DEPARTMENT OF CIVILENGINEERING

M.Tech
in
TRANSPORTATION ENGINEERING

to improve their expertise in the technical content of the course, enhance communication skills,

MAR BASELIOS COLLEGE OF ENGINEERING AND TECHNOLOGY

(Approved by AICTE, Autonomous Institution Affiliated to APJ Abdul Kalam Technological University)

MAR IVANIOS VIDYANAGAR, NALANCHIRA, THIRUVANANTHAPURAM – 695015, KERALA.

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M. TECH DEGREE PROGRAMME in TRANSPORTATION ENGINEERING

CURRICULUM & SYLLABI

Items	Board of Studies (BoS)	Academic Council (AC)
Dates of Approval	05/08/2022	21/11/2022
	28/02/2023	20/03/2023

Head of the Department
Chairman, Board of Studies
Dr. JISHA S.V.
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MAR BASELIOS COLLEGE OF ENGINEERING & TECHNOLOGY
(Autonomous)
Mar Ivanios Vidyanagar
Nalanchira
Thiruvananthapuram-695015

28/03/2023
Principal
Chairman, Academic Council
Principal
Mar Baselios College
of Engineering & Technology
Mar Ivanios Vidyanagar, Nalanchira
Thiruvananthapuram-695015

CURRICULUM & SYLLABI

for

M. TECH DEGREE PROGRAMME

in

TRANSPORTATION ENGINEERING

2022 SCHEME (AUTONOMOUS)

MAR BASELIOS COLLEGE OF ENGINEERING AND TECHNOLOGY

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MAR BASELIOS COLLEGE OF ENGINEERING AND TECHNOLOGY

Vision and Mission of the Institution

Vision

To be an Institution moulding globally competent professionals as epitomes of Noble Values.

Mission

To transform the Youth as technically competent, ethically sound and socially committed professionals, by providing a vibrant learning ambience for the welfare of humanity.

DEPARTMENT OF CIVILENGINEERING

Vision and Mission of the Department

Vision

To be a Centre of Excellence in Civil Engineering education with a global perspective, creating ethically strong engineers for the service of society.

Mission

To provide Engineering Education which can create exemplary professional Civil Engineers of high ethics with strong conceptual foundation coupled with practical insight, to serve the industry and community.

DEPARTMENT OF CIVIL ENGINEERING

M.Tech. Programme in Transportation Engineering

For the students admitted from 2022-2023

Scheduling of Courses

i) Knowledge Segments and Credits

Every course of M. Tech Programme is placed in one of the eight categories as listed in Table 1. No semester shall have more than six lecture-based courses and two laboratory courses, and/or project courses in the curriculum.

Table 1: Credit Distribution and Knowledge Domains

Sl. No.	Category	Category Code	Number of Courses	Total Credits
1	Discipline Core Course	DCC	2	6
2	Program Core Course	PCC	3	9
3	Laboratory Course	LBC	2	2
4	Program Elective Course	PEC	4	12
5	Mandatory Credit Course (Research Methodology & IPR)	RM	1	2
6	Industry/ Interdisciplinary Elective	IEC	1	3
7	Internship	PR	1	3
8	Mini Project		1	2
9	Project		2	27
10	MOOC	MOOC	1	2
11	Audit Course	AC	1	-
Total Mandatory Credits				**68**

ii) Semester-wise Credit Distribution

Semester	I	II	III	IV	Total Credits
Credits for Courses	18	18	16	16	**68**

Semester I							
Slot	**Category Code**	**Course Number**	**Course Name**	**L**	**T**	**P**	**Credit**
A	PCC	22CE261A	Analysis and Design of Pavement Systems	3	0	0	3
B	PCC	22CE261B	Traffic Engineering	3	0	0	3
C	PCC	22CE261C	Urban Transportation Planning	3	0	0	3
D	PEC	22CE262X	Program Elective 1	3	0	0	3
E	PEC	22CE262X	Program Elective 2	3	0	0	3
S	RM	22MC061A	Research Methodology & IPR	2	0	0	2
T	LBC	22CE269A	Pavement Materials and Evaluation Lab	0	0	2	1
Total				**17**	**0**	**2**	**18**

Semester II							
Slot	**Category Code**	**Course Number**	**Course Name**	**L**	**T**	**P**	**Credit**
A	DCC	22MA060E	Probability, Statistics and Mathematical Techniques	3	0	0	3
B	DCC	22CE260A	Economic Appraisal of Projects	3	0	0	3
C	PEC	22CE262X	Program Elective 3	3	0	0	3
D	PEC	22CE262X	Program Elective 4	3	0	0	3
E	IEC	22CE26XX	Industry/Interdisciplinary Elective	3	0	0	3
S	PR	22CE267A	Mini Project	0	0	4	2
T	LBC	22CE269B	Transportation Planning and Traffic Lab	0	0	2	1
Total				**15**	**0**	**6**	**18**

Semester III							
Slot	**Category Code**	**Course Number**	**Course Name**	**L**	**T**	**P**	**Credit**
A	MOOC	-	MOOC	-	-	-	2
B	AC	22AC071X	Audit Course	3	0	0	-
U	PR	22CE277A	Internship	-	-	-	3
W	PR	22CE278A	Dissertation Phase I / Research Project Phase I	0	0	17	11
Total				**3**	**0**	**17**	**16**

Semester IV							
Slot	**Category Code**	**Course Number**	**Course Name**	**L**	**T**	**P**	**Credit**
W	PR	22CE278B	Dissertation Phase II / Research Project Phase II	0	0	24	16
Total				**0**	**0**	**24**	**16**

LIST OF PROGRAM ELECTIVE COURSES

Category Code	Course Number	Course Name	L	T	P	Credit
PEC	22CE262A	Geometric Design of Highways	3	0	0	3
	22CE262B	Advanced Pavement Materials	3	0	0	3
	22CE262C	Pavement Construction and Maintenance	3	0	0	3
	22CE262D	Pavement Asset Management	3	0	0	3
	22CE262E	Traffic Flow Theory	3	0	0	3
	22CE262F	Traffic Simulation Modelling and Applications	3	0	0	3
	22CE262G	Transportation Network Analysis	3	0	0	3
	22CE262H	Road Safety Management	3	0	0	3
	22CE262I	Multimodal Transit Systems	3	0	0	3
	22CE262J	Geoinformatics in Transportation Engineering	3	0	0	3
	22CE262K	Analytical Techniques in Transportation Planning	3	0	0	3
	22CE262L	Green Transportation Systems	3	0	0	3
	22CE262M	Advanced Optimization Techniques for Transportation Engineering	3	0	0	3

INTERDISCIPLINARY ELECTIVE COURSE

Slot	Category Code	Course Number	Course Name	L	T	P	Credit
E	IEC	22CE265A	Highway Safety Engineering	3	0	0	3

INDUSTRY-BASED ELECTIVE COURSE

Slot	Category Code	Course Number	Course Name	L	T	P	Credit
E	IEC	22CE266A	Data Analytics for Smart Transportation Systems	3	0	0	3
E	IEC	22CE266B	Highway Asset Management	3	0	0	3

DETAILED SYLLABI (M1)

M.Tech TRANSPORTATION ENGINEERING

SEMESTER I

PROGRAM CORE COURSES (PCC)

Course Code	Course Name	Category Code	L	T	P	Credit	Year of Introduction
22CE261A	Analysis and Design of Pavement Systems	PCC	3	0	0	3	2022

i) COURSE OBJECTIVES

The objective of this course is to impart knowledge on the fundamental concepts of analysis of pavements and their design. The course includes analysis of axle loads and material characterization for stress-strain analysis and design. The design of flexible and rigid pavements using different approaches adopted worldwide are covered in the syllabus. The students will be introduced to various software used for the analysis and design of pavements.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO1	Apply the fundamental concepts of stress distribution in a pavement system to evaluate the critical stresses and strains.	Apply
CO2	Apply appropriate techniques for axle load data analysis and material characterization for the design of pavements.	Apply
CO3	Design flexible pavements as per different codes of practice.	Apply
CO4	Apply standard provisions to design rigid pavements.	Apply
CO5	Analyze various design options using relevant software for the analysis and design of pavements.	Analyze

iii) SYLLABUS

Introduction to pavements, subsystems, factors affecting pavement design; Material characterization, Failure criteria for the design of pavements; Analysis of axle loads for pavement design.

Stresses and strains in flexible pavements; Design of flexible pavements - AASHTO Method, Asphalt Institute Method, IRC Method.

Stresses in rigid pavements; Design of rigid pavements - PCA method, AASHTO-1993 method and IRC method. Introduction to mechanistic empirical pavement design (MEPD-2004).

Use of software used for the analysis and design of pavements.

iv) REFERENCES

1) Yang H. Huang, *Pavement Analysis and Design*, Prentice Hall,2nd edition, 2008.

2) IRC: 37-2018, *Guidelines for the Design of Flexible Pavements*, Fourth revision, Indian Roads Congress, New Delhi, 2018.

3) IRC: 58-2015, *Guidelines for the Design of Plain Jointed Rigid Pavements for Highways*, Fourth revision, Indian Roads Congress, New Delhi, 2015.

4) AASHTO 1993 - *Guide for Design of Pavement Structures*, American Association of State Highway and Transportation Officials, Washington, D.C., 1993.

5) National Cooperative Highway Research Program, *Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures,* Transportation Research Board, National Research Council, Illinois, 2004.

6) MS-01-2001, *Thickness Design: Asphalt Pavements for Highways & Streets (Manual Series 1)*, The Asphalt Institute, 2001.

7) EB109.01P - *Thickness Design for Concrete Highway and Street Pavements (1984)*, Portland Cement Association, Skokie, Ill.

v) COURSE PLAN

Module	Contents	No. of hours
I	Introduction to Pavements: Types of pavements, Flexible and rigid pavements, Pavement cross-sections and functions of individual layers. Pavement distress considered for design – Rutting/ Fatigue damage/ Temperature cracking/ Moisture damage/ IRI Failure criteria for design of flexible pavements. Boussinesq's theory, Burmister's layer theory - Solutions for one, two and three layered pavement systems.	**8**
II	Traffic characteristics – Traffic volume, growth rate, lane distribution factor, modal distribution, Axle configuration, Equivalent single wheel load for different criteria and Equivalent wheel load factor, Axle load survey, distribution, Truck factors, ESAL and computation of the number of repetitions. Material characterization for soil, granular materials and bituminous materials – Resilient Modulus, Dynamic modulus, rutting and fatigue characteristics. Material characterization for cement concrete pavements – modulus of subgrade reaction. Climate variation – influence of climate in material characteristic functions.	**10**
III	Stresses and strains in flexible pavements: Stress inducing factors in flexible pavements, Vehicle - pavement interaction, Stresses and deflections in homogeneous soil mass. Methods of flexible pavement design: AASHTO-1993 Method, Asphalt Institute Method. Use of latest software for the analysis and design of flexible pavements.	**9**

IV	Methods of flexible pavement design: IRC-37 method. Principles of Mechanistic–Empirical Pavement Design (MEPD). Stresses in Rigid Pavements: Westergaard's theory and assumptions, Types of stresses: Wheel load stresses, Temperature stresses, Frictional stresses, Critical combination of stresses. Use of latest software for the analysis and design of rigid pavements.	**9**
V	Rigid pavement design: PCA method, AASHTO-1993 method and IRC- 58 method.	**9**
	Total hours	**45**

Course Code	Course Name	Category Code	L	T	P	Credit	Year of Introduction
22CE261B	Traffic Engineering	PCC	3	0	0	3	2022

i) COURSE OBJECTIVES

This course gives an introduction to the concepts of traffic engineering, fundamental flow relationships, traffic surveys, traffic engineering control systems and the rules and regulations pertaining to traffic engineering.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO1	Identify the microscopic and macroscopic characteristics of a traffic stream.	Apply
CO2	Examine the relationship between fundamental parameters of a traffic stream.	Analyze
CO3	Apply different statistical techniques to interpret the data collected through various traffic surveys.	Apply
CO4	Apply standard procedures to design the appropriate traffic control measure at a road intersection.	Apply
CO5	Identify the appropriate safety measures and regulations for a given traffic scenario.	Apply

iii) SYLLABUS

Components and characteristics of Traffic stream – road traffic, vehicle and road user.

Traffic stream parameters – Fundamental diagrams of traffic flow, PCU concepts.

Traffic surveys – Data collection and analysis of various traffic parameters.

Studies on parking, headway, pedestrian, accident and congestion.

Traffic controls and regulations, Design of intersections – signals, roundabouts; traffic management measures. Road Safety audit and safety measures.

iv) REFERENCES

1) Roess R. P., McShane W. R. and Prassas E.S., *Traffic Engineering*, Prentice Hall, 5th edition, 2019.
2) Pignataro L. J., *Traffic Engineering -Theory and Practice*, New Jersey: Prentice Hall, 1973 (Digitized in 2011).
3) Kadiyali L. R., *Traffic Engineering and Transport Planning*, Khanna Publishers, 7th edition, 2008.
4) Khisty C. J., and Kent Lall B., *Transportation Engineering*, Prentice Hall of India Pvt. Ltd., 3rd edition, 2012.
5) Papacostas C. S. and Prevedouros P.D., *Transportation Engineering and Planning*, PHI

Publication, 3rd edition, 2009.

