PHY2021 Electromagnetism I
Module Introduction

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I. INTRODUCTION

The aim of this module is to introduce you to electrostatics and magnetostatics. These are the studies of charges at rest and steady currents. The electromagnetic force holds atoms, molecules and materials together and plays a vital role in most day-to-day physics one can observe. For example, TV remote controllers, microwave ovens, any electronic device, mobile phones, glasses and many other things all rely on electromagnetic phenomena to function. Interestingly, electromagnetism is arguably the most complete physical theory we have today, as it describes classical and quantum phenomena with equal effectiveness.

More recent research in electromagnetism has focused on how materials with novel electromagnetic properties can be designed and built. Some famous examples include invisibility cloaks [1] and perfect lenses [2]. Exeter University is a leader in this field, with it's metamaterials centre for doctoral training [3].

These tutorials are not part of the module assessment (problems solved here are not marked). Instead, the aim is to develop problem solving, understanding and intuition. Each week, questions supporting the lectures will be set. These should take approximately 1 hour. The problems will be mostly taken from exam questions, so that students get practice solving these kinds of problems, however some additional 'challenge' questions might be included if they illustrate something important or interesting. Solutions to tutorial problems will be discussed in tutorials (they will not be posted elsewhere).

II. OUTLINE

An outline of the module is as follows:

- **Week 1**: Introduction to Fields
- **Week 2**: Electrostatics
- **Week 3**: Gauss' Law
- **Week 4**: Electric Multipoles
- **Week 5**: Dielectrics, Polarisation and Energy of a Charge Distribution
- **Week 6**: Poisson and Laplace Equations
- **Week 7**: Magnetic field, force and torque
- **Week 8**: Magnetostatics, Magnetic Potentials
- **Week 9**: Faraday and Lenz Laws, Magnetic Properties of Matter
- **Week 10**: Maxwell's Equations
- **Week 11**: Electromagnetic Waves
- **Week 12**: Revision

In addition to this, there are 5 self-study packages

1. Vector analysis, electric fields and Gauss' Law
2. Capacitors
3. DC Electric Circuits
4. Practice Problems
5. Inductance, transformers and inductors

Tutorial problems will follow this pattern, to support lecture material. Depending upon student preferences, self-study material will also be discussed as this is an excellent chance for students to clarify any issues they have with self-study material.

III. USEFUL RESOURCES

The recommended course textbook is 'Introduction to Electrodynamics' by Griffiths [4]. This is an excellent introductory electromagnetism book.

Some other useful resources for this module are:

- The wikipedia pages for the gradient, divergence and curl operators in spherical coordinate systems [5] and for vector calculus identities [6] are extremely useful for reference. You should remember $\boldsymbol{\nabla}, \boldsymbol{\nabla}\cdot, \boldsymbol{\nabla}\times$ in Cartesian coordinates (and you probably will by the end of the module), however if you need them in spherical coordinates for an exam question they will be given.

- The Feynman Lectures (vol. 2 covers electromagnetism) [7]. These go far beyond the scope of the course, but do provide a wider context and interesting perspective.

- For mathematics (vector calculus etc.), Arfken and Weber [8] is very clear. It also has many exercises which link very strongly to electromagnetism.

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[1] Science **312** (5514): 1780–1782 (2006)

[2] Phys. Rev. Lett. **85** (18): 3996-3969 (2000)

[3] Exeter Metamaterials CDT (XM^2), `https://emps.exeter.ac.uk/metamaterials/`

[4] D. J. Griffiths, "Introduction to Electrodynamics" 4^{th} Ed. (Pearson, London, 2013)

[5] Del in cylindrical and spherical coordinates, `https://en.wikipedia.org/wiki/Del_in_cylindrical_and_spherical_coordinates`

[6] Vector calculus identities, `https://en.wikipedia.org/wiki/Vector_calculus_identities`

[7] The Feynman Lectures, `https://www.feynmanlectures.caltech.edu/`

[8] G. B. Arfken and H. J. Weber, "Mathematical Methods of Physicists" 6th Ed. (Elsevier Academic Press, London, 2005)