Scheme of Instruction, Evaluation

and

Syllabi of

M.E. (CIVIL)

with specialization in

TRANSPORTATION ENGINEERING

Regular

With effect from Academic Year 2026-27

DEPARTMENT OF CIVIL ENGINEERING

UNIVERSITY COLLEGE OF ENGINEERING

(Autonomous)

Osmania University

Hyderabad – 500 007, TS, INDIA

Estd.1917

Estd.1929

INSTITUTION

The University College of Engineering is established in the prestigious Osmania University, Hyderabad in the year 1929 having the distinction of being the 6th oldest Engineering College in the then British India. The college become autonomous in the year 1994. Over the decades, the UCE(A), OU has produced several illustrious alumni who brought laurels to the nation at world forums. The college is offering BE in eight branches viz., AI&ML, BME, CE, CSE, EEE, ECE, ME and Mining Engineering; ME in 22 specialisations with majority of them receiving NBA Accreditation. The college offers Ph.D. in all ME specialisations. The college has well established laboratories and research facilities and is well placed in NIRF Rankings. The faculty members are well qualified and several of them received Best Teacher Award from Government of Telangana state. They are serving as expert members on several professional bodies, state and national level committees. The faculty members authored several research publications, text/reference books and extend consultancy services.

Vision

The Vision of the institute is to generate and disseminate knowledge through harmonious blending of science, engineering and technology. To serve the society by developing a modern technology in students' heightened intellectual, cultural, ethical and humane sensitivities, fostering a scientific temper and promoting professional and technological expertise.

Mission

- To achieve excellence in Teaching and Research
- To generate, disseminate and preserve knowledge
- To enable empowerment through knowledge and information
- Advancement of knowledge in Engineering, Science and Technology
- Promote learning in free thinking and innovative environment
- Cultivate skills, attitudes to promote knowledge creation
- Rendering socially relevant technical services to the community
- To impart new skills of technology development
- To inculcate entrepreneurial talents and technology appreciation Programs
- Technology transfer and incubation

DEPARTMENT

The Department of Civil Engineering was established in the year 1929 and was the first Department to commence the undergraduate program at University college of Engineering, Osmania University. Over the years, the Department grew from strength to strength in terms of its academic achievements and infrastructure development. The Department has produced many All India GATE 1st Rankers / Toppers in Indian Civil Services / IES / State Public Service Commission Tests and those who got admitted in to IITs/IISc./Top Universities in the world for higher studies. The renowned alumni of this Department include several successful Engineers in Government Departments / Consultants / Contractors / Academicians who made positive contribution to the development of State and Nation.
Currently, the Department offers BE in Civil Engineering; ME in Structural Engineering, Geotechnical Engineering, Water Resources Engineering and Transportation Engineering specializations and Ph.D.

programs. The Department also has the distinction of enrolling large number of foreign students both at UG and PG level. The Department provides research and consultancy services to various organizations. Several faculty members have received prestigious awards including the Best Teacher awards of the State Government and the Best Publication awards reflecting high standards in teaching and research. Many of the faculty members are listed in several national and international biographical directories. Many of them are serving in Panel of Experts in the State and National level committees. The faculty members have published over 1500 papers in various international and national journals and conferences besides text books and professional books.

Vision

To be as a leading academic department on pace with global standards and contribute to the development of economic, technically viable and useful to societal problems and challenges of civil engineering profession and also contribute to the regional and country's developmental activities.

Mission

- To produce highly competent and capable professionals to face the challenges and provide viable solutions to Civil Engineering problems
- Integration of their knowledge and skills to excel in the profession through continuous learning and contribute to the well-being of the society.
- To enhance the technical knowledge, research aptitude to serve the society in highly competent manner.

Program Educational Objectives:

1. **PEO1**: Apply and enrich technical knowledge in the fields of Highway, Traffic and Transportation Engineering
2. **PEO2**: Exposure to the state-of-art testing techniques / methods of analyzing and designs to be adopted for solving different problems related to Transportation Engineering.
3. **PEO3**: Motivate and engage themselves to carryout innovative research in core and multidisciplinary areas and disseminate the same through publications.
4. **PEO4**: Communicate effectively with peers and practice their profession with regard to societal needs, with ethical responsibilities for sustainable development

Program Outcomes:

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 degree.
PO4	Familiar to use and apply the analysis methods / state of the art testing/construction techniques for solving various problems related to Transportation Engineering
PO5	Able to conduct surveys and design of the transportation engineering infrastructure facilities for safe urban transportation systems.

The PEOs fully integrated with the Vision and Mission of the Department. The Vision and Mission of the Department are mapped with the PEO's and their details are shown below:

Vision Vs. PEOs

Vision of Department	PEO1	PEO2	PEO3	PEO4
	*3**	*3*	*3*	*3*

**3-Strong, 2- moderate 1-Low*

Mission Vs. PEOs

Mission	PEO1	PEO2	PEO3	PEO4
M-1	*3*	*2*	*3*	*3*
M-2	*3*	*2*	*2*	*3*
M-3	*3*	*3*	*3*	*3*
Average	*3.00*	*2.33*	*2.67*	*3.00*

PEOs vs. POs Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	Average PEO's
PEO1	*3*	*1*	*2*	*2*	*2*	*2.00*
PEO2	*2*	*1*	*3*	*3*	*2*	*2.20*
PEO3	*3*	*3*	*3*	*2*	*2*	*2.60*
PEO4	*3*	*3*	*2*	*2*	*2*	*2.40*

Target Grand Average of PEOs:

PEO1	PEO2	PEO3	PEO4
2.67	2.51	2.76	2.80

TABLE-I

Scheme of Instruction and Evaluation for M.E./M. Tech. Programs

w.e.f. 2026-27

S. No.	Course Code	Course Name	Contact hours per week		Scheme of Examination		Credits
			L	P	CIE	SEE	
		SEMESTER-I					
1.		Core-I	3	---	40	60	3
2.		Core-II	3	---	40	60	3
3.		Core-II	3		40	60	3
4.		Program Elective-I	3	---	40	60	3
5.		Program Elective-II	3	---	40	60	3
6.		Program Elective-III	3	---	40	60	3
7.		Laboratory-I	0	2	50	-	1
8.		Seminar	0	2	50	-	1
		TOTAL	**18**	**4**	**340**	**360**	**20**
		SEMESTER-II					
1.		Core-IV	3	---	40	60	3
2.		Core-V	3	---	40	60	3
3.		Core-VI	3	---	40	60	3
4.		Program Elective-IV	3	---	40	60	3
5.		Program Elective-IV	3	---	40	60	3
6.		Open Elective	3	---	40	60	3
7.		Mini Project	---	4	50	---	2
8.		Laboratory-II	---	2	50	---	1
9.		Laboratory-III	---	2	50	---	1
		TOTAL	**18**	**8**	**390**	**360**	**22**
		SEMESTER-III					
1.		Audi Course-I (Online)	2	---	40	60	0
2.		Audi Course-II (Online)	2	---	40	60	0
3.		Dissertation-I	---	20*	100	---	10
		TOTAL	**4**	**20**	**180**	**120**	**10**
		SEMESTER-IV					
1.		Dissertation-II	---	32*	100	100	16
		GRAND TOTAL	**40**	**64**	**1010**	**940**	**68**

Note:

i. Dissertation-II has two parts, CIE - I and CIE - II, at the end of 8th week and 16th week respectively for evaluation of 50 marks each.

ii. Audit Course will be offered in ONLINE/OFFLINE/HYBRID mode and SEE will be conducted in Computer Based Test Mode.

iii. Research Methodology and IPR will be offered as an Audit Course for all PG Programs.

iv. Engineering Research Methodology workshop will be conducted for one week to the Ph.D scholars.

***The student has to work a minimum of 20 hours/week and 32 hours/week at Dissertation - I and II.**

ME CIVIL TRANSPORTATION ENGINEERING

Syllabus with effect from AY 2026-27

TABLE -1

Scheme & Syllabus for

M.E. (Civil Engineering) Specialization in **Transportation Engineering**

With effect from the academic year 2026-27

Type of course	Course Code	Course Name	Contact hours per week		Scheme of Examination		Credits
			L	P	CIE	SEE	
SEMESTER-I							
Core-I	CE401	Pavement Materials Characterization	3		40	60	3
Core-II	CE402	Urban Transportation System Planning	3		40	60	3
Core-III	CE403	Traffic Engineering	3		40	60	3
Program Elective-I	CE411 CE412 CE413	Intelligent Transportation Systems Behavioral Modelling Transportation Modelling & Simulation	3		40	60	3
Program Elective-II	CE414 CE415 CE104	Economic Evaluation and Analysis of Transportation Projects Rural and Regional Transportation Systems Finite Element Methods	3		40	60	3
Program Elective-III	CE416 CE417 CE 124	Statistical Techniques Highway Construction and Quality Control Bridge Engineering	3		40	60	3
Mandatory	CE451	Traffic Engineering Lab	0	2	50	-	1
Mandatory	CE461	Seminar	0	2	50	-	1
		TOTAL	**18**	**4**	**340**	**360**	**20**
SEMESTER-II							
Core-IV	CE404	Design of Highway Infrastructure	3		40	60	3
Core-V	CE405	Pavement Systems Engineering	3		40	60	3
Core-VI	CE406	Analysis of Transportation Systems	3		40	60	3
Program Elective-IV	CE418 CE422 CE420	Pavement Evaluation Maintenance & Management Ground Improvement Techniques Road Safety and Traffic Management	3		40	60	3
Program Elective-V	CE421 CE 305 CE419	Rural Roads High-Speed Rail Infrastructure and Planning Airport Planning & Design	3		40	60	3
Open Elective	OE941CE OE942CE OE941ME OE942ME OE943ME OE941CS OE941EE	Green Building Technology Cost Management of Engineering Projects Operation Research Composite Materials Industrial Safety Business Analytics Waste to Energy	3		40	60	3

	OE942EE OE941EC OE941BM OE942BM OE 941LA	Power Plant Control &Instrumentation Elements of Embedded Systems Medical Assistive Devices Medical Imaging Techniques Intellectual Property Rights					
Mandatory	CE471	Mini Project	0	4	50		2
Mandatory	CE453	Pavement Engineering Lab	0	2	50	-	1
Mandatory	CE452	Highway Materials Lab	0	2	50	-	1
		TOTAL	18	8	390	360	22
SEMESTER-III							
Audit-I	AC 030	Engineering Research Methodology	2		40	60	0
Audit-II	AC 031 AC 032 AC 033 AC 034 AC 035 AC 036 AC 037 AC 038	English for Research Paper Writing Disaster Mitigation & Management Sanskrit for Technical Education Value Education Stress Management by Yoga Personality Development Constitution of India Pedagogy Studies	2		40	60	0
	CE481	Dissertation Major Project Phase-I	---	20*	100	-	10
		TOTAL	4	20	180	**120**	10
SEMESTER-IV							
	CE482	Dissertation Phase-II	---	32*	100	100	16
		GRAND TOTAL	40	64	1010	940	68

CIE : Continuous Internal Evaluation SEE : Semester End Examination

Note:

v. Dissertation-II has two parts, CIE - I and CIE - II, at the end of 8th week and 16th week respectively for evaluation of 50 marks each.

vi. Audit Course will be offered in ONLINE/OFFLINE/HYBRID mode and SEE will be conducted in Computer Based Test Mode.

vii. Research Methodology and IPR will be offered as an Audit Course for all PG Programs.

viii. Engineering Research Methodology workshop will be conducted for one week to the Ph.D scholars.

***The student has to work a minimum of 20 hours/week and 32 hours/week at Dissertation - I and II.**

SEMESTER-I

CE 401	**PAVEMENT MATERIALS CHARACTERIZATION**					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	Understand various tests on subgrade soil, aggregates, bitumen and cement
2	Learn bituminous mix and cement concrete mix designs
3	Learn basic principles of superpave technology of bituminous mixes

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Learn importance of the index properties and the various tests conducted on subgrade soil and road aggregates
CO-2	Can be able to learn on subgrade soil strength in terms of various standard engineering parameters and choose appropriate stabilization technique by using different admixtures.
CO-3	Able to perform design calculations of bituminous mixes designs based on various tests conducted on bitumen and determine optimum binder content.
CO-4	Understand the various tests conducted on bitumen and mixes as per Superpave Technology.
CO-5	Able to perform cement mixes design calculations and apply corrections.

Course outcome	**Program Outcome**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	3	2	2	1
CO-2	3	2	3	2	1
CO-3	3	3	2	2	1
CO-4	2	2	2	2	1
CO-5	2	2	2	2	1

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit – I
Soil and Aggregate: Soil-Classification methods, AASTO Method, USCS, IS Method; Tests on soil: Consistency, Engineering Properties, CBR, and Modulus of sub-grade reaction of soil, selection of

suitable filter for soils, Triaxial method and Dynamic Cone Penetrometer (DCP). Aggregate Origin, Classification, requirements, properties and tests on road aggregates used for flexible and rigid pavements. Blending of aggregates, Importance of aggregate shape factor in mix design.

Unit – II
Methods of Soil Stabilization: Method of sampling and Preparation of Stabilized Soils for Testing, Relation for Moisture content and Dry Density of Stabilized mixes, Thawing & freezing tests for compacted soil cement mix, UCS of Stabilized soil; Stabilization Methods: mechanical soil stabilization, lime-soil, soil-bituminous, foamed bitumen, soil-lime- fly ash mixes, soil-cement.

Unit – III
Bitumen and Bituminous Mix Design; Origin, preparation, Definitions, properties, requirements, criteria for selection of different binders, Types of Bituminous emulsion and Cutbacks, fillers, extenders, polymers, Crum rubber, and rubber modified bitumen and anti-Stripping agents on pavement performance. Blending method of aggregates, Bituminous mix design as per Marshall Mix method, binder content, gradation, Engineering properties: Marshal stability test; example problem, static creep test, Resilient & dynamic modulus test, flexural test, splitting tension test. Introduction to Recycling of bituminous mixes.

Unit – IV
Introduction to Super pave Technology: Methods of selection of suitable ingredients for super pave method, PG bitumen, Gyratory compaction, rolling thin film oven, pressure aging vessel, rotational viscometer, dynamic shear rheometer, bending beam rheometer, direct tension test. Use of super pave perform and grade binder specifications. Comparison between Marshal Mix method and Super pave method. Methods of selection of suitable ingredients for super pave method, PG bitumen, Gyratory compaction

Unit – V
Cement and Cement concrete mixes: Tests on Cement, Requirements of paving concrete, water cement ratio, grade of concrete, mix design with example problem, moisture-corrections, mineral and chemical admixtures, Role of different admixtures in cement concrete performance and tests on fresh and hardened cement concrete. Methods of recycling, equipment, Introduction to recycling of cement concrete. Tests on Cement, Requirements of paving concrete, water cement ratio, grade of concrete, mix design with example problem

Suggested Reading:

1	Paul H. Wright, Karen K. Dixon, *Highway Engineering*, John Wiley & Sons, 7th edition, 2004.
2	Yoder E.J, and Witczak , *Principles of Pavement Design*, M. W. John Wiley & Sons, 1975.
3	Asphalt Institute, *Superpave Mix Design*. Superpave Series No. 2 (SP-02). Asphalt Institute. Lexington, KY, 2001.
4	Srinivasa Kumar R, *Text Book of Highway Engineering*, Universities Press, India, 2014.
5	Related publications/codes of IRC and IS.

Syllabus with effect from AY 2026-27

CE 402	URBAN TRANSPORTATION SYSTEMS PLANNING					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To discuss various urban transportation systems planning process and its components
2	To understand a variety of travel surveys and data collection procedures
3	To review different travel demand forecasting models
4	To examine urban land use models and urban goods transportation models

Course Outcomes:	
On completion of this course, the student will be able to:	
CO-1	Able to apply the planning methodologies.
CO-2	To identify the appropriate data collection methods and its procedures.
CO-3	Able to perform travel demand forecasting.
CO-4	Perform trip distribution and model split analysis.
CO-5	Perform trip assignment and prepare master plan.

Course outcome	**Program Outcome**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	2	1	2	0	1
CO-2	2	2	2	1	1
CO-3	2	2	1	1	1
CO-4	2	1	1	0	1
CO-5	2	2	2	1	0

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit - I
Components of Transportation System and Challenges; Transportation system definition, urban issues, evolution of planning process, demand and supply, challenges, limitation, measure of effectiveness, measure of collectiveness, traffic problem elements, planning and management, models, planning methodologies. Emerging future trends in Transportation Systems.

Unit - II

Data Collection and Travel Surveys; Collection of data, design of survey format, organization of surveys and analysis, study area definition, zoning system, types and sources of data, road side interview method, home interview survey, in-vehicle surveys, sampling, types, various techniques, expansion factors, logical checks, use of secondary sources of data, planning variables, vehicles ownership, projection of data and statistical techniques.

Unit - III

Travel Demand Forecasting; Various trends, overall planning process, short and long term planning, travel attributes, traffic analysis zones, trip generation, category analysis, concept of gravity model, trip distribution, model split and trip assignment and land use transportation interaction.

Unit - IV

Trip Distribution and Model Split Analysis; Growth factor models, synthetic pattern models, gravity model, competing opportunity model, intervening opportunity model, linear programming model and abstract mode model, time series models, aggregate and disaggregate models, mode choice, competing modes, mode split models, trip interchange, Toronto transit model, service ratio model, probabilistic models, discriminate analysis, probit analysis and logit analysis, and probabilistic approaches. Growth factor models, synthetic pattern models, gravity model, competing opportunity model, intervening opportunity model, linear programming model

Unit - V

Traffic Assignment and Plan Preparation; Nodes, links, transport. network, coding, rout characteristics, network skims, various methods, judgment, towpath method, diversion curves, network, assignment, all or nothing assignment, capacity restraint techniques, multi-path assignment technique, graph theory, probabilistic assignment model, allocation of traffic, equilibrium assignment, dynamic assignment, land use transport @ .models, Lowry models, Garin Lowry models, ISGLUTI models, mobility and accessibility, five stage models, choice models, urban goods transport, strategies for the evaluation of alternate transportation plans and plan implementation, framework and case studies, preparation of master plans. Nodes, links, transport. network, coding, rout characteristics, network skims, various methods, judgment.

Suggested Readings:

1	Hutchinson, E.G., Principles of Urban Transport Systems Planning, McGraw Hill, New York, 1974.
2	Ortuzar, J. and Williamson, E.G., Modelling Transport, Wiley, Chinchestor, 1994.
3	Oppenheim, N., Urban Travel Demand Modelling: From Individual Choices to General Equilibrium, Wiley, New York, 1995.
4	Thomas, R., Traffic Assignment Techniques, Avebury Technical, Aldershot, 1991
5	Taniguchi, E., Thompson, R.G, Yamada, T. and Van Duin, R., City Logistics – Network Modelling and Intelligent Transport Systems, Elsevier, Pergamon, Oxford, 2001.
6	Bruton, M.I, Introduction to Transportation Planning, Hutchinson, .London, 1985.
7	Dickey, J.W, Metropolitan Transportation Planning, Tata McGraw Hill, New Delhi, 1975.

