

Engineering Tripos Part IB, 2P5: Electromagnetic Fields and Waves, 2021-22

Course Leader

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Lecturer

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Timing and Structure

Weeks 6-8 Lent term. 6 lectures, 2 lectures/week

Aims

The aims of the course are to:

- To understand what a transmission line is, and how by analysing an equivalent circuit for a short length of the line allows us to understand wave propagation along the line.
- To understand the Maxwell Equations of Electric and Magnetic Fields which allow us to understand the propagation of electromagnetic waves through free space and how such waves interact with other conducting and insulating materials.
- To appreciate how we can engineer the propagation of waves in free space and along transmission lines with a focus on communications applications.

Objectives

As specific objectives, by the end of the course students should be able to:

- To be able to create and solve a wave equation for an ideal transmission line from an equivalent circuit and appreciate how this differs in a lossy transmission line.
- To understand the characteristic impedance of a transmission line, and be able to use this to solve problems involving reflection and transmission of waves along transmission lines.
- To understand the physical significance of the Maxwell Equations and how the differential (vector calculus) form can be produced from the integral form.
- To use the Maxwell Equations to produce a wave equation for the free-space propagation of electromagnetic waves and deduce their behaviour (e.g. direction of propagation relative to the E and H field, the Poynting vector).
- To understand the basic operation of antennas, how to calculate the field around a simple antenna and their figures of merit.
- To use the intrinsic impedance to understand how electromagnetic waves are reflected and transmitted at interfaces with dielectrics
- To understand how electromagnetic waves interact with conductors.

Content

Transmission Lines

- What is a transmission line?

- Ideal transmission line equivalent circuit
- The Telegrapher's Equations
- The wave equation solution to the Telegrapher's Equations
- Expressions for current and voltage waves
- Description of how waves propagate along transmission lines.
- Importance of the wavelength in considering whether wave effects on a line need to be considered
- The 'lossy' transmission line equivalent circuit and how this affects wave propagation
- Characteristic impedance
- Reflections from a load impedance
- Input impedance of a terminated line
- Ringing

The Maxwell Equations in Integral and Differential (Vector Calculus) Form

- The Gauss Law of Electric Fields
- The Gauss Law of Magnetic Fields
- The Faraday Law of Magnetic Fields
- The Ampère-Maxwell Law

Electromagnetic Waves in Dielectrics

- Derivation of wave equation for electric and magnetic fields from the Maxwell Equations
- Expressions for the electric and magnetic fields in plane electromagnetic waves
- Intrinsic impedance
- The power in an electromagnetic wave and the Poynting Vector

Antennas

- What is an antenna and a description of how they work
- How to calculate the field around a simple dipole antenna
- Figures of merit for antennas including the Antenna Gain, Radiation Resistance and Effective Area

Electromagnetic Waves at Interfaces

- Boundary conditions: the conservation of E, D, H and B at interfaces
- Polarised plane electromagnetic waves
- Reflection and refraction of plane waves
- Polarisation by reflection and the Brewster Angle
- Anti-reflection coatings

Electromagnetic Waves in Conducting Media

- Derivation of wave equation for electric and magnetic fields from the Maxwell Equations
- Expressions for the electric and magnetic fields in plane electromagnetic waves
- The Skin Effect
- Intrinsic impedance of a conducting medium
- Waves at conducting interfaces

Booklists

Please refer to the Booklist for Part IB Courses for references to this module, this can be found on the associated Moodle course.

Examination Guidelines

Please refer to [Form & conduct of the examinations](#) [2].

UK-SPEC

The [UK Standard for Professional Engineering Competence \(UK-SPEC\)](#) [3] describes the requirements that have to be met in order to become a Chartered Engineer, and gives examples of ways of doing this.

UK-SPEC is published by the Engineering Council on behalf of the UK engineering profession. The standard has been developed, and is regularly updated, by panels representing professional engineering institutions, employers and engineering educators. Of particular relevance here is the '[Accreditation of Higher Education Programmes](#)' (AHEP) document [4] which sets out the standard for degree accreditation.

The [Output Standards Matrices](#) [5] indicate where each of the Output Criteria as specified in the AHEP 3rd edition document is addressed within the Engineering and Manufacturing Engineering Triposes.

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Links

[1] <mailto:ajf23@cam.ac.uk>

[2] <http://teaching.eng.cam.ac.uk/content/form-conduct-examinations>

[3] <http://www.engc.org.uk/ukspec.aspx>

[4] <http://www.engc.org.uk/standards-guidance/standards/accreditation-of-higher-education-programmes-ahep/>

[5] <http://teaching.eng.cam.ac.uk/content/output-standards-matrices>