University of Glasgow | School of Physics & Astronomy

$$\nabla \cdot \vec{E} = \frac{\rho}{\epsilon_0}$$

$$\nabla \cdot \vec{B} = 0$$

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

$$\nabla \times \vec{B} = \mu_0 \vec{J} + \frac{1}{c^2}\frac{\partial \vec{E}}{\partial t}$$

# PHYS4004 Electromagnetic Theory 1

*Course Information Guide 2023-2024*

# 1 Course Details

| | | | |
|---|---|---|---|
| Lecturer: | Dr. Phillip Litchfield | Schedule: | 18 lectures, Mon. noon; Wed. noon |
| SCQF Credits: | 10 | ECTS Credits: | 5 |
| Assessment: | Examination (100%) | Co-requisites | None* |
| Level: | Honours | | |
| Typically Offered: | Semester 2 | Prerequisites: | Physics 2 |

* Note that the course uses vector calculus throughout, which is introduced in PHYS4011

## Course Aims

This course is compulsory for all third year BSc (Honours) and MSci students and is an elective for the designated degree programme in the School of Physics & Astronomy. The aim is to provide students with an opportunity to develop their knowledge and understanding of the key principles and applications of electromagnetic theory as well as its relevance to current developments in physics. In particular, the following topics will be covered:

- Revision of vector calculus, and the application of divergence and Stokes' theorems;
- Electrostatics;
- Magnetostatics;
- Magnetic materials;
- Electromagnetic induction;
- Maxwell's equations and their applications;
- Electromagnetic waves.

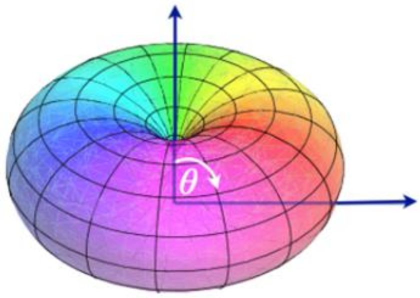



Figure 1: The energy flux dependancy on angular position of a dipole. Credit: Prof. Stephen Barnett, University of Glasgow

# 2 Intended Learning Outcomes

By the end of the course students should be able to:

- Demonstrate knowledge and a broad understanding of electromagnetic theory;
- Describe qualitatively and quantitatively process, relationships and techniques relevant to the topics included in the course outline, and apply these techniques to solve general classes of problems;
- Write down and, where appropriate, either prove or explain the underlying basis of physical laws relevant to the course topics, discussing their applications and appreciating their relation to the topics to the topics of other courses taken.

## 3 Course Outline

***Introduction***: Brief overview of course content; review of vector calculus plus divergence and Stokes' theorems as applied to electromagnetism.

***Electrostatics***: Electrostatic field relations as expressed in Coulomb's and Gauss' Laws; dielectric materials and polarisation, electric displacement, capacitance, boundaries; energy in the electric field.

***Magnetostatics***: Definition of magnetic induction, **B**, in terms of force on a current and the Biot-Savart law; continuity equation; Lorentz force law; magnetic potential; (revision of) Ampère's and Gauss' laws in integral and differential form with examples of their application to systems of simple geometry.

***Magnetic Materials***: Diamagnetism, paramagnetism, ferromagnetism; magnetic dipoles, torques and forces; magnetisation; modifications to Ampère's and Gauss' Laws in a medium (the **H** field); boundary conditions at interfaces; magnetic susceptibility; ferromagnetism and hysteresis.

***Electromagnetic Induction***: Field form of Faraday's law in integral and differential form; Ohm's law; Lenz's law; electromotive force (emf) and work; inductance; magnetic energy in linear magnetic materials.

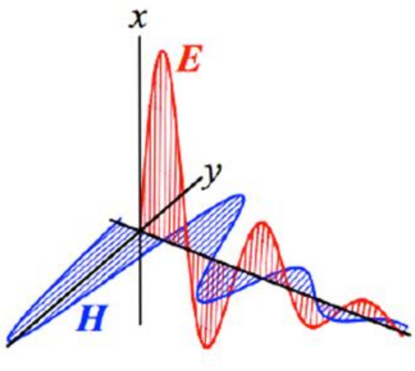
***Maxwell's Equations and applications***: Maxwell's contribution to EM theory (the Ampère-Maxwell law) for time-varying fields; Maxwell's equations in differential and integral form including time variation for special cases (static fields, quasi-static fields, free space).

***Electromagnetic Waves***: The wave equations for magnetic and electric fields B and E; plane wave solutions in vacuum (or dielectric); Poynting's theorem and the Poynting vector (energy density flow); Maxwell's equations in matter; reflection and transmission at interfaces (2D case); Fresnel's equations (normal incidence / 2D case).

## 4 Further Information

Further information can be found on the course Moodle page and at the links below:

- Course specification
- Reading list

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