GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Master of Engineering
Level: PG
Subject Code: ME02000831
Subject Name: Computational Electromagnetics

w. e. f. Academic Year:	2024-25
Semester:	2
Category of the Course:	Professional Elective Course

Prerequisite:	Fundamentals of Electromagnetics
Rationale:	This course equips students with advanced computational techniques to analyze and solve complex electromagnetic problems essential in modern electrical engineering. By integrating theoretical foundations with numerical methods such as FDM, FEM, and MOM, students gain critical skills for designing and optimizing electromagnetic systems. The interdisciplinary applications foster innovation in areas like transformers, rotating machines, and coupled-field problems.

Course Outcome:

Sr. No.	Course Outcome	Weightage
CO-1	**Explain** electromagnetic field concepts and governing equations.	15
CO-2	**Analyze** electromagnetic fields using Maxwell's equations for diverse engineering problems.	20
CO-3	**Design** computational models with FDM, FEM, and MOM techniques.	30
CO-4	**Evaluate** hybrid methods for coupled-field computations in engineering applications.	20
CO-5	**Develop** solutions for electromagnetic device simulations using advanced computational tools.	15

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	2	5	70	30	30	20	150

Content:

Sr no.	Topics	Total Hrs	% weightage.
1	**Introduction to electromagnetic fields**: Review of Vector Analysis: Gradient, divergence, curl, and their physical interpretations, Electric and Magnetic Potentials: Scalar and vector potentials, gauge transformations, Boundary Conditions: Continuity conditions for electric and magnetic fields, Maxwell's Equations: Integral and differential forms, physical significance, Diffusion and Wave Equations: Derivations and applications in electromagnetics, Poynting Vector: Energy flow in electromagnetic fields and power computations. Open and Closed boundary Numerical Methods.	**06**	10
2	**Finite Difference Method (FDM)**: Finite Difference Schemes: Central, forward, and backward difference approximations. Treatment of Irregular Boundaries: Techniques for handling complex geometries. Accuracy and Stability of FD Solutions: Courant-Friedrichs-Lewy (CFL) condition. Finite-Difference Time-Domain (FDTD) Method: Principles, implementation, and applications.	**08**	20
3	**Finite Element Method (FEM)**: Overview of FEM: Concept, advantages, and limitations. Variational and Galerkin Methods: Formulations and their relevance in FEM. Shape Functions: Lower-order and higher-order shape functions for FEM elements. Vector Elements: Nodal and edge-based vector elements. 2D and 3D Finite Elements: Application in complex geometries. Efficient Computations: Sparse matrix handling, solvers, and computational optimization.	**08**	20
4	**Method of Moments (MOM)**: Integral Formulations: Converting differential equations into integral equations. Green's Functions: Definitions, properties, and applications in electromagnetics. Numerical Integration: Techniques for accurate evaluation of integral equations. Other Integral Methods: Boundary Element Method (BEM), Charge Simulation Method (CSM).	**06**	15
5	**Special topics**: Hybrid Methods: Combining FDM, FEM, and MOM for specific applications. Coupled Circuit-Field Computations: Electrical circuit integration with field models. Electromagnetic-Thermal Coupling: Simulating thermal effects in electromagnetic systems. Electromagnetic-Structural Coupling: Interaction between electromagnetic fields and mechanical structures. Solution of Equations: Iterative and direct solvers, convergence criteria.	**08**	20
6	**Applications**: Low and High-Frequency Electrical Devices: Inductors, capacitors, and antennas. Static, Time-Harmonic, and Transient Problems:	**09**	15

	Applications in transformers and rotating machines. Optimization in Design: Using computational methods for efficiency improvements. Emerging Applications: RF designs, wireless power transfer, and advanced electromagnetic devices.		
	TOTAL	**45**	**100**

Reference Books:

1. M. V. K. Chari and S. J. Salon, Numerical methods in electromagnetism, Academic Press, 2000.
2. M. N. O. Sadiku, Numerical techniques in electromagnetics, CRC Press, 1992.
3. N. Ida, Numerical modeling for electromagnetic non-destructive evaluation, Chapman and Hall, 1995.
4. S. R. H. Hoole, Computer aided analysis and design of electromagnetic devices, Elsevier Science Publishing Co., 1989.
5. J. Jin, The Finite Element Method in electromagnetics, 2nd Ed., John Wiley and Sons, 2002.
6. P. P. Silvester and R. L. Ferrari, Finite elements for electrical engineers, 3rd Ed., Cambridge University Press, 1996.

List of Experiments

1. Analyze the magnetic field distribution in a single-phase or three-phase transformer core.
2. Compute the electric field distribution in a high voltage underground cable with a metallic shield
3. Simulate the magnetic field distribution in the stator and rotor of an induction motor
4. Analyze the electric field distribution in a parallel plate capacitor with non-uniform dielectric using FDM.
5. Calculate the electric potential distribution across an insulator with complex geometry.
6. Predict regions of corona discharge in a substation using the Charge Simulation Method.
7. Compute the capacitance matrix of a multi-conductor system using the Charge Simulation Method
8. Determine the current density, and the total current in the fuse.
9. Using the PDE toolbox, write an FEM code to determine the potential at (0.5, 0.9) for the capacitor , considering that the left edge of the bottom plate of the capacitor is at (0, 0).
10. Write a program to plot the electric field and equipotential lines due to two point charges & Four Point Changes
11. Solve the one dimensional boundary value problem using the finite difference method.
12. Write an FDM code to determine TE modes in a rectangular waveguide with dimensions a b
13. Consider the two-element mesh. Using the finite element method, determine the potential within the mesh.

Open Ended Problems/Suggested Student Activities:

Open Source:

1. FEMM
2. SCILAB
3. FreeFEM
4. Elmer FEM
5. NEC2

a. Other Software:

6. ANYSYS
7. COMSOL Multiphysics
8. MATLAB with PDE Toolbox
9. SolidWorks Simulation
10. EMTP (Electromagnetic Transients Program)
11. Altair Flux and SimLab

List of learning website/Standards/Resources:

1. IEEE Xplore Digital Library: https://ieeexplore.ieee.org
2. COMSOL Multiphysics Learning Center :https://www.comsol.com/learning-center
3. ANSYS Learning Hub: https://www.ansys.com/academic
4. Numerical Electromagnetics Code (NEC) Resources https://www.nec2.org
5. CST Studio Suite Resources https://www.3ds.com/products-services/simulia/products/cst-studio-suite/
6. EdX https://www.edx.org
7. Coursera https://www.coursera.org
8. MATLAB (MathWorks) https://www.mathworks.com
9. FEKO Software https://www.altair.com/feko/
10. EMPIRE XPU https://www.empire.de

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