6) Fred L. M. and Scott S., *Principles of Highway Engineering and Traffic Analysis*, John Wiley &; Sons, 5th edition, 2013.
7) Nicholas J. G. and Lester A. H., *Traffic and Highway Engineering*, Cengage Learning India, 5th edition, 2015.
8) Law M. A. and Kelton W. D., *Simulation Modeling and Analysis*, McGraw Hill Higher Education, 5th edition, 2014
9) Adolf D. May, *Traffic Flow Fundamentals*, 1st edition, Pearson, 1990.
10) IRC:93-1985, *Guidelines on Design and Installation of Road Traffic Signals*, Indian Roads Congress, New Delhi, 1985.
11) IRC: 86-2018, *Geometric Design Standards for Urban Roads and Streets*, Indian Roads Congress, New Delhi, 2018.
12) IRC: 64-1990, *Guidelines for Capacity of Roads in Rural Areas*, Indian Roads Congress,New Delhi, 1990.
13) IRC: 93-1985, *Guidelines on Design and Installation of Road Traffic Signals*, Indian Roads Congress, New Delhi, 1985.
14) IRC: 106-1990, *Guidelines for Capacity of Urban Roads in Plain Areas*, Indian Roads Congress, New Delhi.
15) IRC SP: 41-1994, *Guidelines for the Design of At-Grade Intersections in Rural and Urban Areas*, Indian Roads Congress, New Delhi, 1994.
16) IRC : 67-2012, *Code of Practice for Road Signs*, Indian Roads Congress, New Delhi, 2012.
17) *Indian Highway Capacity Manual* (INDO-HCM), Chandra, S., Gangopadhyay S., Velmurugan S. and Ravinder K., CSIR-CRRI, 2017.
18) IRC:SP:88-2019, *Manual on Road Safety Audit*, 1st revision, Indian Roads Congress, New Delhi, 2019.

v) COURSE PLAN

Module	Contents	Hours
I	Objectives and scope of traffic engineering - Components and characteristics of Traffic stream - Microscopic and Macroscopic characteristics - Components of road traffic-the vehicle, static and dynamic characteristics of vehicles, driver and road user, Road characteristics.	**7**
II	Traffic stream parameters - Fundamental diagrams of traffic flow. Flow at different densities - Shock wave phenomenon,Car-Following Theory. Concept of PCU and methods of determination of PCU values, Studies on PCU determination under heterogeneous traffic.	**7**

III	Traffic Surveys - Data collection and Analysis - Measurement of traffic parameters like volume, speed, density Travel time and delay, headways and gaps, Critical Gap - Gap acceptance studies Parking studies, pedestrian studies, accident studies, Congestion studies: Performance measures, intensity, traveler perception, remedial measures. Analysis of traffic data - fitting of distributions, sampling in traffic studies, statistical analysis of traffic stream parameters.	**11**
IV	Design of at-grade intersections-principles and design-channelization - design of rotaries - design of traffic signals- pre timed and actuated-design of signal setting-phase diagrams, timing diagram- signal coordination Capacity and Level of service (LOS) concepts: Definitions, factors affecting LOS, capacity and performance evaluation. Introduction to traffic simulation - different types -application of traffic simulation models for analysis of dynamic traffic systems	**10**
V	Traffic Controls and Regulations-Traffic Signs and Road Markings-Road furniture-street lighting - other traffic control aids-Advanced technologies of traffic control. Traffic laws and ordinances-General regulations, Regulations on vehicles, drivers, pedestrians and traffic-regulations on speed- speed zoning - parking regulations-enforcement of regulations, traffic management measures. Road safety audit and safety measures	**10**
	Total hours	**45**

Course Code	Course Name	Category Code	L	T	P	Credit	Year of Introduction
22CE261C	Urban Transportation Planning	PCC	3	0	0	3	2022

i) COURSE OBJECTIVES

This course aims to understand the concept of Transportation Planning process such as Trip Generation, Trip Distribution, Modal split and Trip Assignment.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO1	Apply the concept of transportation planning for travel demand estimation.	Apply
CO2	Apply theoretical models to distribute the travel demands to various zones of a city.	Apply
CO3	Identify appropriate transportation modes for efficient transport planning.	Apply
CO4	Develop road networks with links and nodes and assign the distributed travel based on optimum time/cost of travel.	Analyse
CO5	Make use of various transportation planning software for the development of the four stage transportation planning processes for cities.	Apply

iii) SYLLABUS

Urban transportation planning – process and concepts.

Methods of travel demand estimation, trip generation models, trip distribution models, modal split models and traffic assignment models.

Study of transportation planning software for development of planning models.

Introduction to land use transport models.

iii) REFERENCES

1) Hutchinson, B.G., *Principles of Urban Transportation System Planning*, Mc-Graw Hill 1990.

2) Bruton M.J., *Introduction to Transportation Planning*, Hutchinson of London, 2000.

3) Venkatramaiah, *Transportation Engineering, Vol: 1*, Universities Press (India), Pvt. Ltd., 2016.

4) John W. Dickey, Walter J. Diewald, Antoine G. Hobeika, Charles J. Hurst, N. Thomas Stephens, Robert C. Stuart and Richard D. Walker, *Metropolitan Transportation Planning*, 2nd edition, Routledge (imprint of Taylor and Francis), 2017 (e-book).

5) *NPTEL lectures on Transportation Planning,* Dr.V.Tamil Arasan, Former Professor of IITM, 2012.

6) C. S. Papacostas and P.D. Prevedouros, *Transportation Engineering and Planning*, 2nd edition, Prentice Hall, 1992.

7) Michael D Meyer and Eric J Miller, *Urban Transportation Planning: A Decision OrientedApproach*, McGraw Hill, 1984.

v) COURSE PLAN

Module	Contents	Hours
I	Introduction to Transportation Planning Practices. Trip generation models - Trip classification - productions and attractions - Trip rate analysis - Multiple regression models - Category analysis - Trip distribution models - Growth factor models, Gravity model. Introducing Transport Planning Softwares	**10**
II	Modal split models - Mode choice behavior - Trip end and trip interchange models - Traffic assignment - Transportation networks - Minimum Path Algorithms - Assignment methods - All or Nothing assignment, Capacity restrained assignment and Multi path assignment - Route-choice behavior. Introducing previous studies on Mode choice analysis and Trip assignment analysis	**10**
III	Introduction to land use transport models. Lowry derivative models - Quick response techniques - Non-Transport solutions for transport problems.	**10**
IV	Urban transportation systems - Mass rapid transit system - Light rail transit - Personal rapid M. Tech transit, guided way systems, cabin taxi, dual mode bus - Para transit systems - Demand responsive system - Intermediate public transport	**10**
V	Future of transportation planning with a particular emphasis on connected and autonomous vehicles (CAVs). This section will examine CAV technology and regulations; key opportunities (benefits) and challenges (risks) associated with CAV development; and strategic paths forward for the transportation planning field.	**5**
	Total hours	**45**

PROGRAM ELECTIVE COURSES (PEC)

Course Code	Course Name	Category Code	L	T	P	Credit	Year of Introduction
22CE262A	Geometric Design of Highways	PEC	3	0	0	3	2022

i) COURSE OBJECTIVES

Goal of this course is to expose the students to the concepts of geometric design elements and the cross-sectional elements. It enables the students to determine the sight distances and the components of horizontal and vertical alignment. It also enables the students to design the various types of intersections, their suitability and various types of facilities for pedestrians, cycles, buses and parking.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Identify the most suitable cross section while designing a roadway.	Apply
CO 2	Apply standard guidelines for the geometric design of horizontal and vertical alignment of different classes of highways.	Apply
CO 3	Identify appropriate geometric design for a given intersection.	Apply
CO 4	Apply relevant guidelines and standards for the design of pedestrian facilities, bus bays and cycle tracks.	Apply

iii) SYLLABUS

Functional classification of highway system, design controls, objectives of geometric design.

Cross section elements, design specifications, pavement surface characteristics, horizontal alignment of roads, vertical alignment of roads.

Introduction to MX roads software.

Geometric design of intersections, miscellaneous elements, pedestrians, cycle tracks, bus bays, design of on-street and off-street parking facilities.

Guidelines for layout design, traffic signs and markings.

iv) REFERENCES

1) AASHTO-2011, *A Policy on Geometric Design of Highways and Streets*, 6th edition, American Association of State Highway and Transportation Officials, Washington D.C. ,2011.
2) L.R. Kadiyali and N.B. Lal, *Principles and Practice of Highway Engineering*, 7th edition, Khanna Publishers, 2019.
3) Khanna S.K., Justo C. E. G. and Veeraragavan A., *Highway Engineering,* 10th edition, Nem Chand and Bros., 2019.

4) Great Britain Ministry of Transport, *Roads in Urban Areas*, HMSO, London, 1974.
5) Jack E Leish and Associates, *Planning and Design Guide: At-Grade Intersections,* A Design Reference Book and Text, Undated.
6) IRC: 86-2018, *Geometric Design Standards for Urban Roads and Streets,* Indian Roads Congress, New Delhi, 2018.
7) IRC: 52- 2001, *Recommendations about Alignment Survey and Geometric Design of Hill Roads*, Indian Roads Congress, New Delhi, 2001.
8) IRC: 64-1990, *Guidelines for Capacity of Roads in Rural Areas*, Indian Roads Congress, New Delhi, 1990.
9) IRC: 3-1983, *Dimensions and Weights of Road Design Vehicles*, Indian Roads Congress, New Delhi, 1983.
10) IRC: 38-1988, *Guidelines for Design of Horizontal Curves for Highways and Design Tables* (First Revision), Indian Roads Congress, New Delhi,1988.
11) IRC: 66-1976, *Recommended Practice for Sight Distance on Rural Highways*,Indian Roads Congress, New Delhi,1976.
12) IRC: 65-2017, *Guidelines for Planning and Design of Roundabouts* (FirstRevision, Indian Roads Congress, New Delhi, 2017.
13) IRC: 92-2017, *Guidelines for the Design of Interchanges in Urban Areas* (First Revision),Indian Roads Congress, New Delhi, 2017.
14) IRC: 103-2012, *Guidelines for Pedestrian Facilities*, 1st Revision, Indian Roads Congress, New Delhi, 2012.
15) IRC SP: 41-1994, *Guidelines for the Design of At-Grade Intersections in Rural and Urban Areas*, Indian Roads Congress, New Delhi, 1994.

v) COURSE PLAN

Module	Contents	No. of hours
I	Functional Classification of Highway System, Design Controls - Topography, Driver characteristics, Vehicle Characteristics, Traffic, Capacity and Level of Service, Design Speed. Objectives of Geometric Design, Cross Section Elements: Design specifications; Pavement Surface characteristics - Skid Resistance, Road Roughness; Camber, Objectives, design standards. Specifications for hill roads.	**9**
II	Horizontal Alignment of Roads: Sight Distances - Stopping Sight Distance, Overtaking Sight Distance and Intermediate Sight Distance; Objectives of horizontal curves; Super elevation; Extra-widening on Curves; Transition Curves - Objectives and Design. Transition Curve setting methods, Introduction to MX Roads software.	**9**

III	Vertical Alignment of Roads: Gradients - Types of Gradients, Design Standards; Vertical Curves - Summit Curves, Valley Curves and Design criteria for Vertical Curves; Importance of Sight Distances for Horizontal and Vertical Curves; Combination of Vertical and Horizontal; Curves - Grade Compensation.	**9**
IV	Geometric Design of Intersections: Types of Intersections; Design Principles for Intersections; Design of At-grade Intersections - Channelization, Objectives; Traffic Islands and Design standards; Rotary Intersection - Concept, Advantages and Disadvantages; Grade separated Interchanges - Types, warrants and Design standards.	**10**
V	Miscellaneous 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, Traffic Signs and Markings.	**8**
	Total Hrs.	**45**

Course Code	Course Name	Category Code	L	T	P	Credit	Year of Introduction
22CE262B	Advanced Pavement Materials	PEC	3	0	0	3	2022

i) COURSE OBJECTIVES:

The main objective of this course is to provide a thorough understanding of material characterization for bituminous and concrete pavements. The course includes topics on the stabilization of weak subgrade soils. It also deals with various sustainable materials used in pavement construction.

ii) COURSE OUTCOMES

After the completion of the course, the student will be able to:

CO 1	Identify the suitability of soil for highway construction and its use in pavement layers through in-situ and laboratory investigations.	Apply
CO 2	Apply various techniques for soil stabilization and ground improvement for pavement construction.	Apply
CO 3	Apply standard procedures to characterize pavement materials such as aggregate, bitumen, bitumen emulsion and foamed bitumen.	Apply
CO 4	Make use of standard procedures to characterize bituminous mixes such as HMA, cold mix and warm mix for pavement construction.	Apply
CO 5	Design bituminous mixes using Marshall method.	Apply
CO 6	Apply Indian Standard specifications to design concrete mixes for rigid pavements.	Apply

iii) SYLLABUS

Relevance of subgrade soil as a foundation for pavements with detailed investigation of its characteristics, soil classification systems and soil stabilization techniques.

Characterization of materials used for pavement construction, namely,aggregates, bitumen, bitumen emulsion, cement, cement concrete.

Bituminous pavement mixes – types, properties and Marshall method of mix design.

Concrete mix design of rigid pavements.

Use of sustainable materials and innovative materials in the construction of bituminous and concrete pavements.

iv) REFERENCES

1) Wright, P. H. and Dixon, K. K., *Highway Engineering*, John Wiley and Sons, 7th edition, 2004.
2) Mallick, R. B. and El-Korchi,T., *Pavement Engineering*, CRC press, 2nd edition, 2017.
3) *Manual for Construction and Supervision of Bituminous Works*, Ministry of Road Transport and Highways (MoRTH), Indian Road Congress, reprint 2008.
4) Hunter, R. N., *Bituminous Mixtures in Road Construction*, Thomas Telford Services Ltd., 1995.
5) Atkins, N. Harold, *Highway Materials, Soils and Concretes*, 4th edition, 2002, Prentice Hall.
6) Read J. And White Oak D., The Shell Bitumen Handbook, 5th edition, Shell Bitumen, Thomas Telford Publishing, London 2003.
7) Relevant IS, IRC, AASHTO and ASTM Standards.

v) COURSE PLAN

Module	Contents	No. of hours
I	**Subgrade Soil Characterization**: Properties of subgrade, different types of soils, Mechanical response of soil, Soil classification, Index and other basic properties of soil, Dynamic properties of soil. Review of laboratory and in-situ procedures for evaluating the mechanical properties of soils. Suitability of different types of soil for the construction of highway embankments and pavement layers. Field compaction and control.	7
II	**Soil Stabilization** - Physical and Chemical modification, Stabilization with admixtures like cement, lime, calcium chloride, fly ash and bitumen. Grouting: Categories of grouting, grout materials, grouting techniques and control. Introduction to ground improvement techniques, Introduction to geo textiles and geosynthetics applications	7
III	**Aggregate Characterization:** Types of aggregates, Sampling of aggregates, Aggregate texture and skid resistance, polishing of aggregates. Proportioning and blending of aggregates: Fuller and Thompson's Equation, 0.45 power maximum density graph, Superpave gradation **Bitumen and Bituminous Concrete Mix Characterization:** Bitumen sources and manufacturing, Chemistry of bitumen.	10

	Rheology of bitumen: Complex shear modulus, phase angle, Multiple stress creep and recovery test and linear amplitude sweep test.	
IV	Modified bitumen: Crumb rubber modified bitumen, natural rubber modified bitumen, polymer modified bitumen. Long-term and short-term ageing and its effect on bitumen performance, tests to simulate ageing of bitumen: RTFOT and PAV. Bitumen emulsion and foamed bitumen: characterization. Bituminous Mixes: Resilient modulus and dynamic modulus,Permanent deformation and fatigue characterization (Recap only) Desirable properties of bituminous mixes, Design of bituminous mixes by Marshall method. Introduction to superpave mix design procedure.	**10**
V	Recycled Asphalt Pavement (RAP) – application and characterization. Cold mix and warm mix technology. **Cement and Cement Concrete Mix Characterization**: IS method of cement concrete mix design, Joint fillers for Jointed Plain Cement Concrete pavements and their characterization. Introduction to other types of concretes: roller-compacted concrete, pre-cast concrete, interlocking paver blocks, pervious concrete for pavement application.	**11**
	Total hours	**45**

Course Code	Course Name	Category Code	L	T	P	Credit	Year of Introduction
22CE262C	Pavement Construction and Maintenance	PEC	3	0	0	3	2022

i) COURSE OBJECTIVES

The objective of this course is to know the recent developments in construction practices and modern equipment's used. This course also introduces the importance for recycling process advanced test procedures and improved mixes/layers.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO1	Apply appropriate techniques for the construction of different layers of highway pavements.	Apply
CO2	Identify suitable plants and equipment for the production and construction of highway pavement layers.	Apply
CO3	Design various components of drainage systems in highway pavements.	Apply
CO4	Make use of recycling technology for the maintenance of pavements.	Apply

iii) SYLLABUS

Construction procedures for various flexible pavement component layers and study on latest equipment used for pavement construction.

Construction of drainage systems in pavements.

Cement Concrete pavement Construction.

Maintenance of pavements. Concepts of reconstruction, recycling etc.

iv) REFERENCES

1) Kadiyali L. R. and Lal N. B., *Principles & Practice of Highway Engineering*, Khanna Publishers, New Delhi, 2005.

