

FINITE ELEMENT METHODS

ENAM 365

Lecture : 3

Tutorial : 2

Practical : 1

Year : III

Part : II

Course Objectives:

The objective of this course is to understand the fundamental concepts of the finite element method, apply direct stiffness, variational, and weighted residual formulations to structural and thermal problems and develop practical skills in FEM programming and error analysis for one-dimensional and two-dimensional engineering applications.

1 Introduction (3 hours)

- 1.1 Historical background
- 1.2 Basic concept and steps of the FEM
- 1.3 Advantages and limitations of FEM
- 1.4 Application of FEM in automotive sector
- 1.5 Finite element packages

2 Direct Stiffness Method (9 hours)

- 2.1 Spring/Bar element
- 2.2 Truss element
- 2.3 Beam element

3 Integral Formulations and Variational Methods (9 hours)

- 3.1 Need for weighted-integral form
- 3.2 Variational calculus
- 3.3 Weak formulation of boundary value problems
- 3.4 Variational methods of approximation: Rayleigh Ritz method and method of weighted residuals

4 Finite Element Method in One Dimensional Problems (9 hours)

- 4.1 Shape functions
- 4.2 Linear, quadratic and cubic elements
- 4.3 Modelling and FE formulation
- 4.4 Application in 1-D heat transfer
- 4.5 Application in 1-D solid mechanics

5 Finite Element Error Analysis (3 hours)

- 5.1 Approximation errors
- 5.2 Various measures of errors
- 5.3 Convergence of the solution
- 5.4 Accuracy of the solution

6 Finite Element Method in Two Dimensional Problems (9 hours)

- 6.1 Linear shape function for 2-D problems
- 6.2 Rectangular elements
- 6.3 Modelling and FE formulations
- 6.4 Application in 2-D heat transfer
- 6.5 Application in 2-D solid mechanics

7 Higher Order Elements (4 hours)

- 7.1 Quadratic and cubic shape functions for 2-D and 3-D problems
- 7.2 Lagrange and serendipity elements

Tutorial (30 hours)

- 1. Solving static analysis problems using spring and bar elements
- 2. Performance of structural modeling for plane and space trusses
- 3. Determination of nodal displacements and internal forces in beam elements
- 4. Application of weak formulation, Ritz and weighted residual methods for approximate solutions
- 5. Calculation of temperature distributions in 1-D heat transfer problems
- 6. Analysis of thermal gradients and heat flux in 2-D heat transfer problems
- 7. Execution of stress and strain analysis for 2-D problems in solid mechanics

Practical (15 hours)

- 1. Implementation of matrix operations and equation-solving algorithms for FEM programming
- 2. Development of FEM programs for the analysis of bar and truss elements
- 3. Coding of FEM procedures for displacement and force analysis in beam elements
- 4. Scripting of numerical solutions using the Ritz method and weighted residual techniques
- 5. Execution of FEM programs to solve 1-D engineering problems
- 6. Performance of computational analysis for 2-D problems using specialized FEM code

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Mark distribution*
1	3	4
2	9	12
3	9	12
4	8	12
5	3	4
6	9	12
7	4	4
Total	45	60

* There may be minor deviation in marks distribution.

References

1. Reddy, J. N. (2005). An introduction to the finite element method. McGraw-Hill Education.
2. Hutton, D. V. (2004). Fundamentals of finite element analysis. McGraw-Hill Education.
3. Logan, D. L. (2007). A first course in the finite element method. Cengage Learning.
4. Bathe, K. J. (1996). Finite element procedures (Latest Edition). Prentice Hall.
5. Rao, S. S. (2004). The finite element method in engineering. Butterworth-Heinemann.
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ADVANCED ELECTRIC VEHICLE SYSTEMS

ENAM 366

Lecture : 3

Tutorial : 2

Practical : 1

Year : III

Part : II

Course Objectives:

The objective of this course is to develop knowledge and skills in advanced electric vehicle architectures, high-performance propulsion systems, and modern energy storage technologies, including fuel cells and supercapacitors. It also focuses on charging, grid integration, and thermal management systems. Upon completion, students will be able to analyze, design, and apply EV technologies through simulation and practical exposure.

