GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Bachelor of Engineering
Level: UG
Branch: Electrical Engineering
Subject Code: BE04009021
Subject Name: Engineering Electromagnetics

w.e.f. Academic Year:	2024-25
Semester:	4
Category of the Course:	Basic Science Course

Prerequisite:	Basics of Electrical Engineering
Rationale:	This course introduces the foundational principles of electromagnetic fields and waves, essential for understanding modern electrical engineering systems like communication, power transmission, and electronic devices. It equips students with analytical and computational skills to solve real-world electromagnetic problems, bridging theory with applications in antennas, transmission lines, and wave propagation.

Course Outcome:

After Completion of the Course, Student will able to:

No	Course Outcomes
01	**Apply** vector calculus to analyze electric and potential fields generated by various charge distributions.
02	**Compute** electric potential, electric field intensity, electric flux density, and capacitance using analytical methods including Poisson's and Laplace's equations.
03	**Evaluate** magnetic field parameters, forces, and torques for different conductor configurations, and relate them to material properties and inductance.
04	**Analyze** time-varying electromagnetic fields, Maxwell's equations, and transmission line behavior for effective circuit and system design.
05	**Comprehend** various modern applications of Electromagnetics.

Teaching and Examination Scheme:

Teaching-Learning Scheme (in Hours per Semester)					Total Credits = TH/30	Assessment Pattern and Marks					Total Marks
						Theory		Tutorial / Practical			
L	T	P	PBL*	TH		ESE (E)	PA (M)	PA (I)	TW/SL (I)	ESE (V)	
45	0	30	15	90	3	70	30	20	30	50	200

Where L = Lecture, T= Tutorial, P= Practical, TW/SL = Term-Work / Self-Learning, TH = Total Hours, ESE = End-Semester Examination, PA = Progressive Assessment

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* **Problem Based Learning (PBL) aims to accommodate learning beyond syllabus as per clause 9.4 of NBA manual.**

Course Content:

Unit No.	Content	No. of Hours	%of Weightage
1.	**Vector Analysis**: Scalars and vectors, vector algebra, coordinate systems (Rectangular, Circular Cylindrical, Spherical), vector components and unit vectors, transformations between coordinate systems.	4	10
2.	**Static Electric Fields**: Coulomb's law, electric field intensity, field due to various charge distributions (point, line, surface, volume), electric flux density, Gauss's law and its applications, divergence, Maxwell's first equation, divergence theorem, electric potential, potential difference, potential gradient, electric dipole.	10	20
3.	**Conductors, Dielectrics and Capacitance**: Current and current density, Ohm's law in point form, continuity equation, boundary conditions (conductor–dielectric, dielectric–dielectric), polarization in dielectrics, capacitance of various configurations (e.g., parallel plate, two-wire line). Derivation and solution of Poisson's and Laplace's equations, uniqueness theorem.	7	15
4.	**Steady Magnetic Fields & Magnetic Forces**: Biot–Savart's law, Ampere's circuital law, curl, Stokes' theorem, magnetic flux and flux density, scalar and vector magnetic potentials, steady magnetic field produced by current-carrying conductors. **Magnetic Forces, Materials and Inductance:** Force on a moving charge, force on a differential current element, force between current elements, torque on a closed circuit, nature of magnetic materials, magnetization and permeability, magnetic boundary conditions, magnetic circuits, inductance and mutual inductances.	10	25
5.	**Time-Varying Fields and Maxwell's Equations**: Faraday's law, transformer and motional electromotive forces, displacement current, Maxwell's equations in integral and point forms. **Transmission Lines**: Physical description of transmission line propagation, transmission line equations, lossless propagation, sinusoidal voltage propagation.	7	15

6.	**Introduction to Modern Applications of Electromagnetics:** Layout of Electrostatic Discharge protected workstation, working of ink-jet printer, RF MEMS, Magnetic Levitation, Hall effect, Electromagnetic pump, Memristor, Concept of Optical Nano-Circuits.	7	15
	Total	**45**	**100**

Suggested Specification Table with Marks(Theory):

Distribution of Theory Marks					
R Level	**U Level**	**A Level**	**N Level**	**E Level**	**C Level**
20	20	25	20	15	0

WhereR:Remember;U:Understanding;A:Application,N:AnalyzeandE:EvaluateC:Create(asperRevisedBloom's Taxonomy)

References/Suggested Learning Resources:

(a) Books:

1. W. H. Hayt, J. A. Buck, "Engineering Electromagnetics", McGraw Hill Education.
2. M.N.O. Sadiku, S.V. Kulkarni, "Principles of Electromagnetics", Oxford University Press.
3. M. N. O. Sadiku, "Elements of Electromagnetics", Oxford University Publication.
4. A Pramanik, "Electromagnetism- Theory and Applications" PHI Learning Pvt. Ltd. , New Delhi.
5. S.P. Seth, "Elements of Electromagnetic fields", Dhanpat Rai & Co.
6. R.K. Shevgaonkar, Electromagnetic Waves, Tata McGraw Hill India.
7. Electromagnetics Fields and Waves Third Edition by Simon Ramo, John Whinnery Wiley India Edition.
8. Narayana Rao, N: Engineering Electromagnetics, Prentice Hall.

b) Open-Source Software:

