *Traffic Engineering and Transport Planning,* Khanna Publishers.
7. Louis J. Pignatro, *Traffic Engineering-Theory and Practice,* Prentice-Hall, Englewood Cliffs, New Jersey.
8. Khisty & Lal, *Transportation Engineering,* Prentice Hall India.
9. C. S. Papacostas and P. D. Prevedouros*, Transportation Engineering & Planning.*

Subject Code: CE 6L404	Subject Name: Analysis and Design of Pavements	L-T-P: 3-1-0	Credit: 04
Pre-requisite(s): None			

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.

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

**The examination for this course may be considered for open book examination system.*

ELECTIVE SUBJECTS			
Subject Code: **CE6L451**	**Subject Name:** Design of Transportation Facilities and Safety	**L-T-P: 3-1-0**	**Credit:04**
Pre-requisite(s): None			

Geometric design provisions for various transportation facilities, Discussion of controls governing geometric design, Route layout and selection, Elements of design - sight distances, horizontal alignment, transition curves, super elevation and side friction. Vertical alignment: - grades, crest and sag curves. Highway cross-sectional elements and their design for rural highways, urban streets and hill roads. At-grade Inter-sections - sight distance consideration and principles of design, channelisation, mini round-abouts, layout and design of round-abouts, Design of signalised intersections, capacity and LOS for signalised intersections, signal design, signal coordination, interchange design templates, entrance and exit ramps, acceleration and deceleration lanes, Bicycle and Pedestrian Facility Design; Parking Layout and Design; Terminal Layout and Design. Accident prevention through better planning, Designing for safety, Highway operation and accident counter measures, Road safety checklists, accident data analysis and its prediction models.

Reference Books:

1. *A policy on geometric design of highways and streets,* American Association of State Highway Officials.
2. *Geometric design standards for urban roads in plains (IRC:86-1983),* The Indian Roads Congress.
3. *Geometric design standards for rural (non-urban) highways (IRC:73-1980),* The Indian Roads Congress, 1980.
4. *Manual of specifications & standards for six laning of highway through public private partnership (IRC: SP: 87-2010),* The Indian Roads Congress.
5. *Manual of specifications & standards for four laning of highway through public private partnership (IRC:SP:84-2009),* The Indian Roads Congress.
6. *Hill road manual (IRC:SP:48-1998),* The Indian Roads Congress.
7. *Guidelines for expressways – Part I,* Ministry of Road Transport & Highways.
8. *Guidelines for the design of interchanges in urban areas (IRC:92-1985),* The Indian Roads Congress.
9. *Roadside design guide,* American Association of State Highway Officials.
10. *Manual of geometric design standards for Canadian roads,* Transportation Associations of Canada.
11. Pline, J.L., *Traffic Engineering Handbook,* Institute of Transportation Engineers.
12. *Manual on Uniform Traffic Control Devices,* Federal Highway Administration.
13. *Highway Capacity Manual 2010,* Transportation Research Board.
14. S.K. Khanna and C.E.G. Justo, *Highway Engineering,* Khanna Publishers, Roorkee, MXRoad Suite and manual for geometric design.

Subject Code: CE6L452	Subject Name: Economic Evaluation of Transportation System	L-T-P: 3-0-0	Credit:03
Pre-requisite(s): None			

Concept of demand, Elasticity of demand, Supply of transport, demand-supply interaction, Public Policy, Travel demand and value of time, Willingness-to-pay, valuation of user's benefit and optimal transport pricing policy, Appraisal and Economic Evaluation of Transportation Projects, Case Studies, Economic evaluation of highway projects in India, Road-users' cost study in India-Objectives and Methodology, Application of HDM Software, Behavioural aspect of transportation planning: Basics of travel behaviour analysis, stated and revealed preference data, experimental design, travel behaviour survey, binary, multinomial, nested logit model, maximum likelihood, case studies on choice modelling and estimation of value of travel attribute .