1 Advanced EV Architectures and System Integration (5 hours)

- 1.1 Comparative analysis of BEV, HEV, PHEV and FCEV architectures from system integration perspective
- 1.2 Advanced hybrid architectures: Through-the-road (TTR), power-split and multi-mode systems
- 1.3 Powertrain components (Motor, inverter and transmission) integration
- 1.4 Torque vectoring and electronic differentials for enhanced stability and performance
- 1.5 Introduction to ISO 26262 and functional safety for traction control
- 1.6 Multi-speed transmissions for EVs: Benefits, challenges and control strategies

2 Electric Propulsion Systems (7 hours)

- 2.1 Advanced electric motor technologies: Axial flux motors, switched reluctance motors (SRM) and wound-rotor synchronous motors
- 2.2 High-speed motors: Design considerations, materials and efficiency
- 2.3 Motor cooling techniques, thermal constraints and performance
- 2.4 Control and modulation strategies
 - 2.4.1 Fundamentals of field oriented control (FOC)
 - 2.4.2 Space Vector PWM (SVPWM) for DC-link utilization
 - 2.4.3 Torque ripple mitigation and sensorless control basics
 - 2.4.4 Advanced control strategies: Model predictive control (MPC) and direct torque control (DTC)
- 2.5 Integrated motor drive (IMD) systems and power-dense architectures: Silicon carbide (SiC) and gallium nitride (GaN)

- 3 Energy Storage Systems (8 hours)**
- 3.1 Advanced battery chemistries: Lithium-iron-phosphate, nickel metal hydride, solid-state batteries, lithium-sulfur (Li-S) and their potential for EVs
 - 3.2 Battery modeling approaches: Equivalent circuit and electrochemical models
 - 3.3 State estimation techniques: SoC, SoH, SoP
 - 3.4 Ultra-fast charging: Technologies, thermal challenges and infrastructure requirements
 - 3.5 Second-life applications of EV batteries: Assessment, repurposing and business models
 - 3.6 Comparative lifecycle assessment (LCA) of advanced batteries
- 4 Hydrogen Fuel Cell Vehicle Systems (5 hours)**
- 4.1 Fundamentals of fuel cell systems and automotive applications
 - 4.2 PEM fuel cell operation and components
 - 4.3 Hydrogen storage methods for vehicles: Compressed, cryogenic and solid-state
 - 4.4 FCEV architectures and component sizing (Fuel cell, battery, DC-DC converter)
 - 4.5 Thermal management and performance characteristics
 - 4.6 Hydrogen production pathways and environmental impact
- 5 Hybrid Energy Storage and Supercapacitor Systems (5 hours)**
- 5.1 Fundamentals of supercapacitors: Electrochemical double-layer capacitance (EDLC), pseudocapacitance, hybrid types
 - 5.2 Comparison with batteries: Power density, energy density, cycle life and charge/discharge characteristics
 - 5.3 Module design and voltage balancing techniques
 - 5.4 Hybrid Energy Storage Systems (HESS): Battery supercapacitor integration
 - 5.5 Applications: Regenerative braking, peak power support, cold-start
- 6 EV Charging and Grid Integration (6 hours)**
- 6.1 Smart charging concepts: V2G, V2H, V2L, V2X
 - 6.2 Communication protocols: ISO 15118, OCPP, cybersecurity basics
 - 6.3 High-power charging infrastructure: Megawatt charging systems (MCS) for commercial EVs, Charging standards and connectors
 - 6.4 Wireless power transfer: Inductive and capacitive systems
 - 6.5 Integration with renewable energy sources and microgrids
- 7 Thermal Management and Vehicle Efficiency (4 hours)**
- 7.1 Integrated thermal management: Battery, motor, power electronics and cabin
 - 7.2 Heat pump systems and energy-efficient HVAC in EVs
 - 7.3 Thermal constraints in fast charging and high-performance driving

8 Vehicle Design for Efficiency and Range Extension

(5 hours)

- 8.1 Automotive aerodynamics for EVs
 - 8.1.1 Impact of drag coefficient (Cd) on high-speed range
 - 8.1.2 Active aerodynamics (Grille shutters and retractable spoilers)
 - 8.1.3 Underbody smoothing and wheel design for turbulence reduction.
- 8.2 Rolling Resistance and Drivetrain Losses
- 8.3 Structural battery packs: Cell-to pack (CTP), Cell-to-chassis (CTC) technology and Load-bearing structural members for weight reduction

Tutorial

(30 hours)

- 1. Calculation of motor torque, power and efficiency requirements for given vehicle performance targets
- 2. Sizing of battery pack cells in series and parallel configuration based on voltage and energy requirements
- 3. Design of supercapacitor module and simulation of battery-supercapacitor hybrid energy storage system (HESS) for regenerative braking
- 4. Sizing of DC fast charging station and economic analysis of vehicle-to-grid (V2G) energy arbitrage
- 5. Calculation of battery heat generation and design of liquid cooling system for ultra-fast charging conditions
- 6. Analysis of drag coefficient reduction strategies and cost-benefit evaluation of vehicle light-weighting
- 7. Comparative lifecycle assessment (LCA) of BEV, FCEV and ICE vehicles including second-life battery economics
- 8. Integrated design project: Component sizing, thermal management and charging infrastructure for a specified EV application
- 9. Design and analysis of EV charging system with renewable energy sources like solar PV

Practical

(15 hours)

- 1. Design and simulation of an electric vehicle powertrain using MATLAB/Simulink
- 2. Performance testing and efficiency mapping of a traction motor using dynamometer setup
- 3. Characterization and state estimation of battery pack using battery management system (BMS) test bench
- 4. Simulation of battery-supercapacitor hybrid energy storage system (HESS) for regenerative braking enhancement
- 5. Case study analysis and presentation on a cutting-edge EV technology (E.g., solid-state battery, hydrogen fuel cell, V2X project)
- 6. Visit to nearest EV manufacturing/service centers, fuel cell vehicle research lab

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Mark distribution*
1	5	6
2	7	12
3	8	10
4	5	6
5	5	6
6	6	10
7	4	5
8	5	5
Total	45	60

* There may be minor deviation in marks distribution.

