DEPARTMENT OF CIVIL ENGINEERING

Course Book for
M. Tech. in Water Resource Engineering

Visvesvaraya National Institute of Technology, Nagpur

JULY 2019

Brief about Civil Engg Department:

Civil Engineering Department is the oldest department in this institute right from the establishment of Government College of Engineering in Nagpur 1956. The department offers the undergraduate course of B.Tech in Civil Engineering and Four Postgraduate Courses of M.Tech as given below.

Program	Description
UG in Civil Engineering	Started with 60 seats in 1956 Intake increased to 71 in 2008 Intake increase to 82 in 2009 Intake increase to 92 in 2010

PG in Civil Engineering Department

1. Environmental Engineering	Started in 1966 (32 seats)
2. Water Resources Engineering	Started in 2005 (20 seats)
3. Construction Technology and Mgt	Started in 2010 (20 seats)
4. Transportation Engineering	Started in 2012 (20 seats)

VISION:

To contribute effectively to the National Endeavour of producing quality human resource of world class standard in civil engineering by developing a sustainable technical education system to meet the changing technological needs of the Country incorporating relevant of social concerns and to build an environment to create and propagate innovative technologies for the economic development of Nation.

MISSION:

The Mission of the Department is to develop students into capable civil engineering graduates by imparting appropriate high quality education in Civil Engineering so that they could be readily adapted by the service sector to meet the challenges faced by the Nation. The program strives for excellence in engineering education and profession. It also aims to promote all round development of the personality of students by suitably involving them in Co-curricular and extra-curricular activities.

TABLE 1. CREDIT REQUIREMENTS FOR POST GRADUTE STUDIES

Postgraduate Core (PC)		**Postgraduate Elective (PE)**	
Category	Credit	Category	Credit
Departmental Core (DC)	37	Departmental Electives (DE)	15
Grand Total PC + PE			52

The number of credits attached to a subject depends on number of classes in a week. For example a subject with 3-1-0 (L-T-P) means it has 3 Lectures, 1 Tutorial and 0 Practical in a week. This subject will have eight credits (3x2 + 1x1 + 0x1 = 8). If a student is declared pass in a subject, then he/she gets the credits

associated with that subject. Depending on marks scored in a subject, student is given a Grade. Each grade has got certain grade points as follows:

Grades	AA	AB	BB	BC	CC	CD	DD	FF
Grade Points	10	09	08	07	06	05	04	Fail

The performance of a student will be evaluated in terms of two indices, viz. the Semester Grade Point Average (SGPA) which is the Grade Point Average for a semester and Cumulative Grade Point Average (CGPA) which is the Grade Point Average for all the completed semesters at any point in time. SGPA and CGPA are:

$$\boldsymbol{SGPA} = \frac{\sum_{semester}(CoursecreditsXGradepoints)forallcoursesexceptaudit}{\sum_{semester}(Coursecredits)forallcoursesexceptaudit}$$

$$\boldsymbol{CGPA} = \frac{\sum_{Allsemester}(CoursecreditsXGradepoints)forallcourseswithpassgradeexceptaudit}{\sum_{Allsemester}(Coursecredits)forallcoursesexceptaudit}$$

Students can Audit a few subjects. i.e., they can attend the classes and do home work and give exam also, but they will not get any credit for that subject. Audit subjects are for self enhancement of students.

Details about Faculty members of Civil Engineering Department

Name of Faculty Member	Designation	Qualifications	Areas of specialization
Mhaisalkar V. A.	Professor	B.E., M.Tech, Ph.D	Environmental Engineering
Gupta R.	Professor	B. E., M.Tech, Ph.D.	Environmental Engineering
Katpatal Y. B.	Professor	B.Sc., M.Tech, MBA, Ph.D	Remote Sensing & GIS
Tembhurkar A. R.	Professor	B.E., M.Tech, Ph.D	Environmental Engineering
Ghare A. D.	Professor	B.E., M.Tech, Ph.D	Hydraulic Engineering
Lataye.D. H.	Professor	B.E., M.Tech, Ph.D	Environmental Engineering
Landge V. S.	Professor	B. E., M.E., Ph.D	Transportation Engineering
Ralegaonkar R.V	Professor	B.E., M.E., Ph.D	Construction Technology & Management
Latkar M. V.	Associate Professor	B.Sc., M.Sc., Ph.D	Environmental Biochemistry
Mandal A.	Associate Professor	B. E., M.E., Ph.D	Geotechnical Engineering
Vasudeo A. D.	Associate Professor	B.E., M.Tech, Ph.D	Water Resources Engineering
Patel A.	Assistant Professor	B.E., M.Tech, Ph.D	Geotechnical Engineering
Dongre S. R.	Assistant Professor	B.E., M.Tech, Ph.D	Environmental Engg.
Wanjari S. P.	Assistant Professor	B.E., M.Tech, Ph.D	Construction Technology & Management
Tawalare A. G	Assistant Professor	B.E., M.Tech	Structural Engg.
Mirajkar A. B.	Assistant Professor	B. E., M.E., Ph.D	Water Resources Engineering
Madurwar M. V.	Assistant Professor	B. E., M.E., Ph.D	Construction Technology & Management
Adhikary S.	Assistant Professor	B.E., M.Tech, Ph.D	Soil Dynamics
Padade A. H.	Assistant Professor	B.E., M.Tech, Ph.D	Geotechnical Engineering
Srinivasan V.	Assistant Professor	B.Tech, M.Tech, Ph.D	Geotechnical Engineering
Karthik B.	Assistant Professor	B.E., M.Tech, Ph.D	Environmental Engineering
Sita Rami Reddy D.	Assistant Professor	B.Tech., M.Tech, Ph.D	Transportation Engineering
Raghu Ram K.	Assistant Professor	B.Tech, M.Tech, Ph.D	Transportation Engineering
Kathuria A.	Assistant Professor	B.Tech, M.Plan, Ph.D	Transportation Engineering
Jain U.	Assistant Professor	B.Tech, M.Plan, Ph.D	Transportation Engineering

Program Educational Outcomes (PEOs)

The program will enable student to

1. Work in planning and operations related to water resources systems in the fields of Civil Engineering.
2. Contribute to the academics and research in the field of water resources engineering.

Program Outcomes (Water Resources Engineering)

PO1: An ability to independently carry out research /investigation and development work to solve practical problems

PO2: An ability to write and present a substantial technical report/document

PO3: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.

PO4: An ability to apply and use modern tools/softwares related with water resources engineering.