E 403	**TRAFFIC ENGINEERING**					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To understand the basic aspects of traffic Engineering.
2	To describe basic techniques for collecting and analysing traffic data, diagnosing problems.

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Knowledge on traffic stream characteristics and apply the statistical concepts and applications in traffic engineering.
CO-2	Able to conduct traffic studies and Identify traffic problems.
CO-3	Solve the problems related to travel time and delay.
CO-4	Knowledge on traffic capacity and level of service.
CO-5	Design a pre-timed traffic signal and determine the signal splits.

Course outcome	**Program Outcome**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	2	2	1	1	2
CO-2	2	1	1	1	3
CO-3	2	2	1	2	1
CO-4	2	2	1	1	1
CO-5	2	2	2	2	1

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit - I
Basic Aspects of Traffic Engineering Aim of traffic engineering, traffic stream components and characteristics, road user characteristics, vehicle characteristics, acceleration characteristics, measure of quality, measures of separation, relationship among traffic parameters and empirical relationships, mechanics of traffic flow, macroscopic approach, microscopic-approach and human factors approach, discrete distributions, binomial distribution, Poisson's distribution, exponential distribution, normal distribution.

Unit - II
Traffic Studies, Measurement and Analysis; Volume studies, speed studies, travel forecasting principles and techniques, design hourly volumes and speed, origin and destination studies, presentation of data and analysis, testing of hypothesis relating to improvements.

Unit - III
Travel Time amid Delay Studies; Various uses, travel time and delay studies, various methods, data collection and analysis, density studies and headways, gap acceptance studies, intersection delay studies, traffic flow theory, queuing theory and simulation models.

Unit - IV
Capacity Analysis of Traffic Facilities; Uninterrupted facilities, interrupted facilities, Level of Service, quality of service as per HCM, factors affecting LOS, computation of capacity and LOS, Measure of effectiveness, highway capacity and performance characteristics, intersection design.
Topics to be taught by Industry Subject Expert Uninterrupted facilities, interrupted facilities, Level of Service, quality of service as per HCM, factors affecting LOS, computation of capacity and LOS,

Unit - V
Traffic Control, Design and Regulation; Traffic signals, types, principles of phasing, time diagram, signalized intersection, saturation flow, saturation headway, capacity of lane group, concept of critical lane group, signal timing, phase plan, phase diagram, splitting of phase, clearance interval, pedestrian requirement, guidelines for protected movements, signal co-ordination, emerging themes, inter-modalism, access management, congestion management, environmental impact assessment.
Topics to be taught by Industry Subject Expert: Traffic signals, types, principles of phasing, time diagram, signalized intersection, saturation flow, saturation headway, capacity of lane group,

Suggested Reading:

1	McShane, W.R., Roess, R.P. and Prassas, E.S., Traffic Engineering. Prentice Hall, Englewood Cliffs, 1997.
2	Highway Capacity Manual, Transportation Research Board, National Research Council, Washington, D.C., 2000.
3	Daganzo, C.R, Fundamentals of Transportation and Traffic Operations, Pergamon, Elsevier Science Inc., New York, 1997.
4	Salter, R.J., Traffic Engineering: Worked Examples, Macmillan, London, 1989.
5	Pignataro, L.J., Traffic Engineering: Theory and Practice, Prentice Hall, Englewood lifts, 1973.
6	Wohl, M. and Martin, B.V, Traffic System Analysis for Engineers and Planners, McGraw Hill, New York, 1983.
7	Drew, D.R., Traffic Flow Theory, McGraw Hill, New York, 1964.

CE 411	**INTELLIGENT TRANSPORTATION SYSTEMS**					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To understand theory of problems of traffic flow and definitions of ITS
2	To learn traffic data acquisition techniques, technologies, deployment plans and their usage
3	To learn various applications of ITS

Course Outcomes:	
On completion of this course, the student will be able to:	
CO-1	Understand of the basic definitions and historical developments of ITS.
CO-2	Ability of understand various data collection techniques using various technologies applicable to ITS.
CO-3	Functional areas of ITS and their conceptual uses.
CO-4	Gain knowledge on ITS architecture and its planning.
CO-5	Ability to understand various applications of ITS for solving traffic flow problems.

Course outcome	**Program Outcome**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	2	2	1	1	2
CO-2	2	2	1	1	1
CO-3	2	2	1	2	1
CO-4	2	2	1	1	1
CO-5	2	2	2	2	1

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit - I
Fundamentals of Intelligent Transportation System (ITS): I Introduction to ITS, Definition of ITS, Objectives of ITS, Benefits of ITS, The historical Context of ITS from both public policy and market economic perspectives, Types of ITS, Historical Background.

Unit - II

Data Requirements for ITS: Basics of ITS, ITS data collection Techniques- Detectors, Automatic Vehicle Location (AVL), Automatic Vehicle Identification (AVI), GIS, data collection using Videos. Importance of telecommunications in the ITS system. Information Management, Traffic Management Centres (TMC). Application of sensors to Traffic management; Data fusion at traffic management centres; Sensor plan and specification requirements; Elements of Vehicle Location and Route Navigation and Guidance concepts.

Unit - III
Functional areas of ITS: Advanced traffic Management Systems (ATMS) , Advanced Traveler Information Systems (ATIS) Commercial Vehicle Operations (CVO), Additional Vehicle Control Systems(AVCS), Advanced Public Transportation System(APTS), Advanced Rural Transportation System (ARTS), ITS user needs and services. Travel and Traffic Management, Public Transportation Management, Electronic Payment, Commercial Vehicle Operations, Emergency management, Advanced Vehicle Safety systems, Information Management..

Unit - IV
ITS Architecture: Regional and Project ITS architecture; Concepts of operations; ITS Models and Evaluation Methods; Planning and Human Factors issues for ITS, Case studies on deployment planning and system design and operation; **ITS and safety**; and ITS security. ITS as a technology deployment program, research, development and business models/modules, ITS Planning.
Topics to be taught by Industry Subject Expert: Regional and Project ITS architecture; Concepts of operations; ITS Models and Evaluation Methods;

Unit - V
ITS Applications: Traffic and Incident Management Systems**; ITS and sustainable mobility**, travel demand management, electronic toll collection, ITS and Road-pricing; Transportation network operations; commercial vehicle operations and intermodal freight; public transportation applications; ITS and regional strategic transportation planning, including regional architectures; ITS and transportation institutions, Automated highway systems-Vehicle in platoons-Integration of Automated Highway System, ITS Programs in the world- Overviews of ITS implementation in developed countries, ITS in developing countries. requirement, guidelines for protected movements, signal co-ordination, emerging themes, inter-modalism, access management, congestion management, environmental impact assessment.
Topics to be taught by Industry Subject Expert: Traffic and Incident Management Systems, , electronic toll collection, ITS and Road-pricing; Transportation network operations; commercial vehicle operations and intermodal freight; public transportation applications

Suggested Reading:

1	Srinivasa Kumar R, Intelligent Transportation Systems, Universities Press, 2022.
2	Joseph S.S.**,** Perspectives on Intelligent Transportation Systems, Springer, 2017.
3	Chowdhury MA and Sadek A., Fundamentals of Intelligent Transportation Systems Planning, Artech House, USA, 2003.

4	Kan Paul Chen and Jhon Miles, Intelligent Transportation Systems- Hand Book, Recommendations for World Road Association (PIARC), 2000
5	Paolo Pagano (Editor), Intelligent Transportation Systems from Good Practices to Standards, CRC Press, 2016.

CE 412	**BEHAVIOURAL MODELLING**					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To review the background of discrete choice analysis and its applications to transportation.
2	To understand the frame work of choice theories and probabilistic theories
3	To establish aggregate forecasting techniques and various sampling theories.
4	To discuss multidimensional choice sets and estimation of the nested logit model.

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Apply the methods of model estimation
CO-2	To demonstrate the methods of estimation of discrete choice theory and statistics for model estimation
CO-3	To explain binary logit model and multinomial logit models including random utility theory
CO-4	To identify various aggregate forecasting techniques and comparing with traditional methods
CO-5	Apply nested logit model travel demand model

Course outcome	**Program Outcome**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	3			2
CO-2	3	3		1	2
CO-3	3	3		2	1
CO-4	3	3		2	1
CO-5	3	2		2	2

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit - I
Introduction & Review of the statistics of Model Estimation: Background of Discrete Choice-analysis, Transportation applications ofDiscrete Choice Analysis. The estimation problem, small sample properties,asymptotic properties, methods of estimation, key statistical tests.

Unit - II
Theories of Individual Choice Behaviour: Introduction, A frame work for choice theories, rational behaviour, economic consumer theory, discrete choice theory, probabilistic theory.

Unit - III
Binary and Multinomial Choice Models: Random utility theory, binary choice models, examples, maximum likelihood estimation, examples. Theory of multinomial choice, multinomial logit models, properties logit, specification of multinomial logit model, estimation of multinomial logit, examples of estimation results

Unit - IV
Aggregate Forecasting Techniques & Theory of sampling: Problem of aggregation across individuals, typology of aggregation methods, a comparison of methods for aggregate forecasting. Basic sampling concepts, sampling strategies, overview, choosing a sample design for discrete choice analysis.
Topics to be taught by Industry Subject Expert Problem of aggregation across individuals, typology of aggregation methods,

Unit - V
Nested Logit and Models of Travel Demand: Multidimensional choice sets, estimating the nested logit model, multinomial probit model, measure of accessibility, derivation of the nested logit model from the generalized extreme value model. Components of travel demand modelling process, behavioural theory, measurement, statistical model structure and estimation.
Topics to be taught by Industry Subject Expert: Multidimensional choice sets, estimating the nested logit model, multinomial probit model, measure of accessibility,

Suggested Reading:

1	Ben-Akiva, M and Lerman, S. R. "Discrete Choice Analysis:Theory and Application to Travel Demand"". The MIT press, Cambridge, Massachusetts, London.
2	Train, K. E. "Discrete Choice Methods with Simulation".Cambridge University Press, London.

CE 413	**TRANSPORTATION MODELLING AND SIMULATION**					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	Introduction to various models of simulation
2	Describe data processing techniques of simulation
3	Explain exact sampling distributions and testing

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Understand the concepts related to modelling
CO-2	Understand the classification of models
CO-3	Able to perform preliminary data processing
CO-4	Build models for transportation simulation
CO-5	Evaluate and validate the models

Course outcome	**Program Outcome**					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	0.3	0.2	0.1	0.2	0.1	0.1
CO-2	0.2	0.3	0.2	0.1	0.1	0.1
CO-3	0.2	0.2	0.3	0.2	0.1	
CO-4	0.3	0.2		0.2	0.2	0.1
CO-5	0.3	0.3		0.2	0.1	0.1

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit - I
Introduction of Modelling: Fundamentals of systemic approach. System modelling, Model structure, Variables, controllable variables, uncontrollable variables, parameters, coefficients and other statistical methods for testing of models and data.

Unit - II

Classification of Models; Classification of models - Linear models, Non-linear models, Time-invariant models, Time-variant models, State-space models, Distributed. parameter models. System Synthesis- - Direct and Inverse Problems, Role of optimization and Examples from transportation engineering.

Unit - III
Preliminary Data Processing: data collection, Regression Analysis-Linear multiple regression analysis; Analysis of residues, Tests of goodness of fit. Spatial Distribution- Polynomial surfaces, Spline functions, Cluster. analysis and Numerical production of contour maps. Time Series Analysis-Auto-cross. correlation analysis, Identification of trend, spectral analysis, Identification of dominant cycles, smoothening techniques, Filters and forecasting.

Unit - IV
Model Building: Choice of Model Structure- A priori considerations, Selection based upon preliminary data analysis, Comparing model structures. Model Calibration- Role of historical data, Direct and Indirect methods of solving inverse problem-Model Validation.
Topics to be taught by Industry Subject Expert: Choice of Model Structure- A priori considerations, Selection based upon preliminary data analysis,

Unit - V
Simulation; Random variables, Basic concepts. Probability density and distribution functions, Expectation and standard deviation of discrete and continuous random variables and their functions, Covariance and correlation, commonly used theoretical Probability distributions: Uniform, Normal, Binomial, Poisson, Negative exponential. Fitting distributions to raw data: Chi-square and Kolmogrov-Smirnov's tests of the goodness of fit. Central limit theorem, various algorithms for generation of Random numbers. Queuing theory: Elements, Deterministic queues. Applications of Monte, Carlo simulation:" Basic concepts. Generation-of synthetic observations, - Statistical interpretation of the output, Evaluation of definite integrals and examples.
Topics to be taught by Industry Subject Expert: Random variables, Basic concepts. Probability density and distribution functions, Expectation and standard deviation of discrete and continuous random variables and their functions, Covariance and correlation, commonly used theoretical Probability distributions

Suggested Reading :

1	Bratley, P., Fox B. L., Schrage, L. E. B., Guide to Simulation, Springer-Verlag, New York 1983.
2	Leigh, J. R., Modelling and Simulation, Peter Peregrinus, London, 1983.
3	Bernard, Z., Theory of Modeling and Simulation, John- Wiley, New York, 1976.
4	Ortuzar, J. and Willumsen, L.G, Modelling Transport, Wiley, Chinchestor, 1994
5	Hansher, D. A., and Button. K. J., Handbook of Transport Modelling, Pergamon, Oxford, UK, 2000

CE 414	**ECONOMIC EVALUATION AND ANALYSIS OF TRANSPORTATION PROJECTS**					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	Provide knowledge in project formulation and project development.
2	To understand the principles and methods of economic analysis.
3	Study the Transportation related Environmental Impacts.

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Formulate and prepare Detailed Project Report for a highway project.
CO-2	Able to estimate Road user costs.
CO-3	Apply the methods of economic analysis for highway projects.
CO-4	Knowledge on Capital financing, Economic Analysis of BOT and BOOT projects.
CO-5	Prepare Environmental Impact Assessment Report.

Course outcome	**Program Outcome**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	2	3	1	2	1
CO-2	2	1	1	1	0
CO-3	3	2	1	2	1
CO-4	2	2	1	2	1
CO-5	2	2	1	2	1

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit - I
Transportation Projects Formulation and Development: Requirements in project formulation. Components of project, Non-monetary and monetary Criteria in formulation of project. Decision making Criteria input in Project formulation. Preparation of DPR – Guidelines Transport Projects and development: preparation of Project, Highway Planning, Traffic infrastructure, Project formulation, Road Network project development

Unit - II

Economic Evaluation of Transportation plans: Need for Economic Evaluation; Principles of Economic evaluation; Welfare economics; Social costs, Vest charge, Rate of Return. Value of travel time savings; Economic concept of evaluation of travel time savings, issues connected with evaluation of travel time savings. Vehicle operating costs; Components of VOC, Road user cost study in India; Accident costs; Methodologies for economic evaluation of an accident; Factors involved.

Unit - III
Methods of Economic Analysis: Cash flow diagrams, Time value of money, Inflation, Interest, Depreciation, Cost and benefit components, discounting criteria. Equivalent Uniform Annual cost Method; Present worth of cost method; Equivalent uniform annual net return method; Net-present value method; Benefit cost ratio method; Rate of Return Method; Application of these methods to numerical examples.

Unit - IV
Analysis of variable costs and Transportation Asset Management: Types of Capital Financing; valuation; Project appraisal by shadow pricing with case studies. Economic Analysis of BOT and BOOT projects and allocations. Introduction and scope of asset management in India.
Topics to be taught by Industry Subject Expert: Types of Capital Financing; valuation; Project appraisal by shadow pricing with case studies.

Unit - V
Environmental Impact Assessment: Basic concepts, Objectives, Transportation related Environmental Impacts - Vehicular Impacts - Safety and Capacity Impacts - Roadway Impacts – Construction Impacts, Environmental Impact Assessment-Environmental Impact Statement, Environment Audit, Typical case studies.
Topics to be taught by Industry Subject Expert: Basic concepts, Objectives, Transportation related Environmental Impacts - Vehicular Impacts - Safety and Capacity Impacts

Suggested Reading:

1	Transportation Engineering Economics - Heggie. I.G., McGraw Hill Publishers
2	Economic Analysis for Highways - Winfrey. R; International Text Book Company.
3	Traffic Engineering and Transport Planning - L. R. Kadiyali, Khanna Publishers.
4	Road User Cost Study, CRRI.
5	Road Project Appraisal for Developing Countries, J. W. Dickey, John Wiley & Sons.
6	Construction Management & Planning, B.Sengupta, H.Guha, Tata McGraw Hill, New Delhi

CE 415	RURAL AND REGIONAL TRANSPORTATION SYSTEMS					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To impart knowledge on planning and development concepts.
2	To analysis data for transpiration needs forecasting.
3	To make the students capable for analysis of frieght transportation needs.

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Knowledge on planning and development concepts.
CO-2	Understand methodology and models for rural transportation system.
CO-3	Develop population forecasting models.
CO-4	Perform fright transportation analysis.
CO-5	Conduct regional transportation case studies.

Course outcome	**Program Outcome**					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	3	1	2	2	2	
CO-2	3	3		2	1	1
CO-3	2	3		3	1	1
CO-4	2	3		2	2	1
CO-5	3	2		2	3	

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit - I
Planning and Development concepts: Planning of Rural roads, concept of network planning, rural road plan, road alignment and surveys, Governing factors in route selection, factors considered for alignment. Regional analysis and development concepts

Unit - II

Methodology and Models for Rural Transportation System: The role of transportation planning in the overall regional transportation system. Methodology and models for regional transportation system Planning and implementation framework. Statistical methods for validation of models.

Unit - III
Population forecasting Models; Various methods of forecasting models: Cohart survival model, Interregional cohart survival model and Input output models. Rural transport planning process.

Unit - IV
Freight transportation analysis: Survey methods, data collection, forecasting of freight transportation, analysis, model development, truck terminal planning and management. Planning and management of freight transportation.
Topics to be taught by Industry Subject Expert: Freight transportation analysis: Survey methods, data collection, forecasting of freight transportation, analysis,

Unit - V
Regional transportation case studies; Various case studies in regional and rural transportation planning.
Topics to be taught by Industry Subject Expert: Regional transportation case studies

Suggested Reading :

1	D. Salvo Perspectives in Regional Transportation Planning, Lexington Books, USA, 1974.
2	Mishra Sundaram and Prakash Rao, Regional Development Planning in India, Vikas Publishing House Pvt. Ltd., 1974.
3	Seminar, Road -and Road Transport in Rural Areas, Nov. 19-21, 1985, CRRI, New Delhi.

CE 104	**FINITE ELEMENT METHODS**					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	Learn the rudiments of finite element analysis.
2	Study the fundamentals of domain discretization, interpolation, application of boundary conditions, assembly of global matrices, and solution of the resulting algebraic systems.
3	Explain the core concepts of variational and weighted residual methods in FEM.
4	Derive the element stiffness matrix for 1-D, 2-D and 3-D problems.
5	Formulate the simple structural problems in to finite elements.