2) Atkins H., *Highway Materials, Soils and Concrete,* Pearson Prentice Hall, 2002.

3) Relevant IRC codes for construction of bituminous & concrete roads.

4) Chakraborty, P. and Das, A., *Principles of Transportation Engineering*, Prentice Hall India Learning Pvt. Ltd., 2003.

5) *Manual for Construction and Supervision of Bituminous Works*, Ministry of Road Transport and Highways, IRC reprint 2008.

6) Delatte N. J., *Concrete Pavement Design, Construction and Performance*, 2nd edition,CRC Press, 2017.

7) Hunter R. N., *Bituminous Mixtures in Road Construction*, Thomas Telford Services Ltd., 1995.

8) Mallick R. B., and Korchi T.E., *Pavement Engineering: Principles and Practice*, 3rd edition, CRC Press, 2017.

9) Guyer J. P., *An Introduction of Asphalt Concrete Pavement Recycling (Street and Highway Engineering)*, Createspace Independent Pub, 2014.

v) COURSE PLAN

Module	Contents	No. of hours
I	Components of road and pavement structure including subgrade, drainage system, functions, requirements and sequence of construction operations. Plants and equipment for production of materials - crushers, mixers, bituminous mixing plants, cement concrete mixers – various types, advantages and choice. Drainage – Assessment of drainage requirements for the road and design of various components, drainage materials, Construction of surface and subsurface drainage system and design of filter materials for roads. Drainage of urban roads, problems.	**9**
II	Pre-construction surveys and marking on ground. Specifications and steps for the construction of road formation in embankment and cut, construction steps for subgrade (preparation of subgrade) in cutting, filling and at grade. Construction steps for granular sub-base, quality control tests.	**9**
III	Different types of granular base course –WMM, CRM, WBM, specifications, construction method and quality control tests. Different types of bituminous layers for binder and surface courses, their specifications (as per IRC and MORTH), construction method and quality control tests. Special structural courses like stone matrix asphalt and construction of porous asphalt.	**9**

IV	Different types of sub-base and base course for cement concrete (CC) pavement and construction method. Construction of cement concrete pavements and joints, quality control during construction. Construction of special Cement concrete pavements like interlocking concrete block pavements (ICBP), Continuously reinforced cement concrete pavements (CRCP), Fibre reinforced cement concrete pavements (FRCP), white topping, Ultra thin white topping etc. General Aspects: Quality assurance, statistical approach, quality system for road construction. Safety aspects during road construction and maintenance works. Installation of various traffic safety devices and information system.	**9**
V	Road maintenance works - day to day and periodic maintenance works of various components of road works and road furniture. Preventive maintenance of road drainage system, pavements and other components of road. Preparation of existing pavement - patching, profile correction, Special measures to deal with reflection cracks in pavement layers, slipperiness of surface, etc. Requirements and methods for rehabilitation, recycling and re-construction.	9
	Total hours	**45**

Course Code	Course Name	Category Code	L	T	P	Credit	Year of Introduction
22CE262D	Pavement Asset Management	PEC	3	0	0	3	2022

i) COURSE OBJECTIVES

This course outlines the various types of pavement distresses, its causes and remedies and the importance of pavement condition evaluation and prediction. It also includes the fundamentals and various levels of pavement management system.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO1	Apply the deduct value method to estimate the pavement condition index.	Apply
CO2	Make use of non-destructive tests for structural evaluation of pavements.	Apply
CO3	Compare the various pavement performance prediction models.	Analyse
CO4	Select the priority of maintenance and rehabilitation actions to be carried out on highways.	Analyse

iii) SYLLABUS

Pavement management process – Concepts, levels, application of Pavement Management System.

Pavement condition data requirements – data needs, characterizing pavement performance, evaluation of structural capacity of pavements, surface distress condition, evaluation of safety

Determining present and future needs and priority programming of rehabilitation and maintenance – deterioration prediction models, determining needs, priority programming.

Rehabilitation design and economic analysis – alternate strategies of design and rehabilitation, economic evaluation of alternate pavement design strategies and selection of optimal strategies.

Application of Highway Development and Management Tool (HDM-4) in pavement management.

Implementation of Pavement Management System.

iv) REFERENCES

1) Shahin M.Y., *Pavement Management for Airports, Roads and Parking lots*, Springer, 2nd edition, 2006.
2) Haas R., Hudson W. R. and Falls L.C., *Pavement Asset Management*, Scrivener Publishing, 2015.

3) Huang Y. H., *Pavement Analysis and Design,* Prentice Hall, 2nd edition, 2004.
4) IRC: 81-1997, *Guidelines for Strengthening of Flexible Road Pavements Using Benkelman Beam Deflection Technique*, Indian Roads Congress, New Delhi, 1997.
5) IRC: 82-2015, *Code of Practice for Maintenance of Bituminous Road Surfaces*, Indian Roads Congress, New Delhi, 2015.
6) *AASHTO Guidelines for Pavement Management Systems*, American Association of State Highway and Transportation Officials, 1990.

v) COURSE PLAN

Module	Contents	No. of hours
I	Introduction to Pavement Management systems, Factors affecting pavement surface condition, Pavement distresses, causes,methods of measurement, Maintenance treatments, Pavement Condition Survey- Pavement Condition Index (PCI) – Estimation of PCI by Shahin s'Deduct value method- Pavement surface condition:Skid resistance .	**9**
II	Characterization of roughness- Equipment for measuring roughness, profile indices, International Roughness Index (IRI), Factors affecting pavement structural condition, Structural evaluation by Non-Destructive Tests, Types – Benkelman Beam Deflection (BBD) measurement.	**9**
III	Falling Weight Deflectometer, Design of overlay using BBD data (IRC method), Destructive structural evaluation, Structural Capacity Index, Pavement performance prediction models: Mechanistic – Empirical, Regression, Stochastic, Static and Dynamic models.	**9**
IV	Pavement Management System (PMS): Concept, Objectives, Components of PMS, PMS functions, General Structure, T y p e s o f pavement Maintenance actions: Preventive and Corrective maintenance, Maintenance policy, Pavement management levels: Network, Programme and Project level, Priority programming of maintenance and rehabilitation actions.	**9**
V	Life Cycle Cost Analysis, Heuristic Approach: Decision Matrix and Decision Tree based on Economic Evaluation and Optimization, Tools for Pavement Management: HDM-4, Road Economics Decision Model.	**9**
	Total hours	**45**

Course Code	Course Name	Category Code	L	T	P	Credit	Year of Introduction
22CE262E	Traffic Flow Theory	PEC	3	0	0	3	2022

i) COURSE OBJECTIVES

The goal of this course is to make student understand different theories of traffic flow. The concepts of queuing theory and shockwave theory for analysing traffic flow is also included.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Apply traffic modelling concept based on microscopic or macroscopic approach.	Apply
CO 2	Develop empirical and analogy based models of traffic flow.	Apply
CO 3	Apply the principles of queuing theory to analyse delay at intersections.	Apply
CO 4	Apply shockwave theory to analyse bottleneck situations on highways.	Apply

iii) SYLLABUS

Probabilistic Analysis of Traffic Stream Characteristics.

Microscopic traffic flow models – Car following theories.

Macroscopic traffic flow models – Fluid Dynamic Models.

Transients in Traffic Flow – Shock Wave Analysis; Queuing Theory and Applications.

iv) REFERENCES

1) TRB - SR No.165 - *Traffic Flow Theory*, Transportation Research Board, Washington, 1976.
2) Gartner N. H., Rathi A. J. and Messer C. J., *Traffic Flow Theory – A Revised Monograph*, Transportation Research Board, Washington, 1997.
3) May A. D., *Traffic Flow Fundamentals*, Prentice-Hall, NJ, 1990.
4) Drew D. R., *Traffic Flow Theory and Control*, McGraw-Hill, New York, 1968.
5) *TRB: Highway Capacity Manual*, Transportation Research Board, Washington DC, 2000.
6) McShane W. R. and Roess R. P., *Traffic Engineering*, Prentice-Hall, NJ, 2010.
7) Mannering F. L. and Kilareski W.P., *Principles of Highway Engineering and Traffic Analysis*, John Wiley & Sons, 2008.
8) Neylor T.H.., *Computer Simulation Techniques*, John Wiley, 1966.
9) Gazis Denos C., *Traffic Theory*, Kluwer Academic Publishers, Norwell, MA, 2002.

v) COURSE PLAN

Module	Contents	No. of hours
I	Introduction and Overview - Importance and significance of traffic flow theory Objectives of traffic systems and performance measures, Performance measures for various objectives Microscopic and Macroscopic Traffic Characteristics - Headways, Spacing, Occupancy, Speed, Density, Volume. Relationship between micro and macroscopic stream characteristics; Measures and Devices to collect traffic data; Differences between space mean and time-mean speed.	**10**
II	Probabilistic Analysis of Traffic Stream Characteristics. Basic distributions and properties Distributions of speeds, headways etc. Statistical gap acceptance models, Generation of Random Variables.	**9**
III	Microscopic traffic flow models- Car following theories Car-Following Theory, Linear and Non-linear Car Following Models-Assumptions and Results from Pipes, Forbes and GM family of car-following models; Acceleration Noise Analysis of local and asymptotic stability of traffic flow Introduction to simulation- Philosophy of Simulation Modelling, Formulation of Simulation Model.	**8**
IV	Macroscopic traffic flow models - Fluid Dynamic Models Fluid Flow Analogy Approach, Boltzman like Behaviour of Traffic Flow, First-order fluid-dynamic models - LightHill Whitham and Richards (LWR), Second-order fluid dynamic models multi-regime models, Two-fluid model.	**9**
V	Transients in Traffic Flow - Shock Wave Analysis; Time-space diagram, Accumulation diagram, Principles and Definitions Types of shockwaves arising in various traffic settings, Applications and uses of shock wave analysis; Queuing Theory and Applications Fundamentals of Queuing Theory-Definitions and Principles of queuing theory; Applications and properties of single server queues for traffic management.	**9**
	Total Hrs.	**45**

Course Code	Course Name	Category Code	L	T	P	Credit	Year of Introduction
22CE262F	Traffic Simulation Modelling and Applications	PEC	3	0	0	3	2022

i) COURSE OBJECTIVES

Goal of this course is to give an introduction of different types of simulation, methods of random number generation, random number testing, and generation of random variates. It also gives an overview of queuing models and introduction to the various steps involved in development of traffic simulation models under heterogeneous condition.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO1	Choose appropriate statistical models for traffic simulation.	Apply
CO2	Apply different techniques to generate random numbers for various distributions and conduct hypothesis testing.	Apply
CO3	Apply different methods to generate random variates for statistical distributions used in traffic engineering.	Apply
CO4	Make use of concepts of queuing theory and characteristics of queuing systems for measuring its performance.	Apply
CO5	Develop simulation models under homogeneous and mixed traffic conditions.	Apply

iii) SYLLABUS

Statistical models in simulation and overview of probability and statistics.

Random number generation-properties, techniques and various tests, random variate generation, various techniques and methods for generation. Queueing Theory and models-Concepts and characteristics of queueing systems.

Simulation in traffic engineering- Application of traffic simulation models, simulation of queueing models, discrete simulation models.

iv) REFERENCES

1) Law M. A. and Kelton W. D., *Simulation Modeling and Analysis*, McGraw Hill Higher Education, 3rd edition, 2000.
2) Deo, N., *System Simulation by Digital Computer*, Prentice Hall India, 1978.
3) Drew D.R., *Traffic Flow Theory and Control*, McGraw Hill, 1968.
4) May A. D., *Traffic Flow Fundamentals*, Pearson, 1990.
5) Ross S. M., *Simulation*, Elsevier, 5th edition, 2013.
6) Dowling R., Skabardonis A. and Alexiadis V., Traffic *Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software*, Federal Highway Administration, 2004.

Approved in the BoS held on 05/08/2022 and AC held on 21/11/2022

7) Roess R., Prassas, E. and McShane, W., *Traffic Engineering*, 5th edition, Pearson, 2019.
8) Washington S., Karlaftis M. and Mannering F., *Statistical and Econometric Methods for Transportation Data Analysis*, Chapman & Hall/CRC, 2020.
9) Henderson S., and Nelson B., *Handbooks in Operations Research and Management Science*, Elsevier, 1st edition, 2006.
10) Chung C. A*., Simulation Modeling Handbook,* CRC Press, 1st edition, 2019.

v) COURSE PLAN

Module	Contents	No. of hours
I	Introduction to traffic simulation - Definitions, advantages and disadvantages, different types, simulation languages. Statistical models in simulation - discrete distribution, continuous distribution.	**9**
II	Monte Carlo techniques, stochastic simulations. Random Number Generation: Properties of random numbers, generation of true and pseudo random numbers, techniques for generating random numbers. Hypothesis testing, various tests for uniformity (Kolmogorov-Smirnov and Chi-Square) and independence (runs, autocorrelation, gap, poker).	**9**
III	Random Variate Generation: Different techniques to generate random variate- inverse transform technique, direct transformation technique, convolution method and acceptance rejection techniques, algorithms for generation of random variates for different distributions.	**9**
IV	Queueing Models: Queueing theory concepts, characteristics of queueing systems, queueing notations, measures of performance of queueing systems. Steady state behaviour of Markovian models (M/G/1, M/M/1, M/M/c). Simulation in Traffic Engineering: Application of traffic simulation models for analysis of dynamic traffic systems and design - input data preparation, calibration, validation, analysis of output.	**9**
V	Models for vehicle arrival and related models - development of simulation models for mid-block and intersections under homogenous and mixed traffic. Simulation of queueing models using relevant software. Discrete simulation models: Cellular automata concepts, discretization of time and space, rules for acceleration, deceleration, randomization, and vehicle updation, examples. Introduction to Vissim software and its applications.	**9**
	Total hours	**45**

Course Code	Course Name	Category Code	L	T	P	Credit	Year of Introduction
22CE262G	Transportation Network Analysis	PEC	3	0	0	3	2022

i) COURSE OBJECTIVES

The goal of this course is to introduce the basic concepts of transportation network analysis and to explore some of its applications. The focus of analysis of transportation networks are on a larger area, such as a city or metropolitan region, rather than on a specific intersection or roadway.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Apply network flow concepts in various traffic engineering applications.	Apply
CO 2	Model complex transportation network optimization and equilibrium problems using mathematical programming.	Apply
CO 3	Identify appropriate solutions for transportation network optimization and equilibrium problems.	Apply
CO 4	Model a variety of transportation planning problems as network models.	Apply

iii) SYLLABUS

Network flows – Applications, definitions;

Shortest Path Algorithms – Label setting, Dijkstra's and Dial's algorithms, optimality conditions;

Minimum cost network assignment – optimality conditions; Network equilibrium analysis; principles and optimization formulations, Applications – Applications of min-cost, max-flow, and shortest path algorithms to transportation and infrastructure networks.

iv) REFERENCES

1) Boyles S. D., Lownes N. E. and Unnikrishnan A. Lida, Y., *Transportation Network Analysis*, Version 0.89 (Public beta), 2021.
2) Ahuja, R., Magnanti, T.L., and Orlin, J.B., *Network Flows: Theory, Algorithms and Application*, Prentice Hall, New Jersey, 1993.
3) Bell, M.G.H., and Lida, Y., *Transportation Network Analysis*, Wiley Publishers, 1997.
4) Sheffi, Y. *Urban transportation networks: Equilibrium analysis with mathematical programming methods*, Prentice Hall Inc., 1985.

v) COURSE PLAN

Module	Contents	No. of hours
I	Network flows: Applications, definitions, graphs, paths, trees, cycles, loops, walk, network representation (adjacency list and matrices) and basic network transformations; Network algorithms; Complexity, Search Algorithms, Strategies for designing polynomial algorithms.	**9**
II	Shortest Path Algorithms: Label setting, Dijkstra ' s and Dial ' s algorithms, Optimality conditions, label correcting algorithms and optimality conditions, detecting negative cycles, all-pair shortest path algorithms; pre-flow push polynomial time algorithms, capacity scaling techniques.	**10**
III	Minimum cost network assignment: optimality conditions, cycle-canceling algorithm, Successive shortest path algorithm, otherpolynomial time variants.	**7**
IV	Definitions of network equilibrium - mathematical formulation of traffic equilibrium - User Equilibrium, System Optimal and Stochastic User Equilibrium - equilibrium between modes. Network equilibrium analysis; principles and optimisation formulations, Frank-Wolfe algorithm; Special cases and variants.	**10**
V	Applications: Applications of min-cost, max-flow, and shortest path algorithms to transportation and infrastructure networks: transportation networks, airline, freight, facility location, logistics, network design. Introduction to Computer Software: Principles of TRIPS, EMME, CUBE, Demo Versions, Case studies	**9**
	Total hours	**45**

Course Code	Course Name	Category Code	L	T	P	Credit	Year of Introduction
22CE262H	Road Safety Management	PEC	3	0	0	3	2022

i) COURSE OBJECTIVES

Goal of this course is to introduce the concepts of road safety management system, road safety-based design techniques, methods of road safety audit and crash mitigation measures.

ii) COURSE OUTCOMES

After the completion of the course, the student will be able to:

CO1	Develop a road safety management system after identification of causative factors.	Apply
CO2	Model crash data using statistical techniques.	Apply
CO3	Examine the safety of a highway system by conducting road safety audit.	Analyse
CO4	Apply suitable techniques for crash reconstruction using the data collected.	Apply
CO5	Identify appropriate crash mitigation measures in the design, construction and operation of highways.	Apply

iii) SYLLABUS

Fundamental concepts of traffic safety – principles and practices.