Scheme of Instructions for M Tech (Water Resource Engineering) (2015 onwards batches)

Program Core(PC)		**Program Elective (PE)**	
Category	Credit	Category	Credit
Departmental Core (DC)	37	Departmental Elective (DE)	15
		Total	
Grand total PC+PE			52

I Semester				**II Semester**			
CORE				**CORE**			
Code	**Course**	**L-T-P**	**Cr**	**Code**	**Course**	**L-T-P**	**Cr**
MAL 401	Finite Difference methods for Differential Equations	3-0-0	3	CEL 514	Applied Surface Hydrology	3-0-0	3
CEL 526	Groundwater Hydrology	3-0-0	3	CEL 414	Water Distribution Systems	3-1-0	4
CEL 531	Spatial Analyses for Resources Management	3-0-0	3	CEL 528	Water Resources Systems	3-0-0	3
CEP 531	Spatial Analyses for Resources Management*	0-0-2	1				
CEP 503	Water Resources Engineering Laboratory	0-0-4	2				
CEL 527	Free Surface Flows	3-0-0	3				
			15				**10**
ELECTIVE (Any One)				**ELECTIVE (Any Three)**			
CEL 406	Advanced Concrete Technology	3-0-0	3	CEL 419	River Engineering	3-0-0	3
CEP 406	Advanced Concrete Technology*	0-0-2	1	CEL 525	Earthen Dams	3-1-0	4
CEL 515	Advanced Fluid Mechanics	3-0-0	3	CEL 530	Water Power Engineering	3-0-0	3
CEL 518	Coastal Engineering	3-0-0	3	CEL 432	Environmental Impact Assessment	3-0-0	3
				CEL 529	Close Conduit Flows	3-0-0	3
				CEL 516	Modeling Techniques	3-0-0	3
				CEL510	Environmental Management	3-0-0	3
				CEL 542	Introduction to Climate Change	3-0-0	3
				CEL 532	Design of Experiments	3-0-0	3
	5 DC + 1 DE = 18/19 Credits				**3 DC + 3 DE = 19/20 Credits**		
III Semester				**IV Semester**			
CED 502	Project I	0-0-0	3	CED 502	Project II	0-0-0	9
ELECTIVE (Any One)							
CEL 418	Energy Conversion and Environment	3-0-0	3				
CEL 421	Hydraulic Structures I	2-1-0	3				
CEL 517	Hydraulic Structures II	2-1-0	3				
CEL 431	Water Quality Modeling	3-0-0	3				
CEL541	Water Distribution System Design	3-0-0	3				
CEL 561	Risk Analysis and Decision Making	3-0-0	3				
	1 DC + 1 DE = 6 Credits				**1 DC = 9 Credits**	**9**	

* Student must register both for practical and Theory of a course.

MAL401 – Finite Difference methods for Differential equations [(3-0-0); Credit: 3]

Course outcomes:
1. Students are able to solve ordinary differential equations numerically
2. Students are exposed to solve special class of partial differential equations numerically

Finite difference methods: finite difference approximations for derivatives, boundary value problems with explicit boundary conditions, implicit boundary conditions, Quasilinearization, Cubic splines and their application for solving two point boundary value problems.
Solution of Partial Differential Equations: Classification of partial differential equations, finite difference approximations for partial derivatives and finite difference schemes for:
Parabolic equations: Schmidt's two level, multilevel explicit methods, Crank-Nicolson's method.
Hyperbolic Equations : Explicit methods, implicit methods, one space dimension, two space dimensions.
Elliptic equations: Laplace equation, Poisson equation, iterative schemes.
Computation using MATLAB.

Text Books:
1. G.D. Smith: Numerical solution of Partial Differential equations, Finite Difference methods, Oxford University Press, 1985.
2. M.K. Jain, S.R.K. Iyengar & R.K. Jain: Numerical Methods for Scientific & Engineering Computation, New Age International Publishers, 1996.
Reference Books:
1. DR. Lothar Collatz : The numerical treatment of differential equations, Springer-Verlag, New York 1960.
2. K.W. Morton & D.F. Mayers: Numerical solution of Partial differential equations, Cambridge University press. 2005.
3. M.K. Jain : Numerical solution of Differential equations, Wiley Eastern, New Delhi, 1984.

CEL 406 - ADVANCED CONCRETE TECHNOLOGY [(3-0-0); Credits: 3]

Course Outcomes:

1. Preparing a Concrete Mix Design with using environmental friendly materials such as Fly ash, Silica Fumes, Metakaolin & GGBS.

2. Carrying out Non Destruction Testing of Concrete using Core Test, UPV and Rebound Hammer
3. latest methodology of Concrete Technology in World

Review of properties of cement, their physical and chemical properties, special purpose cements, Classification and properties of aggregates, soundness of aggregates, alkali aggregate reaction, thermal properties of aggregates, Importance of shape and Surface area and grading, gap graded and aggregates. Admixtures & construction chemicals, Use of Fly Ash, Silica Fumes, Metakaolin& GGBS in concrete.
Rheological behavior of concrete, requirements of workability of concrete, Effect of environmental conditions, Strength properties of hardened concrete, Impact, Dynamic and fatigue behaviour of concrete, shrinkage and creep of concrete, behaviour of concrete under fire.
Permeability and Durability of concrete, Parameters of durability of concrete, chemical attack on concrete, Production of concrete; batching mixing, transportation, placing, compaction of concrete. Special methods of concreting and curing of concrete, Hot weather and cold weather concreting, Guniting (Shotcreting)/
Concrete mix design, Basic considerations and choice a mix proportions, various methods of mix designs including IS Code method. Quality control and quality assurance of concrete, Acceptance criteria, Quality management in concrete construction, Inspection and testing of concrete. Non-destructive testing of concrete, core test and load test.
Special concrete such as high strength, Lightweight, heavy weight, vacuum processed concrete.
Mass concrete, high performance concrete, Pumpable concrete, Self Compacting concrete, Air entrained concrete, Ferro cement, fiber reinforced concrete, Polymer impregnated concrete. Jet concrete. Deterioration and repair technology of concrete, Distress and type of repairs, crack sealing techniques**.**

REFERENCE BOOKS:

1. Gambhir M.L: Concrete Technology Tata McGraw Hill (Second Edition) 1995.
2. M.S.Shetty, Concrete Technology S.Chand& Company New Delhi 2005 .
3. P.KumarMehata, Paulo & J.M. Monteiro, Concrete microstructure, properties & materials, Prentice Hall INC &Mcgraw Hill USA.
4. Short &Kenniburg, Light Weight Concrete, Asia Publishing House, Bombay 1963.
5. Orchard D.F.; Concrete Technology -Vol I. & II Applied Science Publishers (Fourth Edition) 1979.
6. Neville A.M., J.J.Brook Properties of Concrete Addison Wesley 1999.