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Build and analyze the FEA models for various engineering problems related to highway and pavements
CO-2	Identify the information requirements and sources for analysis, design and evaluation.
CO-3	Use the standard finite element software to solve the structural engineering problems
CO-4	Interpret the results obtained from FEA software, not only in terms of conclusions but also awareness of limitations.
CO-5	To solve FEM problems using weight residual techniques.

Course outcome	**Program Outcome**					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	3	3		2	1	1
CO-2	3	3		2	1	1
CO-3	3	4		2	1	
CO-4	3	2		3	2	
CO-5	2	3		3	1	1

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit - I
Introduction to FEM:Types of problems – Types of materials – Elastic, inelastic situations – Types of forces - Body forces, surface traction, point loads – Deformable bodies – Types of deformations – Homogeneous, non-homogeneous problems – Equations of equilibrium for elastic 2-D, 3-D

continua - Equilibrium equations for 2-D, 3-D boundary elements – Boundary conditions – Strain-displacement relation for 2-D, 3-D problems – Stress-strain relation for 2-D, 3-D problems – Plane stress, plane strain problems.
Virtual work formulation:Application to problems of plane trusses with static indeterminacy not exceeding three.
Finite difference method with central differences:Solving ODE‘s and PDE‘s with central differences - Application to beam and plate bending problems of simple geometry.

Unit - II

Variational formulation: Finite element formulation - Stationarity of functional - Given the functional or differential equation – Number of elements limited to two.

1-D Elements:Strain-displacement relation matrix - Stiffness matrix - Minimum potential energy approach - Rayleigh-Ritz Method - Introduction to natural coordinates - Stiffness matrix of second order bar element - Axial bar subjected to point loads, body forces and surface traction forces - Problems with kinematic indeterminacy not exceeding two.

2-D Triangular elements**:** Displacement models - Criterion for convergence - Geometric invariance - Conforming and non-conforming elements - 3-node triangular (CST) element - Strain-displacement matrix - Area coordinates, shape functions - Element stiffness and load matrices – Assembly of global stiffness and load matrices - Problems with kinematic indeterminacy not exceeding three.

2nd Order triangular elements:Shape functions – Degradation technique - Strain-displacement matrix - Expression for stiffness matrix - Load matrices due to body forces and surface traction.

Unit - III

Iso-parametric elements: Quadrilateral elements: **S**hape functions using natural coordinates - Strain-displacement matrices - Load matrices for body force and surface traction - Stiffness matrix - Load matrices for 4-node quadrilateral elements - Gauss quadrature of numerical integration - Problems with rectangular elements, kinematic indeterminacy not exceeding three.

2nd Order Quadrilateral elements:- Shape functions for 2nd order quadrilateral elements and for elements of with serendipity - Strain-displacement matrix - Load matrices for body force and surface traction

Unit - IV

Method of weighted residuals: Galerkin’s method of weighted residuals: Application to problems of mathematics and structural engineering, number of trial functions not exceeding two.

Galerkin’s finite element method: Weak form of trial function - Application to problems of mathematics and structural engineering, number of elements limited to two.

Axi-symmetric problems:Strain-displacement matrix - Stress-strain relationship - Stiffness matrix for 3-noded ring element - Load matrices for body force and surface traction - Problems with kinematic indeterminacy not exceeding three.

Topics to be taught by Industry Subject Expert: Method of weighted residuals: Galerkin’s method of weighted residuals: Application to problems of mathematics and structural engineering, number of trial functions not exceeding two.

Galerkin's finite element method

Unit - V
Tetrahedron elements:Volume coordinates, Strain-displacement matrix - Stiffness matrix - Load matrices due to body force and surface traction - Introduction to hexahedron (brick) elements. Non-linear Finite element analysis:Introduction – Problems with material non-linearity – Problems with geometric non-linearity – Problems with both material and geometric non- linearity. Introduction to MSC Nastran:Illustration on different modules of Nastran - Structural engineering applications of the package - Creation of a simple 1-D model, 2-D model and a 3-D model - Analysis and post processing of the results.
Topics to be taught by Industry Subject Expert: Tetrahedron elements:Volume coordinates, Strain-displacement matrix - Stiffness matrix - Load matrices due to body force and surface traction - Introduction to hexahedron (brick) elements. Non-linear Finite element analysis

Suggested Reading :

1	R.D. Cook, "Concepts and Application of Finite Element Analysis", John Wiley and Sons, 1981.
2	O.C. Zienkiewicz and R.L. Taylor, "The Finite Element Method, Volume 1: The Basis", McGraw-Hill, London, 1989.J.N. Reddy, "An Introduction to the Finite Element Method", McGraw-Hill, New York, 1993.
3	David V. Hutton, "Fundamentals of Finite Element Analysis", Tata McGraw-Hill, New Delhi, 2005.
4	K.J. Bathe, "Finite Element Procedures", Prentice Hall of India, New Delhi, 2006.
5	T.R. Chandrupatla and A.D. Belegundu, "Introduction to Finite Elements in Engineering", Prentice Hall of India, New Delhi, 2001.
6	P. Seshu, "Finite Element Analysis", Prentice Hall of India, New Delhi, 2003.

CE 416	**STATISTICAL TECHNIQUES**					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To introduce fundamental knowledge of sampling technique.
2	To describe basic statistical techniques such as statistical distributions and correlation methods.
3	To impart knowledge on exact sampling distributions and the tests of significance.

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Use sampling techniques for conducting various surveys related to transportation Engineering
CO-2	Apply the statistical distributions to traffic problems
CO-3	Decide best fit and develop the regression equations for the given variables
CO-4	Apply multi-variant data distributions.
CO-5	Applications of sampling distributions in Highway and Traffic Engineering problems.

Course outcome	**Program Outcome**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	3	3	3	3
CO-2	2	2	2	2	2
CO-3	2	2	2	2	2
CO-4	1	0	0	2	0
CO-5	0	0	0	1	1

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit - I
Introduction: Frequency distribution; Measures of central tendency; Measures of dispersion; Standard error, Moments (about mean, arbitrary numbers and origin); Skewness; Kurtosis; Sampling-Definitions and Applications; Simple random sampling; Stratified sampling; Systematic sampling; Sample size determination; Applications in Highway and Traffic Engineering

Unit - II

Statistical Distribution; Probability, Bayes' Theorem; Binomial, Poisson, Exponential and Normal distributions; Fitting of distributions; Mean and variance; Chi-square test of goodness-of-fit; Applications in Highway and traffic Engineering. Mathematical expectation.

Unit - III
Regression and Correlation: Linear regression and correlation; Multiple correlation; Multiple correlation coefficient; Standard error of estimate; Analysis of variance; Curvilinear regression; Applications in Transportation Engineering.

Unit - IV
Multi Variate Data Distributions; Types of data; Basic vectors and matrices; Simple estimate of centroid, Standard deviation Variance and covariance; Correlation matrices; Principal component analysis; Time series analysis. Estimation-Point Estimation interval Estimation, Box Plot, Maximum likelihood estimation, Biased & Non-Biased Estimation.
Topics to be taught by Industry Subject Expert: Types of data; Basic vectors and matrices; Simple estimate of centroid, Standard deviation Variance and covariance

Unit - V
Exact Sampling Distributions and Tests of Significance; Chi-square distribution; students t-distribution; Snedectors F-distribution. Large sample and small sample tests; Tests for single mean. Means of two samples, Proportions, two variances, two observed correlation coefficients, paired T-tests, Applications. Intervals for mean, variance and regression Coefficients; Applications in Highway and Traffic Engineering Problems.
Topics to be taught by Industry Subject Expert: Chi-square distribution; students t-distribution; Snedectors F-distribution. Large sample and small sample tests; Tests for single mean. Means of two samples, Proportions, two variances

Suggested Reading:

1	Basic Statistics - Simpson and Kafks; Oxford and IBH Calcutta,1969.
2	Fundamentals of Mathematical Statistics - Gupta, S.C. and Kapoor, K. V. Sultanchand
3	Multivariate Data Analysis – Cootey W.W &Cochens P.R; John Wiley & Sons

CE 417	**HIGHWAY CONSTRUCTION AND QUALITY CONTROL**					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To introduce the concepts related to construction planning and management.
2	The students are expected to understand the principles and techniques of various methods of pavement construction.
3	Understand the quality control methods and techniques for flexible and rigid pavements

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Plan and control construction related activities.
CO-2	Gain knowledge about different methods and techniques of base, sub base and drainage construction.
CO-3	Understand bituminous pavement construction procedure
CO-4	Understand cement concrete pavement construction procedure
CO-5	Able to perform quality control checks on pavements.

Course outcome	**Program Outcome**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	2	1	1	1	1
CO-2	2	1	1	2	1
CO-3	3	1	2	2	1
CO-4	3	1	2	2	1
CO-5	1	2	1	1	1

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit - I
Construction Planning and Management: Need and significance of Highway construction planning, Role of labour and machinery in construction; Time, cost and resource management of projects for planning, scheduling, Control and forecast using networks with Bar chart, Critical Path Method (CPM), PERT; Personal, material and finance management, Safety Engineering. Various types of equipment for excavation, grading and compaction - their working principle, advantages and limitations; cement concrete and Bituminous concrete plants.

Unit - II
Construction of Base, Sub base & Drainage layer: General construction, Earth work, Roadway and Drain excavation, Excavation and blasting, Embankment construction, Selection and proportioning of soil elements. Construction of: Earth & Roads, Gravel base, Cement stabilized sub bases, WBM, WMM, Unbound cement bases, Shoulders, Turfing sand, Drains, Sand wicks, Rope drains, Geo-textile drainage, Pre loading techniques. Field Control checks.

Unit - III
Bituminous Pavement Construction: Preparation and laying of Tack Coats, Seal coats, Slurry seal coats, Classification of hot mix paving, Bituminous Macadam, Penetration macadam, Built-up spray grout, Semi dense Asphalt concrete, Interface treatment and overlay construction, IRC specifications, Determination of job mix formula, Types of Mix plants, Introduction to Mechanical Mixers, Pavers, spreaders and Finishes.

Unit - IV
Cement Concrete Construction: Construction of Cement roads Manual and Mechanical methods, use of distributed steel reinforcement, interlocking block pavements, construction: interlocking block pavements, joints in concrete and reinforced concrete pavements and overlay construction, Drainage, Maintenance of roads, Construction of: Hill Roads, Desert Roads and Roads in swampy & Water-logged Areas' and Black cotton Soils, Bridge construction and Inspection Equipment - related equipment. Construction of Cement roads Manual and Mechanical methods, use of distributed steel reinforcement, interlocking block pavements, construction: interlocking block pavements, joints in concrete and reinforced concrete pavements and overlay construction,

Unit - V
Quality Control: Introduction, Requirements of a Highway Project requisite, Specifications and Code of Practice, Quality assurance, Quality Control - ISO 9000, Elements of Quality Assurance System, Distinguish Quality Assurance & Quality Control, Sampling techniques, Tolerance & Controls related to profile and compaction, methods in quality control. Introduction, Requirements of a Highway Project requisite, Specifications and Code of Practice, Quality assurance, Quality Control.

Suggested Reading:

1	Pavement and surfacing for Highway & Airports, MichealSargious, Applied science Publishers Limited.
2	IRC Codes for Flexible and Rigid Pavements design
3	Highway Engineering, Paul H.Wright, Karen K.Dixon, John Wiley& Sons,.7th edition.2004
4	Construction planning. Equipment and methods, PeurifoyR.C,andC.J.Shexnaydr, McGraw Hill, 2002
5	TheAsphalt Handbook, MS-4, Asphalt Institute, Maryland, 1989
6	IRC: Special Publication 11, Handbook on Quality Control for Construction of Roads and Ruwaways, IRC, 1988

7	Specifications for Hotmix plant, IS:5890-1970andIS:3066-1965, New Delhi.

CE 124	BRIDGE ENGINEERING					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	Learn the hydraulic, geological and geo-technical aspects in bridge design.
2	Analyse, design and detail the bridge deck and box girder systems, steel and composite bridges.
3	Analyse and design the sub-structures, bridge bearings and various long span bridges.

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Understand the fundamentals and codes of practice of bridge design.
CO-2	Design the bridge deck and box girder systems using appropriate method.
CO-3	Devise the steel truss and composite steel-concrete bridges.
CO-4	Propose the sub-structure components such as pier, abutments, etc. and bridge bearings.
CO-5	Design the various types of long span bridges, curved and skew bridges.

Course outcome	**Program Outcome**					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	6	1	2	1	-	-
CO-2	6	2	1	1	-	-
CO-3	6	2	1	1	-	-
CO-4	6	5	1	1	5	-
CO-5	6	2	1	1	-	-

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit - I
Introduction:

Types of bridges, materials of construction, codes of practice (Railway and Highway Bridges), aesthetics, loading standards (IRC, RDSO, AASHTO), recent developments box girder bridges, historical bridges (in India and overseas). Planning and layout of bridges, hydraulic design, geological and geo-technical considerations; Design aids, computer software, expert systems.

Unit - II
Concrete Bridges: Bridge deck and approach slabs, Slab design methods, design of bridge deck systems, slab-beam systems (Guyon-Massonet and Hendry Jaeger Methods), box girder systems, analysis and design. Detailing of box girder systems.

Unit - III
Steel and Composite Bridges: Introduction to composite bridges, Advantages and disadvantages, Orthotropic decks, box girders, composite steel-concrete bridges, analysis and design, truss bridges.

Unit - IV
Sub-Structure: Piers, columns and towers, analysis and design, shallow and deep foundations, caissons, abutments and retaining walls. **Bridge appurtenances:** Expansion joints, design of joints, types and functions of bearings, design of elastomeric bearings, railings, drainage system, lighting.
Topics to be taught by Industry Subject Expert: Piers, columns and towers, analysis and design, shallow and deep foundations, caissons, abutments and retaining walls.

Unit - V
Long span bridges: Design principles of continuous box girders, curved and skew bridges, cable stayed and suspension bridges, seismic resistant design, seismic isolation and damping devices. Construction techniques (cast in-situ, prefabricated, incremental launching, free cantilever construction), inspection, maintenance and rehabilitation, current design and construction practices.
Topics to be taught by Industry Subject Expert: Design principles of continuous box girders, curved and skew bridges, cable stayed and suspension bridges, seismic resistant design, seismic isolation and damping devices.

Suggested Reading :

1	Bridge Engineering Handbook", Wai-Fah Chen LianDuan, CRC Press, USA, 2000.
2	Design of Highway Bridges", Barker, P.M. and Puckett, J.A., John Wiley & Sons, New York, 1997.
3	Theory and Design of Bridges", Xanthakos, P.P., John Wiley & Sons, New York, 1994.

CE 451	**TRAFFIC ENGINEERING LAB**					
Pre-requisites			**L**	**T**	**P**	**C**
			-	-	2	1
Evaluation	**SEE**		**CIE**		25 Marks	
Course Objectives:						
The course is taught with the objectives of enabling the student to:						
1	Understand and apply the principles of Traffic Engineering					
2	Able to conduct traffic surveys and analyze the data					
3	Preparing the technical report and presenting the seminar in domain area to disseminate knowledge among professional peers.					

Program Articulation Matrix

Course Outcome	Program Outcome				
	PO1	PO2	PO3	PO4	PO5
CO1	2	1		2	2
CO2	1	2	1	2	1
CO3	1	2		2	1

Experiments:

4. Introduction to Traffic Engineering Laboratory and familiarization with traffic engineering instruments and surveys.
5. Traffic Volume Count Survey and traffic composition analysis.
6. Spot Speed Survey and speed distribution analysis.
7. Speed and Delay Study by Moving Observer Method.
8. Speed and Delay Study at a Signalized Intersection.
9. Traffic Flow Directional Distribution Survey at an Intersection.
10. Traffic Signal Design using Webster's Method.
11. Parking Survey and parking characteristics analysis.
12. Introduction to PTV VISSIM Software (Student version): Familiarization with the software interface, creation of a simple three-legged intersection, traffic data input, and simulation of traffic flow.
13. Traffic Simulation using PTV VISSIM **(**Student version)**:** Simulation of a three-legged signalized intersection and demonstration of traffic signal design using Webster's method and traffic data input.

Note: All tests as per IRC guidelines

CE 461	**SEMINAR**					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	1.5
Evaluation	**SEE**	25 Marks	**CIE**			

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	Identify appropriate topic of relevance.
2	Update literature on technical articles of selected topic and develop comprehension.
3	Prepare a technical report.
4	Deliver presentation on specified technical topic.

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Identify a topic in advanced areas of Transportation Engineering and Literature Review
CO-2	Identify gaps and define objectives & scope of the work
CO-3	Employ the ideas from literature and develop research methodology
CO-4	Develop a model, experimental set-up and / or computational techniques necessary to meet the objectives.
CO-5	Report Writing, and presentation skills

CO-PO MAPPING

Course Outcome	Program Outcome				
	PO1	PO2	PO3	PO4	PO5
CO1	3	2	3	3	2
CO2	3	2	3	3	1
CO3	2	2	1	1	1
CO4	3	2	2	3	2
CO5	2	3	2	3	1

At least two faculty members will be associated with the seminar presentation to evaluate and award marks.

SEMESTER-II

CE 404	**DESIGN OF HIGHWAY INFRASTRUCTURE**					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To provide an overview of concepts involved in geometric design of Highways, horizontal & vertical alignment of roads & pedestrian facilities.
2	Identify key design elements for intersections.
3	Describe usage of traffic control devices.

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Understand the concepts and applications of the elements involved in Highway Geometric Design.
CO-2	Able to design Horizontal and Vertical Curves.
CO-3	Apply the principles of Intersection design.
CO-4	Apply the principles of Intersection design.
CO-5	Able to understand pedestrian elements, bus bays, cycle tracks, subways.

Course outcome	**Program Outcome**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	2	1	0	1	2
CO-2	2	1	1	2	1
CO-3	2	1	1	2	1
CO-4	1	1	2	1	0
CO-5	2	1	1	1	1

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit - I
Geometric Design of Highways: Functional classification of Highway system; Design controls - Topography, Driver characteristics, Vehicle characteristics. Traffic Capacity and Level of Service, Design speed. Objectives of Geometric Design. Road Margins - design specifications; Pavement surface characteristics - Skid Resistance, measurement of skid resistance; Road roughness, measurement of Road roughness; Camber design and standards.

Unit - II

Horizontal and Vertical Alignment: Sight Distance - SSD, OSD and ISD. Horizontal curves, Super elevation; computing of super elevation; attainment of super elevation; Extra widening on curves; Transition curves - Objectives and Design. Gradients - Types of Gradients, Design Standards; Summit Curves, Valley curves and Design criteria. Combination of Vertical and Horizontal curves - Grade Compensation. Importance of Sight Distances for Horizontal and Vertical curves.