Strategies adopted in various ccountries, safety at intersections.

Analysis and interpretation of crash data, Crash mitigation measures, Road safety audit.

iv) REFERENCES

1) Ezra Hauer, *Observational Before-After Studies in Road Safety*, Pergamon Press, 1997 (reprinted 2002).
2) Institute of Transportation Engineers (ITE), *The Traffic Safety Toolbox: A Primer on Traffic Safety*, ITE, 1999.
3) J. Stannard Baker, *Traffic Collision Investigation*, Northwestern University Center for Public Safety, 2002.
4) Leonard Evans, *Traffic Safety*, Science Serving Society, 2004.
5) Lynn B. Fricke, *Traffic Accident Reconstruction*, Northwestern University Center for Public Safety, 1990.
6) Ogden K.W., *Safer Roads: A Guide to Road Safety Engineering*, Avebury Technical, 1996.
7) Popkess C.A, *Traffic Control and Road Accident Prevention*, Chapman and Hall, 1997

8) Rune Elvik and Truls Vaa, *The Handbook of Road Safety Measures*, Elsevier, 2009.
9) Simon Washington, Matthew Karlaftis, and Fred Mannering, *Statistical and Econometric Methods for Transportation Data Analysis*, Chapman & Hall/CRC Press, 2003.
10) M. N. Shreehari, K. V. Ramesh, *National Conference on Traffic Engineering and Road Safety in India: Problems & Prospects*, Traffic Engineers & Safety Trainers, 2004.
11) Martin Belcher, Steve Proctor, Phil Cook, *Practical Road Safety Auditing*, I C E Publishing, 2015
12) Becky P. Y. Loo, Tessa Kate Anderson, *Spatial Analysis Methods of Road Traffic Collisions*, CRC Press, 2015.

v) COURSE PLAN

Module	Contents	No. of hours
I	Introduction to safety: Road crashes, Trends, causes, Collision and Condition diagrams, Highway safety, human factors, Vehicle factors Road Safety Management System: Multi-causal dynamic systems approach to safety, crash vs accident, road safety improvement strategies, elements of a road safety plan, Safety Data Needs.	**11**
II	Statistical Interpretation and Analysis of Crash Data: Before-after methods in crash analysis, Advanced statistical methods, Black Spot Identification & Investigations, Crash data modeling - Case Studies.	**8**
III	Road Safety Audits: Key elements of a road safety audit, Road Safety Audits & Investigations, Crash investigation and analysis, Methods for identifying hazardous road locations, Case Studies. Crash risk assessment programs.	**8**
IV	Crash Reconstruction: Describe the basic information that can be obtained from the roadway surface, identify fundamentals related to crash reconstruction, speed for various skid, friction, drag, and acceleration scenarios, variables involved in jump and flip crashes, variables involved in pedestrian crashes, Case Studies.	**9**
V	Mitigation Measures: Crash prevention by better planning and design of roads, Crash countermeasures, Highway operation and crash control measures, Highway safety measures during construction, Highway geometry and safety, Geometric design consistency and safety.	**9**
	Total hours	**45**

Course Code	Course Name	Category Code		L	T	P	Credit	Year of Introduction
22CE262I	Multimodal Transit Systems	PEC		3	0	0	3	2022

i) COURSE OBJECTIVES

The goal of this course is to introduce the concepts of Travel demand management and sustainable principles in planning, operation and management of urban public transit systems. It also gives an overview of Intelligent Transportation systems and non- motorized urban transport.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Apply the concepts of vehicular level of service for measuring the performance of a given transit system.	Apply
CO 2	Apply standard procedures for the planning of NMT systems.	Apply
CO3	Estimate the level of service of bicycle and pedestrian facilities of a given roadway.	Apply
CO4	Estimate the multimodal level of service for the design of multimodal transfer facilities for a given road network.	Apply

iii) SYLLABUS

Urbanization and transport, key issues in urban transportation, challenges in urban transportation, travel demand modelling overview.

Introduction to public transportation – basic operating elements of public transportation, bus transportation, intermediate public transportation, public transportation, bus rail transit capacity, transit stop.

Non- Motorised Transportation (NMT) planning, basic NMT characteristics, pedestrian level of service (PLOS) based on flow models.

Bicycle facilities and level of service (BLOS), and bicycle compatibility index (BCI).

Sustainable strategies for urban transportation.

iv) REFERENCES

1) G. Sammer and W. Saleh, *Travel Demand Management and Road User Pricing: Success, Failure and Feasibility*, AshGate 2009.

2) S. Ison and T. Rye, *The Implementation and Effectiveness of Transport Demand Management Measures - An International Perspective*, Ashgate, 2008.

3) R. Tolley, *Sustainable Transport: Planning for Walking and Cycling in Urban*

Environment, Woodhead Publishing Ltd., 2003.

4) Fruin J. J. , *Pedestrian Planning and Design*, McGraw Hill Publication, 1987.
5) Hudson M., *The Bicycle Planning*, Open Books, 1982.
6) M. A. Chowdhury and A. W. Sadek, *Fundamentals of Intelligent Transportation Systems Planning*, Artech House, Inc. Boston, 2003.
7) J. M. Sussman, *Perspectives on Intelligent Transportation Systems (ITS)*, MIT, Springer, 2008.
8) Ceder, A., *Public Transit Planning and Operation: Modeling, Practice and Behavior*, 2nd edition, CRC Press, 2016.
9) Garber N. J. and Hoel L. A., *Traffic & Highway Engineering*, 5th edition, Cengage Learning, 2015.
10) IRC 103:2012, *Design of Pedestrian Facilities*, Indian Road Congress, New Delhi, 2012.IRC 11: 2015, *Design and Layout of Cycle Tracks,* Indian Road Congress, NewDelhi,2015.
11) Indo-Highway Capacity Manual (HCM)-2018, CSIR-CRRI, New Delhi.
12) *Transit Oriented Development Guidance* Document, Sustainable Urban Transportation Project, Ministry of Urban Development, Government of India, 2016.
13) *NMT Guidance Documen*t, Sustainable Urban Transportation Project, Ministry of Urban Development, Government of India, 2016.
14) Public Bicycle Sharing Guidance Document, Sustainable Urban Transportation Project, Ministry of Urban Development, Government of India, 2016.

v) COURSE PLAN

Module	Contents	No. of hours
I	Overview of urban transportation-Urbanization and Transport, Key issues and Challenges, Travel demand modelling overview, Vehicular Level of Service (LOS) overview. Public Transportation-Introduction, basic operating elements, Bus Transportation, Financing public transportation, Transit marketing, Rail transportation, Intermediate Public Transportation, Measuring performance of transit systems.	**9**
II	Advanced operation concepts of public transportation, Bus and Rail Transit Capacity, Station Capacity, Transit Stop Location. Introduction to NMT Systems, Data collection and analysis in NMT Planning, complementarity and selection of interventions, Alternative Selection through Economic & Financial Analysis, Basic NMT Characteristics.	**9**
III	Pedestrian Data Collection and Flow Characteristics, PTS Case Studies, Pedestrian flow characteristics on facilities, Pedestrian Level of Service (PLOS) based on Flow models Other types of Pedestrian Level of Service, HCM 2010	**9**

	Methodology for PLOS, Bicycle Facilities and Level of Service (BLOS), BLOS and Bicycle Compatibility Index (BCI), NMT Design Principles, Design of Pedestrian Infrastructure, Design of Cycling Infrastructure.	
IV	Travel Demand Management overview, Push measures cases, Pull measure cases Parking Studies, Transit Oriented Development (TOD), Introduction to Intelligent Transportation Systems, ITS components, applications and communication, ITS Architecture Electronic Toll Collection, Public Bicycle Sharing (PBS) System with ITS.	**9**
V	Types of Transit Modes - Buses - LRT, RTS - Air cushioned and Maglev System, Dual Mode Buses, Para Transit - Dial - a - Ride - Taxi- Jitneyand Ride sharing - PRT Networks -DRTS Technological Characteristics - Resistances, acceleration & velocity Profiles - Operational characteristics speed, capacity & payloads - Route capacity - Comfort conditions - Performance relationships - Publicand Private Operations - Modes for Intercity Transport. Mulltimodal Level of Service (MMLOS), Design of multimodal transfer facilities, Park & Ride.	**9**
	Total Hrs.	**45**

Course Code	Course Name	Category Code	L	T	P	Credit	Year of Introduction
22CE262J	Geoinformatics in Transportation Engineering	PEC	3	0	0	3	2022

i) COURSE OBJECTIVES

This course introduces the basic concepts of geoinformatics in the context of transportation planning, traffic engineering, and transportation system management. It also involves database development for doing transportation analysis in GIS environment.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Make use of geometric transformation techniques for development of data models.	Apply
CO 2	Apply data analysis techniques for preparation of GIS maps.	Apply
CO 3	Apply GIS techniques in traffic studies, transportation planning and system management.	Apply
CO 4	Examine transportation systems characteristics using GIS software.	Analyse

iii) SYLLABUS

Introduction to geospatial data, data models, components of GIS, applications. Transportation planning using GIS, Traffic Analysis Zone (TAZ) and screen lines, Four stage planning process, Network representation of a transportation System.

Introduction to Intelligent Transport System, Public transportation management system, Application of GIS in vehicle routing analysis and visualizations of traffic data in GIS, travel time analysis using GPS-GIS integration.

GIS-T applications – scope of TransCAD and EMME in transportation planning.

iv) REFERENCES

1) Chang K T, *Introduction to Geographic Information Systems,* Tata McGraw Hill Publishing Company Ltd., 8th edition, 2015.
2) Miller H J and Shaw S L, *Geographic Information Systems for Transportation: Principles and Applications*, Oxford University Press, 1st edition, 2001.
3) Longley P A, Goodchild M F, Manguire D J and Rhind D W, *Geographical Information Systems: Principles, Techniques, Management and Applications*, John Wiley & Sons, 2nd edition, 2005.
4) Scholten H J and Stillwen J C H, *Geograhical Information Systems for Urban & Regional Planning*, Kulwer Academic Publisher, 1990.

5) Lo C P and Yeung A K W, *Concepts and Techniques of Geographic Information Systems*, Pearson Education, 2nd edition, 2016.

v) COURSE PLAN

Module	Contents	No. of hours
I	Brief introduction to geospatial data, map projection and coordinates systems. Data models: Topological and non-topological vector data, topology rules, georelational data model, object-based data model, Interface- Encapsulation, inheritance, polymorphism Data models for Composite features; TIN, Region and Routes. Raster data model- nature and elements, types, data storage, data compression, Data conversion.	**9**
II	Geometric transformation- map to map and image to map transformations, transformation methods, Affine transformation, RMS error, resampling, pyramiding, geospatial data quality and standards: Data quality-accuracy, precision, errors, uncertainty, sources of errors, components and assessment of data quality, Data standards- classification of standards in GIS, components, international geospatial data standards. Spatial data editing errors, topological and non-topological editing. Attribute data input and management- type of attribute data, Relational model, normalization, types of relationships, attribute data entry. (Exposure to GIS tools can be given through assignments or mini projects).	**9**
III	Data exploration and analysis: Data exploration- descriptive statistics, graphics, attribute data and spatial data query, map manipulation. Vector data analysis-buffering, overlay, slivers, distance measurement, pattern analysis, Raster data analysis- Local operations-reclassification, neighborhood operations, zonal operations, physical distance measurement.	**9**

IV	Application of GIS in Transportation Planning: Application of GIS in urban planning, Travel Demand Estimation Traffic Analysis Zone (TAZ) and screen lines, Four Stage Planning Process (Brief description only), Network representation of a transportation System, Shortest Path determination, GIS based Transportation Planning, Spatial and Non spatial data for land use and transportation. Intelligent information system for road accessibility study, location of transport terminals and roadside facilities, bus stops, Decision support systems for land use planning, Applications of Aerial Photography and Satellite Imageries.	**9**
V	Application of GIS in Highway and Traffic Engineering: GIS based Highway alignment, GIS based road network planning, GIS based traffic congestion analysis and accident investigation, Route optimization, bus route rationalization, utility management, Application of GIS in vehicle routing analysis and visualisations of traffic data in GIS Integration of GPS and GIS, Travel time analysis using GPS-GIS integration. GIS-T applications: Scope of TransCAD and EMME in Transportation Planning (Introduction only) .	**9**
	Total Hrs.	**45**

Course Code	Course Name	Category Code	L	T	P	Credit	Year of Introduction
22CE262K	Analytical Techniques in Transportation Planning	PEC	3	0	0	3	2022

i) COURSE OBJECTIVES

The goal of this course is to introduce the concepts of multivariate data analysis technique, network flow theory, econometric models and its application in transportation problems.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Apply various data analysis techniques for analyzing problems in traffic and transportation planning.	Apply
CO 2	Apply network transformation algorithms for solving a given transportation network problem.	Apply
CO 3	Apply the concepts of latent variable modeling for a given transportation planning problem.	Apply
CO 4	Apply the concepts of discrete outcome modelling for a given transportation network problem.	Apply

iii) SYLLABUS

Multivariate data analysis techniques- data, estimation of centroid, standard deviation, factor analysis, cross classification procedure, applications.