CEP 406 - ADVANCED CONCRETE TECHNOLOGY **[(0-0-2); Credits: 1]**

Laboratory work comprises of 8 practical related with syllabus.

CEL -414 WATER DISTRIBUTION SYSTEMS [(3-1-0); Credits 4]

Course Outcomes:

1. Introduction to Water Distribution Networks
2. Methods for Analysis
3. Types of Analysis
4. Methods for Designs

General Hydraulic Principles, Head loss formulae- Darcy-Weisbach formula, Hazen – Williams formula, Modified Hazen-Williams formula, Series and Parallel connection of Pipes, Equivalent Pipes, Analysis of branched Water Distribution Networks.

Formulation of Equations for looped Water Distribution Networks, Analysis of flow in looped networks using Hardy Cross, Newton-Raphson and Linear Theory method, Introduction of Gradient method and other methods of analysis.

Reservoirs, Pumps and Valves (check valve, flow control valve and pressure reduces valve) in Water distribution systems. Flow dependent analysis of multi-reservoir systems, Introduction to head-dependent analysis.

Node flow analysis of water distribution networks: Node head–flow relationships, Direct and Indirect methods, Application of NFA technique to serial networks.

Optimal and Economical diameter of pumping main, Design of pumping main considering diameter as continuous as well as discrete variable. Water hammer consideration.

Design of water distribution networks using Critical Path Method, Formulation of optimization model, Application of Cost-head loss ratio method and Linear Programming Technique to optimal design of branched networks.

Determining number of branching configuration for a looped network, Use of path concept and minimum spanning tree concept, Application of critical path method for design of looped networks. Introduction to methods for Looped WDNs.

REFERRENCE:

1. Bhave, P. R. and Gupta R., Analysis of Water Distribution Networks, Narosa Publishing Co, New Delhi.
2. Bhave P. R., Optimal Design of Water Distribution Networks Narosa Publishing Co, New Delhi.
3. Jeppson R.W., Analysis of flow in pipe networks, Ann Arbon Science, Michigan USA.
4. Walksi T-M, Analysis of water distribution System Van Nostand Reinheld G, New York USA, 1984.
5. CPHEEO, Manual on Water Supply and Treatment, Ministry of Urban Development G0I.

CEL -418 ENERGY CONVERSION AND ENVIRONMENT [(3-0-0);Credits 3]

Course Outcomes:

1. Understand and apply basic concept of waste to energy technology and environmental protection.
2. Capable to conduct environmental appraisal, perform energy audit and assessment of energy potential of energy sources
3. Capable to design energy conversion systems
4. Understand contemporary environmental and social issues related to energy conversion

Significance of Energy Conversion and Environment, Overview of Global and Indian Energy Scenario; Environmental Impacts of Energy Conversion, Principles of Waste Minimization and Energy Recovery,Renewable and Non- Renewable Energy Sources;Estimation of Potential of Energy Recovery form various Sources, Energy economics; Energy Conversion Methods: Thermal, hydro, nuclear, solar, wind, tidaletc their principles and application, Waste to Energy options: physical, thermo chemical and bio chemical processes: pelletization, bricquetiation, Combustion, Gasification, pyrolysis; Fuels Derived anaerobic digestion , Biogas Technology, Future Technologies for Waste to Energy Systems; Introduction to Microbial Fuel cell, Gas generations and collection in landfills, Measurements and Control; Energy and Resources Conservation Strategies and Policies; Environmental Appraisal, Energy audit, Carbon Foot prints, Sustainable Energy-Efficient systems, Intelligent Green Building, Case studies of sustainable Energy Projects in the field of Water Resources, Infrastructure and Environmental System.

REFERRENCE:

1. Fowler J. M. Energy and the Environment McGraw Hill New York 2nd edition.
2. B.H. Khan, Non Conventional Energy Resources, 2ndEdition , McGraw Hill Companies.
3. G.D.Rai, Non Conventional Energy Source, Standard Publishers Distributors.
4. D. O. Hall, G. W. Barnard and P. A. Moss, Biomass for Energy in the Developing Countries, Current Roles, Potentials, Problems, Prospects, Pergamon Press Ltd, 1st edition.
5. W. C. Turner, Energy Management Handbook Wiley Newyork 1st edition.
6. P. Meier, Energy System Analysis for Developing countries, Sringer Verlag 1st edition.
7. Dorthy J De Renzo, Energy from Bioconversion of Wate materials, Noyes data Corporation USA 1st edition.
8. Francis A.Domino Energy from Solid Waste – Recent Development, Noyes data Corporation USA 1st edition.
9. Oliver S. Owen , Daniel D. Chiras, Natural Resource Conservation – Management for Sustainable Future Prentice Hall Publications 6th edition.
10. McGraw Hill George Tachonobanoglous, Hilary Thesin, Samuel Vigil 1st International Edn.

CEL -419 RIVER ENGINEERING **[(3-0-0); Credits 3]**

Course Outcomes :

1. To identify the flow regimes in river flows (PO3)
2. To find out sediment loads from river and conduits (PO3)

Origin and properties of sediments : Nature of sediment problems , origin and formation of sediments , properties of sediments , incipient motion of sediment particles , tractive force approach, cohesive materials.

Regimes of flow : Description of regimes of flow , ripple , dune , antidune , prediction of regimes of flow.

Resistance to flow & velocity distribution in alluvial streams : velocity distribution in turbulent flow over rough boundaries, resistance and velocity distribution in alluvial streams.

Bed load transport & saltation: Bed load equations, bed load equations based upon dimensional considerations and semi-theoretical equations, general comments on bed load equations , saltation.

Suspended load transport : Mechanism of suspension, equation of diffusion , sediment distribution equation , relations for suspended load, wash load , transport of suspended sediment.

Total load transport : sediment samplers design of canals carrying sediment laiden water

Types of sediment samplers

Design of channels carrying sediment laiden water

Sediment transport through pipes

REFERENCE BOOKS:

1. Garde R J and RangaRaju K G, Mechanics of Sediment Transportation and Alluvial Stream Problems Wiley Eastern Ltd., 1985.
2. Yang C.T., Sediment Transport- Theory and Practice The McGraw Hill Companies Inc. 1996.
3. Chang H.H., Fluvial Processes in River Engineering John Wiley 1988.
4. Simons D.B. and Senturk F., Sediment Transport Technology, Water Resources Publications, Fort Collins, Colorado 1977.