Unit - III
Design of Intersections: Types of Intersections; Design Principles for Intersections; Design At-grade Intersections – Channelisation, Objectives; Traffic Islands and Design standards, Rotary Intersection - Concept, Advantages and Disadvantages; Grade separated Interchanges - Types, warrants and Design standards as per IRC.

Unit - IV
Traffic Signs and Road Markings: Types of Road Signs; Guidelines for the provision of Road Signs; Caution Signs, Regulatory signs. Information signs - Design standards. Road markings - Objectives of Road markings; Types of Road Marking, Role of Road markings in Road Safety and Traffic Regulation; Specification for Road Marking Highway Appurtenances-Delineators, Traffic Impact Attenuators, Safety Barriers.
Topics to be taught by Industry Subject Expert: Types of Road Signs; Guidelines for the provision of Road Signs; Caution Signs, Regulatory signs. Information signs - Design standards. Road markings

Unit - V
Pedestrian Elements: Requirements of Pedestrians; Pedestrian facilities on Urban Roads; Cycle Tracks - Guidelines and Design standards; Bus bays-Types and Guide lines-Design of On street and Off street parking facilities - Guidelines for lay out Design. Design of Subways and foot over bridges.
Topics to be taught by Industry Subject Expert: Requirements of Pedestrians; Pedestrian facilities on Urban Roads; Cycle Tracks - Guidelines and Design standards; Bus bays

Suggested Reading:

1	Principles and Practice of Highway Engineering, L.R.Kadiyali and N.B.Lal, Khanna Publications.
2	Traffic Engineering and Transportation Planning, L.R.Kadiyai, Khanna Publications
3	Highway Engineering, C.E.G.Justo and S.K.Khanna, Nem Chand and Brothers
4	IRC Codes for signs, Markings and Mixed Traffic Control in Urban Areas.

CE 405	**PAVEMENT SYSTEMS ENGINEERING**					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	Introduction to various factors affecting pavements design
2	Analysis of stresses in flexible and rigid pavements
3	Concepts of mechanistic empirical methods of flexible and rigid pavements

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Application of basic principles in pavement design and analyze the inputs for pavement design
CO-2	Analyze stresses in flexible pavement
CO-3	Analyze stresses in rigid pavement and dowel bars
CO-4	Design of flexible pavement including filter and drainage layers
CO-5	Design of rigid pavement including dowels and tie bars

Course outcome	**Program Outcome**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	3	2	3	3
CO-2	3	2	3	3	1
CO-3	3	3	2	3	1
CO-4	3	2	2	3	1
CO-5	3	2	3	3	1

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit – I
Introduction to Pavement Design: Types of Pavements, Functions of pavement, types of pavements and functions of their individual Layers, Factors affecting pavement selection,Various Factors affecting pavement design, Traffic factors, Climatic factors, Classification of Axle Types and Articulated Commercial Vehicles, Standard Axle load, Legal Axle and Gross weights on single and multi-units, Methods of measurement of Axle Load and Truck Weight , Tire Pressure, Contact pressure, ESAL concepts, Fourth power rule, factors affecting VDF, Traffic Analysis: ESAL, VDF, 98the percentile axle load, lane distribution, Directional distributions, Effect of Transient & Moving loads.

Unit – II
Stresses in Flexible Pavement: Vehicle-Pavement Interaction, Stress inducing factors in flexible pavement, Stress in Flexible Pavements: Visco-Elastic Theory and Assumptions. Layered system concepts, Stresses in one and two and Linear Elastic Multi-layered Pavement System. Boussinsq theory and assumptions. Burmister Theory and assumptions. Overview on Softwares used for stress analysis.

Unit – III
Stresses in Rigid Pavement: Stresses in Rigid Pavements: Westergaard's theory and Assumptions, Stresses due loading, warping and Frictional Stresses, critical locations of wheel loads on a rigid pavement, Equivalent circular contact area considered for rigid pavement design, Influence of Temperature and moisture, Critical Combined stress Due to Warping and load, Critical combination of stresses in India, Friberg's Analysis of Dowel Bars and deflection of dowels at joints. Overview on software/charts for analysis of rigid pavements

Unit – IV
Design of Flexible pavement: Empirical Methods and their limitations, overview on Pure Mechanistic Method,Mechanistic Design Methodology for Pavements: General Methodology, Classification of design methods; Benefits of Pavement Design Based on M–E Method, Pavement Design Concepts; Flexible Pavement Design Concepts, IRC Method as per IRC37-2018, Salient features of IRC:37-2018, Sub-surface drainage considerations and design of drainage and filter layers, Design Criteria, IRC specifications.
Topics to be taught by Industry Subject Expert: Empirical Methods and their limitations, overview on Pure Mechanistic Method,Mechanistic Design Methodology for Pavements

Unit – V
Design of Rigid Pavements: Types of Rigid Pavements, Pavement Joints, Introduction to Mechanistic Design Process, main factors are considered for the design of rigid pavements, Top-down cracking (TDC) and bottom-up cracking (BUC), Critical location of placement of first rear axle considered for determination of max. edge flexural stress for BUC case and max. tensile stress for TDC case. Design Criteria, IRC specifications, Dowel bar design and design of tie bars as per IRC:58-2015.
Topics to be taught by Industry Subject Expert: Types of Rigid Pavements, Pavement Joints, Introduction to Mechanistic Design Process, main factors are considered for the design of rigid pavements, Top-down cracking (TDC) and bottom-up cracking (BUC),

Suggested Reading:

1	Yang H. Huang, *Pavement Analysis & Design*, Prentice Hall Inc.
2	Yoder J. &Witzac, *Principles of Pavement Design*, John Wiley & Sons
3	Srinivasa Kumar R, *Transportation Engineering*, Universities Press, 2019
4	Srinivasa Kumar R, *Pavement Design*, Universities Press, 2012
5	IRC:58-2015, IRC:37-2018 and Other relevant IRC Codes

CE 406	**ANALYSIS OF TRANSPORTATION SYSTEMS**					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To discuss various components of urban transportation systems and its innovation
2	To understand the concepts of linear programming formulation and various methods
3	To review different transportation and assignment formulations and problems
4	To examine various non-linear programming and decision theories

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	To describe and evaluate various transportation systems impacts on society and economy
CO-2	To identify the different solutions for linear programming problems including sensitivity analysis.
CO-3	To demonstrate effective way of understanding transportation and assignment problems
CO-4	Able to analyse network flows.
CO-5	To explain various issues related to uncertainty and decision theories.

Course outcome	**Program Outcome**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	2	1	1	1	1
CO-2	1	2	1	1	1
CO-3	1	2	1	1	1
CO-4	1	2	0	2	1
CO-5	2	2	0	1	1

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit - I
Introduction to Transportation Systems: Goals and Scope of Transportation System Analysis, components of transportation system, Transportation innovations, Social and economic impacts of transportation, Decision makers and their options, Vehicle factors and Human factors

Unit - II
Linear Programming for Transportation: Formulation of Linear Programming, Graphical solutions, Simplex method, revised simplex method, Duality simplex problem, degeneracy, Big M method, sensitivity analysis and computer solutions for linear programming problems.

Unit - III
Transportation and Assignment Problem: Introduction, mathematical model formulation, Types of Transportation problem - North West corner cell, least cost cell and Vogel's Approximation. Assignment Problem-Introduction, Zero- one programming model. Types of Assignment Problem-Hungerian Method, Branch and Bound Technique.

Unit - IV
Analysis of Network Flows: Introduction, Types of network techniques - shortest path model, minimum spanning tree model and maximal flow model. Project management- CPM and PERT. Introduction, Types of network techniques - shortest path model, minimum spanning tree model and maximal flow model.

Unit - V
Non-Linear Programming and Decision Theory: Formulation, Characteristics of non-linear programming, convexity of a function, unconstrained single and multivariable problems, constrained optimization, quadratic programming, convex programming-gradient search, frank wolf algorithm and golden search code. Decision theory - introduction, game theory, terminologies of game theory, game with pure strategies, game with mixed strategies, dominance property and graphical solutions. Formulation, Characteristics of non-linear programming, convexity of a function, unconstrained single and multivariable problems.

Suggested Reading:

1	Hillier, F.S and Lieberman, G. J, Introduction to Operations Research, McGraw-Hill, Seventh Edition, 2001.
2	Ravindran, A, Philips, D.T and Solberg, J. J, Operations Research: Principles and Practice, John Wiley and Sons, Second Edition 2000.
3	Render, B, Stair, R. M, Quantitative Analysis for Management, Prentice Hall of India Private Limited, Seventh Edition, 2000
4	Wayne L. Winston, Operations Research: Applications and Algorithms, Duxbury Press, Third Edition, 1994.
5	Taha, H.A Operations Research: An Introduction, Prentice Hall of India Private Limited, Seventh Edition, 2003.
6	Paneerselvam, R. Operations Research, Eastern Economy Edition, Prentice Hall of India Private Limited, New Delhi- 2002.

CE 418	**PAVEMENT EVALUATION, MAINTENANCE AND MANAGEMENT**					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	Understand the basic working principles of various NDT equipment used for pavement evaluation
2	Describe design aspects of overlay thickness of pavements
3	Impart knowledge regarding the different types of distresses, PMS and LCCA of pavements

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Apply and acquainted with the fundamental principles of Pavement and understand functional evaluate by using different equipment
CO-2	Awareness about various NDT equipment used for structural pavement evaluation of flexible and rigid pavements
CO-3	Evaluating the distress condition of pavements through surface condition surveys and learn possible alternative treatments
CO-4	Understanding the basic components of pavement management systems and Capacity to perform and apply LCCA to optimize funding expenditures
CO-5	Understand the maintenance needs and propensity for application of knowledge towards of flexible and rigid pavements by using different type of layers.

Course outcome	**Program Outcome**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	2	3	2	1
CO-2	1	1	1	1	1
CO-3	3	2	3	2	1
CO-4	2	2	3	2	1
CO-5	2	2	3	2	1

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit - I
Introduction to Pavement Inventories and Functional Evaluation: Purposes, Classification of pavement evaluation, Basic concept of pavement evaluation and management; functional Evaluation: AASHTO Serviceability concept, International Road Roughness Experiment, Methods

of Measuring Roughness: World Bank Roughness Measurement Systems, Response type & Profile type; IRI: Quarter Car Model, Classification of equipment used for Measurement : MERLIN, Bump Integrator, Dipstick and High speed laser-profiler. Riding Number; Pavement Safety Evaluation: Skid Resistance, measurement of skid, skid resistance, Change of Skid resistance with time, traffic and climate; Control of Skid Resistance.

Unit - II
Structural Evaluation: Purpose, Destructive Structural Evaluation, Non-destructive structural evaluation, Pavement Deflection: Different Methods of NDT (Working Principles): Benkelman Beam and limitations of BB, LaCroixDeflectometer, Dynaflect, Road Ratar, Rolling Dynamic Deflectometer, Loadman, Different Types of Falling Weight Deflectometers (FWD) for evaluation of rigid and flexible pavements; Working principle of Geophone, Factors influencing deflections. Overlay design as per IRC:81; Back-calculation of Pavement Layer Moduli and detection of loss of bonding of cement concrete pavements using FWD data.

Unit - III
Distress/failures Surveys: Distress, definitions, significance of distress measurement,Categorisation of distresses in asphalt pavement: identification, causes and measurement of distresses of Bituminous and Concrete pavements; Visual Rating and severity levels; symbols of distresses observed,PSI, PCI, Distress modes; Distresses and the possible options of repairs to treat distortion, deformation, deterioration disintegration of bituminous and concrete pavements.

Unit - IV
Pavement Maintenance Management: Purpose of PMS, Uses of PMS, Basic terminology used in PMS, Components of PMS and related activities, Major steps in implementing PMS -Network and project level analysis, Pavement performance prediction models , Budgeting; Prioritization Techniques; Feedback system, Pavement Preservation, Decision tree, Methods of Priority Ranking, Basic approaches of PMS, Pavement Life Cycle Cost Analysis (LCCA): Cost Components, Basic steps in LCCA, Solution of LCCA – with typical Components involved.
Pavement Maintenance Management: Purpose of PMS, Uses of PMS, Basic terminology used in PMS, Components of PMS and related activities, Major steps in implementing PM

Unit - V
Highway Maintenance and Treatments: Need of Highway maintenance, Types of maintenance for flexible and rigid pavement layers; WBM, WMM, Bituminous and Cement Concrete pavements; Surface texturing practices, Details of overlay and seal coats: Slurry seal (IRC: SP:81), Open Graded Friction Course,Fibre-stabilized Stone Matrix Asphalt (IRC: SP:79), Microsurfacing, Surface dressing, Semi-Dense Bituminous Concrete, Dense Bituminous Concrete and Bituminous Concrete. Highway Maintenance and Treatments: Need of Highway maintenance, Types of maintenance for flexible and rigid pavement layers; WBM, WMM, Bituminous and Cement Concrete pavements; Surface texturing practices, Details of overlay and seal coats.

Suggested Reading:

1	Haas and Hudson W.R. *Pavement Management Systems* - McGraw Hill publications

2	Srinivasa Kumar R, *Pavement Evaluation Maintenance and Management*, Universities Press, 2014.
3	*Hand Book of Highway Engineering,*RoberF.Baker, Editor, L.G Byrd D.GraritMikle, Associate Edotor, Van Nostrand Reinhold Comp, 1.975
4	Shahin M.Y. 1994 - Pavement Management for airports, roads and parking lots, 1994.
5	Relevant IRC/Morth Codes and manuals

CE 419	HIGH-SPEED RAIL INFRASTRUCTURE AND PLANNING					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To understand the fundamentals of railway engineering and the planning principles of conventional and high-speed rail systems.
2	To develop knowledge of railway track components, geometric alignment design, and infrastructure requirements for high-speed rail corridors.
3	To understand modern railway operations, advanced signalling, train control systems, and safety practices adopted in high-speed rail networks.

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Explain the fundamentals of railway engineering, high-speed rail systems, corridor planning, and railway alignment surveys.
CO-2	Describe the functions and performance of railway track components, permanent way, and track maintenance practices.
CO-3	Apply geometric design principles for planning and designing high-speed rail alignments considering operational and safety requirements.
CO-4	Analyze the infrastructure requirements of high-speed rail systems, including track structures, formation, bridges, tunnels, stations, and associated facilities.
CO-5	Explain modern railway operations, advanced signaling, train protection, interlocking, and intelligent train control systems used in high-speed rail networks.

Course outcome	**Program Outcome**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	2	1	0	1	1
CO-2	1	2	1	1	2
CO-3	2	2	1	1	3
CO-4	1	1	2	1	1
CO-5	2	1	1	1	1

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit - I
Railway Track Components and Permanent Way

Requirements of a good railway track; Components of permanent way; Rails: requirements, rail sections, manufacture, rail wear, rail defects, rail failures and rail flaw detection; Sleepers: functions, requirements, types and sleeper density; Ballast: functions, requirements, types, ballast section and drainage; Track stresses; Elastic behaviour of track; Coning of wheels; Tilting of rails; Creep of rails—causes, effects, measurement and prevention; Maintenance of permanent way.

Unit - II

Rail Alignment Planning and Geometric Design

Principles of High-Speed Rail planning; Route selection criteria; Corridor planning; Passenger demand considerations; Alignment design requirements for High-Speed Rail; Horizontal and vertical alignment; Design speed considerations; Minimum curve radius; Transition curves; Super-elevation and cant deficiency; Vertical curves and gradients; Tunnel and bridge approaches; Land acquisition and environmental considerations; Safety and ride comfort requirements; Comparison between conventional and High-Speed Rail alignment standards.

Unit - III

Rail Alignment Planning and Geometric Design

Principles of High-Speed Rail planning; Route selection criteria; Corridor planning; Passenger demand considerations; Alignment design requirements for High-Speed Rail; Horizontal and vertical alignment; Design speed considerations; Minimum curve radius; Transition curves; Super-elevation and cant deficiency; Vertical curves and gradients; Tunnel and bridge approaches; Land acquisition and environmental considerations; Safety and ride comfort requirements; Comparison between conventional and High-Speed Rail alignment standards.

Unit - IV

High-Speed Rail Infrastructure

High-Speed Rail track systems; Ballasted and ballastless (slab) tracks; Formation and subgrade requirements; Earthwork, embankments and cuttings; Blanketing layer; Ground improvement techniques; Bridge and viaduct structures; Tunnel infrastructure; Station planning for High-Speed Rail; Overhead electrification systems; Fencing and intrusion protection; Noise and vibration mitigation; Inspection and maintenance practices for High-Speed Rail infrastructure. Ballastless track systems; Viaduct construction; Tunnel construction methods; High-Speed Rail station infrastructure; Ground improvement and quality control practices.

Unit - V

Railway Operations, Signaling and Intelligent Systems

Points and crossings; Turnouts for conventional and High-Speed Rail; Level crossings and grade separation; Inspection and maintenance of switches and crossings; Principles of signalling; Train protection and train control systems; Electronic interlocking; Automatic block signalling;

Communication Based Train Control (CBTC); European Train Control System (ETCS); Automatic Train Protection (ATP); Automatic Train Operation (ATO); Railway communication systems; Asset monitoring and intelligent maintenance systems; Safety management in High-Speed Rail operations. Modern signalling systems; ETCS and ATP applications; Electronic interlocking; High-Speed Rail operation and maintenance practices.

Suggested Reading:

1	Chandra, S.andAgarwal.M.M. "Railway Engineering". Oxford University Press, New Delhi, 2007.
2	Rangwala, K. S. "Principles of Railway Engineering". Charotar publishing House, India (1991)
3	Srinivasa Kumar R, “Transportation Engineering (Railways, Airport, Docks & Harbors)” Universities Press, 2014.

CE 420	**ROAD SAFETY AND TRAFFIC MANAGEMENT**					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	Introduction to various factors considered for road safety and management
2	Explain the road safety appurtenances and design elements
3	Discuss the various traffic management techniques

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Prepare accident investigation reports and database
CO-2	Apply design principles for roadway geometrics improvement with various types of traffic safety appurtenances/tools
CO-3	Design traffic signals including visual perception and road markings
CO-4	Understand traffic management techniques and pedestrian safety
CO-5	Manage traffic including incident management

Course outcome	**Program Outcome**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	2	1	0	1	1
CO-2	1	2	1	1	2
CO-3	2	2	1	1	3
CO-4	1	1	2	1	1
CO-5	2	1	1	1	1

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit - I
Road accidents: Causes, scientific investigations and data collection, Analysis of individual accidents to arrive at real causes, statistical methods of analysis of accident data, Basic concepts of Road accident statistics, Safety performance function: The empirical Bayes method Identification of Hazards road location. Application of computer analysis of accident data.

Unit - II

Safety in Road Design: Operating the road network for safety, highway operation and counter measures, road safety audit, principles-procedures and practice, code of good practice and checklists, vehicle design factors & Driver characteristics influencing road safety.