Reference Books:

1. *Studies in the economics of transportation* by Beckmann et al.
2. *Applied Transport Economics* by Stuart Cole
3. McCarthy, P. *Transportation Economics,* Blackwell Publishers
4. *Transportation Decision Making: Principles of Project Evaluation and Programming,* Wiley, by Kumares C. Sinha, Samuel Labi,
5. C. Jotin Khisty, B. Kent Lall, *Transportation Engineering: An Introduction,* Prentice Hall.
6. Indian Roads Congress, *"Manual for Road Investment Decision Model",* Special Publication 38, New Delhi.
7. Indian Roads Congress, *"Manual on Economic Analysis of Highway Projects",* Special Publication 30, New Delhi. Revised version.
8. John Hibbs, *Transport Economics & Policy: A Practical Analysis of Performance, Efficiency and Marketing Objectives* Kogan Page,.
9. *Economics of Urban Transport* by Kenneth A Small and Erik T Verhoef
10. *Principles of Traffic and Highway Engineering* by Garber and Hoel
11. *Economic Evaluation of highway projects in India*-IRC
12. *Road Users cost study in India* - IRC
13. Swait, Louviere and Hensher, *Stated Preference Methods*
14. Moshe Ben Akiva, *Discrete Choice Analysis: Theory and Analysis to Travel Demand*
15. *Applied choice analysis: A Primer* by David Hensher and Willium Greeene
16. *Discrete choice methods with simulation-* by Kenneth Train
17. *HDM Software and manuals*
18. *LIMDEP with NLOGIT Software and manual*
19. *ALOGIT Software and manual*
20. *NGENE Software*

Subject Code: **CE6L453**	**Subject Name** Analysis of Transportation Systems	**L-T-P: 3-0-0**	**Credit:03**
Pre-requisite(s): None			

Transportation demand theory, supply theory and their interaction, transportation network and its analysis, shortest-path algorithm, concept in minimization problems and convex optimization, mathematical formulation of user equilibrium (UE) and System optimal (SO) traffic assignment methods, Uniqueness of UE and SO traffic assignment, solution of UE and SO traffic assignment, traffic assignment with variable demand and link-interaction, combined distribution-assignment models, Supernetworks, Stochastic network loading and stochastic user-equilibrium, multi-class assignment, basics of optimal network geometry and non-convex functions, concept of dynamic traffic assignment, brief introduction of probabilistic modelling, Queuing theory and its applications, spatially distributed queues, application of network models, Simulation in the urban context.

Reference Books:

1. YosefSheffi, *Urban Transportation Networks*
2. *Transportation Systems Engineering: Theory and Methods* by Ennio Cascetta
3. Marvin L. Manheim, *Fundamentals Of Transportation Systems Analysis, Volume 1*
4. *Urban travel demand modelling* by Norbert Oppenheim
5. *Urban Operations Research* by Larson and Odoni
6. Ran, B., and Boyce, D. E., *Modeling Dynamic Transportation Network - An Intelligent Transportation System Oriented Approach,* Springer-Verlag, Heidelberg
7. *TRANSCAD and TransModeller,* VISSIM and VISSUM

Subject Code: **CE6L454**	**Subject Name** Pavement Evaluation and Management	**L-T-P: 3-1-0**	**Credit:04**
Pre-requisite(s): None			

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

Reference Books:

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

Subject Code: **CE6L455**	**Subject Name** Airport Planning and Design	**L-T-P: 3-0-0**	**Credit:03**
Pre-requisite(s): None			

Air transport and its characteristics, Capacity and configuration, Runway and Taxi way design, Design, maintenance and rehabilitation of airfield pavements, terminal area lay-out, air traffic control, Grading and drainage, Environmental guidelines for airport projects, air-traffic demand estimation.

Reference Books:

1. Khanna,S. K., Arora A. K. and Jain S. S., *Airport Planning and Design,* Nem Chand & Bros.
2. Ashford, N. and Wright, P.H., *Airport Engineering,* Third ed, John Wiley & Sons
3. Robert Horonjeff, Francis X. McKelvey, William J. Sproule and Seth B. Young, *Planning and Design of Airports,* Fifth Ed., McGraw Hill Pub.

