The University Of Sheffield.

Electronic & Electrical Engineering.

EEE345 ENGINEERING ELECTROMAGNETICS

Credits: 10

Course Description including Aims

1. To develop an understanding of the physical behaviour of electric and magnetic fields.
2. To develop a mathematical basis for calculating fields in engineering applications.
3. To apply these ideas to solve practical problems in electronic and electrical engineering.

Outline Syllabus

Electrostatic fields Gauss's theorem, Laplace's equation, solution in simple geometries, Poisson's equation, numerical and analytical methods for calculating fields, application to pn junction diode and parallel plate capacitor.

Magnetostatic fields Ampère's law, Stokes' theorem, scalar and vector magnetic potentials, calculation of static fields.

Low frequency time-varying fields Faraday's law, diffusion equation, skin depth, 1-D eddy current in thick and thin plates, AC resistance.

Waves in 1D, reflection, decay, wave equation. Pulse propagation, speed, wavelength, forward and backward solutions.

Transmission lines: distributed impedance and admittance, wave equation in 1D, propagation constant, dispersion, characteristic impedance, lossless line, microstrip, power transmission, coaxial cable, reflection, standing waves, input impedance of terminated line.

Electric and magnetic fields in coax, plane waves.

TEM propagation, wavelength, speed, transverse nature, impedance of free space, energy density, resistive and radiative losses, Poynting's vector, radiated power, absorption length, eddy currents and optical fibres.

Electromagnetic waves in 3D, wavevector, wave equation in 3D, interface conditions, reflection and refraction of waves at dielectric and metallic interfaces, total internal reflection, basic introduction to optics, principles of waveguiding.

Time Allocation

24 lectures including two tutorials

Recommended Previous Courses

2nd year courses EEE223 Energy Management and Conversion and MAS241 Mathematics.

Assessment

2 hour examination, answering 3 out of 4 questions.

Recommended Books

Hammond, P.	*Electromagnetism for engineers*	Pergamon Press 1986
Cheng, D.K.	*Field and wave electromagnetics*	Addison-Wesley 1989
Demarest, K.R.	*Engineering Electromagnetics*	Prentice Hall, 1998
Hayt, W.H.	*Engineering Electromagnetics*	McGraw-Hill, 1989
Kalluri, D.K.	*Principles of Electromagnetic Waves and Materials*	CRC Press, 2013

Objectives

On completion of the module successful students will be able to

1. Perform a range of vector operations.
2. Select and apply appropriate techniques for calculating electrostatic or magnetic fields in a range of simple practical devices.
3. Identify and specify approximate models and boundary conditions for a range of devices.
4. Demonstrate familiarity with the ideas of pulse and wave propagation in 1D and 3D.
5. Appreciate the main features of electrical transmission lines and to be able to perform calculations on them.
6. Appreciate the principles of electromagnetic plane wave propagation and of reflection and refraction at dielectric and metallic interfaces.

Detailed Syllabus

Static and low frequency electromagnetics

1. Co-ordinate systems, vector quantities, basic vector operators - multiplication, integration.
2. Gauss's Law, application to the calculation of capacitance in a co-axial cable.
3. Gradient operator, divergence operator and Divergence Theorem, Laplacian operator, Laplace's equation, Poisson's equation.
4. Electrostatic field calculations, numerical vs analytical solution techniques.
5. Calculation of the electric fields in a parallel plate capacitor and a pn junction.
6. Magnetic fields, Ampère's law, curl operator.
7. Scalar and vector magnetic potentials, boundary conditions in magnetic field problems - infinite permeability sheet, superconducting sheets, symmetrical boundary conditions, boundary conditions for current sheets.
8. Method of variable separation, calculation of magnetostatic field distributions in MAGLEV track and in permanent magnet machines.
9. Time varying magnetic fields, diffusion equation, and displacement current.
10. 1-D eddy current flow in thick and thin plates.
11. AC resistance of a circular conductor.

Transmission line and Electromagnetic Waves

1. Introduction, course contents, books, waves and pulses $\Rightarrow$ wave equation, phasor notation, attenuation.
2. Transmission lines I, distributed C, L, R & G, derivation of wave equation, speed on lossless line, fixed frequency propagation, phasors, complex impedances, forward and backward waves.
3. Transmission lines II, attenuation, characteristic impedance Z_0, reflection coefficient, examples of T-lines.
4. C and L for coax, Z_0, v independent of geometry, TEM propagation.
5. Voltage standing wave ratio and mismatched loads.

6. Apparent impedance, matching, capacitive and inductive lines, tuning stubs.
7. Plane, parallel T-lines, C and L $\Rightarrow$ TEM waves, Z_0, v, sketched derivation from Maxwell's equations.
8. Stored and radiated power in electromagnetic waves, Poynting's vector, loss, absorption coefficient.
9. Skin depth, Radar Absorbent Materials, plane waves in a general direction, dielectric interface conditions on ***E***, ***D***, ***B*** and ***H***.

Basic Optics

1. Relationship between dielectric and optical properties of a material
2. Snell's law, Fresnel's equations for Reflection and Transmission, Brewster angle
3. anti-reflective coatings, including refractive index matching, $\lambda/4$ plates and interference coatings
4. Polarisation, electrostatic dipole and static dipole fields, electrodynamic dipole and characteristic radiation pattern

UK-SPEC/IET Learning Outcomes

Outcome Code	Supporting Statement
SM1p	Fundamental electromagnetic theory, such as Gauss's law, Ampere's Law, Faradays Induction Law, and all Maxwell's equations together. The governing principles for transmission line effects are reviewed and discussed in engineering context. Derivation of optical laws from electromagnetic theory. Assessed by exam
SM1m	Applications of the governing electromagnetic theory to solve engineering problems in electron devices, communication systems and electrical machinery and applied understanding of basic optical principles are the integral part of this course. Assessed by exam
SM2p/SM2m	Mathematic fundamentals that underpin the modern electromagnetism are reviewed and used to solve practical engineering electromagnetic problems analytically and numerically. This helps to develop student's mathematical and analytical skills. Assessed by exam
SM3p/SM3m	Static, low frequency and high frequency electromagnetic fields are all covered. This equips students with fundamental knowledge and tools for dealing with engineering problems in many electronic and electrical engineering disciplines. Assessed by exam
EA1p / EA1m	Maxwell's equations form the fundamental principle of all electronic and electrical engineering and applicationsto key engineering problems in electronics, electrical engineering, magnetics and optics are discussed.
EA2p	Analysis of and solutions to engineering problems are linked to performance indicators, such as eddy current loss in silicon steel and in solid conductors, transmission line characteristic impedance, skin depth and absorption coefficient, etc. Assessed by exam.
EA2m	The students will be enabled to describe the function and to evaluate the basic performance of components in various electric circuits and optical systems.
EA3p/EA3m	The principle of modern numerical tools for solving complex engineering electromagnetic problems is explained. Although the course does not provide practical training for these tools, many students use finite element tools/solvers for numerical analysis of electromagnetic fields as part of their third year projects.
D3m/D3p	Different types of anti-reflective coatings are discussed, and the students should be able to choose one or a combination of several of them to produce an appropriate design for a given problem.
ET2m/ET2p	The importance of transmission line optimisation for electricity suppliers, of optimal electronic signal transfer between integrated circuits in computers and of

anti-reflective coatings for suppliers of optical components will be highlighted in the appropriate context.