Unit - III
Road Signs and Traffic Signals: Classification, Location of Signs, measures of sign effectiveness, Types of visual perception, sign regulations, sign visibility, sign variables, Text versus symbols. Road Marking: Role of Road markings, Classification, visibility. Traffic Signals: Need, Signal face. Illumination and location of Signals, Factors affecting signal design, pedestrians' safety, fixed and vehicle actuated signals. Design of signa1s, Area Traffic control. Delineators, Traffic Impact Attenuators, Road side rest areas, Safety Barriers, Traffic Aid Posts.

Unit - IV
Traffic Management Techniques: Integrated safety improvement and Traffic Calming Schemes, Speed and load limit, Traffic lights, Safety cameras, Tests on driver and vehicles, pedestrian safety issues, Parking, Parking enforcement and its influence on Accidents. Travel Demand Management; Methods of Traffic management measures: Restriction of Turning Movements, One way streets, Tidal Flow Operation Methods, Exclusive Bus Lanes and Closing Side-streets; Latest tools and techniques used for Road safety and traffic management. Road safety issues and various measures for road safety; Legislation, Enforcement, Education and Propaganda, Air quality, Noise and Energy Impacts; Cost of Road Accidents.
Topics to be taught by Industry Subject Expert: Integrated safety improvement and Traffic Calming Schemes, Speed and load limit, Traffic lights, Safety cameras, Tests on driver and vehicles, pedestrian safety issues, Parking, Parking enforcement and its influence on Accidents.

Unit - V
Incident Management: Introduction, Characteristics of Traffic Incidents, Types of Incidents, Impacts, Incident management process, Incident traffic management; Applications of ITS: Motorist information, Equipment used; Planning effective Incident management program, Best practice in Incident management programs. National importance of survival of Transportation systems during and after all natural disasters especially cyclones, earthquakes, floods etc and manmade disasters like sabotage, terrorism etc.
Topics to be taught by Industry Subject Expert: Introduction, Characteristics of Traffic Incidents, Types of Incidents, Impacts, Incident management process, Incident traffic management;

Suggested Reading:

1	Guidelines on Design and Installation of Road Traffic Signals, IRC:93.
2	Specification for Road Traffic Signals, IS: 7537-1974.
3	Principles and Practice of Highway Engineering by L.R. Kadiyali and N.B.Lal.
4	Hand book of T.E. Myer Kutz, Editor McGraw Hill, 2004
5	Srinivasa Kumar R, "Introduction to Traffic Engineeeing,"Universities Press, 2017.

CE 421	**RURAL ROADS**					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	Introduction to various factors affecting road alignment and planning
2	Introduction to inputs required and design of flexible and pavements
3	Concepts, equipment and procedures applicable for construction and maintenance of rural roads.

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Acquaintance with development of rural road network in India and learn to conduct alignment surveys
CO-2	Application of basic principles in design of flexible pavement rural roads with different combination of layer compositions
CO-3	Ability to analyze stresses in concrete pavement and application of basic principles in design of cement concrete pavements used for rural roads
CO-4	Comprehensive understanding regarding the rural roads construction using different equipment and materials
CO-5	Learn about use of waste materials in road construction and ability to apply knowledge to take up appropriate maintenance measures.

Course outcome	**Program Outcome**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	2	3	3	2
CO-2	3	2	3	3	1
CO-3	1	1	1	1	
CO-4	1	0	1	1	1
CO-5	1	1	2	2	

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit - I
Planning and Alignment: The Jayakar Committee, Initial Major Road Development Plans in India, Classification of Roads, Overview on Road Network in India, National Rural Roads Development Agency, PMGSY, BharathNirman, DRRP, Core Network. Planning of Rural roads, road alignment

and surveys. Governing factors in route selection, factors considered for alignment; Reconnaissance Survey; Preliminary Surveys, Final Location Survey; Details of scales applicable for drawings.

Unit - II
Guidelines and Design of Flexible Pavements: Introduction, Factors governing design, Calculation of traffic data, Salient features of DCP, Design procedure, pavement components, design of flexible pavement as per IRC: SP:72-2014: Design of Gravel/Soil-Aggregate Roads, Recommended Pavement Designs. Types of drainage, General criteria for road drainage and shoulders, system of drainage, surface and subsurface systems.

Unit - III
Guidelines and Design of Cement Concrete Pavements: Factors governing design, Calculation of traffic data, pavement components, Design of Slab thickness as per IRC: SP:62-2014, Sub-base types, calculation of stresses: Computation of equivalent radius of contact area of a dual-wheel, load stresses, temperature stresses, Recommended design procedure; Joints: Types of Joints and their details, Material used and specifications as per MORD.

Unit - IV
Equipments used for road construction, Construction details of Subgrade, Sub-base and base courses: GSB, WBM, WMM, Quality Control in Construction steps of bituminous pavements as per IRC: SP:72 and MORD specifications: Properties of Fly ash, aggregates, soil, sand, bitumen, emulsions, foamed bitumen and other locally available materials, Quality Control in Construction Construction steps of concrete pavements as per IRC: SP:62 and MORD specifications: Properties of Fly ash, aggregates, soil, cement, sand and other locally available materials, Quality Control in Construction. Equipments used for road construction, Construction details of Subgrade, Sub-base and base courses: GSB, WBM, WMM, Quality Control in Construction steps of bituminous pavements

Unit - V
Waste Materials for Pavement Construction: Introduction, Fly ash for road construction, Design & Construction of Fly ash embankments, Lime fly ash stabilized soil. Lime fly ash bound Macadam as per IRC: SP:58, Control of compaction (IS:2720-27), Construction steps. Introduction, Fly ash for road construction, Design & Construction of Fly ash embankments, Lime fly ash stabilized soil.

Suggested Reading:

1	Specifications for Rural Roads, First Revision, Published by IRC, New Delhi, 2014 and Training Manuals and Guidelines available at http://pmgsy.nic.in/
2	Quality Assurance Handbook for Rural Roads, Volume-I and Volume-II, NRRDA, MORD, 2007.
3	IRC: SP-20, 2002, IRC: SP72 and IRC: SP:62, IRC: SP:58 and other related code of IRC
4	Construction of Rural Roads, Learning Unit 2.2.1, Published by International Labor Organization, New Delhi, https://rural.nic.in/sites/default/files/2.2.1Roads_English.pdf
5	Srinivasa Kumar R, Text Book of Highway Engineering, Universities Press, 2014.

CE 305	**GROUND IMPROVEMENT TECHNIQUES**					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To understand the objectives, necessity and scope of ground improvement techniques
2	To learn different methods of insitu densification of cohesive, cohesionless soils
3	To learn the classification, functions and applications of Geosynthetics in ground improvement
4	To learn the process of identification of necessity for ground improvement, finding alternative methods and recommendation of the ideal technique through case studies

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Ability to understand the necessity of ground improvement and evaluation of potential of a ground for improvement
CO-2	comprehensive understanding about the improvement of in-situ cohesive soils as well as Cohesion less soils
CO-3	Knowledge of Grouting & other soil stabilization methods and competence to apply them for ground improvement
CO-4	Ability to understand and implement the Geosynthetic applications
CO-5	Competence to analyse an in-situ ground, identification of ground improvement techniques feasible, selection of the ideal method, its implementation and evaluation of improvement level

Course outcome	**Program Outcome**					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	2	2	2		1	3
CO-2	3		3	1		2
CO-3	3		3	1		2
CO-4	3		3	1		2
CO-5			3	1	1	3

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit – I
Introduction: Objectives and necessity of Ground Improvement – Formation of Rock and soils – Alteration of ground after its formation – Reclaimed soils – , Types and distribution of Soils in

India - marine, black cotton soils (expansive), lateritic, alluvial, desert, peaty Soils etc - Ground improvement potential – Geotechnical processes

Unit – II
Surface Compaction methods: Compaction Mechanism - moisture density relationship – Factors affecting compaction – Laboratory evaluation of Compaction Characteristics – Field Surface Compaction Methods – Compaction procedure – Specification – Quality Control aspects. **In-situ Densification of Cohesionless Soils:** Necessity for Deep compaction – Vibration methods – Vibro-compaction methods (Blasting, Vibratory probe, Dynamic compaction / heavy tamping), Vibro-displacement Methods (Displacement Piles, Sand Compaction Piles), vibro-replacement cum displacement methods (Vibro-floatation, Stone Columns).

Unit – III
In-situ Densification of Cohesive Soils: **Drainage methods** – Methods of dewatering systems - selection of pumps and accessories **Pre-compression methods** – Concept & benefit of pre-compression -consolidation of Clayey soils – Pre-loading technique – consolidation acceleration methods - consolidation aided with vertical drains – Sand Drains - Pre-fabricated vertical drains, Consolidation by Electro-osmosis and vacuum compression methods - Compression monitoring.

Unit – IV
Grouting: Aspects of grouting – Types of grout materials – Classification based on Groutability Ratio - grouting procedure – Applications of grouting in ground improvement. **Soil Stabilisation:** Types and suitability of stabilization methods - Mechanical, Cementing methods – Aggregants and dispersants – Stabilization procedure – quality control in Soil Stabilization.
Topics to be taught by Industry Subject Expert Aspects of grouting – Types of grout materials – Classification based on Groutability Ratio - grouting procedure

Unit – V
Geo-Synthetics: Classification of Geosynthetics – Functions and applications – Concept of design by function. **Reinforced Soil Walls** – Components of a RSW – Types of facia – Types of Reinforcement & factors influencing the selection - Design of RSW – construction procedure - Gabions.
Classification of Geosynthetics – Functions and applications – Concept of design by function.

Suggested Reading:

1	H.R. Hausmann, (2013), *Principles of Ground Modification*, Mc-Graw Hill Publications.
2	P.Nicholson, (2015), *Soil Improvement and Ground Modification Methods*, Butterworth-Heinemann Ltd.
3	Purushotham Raj, (2016), *Ground Improvement Techniques*, Laxmi Publications.
4	R.M.Koerner, (2012), *Designing with Geosynthetics Vol-1&2*, Prentice Hall Inc.
5	Indrarathna, Chu, Cholachat, (2015), *Ground Improvement Case Histories*, Butterworth-Heinemann Publications.

CE 422	**AIRPORT PLANNING AND DESIGN**					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To understand basic terminology and standards relate Airport Engineering.
2	To know the various components of airport and runway components.
3	To understand the various methods of air travel demand analysis.

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Understand the concepts related to airport planning.
CO-2	Understand the design elements related to runway design and perform capacity analysis.
CO-3	Conduct surveys, develop and design new airports with ICAO/FAA geometric standards.
CO-4	Able to perform air travel demand analysis.
CO-5	Develop plans for installation of various types of devices pertaining to Air Traffic Controls.

Course outcome	**Program Outcome**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	0	1	1	1	0
CO-2	2	2	1	1	1
CO-3	2	2	2	2	2
CO-4	2	2	1	2	1
CO-5	2	1	1	0	1

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit - I
Airport Planning: Growth of Air Transport, Technological Developments, Institutional Development for Planning, Regulatory Practices; Aircraft characteristics related to airport planning and design, Future trends in Air craft design and Airport Planning; Airport master plan, site selection, planning surveys etc. Airport Obstructions: Zoning Laws, Classification, Approach and Turning Zones.

Unit - II

Runway Design and Airport Capacity: Runway Orientation, Basic Runway Length and Factors affecting, Correction for elevation, temperature and gradient as per ICAO and FAA, Run way Geometric Design. Airport Capacity: Classification and Standards; Capacity of Airport, Runway, Taxiway and Gate; Delays; Configuration of Airport and Configuration; Runway Intersection Design; Terminal Facilities and Standards: Planning Concepts. Taxiway Design: Factors affecting Taxiway Design, Geometric Design as per ICAO, Exit taxiways, Fillets, Separation clearance, Holding Apron, Turn Around.

Unit - III
Design of Airport Pavements: Design factors, Calculation of ESWL with different wheel load configurations and methods, Repetition of loads, failure criteria; Flexible Pavements Design: US corps of Engineers Method, FAA method; Rigid Pavement Design methods: US corps of Engineers method, PCA Method, FAA method, LCN Method and CAN-PCN System.; Overlays; Drainage: Surface and subsurface methods, filter materials, Special characteristics and requirements of Airport Drainage. Airfield Pavement Maintenance and Rehabilitation: Need, Failures, Evaluation of flexible and Rigid Pavements, Strengthening of Airfield Pavements and maintenance operations.

Unit - IV
Air Travel Demand Analysis: The Demand Analysis, Microanalysis of Air Travel Demand, Calibration of Macro analysis of Air Travel Demand, Disaggregate Models Route Frequency planning. Air travel choice Models, Simultaneous Models of Demand and supply. Optimal Route Frequency Planning.
The Demand Analysis, Microanalysis of Air Travel Demand, Calibration of Macro analysis of Air Travel Demand, Disaggregate Models Route Frequency planning

Unit - V
Air Traffic Controls (ATC): Visual Aids: marking and lighting; Need, Network and Aids for ATC, Radio equipment; Design of Heliports and STOLPORTS: Design Factors, Planning, Site selection. Geometric Designs, Visual Aids.
Topics to be taught by Industry Subject Expert: Visual Aids: marking and lighting; Need, Network and Aids for ATC, Radio equipment;

Suggested Reading:

1	Principles of Pavement Design, Yoder E.J. and Witczak M. W.John Wiley &-Sons, 1975.
2	Transportation Engineering (Railways, Airports, Docks &Harbours), R. Srinivasa Kumar, Universities Press, 2014.
3	Air Port Engineering, Norman Ashford and Paul H Wright, M.W.JohnWHey& Sons.
4	The Planning and Design of Airports, Robert Horojeff, McGrawHill Book Co.
5	Airport Planning and Design, S.K. Khanna, Arora and S.S. Jain,Nem Chand & Bros. Roorkee.

OE 941 CE	**GREEN BUILDING TECHNOLOGY**					
(OPEN ELECTIVE)						
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Exposure to the green building technologies and their significance.
2	Understand the judicial use of energy and its management.
3	Educate about the Sun-earth relationship and its effect on climate.
4	Enhance awareness of end-use energy requirements in the society.
5	Develop suitable technologies for energy management

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Understand the fundamentals of energy use and energy processes in building.
CO-2	Identify the energy requirement and its management.
CO-3	Know the Sun-earth relationship vis-a-vis its effect on climate.
CO-4	Be acquainted with the end-use energy requirements.
CO-5	Be familiar with the audit procedures of energy

Course outcome	**Program Outcome**					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	3	3	3	2	1	2
CO-2	3	2	3	2	1	1
CO-3	3	2	3	2	1	2
CO-4	3	2	3	2	1	2
CO-5	3	2	3	2	1	1

Unit – I
Overview of the significance of energy use and energy processes in building - Indoor activities and environmental control - Internal and external factors on energy use and the attributes of the factors - Characteristics of energy use and its management - Macro aspect of energy use in dwellings and its implications.

Unit – II
Indoor environmental requirement and management - Thermal comfort - Ventilation and air quality – Air-conditioning requirement - Visual perception - Illumination requirement - Auditory requirement.

Unit – III
Climate, solar radiation and their influences - Sun-earth relationship and the energy balance on the earth's surface - Climate, wind, solar radiation, and temperature - Sun shading and solar radiation on surfaces - Energy impact on the shape and orientation of buildings.

Unit – IV
End-use, energy utilization and requirements - Lighting and day lighting - End-use energy requirements - Status of energy use in buildings Estimation of energy use in a building. Heat gain and thermal performance of building envelope - Steady and non-steady heat transfer through the glazed window and the wall - Standards for thermal performance of building envelope - Evaluation of the overall thermal transfer.

Unit – V
Nuclear Medicine–Radioisotopes in medical diagnosis, Basic instrumentation- Radiation Energy management options - Energy audit and energy targeting - Technological options for energy management.

Suggested Reading:

1	Bryant Edwards (2005): Natural Hazards, Cambridge University Press, U.K.
2	Carter, W. Nick, (1991): Disaster Management, Asian Development Bank, Manila.
3	Sahni, Pardeep et.al. (eds.) (2002), Disaster Mitigation Experiences and Reflections, Prentice Hall of India, New Delhi.
4	Bryant Edwards (2005): Natural Hazards, Cambridge University Press, U.K.

OE 942 CE	**COST MANAGEMENT OF ENGINEERING PROJECTS**					
(OPEN ELECTIVE)						
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Introduce the concepts of cost management
2	Fundamentals of cost overruns
3	Introduce the concepts of Quantitative techniques for cost management Linear Programming, PERT/CPM.

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Understanding of strategic cost management process, control of cost and decision making based on the cost of the project.
CO-2	Ability to appreciative detailed engineering activities of the project and execution of projects
CO-3	Preparation of project report and network diagram
CO-4	Able to plan Cost Behavior , Profit Planning , Enterprise Resource Planning, Total Quality Management.
CO-5	Applications of various quantitative techniques for cost management

Course outcome	**Program Outcome**					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	2	1	3	2	1	1
CO-2	3	2	1	1	2	-
CO-3	2	2	2	3	2	1
CO-4	1	3	1	2	1	1
CO-5	1	1	2	3	2	3

Unit – I
Introduction and Overview of the Strategic Cost Management Process-Cost concepts in decision-making; relevant cost, Differential cost, Incremental cost and Opportunity cost. Objectives of a Costing System- Inventory valuation- Creation of a Database for operational control; Provision of data for Decision-Making.

Unit – II

Project: meaning, Different types, why to manage, cost overruns centres, various stages ofproject execution: conception to commissioning- Project execution as conglomeration of technical and non- technical activities- Detailed Engineering activities.

Unit – III
Pre project execution main clearances and documents Project team: Role of each member. Importance Project site: Data required with significance. Project contracts. Types and contents. Project execution Project cost control. Bar charts and Network diagram. Project commissioning: mechanical and process

Unit – IV
Cost Behavior and Profit Planning Marginal Costing; Distinction between Marginal Costing and Absorption Costing; Break-even Analysis, Cost-Volume-Profit Analysis. Various decision-making problems- Standard Costing and Variance Analysis. Pricing strategies: Pareto Analysis. Target costing, Life Cycle Costing. Costing of service sector- Just-in-time approach, Material Requirement Planning, Enterprise Resource Planning, Total Quality Management and Theory of constraints- Activity-Based Cost Management, Bench Marking; Balanced Score Card and Value-Chain Analysis. Budgetary Control; Flexible Budgets- Performance budgets- Zero-based budgets. Measurement of Divisional profitability pricing decisions including transferpricing.

Unit – V
Quantitative techniques for cost management, Linear Programming, PERT/CPM,- Transportation problems, Assignment problems, Simulation, Learning Curve Theory.

Suggested Reading:

1	Cost Accounting A Managerial Emphasis, Prentice Hall of India, NewDelhi
2	Charles T. Horngren and George Foster, Advanced ManagementAccounting
3	Robert S Kaplan Anthony A. Alkinson, Management &CostAccounting
4	Ashish K. Bhattacharya, Principles & Practices of Cost Accounting A. H. Wheelerpublisher
5	N.D. Vohra, Quantitative Techniques in Management, Tata McGraw Hill Book Co.Ltd.