CEL -525 EARTHEN DAMS [(3-1-0); Credits 4]

Course Outcomes:

1. Ability to analyze slope stability with different methods.(PO1, PO4))
2. Development of concept for seepage analysis. (PO2, PO4))
3. Develop clear idea on construction aspects for earth embankment, protection and remedial measures.(PO2)

Introduction, types and advantages of embankment dams.
Factors affecting the designs of Embankment Dams, Safely criteria.
Theoretical Analysis of seepage through embankment and its application.Control of seepage through embankment dams.
Stability analysis including seismic stability.
Construction aspects.
Instrumentation in dams.Typical problems and their solutions in embankment dams.Rockfill dams.

REFERENCE BOOKS:

1. Sower &Sally, Earth and Rock Fill damsAsia publishing house.
2. Creager, Justine, HindsEngineering for DamsJohn Wiley & Sons.
3. U. S. B. R. Design of Small Dams,IBH Publisher.

CEL-421 HYDRAULIC STRUCTURES –I **[(2-1-0); Credits 3]**

Course Outcomes :

1. To design different types of spillways and energy dissipaters.(PO1,PO3)
2. To design river training works.(PO1,PO3)

Spillways : Necessity, components and classification, Estimation of spillway design flood
Design considerations of overflow/ ogee spillways: Design as per IS, Effect of submergence by tail water, Effect of silting upstream of spillway, Discharge coefficients versus crest pressures
Design considerations of side channel spillways and chute spillways, Effect of contraction
Design considerations of shaft spillways
Design principles for culverts and small bridges, causeways and box culverts
River behavior, control and training, design of guide banks
Design of hydraulic jump type energy dissipater- stilling basin as per IS

REFERENCE BOOKS :

1. Punmia B.C, Pande B.B, Irrigation and Water Power Engineering,
2. Garg S, Irrigation and Hydraulic Structures,
3. Design of Small Dams, US bureau of Reclamation

CEL- 526 GROUNDWATER HYDROLOGY **[(3-0-0); Credits 3]**

Course Outcomes:

Student should be able

1. To understand different geological formations.
2. To calculate permeability of different types of soil.
3. To know about salt water intrusion and pollutant transport through soil.

Introduction : Occurrence of ground water, geological formations as aquifers; types of aquifers.

Ground Water movement : Darcy's law, permeability and its measurement, tracing of ground water movement, fundamental equations for steady and unsteady ground water flow, flow nets.

Well hydraulics : Steady flow in confined, semi-confined and unconfined aquifers, radial flow, superposition; multiple well system. Different methods of well construction; construction of well casings and screens, natural and artificial gravel packed wells. Safe yields, estimation, pumping and recuperation tests.

Two dimensional flow, methods of solution, infiltration galleries, Ground-water replenishment, recharge of ground water, different methods.

Salt water intrusion : Concept; interface and its location; control of intrusion.

Pollutant transport : Plume Transport, source identification, tracer methods.

REFERENCES BOOKS:

1. David Reith Todd, Groundwater Hydrology John Wiley publishers 2002.
2. Ragunath H M Groundwater & Well Hydraulics , Wiley Eastern Ltd, New Delhi 2000.
3. Freeze &Chezzy, Groundwater Hydrology John Wiley publishers

CEL -527 FREE SURFACE FLOWS **[(3-0-0); Credits 3]**

Course Outcomes:

1. To analyze uniform and critical flows (PO3)
2. To determine flow profiles, GVF profiles and RVF parameters (PO3)
3. To appreciate the SVF and unsteady channel flows (PO3)

Review of uniform flow formulae and computation of uniform flow, critical flow, specific force, Boundary shear stress, compound channel section

Theory of gradually varied flow, Dynamic equation in various forms, hydraulic exponents N and M, types of surface profiles and their classification. Analysis of surface profiles, Computation of gradually varied flow, different methods of computation – Bresse's and Chow's method of direct integration, Direct step and standard step method, Graphical integration method, Numerical methods.

Rapidly varied flow : Flow over spillways. Theory of hydraulic jump, length and location of hydraulic jump, jump in sloping channel, applications of hydraulic jump, transitions.

Theory of spatially varied flow : Dynamic equation with increasing discharge and decreasing discharge, computation of profile

Unsteady flow in open channels: Fundamental equations of unsteady flow in open channels, waves and their classification, Saint Venant equations, celerity of a wave, surges, dam-break problem, flood routing

REFERENCE BOOKS:

1. RangaRaju K. G.Flow Through Open ChannelTata McGraw Hill Publication2003.
2. Subramaya K.Flow in open channels, Flow in open channels, Tata McGraw Hill Publication2002.
3. VenTe ChowOpen Channel HydraulicsMcGraw Hill Publication1996.

CEL 528 WATER RESOURCES SYSTEMS [(3-0-0); Credits 3]

Course Outcomes:

1. To understand water resources project planning aspects.
2. To understand water resources project principals and its economics.
3. To understand water resources project optimization.

Scope of water resources engineering

Planning for water resources development : objective, multipurpose projects, different purposes, items to be considered in planning for different purposes, hydrologic appraisal of water resources.

Project formulation, project investigation and planning reconnaissance, detailed investigations and final planning, economics of water resources planning.

Principles of engineering economics, equivalence of kind time, tangible and intangible values.

Mathematics of economic analysis, discounting factors and different discounting techniques.

Economic planning for flood control, domestic and industrial water supply, irrigation and hydroelectric power; cost allocation in multipurpose projects.

Optimization of water resources development, graphic optimization techniques for single purpose and dual purpose projects. Analytical optimization techniques.Applications of linear and dynamic programming techniques.

REFERENCE BOOKS:

1. Linsley R. K. and Franzini J. B.Water Resources EngineeringMcGrawHill Book Co., New York1964.
2. Ralph A. Wurbs, Wesley P JamerWater Resources EngineeringPrentice Hall2002.
3. Duggal K N &Soni J P,Elements of Water Resources EngineeringNew Age International Publishers.

CEL- 529 CLOSE CONDUIT FLOWS **[(3-0-0); Credits 3]**

Course Outcomes :

1. To analyse steady flow through conduits and pump pipe systems.(PO3)
2. To analyse unsteady flow in pips and find surges.(PO3)

Steady flow through closed conduits : Empirical formulae for frictional loss for flow through pipes, Minor losses, Pipes connected in series, parallel, Flow through a by pass, Syphon, Three reservoir case, Transmission of power, pipe network – Hardy Cross method, Loss of head in a pipe with varying discharge, Loss of head in non circular conduits, Flow through nozzle fitted to pipe, Flow in pipe bends, Loss of head in tapering pipes, Time of discharge from one reservoir to another, Pipeline with a pump or a turbine

Unsteady flow in closed conduits : Unsteady Bernoulli's equation, Mass oscillations in U-tube, time of establishment of flow in pipeline

Water hammer phenomenon : Fundamental differential equations, rigid column theory, elastic wave in single and complex conduits, calculation of water hammer pressure, Allievi's theory and use of allievi's charts, effect of friction, method of characteristics, Water hammer pressures in pumping systems, analysis of flow in surge tank systems. Calculation of maximum surges, study of stability problem, Thoma's criteria.