Network Flow Theory- basic concepts and definitions, forward and reverse starrepresentations, network transformations, applications.

Econometric models, latent variable models, structural equation modeling, duration models, discrete outcome models.

iv) REFERENCES

1) R. K. Ahuja, Thomas L. Magnanti, J. B. Orlin, *Network Flows: Theory, Algorithms and Applications*, 1st edition, Prentice Hall, 2015.
2) Juan de Dios Ortúzar, Luis G. Willumsen, *Modelling transport*, 4th edition, Wiley Publications, 2011.
3) Kalyanmoy Deb, *Muliti-Objective using Evolutionary Algorithms*, 1st edition, Wiley Publications, 2001.
4) Simon Washington, Matthew G. Karlaftis, Fred Mannering, Panagiotis Anastasopoulos, *Statistical and Econometric Methods for Transportation Data Analysis*, 3rd edition, CRC Press LLC, 2020.
5) Cooley, W. W. und P. R. Lohnes: Multivariate data analysis. J. Wiley and Sons Inc.,

New York 1971.

6) Alan Wilson, *Entropy in Urban and Regional Modelling (Routledge Revivals)*, Routledge, 2013..

7) Adib K. Kanafani, *Transportation Demand Analysis*, McGraw – Hill, 1983.

v) COURSE PLAN

Module	Contents	No. of hours
I	Types of data, basic vectors and matrices, Sample Estimation of centroid, Standard deviation, Dispersion, Variance and Covariance, Correlation matrices, Principle component, Factor Analysis, Cluster Analysis, Cross Classification procedure in Multivariate data analysis, Application to problems in traffic and Transportation Planning.	**10**
II	Basic Concepts and definitions - directed and undirected graphs-nodelinks -trees-path-cycles-connectivity - cut, network representation - Node-arc incidence Matrix, Node-Node adjacency Matrix- adjacency Lists- forward and reverse star representations.	**9**
III	Network transformations- berth and search algorithms-formulation of shortest path problem- maximum flow problem-minimum cost flow problem- algorithm- applications in transportation network problem .	**9**
IV	Latent Variable Models - Structural Equation modelling - Duration models -Hazard based duration models -Non parametric, semi parametric and fully parametric models .	**9**
V	Discrete outcome models - Multinomial Logit Models - Nested Logic Models -Discrete Continuous models (Overview Only).	**8**
	Total Hrs.	**45**

Course Code	Course Name	Category Code	L	T	P	Credit	Year of Introduction
22CE262L	Green Transportation Systems	PEC	3	0	0	3	2022

i) COURSE OBJECTIVES

The goal of this course is to introduce the concepts of sustainable planning and design and thereby suggest sustainable solutions for transportation related problems. It also outlines the procedure for Environmental impact assessment of transportation projects.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Make use of sustainable transportation planning principles for development of sustainable transportation networks.	Apply
CO 2	Identify the transportation needs of special populations.	Apply
CO 3	Assess the environmental impacts of transport related projects.	Apply
CO 4	Apply the concepts of sustainable transportation for retro fitting existing urban areas for reducing congestion and emissions.	Apply

iii) SYLLABUS

Introduction to the concept of sustainability, basic principles, sustainable transportation planning, land use and travel behaviours, networks, automobile dependence and impacts, design for sustainable transportation, vulnerable road users, professional praxis and paradigm shift, innovations, case studies, emerging concepts, congestion and pollution management, sustainability through public transport, EIA of Transportation Projects.

iv) REFERENCES

1) Mc Clintock, H., Planning for Cycling: Principles, Practice and Solutions for Urban Planners, CRC Press, 1st edition, 2002.
2) Frumkin, H., Frank, L. and Jackson, R.J., Urban Sprawl and Public Health, designing, planning, and Building for Healthy Communities, Island Press, 1st edition, 2013.
3) Newman, P. and Kenworth, J. Sustainability and Cities – Overcoming Automobile Dependence, Island Press, 2013.

v) COURSE PLAN

Module	Contents	No. of hours
I	Introduction: Sustainable transportation, definition, necessity, fundamental principles, quantifying sustainability. Sustainable transportation planning: land use and travel behaviour; Sustainable Transportation Networks; built environment and public health; transportation demand management. Automobile dependence and oil consumption; the transportation needs of special populations (elderly, children, disabled and immigrants)	**9**
II	Design for Sustainable Transportation: design of bicycle and pedestrian facilities; safety issues for pedestrians and bicyclists; Bicycle and pedestrian planning, Professional praxis; principles of applying professional praxis under a state of paradigm shift	**9**
III	Environmental Impact Assessment For Transportation Projects: Basic Concepts, Objectives, Transportation Related Environmental Impacts - Vehicular Impacts - Safety &Capacity impacts - Roadway Impacts - Construction Impacts, Environmental Impact Assessment - Environmental Impact Statement, Environment Audit, Typical case studies.	**9**
IV	Retro fitting existing urban areas; Innovative transportation solutions, case studies. Paradigm shift in planning, Emerging concepts in sustainable transportation: green vehicles and green roads, green and alternate fuels; managing congestion: car- sharing, pricing control: congestion and emission pricing.	**9**
V	Sustainable public transport: promoting public transport: principles involved and techniques, miscellaneous transportation systems, integrated public transport systems	**9**
	Total Hrs.	**45**

Course Code	Course Name	Category Code	L	T	P	Credit	Year of Introduction
22CE262M	Advanced Optimization Techniques for Transportation Engineering	PEC	3	0	0	3	2022

i) COURSE OBJECTIVES

It aims at introducing the use of quantitative methods and techniques for effectivedecision making; model formulation and applications that are used in solving decision making problems related to transportation engineering. It also provides proficiency with tools in optimization including fundamental applications of these tools in contexts involving uncertainty and scarce or expensive resources.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO 1	Apply the concepts of probability and statistics for taking management decisions.	Apply
CO 2	Apply techniques of dynamic programming and reliability in traffic and pavement management systems.	Apply
CO 3	Apply the concept of game theory for network flow analysis.	Apply
CO 4	Assess the trends and characteristic moments for a given time series model.	Apply

iii) SYLLABUS

Concept of uncertainty – Markov analysis, stochastic random process, Dynamic programming approach – applications.

Game theory – solving mixed strategy game; Replacement models.

Fundamentals of network flow theory – shortest route problems – solution of maximum flow model – formulation of CPM-PERT Network.

Time series models – Forecasting models, measurement of trends.

Classical optimization – Optimal problem formulation, Multi criteria mathematical programming problems, Applications of optimization in traffic and pavement management

iv) REFERENCES

1) K. Sharma., *Operations Research Theory & Applications*, 3rd edition, Macmillan India Ltd, 2007.
2) P. K. Gupta and D.S. Hira, *Operations Research*, S. Chand & Co., 2007.
3) J K Sharma., *Operations Research, Problems and Solutions*, 3rd edition, Macmillan India Ltd.
4) N. V. S. Raju, *Operations Research*, HI-TECH, 2002.

v) COURSE PLAN

Module	Contents	No. of hours
I	Probability and statistical analysis for management decisions. Concept of uncertainty-Markov analysis - stochastic random process-transition probability-Markov chain-steady state condition.	**9**
II	Brief introduction to linear programming, Dynamic programming and reliability. Characteristics of dynamic programming. Dynamic programming approach applications in traffic and pavement management-smothering, capital budgeting, StageCoach/Shortest Path, and Reliability problems-formulation	**9**
III	Basics of Game theory. Concept-Two person zero-sum game-pure and mixed strategy-Games-saddle point-Odds method-Dominance Method and graphical method for solving mixed strategy game.	**9**
IV	Replacement Models - Deteriorating items with increasing maintenance cost and constant money value - Items that fail suddenly -Replacement policy: individual and group. Fundamentals of network flow theory	**8**
V	Network representation- Minimal spanning tree algorithm-shortest route problems-Maximum flow model-linear programming-excel spreadsheet solution of maximum flow model-minimum cost capacitated flow problems- formulation (LPP)-capacitated network simplex algorithm-LPP formulation of CPM-PERT Network. Time series models: Forecasting models-introduction to time series models-characteristics moments in a time series-measurement of trends- ARMA-ARIMA	**10**
	Total Hrs.	**45**

RESEARCH METHODOLOGY & IPR (RM)

Course Code	Course Name	Category Code	L	T	P	Credit	Year of Introduction
22MC061A	Research Methodology & IPR	RM	2	0	0	2	2022

i) COURSE OBJECTIVES

This course is intended to prepare the M. Tech students to carry out their dissertation/ research project work effectively, with a research bias. The student will be able to formulate a viable research problem, do a critical analysis of publications in the area of research, and identify a research method suitable for the work. The student will achieve the capability to write a technical paper based on his/her dissertation/ research project.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO1	Explain research ethics, Citation, Impact factor and Plagiarism	Apply
CO2	Formulate a research problem, make a suitable research design, and identify the data collection methods	Apply
CO3	Analyse the collected data	Analyse
CO4	Explain the role of IPR and Patent law in fostering research work, leading to creation of improved products, thus supporting economic growth and social benefits	Apply
CO5	Develop a technical paper for publication	Apply

iii) SYLLABUS

Introduction to Research Methodology- motivation for research, types of research, ethical issues. Identifying a research area and collecting related literature. Research problem- scope objectives, literature review, identifying research gaps, and formulate the research problem. Research design and methods, data collection and analysis . Copy right – royalty - IPR and patent law. Process of patenting and development, Procedure for grant of patents. Copy left- open access, citation, plagiarism, Impact factor. Writing a technical paper.

iv) REFERENCES

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) Ramappa T., *Intellectual Property Rights Under WTO*, S. Chand, 2008.
4) Robert P. Merges, Peter S. Menell, Mark A. Lemley, *Intellectual Property in New*

Technological Age, 2016.

5) Mayall, *Industrial Design*, McGraw Hill, 1992. Niebel, "Product Design", McGraw Hill, 1974.

v) COURSE PLAN

Module	Contents	Hours
I	**Introduction to Research Methodology**: Motivation towards research, Types of research. Professional ethics in research: Ethical issues, ethical committees. Identification of major conferences and important journals in a chosen area of interest. Collection of at least 10 published papers on a research problem in the chosen area.	6
II	**Defining and formulating the research problem:** Literature Survey, Analysing the collected papers to understand how the authors have identified the research gaps, arrived at their objectives, and formulated their research problem. Understanding how their research work is different from the previous works in the chosen area.	6
III	**Research design and methods:** Analyzing the collected papers to understand how the authors have formulated the research methods, both analytical methods and experimental methods. Data Collection and analysis: Analyzing the collected papers to understand the methods of data collection, data processing, analysis strategies, and tools used for analyzing the data.	6
IV	**Copy right** - royalty - Intellectual property rights and patent law - Process of Patenting and Development, Procedure for grant of patents. **Reproduction of published material**: Copy left- Open access, Citation and acknowledgement. Plagiarism, Impact factor.	6
V	**Technical writing** - Structure and components of a typical technical paper, abstract and conclusion, illustrations and tables, bibliography, referencing and footnotes. Writing a technical paper -based on the identified research problem, and using the collected papers, Literature survey, Problem formulation, and Research design, and a hypothetical result.	6
	Total hours	**30**

LABORATORY COURSES (LBC)

Course Code	Course Name	Category Code	L	T	P	Credit	Year of Introduction
22CE269A	Pavement Materials and Evaluation Lab	LBC	0	0	2	1	2022

i) COURSE OBJECTIVES

Goal of this course is to impart knowledge for conducting different tests to characterize aggregates and bitumen to assess their suitability for use under different climatic conditions and types of pavement construction. The course also deals with the design of bituminous mixes (hot mix and cold mix) and estimation of their strength. The course includes study on functional and structural evaluation of pavements.

ii) COURSE OUTCOMES

After the completion of the course the student will be able to:

CO1	Experimentally analyze the suitability of aggregates and bitumen for bituminous constructions.	Analyze
CO2	Make use of standard procedures to characterize bitumen emulsion.	Apply
CO3	Apply code provisions to design bituminous mixes.	Apply
CO4	Apply standard test procedures to assess the performance of bituminous mixes.	Apply
CO5	Utilize standard test procedures to examine the functional and structural adequacy of pavement structures.	Apply

iii) SYLLABUS

Tests on aggregates, bitumen and emulsion.

Tests on bituminous mixes.

Extraction of binder from bituminous mixes.

Structural and functional evaluation of pavements.

iv) REFERENCES

1) Relevant IS/ASTM/AASHTO standards for the conduct of material characterization experiments of aggregates, bitumen and emulsion.
2) Relevant IS/ASTM/AASHTO standard specifications for material characterization and design of bituminous mixes.
3) Relevant IS standards for the functional and structural evaluation of pavement structures.

v) COURSE PLAN

Experiment Cycle	Contents	No. of hours
I	**Test on aggregates** Sieve Analysis Aggregate impact test Los Angeles abrasion test Shape test Stripping value	3
II	**Test on bitumen for Viscosity grading and performance grading** Viscosity test using Rotational viscometer and Vacuum capillary viscometer Softening point test Ductility test Penetration test Tests for performance grading using Dynamic Shear Rheometer (Study/ demonstration) Tests on bitumen emulsion	15
III	**Test on bituminous Mixes** Marshall Mix design Indirect tensile strength test Rut wheel test Preparation and test on cold mixes Bitumen extraction test	12
IV	**Pavement evaluation** Roughness measurement using MERLIN Benkelman beam deflection study and analysis Falling weight deflectometer study (demonstration)	10
	Total hours	40

DETAILED SYLLABI (M2)
M.Tech TRANSPORTATION ENGINEERING
SEMESTER II

DISCIPLINE CORE COURSES (DCC)

Course Code	Course Name	Category Code	L	T	P	Credit	Year of Introduction
22MA060E	Probability, Statistics and Mathematical Techniques	DCC	3	0	0	3	2022

i) COURSE OBJECTIVES

The objective of the course is to equip the students with the concepts in probability distributions, statistical inference, correlation and regression analysis, design of experiments and time series.

ii) COURSE OUTCOMES

After the completion of the course, the student will be able to:

CO1	Apply the concepts of probability distribution to fit appropriate distributions to various data in transportation engineering.	Apply
CO2	Use statistical inference to examine characteristics of a population based on its sample characteristics and interpret the statistical significance of difference between groups of data.	Apply
CO3	Apply appropriate technique to find the optimal solution of a given transportation problem.	Apply
CO4	Apply time series modelling to identify the underlying causes of trends or systemic patterns in data over time.	Apply
CO5	Determine the principal components of a given multi-dimensional data.	Apply

iii) SYLLABUS

Probability mass functions and probability density functions – distribution functions - mean and variance - fitting of distributions - applications. Statistical inference - sampling distributions – testing of hypotheses – Regression analysis - curve fitting. Analysis of variance – Randomized block designs - latin square designs – applications - Transportation problem. Time series models - testing of ARIMA models. Multivariate Analysis - covariance matrix and principal components..

(iv) REFERENCES

1) Gupta S.C. and Kapoor V.K, *Fundamentals of Mathematical Statistics*, Sultan Chand and Sons, 1978.
2) Richard A. Johnson, Miller and Freunds, Probablity and Statistics for Engineers, Prentice Hall of India, 2007.
3) Benjamin Jack R. and Comell C. Allin, *Probability Statistics and Decision for Civil Engineers*, Mc-Graw Hill, 1997.