OE 941 ME	**OPERATION RESEARCH**					
(OPEN ELECTIVE)						
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	To understand the dynamic programming to solve problems of discrete and continuous variables
2	To apply the concept of non-linear programming and carry out sensitivity analysis
3	To understand deterministic and probabilistic inventory control models.

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	To understand the basics of OR, including mathematical modeling, feasible solutions and optimization.
CO-2	Able to carry out sensitivity analysis.
CO-3	Apply PERT/CPM in project management.
CO-4	Select appropriate inventory control model.
CO-5	Able to apply dynamic programming and understand the concept of non-linear programming.

Course outcome	**Program Outcome**					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	1	1	3	2	1	2
CO-2	3	1	2	3	2	-
CO-3	1	3	3	1	2	2
CO-4	3	2	1	3	1	1
CO-5	2	1	3	2	2	2

Unit–I
Development, Different Phases, Characteristics, Operations Research models and applications. Linear Programming Problem: Introduction, Basic Assumptions, Formulation, graphical method, simplex method: Big M and Two Phase method.

Unit–II
DUALITY: Duality theory, primal-dual relationships, Economic interpretation, Dual simplex method, Post optimal or sensitivity analysis.

Unit–III
Project Management: Introduction to PERT and CPM, critical Path calculation, float calculation and its importance. Cost reduction by Crashing of activity. **Inventory models** – Economic order quantity models – Quantity discount models – Stochastic inventory models – Multi product models – Inventory control models in practice.

Unit–V
Queuing models - Queuing systems and structures – Notation parameter – Single server and multi server models – Poisson arrivals – Exponential service times – with finite population – Infinite population. Dynamic Programming: Characteristics, principle of optimality, deterministic problems.

Unit–IV
Sequencing Models: Introduction, General assumptions, processing n jobs through 2 machines, processing 'n' jobs through m machines. **Game Theory**: Introduction, Characteristics of Game Theory, Dominance theory, Mixed strategies (2 x 2, m x 2), Algebraic and graphical methods. **Nonlinear programming problem: -** Kuhn-Tucker conditions.

Suggested Reading:

1	H.A. Taha, Operations Research, An Introduction,PHI,2008
2	H.M. Wagner, Principles of Operations Research, PHI,Delhi,2010
3	J.C. Pant, Introduction to Optimization: Operations Research, Jain Brothers, Delhi, 2008.
4	Frederick S. Hillier, Gerald J. Lieberman, Operations Research, 10thEdition, McGraw Hill Pub. 2017.
5	Pannerselvam, Operations Research: Prentice Hall of India, 2010.
6	Ronald L. Rardin, Optimization in Operations Research, First Indian Reprint, Pearson Education Asia. 2002,

OE 942 ME	**COMPOSITE MATERIALS**					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	Study the concepts of composite construction.
2	Learn analysis and designs of composite beams, floors, columns and trusses as per the recommendations of IS codes of practice.
3	Apply the concepts for design of multi-storey composite buildings.
4	Scope of analysis is restricted to skeletal structures subjected to prescribed dynamic loads.

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Understand the fundamentals of composite construction, and analysis and designs of composite beams.
CO-2	Analyse and design the composite floors/pavements
CO-3	Select suitable materials for composite columns,
CO-4	Analyse composite trusses and understand connection details.
CO-5	Analyse and design the multi-storey composite buildings

Course outcome	**Program Outcome**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	2	1	3	2	1
CO-2	3	2	1	1	2
CO-3	2	2	2	3	2
CO-4	1	3	1	2	1
CO-5	1	1	2	3	2

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit - I
Introduction of composite constructions:Benefits of composite construction - Introduction to IS - BS and Euro codal provisions. Composite beams:Elasticbehaviour of composite beams - No and full interaction cases - Shear connectors - Ultimate load behaviour - Serviceability limits - Effective breadth of flange - Interaction between shear and moment - Basic design consideration and design of composite beams.

Unit - II
Composite floors:Structural elements - Profiled sheet decking - Bending resistance - Shear resistance - Serviceability criterion - Analysis for internal forces and moments - Design of composite floors.

Unit - III
Composite columns:Materials - Concrete filled circular tubular sections - Non-dimensional slenderness - Local buckling of steel sections - Effective elastic flexural stiffness - Resistance of members to axial compressions - Composite column design - Fire resistance.

Unit - IV
Composite trusses:Design of truss - Configuration - Truss members - Analysis and design of composite trusses and connection details.

Unit - V
Design of multi-storey composite buildings:Design basis - Load calculations - Design of composite slabs with profile decks - Composite beam design - Design for compression members - Vertical cross bracings - Design of foundation.

Suggested Reading:

1	R.P. Johnson, “Composite Structures of Steel and Concrete - Beams, Slabs, Columns and Frames in Buildings”, Blackwell Publishing, Malden, USA, 2004.
2	“INSDAG Teaching Resources for Structural Steel Design”, Vol-2, Institute for Steel Development and Growth Publishers, Calcutta, India.
3	“INSDAG Handbook on Composite Construction – Multi-Storey Buildings”, Institute for Steel Development and Growth Publishers, Calcutta, India.
4	“INSDAG Design of Composite Truss for Building”, Institute for Steel Development and Growth Publishers, Calcutta, India.
5	“INSDAG Handbook on Composite Construction – Bridges and Flyovers”, Institute for Steel Development and Growth Publishers, Calcutta, India.
6	IS: 11384-1985, “Code of Practice for Composite Construction in Structural Steel and Concrete”, Bureau of Indian Standards, New Delhi, 1985.

OE 943 ME	**INDUSTRIAL SAFETY**					
	(OPEN ELECTIVE)					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Causes for industrial accidents and preventive steps to be taken.
2	Fundamental concepts of Maintenance Engineering.
3	About wear and corrosion along with preventive steps to be taken
4	The basic concepts and importance of fault tracing.
5	The steps involved in carrying out periodic and preventive maintenance of various equipments used in industry

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Identify the causes for industrial accidents and suggest preventive measures.
CO-2	Identify the basic tools and requirements of different maintenance procedures.
CO-3	Apply different techniques to reduce and prevent Wear and corrosion in Industry.
CO-4	Identify different types of faults present in various equipments like machine tools, IC Engines, boilers etc.
CO-5	Apply periodic and preventive maintenance techniques as required for industrial equipments like motors, pumps and air compressors and machine tools etc

Course outcome	**Program Outcome**					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	2	1	3	2	1	1
CO-2	3	2	1	1	2	-
CO-3	2	2	2	3	2	1
CO-4	1	3	1	2	1	1
CO-5	1	1	2	3	2	3

Unit – I
Industrial safety: Accident, causes, types, results and control, mechanical and electrical hazards, types, causes and preventive steps/procedure, describe salient points of factories act 1948 for health and safety, wash rooms, drinking water layouts, light, cleanliness, fire, guarding, pressure vessels, etc, Safety color codes, Fire prevention and firefighting, equipment and methods.

Unit – II
Fundamentals of Maintenance Engineering: Definition and aim of maintenance engineering, Primary and secondary functions and responsibility of maintenance department, Types of maintenance, Types and applications of tools used for maintenance, Maintenance cost & its relation with replacement economy, Service life of equipment.

Unit – III
Wear and Corrosion and their Prevention: Wear- types, causes, effects, wear reduction methods, lubricants-types and applications, Lubrication methods, general sketch, working and applications of Screw down grease cup, Pressure grease gun, Splash lubrication, Gravity lubrication, Wick feed lubrication, Side feed lubrication, Ring lubrication, Definition of corrosion, principle and factors affecting the corrosion, Types of corrosion, corrosion prevention methods.

Unit – IV
Fault Tracing: Fault tracing-concept and importance, decision tree concept, need and applications, sequence of fault finding activities, show as decision tree, draw decision tree for problems in machine tools, hydraulic, pneumatic, automotive, thermal and electrical equipment's like, any one machine tool, Pump, Air compressor, Internal combustion engine, Boiler, Electrical motors, Types of faults in machine tools and their general causes.

Unit – V
Periodic and Preventive Maintenance: Periodic inspection-concept and need, degreasing, cleaning and repairing schemes, overhauling of mechanical components, overhauling of electrical motor, common troubles and remedies of electric motor, repair complexities and its use, definition, need, steps and advantages of preventive maintenance. Steps/procedure for periodic and preventive maintenance of Machine tools, Pumps, Air compressors, Diesel generating (DG) sets, Program and schedule of preventive maintenance of mechanical and electrical equipment, advantages of preventive maintenance. Repair cycle concept and importance.

Suggested Reading:

1	H. P. Garg, "Maintenance Engineering", S. Chand and Company
2	Audels, "Pump-hydraulic Compressors", Mcgraw Hill Publication
3	Higgins & Morrow, "Maintenance Engineering Handbook", Da Information Services.
4	Winterkorn, Hans, "Foundation Engineering Handbook", Chapman & Hall London

CE 941 CS	**BUSINESS ANALYTICS**					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	Understanding the basic concepts of business analytics and applications.
2	Study various business analytics methods including predictive, prescriptive and prescriptive analytics.
3	Prepare the students to model business data using various data mining, decision making methods.

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	To understand the basic concepts of business analytics.
CO-2	Identify the application of business analytics and use tools to analyze business data.
CO-3	Become familiar with various metrics, measures used in business analytics.
CO-4	Illustrate various descriptive, predictive and prescriptive methods and techniques.
CO-5	Model the business data using various business analytical methods and techniques.

Course outcome	**Program Outcome**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	2	1	3	2	1
CO-2	3	2	1	1	2
CO-3	2	2	2	3	2
CO-4	1	3	1	2	1
CO-5	1	1	2	3	2

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit – I
Introduction to Business Analytics: Introduction to Business Analytics, needand science of data driven (DD) decision making, Descriptive, predictive, prescriptive analytics and techniques, Big data analytics, Web and Social media analytics, Machine Learning algorithms, framework for decision making, challenges in DD decision making and future.

Unit – II
Descriptive Analytics: Introduction, data types and scales, types of measurementscales, population and samples, measures of central tendency, percentile, decile and quadrille, measures of variation, measures of shape-skewness, data visualization.

Unit – III
Forecasting Techniques: Introduction, time-series data and components,forecasting accuracy, moving average method, single exponential smoothing, Holt's method, Holt-Winter model, Croston's forecasting method, regression model for forecasting, Auto regression models, auto-regressive moving process, ARIMA, Theil's coefficient

Unit – IV
Decision Trees: CHAID, Classification and Regression tree, splitting criteria,Ensemble and method and random forest. **Clustering**: Distance and similarity measures used in clustering, Clustering algorithms, K-Means and Hierarchical algorithms, **Prescriptive Analytics**-Linear Programming(LP) and LP model building.

Unit – V
Six Sigma: Introduction, introduction, origin, 3-Sigma Vs Six-Sigma process,cost of poor quality, sigma score, industry applications, six sigma measures, DPMO, yield, sigma score, DMAIC methodology, Six Sigma toolbox.

Suggested Reading:

1	U Dinesh Kumar, "Data Analytics", Wiley Publications, 1st Edition, 2017
2	Marc J. Schniederjans, Dara G. Schniederjans, Christopher M. Starkey, "Business analytics Principles, Concepts, and Applications with SAS", Associate Publishers, 2015
3	S. Christian Albright, Wayne L. Winston, "Business Analytics - Data Analysis and Decision Making", 5th Edition, Cengage, 2015

Web Resources:

1	https://onlinecourses.nptel.ac.in/noc18-mg11/preview
2	https://nptel.ac.in/courses/110105089/

CE 941 EE	**WASTE TO ENERGY**					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To know the various forms of waste
2	To understand the processes of Biomass Pyrolysis
3	To learn the technique of Biomass Combustion.

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Understand the concept of conservation of waste
CO-2	Identify the different forms of wastage
CO-3	Chose the best way for conservation to produce energy from waste
CO-4	Explore the ways and means of combustion of biomass
CO-5	Develop a healthy environment for the mankind

Course outcome	**Program Outcome**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	-	3	2	3
CO-2	3	-	3	2	3
CO-3	3	-	3	2	3
CO-4	3	-	3	2	3
CO-5	3	-	3	2	3

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively

Unit – I
Introduction to Energy from Waste: Classification of waste as fuel – Agro based, Forest residue, Industrial waste - MSW – Conversion devices – Incinerators, gasifiers, digestors

Unit – II
Biomass Pyrolysis: Pyrolysis – Types, slow fast – Manufacture of charcoal – Methods Yields and application – Manufacture of pyrolytic oils and gases, yields and applications.

Unit – III
Biomass Gasification: Gasifiers – Fixed bed system – Downdraft and updraft gasifiers Fluidized bed gasifiers – Design, construction and operation – Gasifier burner arrangement for thermal heating – Gasifier engine arrangement and electrical power – Equilibrium and kinetic consideration in gasifier operation.

Unit – IV
Biomass Combustion: Biomass stoves – Improved chullahs, types, some exotic designs, Fixed bed combustors, Types, inclined grate combustors, Fluidized bed combustors, Design, construction and operation - Operation of all the above biomass combustors.

Unit – V
Biogas: Properties of biogas (Calorific value and composition) - Biogas plant technology and status - Bio energy system - Design and constructional features - Biomass resources and their classification - Biomass conversion processes - Thermo chemical conversion - Direct combustion - biomass gasification - pyrolysis and liquefaction - biochemical conversion anaerobic digestion - Types of biogas Plants – Applications - Alcohol production from biomass Bio diesel production - Urban waste to energy conversion - Biomass energy Program in India.

Suggested Reading:

1	Non Conventional Energy, Desai, Ashok V., Wiley Eastern Ltd., 1990.
2	Biogas Technology - A Practical Hand Book - Khandelwal, K. C. and Mahdi, S. S., Vol. I & II, Tata McGraw Hill Publishing Co. Ltd., 1983.
3	Food, Feed and Fuel from Biomass, Challal, D. S., IBH Publishing Co. Pvt. Ltd., 1991.
4	Biomass Conversion and Technology, C. Y. WereKo-Brobby and E. B. Hagan, John Wiley & Sons, 1996.

OE 942 EE	**POWER PLANT CONTROL AND INSTRUMENTATION**					
	(OPEN ELECTIVE)					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	The operation of different types of power plants.
2	The basic working principle of instruments for measurement of electrical and non-electrical quantities like Temperature Pressure flow level measurements.
3	The instrumentation and protection systems applied in thermal power plant.
4	The control techniques employed for the operation of modern power generationplant

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Explain the different methods of power generation. Along with Piping and Instrumentation diagram of boiler.
CO-2	Select various measurements involved in power generation for measuring electrical and non-electrical parameters.
CO-3	Identify the different types of analyzers used for scrutinizing boiler steam and water.
CO-4	Model different types of controls and control loops in boilers.
CO-5	Illustrate the methods of monitoring and control of different parameters like speed, vibration of turbines

Course outcome	**Program Outcome**					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	3	1	-	-	-	2
CO-2	3	1	-	-	-	2
CO-3	3	1	-	-	-	2
CO-4	3	1	-	-	-	2
CO-5	3	1	-	-	-	2

Unit – I
Brief survey of methods of power generation, hydro, thermal, nuclear, solar and wind power, importance of instrumentation in power generation, thermal power plants, block diagram, details of boiler processes, Piping and Instrumentation diagram of boiler, cogeneration.

Unit – II
Electrical measurements, current, voltage, power, frequency, power factor etc, non-electrical parameters, flow of feed water, fuel, air and steam with correction factor for temperature, steam pressure and steam temperature, drum level measurement, radiation detector, smoke density measurement, dust monitor.

Unit – III
Flue gas oxygen analyzer: Analysis of impurities in feed water and steam, dissolved oxygen analyzer. Chromatography, pH meter, fuel analyzer, pollution monitoring instruments.

Unit – IV
Combustion control, air / fuel ratio control, furnace draft control, drum level control, main steam and reheat steam temperature control, super heater control, air temperature, distributed control system in power plants, interlocks in boiler operation.

Unit – V
Speed, vibration, shell temperature monitoring and control, steam pressure control, lubricant oil temperature control, cooling system.

Suggested Reading:

1	Sam G. Dukelow, The Control of Boilers, Instrument Society of America, 2nd Edition, 2010.
2	P.K. Nag, „Power Plant Engineering‟, Tata McGraw-Hill, 1st Edition, 2001.
3	S.M. Elonka and A.L. Kohal, “Standard Boiler Operations”, Tata McGraw-Hill, 1st Edition, 1994.
4	R K Jain, “Mechanical and Industrial Measurements”, Khanna Publishers, 1st Edition, 1995.
5	E Al Wakil, “Power Plant Engineering”, Tata McGraw-Hill, 1st Edition, 1984.

OE 941 EC	**ELEMENTS OF EMBEDDED SYSTEMS**					
	(OPEN ELECTIVE)					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Understanding various Embedded Design strategies
2	Designing Micro controller based Embedded Systems
3	Designing FPGA Based Embedded Systems

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Understand Embedded Design Strategies and architecture of Arduino Board
CO-2	Program using various onboard components of Arduino
CO-3	Design real time interfacing with Arduino
CO-4	Understand Design Flow of FPGA, programming FPGA using Verilog HDL
CO-5	Implement combinational and sequential circuits using verilog HDL

Course outcome	**Program Outcome**					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	2	1	3	2	1	1
CO-2	3	2	1	1	2	-
CO-3	2	2	2	3	2	1
CO-4	1	3	1	2	1	1
CO-5	1	1	2	3	2	3

Unit – I
Embedded Systems Design Strategies: Micro Controller, DSP, FPGA,Introduction to Arduino (Micro controller Board), Components of Arduino, Architecture and Pin Configuration of ATMega328, Ports of ATMega328.