References

1. Ehsani, M., Gao, Y., Longo, S., Ebrahimi, K. (2018). Modern electric, hybrid electric, and fuel cell vehicles: Fundamental theory and design. CRC Press.
2. Husain, I. (2021). Electric and hybrid vehicles: Design fundamentals. CRC Press.
3. Valera, H., Agarwal, A. K. (Eds.). (2025). Battery electric vehicles, e-fuel powered hybrids and fuel cell powertrains. Springer Nature.
4. Larminie, J., Lowry, J. (2012). Electric vehicle technology explained. Wiley.
5. Plett, G. L. (2015). Battery management systems. Artech House.

AUTOMOBILE ECONOMICS AND ENTERPRISES

ENAM 367

Lecture : 3

Tutorial : 2

Practical : 1

Year : III

Part : II

Course Objectives:

The objective of this course is to provide knowledge of the economic, financial, and managerial aspects of automobile systems and transport enterprises. It focuses on vehicle cost analysis, taxation, insurance, regulatory frameworks, and economic decision-making in transport operations. Upon completion, students will be able to evaluate enterprise development concepts and emerging trends such as CKD/SKD assembly, electric mobility, and sustainable transport systems.

1 Introduction to Automobile Economics (3 hours)

- 1.1 Concept and structure of transportation systems
- 1.2 Classification: Road, rail, air, water transport systems
- 1.3 Historical development of road transportation (Global and Nepal context)
- 1.4 Modes of transportation and modal choice criteria
- 1.5 Types of transport operations: Private, public, contract carriage
- 1.6 Role of economics in transport decision-making
- 1.7 Vehicle life cycle costing (LCC) approach
- 1.8 Fixed, variable and semi-variable cost concepts
- 1.9 Introduction to cost optimization in automobile systems

2 Vehicle Ownership, Operating Cost and Depreciation (5 hours)

- 2.1 Components of vehicle ownership
- 2.2 Operating costs: Fuel, maintenance, tires, wages, overheads
- 2.3 Cost per kilometer and cost per ton-km/passenger-km
- 2.4 Break-even analysis in vehicle operation
- 2.5 Depreciation: Concept, causes and significance
- 2.6 Methods of depreciation: Straight-line, declining balance, sum-of-years-digits, units of production methods
- 2.7 Salvage value, residual value and scrap value
- 2.8 Replacement analysis and economic life determination
- 2.9 Sensitivity analysis for cost variation
- 2.10 Numerical problems and case-based analysis

3 Vehicle Valuation, Taxation and Financing (5 hours)

- 3.1 Purpose and principles of vehicle valuation

- 3.2 Market value versus book value versus insured declared value (IDV)
- 3.3 Factors affecting vehicle valuation
- 3.4 Service life estimation and obsolescence
- 3.5 Transport taxation: Objectives, principles and structure
- 3.6 Goods versus passenger vehicle taxation systems
- 3.7 Toll tax systems and Build-Operate-Transfer (BOT) models
- 3.8 Vehicle financing systems
 - 3.8.1 Loan structures and interest calculations
 - 3.8.2 EMI (Equated monthly installment) analysis
 - 3.8.3 Lease versus hire purchase versus outright purchase
- 3.9 Economic evaluation of financing alternatives

4 Motor Insurance and Insurer Liability (5 hours)

- 4.1 Principles of insurance and risk management
- 4.2 Types of motor insurance: Third-party insurance; Comprehensive insurance
- 4.3 Policy structure, terms and conditions
- 4.4 Insurer's liability and limitations
- 4.5 Accident claim procedures and documentation
- 4.6 Claim settlement process and dispute resolution
- 4.7 Role of surveyor and loss assessor
- 4.8 Preparation of bill of quantities (BOQ) for vehicle repair estimation
- 4.9 Depreciation on parts and its impact on claims
- 4.10 Fraud detection and risk mitigation

