Electromagnetism section 0: Overview

This section contains some important information about the course itself

0.1 Lecturer details

Dr Vijay Tymms

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Blackett Laboratory (Physics) office 312

Office hours are **Tuesday 12 noon - 1pm and Thursday 12 noon - 1pm** for most of the term.

Professor Martin McCall

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Office hours to be confirmed

0.2 Lecture details

Timetable: No fixed timetable.

Duration: The course runs from week 4 to week 11 in the 2nd term.

Number of lectures: 24 lectures at 50 minutes each.

Sections: The course is split into 9 sections each of variable length

Division of labour: MM and VT are jointly and severally responsible for all the material in the course though VT has written the majority of the first half and MM the majority of the second. Lectures will also be VT for the first half and MM for the second, though we will make cameo appearances in each other's lectures.

Course notes: We supply notes at the start of our parts of the course. The course notes contain the essential information but you will be expected to add to them on occasions. After the lecture there will sometimes be minor modifications made to the notes. The modified notes will not be distributed but will appear on Blackboard and you will be notified of amendments.

Problem sheets: Non assessed problems are provided. They are designed to assist with your knowledge and understanding of the course and are to be completed in your own time and possibly in Academic Tutorials. They are split into three types: (1) discussion questions, (2) numerical questions and (3) problems. Answers and solutions to (2) and (3) will appear on Blackboard in the week the relevant section is completed in lectures, and will offer varying degrees of detail. Sometimes just a numerical answer and a hint will be proffered and sometimes a detailed worked solution. It is entirely up to you when you choose to use the solutions and how you use them. No solutions will be presented for discussion questions though these will often be discussed in the lectures.

Assessed problem sheets and tutorial discussion questions: Assessed problem sheets and tutorial discussion problems will be distributed in the final lecture of every week according to the first year schedule.

June Exam: The majority of the summative assessment for the course comes from the Electricity & Magnetism and Relativity exam on Wednesday 13th June

0.3 Learning outcomes

On completing the course students will:

1. understand the concept of charge, charge density, know that charge is quantised, conserved and appreciate the magnitudes of electric charges in most physical situations
2. use Coulomb's law for the force between charges and the principle of superposition for discrete and continuous arrangements of charges
3. know the definition of electric current and the ampere
4. have practical experience of charging by friction and induction
5. know and understand how to compute electric field strength and appreciate the magnitudes of field strengths in physical situations
6. know how to use and interpret field lines in electrostatics
7. perform calculations on electric dipoles and more complicate dipole-like situations
8. appreciate and know how to predict the behaviours of charges in conductors with and without an external field
9. state and explain the meaning of Gauss's law
10. prove Gauss's law for an arbitrary volume and arrangement of charges
11. know and recognise differential and integral forms of the law
12. know how to use Gauss's law to find the field strength due to symmetric charge distribution
13. appreciate how Gauss's law applies to gravitational fields in classical mechanics
14. understand and use the concepts of electric potential and electric potential difference

15. find the binding energy and potential due to a point charge
16. know how to sketch and use equipotential lines in electrostatic situations
17. appreciate and know how to use the idea of the electrostatic fields as a conservative field
18. define and use the concepts of capacitance and capacitors
19. calculate the capacitance of a general arrangement of conductors
20. find the energy stored and energy density in an arrangement of charged conductors
21. appreciate the role of dielectrics in capacitors
22. provide a qualitative explanation of the need for a displacement current
23. explain why current is a scalar but current density is a vector
24. derive the continuity equation for flow of charge and appreciate how it is a statement of the conservation of charge
25. derive Ohm's law as $\boldsymbol{J} = \sigma \boldsymbol{E}$
26. have a basic understanding of the origin of magnetism and properties of the magnetic field
27. know the magnetic equivalent of Gauss's law and the connection with magnetic monopoles (which may not exist)
28. know the basic Lorentz force law for a charge moving in electric and magnetic fields and be able to calculate the motion of a charged particle under these circumstances
29. understand how the Lorentz force underlies the Hall effect
30. know how to extend the Lorentz force to a current element
31. know and apply the Biot-Savart law to calculate the magnetic field in the presence of simple current configurations
32. understand Ampere's law and be able to use it to calculate the field
33. understand what is meant by a magnetic dipole
34. understand electromagnetic induction and Faraday's law
35. calculate the EMF induced in a simple circuit as the magnetic flux linking it changes
36. appreciate how electric and magnetic fields are modified in a material medium
37. understand the concepts of polarisation, electric displacement, dielectric constant and their relationship
38. have experience in diamagnetism, paramagnetism and ferromagnetism and have a qualitative understanding of what they are in terms of magnetic dipoles

There are five branches of physics that are the building blocks of the subject that every physicist must know. These are:

1) Classical mechanics
2) Special relativity
3) Electromagnetism
4) Quantum mechanics
5) Thermodynamics

Much of the first two years of the IC Physics degree is devoted to making sure you have a firm grounding in these five areas. This is the first of two core courses in electromagnetism you take. Several other compulsory and optional courses will enhance your understanding throughout the degree.

0.4 Assumed prior knowledge

All your A level mathematics and mathematics covered in term 1. Vector calculus is also used extensively.

A basic knowledge of high school physics, plus all physics met during the first term will be assumed.

0.5 Syllabus

Attendees of this course have come from a broad range of backgrounds and have covered a wide range of high school level syllabuses. This means that some of you will know a lot more electromagnetism than others already. This course will start from the beginning and become quite advanced by the end. This means that all students will find some of the course to be revision, but it will vary from person to person. No-one will find the whole of the course to be revision, and people's understanding of familiar concepts will be further enhanced by the course in all cases.

Section 1: Electric charge
Section 2: Electric fields
Section 3: Gauss's law
Section 4: Electrostatic energy
Section 5: Capacitance
Section 6: Current and Ohm's law
Section 7: Static magnetic fields
Section 8: Time varying magnetic fields
Section 9: Maxwell's equations

0.6 Recommended Textbooks

Essential

Sears and Zemansky's University Physics with Modern Physics, 12th Edition (2008), Young and Freedman (9780321501301) – ***the recommended text for all first year undergraduates. All students should have access to a copy.***

A drawback of this textbook is that it does not make proper use of vector calculus as we do. A benefit is the immense range of end-of-chapter problems.

Also useful

Introduction to Electrodynamics, David J. Griffiths, Pearson 2012

The Feynman Lectures on Physics, Volume 2 Feynman, Leighton and Sands, Addison Wesley 1964

Electricity and Magnetism, E.M. Purcell and D.J. Morin, Harvard University 2013

Electromagnetic Fields and Waves, P. Lorrain and D. Corson, W.H. Freeman and Co Ltd, 2nd revised edition 1970

0.7 Feedback for the lecturers

We strive to make this course as clear as professional and useful as possible and are always looking to improve all aspects of the course. To help us do this we listen to student feedback and, when appropriate, implement changes. There are two main formats for you to provide feedback:

1. Day to day feedback

If you have any comments on any aspect of the course, from spotting typos in the notes, to seeing things that aren't wrong but confusingly phrased, to some aspect of the lecturing style which maybe doesn't appeal, to spotting an example of a topic that you think it would be beneficial to include then let us know. The best way is by emailing (having to put something into words really helps clarify what one wants to ask) though speaking to us directly at Office Hours or after a lecture (not before please!) is fine as well.

2. Online “SOLE” Evaluation

After the course you will be invited to fill in a standard Imperial College online evaluation form with space for comments on the course. (Obviously any changes implemented as a result of this will get put in the following year but it is very helpful for us if you fill it in.)