REFERENCE BOOKS:

1. Streter V L and Wylie E D, Fluid Transients, McGraw Hill Book Co.
2. Subramanya K.,Theory and Applications of Fluid Mechanics,Tata McGraw Hill Publication.
3. Garde R.J. andMirajgaokar A.G.,Engineering Fluid Mechanics,Scitech Publication.

CEL 531 SPATIAL ANALYSIS FOR RESOURCES MANAGEMENT [(3-0-0); Credits: 3]

Course Outcomes:

CO1. Understand Digital Data collected from satellite in Raster and vector Formats
CO2. Digital Image analysis and Classification
CO3. Spatial analysis in GIS
CO4. Active Remote sensing like RADAR and LIDAR
CO5. Information generation and management from spatial analysis

Fundamentals of Geoinformatics: Raster and Vector Data, Resolutions of RS data, Thermal and Radar Sensing, spatial and non spatial information, attribute data collection, data formats, data conversions. RS as a technology for data extraction technique, multithematic data extraction using multispectral sensors, thematic map generation.

Overlay analyses, Buffer analyses, Query shell. Spatial analysis, Modeling of spatial data, Network analysis, digital terrain elevation models, Customization and Decision Support Systems.

Applications of Geoinformatics for spatial management of resources: Run-off estimations, infiltration characteristics, groundwater potential and recharge characteristics, Watershed management, watershed prioritization, Sediment yield estimation, reservoir capacity studies, Spatial analyses for Environment Impact assessment, Monitoring and feedback, Natural indices, Concept of E-Governance using Geoinformatics. Integrated applications using various technologies within Geoinformatics; methods and approach.Real time and temporal analysis using Geoinformatics.

Multidisciplinary applications of Geoinformatics; integration of various segments.Geoinformatics for resources management and utilities management.

REFERENCE BOOKS:

1. C.P LO Albert KW YeungConcepts and techniqes of Geographic Infromation Systems Pritince Hall of India, 2002.
2. C.S. Agrawal& P K Garg, Text Book on Remote Sensing Wheeler First.
3. Paul A. Longley, M. Goodchild, David Maguire, David Rhind, Geographic Information Systems and Science, Wiley, First.
4. Geographic Informaiton System and Enviornment Modeling, Keith C. Clerk, BradelyO Parks, Michel P Crane, Pritince Hall of India, 2002.
5. John R Jensen, Remote Sensing of the Environment ..an Earth Resource Perspective, Pearson Education, 2006.

CEP 531 SPATIAL ANALYSIS FOR RESOURCES MANAGEMENT [(0-0-2); Credits: 1]

Course Outcomes:

1. Digital Data, resolution and Formats
2. Data preparation and image registration
3. Digital Image analysis and Classification
4. Vector Data generation, topology building and attribution
5. Interpolation, Overlay, Buffer and Network analysis
6. Thematic maps generation
7. Models for Resource analysis

Practical

1. Spatial Digital Data and its Formats
2. Digital Image analysis and Classification
3. Vector Data generation, topology building and attribution
4. Overlay, Buffer and Network analysis
5. Models for Resource analysis.

CEL 431 WATER QUALITY MODELING [(3-0-0); Credits 3]

Course Outcomes:

1. To understand Hydrology system and related models.
2. To understand water quality assessment parameters.
3. Environmental modeling

Definition; Classification; Example and Models of Hydrology Systems.
Introduction to river, estuarine and lake thermodynamics, Stratification of lakes, Dissolved Oxygen Model for streams, Temperature Models, Predication of fate of organisms and toxic substances.
Models for predicting water quality changes in water distribution systems.
Computational methods in Environmental Modelling.

REFERENCE BOOKS:

1. Gilbert M. Masters,Introduction to Env. Engg and Science,Prentice-Hall, India.
2. Thomann, R.V. and Muller , J.A.,Principles of Surface Water Quality Modelling and control, Harper International Edition.
3. Tchobanoglous G. Schroeder , ED,Water Quality,Addison-Wesley Publishing Co. Reading Massachusetts

CEL 432 ENVIRONMENTAL IMPACT ASSESSMENT [(3-0-0); Credits 3]

Course Outcomes:

1. The students will be able to assess the impact on the environment of various environment management techniques.
2. The students will be able to analyze the impact on environment due to some new developmental activities.

Evolution of EIA; EIA at project; Regional and policy levels; EIA process in India and other countries; EIA methodologies; Screening and scoping criteria; Rapid and Comprehensive EIA; Environmental health impact assessment, Environment risk analysis; Uncertainties; Practical Applications of EIA; Baseline collection of data; Prediction and assessment of impacts of physical biological and socio-economic environment; Development of environment management plan; Post project monitoring; EIA report and EIS; Review process. Case histories of applications for industrial; Water resources and irrigation projects; ports and harbours, Mining, Transportation and other projects sectors

REFERENCE BOOKS:

1. Canter, L. Environmental Impact Assessment, McGraw Hill 1977
2. Rau, GJ. And Wooten, C.D., Environmental Impact Analysis Handbook, McGraw Hill 1980
3. Ministry of Environment and Forests, GoI, Current Documents on Guidelines for EIA.

CEL 530 WATER POWER ENGINEERING [(3-0-0); Credits 3]

Course Outcomes: The students must be able to;

1. understand and analyze power potential, demand and its estimation.(PO3)
2. understand the all the components, its operation and its significance of a water power generation system.(PO1, PO3))

1. Water Power :Introduction Sources of Energy , Role of Hydropower in a plant system, Estimation of water power potential.
2. Electrical Load on Hydro Turbines : Load Curve, load Factor, Capacity Factor, utilization factor, Diversity Factor, load Duration Curve, Firm Power, Secondary Power , Prediction of load.
3. Types of hydro power plant : classification of hydel plants, Run of river plants, General Arrangements of Run of River Plants, Valley Dam plants, Diversion Canal Plants, High Head diversion plants, Storage and pondage , Pumped storage power plants, Advantages of Pumped storage power plants, Types of Pumped storage power plants.
4. Penstocks : General classification, design criteria, Economical diameter , Anchor blocks, Conduit valves, Bends and manifolds.
5. Turbines : Introduction, main types of turbines, Hydraulics of turbines, Velocity Triangles and nomenclature, Basic flow equations, Draft tubes, Caviation in turbines, Turbine model testing, characteristics of turbines.
6. Water Hammer and Surges : Introduction, Water Hammer, Transients caused by turbine, Load acceptance and rejection, Resonance in Penstocks, Channel Surges, Surge tanks.
   Intakes : types losses, Air entertainment, Intel aeration, Canals, Forebay, Tunnel.