4) Dallas E Johnson, *Applied Multivariate Methods for Data Analysis*, Thomson and Duxbburg Press, Singapore, 2002.
5) Jay L. Devore, *Probability and statistics for Engineering and Sciences*, Thomson and Duxbburg Press, Singapore, 2002.
6) Richard A Johnson and Dean W. Wichern, *Applied Multivariate Statistical Analysis*, Pearson Education, 2002.
7) Irwin Miller and Marylees Miller, *Mathematical Statistics,* Pearson Education Inc., 2004.
8) S. D. Sharma, *Operations Research*, Kedar Nath and Ram Nath ‑Meerut, 2008.
9) David C Lay., Steven R. L. and Judi J.M. Linear Algebra and its applications, Pearson Education, Fifth Edition, 2016.
10) Washington S. Karlafitis M. and Mannering F. Statistical and Econometric Methods for Transportation Data Analysis, Chapman and Hal, First Edition, 2003.

(v) COURSE PLAN

Module	Contents	No. of hours
I	Probability mass functions and probability density functions, distribution functions, mean and variance. Binomial, Poisson, Exponential, Gamma, and Normal distribution ‑ Mean and variance Fitting of distributions, Applications in transportation engineering.	7
II	Statistical Inference: Sampling distributions - Interval estimation of population parameters. Testing of hypotheses – Large sample tests for mean and proportion – t-test, F-test and Chi-square test. Linear regression and correlation, Curve fitting – method of least squares – normal regression analysis, multiple linear regression.	10
III	Analysis of variance – One-way designs, randomized block designs – Factorial experiments – Latin Square designs, applications. Transportation problem, Balanced transportation problem, Unbalanced transportation problem. Initial BFS by VAM and optimal Solution by MODI method	10
IV	Time Series Models: Components of time series – smoothing – measuring forecasting accuracy – testing of ARIMA models.	8
V	Multivariate Analysis: Co-variance matrix – correlation matrix, multivariate normal density function, principal components – sample variation by principal components – principal components by graphs.	10
	Total hours	**45**

Course Code	Course Name	Category Code	L	T	P	Credit	Year of Introduction
22CE260A	Economic Appraisal of Projects	DCC	3	0	0	3	2022

i) COURSE OBJECTIVES:

The goal of this course is to introduce about various costs and benefits associated with highway projects. The course also discusses concepts such as fare policy for bus transit, pricing theory and congestion pricing. It also introduces the various methods of economic analysis and stages of project appraisal.

ii) COURSE OUTCOMES:

After the completion of the course the student will be able to:

CO1	Explain the concepts of elasticity of demand and supply and the supply-and-demand model.	Understand
CO 2	Apply various guidelines to identify and measure transportation costs for economic analysis.	Apply
CO3	Identify the benefits associated with transport projects for economic and financial appraisal in the preparation of feasibility report.	Apply
CO 4	Apply different methods of economic evaluation for estimating the viability of transport projects.	Apply
CO5	Identify the viability and risks of various schemes of financing road infrastructure projects.	Apply

iii) SYLLABUS:

Demand and supply of transport, elasticity of demand and supply concepts, supply-and-demand model, costs and benefits.
Identification and measurements of transportation costs and benefits.
Tools for economic evaluation.
Econometrics and project appraisal, Economic and financial appraisal, financing transport infrastructure, preparation of projects, feasibility reports, economic analysis.
Risk analysis

iv) a) TEXT BOOKS :

1) Winfrey R, Highway Economic Analysis for Highways, International Textbook Company, 2007 (Digitized), 1st edition (1969).
2) Kadiyali L R and Lal N B, *Principles and Practice of Highway Engineering (Including Expressways and Airport Engineering)*, Khanna Publishers, 7th edition, 2019.
3) Cole S, Applied Transport Economics: Policy Management and Decision Making, Kogan Page

India, 3rd edition, 2005.

b) REFERENCES:

1) IRC: SP: 30-2009, Manual on Economic Evaluation of Highway Projects in India, 2nd revision, Indian Roads Congress, New Delhi, 2009

2) Maitri V and Sarkar P K, Theory and Application of Economics in Highway and Transport Planning, Standard Publishers, 2nd edition, 2017

3) Button K, Transport Economics, Edward Elgar Publishing Ltd., 3rd edition, 2010.

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v) COURSE PLAN:

Module	Contents	No. of hours
I	Introduction - Significance of transport, need for economic evaluation, demand and supply of transport, Elasticity of demand and supply, concepts and principles of highway engineering economy. Supply and demand Models. Consumer's surplus and social surplus criteria, framework of social accounting - accounting rate of interest, social opportunity cost, rate of interest, social time preference rate of interest, accounting prices of goods and services. Transport Costs - Identification and measurements of transportation costs - Capital cost, Inflation cost, Interest during construction, Maintenance cost, Road user costs, Fixed and operating costs. Accident cost, Methodology for monetary evaluation of passenger's travel time, Value of increased comfort and convenience.	**10**
II	Benefits due to Transport Improvements: Direct Benefits: Reduced vehicle operation costs, value of travel time savings, value of increased comfort and convenience, cost of accident reduction, reduction in maintenance cost. Negative benefits due to increased noise and air pollution. Indirect Benefits: Increased land values, increased development and demand. Congestion cost and pricing, Fare policy for bus transit.	**9**
III	Interest and Compound interest equations, discount cash flow, Method of economic evaluation - Rate of return, Net present value, Internal rate of return method, First year rate of return, Present worth of cost, EUAC, Benefit cost ratio.	**9**
IV	Econometrics & Project Appraisal, Econometrics of industrial location, Project Appraisal - Technical Appraisal, Social Appraisal - Social Cost Benefit analysis.	**8**

	Comparison of various methods of economics analysis, case studies and problems, Economic evaluation of mass transit projects. Application economic theory in traffic assignment problem.	
V	Financing transport infrastructure - methods – Private Public Partnership (PPP) - Toll collection - Economic viability of Build-Operate-Transfer Schemes – Risk Analysis - Case Studies.	**9**
	Total hours	**45**

INDUSTRY ELECTIVE

Course Code	Course Name	Category	L	T	P	Credit	Year of Introduction
22CE266B	Highway Asset Management	IEC	3	0	0	3	2022

i) COURSE OBJECTIVES:

The goal of this course is to introduce the students to industry practices on the management of highway assets. The course will give in-depth information on the various aspects of pavement evaluation, maintenance and management, regarding Indian conditions. The course also deals with the various safety standards in the highway construction industry.

ii) COURSE OUTCOMES:

After the completion of the course, the student will be able to:

CO1	Explain the standards and specifications pertaining to highway assets.	Understand
CO2	Apply standard procedures to evaluate the structural and functional condition of pavements.	Apply
CO3	Explain the concepts of pavement management system.	Understand
CO4	Choose appropriate maintenance strategies for highways based on fied data.	Analyse
CO5	Take part in project planning, monitoring and quality control.	Analyse
CO6	Explain the various safety measures, standards and plans related to highway construction.	Understand

iii) SYLLABUS:

Highway asset management, pavement asset management.

Pavement management system.

Pavement evaluation and maintenance.

Bidding, contract preparation, planning, project monitoring and quality control.

Safety in highway projects.

iv) a) TEXT BOOKS:

1) Haas R C G, Hudson W R and Zaniewski J P, Modern Pavement Management, Krieger Publications, Original edition, 1994.

2) Haas R C G and Hudson W R, Pavement Management Systems, McGraw-Hill Inc., US, 1st edition, 1978.

b) REFERENCES:

1) Srinivasa Kumar R, *Pavement Evaluation and Maintenance Management System,* Universities

Press (India) Private Limited, 1st edition, 2020.

2) HDM-4 Documentation, Version 2, HDM Global, TRL Software Bureau, UK.

v) COURSE PLAN:

Module	Contents	Hours
I	Introduction to Highway Asset Management: Brief overview of highway assets, Importance of highway assets on a regular day-to-day highway operations, standards and specifications pertaining to highway assets.	**9**
II	Pavement Asset Management: Pavement investigations, Structural evaluation, Functional evaluation, Data analysis of FWD and NSV, Estimation of structural capacity and functional capacity of highways based on the investigations data, Introduction to Pavement Management System (PMS).	**10**
III	Pavement Maintenance: Routine maintenance techniques and technologies, Preventive maintenance techniques and technologies, Major maintenance techniques and technologies, Hands-on experience in preparation of strategy using data from Indian highways	**9**
IV	Major Maintenance execution: Planning of major maintenance, Bidding procedure, Contract preparation, Machinery and manpower planning, Project monitoring, Quality control by statistical methods, Hand-on experience in project planning and monitoring. Introduction to HDM-4.	**9**
V	Safety during highway maintenance: Safety in the construction industry, Safety measures, Safety programmes, Safety awareness and implementation of safety plan, Current safety standards in India, Improvements in safety standards required for Indian conditions	**8**
	Total hours	**45**

INTERDISCIPLINARY ELECTIVE

Course Code	Course Name	Category Code	L	T	P	Credit	Year of Introduction
22CE265A	Highway Safety Engineering	3	0	0	3	3	2022

i) COURSE OBJECTIVES

This course aims to introduce the various traffic stream parameters, identify the causes of road crashes, and develop a road safety management system.

It also outlines the statistical interpretation and analysis of crash data, the conduct of road safety audits, crash reconstruction and measures for crash mitigation.

ii) COURSE OUTCOMES

After the completion of the course, the student will be able to:

CO1	Make use of the data collected from traffic surveys to estimate the traffic stream parameters.	Apply
CO2	Develop a road safety management system after the identification of causative factors.	Apply
CO3	Make use of statistical techniques for crash data analysis and standard procedures for carrying out road safety audit.	Apply
CO4	Apply suitable techniques for crash reconstruction using the data collected.	Apply
CO5	Identify appropriate crash mitigation measures in the design, construction and operation of highways.	Apply

iii) SYLLABUS

Introduction to traffic parameters, statistical analysis of traffic data.

Introduction to safety: Road crashes, trends, causes.

Road Safety Management System, Black Spot Identification & Investigations.

Statistical Interpretation and Analysis of Crash Data, Road safety audit.

Crash Reconstruction and Mitigation Measures.

iv) REFERENCES

1) Ezra Hauer, *Observational Before-After Studies in Road Safety*, Pergamon Press, 1997 (reprinted 2002).
2) Institute of Transportation Engineers (ITE), *The Traffic Safety Toolbox: A Primer on Traffic Safety*, ITE, 1999.
3) J. Stannard Baker, *Traffic Collision Investigation*, Northwestern University Center for Public Safety, 2002.
4) Leonard Evans, *Traffic Safety*, Science Serving Society, 2004.
5) Lynn B. Fricke, *Traffic Accident Reconstruction*, Northwestern University Center for

Public Safety, 1990.

6) Ogden K.W., *Safer Roads: A Guide to Road Safety Engineering*, Avebury Technical, 1996.
7) Popkess C.A, *Traffic Control and Road Accident Prevention*, Chapman and Hall, 1997
8) Rune Elvik and Truls Vaa, *The Handbook of Road Safety Measures*, Elsevier, 2009.
9) Simon Washington, Matthew Karlaftis, and Fred Mannering, *Statistical and Econometric Methods for Transportation Data Analysis*, Chapman & Hall/CRC Press, 2003.
10) M. N. Shreehari, K. V. Ramesh, *National Conference on Traffic Engineering and Road Safety in India: Problems & Prospects*, Traffic Engineers & Safety Trainers, 2004.
11) Martin Belcher, Steve Proctor, Phil Cook, *Practical Road Safety Auditing*, I C E Publishing, 2015
12) Becky P. Y. Loo, Tessa Kate Anderson, *Spatial Analysis Methods of Road Traffic Collisions*, CRC Press, 2015.

v) COURSE PLAN

Module	Contents	No. of hours
I	Introduction to traffic parameters-speed, volume, density. Measurement of traffic parameters –traffic surveys, data collection and analysis – travel time and delay, headways and gap acceptance studies, parking studies, pedestrian studies, accident studies, congestion studies. Analysis of traffic data – fitting of distributions, sampling in traffic studies, statistical analysis of traffic stream parameters.	**8**
II	Introduction to safety: Road crashes, trends, causes, collision and condition diagrams, approaches. Road Safety Management System: road safety improvement strategies, elements of a road safety plan, safety data needs. Strategies adopted in various countries. Traffic management measures and their influence on accident prevention.	**8**
III	Statistical Interpretation and Analysis of Crash Data - Before-after studies in crash analysis. Black Spot Identification & Investigations, Case Studies Road safety audit: stages of auditing, key elements of a road safety audit, Methods for identifying hazardous road locations, Case Studies.	**11**
IV	Crash Reconstruction: Describe the basic information that can be obtained from the roadway surface, identify fundamentals related to crash reconstruction, speed for various skid, friction, drag, and acceleration scenarios, variables involved in jump and flip crashes, variables involved in pedestrian crashes, Case Studies.	**9**

V	Mitigation Measures: Crash prevention by better planning and design of roads, Crash countermeasures, Highway operation and crash control measures, Highway safety measures during construction, Highway geometry and safety, Geometric design consistency and safety. Traffic calming Measures.	**9**
	Total hours	**45**

LABORATORY COURSES (PCC)

Course Code	Course Name	Category Code	L	T	P	Credit	Year of Introduction
22CE269B	Transportation Planning and Traffic Lab	LBC	0	0	2	1	2022

i. COURSE OBJECTIVES:

The goal of this course to provide a thorough understanding of the various procedures involved in collecting and analyzing traffic inventory. The course also discusses the methods of data collection for estimating the traffic stream parameters, traffic noise and vehicular emission. An introduction to different software for traffic simulation and transportation planning is also included in the course.

ii. COURSE OUTCOMES:

After the completion of the course the student will be able to:

CO 1	Make use of relevant procedures to identify, classify and record the various traffic control devices, pedestrian facilities and parking features in a traffic corridor..	Apply
CO 2	Apply standard techniques to collect data and estimate the various micro and macroscopic characteristics of a traffic stream and their inter-dependencies.	Apply
CO3	Examine the extend of noise pollution and vehicular emission in a traffic corridor	Apply
CO 4	Ultilize relevant software applications for traffic simulation and transportation planning	Apply

iii. SYLLABUS

Road inventory survey.
Study on traffic stream characteristics
Study on traffic noise and vehicular emissions.
Traffic simulation and transportation planning using relevant software.

iv. REFERENCES

1) Kadiyali L R, *Traffic Engineering and Transport Planning*', Khanna Publishers, 7th edition, 2008.
2) O'Flaherty C A, *Transport Planning and Traffic Engineering,* CRC Press, 1st edition, 1997 (ebook-2018)
3) *Indian Highway Capacity Manual (Indo-HCM*), CSIR - CEentral Road Research Institute, New Delhi, 2017.
4) Relevant IRC publications.
5) *The Noise Pollution (Regulation & Control) Rules*, 2000 (Amendment 2010), Ministry of Environment and Forests, Government of India., (Amendment 2010),

Ministry of Environment and Forests, Government of India.