Unit – II
Interfacing: Interfacing Switches, LEDs, Analog to Digital Converter, Digital to Analog Converter, Interfacing and Programming I2C, SPI

Unit – III

Real Time Programming: InterfacingKey Pad, 7-segment display, LCD, Interfacing Sensors, Interfacing Stepper Motor**,** USB programming

Unit – IV
FPGA Based Embedded Design: FPGA Design flow, Introduction to Verilog HDL**,** Basic building blocks, Data types of Verolog HDL, Behavioral Modelling, Data Flow Modelling, Structural Modelling, Hierarchal Structural Modelling, Case Studies on Verilog HDL descriptions of Basic Circuits

Unit – V
Modelling of Circuits: Verilog HDL Implementation of Combinational MSI Circuits, Verilog HDL Implementation of Sequential MSI Circuits, Finite Sate Machine Design, Tasks and Functions, Introduction to Test Benches

Suggested Reading:

1	Ming-Bo Lin, Digital System Designs and Practices Using Verilog HDL and FPGAs, Wiley India, 2008
2	Samir Palnitkar, Verilog HDL: A Guide to Digital Design and Synthesis, Pearson Education, 2005
3	Simon Monk, Programming Arduino: Getting Started with sketches, Mc.Hill, 2016

Web Resources:

1	www.arduino.cc
2	www.learn.sparkfun.com/tutorials/arduino

OE 941 BM	**MEDICAL ASSISTIVE DEVICES**					
	(OPEN ELECTIVE)					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	To extend knowledge of the amputee, of lost and remaining functions affecting locomotion, and to collect information on the best possible medical treatment.
2	To improve fitting techniques and practices, including training, so that existing devices might be used with greater comfort and function.
3	To develop improved lower-extremity devices

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Apply fundamental knowledge of engineering in rehabilitation
CO-2	Apply analytical skills to assess and evaluate the need of the end-user
CO-3	Develop self-learning initiatives and integrate learned knowledge for problem solving
CO-4	Understand the basics of robotics and apply their principles in developing prosthetics
CO-5	Apply the knowledge of computers in solving rehabilitation problems

Course outcome	**Program Outcome**					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	2	1	3	2	1	1
CO-2	3	2	1	1	2	-
CO-3	2	2	2	3	2	1
CO-4	1	3	1	2	1	1
CO-5	1	1	2	3	2	3

Unit – I
Introduction to Rehabilitation Engineering, Measurement and analysis of human movement, Disability associated with aging in the workplace and their solutions, clinical practice of rehabilitation engineering.

Unit – II
Assistive Technology, Seating Biomechanics and systems. Wheeled Mobility: Categories of Wheelchairs. Wheelchair Structure and Component Design. Ergonomics of Wheel chair propulsion. Power Wheelchair Electrical Systems. Control. Personal Transportation. Auxiliary devices and systems.

Unit – III
Sensory augmentation and substitution: Visual system: Visual augmentation. Tactual vision substitution, Auditory vision substitution; Auditory system: Auditory augmentation. Cochlear implantation, Visual auditory substitution, Tactual auditory substitution, Tactual system: Tactual augmentation. Tactual substitution. Measurement tools and processes: fundamental principles, structure, function; performance and behavior. Subjective and objective measurement methods.

Unit – IV
Rehabilitation Robotics, Major Limb Prosthetic Devices, Orthotic Devices, Types of orthotics and prosthetics, Intelligent prosthetic Knee, Prosthetic Hand, Controlled orthotics and prosthetics FES system, Restoration of Hand function, Restoration of standing and walking, Myo-electric Hand.

Unit – V
Augmentative and Alternative communication technology, Computer applications in Rehabilitation Engineering, telecommunications, and Web Accessibility.

Suggested Reading:

1	Robinson C.J., *Rehabilitation Engineering*, CRC Press, 1995.
2	Ballabio E., et al., *Rehabilitation Technology*, IOS Press, 1993.
3	Rory A Cooper, HisaichiOhnabe, Douglas A. Hobson, *Series in medical physis and biomedical engineering: An introduction to rehabilitation engineering*, Taylor and Francis Group, London, 2007.
4	Joseph D. Bronzino*The biomedical engineering handbook -biomedical engineering fundamentals*, 3rdEd., CRC Press, Taylor & Francis Group, London, 2006.

OE 942 BM	**MEDICAL IMAGING TECHNIQUES**					
	(OPEN ELECTIVE)					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	To familiarize the students with various medical imaging modalities.
2	To make learners understand the principles, detectors and operating procedures of X-ray, CT, MRI, ultrasound, PET and SPECT.
3	To make the students learn the advantages, disadvantages and hazards of various medical imaging equipment.

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Interpret the working principle and operating procedure and applications of X-ray equipment.
CO-2	Understand the image reconstruction techniques and applications of CT.
CO-3	Summarize the image acquisition and reconstruction techniques in MRI.
CO-4	Comprehend the working principle, modes and medical applications of ultrasound imaging.
CO-5	Examine the operation and applications of PET, SPECT and radio nuclide instrumentation.

Course outcome	**Program Outcome**					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	2	1	3	2	1	1
CO-2	3	2	1	1	2	-
CO-3	2	2	2	3	2	1
CO-4	1	3	1	2	1	1
CO-5	1	1	2	3	2	3

Unit – I
X ray Imaging: Electromagnetic spectrum, Production of X-rays, X-ray tubes- Stationary and Rotating Anode types, Block diagram of an X-Ray Machine, Collimators and Grids, Timing and Exposure controls. X-Ray Image visualization-Films, Fluorescent screens, Image Intensifiers. Dental X-Ray machines, Portable and mobile X-Ray units, Mammographic X-Ray equipment,

Digital Radiography and flat panel detectors. Radiation safety, ALARA principle, Dose units and dose limits, Radiation dosimeters and detectors.

Unit – II
Computed Tomography: Basic principles, CT number scale, CT Generations. Major sub systems- Scanning system, processing unit, viewing unit, storage unit. Need and Principle of sectional imaging, 2D image reconstruction techniques - Iteration and Fourier methods. Applications of CT - Angio, Osteo, Dental, Perfusion (Body &Neuro), Virtual Endoscopy, Coronary Angiography.

Unit – III
Magnetic Resonance Imaging: Principles of NMR imaging systems, Image reconstruction techniques-Relaxation processes, imaging/ pulse sequences. Sub systems of an NMR imaging system, NMR detection system, types of coils, biological effects and advantages of NMR imaging. Functional MRI - The BOLD effect, intra and extra vascular field offsets, source of T2* effects, Creating BOLD contrast sequence optimization sources and dependences of physiological noise in fMRI.

Unit – IV
Ultrasound Imaging: - Principles of image formation -Imaging principles and instrumentation of A-mode, B-Mode, Gating Mode, Transmission mode and M-mode. Basics of multi-element linear array scanners, Digital scan conversion. Doppler Ultrasound and Colour Doppler imaging, Image artifacts, Biological effects, Ultrasound applications in diagnosis, therapy and surgery.

Unit – V
Nuclear Medicine–Radioisotopes in medical diagnosis, Basic instrumentation- Radiation detectors, Pulse height analyzer, Rectilinear scanner, Gamma camera. Emission Computed Tomography (ECT), Principle and instrumentation of Single Photon Emission Computed Tomography(SPECT) and Positron Emission Tomography (PET). Comparison of SPECT, PET and combined PET/ X-ray CT.

Suggested Reading:

1	Khandpur R.S., *Handbook of Biomedical Instrumentation*, Tata McGraw Hill, 2016.
2	S Webb, "*The Physics of Medical Imaging*", Adam Highler, Bristol Published by CRC Press, 1988.
3	A C Kak, "*Principle of Computed Tomography*", IEEE Press New York, 1988.
4	Hykes, Heorick, Starchman, *Ultrasound physics and Instrumentation* MOSBY year book, 2nd Ed. 1992.
5	Stewart C.Bushong, *Magnetic Resonance Imaging- physical and biological principles*, MOSBY, 2nd Ed., 1995.

OE 941 LA	INTELLECTUAL PROPERTY RIGHTS					
	(OPEN ELECTIVE)					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Acquaint the students with basics of intellectual property rights with special reference to Indian Laws and its practices.
2	Compare and contrast the different forms of intellectual property protection in terms of their key differences and similarities.
3	Provide an overview of the statutory, procedural, and case law underlining these processes and their interplay with litigation.

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Understand the concept of intellectual property rights.
CO-2	Develop proficiency in trademarks and acquisition of trade mark rights.
CO-3	Understand the skill of acquiring the copy rights, ownership rights and transfer.
CO-4	Able to protect trade secrets, liability for misappropriations of trade secrets.
CO-5	Apply the patents and demonstration of case studies.

Course outcome	**Program Outcome**					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	2	1	3	2	1	1
CO-2	3	2	1	1	2	-
CO-3	2	2	2	3	2	1
CO-4	1	3	1	2	1	1
CO-5	1	1	2	3	2	3

Unit – I
Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

Unit – II
Trade Marks: Purpose and function of trademarks, acquisition of trade mark rights, protectable matter, selecting, and evaluating trade mark, trade mark registration

processes.

Unit – III
Law of copy rights: Fundamental of copy right law, originality of material, rights of reproduction, rights to perform the work publicly, copy right ownership issues, copy right registration, notice of copy right, international copy right law. Law of patents: Foundation of patent law, patent searching process, ownership rights and transfer**.**

Unit – IV
Trade Secrets: Trade secrete law, determination of trade secrete status, liability for misappropriations of trade secrets, protection for submission, trade secrete litigation. Unfair competition: Misappropriation right of publicity, false advertising.

Unit – V
New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.

Suggested Reading:

1	Halbert, “Resisting Intellectual Property”, Taylor & Francis Ltd, 2007.
2	“Mayall, “Industrial Design”, McGraw Hill,1992
3	“Niebel, “Product Design”, McGraw Hill,1974.
4	“Asimov, “Introduction to Design”, Prentice Hall,1962.
5	“Robert P. Merges, Peter S. Menell, Mark A. Lemley, “Intellectual Property in New Technological Age”,2016.
6	T. Ramappa, “Intellectual Property Rights Under WTO”, S. Chand,2008

MC070	**MINI PROJECT**					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	2
Evaluation	**SEE**		**CIE**		50 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	Identify engineering problems in multidisciplinary area reviewing available literature
2	to formulate a real time problem

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Identify a topic in advanced areas of Transportation Engineering and Literature Review
CO-2	Identify gaps and define objectives & scope of the work
CO-3	Employ the ideas from literature and develop research methodology
CO-4	Develop a model, experimental set-up and / or computational techniques necessary to meet the objectives.
CO-5	Report Writing, and presentation skills

CO-PO MAPPING

Course Outcome	Program Outcome				
	PO1	PO2	PO3	PO4	PO5
CO1	3	2	3	3	2
CO2	3	2	3	3	1
CO3	2	2	1	1	1
CO4	3	2	2	3	2
CO5	2	3	2	3	1

Syllabus Content:

Mini Project will have mid semester presentation and end semester presentation. Mid semester presentation will include identification of the problem based on the literature review on the topic referring to latest literature available. End semester presentation should be done along with the report on identification of topic for the work and the methodology adopted involving scientific research, collection and analysis of data, determining solutions highlighting individuals' contribution. Continuous assessment of Mini Project at Mid Semester and End Semester will be monitored by the departmental committee.

CE 453	**PAVEMENT ENGINEERING LAB**					
Pre-requisites			**L**	**T**	**P**	**C**
			-	-	2	1
Evaluation	**SEE**		**CIE**		25 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To Characterize the pavement materials
2	To conduct various standard pavement evaluation tests on pavements
3	To design overlays

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Characterize pavement materials & bituminous mix design
CO-2	Evaluate different types of pavements.
CO-3	Measure the structural response characteristics of in-service pavements & Overlay design

Program Articulation Matrix

Course Outcome	Program Outcome				
	PO1	PO2	PO3	PO4	PO5
CO1	2	1	1	2	1
CO2	1	2	1	1	
CO3	1	2	1	1	1

1. Tests on Aggregates
2. Tests on Bitumen
3. Bituminous Mix Design
4. California Bearing Ratio test
5. Field Density
6. Bitumen Content
7. Pavement Condition Rating unevenness using MERLIN
8. Field Evaluation by Dynamic Cone Penetrometer
9. Overlay design using Benkelman beam
10. Falling Weight Deflectometer studies(demo)

Note: All tests as per IS, ASTM, AASHTO, TRL, IRC procedures/specifications and guidelines

CE 452	**HIGHWAY MATERLAS LAB**					
Pre-requisites			**L**	**T**	**P**	**C**
			-	-	2	1
Evaluation	**SEE**		**CIE**		25Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To conduct various standard tests on aggregate and bitumen
2	To understand the properties of bituminous mixes

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Characterize the pavement materials.
CO-2	Perform quality control tests on pavement material and pavements
CO-3	Bituminous mix design

Program Articulation Matrix

Course Outcome	Program Outcome				
	PO1	PO2	PO3	PO4	PO5
CO1	2	1	1	2	1
CO2	1	2	1	1	
CO3	1	2	1	1	1

1. Aggregate Tests

2. Bitumen and Tar Tests as per IS code provisions

3. Stone Polishing Value test

4. Mix design for Bituminous mixes

5. California Bearing Ratio Test

6. Soil Classification & Grain size analysis .

Note: All tests as per IS, ASTM, AASHTO, TRL, IRC procedures/specifications and guidelines

SEMESTER-III

AC030	**ENGINEERING RESEARCH METHODOLOGY**					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	-
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	Introduce the conceptual and philosophical foundation of research methodology for Scientific and Engineering Research
2	Provide an understanding of the importance of literature review and formulating of a good research problem
3	Offer procedural instruction on how to plan, design & conduct research projects and interpret the data

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Demonstrate the knowledge of research processes (reading, evaluating, and developing) and formulate a research problem
CO-2	Perform literature reviews, present research ideas, plan research projects, and to explain the rationale for research ethics
CO-3	Understand the importance of innovation & patenting and will be aware of rules and regulations about Intellectual Property Rights
CO-4	Choose relevant sampling methods for qualitative and quantitative data collection and processing
CO-5	Apply various statistical methods for proper characterization, stigmatization, presentation and interpretation of the result of research, to test the Hypothesis by using SPSS software and similar software

Course outcome	**Program Outcome**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	-	-	-	-	1
CO-2	-	-	1	-	1
CO-3	-	-	1	-	1
CO-4	-	-	2	-	2
CO-5	-	-	1	-	2

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit – I

Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations

Unit – II
Effective literature studies approaches, analysis Plagiarism, Research ethics.Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee. Preparation of thesis

Unit – III
Patenting and Development: technological research, innovation, patenting, and development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT Patent Rights.

Unit – IV
Data collection and measurement Methods in Civil Engineering: Primary data through:- communication, Designing Questionnaire, Qualitative Research sampling and sampling designs Attitude measurement and scales Data presentation and analysis: Data processing, Univariate and Bivariate analysis, Correlational analysis
Topics to be taught by Industry Subject Expert: Measureable features of a flood (Elevation, discharge, volume, and duration), flood forecasting (unit hydrograph method, meteorological and snow data, and snow field air temperatures), operation of flood forecasting systems.

Unit – V
Descriptive Statistics: Measure of central tendency, Measure of central dispersion, Measure of skewness, Measure of kurtosis, parametric and statistic sampling and non-sampling errors, standard error and central limit theorem, sampling distribution, degree of freedom, hypothesis of testing, test statistics and critical region, procedure for hypothesis testing for mean and variance. Introduction to linear regression model and multi-linear regression models, mathematical basis and introduction to SPSS.
Topics to be taught by Industry Subject Expert: Mathematics of flood routing, various methods of flood routing, Hydrologic and Hydraulic routing.

Suggested Reading:

1	Stuart Melville and Wayne Goddard, “Research methodology: an introduction for science & Engineering students”
2	Ranjit Kumar, 2nd Edition, “Research Methodology: A Step by Step Guide for beginners”
3	Halbert, “Resisting Intellectual Property”, Taylor & Francis Ltd ,2007.
4	Mayall, “Industrial Design”, McGraw Hill, 1992.
5	T. Ramappa, “Intellectual Property Rights Under WTO”, S. Chand, 2008
6	R. Kothari. "Research Methodology - Methods and Techniques", 2nd Edition, New Delhi, New Age International (P) Limited, 2003

AC 032	**DISASTER MITIGATION AND MANAGEMENT**					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	-
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	Introduction of various types of disasters and its effect on structures.
2	Learning of quality assurance and damage assessment of structures
3	Educate different types of repair, strengthening, rehabilitation and retrofitting techniques
4	Awareness about flood characteristics and flood forecasting systems
5	Description of Flood mitigation, adjustment, and regulation

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Understand the fundamentals of disaster and seismic performance of buildings
CO-2	Able to assess various damages in structures and give assurance of quality of concrete
CO-3	Decide the appropriate repair, strengthening, rehabilitation and technique required for a case study of building.
CO-4	Applications of flood routing, flood forecasting and space time characteristics of rainfall.
CO-5	Advanced understanding of flood plain adjustments and employment of appropriate technologies for flood mitigation.

Course outcome	**Program Outcome**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	2	1	1	1	1
CO-2	2	2	2	2	1
CO-3	2	2	1	1	1
CO-4	2	2	1	1	0
CO-5	2	2	1	1	1

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit - I
Disaster: Classifications - Causes - Impacts including social, economic, political, environmental, health, psychosocial, etc. Hazard, Vulnerability, Resilience, Risks.-Disaster-Different types of cold wave-heat wave- droughts- floods-Effect of climate change on Processes.
Natural and Manmade disasters- *Impact of drought, review of past disasters and drought in India, its classification and characteristics. Classification of drought, causes.*

Unit - II
Flood characteristics and forecasting: Measureable features of a flood (Elevation, discharge, volume, and duration), flood forecasting (unit hydrograph method, meteorological and snow data, and snow field air temperatures), operation of flood forecasting systems-CWC Recommendations on Floods on reservoir.

Unit - III
Flood Mitigationand Rehabilitation: Flood mitigation reservoirs(purpose, location, size and operation) levees and flood walls (location, maintenance and flood fighting), flood ways, channel improvements, evacuation and flood proofing, land management, flood plain management, estimating benefits of flood mitigation-National Disaster Management Authority- objectives and Provisions of NDMA –Disaster Management Act- 2005

Unit - IV
Disaster Risk and Mitigation Strategies: - Introduction of Risk, Problems on computation of risk, significance of and objectives of mitigation, types and strategies guidelines for mitigation of natural disasters like floods, earthquake, fire hazards, mitigation plans based on causes and effects.
Topics to be taught by Industry Subject Expert :

Unit - V
Disaster preparedness and Management: Steps in disaster preparedness-strengthening of community based disaster preparedness- Developing Action plan- Repair of materials, Common types of repairs – Repairs of underwater structures- Gunting- shortcrete-techniques in Civil Engineering- Repair in concrete structures –Repair of structures distressed due to corrosion, fire, Leakage, earthquake, Retrofitting techniques.
Topics to be taught by Industry Subject Expert :

Suggested Reading : (five for BE and up to seven for ME)

1	VenTe Chow (1964), 'Hand Book of Applied Hydrology', McGraw-Hill Publishers, New York
2	Barry A. Richardson (1991) "*Defects and Deterioration in Buildings*", E &FN Spon Press, London, 1991
3	Varshney, R. S. (1979), 'Engineering Hydrology', Nem Chand Publishers, Roorkee.
4	Bungey, J.H (1989) "*Testing of Concrete in Structures*", Chapman and Hall, New Delhi
5	A.R. Santakumar (2006) "*Concrete Technology*", Oxford University Press,New Delhi.6.
6	Gupta Anil K, and Sreeja S. Nair. (2011). *Environmental Knowledge for Disaster Risk Management*, NIDM, New Delhi.