REFERENCE BOOKS:

1. Dandekar M. M. & Sharma K. N. ; Water Power Engineering; Vikas Publishing House Pvt. Ltd. , New Delhi, 2003
2. Streeter V. L. & Wylie E. B.; Hydraulic Transient; McGraw Hill Book Company, New York, 1990
3. ChaudharyHanif; Applied Hydraulic Transients; Van Nostrand Rein Hold Company, New York, 1992
4. Sharma R.K. & Sharma T.K.; A Text book of Water Power Engineering, S. Chand Publication, 2003

CEP-503 WATER RESOURCES ENGG LAB [(0-0-4); Credits 2]

Course Outcomes:

1. The students will be able to understand the practical applications of flow measurement devices and flow properties.
2. The students will be able to calculate sediment load.

List of experiments :

1. Hydrostatic forces on immersed body.
2. Determination of viscosity of fluid.
3. Pumps in parallel.
4. Pumps in series.
5. Forced and Free vortices.
6. Flow visualization by laminar force table.
7. Study of sediment transport mechanism.
8. Experiment on Osborne Reynolds apparatus.
9. Energy losses in pipes.
10. Calculation of cavitation force.

CEL- 514 APPLIED SURFACE HYDROLOGY [(3-0-0); Credits 3]

Course Outcomes :

1. To estimate the components in the hydrological cycle and express the natural data (PO3)
2. To carry out analysis of hydrographs and flood frequency (PO3)
3. To learn a topic in hydrology and water resources domain by independent study and present a seminar (PO2)

Rainfall measurement, recording and non-recording gauges, radar measurement, raingauge network.
Space-time characteristics – double mass curve.Station-year method, interpolation of rainfall records, average rainfall depth, area duration analysis.

Frequency analysis – Area depth relationship, seasonal variation, calculated risk, frequency for storm transportation, probable maximum precipitation.

Evapotranspiration, evaporation – nature of process from free water surfaces, factors affecting measurement, estimation and reduction from soil surfaces. Transpiration – Nature of process, factors affecting, determination, evapotranspiration – methods of estimation, equations.

Infiltration – factors affecting measurement, infiltrometers and hydrograph analysis, infiltration in computation of runoff for small and large watersheds, infiltration indices, Runoff : factors affecting rainfall – runoff relationship.

Hydrographs ; features, components, base flow separation, Unit hydrograph theory, analysis, application and modification, instantaneous unit hydrograph and deptual models. Variability of runoff – flow duration and flow mass curves.

Floods : Characteristics; elevation, discharges, volume and duration flood formulae, discharge – frequency and stage – frequency curves, maximum probable flood, design flood and its estimation.

Statistical Analysis : Importance in hydrology, frequency probability and statistical distribution, recurrence, interval probability paper, reliability of analysis; applications to rain fall, stream flow, flood and drought studies.

REFERENCE BOOKS:

1. Chow VenTe, Maidment R David, Mays W Larry, Applied Hydrology McGraw-Hill New Delhi 1998.
2. Linsley , Kohler &Paulhus, Engineering Hydrology, McGraw Hill.
3. Subramanya K, Engineering Hydrology Tata McGraw-Hill, New Delhi 1996.Dr. P. Jayarami Reddy A Text Book of Hydrology Laxmi Publications, New Delhi

CEL- 515 ADVANCED FLUID MECHANICS [(3-0-0); Credits 3]
Course Objectives :

1. To carry out the analysis of ideal fluid flows. (PO3)
2. To develop insight into the behavior of the real fluid flows including boundary layer and turbulence. (PO3)

Principles of ideal fluid flow : fundamental equations, velocity potential and stream functions for two dimensional flow patterns, uniform flow, sources, sink and vortex flow, doublet, solution of physical problems, free stream lines.

Flow of real fluids, Navier-Stoke's equations, some solutions of practical problem, boundary layer theory; boundary layer equations for two dimensional flows; some methods for their solutions, turbulent boundary layers, separation, boundary layer control.

Transition from laminar to turbulent flow; problem of stability.
Turbulent flow; Reynolds equations; theories of turbulence, free turbulent flow; turbulent flow in pipes and open channels.

REFERENCE BOOKS:

1. Yuan S. W., Foundations of Fluid Mechanics, Prentice – Hall India Pvt. Ltd., New Delhi.
2. Narasimhan S., Engineering Fluid Mechanics, Orient Longman Ltd.
3. Garde R. J.,Tubulent Flow, Wiley Eastern Ltd.

CEL – 516 MODELING TECHNIQUES **[(3-0-0); Credits 3]**

Course Objectives :

Course Objectives:

1. To understand the behavior of waves (PO3)
2. To analyse the shore processes and the effect of waves on structures (PO3)

Purpose and utility of hydraulic models; principles of dimensional analysis, Raleigh method, Buckingham's pi method, non-dimensional parameters and their application to practical problems, principles of hydraulic similitude, different types of similarity and model laws, scale effect. Types of hydraulic models such as distorted and undistorted, movable bed models, effect of earth's rotation, models for spillways, energy dissipators and flood control. Principles of design and construction, interpretation of model results, mathematical modelling and regression techniques

Finite Difference Method: explicit & implicit schemes, application to water resources. Finite element method: domain selection, introduction to problems solving techniques

Advanced techniques in water resources: Introduction to Fuzzy Logic, Introduction to Artificial neutral network, Introduction to genetic algorithm

REFERENCE BOOKS:

1. Yalin M S,Theory of Hydraulic Models,Macmillan, London.
2. Sharp J J,Hydraulic Modeling,Butterworth Group.
3. Novok P and Cabelka J,Models in Hydraulic Engineering: Physical Principals and Design Applications, Vol 4,Pitman Advanced Publishing.

