Honours Advanced Electromagnetic Theory

COURSE OUTLINE

Electromagnetism is a core subject in physics that pervades almost all branches of physics. Therefore its mastery is very important for a career in physics, especially if you are considering doing a PhD. Honours AET builds on the Senior EM course and attempts to provide a mathematically more advanced treatment of the theory. The course is based mostly on the text: *Classical Electrodynamics*, by J. D. Jackson (in closed reserve at SciTech Library). Comprehensive lecture notes will be provided during the course via Blackboard.

The Details

| **Credit points** | 1 full Honours course |
| **Offered** | Semester 1 |
| **Assumed knowledge** | Senior Electromagnetism |
| **Classes** | 20 hours of lectures |
| **Assessment** | 4 assignments, and a 3-hour final exam |
| **Lecturer** | A/Prof. Serdar Kuyucak, School of Physics, room 438, Phone: 9036 5306, Email: serdar@physics.usyd.edu.au |

Unit of study goals

(a) To present an advanced formulation of the electromagnetic theory that emphasizes the unity of the electric and magnetic phenomena, culminating in Maxwell’s equations.

(b) To study the consequences of Maxwell’s equations in detail from creation of EM radiation to its propagation and interaction with matter.

(c) To develop mathematical techniques, such as partial differential equations and special functions, Green function, Fourier series and transform, and apply them to solution of diverse range of problems in electromagnetism.

Your learning commitments

Solving the assignment problems is an essential part of the course. As well as preparing you to the final exam, they count for 40% of the total mark. The time you spent on the assignments will depend on your problem solving skills. If you get stuck on a problem, it is OK to seek help from others (including the lecturer). However, this should be limited to getting general advice that will put you on the right track and should never extend to copying the whole solution. Such a practice is likely to result in a large discrepancy between the assignment and exam marks, and will have an adverse affect on your final mark (see also Academic Dishonesty/Plagiarism in Generic Details below).

Assignments and Assessment

Assessment will be based on a 3-hour open notebook final examination (60 marks) and four assignments (10 marks each). There will be one assignment at about every fortnight so you will have a fortnight to complete it. Assignments should be submitted to the Student Office on the due date by 5pm. Assignments submitted late without permission will incur a 10% penalty for each day they are late.
Lecture Content (weekly) and Specific Objectives

1. Electrostatics: Coulomb's law, concept of electric field, Gauss's law, electric potential, Poisson and Laplace equations, multipole expansion, electrostatic energy.  
   **Specific objectives:** Understand the basic concepts of electric field and potential, and how they can be obtained from integrals or differential equations; learn how to apply the multipole expansion to evaluate these quantities approximately.

2. Boundary value problems in electrostatics: Image charge method, Green function, solution of Laplace equation in rectangular and spherical coordinates.  
   **Specific objectives:** Use the series solution of PDE to solve the Laplace equation in rectangular and spherical coordinates; derive the Green function for a plane and spherical boundary from image charge solutions; use the Green function to solve boundary value problems in electrostatics.

3. Fields in macroscopic media: Polarizability and electric susceptibility, microscopic basis, field equations and electrostatic energy in dielectric media, boundary-value problems with dielectrics, numerical solutions for arbitrary geometries.  
   **Specific objectives:** Understand the microscopic basis of how electric fields and potentials are modified in media; use the boundary conditions to solve the Laplace equation at interfaces involving different media; obtain numerical solutions of the electric potential from the boundary equations.

4. Magnetostatics: Magnetic monopoles, Ampere's law, magnetic field and vector potential, multipole expansion, magnetic moment, torque on current distribution, boundary value problems in magnetostatics.  
   **Specific objectives:** Understand the concepts of the magnetic field and potential, and learn how to obtain them from integrals or differential equations; use the multipole expansion to obtain approximate expressions; apply boundary conditions to solve problems involving interfaces.