6) *Bharat Stage Emission Standards- VI*, Central Pollution Control Board, Ministry of Environment, Forest and Climate Change, 2020

v. COURSE PLAN

Experiment Cycle	Contents	No. of hours
I	Inventory on: a) Traffic control devices b) Pedestrian facilities c) Parking facilities Study on traffic stream characteristics: a) Travel time and delay - moving car observer method b) Spot speed - using Radar gun/Enoscope c) Turning movement and peak hour factor - by videographic technique d) Gap at intersections - method suggested by Indo-HCM e) Sight distance - at horizontal curve and an uncontrolled intersection f) Saturation flow rate, headway and queuing analysis - by manual/videographic technique g) Level of service at signalized intersection - Indo HCM h) Parking study at an establishment by license plate method Study on: i) Traffic noise at a midblock section j) Vehicle emission	**20**
II	Software applications in Traffic Engineering and Transportation Planning a) VISSIM Traffic flow simulation at a midblock b) VISUM Mode shift analysis for a specific scenario c) Introduction to Trans CAD Route/mode choice modeling for a specific scenario	**10**
	Total hours	**30**

DETAILED SYLLABI (M3)
M.Tech TRANSPORTATION ENGINEERING
SEMESTER III

List of MOOC Courses					
Sl. No.	Course Code	Course Name	Duration	Offering Platform	Course Institution
1.	noc23-ce20	Characterization of construction materials	12weeks	nptel	IITM
2.	noc20-ce04	Mechanical characterization of bituminous materials	12weeks	nptel	IITM
3.		Geosynthetics and Reinforced Soil Structures	12weeks	nptel	IITM
4.		Introduction To Multimodal Urban Transportation Systems (MUTS).	12weeks	nptel	IITKGP

Sl. No.	Course Code	Course Name	Duration	Offering Platform	Course Institution
1.	noc23-ce20	Characterization of construction materials	12weeks	nptel	IITM

Course Instructor

Dr. Manu Santhanam ,Professor, Department of Civil Engineering, IIT Madras.
Dr. Piyush Chaunsali, Assistant Professor,Department of Civil Engineering, IIT Madras.

Course Plan

Week 1: Introduction to course; Structure of Construction Materials – An Overview

Week 2: Calorimetry

Week 3: X-ray diffraction

Week 4: X-ray diffraction

Week 5: Thermal analysis

Week 6: Surface area measurement

Week 7: Optical microscopy

Week 8: Scanning electron microscopy

Week 9: Image analysis

Week 10: Spectroscopic techniques

Week 11: Mercury intrusion porosimetry

Week 12: Impedance analysis and ultrasonic methods

Sl. No.	Course Code	Course Name	Duration	Offering Platform	Course Institution
2.	noc20-ce04	Mechanical characterization of bituminous materials	12weeks	nptel	IITM

Course Instructor

Dr. J. Murali Krishnan , Professor, Department of Civil Engineering, IIT Madras.
Dr. Neethu Roy,Asst. Dean (R&D) and Professor, Department of Civil Engineering,MBCET,TVM.
Dr. A. Padma Rekha, Associate Professor,Department of Civil Engineering, SRM Institute of Science and Technology.
Dr. M. R. Nivitha ,faculty, Department of Civil Engineering, PSG College of Technology, Coimbatore.

Course Plan

Week 1: Introduction to bituminous pavements and Overview of distresses

Week 2: Introduction to linear viscoelasticity

Week 3: Introduction of material functions for viscoelastic materials

Week 4: Influence of temperature on the linear viscoelastic response

Week 5: Introduction to refinery processing of bitumen

Week 6: Introduction to the grading system for bitumen

Week 7: Industry lecture on Dynamic Shear Rheometer - Dharmesh Gala from Anton Paar;

Performance grading of bitumen

Week 8: Modifiers for bitumen; Performance characterization of modified bitumen

Week 9: Introduction to Bituminous Mixture and the associated volumetrics

Week 10: Stiffness modulus (van der Poel), dynamic modulus, and resilient modulus of bituminous

mixtures - experimental protocol, and post-processing.

Week 11: Simulation of rutting of bituminous mixtures in the laboratory

Week 12: Simulation of fatigue damage of bituminous mixtures in the laboratory

Sl. No.	Course Code	Course Name	Duration	Offering Platform	Course Institution
3.		Geosynthetics and Reinforced Soil Structures	12weeks	nptel	IITM

Course Instructor

Dr.K.Rajagopal, Professor, Department of Civil Engineering, IIT Madras.

Course Plan

Week 1: Introduction to Geosynthetics

Week 2: Strength of reinforced soils

Week 3: Different Types of Soil Retaining Structures

Week 4: External Stability Analysis of Reinforced Soil Retaining Walls

Week 5: Design of Reinforced soil Retaining walls - simple geometry

Week 6: stability analysis of soil slopes- Infinite slopes

Week 7: stability analysis of reinforced soil slopes - bilinear wedge analysis Week 8: Reinforced soil for supporting shallow foundations

Week 9: Accelerated consolidation of soft clays using geosynthetics

Week 10: Drainage application of geosynthetics

Week 11: Erosion control using geosynthetics

Week 12: Geosynthetics for construction of municipal and hazardous waste landfills

Sl. No.	Course Code	Course Name	Duration	Offering Platform	Course Institution
4.		Introduction To Multimodal Urban Transportation Systems (MUTS).	12weeks	nptel	IITKGP

Course Instructor

Dr.Arkopal Kishore Goswami, Department of RCG, School of Infrastructure Design Management, IIT Kharagpur

Course Plan

Week 1: Overview of urban transportation

Week 2: Public Transportation

Week 3: Public Transportation

Week 4: Public Transportation

Week 5: Non-Motorised Transportation (NMT) Planning

Week 6: Non-Motorised Transportation (NMT) Planning

Week 7: Non-Motorised Transportation (NMT) Planning

Week 8: Non-Motorised Transportation (NMT) Planning

Week 9: Urban Transport & Sustainability

Week 10: Urban Transport & Sustainability

Week 11: Urban Transport & Sustainability

Week 12: Urban Transport & Sustainability

	List of Audit Courses
Sl. No.	**Course Name**
1.	English for Research Paper Writing
2.	Business Communication and Presentation Skills
3.	Ethics & Human Values
4.	Pedagogy Studies
5.	Stress Management by Yoga
6.	Personality Development through Life Enlightenment Skills
7.	Cost Management of Engineering Projects
8.	Operations Research
9.	Composite Materials
10.	Energy from Waste
11.	Entrepreneurship Development
12	Principles of Automation
13	Universal Human Values

ASSESSMENT PATTERN
(2022 SCHEME)

(i) CORE COURSES

Evaluation can include application, analysis and design based questions (for both Continuous internal evaluation and End semester examination).

Continuous Internal Evaluation: 40 marks

Micro project/ Course based project: 20 marks
(The project shall be done individually. Group projects not permitted)

Course based task/ Seminar/Quiz: 10 marks

Continuous Assessment Test (CAT), 1 No: 10 marks
(CAT shall include three modules, approximately 60% of the syllabus)

End Semester Examination (ESE): 60 marks

The ESE shall be conducted by the CoE. The examination will be for 150 minutes.

The question paper will have two parts; Part A and Part B.

Part A contain 5 questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 5 marks for each question. Students are required to answer all questions.

Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/ practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module, of which student are required to answer any five. Each question shall carry 7 marks.

(ii) ELECTIVE COURSES

Evaluation can include application, analysis and design based questions (for both Continuous internal evaluation and End semester examination).

Continuous Internal Evaluation: 40 marks

Preparing a review article based on peer reviewed Original publications: 15 marks
(minimum 10 publications shall be referred)

Course based task/ Seminar/ Data collection and interpretation: 15 marks

Continuous Assessment Test (CAT), 1 No: 10 marks
(CAT shall include three modules, approximately 60% of the syllabus)

End Semester Examination: 60 marks

The ESE will be conducted by the CoE. The examination will be for 150 minutes.
The question paper will have two parts; Part A and Part B.
Part A will contain 5 questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students are required to answer all questions.
Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/ practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module, of which student are required to answer any five. Each question shall carry 7 marks.

(iii) RESEARCH METHODOLOGY & IPR/ AUDIT COURSE

Continuous Internal Evaluation: 40 marks

Course based task: 15 marks

Seminar/Quiz: 15 marks

Continuous assessment Test (CAT), 1 No: 10 marks
(CAT shall include three modules, approximately 60% of the syllabus)

End Semester Examination: 60 marks

The ESE will be conducted by the CoE. The examination will be for 150 minutes.

The question paper will contain 7 questions, with minimum one question from each module, of which students are required to answer any five. Each question shall carry 12 marks.

(iv) INTERNSHIP

Internship for the M.Tech students is accepted as a matter of policy in ensuring the immersive learning by the students. Internships are educational and career development opportunities, providing practical experience in a field or discipline. They are structured, short-term, supervised placements often focused around particular tasks or projects with defined timescales. An internship may be compensated or non-compensated by the organization providing the

internship. The internship has to be meaningful and mutually beneficial to the intern and the organization. It is important that the objectives and the activities of the internship program are clearly defined and understood. The internship offers the students an opportunity to

(i) Gain hands-on industrial or organizational exposure

(ii) Integrate the knowledge and skills acquired through the coursework

(iii) Interact with professionals and other interns, and

(iv) Improve their presentation, writing, and communication skills.

Internship often acts as a gateway for final placement for many students.
A student shall opt for carrying out the Internship at an Industry/ Research Organization or at another institute of higher learning and repute (Academia). The organization for Internship shall be selected/ decided by the students on their own after getting approval from the respective PG Programme Coordinator. Every student shall be assigned an internship Supervisor/ Guide at the beginning of the Internship. The training shall be related to their specialization and must be carried out immediately after the second semester ESE, for duration of six to eight weeks. On completion of the course, the student is expected to be able to develop skills in facing and solving the problems experiencing in the related field.

Objectives

- Exposure to the industrial environment, which cannot be simulated in the class room and hence creating competent professionals for the industry.
- Provide possible opportunities to learn understand and sharpen the real time technical/ managerial skills required at the job.
- Exposure to the current technological developments relevant to the subject area of training.
- Create conducive conditions with quest for knowledge and its applicability on the job.
- Understand the social, environmental, economic and administrative considerations that influence the working environment.
- Expose students to the engineer's responsibilities and ethics.

Benefits of Internship

Benefits to Students

- An opportunity to get hired by the Industry/ organization.

- Practical experience in an organizational setting & Industry environment.
- Excellent opportunity to see how the theoretical aspects learned in classes are integrated into the practical world. On-floor experience provides much more professional experience which is often worth more than classroom teaching.
- Helps them decide if the industry and the profession is the best career option to pursue.
- Opportunity to learn new skills and supplement knowledge.
- Opportunity to practice communication and teamwork skills.
- Opportunity to learn strategies like time management, multi-tasking etc in an industrial setup.
- Makes a valuable addition to their resume that enhances their candidacy for higher education/ placement.
- Creating network and social circle and developing relationships with industry people.
- Provides opportunity to evaluate the organization before committing to a fulltime position.

Benefits to the Institute

- Build industry academia relations.
- Makes the placement process easier.
- Improve institutional credibility & branding.
- Helps in retention of the students.
- Curriculum revision can be made based on feedback from Industry/ students.
- Improvement in teaching learning process.

Benefits to the Industry

- Availability of ready to contribute candidates for employment.
- Year round source of highly motivated pre-professionals.
- Students bring new perspectives to problem solving.
- Visibility of the organization is increased on campus.
- Quality candidate's availability for temporary or seasonal positions and projects.
- Freedom for industrial staff to pursue more creative projects.
- Availability of flexible, cost-effective workforce not requiring a long-term employer

commitment.

- Proven, cost-effective way to recruit and evaluate potential employees.
- Enhancement of employer's image in the community by contributing to the educational enterprise.

Types of Internships

- Industry Internship with/ without Stipend
- Government / PSU Internship (BARC/ Railway/ ISRO etc.)
- Internship with prominent education/ Research Institutes
- Internship with Incubation centers/ Start-ups

Guidelines

- All the students need to go for internship for minimum duration of 6 weeks and a maximum duration of 8 weeks.
- Students can take up mini projects, assignments, case studies, and so on by discussing it with authority from the host organization/ industry concerned and can work on it during the internship.
- All students should compulsorily follow the rules and regulations as laid by industry.
- Every student should take prior permissions from concerned industrial authority if they want to use any drawings, photographs or any other document from the industry.
- Student should follow all ethical practices and Standard operating procedure (SOP) of industry.
- Students have to take necessary health and safety precautions as laid by the industry.
- Student should contact his /her Guide/Supervisor from the College on a weekly basis to communicate the progress.
- Each student has to maintain a diary/log book
- After completion of internship, students are required to submit
    - ✓ Report of work done
    - ✓ Internship certificate

- ✓ Feedback from employer/ internship mentor
- ✓ Proof of Stipend received (if applicable).

Total Marks 100: The marks awarded for the Internship will be on the basis of

(i) Evaluation done by the Industry
(ii) Student's diary/ Daily log
(iii) Internship Report and
(iv) Comprehensive Viva Voce.

Continuous Internal Evaluation: 50 marks

Student's diary/ Daily Log: 25 Marks
Evaluation done by the Industry: 25 Marks

Student's Diary/ Daily Log: 25 marks

The main purpose of writing Student's Diary/ Daily Log is to cultivate the habit of documenting and to encourage the students to search for details. It develops the students' thought process and reasoning abilities. The students should record in the diary the day to day account of the observations, impressions, information gathered and suggestions given, if any. It should contain the sketches & drawings related to the observations made by the students. The daily training diary should be signed after every day by the supervisor/ in charge of the section where the student has been working. The diary should also be shown to the Faculty Mentor visiting the industry from time to time and got ratified on the day of his visit. Student's diary will be evaluated on the basis of the following criteria:

- ➢ Regularity in maintenance of the diary
- ➢ Adequacy & quality of information recorded
- ➢ Drawings, design, sketches and data recorded
- ➢ Thought process and recording techniques used
- ➢ Organization of the information.

The format of Student's Diary/ Daily Log

Name of the Organization/Section:

Name and Address of the Section Head:

Name and Address of the Supervisor:

Name and address of the student:

Internship Duration: From ..... To .....

Brief description about the nature of internship:

Day	Brief write up about the Activities carried out: Such as design, sketches, result observed, issues identified, data recorded, etc.
1	
2	
3	

Signature of Industry supervisor Signature of Head/ HR Manager

Office Seal

The format of Student's attendance Sheet

Name of the Organization/ Section:

Name and Address of the Section Head:

Name and Address of the Supervisor:

Name and address of the student:

Internship Duration: From .... To ....

Month & Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
Month & Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
Month & Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	

Signature of Industry supervisor Signature of Head/ HR Manager

Office Seal

Note:

- Student's Diary/ Daily log shall be submitted by the students along with attendance record and an evaluation sheet duly signed and stamped by the industry to the Institute immediately after the completion of the training.
- Attendance Sheet should remain affixed in daily training diary. Do not remove or tear it off.
- Student shall sign in the attendance column. Do not mark 'P'.

- Holidays should be marked in red ink in the attendance column. Absence should be marked as 'A' in red ink.