CEL- 517HYDRAULIC STRUCTURES-II [(2-1-0); Credits 3]

Course Objectives :

1. To carry out the design and analysis of weirs on permeable foundations and canal regulator works.(PO3)
2. To design canal falls, cross drainage works and modern spillways.(PO1)

Design of weirs and barrages over permeable foundations : Causes of failure, Bligh's and Lane's creep theory, Khosla's theory and method of independent variables, standard profiles, corrections, exit gradient, plotting of HGL, Design of d/s and u/s protection works, length of pucca concrete floor
Canal falls : Types and design principles
Canal regulation works : Alignment of offtaking channels, Distributaries, head regulator, cross regulator and their design, weir type and regulator type escapes, metering flumes, types of modules, Kennedy's gauge outlet
Design considerations for cross drainage works : Fluming the canal, Hind's method for design of transition, Design of pucca canal trough
Hydraulics of outlet works : Sluiceways, river intakes, simple submerged intakes, trash racks
Preliminary concepts of design of stepped spillways and labyrinth weirs

REFERENCE BOOKS:

1. Punmia B.C. and Pande B.B. Lal,Irrigation and Water Power Engineering,Laxmi Publications Pvt. Ltd.
2. GargSantosh Kumar,Irrigation Engineering and Hydraulic Structures,Khanna Publishers, New Delhi.
3. U.S. Bureau Reclamation, Design of Small Dams, Oxford and IBH Publication Co., New Delhi

CEL-518 COASTAL ENGINEERING **[(3-0-0); Credits 3]**

Course Objectives:

3. To understand the behavior of waves(PO3)
4. To analyse the shore processes and the effect of waves on structures(PO3)

Introduction : The coastal zone and its study,Introduction to water waves, Classification of waves, A review of potential flow fundamentals , Wave properties

Derivation of linear wave theory, Calculation of wave length, L, methods, Calculation of pressure, velocity, acceleration, Calculation of energy, group celerity, tables, Superposition of waves and standing waves, Energy and energy propagation in waves

Shoaling of waves, Wave transformations, Refraction of waves, Diffraction of waves, Wave breaking in deep and shallow water, Winds over the sea and wave generation, Wave prediction

Wave forces on pile structures ,Wave forces on wall type structures Rubble-mound stability, Hudson formula, Testing of Models in Wave Flumes

Tides, Water levels ,Nonlinear waves, Introduction to different types of offshore structures

Basic shore processes ,Shore protection alternatives, Artificial beach nourishment

REFERENCE BOOKS:

1. Dean and Dalrymple,Water Wave Mechanics for Engineers and Scientists, Dean and Dalrymple,McGrawHill Book Co., New York.
2. Wiegel,Oceanographical Engineering,

CEL – 561RISK ANALYSIS AND DECISION MAKING [(3-0-0); Credits 3]

Course Outcomes:

1. Understand and apply basic principles of decision making and risk analysis
2. Develop cause- consequences diagram, Analyze and evaluate risk for various environmental engineering, water resources engineering and construction technology.

Need of Decisions and Risk analysis for construction management, Decision Models, Risk and Uncertainty, Theory and Techniques of Decision and Risk Analysis, Qualitative and Quantitative risk analysis tools /methods, Modelling Value Systems, Value Management for Construction, Competitive Bidding and Risk Sharing, Strategic and integral planning, Decisions making for site selection, construction , execution and operation of projects, Documentation, Project proposals, Economic Analysis, Legal Aspects of project management, Environmental appraisal, ISO 14000, Hazards identification, analysis and risk assessment, Accident and incident Analysis and control systems, IS 3786, S.H.E. Management IS15001, Training &Education Management Oversight and risk tree, Risk control and Treatment, Risk management and Internal control, Risk mitigation, Risk management plan, IT and IS for Risk management

REFERENCE BOOKS:

1. Melvin W. Lifson, Edward F. Shaifer, Decision and Risk Analysis for Construction Management, John Wiley & Sons1st.
2. Ian Cameron, Raghu Raman, Process Systems Risk managementElseveir Academics Press2005.
3. Chris MarrisonFundamentals of Risk MeasurementsTata McGraw Hill2002.
4. Han Buhliman, Mathematical Methods in Risk TheorySpringler- Verlang Berlin Heidelberg1970.
5. Calow PHand book of Environmental Risk Assessment and MnagementBlackwell Science Ltd. Oxford, Uk1998.

CEL 510 ENVIRONMENTAL MANAGEMENT [(3-0-0); Credits: 3]

Course Outcomes:

1. Understand the environmental, social and economic framework in which environmental management decisions are made understand the life cycle perspective, systems approach and environmental technologies for converting process, products and service related industrial environmental problems into opportunities to improve performance
2. Anticipate, recognize, evaluate, and control environmental issues in a variety of sectors and industries and liaison with federal, state, and local agencies and officials on issues pertaining to environmental protection
3. Recognize, evaluate, and control factors in the workplace and the environment that cause health and environmental hazards and utilize quantitative knowledge and skills and modern tools and technologies to assess, analyze, plan, and implement environmental management systems
4. Obtain, update, and maintain plans, permits, and standard operating procedures.
5. Prepare, review, and update environmental monitoring and assessment Report sand Monitor progress of environmental improvement programs

Syllabus:

Environmental problems and issues at global and national level, sustainable development(SD), Indicators of sustainable development, regional carrying capacity based planning, National Environmental Policy(NEP), Climate change, its impacts, adaptation and mitigation.

Waste minimization and pollution prevention strategies – Tools of corporate environmental management; ISO 14000, TC 207 structure, Environmental Management System (ISO : 14001), General requirements ; Cleaner technology(CT) of production, waste management hierarchy implementation of CT, barriers for adoption of CT

Life cycle assessment, methodological framework

Environmental impact assessment, Methodologies for EIA, Environmental management plan (EMP) , environmental monitoring plan, EIS, case studies of infrastructure and industrial projects

Indian environmental legislations and major environmental acts such as Water Act (1974), Air Act (1981), Environmental (Protection) Act (1986); International Environmental Treaties; Kyoto protocol, Montreal protocol, COP21, CDM

Ecomark , objectives, criteria, general and specific requirements, ;

Design for Environment(DFE), strategy, implementation

Environmental audit, methodology, Benefits of EA to Industry

Overview of technologies, regulatory standards for industrial wastewaters and atmospheric emission.

REFERENCES

1. Richard Welford, Corporate Environmental Management Systems and Strategies, Universities Press (I) Ltd., Hyderabad, 1996.
2. Paul L. Bishop, Pollution Prevention: Fundamental and Practice, McGraw Hill, International, 2000. Freeman, H.M., Industrial Pollution Prevention Handbook, McGraw Hills 1995
3. Ministry of Environment, Forests and Climate Change(MoEFCC), Govt. of India web site

CEL 542 INTRODUCTION TO CLIMATE CHANGE [(3-0-0); Credits 3]

Course Outcomes:

1.To provide basic understanding of climate change.
2. To provide knowledge about important climate variables and prediction of changes in the climate system.
3. To analyse the causes and effects of climate change on environment & human society.
4. To elaborate upon the various adaptation and mitigation strategies to combat climate change.