Subject Code: **CE6L456**	**Subject Name** Public Transportation System	**L-T-P: 3-0-0**	**Credit:03**
Pre-requisite(s): None			

Urban Passenger Transport Modes Classifications, Role of Mass Transportation System, Transit Modes and Characteristics, System Performance, Capacity, Quality of Service, efficiency and utilization, trip makers' perception analysis to various travel attributes, Willingness-to-pay estimation, demand analysis and user's benefit policy issue with reference to public transportation service improvement, optimal transport pricing policy, planning Issues, Route Determination, Network Design, Service Policy and Schedule development, Life Cycle cost in public transportation, Scheduling, Priority Measures and their Implementations, Issues and Challenges related to development of Mass Transportation System, Para-transits

Reference Books:

1. *Public Transit Planning and Operation: Theory, Modelling and Practice* by Avishai Ceder
2. *Urban Transit Systems and Technology* by Vukan R. Vuchik.
3. *Urban Transit: Operations, Planning and Economics* by Vukan R. Vuchik
4. *Studies in the economics of transportation* by Beckmann et al.
5. *Applied choice analysis: A Primer* by David Hensher and Willium Greeene
6. *Transportation Decision Making: Principles of Project Evaluation and Programming, Wiley, 2007* by Kumares C. Sinha, Samuel Labi
7. *Fundamentals of Transportation Engineering* by Fricker and Whitford
8. *Public Transportation related analysis using software like TRANSCAD, CUBE Software*

LABORATORY COURSES			
Subject Code: CE6P401	**Subject Name: Pavement Materials Laboratory**	**L-T-P: 0-0-3**	**Credit: 02**
Pre-requisite(s): None			

Tests on Soils: Density of soil, CBR, Determination of Field CBR using Dynamic Cone Penetrometer

Tests on Aggregate: gradation, shape tests, specific gravity, water absorption, aggregate crushing value, Los Angeles abrasion value, aggregate impact value.

Tests on Bitumen: penetration, viscosity, flash and fire point, ductility and elastic recovery, softening point, specific gravity, Ageing of Bitumen, Rheology of Bitumen using Dynamic Shear Rheometer

Tests on Bituminous Mixes: Marshall mix design, Bitumen content determination using centrifuge extractor.

Reference Books:

1. *Highway Material Testing Laboratory Manual* by Khanna S. K., Justo, C.E.G and Veeraraghavan, A., Nem Chand & Bros.
2. *Various IRC, ASTM and AASTHO Codes*

Subject Code: CE6P402	Subject Name: Traffic Engineering Studies	L-T-P: 0-0-3	Credit: 02

Pre-requisite(s): None

*Volume studie*s: Direction, Duration and Classification of Traffic Volume at Mid-Block Section and Intersections, Headway Distributions
Speed studies: Spot Speed Studies
Journey time and delay studies: Travel Time and Delay Studies by Floating Car Method
Arrival pattern studies of vehicles, Queue discharge characteristics
Gap acceptance studies: Study of Gaps, Lags, Critical Gaps
Intersection delay studies: Delay Measurement at Intersections
Highway Capacity Estimation: Videographic method, Dynamic PCU

Reference Books:

1. Currin, T. R. (2013). *Traffic Engineering-A Manual for Data Collection and Analysis*, 2nd Edition, Cenage Learning.
2. Slinn, M. Guest, P., Mattehews, P. (2006). *raffic Engineering Design-Principles and Practice, 2nd Edition Elseiver.*
3. *Highway Capacity Manual, 2010*
4. *Relevant Indian Roads Congress (IRC) Codes*

Subject Code: CE6P404	Subject Name: Transportation Systems Planning Studio	L-T-P: 0-0-3	Credit: 02
Pre-requisite(s): None			

Parking study, OD study, travel demand survey, questionnaire development of mode choice, trip generation, trip distribution, mode choice model parametric and non-parametric modelling, dealing with different transportation planning packages and traffic engineering packages, economic analysis and accident analysis

Reference Books:

1. Simon P. Washington, Matthew G. Karlaftis, Fred L. Mannering, *Statistical and Econometric Methods for Transportation Data Analysis,* CRC Press
2. *User Manuals of various packages*
3. *Relevant Indian Roads Congress (IRC) Codes*
4. Williumsen and Ortuzar, *Modelling Transport*