Evaluation done by the Industry: 25 marks

Format for Supervisor Evaluation of Intern

Student Name : Date:

Supervisor Name : Designation:

Company/ Organization :

Internship Address:

Dates of Internship: From_____ To_____

Please evaluate intern by indicating the frequency with which you observed the following parameters

Parameters/ Marks	Needs improvement (0 - 0.25 marks)	Satisfactory (0.25 -0.5 marks)	Good (0.75 marks)	Excellent (1 mark)
Behavior				
Performs in a dependable manner				
Cooperates with coworkers and supervisor				
Shows interest in work				
Learns quickly				
Shows initiative				
Produces high quality work				
Accepts responsibility				
Accepts criticism				
Demonstrates organizational skills				
Uses technical knowledge and expertise				
Shows good judgment				

Demonstrates creativity/ originality				
Analyzes problems effectively				
Is self reliant				
Communicates well				
Writes effectively				
Has a professional attitude				
Gives professional appearance				
Is punctual				
Uses time effectively				

Overall performance of student Intern (Tick one):

Needs improvement (0 - 0.50 mark) Satisfactory (0.50 – 1.0 mark)
Good (1.5 mark) Excellent (2.0 mark)

Additional comments, if any (2 marks) :

Signature of Industry Supervisor *Signature of Section Head/HR Manager*

Office Seal

End Semester Evaluation (External Evaluation): 50 Marks

Internship Report: 25 Marks

Comprehensive Viva Voce: 25 Marks

Internship Report: 25 marks

After completion of the internship, the student should prepare a comprehensive report to indicate what he has observed and learnt in the training period and should be submitted to the faculty mentor. The student may contact Industry Supervisor/ Faculty Mentor for assigning special topics and problems and should prepare the final report on the assigned topics. Student's Diary/ Daily log will also help to a great extent in writing the industrial report since much of the information has already been incorporated by the student into the diary. The training report should be signed by the Internship supervisor, PG Programme Coordinator and Faculty Mentor.
The Internship report will be evaluated on the basis of following criteria:

- Originality
- Adequacy and purposeful write-up
- Organization, format, drawings, sketches, style, language etc.
- Variety and relevance of learning experience
- Practical applications, relationships with basic theory and concepts taught in the course.

Comprehensive Viva Voce: 25 marks

Viva Voce will be done by a committee comprising Faculty mentor, PG Programme Coordinator and an external expert (from Industry or research/ academic Institute). This committee will be evaluating the internship report also.

(v) LABORATORY COURSES

The laboratory courses will have only Continuous Internal Assessment and carries 100 marks. Final assessment shall be done by two examiners; one examiner will be a senior faculty from the same department.

(vi) INDUSTRY BASED ELECTIVES/ INTERDISCIPLINARY ELECTIVES

Engineering students frequently aspire to work in areas and domains that are key topics in the industry. There are concerns by recruiters that skill sets of engineering students did not match with the Industry requirements, especially in the field of latest topics.
Interdisciplinary knowledge is critical for connecting students with current industry trends, where multitasking is the norm. Interdisciplinary knowledge aids in the bridge building process between academic institutions and industry. It aids students in expanding their knowledge and innovating by allowing them to create something new. While core engineering courses provide students with a strong foundation, evolving technology necessitates new methods and approaches to progress,

prosperity, and the inculcation of problem-solving techniques. Other courses' knowledge, on the other hand, can assist them to deal with any scenario more effectively. Interdisciplinary courses may be one approach to address such needs, as they can aid in the enhancement of engineering education and the integration of desirable specialized subjects into the current engineering education system. This will enable students to fulfill the current industry demands. Students with multi disciplinary knowledge and projects are more likely to be placed in top industries, according to the placement trend. The future of developing engineers will be influenced by their understanding of emerging technology and interdisciplinary approaches.

Rapid technological advancements and the onset of the fourth industrial revolution have resulted in a massive revival in the way engineering works in the industry. Projects necessitate the integration of knowledge and abilities from a diverse variety of engineering specialties, with the barriers between them becoming increasingly blurred.

Students can choose courses offered by other departments/ Industries that cover a wide range of highly relevant topics such as artificial intelligence, internet of things, big data, automation, and other software or other relatable courses. In the case of Industry based electives the course shall handled by the expert in the industry and the faculty in the college.

Assessment pattern for Interdisciplinary electives:

Continuous Internal Evaluation: 40 marks

Preparing a review article based on peer reviewed Original publications: 15 marks
(minimum 10 publications shall be referred)

Course based task/ Seminar/ Data collection and interpretation: 15 marks

Continuous assessment Test (CAT), 1 No: 10 marks
(CAT shall include three modules, approximately 60% of the syllabus)

End Semester Examination: 60 marks

The ESE will be conducted by the CoE. The examination will be for 150 minutes.

The question paper will have two parts; Part A and Part B.

Part A will contain 5 questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students).Students should answer all questions.

Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/ practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student are required to answer any five. Each question shall carry 7 marks.

Assessment pattern for Industry based electives:

Continuous Internal Evaluation: 40 marks

The continuous internal evaluation will be done jointly by the expert in the Industry and the faculty in the college.

Micro project/ Course based project: 20 marks
(The project shall be done individually. Group projects not permitted)

Course based task/Seminar/Quiz: 10 marks

Continuous assessment Test (CAT), 1 No: 10 marks
(CAT shall include three modules, approximately 60% of the syllabus)

End Semester Examination: 60 marks

The ESE will be conducted by the CoE. The examination will be for 150 minutes.
The question paper shall be prepared jointly by the expert in the industry and the faculty in the college. The question paper will contain 7 questions, with minimum one question from each module of which student should answer any five. Each question shall carry 12 marks.
The first valuation of the answer scripts shall be done by the expert in the Industry handling the course, and the second valuation shall be done by the faculty in the college. In the situation when the expert in the Industry is not available for first valuation, the college shall appoint an expert for this valuation.

(vii) MOOC COURSES

The MOOC course shall be considered only if it is conducted by the agencies namely AICTE/ NPTEL/ SWAYAM/ NITTTR. The MOOC course should have a minimum duration of 8 weeks and the content of the syllabus shall be enough for at least 40 hours of teaching. The course should have a proctored/ offline end semester examination. The students can do the MOOC according to their convenience starting from first semester, but shall complete it by fourth semester. The list of MOOC courses will be provided by the concerned BoS if at least 70% of the course content match with the area/ stream of study. The course shall not be considered if its content has more than

50% of overlap with a core/ elective course in the concerned discipline.
A certificate of successful completion of the MOOC course (as per the evaluation pattern of the respective agency conducting the MOOC) is to be duly produced for verification. Two credits will be awarded to all students whoever successfully completes the MOOC course.

(viii) MINIPROJECT

Mini project can help to strengthen the understanding of student's fundamentals through application of theoretical concepts and to boost their skills and widen the horizon of their thinking. The ultimate aim of an engineering student is to resolve a problem by applying theoretical knowledge. Doing more projects enhances problem solving skills. The Mini project ensures preparedness of students to undertake Dissertation/ Research project. Students should identify a topic of interest in consultation with PG Programme Coordinator that should lead to their Dissertation/ Research project. Demonstrate the novelty of the project through the results and outputs. The progress of the mini project is evaluated based on three reviews, two interim reviews and a final review. A report is required to be submitted before the final review. Mini project has continuous internal assessment for a total of 100 marks.

Interim evaluations: 40 marks

First evaluation: 20 marks
Second evaluation: 20 marks

Final evaluation: 60 marks

Evaluation by a Committee: 30 marks

The committee will evaluate the demonstration of functionality/ specifications, clarity of presentation, oral examination, and knowledge on the project work.

Report: 10 marks

The committee will evaluate the technical content, and adequacy of references. Permitted plagiarism level is not more than 25%.

Supervisor/ Guide: 20 marks

(ix) DISSERTATION/ RESEARCH PROJECT

Research Project:

Students selected for track 2 shall carry out their Research project only in the college, under the guidance of a supervisor assigned by the DLAC.

Dissertation:

All categories of students in track 1 are to carry out the Dissertation in the college or can work either in any CSIR/ industrial R&D organization/ any other reputed Institute which have facilities for dissertation work in the area proposed.

Dissertation outside the Institute:

For doing Dissertation outside the college, the following conditions are to be met:

- They have completed successfully the course work prescribed in the approved curriculum up to the second semester.
- The student has to get prior approval from Dean (PGSR), on recommendation from the concerned DLAC.
- Students availing this facility should continue as regular students of the College.
- Facilities required for doing the dissertation shall be available in the Organization/ Industry (A certificate stating the facilities available in the proposed organization and the time period for which the facilities shall be made available to the student, issued by a competent authority from the Organization/ Industry shall be submitted by the student along with the application).
- The student should have an external as well as an internal supervisor. The internal supervisor shall belong to the college and the external supervisor shall be a Scientist or Engineer from the Institution/ Industry/ R&D organization with which the student is associated for doing the Dissertation work. The external supervisor shall be with a minimum Post graduate degree in the related area.
- The course work in the 3rd semester is to be completed as per the curriculum requirements:
    - (i) MOOC can be completed as per the norms specified in this curriculum.
    - (ii) Audit course is to be carried out either in the College or by self-learning. However, for self-learning students, all assessments shall be carried out in the college as in the case of regular students.
- The student has to furnish his/her monthly progress as well as attendance report signed by the external supervisor and submit the same to the concerned Internal supervisor.
- The external supervisor is to be preferably present (online/ offline) during all stages of evaluation of the Dissertation.

Internship leading to Dissertation:

The students who, after completion of 6 to 8 weeks internship at some reputed organization, are allowed to continue their work as dissertation for the third and fourth semester can do so only after getting approval from Dean (PGSR) on recommendation from the concerned DLAC. Such students shall make a brief presentation regarding the work they propose to carry out before the DLAC for a detailed scrutiny and to resolve its suitability for accepting it as an M.Tech Dissertation. These students will be continuing as regular students of the college in third semester for carrying out all academic requirements as per the curriculum/ regulation. However, they will be permitted to complete their Dissertation in the Industry/ Organization (where they have successfully completed their internship) during fourth semester.

Dissertation as part of Employment:

Students may be permitted to discontinue the programme and take up a job, provided they have successfully completed all the courses till the second semester (FE status students are not permitted) prescribed in the approved curriculum. The dissertation work can be done during a later period either in the organization where they work if it has R & D facility, or in the College. Such students should submit application with details (copy of employment offer, plan of completion of their project etc.) to the Dean (PGSR) through the HoD for approval. When the students are planning to do the Dissertation work in the organization with R & D facility where they are employed, they shall submit a separate application with the following details:

- Name of R&D Organization/Industry
- Name and designation of an external supervisor from the proposed Organization/Industry (Scientists or Engineers with a minimum post graduate degree in the related area) and his/her profile with consent
- Name and designation of a faculty member of the College as internal supervisor along with his/her consent
- Letter from the competent authority from the Organization/ Industry granting permission to do the Dissertation
- Details of the proposed work along with the work plan

DLAC will scrutinize the proposal and forward to Dean (PGSR) for approval.
When students are doing dissertation work along with the job in the organization (with R & D facility) where they are employed, the dissertation work shall be completed in four semesters normally (two semesters of dissertation work along with the job may be considered as equivalent to one semester of dissertation work at the college). Extensions may be granted based on requests

from the student and recommendation of the supervisors such that he/she will complete the M. Tech programme within four years from the date of admission as per the regulation. Method of assessment and grading of the Dissertation will be the same as in the case of regular students.
The course work in the 3rd semester for such students is to be completed as per the curriculum requirements

(i) MOOC can be completed as per the norms specified in this curriculum.

(ii) Audit course is to be carried out either in the College or by self-learning. However, for self-learning students, all assessments shall be carried out in the college as in the case of regular students.

Marks distribution:

Phase I:	**Total marks: 100**	
	Continuous Internal Evaluation:	100 marks
Phase II:	**Total marks: 200**	
	Continuous Internal Evaluation:	100 marks
	End Semester Examination:	100 marks

Final report of Dissertation/ Research Project:

Students must submit the final report of Dissertation/ Research project on or before the specified deadline. If the report is not submitted on or before the specified deadline, an extension of time up to a maximum of 30 days may be given for the submission of the report with due approval obtained from the HoD.

If a student fails to submit the final report of Dissertation/ Research project on or before the specified deadline/ extended deadline, he/ she is deemed to have failed in Project work and shall re-register for the same in the immediate next semester.

If a student does not appear for the ESE/ fails in the ESE, he/ she is deemed to have failed in Dissertation/ Research Project Phase II and shall have to re-register for the same in the immediate next semester.

(x) TEACHING ASSISTANCESHIP (TA)

All M.Tech students irrespective of their category of admission, shall undertake TA duties for a minimum duration as per the curriculum. Being a TA, the student will get an excellent opportunity

to improve their expertise in the technical content of the course, enhance communication skills, obtain a hands-on experience in handling the experiments in the laboratory and improve peer interactions.

The possible TA responsibilities include the following: facilitate a discussion section or tutorial for a theory/ course, facilitate to assist the students for a laboratory course, serve as a mentor for students, and act as the course web-master. TAs may be required to attend the instructor's lecture regularly. A TA shall not be employed as a substitute instructor, where the effect is to relieve the instructor of his or her teaching responsibilities. Students who are doing their dissertation work outside the college are not required to do TA work during their second year.

Handling a tutorial session:

(i) Meet the teacher concerned and understand the responsibilities well in advance, attend the lectures of the course for which the student is a tutor, work out the solutions for all the tutorial problems himself/herself, approach the teacher if he/she finds any discrepancy or if he/she needs help in solving the tutorial problems, use reference text books, be innovative and express everything in English only.

(ii) Try to lead the students to the correct solutions by providing appropriate hints rather than solving the entire problem by themselves, encourage questions from the students, lead the group to a discussion based on their questions, plan to ask them some questions, be friendly and open with the students, simultaneously being firm with them.

(iii) Keep track of the progress of each student in the assigned group, give a periodic feedback to the student about his/her progress, issue warnings if the student is consistently under-performing, report to the faculty if TA finds that a particular student is consistently underperforming, pay special attention to slow-learners and be open to the feedback and comments from the students and faculty.

(iv) After the tutorial session TA may be required to grade the tutorials/assignments/tests. Make sure that TA work out the solutions to the questions own their own, and compare it with the answer key, think and work out possible alternate solutions to the same question, understand the marking scheme from the teacher prior to the evaluation.

(v) Consult the teacher and make sure that there is no partiality to any student/ students while grading. They will follow basic ethics in this regard.

Handling a laboratory Session:

(i) Meet the faculty – in- charge a few days in advance of the actual lab class and get the details of the experiment, get clarifications from him/her regarding all aspects of the experiment and the expectations, prepare by reading about the theoretical background of the experiment, know the physical concepts involved in the experiment, go to the laboratory and check out the condition of the equipment/instrumentation, perform the laboratory experiment at least once one or two days before the actual laboratory class, familiarize with safety/ security aspects of the experiment / equipment/laboratory, prepare an instruction sheet for the experiment in consultation with the faculty, and keep sufficient copies ready for distribution to students for their reference.

(ii) Verify condition of the equipment/set up about 30 minutes before the students arrive in the class and be ready with the hand outs, make brief introductory remarks about the experiment, its importance, its relevance to the theory they have studied in the class, ask the students suitable questions to know there level of preparation for the experiment, discuss how to interpret results, ask them comment on the results.

(iii) Correct/evaluate/grade the submitted reports after receiving suitable instructions from the faculty in charge, continue to interact with students if they have any clarifications regarding any aspect of the laboratory session, including of course grading, Carefully observe instrument and human safety in laboratory class, Preparing simple questions for short oral quizzing during explanation of experiments enables active participation of students, facilitate attention, provides feedback and formative assessment.