1. **Scilab** (https://www.scilab.org/) – An open-source alternative to MATLAB, useful for circuit analysis, transformer calculations, and motor performance analysis.
2. **Octave** (https://www.gnu.org/software/octave/) – Useful for numerical calculations and simulation of electrical machines.
3. **FEMM (Finite Element Method Magnetics)** (http://www.femm.info/) – Used for electromagnetic field analysis of transformers and induction motors.

c) Websites for Learning and Simulation:

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1. **All About Circuits** (https://www.allaboutcircuits.com/) – Excellent resource for learning about transformers, motors, and electrical engineering concepts.
2. **Electrical4U** (https://www.electrical4u.com/) – Provides detailed explanations of electrical machines, transformers, and motor operation.
3. **MIT OpenCourseWare** (https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/) – Free courses on electrical machines and power electronics.
4. **CircuitLab (Free with limited access)** (https://www.circuitlab.com/) – Web-based circuit simulator for testing transformer and motor circuits.
5. **Virtual Labs by IITs (Government of India Initiative)** (https://vlab.co.in/) – Simulations and experiments related to transformers and induction motors.

Suggested Course Practical List (15 Experiments)

1. Solutions of problems based on Vector Analysis using MATLAB/Octave
2. Solution of problems on Electric field intensity for line charge and surface charge using MATLAB/Octave/VLAB
3. Solution of problems on Electric flux density using MATLAB/Octave/VLAB
4. Simulate electric field distribution using FEMM for given charge configurations.
5. Exercise based on potential and potential gradient using MATLAB/Octave/VLAB
6. Exercise based on current and current density using MATLAB/Octave
7. Examples based on Poisson's and Laplace's equation using MATLAB/Octave
8. Solve Laplace's equation numerically for a 2D geometry using Python.
9. Solve examples based on steady magnetic field using MATLAB/Octave
10. Measure magnetic flux density using Hall-effect sensors and compare with Biot-Savart predictions.
11. MATLAB/Octave exercise of plotting magnetic field
12. Analyze standing wave patterns on transmission lines with a VNA (Vector Network Analyzer

- **Suggested Activities for Problem Based Learning**

No.	Activity Name	Units Mapped	Hours	Brief Description	Evaluation Criteria	Link or Source
1	Field Line Visualization	Units 1 & 2	4 (2 + 2)	Use PhET or Falstad EM Field Simulator to visualize electric and magnetic field lines for various charge or current configurations.	Report with screenshots, interpretation of field patterns.	PhET Interactive Simulations, EM Field Simulator (falstad.com)

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2	Technical Video-Based Learning	Units 1 to 5	5	Watch curated educational videos explaining Gauss's Law, Ampere's Law, Faraday's Law, and Maxwell's Equations.	Reflection report + oral discussion.	Khan Academy, MIT OCW, The Engineering Mindset (YouTube)
3	Problem Solving / Coding	Units 1 to 4	6 (3 + 3)	Solve electromagnetic field problems using Python (NumPy, Matplotlib) or MATLAB/Scilab for plotting electric/magnetic field variations and wave propagation.	Code correctness, plots, explanation of results.	Jupyter Notebook, Google Colab, Scilab / Octave
4	Complex Problem Solving	Units 2 to 3	5	Attempt advanced textbook or research-level problems involving field superposition, boundary conditions, and EM wave propagation.	Solution method, analytical clarity, accuracy.	Advanced textbooks, research articles
5	Animation / Simulation Exploration	Units 4 & 5	4	Explore interactive physics simulations or GeoGebra 3D to visualize electromagnetic wave propagation,	Report with visuals + explanation of observed phenomena.	Interactive Physics, GeoGebra 3D Graphics

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				reflection, and interference.		
6	Research Paper Discussion	Units 3 to 6	3	Read and discuss introductory research papers on electromagnetics applications such as wireless charging, antennas, or EM shielding.	Presentation + technical understanding.	IEEE Xplore, ScienceDirect
7	Poster / PPT Preparation	Units 1 to 6	3	Prepare a digital poster or PowerPoint on key EM topics such as Maxwell's Equations, displacement current, or EM wave applications.	Clarity, design, and technical content.	Canva, PowerPoint, Prezi
8	Conceptual Model Building	Units 1 & 2	3	Develop simple physical or visual models (using cardboard, wires, magnets) to demonstrate EM field or induction concepts.	Creativity, model functionality, explanation.	DIY materials, craft supplies
9	Industrial Exposure (Virtual)	Units 4 to 6	3	Watch virtual tours or documentaries of industries applying electromagnetics (motors, MRI, communication). Summarize	Report + practical relevance discussion.	YouTube documentaries, virtual factory tours

				observations.		
10	Group Discussion (Technical Topics)	Units 2 to 6	2	Participate in discussions on the applications and limitations of electromagnetic laws in real-world systems (e.g., power lines, radar).	Depth of understanding, participation.	Collaborative document tools, group discussion platforms
11	Case Study Based Learning	Units 4 to 6	2	Analyze real-world cases involving EM effects (e.g., lightning protection, signal interference). Present findings with references.	Case analysis quality, interpretation, sources cited.	News reports, scientific articles, online forums

List of Laboratory Resources Required:

1. Vector Network Analyzer (VNA)
2. Helmholtz Coils, Hall Probes
3. Software: FEMM, ANSYS

- All suggested activities must be related to the course outcomes of Fundamentals of Electromagnetics, This is suggested list only, the faculty can create, alter his/her own list.
- You can create **rubrics** based on clarity, technical depth, creativity, and practical relevance.
- For internal assessment, faculty can **evaluate based on submitted reports, presentations, or reflections**.

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