5 Motor Vehicle Act and Transport Regulations (4 hours)

- 5.1 Legal framework governing motor vehicles
- 5.2 Driver and conductor licensing procedures
- 5.3 Vehicle registration and documentation
- 5.4 Permits: Private, commercial, inter-state operations
- 5.5 Traffic rules, road safety regulations and enforcement
- 5.6 Functions of transport authorities (RTO/DoTM context)
- 5.7 Vehicle inspection, testing and certification
- 5.8 Environmental compliance and emission standards
- 5.9 Offences, penalties and legal implications

6 Passenger and Freight Transport Planning and Management (7 hours)

- 6.1 Passenger transport systems: Structure and organization
- 6.2 Depot layout, fleet management and maintenance planning
- 6.3 Scheduling techniques and route optimization
- 6.4 Reservation and ticketing systems (Manual and digital)
- 6.5 Fare structures and pricing strategies
- 6.6 Public relations and passenger service quality

- 6.7 Freight transport systems: Logistics and supply chain integration
- 6.8 Goods handling, storage and warehousing economics
- 6.9 Freight rate determination and costing
- 6.10 Transport management information systems (MIS)
- 6.11 Planning of new transport enterprises
- 6.12 Geographic and economic factors in route selection
- 6.13 Vehicle selection and capacity planning
- 6.14 Urban transit systems and trip planning

7 Fuel Consumption, Emission and Environmental Economics (3 hours)

- 7.1 Fuel consumption models and influencing parameters
- 7.2 Energy efficiency and fuel economy standards
- 7.3 Vehicle emission characteristics and pollutants
- 7.4 Environmental impact and external costs of transport
- 7.5 Pollution control mechanisms and certification
- 7.6 Cost-benefit analysis of emission control technologies
- 7.7 Carbon footprint and sustainability considerations

8 CKD, SKD and Automotive Industry Economics (4 hours)

- 8.1 Concepts: CBU, SKD and CKD manufacturing systems
- 8.2 Comparative analysis of assembly vs full manufacturing
- 8.3 Import duty structure and trade policies
- 8.4 Cost comparison: CKD vs CBU vs local manufacturing
- 8.5 Localization strategies and value addition
- 8.6 Supply chain and vendor development
- 8.7 Automotive industry structure in Nepal and global trends
- 8.8 Government policies and industrial incentives

9 Modern Mobility and EV Conversion Economics (5 hours)

- 9.1 Introduction to electric mobility and sustainable transport
- 9.2 EV conversion (Retrofitting): Concept and applications
- 9.3 Technical components required for conversion
- 9.4 Cost estimation of EV conversion
- 9.5 Regulatory and certification requirements
- 9.6 Operating cost comparison: ICE versus EV
- 9.7 Maintenance cost analysis
- 9.8 Battery lifecycle, replacement cost and recycling economics
- 9.9 Life cycle cost comparison (ICE versus EV)
- 9.10 Payback period and investment analysis

10 Automobile Enterprises and Entrepreneurship (4 hours)

- 10.1 Introduction to automobile-related enterprises

- 10.2 Federation of Nepalese National Transport Entrepreneurs (FNNT) and associated local committees
- 10.3 Types of transport companies, workshops, dealerships, EV startups
- 10.4 Business model development in automobile sector
- 10.5 Feasibility study and project evaluation
- 10.6 Costing, pricing and profitability analysis
- 10.7 Marketing and service strategies
- 10.8 Regulatory compliance and licensing for enterprises
- 10.9 Basics of financial planning and risk management
- 10.10 Innovation and future trends in automotive enterprises

Tutorial

(30 hours)

1. Vehicle cost analysis and break-even evaluation
2. Depreciation and replacement decision problems
3. Fuel economy and operating efficiency analysis
4. Insurance and claim settlement numerical exercises
5. EMI and financing calculations
6. Taxation and toll cost evaluation
7. Transport profitability and route analysis
8. EV conversion economic feasibility studies

Practical

(15 hours)

1. Study and estimation of vehicle operating costs
2. Cost per km and fuel economy analysis
3. Depreciation calculation using different methods
4. Vehicle financing analysis (EMI and loan repayment schedule)
5. Passenger fare and freight rate calculation
6. Case study on transport enterprise or EV conversion project

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Mark distribution*
1	3	4
2	5	7
3	5	7
4	5	7
5	4	5
6	7	9
7 and 8	7	9
9	5	7
10	4	5
Total	45	60

* There may be minor deviation in marks distribution.

References

1. Tirupathi, R. V. (2019). Transport economics and management. McGraw-Hill Education.
2. Khanna, O. P., Arora, M. (2018). Automobile engineering. Dhanpat Rai Publications.
3. Button, K. (2020). Transport economics. Edward Elgar Publishing.
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5. Chan, C. C. (2017). Modern electric vehicle technology. Oxford University Press.
6. Panneerselvam, R. (2012). Engineering economics. PHI Learning.
7. Wells, P. (2013). Business models and the automotive industry. Springer.
8. Government of Nepal. Motor vehicle and transport management act and regulations. Government of Nepal.