Course Syllabus

The Basics of Climate Change Science: The Earth's Energy Balance, negative entropy and mitigation, Greenhouse Gases, Aerosols and atmospheric brown cloud, Impact of CO_2 increase on climate change, Other Drivers of Climate Change, Adaptation strategy, Recent Climate Change impact at local and global scale, Sustainable Energy for All

Paleoclimatology: Glaciar Ice and Ice Core Dating, Other measurement techniques, Heinrich events , Dansgaard-Oeschger (D-O) events and their relevance in climate studies

Ecological Impacts of Climate change: Anthropogenic activities and climate change, Rising of sea level and consequences, Impact on biodiversity and extinction of endemic species, Changing of food chain, Agricultural shifts, Impact of climate change on health

Policy and Legislative issues in Climate Change: The UNFCCC, The Montreal Protocol, From Kyoto to Copenhagen, Towards COP21, ICMR, ICAR & IARI

Goal to Set Climate Change Prevention: Limiting the Mean Surface Temperature Increase Below 2-Degrees Celsius vs. Pre-Industrial Levels, Global Emissions Reduction Pathway for the 2-Degree Limit, Potential Emissions from Fossil Fuel Reserves & Resources

Mitigation Strategy: Grid Management of Power Systems with High Penetration of Renewable Energies, Carbon Capture & Sequestration, Electric Vehicles and Advanced Biofuels , The Role of Technology Roadmaps and Roundtables, Introduction to Climate Modeling (GCM and RCM Models)

Reference Books:

1. Climate Change and India – Vulnerability Assessment and Adaptation; Edited by P. R. Shukla, Subodh K. Sharma, N. H. Ravindranath, AmitGarg, Sumana Bhattacharya , Universities Press , 2003
2. Climate Change and India – Vulnerability Assessment and Adaptation; Edited by P. R. Shukla, Subodh K. Sharma, N. H. Ravindranath, AmitGarg, Sumana Bhattacharya , Universities Press , 2003
3. Climate Change and Chemicals Environmental and Biological, aspects; Golam Kibria, A. K. Yousef Haroon, Dayunthi Nugegoda and Gavin Rose, Published by New India Publishing Agency, 2010
4. Global Warming – The Complete Briefing, third edition; John Honghton, Cambridge University Press, 2004,
5. Climate Change- Causes Effects and Solutions; John T. Hardy, Wiley
6. Paleoclimatology, Third Edition, Reconstructing Climate of the Quaternary; Raymond S. Bradley, Elsevier Inc.

CEL 532 DESIGN OF EXPERIMENTS [(3-0-0); Credits: 3]

Course Outcomes:

1. To understand the importance of statistical design of experiments
2. To choose an appropriate experimental design based on the study objectives
3. To analyze the data collected based on the design used and its underlying assumptions
4. To interpret the results of the experiment and report the conclusions

Introduction Strategy of Experimentation, Some Typical Applications of Experimental Design, Basic Principles, Guidelines for Designing Experiments

Experiments with a Single Factor: The Analysis of Variance(ANOVA),The Analysis of Variance, Analysis of the Fixed Effects Model, Decomposition of the Total Sum of Squares Statistical Analysis, Estimation of the Model Parameters, Unbalanced Data, Model Adequacy Checking, Determining Sample Size, The Random Effects Model, A Single Random Factor, Analysis of Variance for the Random Model, The Regression Approach to the Analysis of, Least Squares Estimation of the Model Parameters, The General Regression Significance Test.

Experimental designs: Randomized complete block design (RCBD), experimental designs: Variants of RCBD such as Latin Square, central composite design, etc. Experimental designs: Full factorial experiments Experimental designs: 2k factorial experiments, Experimental designs: Fractional factorial experiments, Experimental designs: 2k-p factorial experiments, Response surface methodology (RSM)

Laboratory quality control: **Standard control chart concepts: X-bar and range charts,** Shewhart Chart,

Limit of detection: **approach to estimating the MDL, a**nalyzing censored data,

REFERRENCES:

1. M.R. Speigel, Probability and Statistics, McGraw Hill
2. D. C. Montgomery “Design and Analysis of Experiments”, John-Wiley-India

Pre-requisite: Basic statistics

CEL-541 WATER DISTRIBUTION SYSTEM DESIGN **[(3-0-0); Credits: 3]**

Course Outcomes:
Upon completing this course, the students shall be able to:
1. Carry out crisp value and uncertaintybased analysis of a given water distribution network.
2. Understand the ways to handle uncertainties in network
3. Analyze the reliability of a given network and
4.Optimize water distribution network for a given reliability.

Analysis of distribution networks with controlling elements, Rules for solvability of pipe networks, Unknown pipe characteristics in network analysis

Performance of water distribution networks under deficient condition, Various models, Bhave'sNFA method, Performance of primary and secondary networks under deficient condition.

Fuzzy analysis of Water Distribution Networks – Fuzzy parameters, Membership function, Methods to obtain membership functions of dependent parameters using Optimization method and Method based on Impact table

Reliability Analysis – Factors affecting reliability, Topological and hydraulic redundancy, Concepts and measures in reliability analysis, Introduction to analytical and simulation methods, Reliability factors.

Uncertainty analysis – Monte Carlo simulation, FORM method etc.

Design of Water Distribution Networks
i) Minimum cost design, ii) Flexible design based on flow distribution models, iii) Reliability based design iv) Resiliency based design

Text Books

i) Bhave, P. R. and Gupta R. *Analysis of water distribution networks,* Narosa Publishing House Pvt. Ltd., 2006
ii) Bhave, P. R. *Optimal design of water distribution networks,*Narosa Publishing House, New Delhi, 2003.
iii) Walski, T. M. "Analysis of water distribution systems". Van Nostrand Reinhold Co., New York, USA, 1984.
iv) Walski, T. M., Gessler, J., and Sjostrom, J. M. Water Distribution Systems: Simulation and Sizing. Lewis publishers, Inc. Chelsea, Michigan, USA, 1990.

Reference Books

i) Patrick D. T. O'Connor, "Practical reliability Engineering", John Wiley and Sons., Ltd. Fourth edition, 2003.
ii) CPHEEO Manual on Water supply and Treatment, Ministry of urban development, New Delhi,
iii) Mays, L. W. ed. "Reliability analysis of water distribution systems", ASCE, New York, USA.
iv) L. W. Mays, ed. Water distribution systems handbook,The McGraw-Hill Cos., New York, USA.