AC 031	**ENGLISH FOR RESEARCH PAPER WRITING**					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	-
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	Understand that how to improve your writing skills and level of readability
2	Learn about what to write in each section
3	Understand the skills needed when writing a Title Ensure the good quality of paper at very first-time submission

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Able to plan and prepare paragraphs
CO-2	Writing of abstracts
CO-3	Providing of critical and thorough review of literature
CO-4	Able to exhibit key skills for writing titles
CO-5	Able to show key and necessary skills for paper writing

Course outcome	**Program Outcome**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	-	-	-	-	-
CO-2	-	-	1	-	-
CO-3	-	-	1	-	1
CO-4	-	-	2	-	3
CO-5	-	-	2	-	2

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit - I

Planning and Preparation, Word Order, Breaking up long sentences, Structuring Paragraphs and Sentences, Being Concise and Removing Redundancy, Avoiding Ambiguity and Vagueness

Unit - II
Clarifying Who Did What, Highlighting Your Findings, Hedging and Criticizing, Paraphrasing and Plagiarism, Sections of a Paper, Abstracts. Introduction

Unit - III
Review of the Literature, Methods, Results, Discussion, Conclusions, The Final Check.

Unit - IV
Key skills are needed when writing a Title, key skills are needed when writing an Abstract, key skills are needed when writing an Introduction, skills needed when writing a Review of the Literature
Topics to be taught by Industry Subject Expert: Process of Writing a research paper

Unit - V
Skills are needed when writing the Methods, skills needed when writing the Results, skills are needed when writing the Discussion, skills are needed when writing the Conclusions - Useful phrases, how to ensure paper is as good as it could possibly be the first- time submission
Topics to be taught by Industry Subject Expert: Research Paper Publication Problems

Suggested Reading:

1	C. R Kothari, Gaurav, Garg, Research Methodology Methods and Techniques, New Age International Publishers. 4th Edition.
2	Day R (2006) “How to Write and Publish a Scientific Paper”, Cambridge University Press
3	MLA “Hand book for writers of Research Papers”, East West Press Pvt. Ltd, New Delhi, 7th Edition.
4	LauriRozakis, Schaum’s, “Quick Guide to Writing Great Research Papers”, Tata McGraw Hills Pvt. Ltd, New Delhi.
5	NPTEL: https://onlinecourses.nptel.ac.in/noc18_mg13/preview

AC033	**SANSKRIT FOR TECHNICAL KNOWLEDGE**					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	0
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives : (3 to 5)	
The course is taught with the objectives of enabling the student to:	
1	To get a working knowledge in illustrious Sanskrit, the scientific language in the world
2	Learning of Sanskrit to improve brain functioning
3	Learning of Sanskrit to develop the logic in mathematics, science & other subjects enhancing the memory power
4	The engineering scholars equipped with Sanskrit will be able to explore the huge knowledge from ancient literature

Course Outcomes : (5)	
On completion of this course, the student will be able to :	
CO-1	Understanding basic Sanskrit language
CO-2	Ancient Sanskrit literature about science & technology can be understood
CO-3	Being a logical language will help to develop logic in students
CO-4	
CO-5	

Course outcome	**Program Outcome**					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO6**
CO-1			1			
CO-2		1				2
CO-3		1	1			1
CO-4						
CO-5						

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit – I

Alphabets in Sanskrit,Past/Present/Future Tense, Simple Sentences

Unit – II
Order Introduction of roots Technical information about Sanskrit Literature

Unit – III
Technical concepts of Engineering-Electrical, Mechanical, Architecture, Mathematics

Unit – IV
Topics to be taught by Industry Subject Expert :

Unit - V
Topics to be taught by Industry Subject Expert :

Suggested Reading : (five for BE and up to seven for ME)

1	"Abhyaspustakam" – Dr.Vishwas, Samskrita-Bharti Publication, New Delhi
2	Teach Yourself Sanskrit" PrathamaDeeksha-VempatiKutumbshastri, Rashtriya Sanskrit Sansthanam, New Delhi Publication
3	"India's Glorious Scientific Tradition" Suresh Soni, Ocean books (P) Ltd., New Delhi.

AC034	**VALUE EDUCATION**					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	0
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives : (3 to 5)	
The course is taught with the objectives of enabling the student to:	
1	Understand value of education and self- development
2	Imbibe good values in students
3	Let the should know about the importance of character
4	

Course Outcomes : (5)	
On completion of this course, the student will be able to : (use the phrases such as, describe / differentiate / perform / analyze / design / demonstrate etc.,)	
CO-1	Knowledge of self-development
CO-2	Learn the importance of Human values
CO-3	Developing the overall personality
CO-4	
CO-5	

Course outcome	**Program Outcome**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	1	1			1
CO-2	1				
CO-3					
CO-4	1				
CO-5	1				

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit - I
Values and self-development –Social values and individual attitudes. Work ethics, Indian vision of humanism-Moral and non- moral valuation. Standards and principles-Value judgements

Unit - II
Importance of cultivation of values-Sense of duty. Devotion, Self-reliance. Confidence, Concentration. Truthfulness, Cleanliness-Honesty, Humanity. Power of faith, National Unity. Patriotism. Love for nature ,Discipline.

Unit - III
Personality and Behavior Development - Soul and Scientific attitude. Positive Thinking. Integrity and discipline. • Punctuality, Love and Kindness. • Avoid fault Thinking-Free from anger, Dignity of labour-Universal brotherhood and religious tolerance-True friendship. • Happiness Vs suffering, love for truth-Aware of self-destructive habits-Association and Cooperation-• Doing best for saving nature

Unit - IV
Character and Competence –Holy books vs Blind faith.-Self-management and Good health-Science of reincarnation-Equality, Non-violence, Humility, Role of Women-All religions and same message-Mind your Mind, Self-control-• Honesty, Studying effectively

Unit - V

Suggested Reading : (five for BE and up to seven for ME)

1	Chakroborty, S.K. “Values and Ethics for organizations Theory and practice”, Oxford University Press, New Delhi

AC 035	**STRESS MANAGEMENT BY YOGA** (AUDIT COURSE - II)					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	-
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	Creating awareness about different types of stress and the role of yoga in the management of stress.
2	Promotion of positive health and overall wellbeing (Physical, mental, emotional, social and spiritual).
3	Prevention of stress related health problems by yoga practice.

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	To understand yoga and its benefits.
CO-2	Enhance Physical strength and flexibility.
CO-3	Learn to relax and focus.
CO-4	Relieve physical and mental tension through asanas
CO-5	Improve work performance and efficiency.

Course outcome	**Program Outcome**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1					
CO-2					
CO-3				1	
CO-4					1
CO-5					1

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit - I
Meaning and definition of Yoga - Historical perspective of Yoga - Principles of Astanga Yoga by Patanjali.

Unit - II
Meaning and definition of Stress - Types of stress - Eustress and Distress. Anticipatory Anxiety and Intense Anxiety and depression. Meaning of Management- Stress Management.

Unit - III
Concept of Stress according to Yoga - Stress assessment methods - Role ofAsana, Pranayama and Meditation in the management of stress.

Unit - IV
Asanas- (5 Asanas in each posture) - Warm up - Standing Asanas - Sitting Asanas - Prone Asanas - Supine asanas - Surya Namaskar
Topics to be taught by Industry Subject Expert: Asanas- (5 Asanas in each posture) - Warm up - Standing Asanas

Unit - V
Pranayama- Anulom and Vilom Pranayama - Nadishudhi Pranayama – KapalabhatiPranayama - Bhramari Pranayama - NadanusandhanaPranayama.Meditation techniques: Om Meditation - Cyclic meditation : Instant Relaxation technique (QRT), Quick Relaxation Technique (QRT), Deep Relaxation Technique (DRT)
Topics to be taught by Industry Subject Expert: Pranayama- Anulom and Vilom Pranayama - Nadishudhi Pranayama – KapalabhatiPranayama - Bhramari Pranayama - Nadanusandhana

Suggested Reading:

1	Yogic Asanas for Group Training - Part-I": Janardhan Swami YogabhyasiMandal, Nagpur.
2	"Rajayoga or Conquering the Internal Nature" by Swami Vivekananda, AdvaitaAshrama (Publication Department), Kolkata.
3	Nagendra H.R nadNagaratna R, "Yoga Perspective in Stress Management", Bangalore, Swami Vivekananda Yoga Prakashan
4	https://onlinecourses.nptel.ac.in/noc16_ge04/preview
5	https://freevideolectures.com/course/3539/indian-philosophy/11

AC 036	**PERSONALITY DEVELOPMENTTHROUGH LIFE ENHANCEMENT SKILLS**					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	-
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To learn to achieve the highest goal happily.
2	To become a person with stable mind, pleasing personality and determination.
3	To awaken wisdom among themselves.

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Develop their personality and achieve their highest goal of life.
CO-2	Lead the nation and mankind to peace and prosperity.
CO-3	To practice emotional self regulation.
CO-4	Develop a positive approach to work and duties.
CO-5	Develop a versatile personality.

Course outcome	**Program Outcome**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1					
CO-2					
CO-3					
CO-4					1
CO-5					1

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit - I
Neetisatakam – Holistic development of personality - Verses 19, 20, 21, 22 (Wisdom) - Verses 29, 31, 32 (Pride and Heroism) - Verses 26,28,63,65 (Virtue)

Unit - II
Neetisatakam – Holistic development of personality (cont'd) - Verses 52, 53, 59 (dont's) - Verses 71,73,75& 78 (do's) - Approach to day to day works and duties.

Unit - III
Introduction to Bhagavadgeetha for Personality Development - ShrimadBhagawadGeeta: Unit 2 – Verses 41, 47, 48 - Unit 3 – Verses13,21,27,35 - Unit 6 – Verses 5,13,17,23,35 - Unit 18 – Verses 45, 46, 48 Unit – 6: Verses 5, 13, 17, 23, 35; Unit – 18: Verses 45, 46, 48

Unit - IV
Statements of basic knowledge - ShrimadBhagawadGeeta: Unit 2- Verses 56, 62,68 - Unit 12 – Verses 13, 14, 15, 16, 17, 18 - Personality of Role model from ShrimadBhagawatGeeta

Unit - V
Role of Bahgavadgeeta in the present scenario - Unit 2 – Verses 17 – Unit 3 – Verses 36, 37, 42 - Unit 4 – Verses 18, 38, 39 - Unit 18 – Verses 37, 38, 63.

Suggested Reading:

1	"Srimad Bhagavad Gita" by Swami SwarupanandaAdvaita Ashram (Publication Department), Kolkata
2	Bhartrihari's Three Satakam (Niti-sringar-vairagya) by P.Gopinath, Rashtriya Sanskrit Sansthanam, New Delhi
3	NTPEL:http://nptel.ac.in/downloads/109104115

AC 037	**CONSTITUTION OF INDIA**					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	-
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	The history of Indian Constitution and its role in the Indian democracy.
2	Address the growth of Indian opinion regarding modern Indian intellectuals' constitutional role and entitlement to civil and economic rights as well as the emergence of nationhood in the early years of Indian nationalism.
3	Have knowledge of the various Organs of Governance and Local Administration.

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Understand the making of the Indian Constitution and its features.
CO-2	Understand the Rights of equality, the Right of freedom and the Right to constitutional remedies.
CO-3	Have an insight into various Organs of Governance - composition and functions.
CO-4	Understand powers and functions of Municipalities, Panchayats and Co-operative Societies.
CO-5	Understand Electoral Process, special provisions.

Course outcome	**Program Outcome**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	-	-	-	-	-
CO-2	-	-	-	-	-
CO-3	-	-	-	-	-
CO-4	-	-	-	-	-
CO-5	-	-	-	-	-

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit – I
History of making of the Indian constitutions: History, Drafting Committee (Composition & Working). Philosophy of the Indian Constitution: Preamble, Salient Features.

Unit - II
Contours of Constitutional Rights and Duties Fundamental Rights, Right to Equality, Right to Freedom, Right against Exploitation, Right to Freedom of Religion, Cultural and Educational Rights, Right to Constitutional Remedies, Directive Principles of State Policy, Fundamental Duties.

Unit - III
Organs of Governance: Parliament: Composition, Qualifications, Powers and Functions, Union executives: President, Governor, Council of Ministers, Judiciary, appointment and transfer of judges, qualifications, powers and functions

Unit - IV
Local Administration - District's Administration head: Role and importance. Municipalities: Introduction, ayor and role of Elected Representative, CEO of Municipal Corporation. Panchayati Raj: Introduction, PRI: ZillaPanchayat, Elected Officials and their roles, CEO ZillaPanchayat: positions and role. Block level: Organizational Hierarchy (Different departments) Village level: role of elected and appointed officials. Importance of grass root democracy.

Unit - V
Election commission: Election Commission: Role and functioning, Chief Election Commissioner and Election Commissioners, State Election Commission :Role and functioning. Institute and Bodies for the welfare of SC/ST/OBC and women

Suggested Reading:

1	The Constitution of India", 1950 (Bare Act), Government Publication.
2	Dr. S. N. Busi, Dr. B. R. Ambedkar, "Framing of Indian Constitution", 1st Edition, 2015.
3	M. P. Jain, "Indian Constitution Law", 7th Edn., Lexis Nexis, 2014.

4	D.D. Basu, “Introduction to the Constitution of India”, Lexis Nexis, 2015.
5	http://www.nptel.ac.in/courses/103107084/Script.pdf

AC038	**PEDAGOGY STUDIES**					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	0
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Review existing evidence on the review topic to inform Program design and policy making undertaken by the DfID, other agencies and researchers.
2	Identify critical evidence gaps to guide the development.

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	What pedagogical practices are being used by teachers in formal and informal classrooms in Developing countries?
CO-2	What is the evidence on the effectiveness of these pedagogical practices, in what conditions, and with what population of learners?
CO-3	How can teacher education (curriculum and practicum) and the school curriculum and guidance materials best support effective pedagogy?

Course outcome	**Program Outcome**					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	
CO-1	1		1		1	
CO-2					1	
CO-3	1	1	1		1	

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit - I

Introduction and Methodology:

- Aims and rationale, Policy background, Conceptual framework and terminology
- Theories of learning, Curriculum, Teacher education.
- Conceptual framework, Research questions.
- Overview of methodology and Searching.

Unit - II
• Thematic overview: Pedagogical practices are being used by teachers in formal and informal classrooms in developing countries. • Curriculum, Teacher education

Unit - III
• Evidence on the effectiveness of pedagogical practices Methodology for the in depth stage: quality assessment of included studies. • How can teacher education (curriculum and practicum) and the school • Curriculum and guidance materials best support effective pedagogy? • Theory of change. • Strength and nature of the body of evidence for effective pedagogical practices. • Pedagogic theory and pedagogical approaches. • Teachers' attitudes and beliefs and Pedagogic strategies

Unit - IV
• Professional development: alignment with classroom practices and followup support • Peer support • Support from the head teacher and the community. • Curriculum and assessment • Barriers to learning: limited resources and large class sizes

Unit - V
• Research gaps and future directions • Research design • Contexts • Pedagogy • Teacher education • Curriculum and assessment • Dissemination and research impact

Suggested Reading :

1	Ackers J, Hardman F (2001) *Classroom interaction in Kenyan primary schools*, Compare, 31 (2): 245-261.
2	Agrawal M (2004) *Curricular reform in schools: The importance of evaluation, Journal of Curriculum Studies*, 36 (3): 361-379.

3	Akyeampong K (2003) *Teacher training in Ghana - does it count? Multi-site teacher education research project (MUSTER) country report 1*. London: DFID.
4	Akyeampong K, Lussier K, Pryor J, Westbrook J (2013) *Improving teaching and learning of basic maths and reading in Africa: Does teacher preparation count?* International Journal Educational Development, 33 (3): 272–282.
5	Alexander RJ (2001) Culture and pedagogy: *International comparisons in primary education*. Oxford and Boston: Blackwell.
6	Chavan M (2003) *Read India: A mass scale, rapid, 'learning to read' campaign*.
7	www.pratham.org/images/resource%20working%20paper%202.pdf.

CE 481	**DISERTATION PHASE- I**					
Pre-requisites			**L**	**T**	**P**	**C**
			6	-	-	10
Evaluation	**SEE**	60 Marks	**CIE**		100 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	Define the statement of research problem.
2	Update the literature in chosen area of research and establish scope of work.
3	Develop the study methodology.
	Carryout basic theoretical study/experiment.

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Identify a research gap based on the review of literature and try to innovate with set objective based on experimental /analytical / simulation in transportation Engineering and Literature Review
CO-2	recognize procedure and research methodology with a concern of society/Environmental and ethics
CO-3	prepare a report/documentation in a standard format
CO-4	presentation in order with appropriate figures and PPT
CO-5	performance on viva voce to defend the work based on subject knowledge using PPT

Program Articulation Matrix

Course Outcome	Program Outcome				
	PO1	PO2	PO3	PO4	PO5
CO1	3	2	3	3	2
CO2	3	2	3	3	1
CO3	2	2	1	1	1
CO4	3	2	2	3	2
CO5	2	3	2	3	1

Each student will be attached to a faculty member, (guide) for Major Project Phase-I during the Third

Semester. The student will carry out the literature and methodology of project which may be the development of Software - Hardware - Simulation Studies - Design - Analysis - Experimental related to the specialization. The work will be monitored regularly by the guide. At the end of the Semester, Student will write the report on the work done and submit to the guide. Student has to present the work before two faculty members (one guide and other to be appointed by Chairman BOS) on a fixed day during the last week of the semester in which Major Project Phase-I is offered. The sessional marks will be awarded jointly by these two examiners based on the report, the presentation and viva voce

SEMESTER-IV

CE 482	**DISSERTATION PHASE-II**					
Pre-requisites			**L**	**T**	**P**	**C**
			6	-	-	16
Evaluation	**SEE**	Viva Voice	**CIE**		200 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	Expand on the defined research problem in dissertation.
2	Conduct laboratory/analytical studies.
3	Analyse data, develop models, offer solutions and give conclusions.

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Develop on the defined research problem in dissertation.
CO-2	Carry out laboratory/analytical studies.
CO-3	Evaluate data, develop models, offer solutions and give conclusions.
CO-4	Present research in the form of report
CO-5	Performance on viva voce to defend the work based on subject knowledge using PPT

CO-PO MAPPING

Course Outcome	Program Outcome				
	PO1	PO2	PO3	PO4	PO5
CO1	3	2	3	3	2
CO2	3	2	3	3	1
CO3	2	2	1	1	1
CO4	3	2	2	3	2
CO5	2	3	2	3	1

Each student will continue the project in Major Project Phase-II during fourth semester which is based on the work decided in earlier semester The student will carry out the project which may be the development of Software - Hardware - Simulation Studies - Design - Analysis - Experimental related to the specialization. The work will be monitored regularly by the guide. At the end of the Semester, Student will write the report on the work done and submit to the guide. Student has to present the work before two faculty members (one guide and other to be appointed by Chairman BOS) on a fixed day during the last week of the semester in which mini project is offered. The sessional marks will be awarded jointly by these two examiners based on the report, the presentation and viva voce.