5. Time varying fields: Faraday's law, Maxwell equations, potential form, wave equations, Green function, energy in electromagnetic field, conservation of energy—Poynting's theorem, Maxwell stress tensor and conservation of momentum.  
   **Specific objectives:** Obtain the Maxwell equations; study their time dependent solutions in terms of potentials (wave equation); show that Maxwell's equations conserve energy, momentum and angular momentum; understand the role of Poynting vector and Maxwell's stress tensor in conservation laws.

6. Electromagnetic waves: Plane waves, states of polarization, reflection and refraction at a boundary, waves in dielectric and conducting media, superposition, dispersion relations.  
   **Specific objectives:** Solve the wave equation and study the behaviour waves at boundaries and various media, e.g., reflection and refraction at a boundary, dispersion in a dielectric media and dissipation in a conducting media.

   **Specific objectives:** Solve the Maxwell equations for simple radiating systems; obtain the solutions for a dipole and quadrupole radiator; solve the Maxwell equations for atoms in an EM field to discuss scattering and diffraction.

8. Special relativity and EM: Lorentz transformations, electromagnetic field tensor and covariance of Maxwell equations, field of moving charges.  
   **Specific objectives:** Apply the Lorentz transformations to EM fields and show that the theory is invariant; write the Maxwell equations in a covariant form using the EM field tensor; find the EM fields of charged particle in uniform motion from the Lorentz transformations.

9. Relativistic dynamics of particles and electromagnetic fields: Lagrangian and Hamiltonian for a charged particle in external EM field, motion in uniform static EM fields, Lagrangian and Hamiltonian for the EM field, covariant forms of the stress tensor and energy-momentum conservation.  
   **Specific objectives:** Solve the equations of motion for a relativistic charged particle in uniform EM fields; derive the Lagrangian and Hamiltonian for the EM field.

10. Radiation by moving charges: Lienard-Wiechert potentials, power radiated by an accelerated charge, extremely relativistic motion, Thomson scattering  
    **Specific objectives:** Derive the Lienard-Wiechert potentials for a relativistic particle in arbitrary motion; find the power radiated in the special cases of linear and circular acceleration (synchrotron radiation).
Generic Details for Honours Courses

Academic Dishonesty/Plagiarism
We will NOT accept assessments that are simply copied. Copying the work of another person without acknowledgment is plagiarism and contrary to University policies on Academic Dishonesty and Plagiarism (http://sydney.edu.au/ab/policies/Academic_Honesty_Cwk.pdf).

Academic Dishonesty means seeking to obtain or obtaining academic advantage (for example, in assessments) by dishonest or unfair means or knowingly assisting another student to do so. Academic Dishonesty includes, but is not limited to:

(a) recycling – that is, the resubmission for assessment of work that is the same, or substantially the same, as work previously submitted for assessment in the same or in a different unit of study (except in the case of legitimate resubmission with the approval of the examiner for purposes of improvement);
(b) fabrication of data;
(c) the engagement of another person to complete or contribute to an assessment or examination in place of the student, whether for payment or otherwise or accepting such an engagement from another student;
(d) communication, whether by speaking or some other means, to other candidates during an examination;
(e) bringing into an examination forbidden material such as textbooks, notes, calculators or computers;
(f) attempting to read other student’s work during an examination;
(g) writing an examination or test paper, or consulting with another person about the examination or test, outside the confines of the examination room without permission;
(h) copying from other students during examinations;
(i) Inappropriate use of electronic devices to access information during examinations.

Plagiarism means presenting another person’s work as one’s own work by presenting, copying or reproducing it without acknowledgement of the source. Plagiarism is a form of Academic Dishonesty, but is treated separately. Plagiarism includes presenting work for assessment, publication, or otherwise, that includes:

(a) phrases, clauses, sentences, paragraphs or longer extracts from published or unpublished work (including from the Internet) without acknowledgement of the source; or
(b) the work of another person, without acknowledgement of the source and presented in a way that exceeds the boundaries of legitimate cooperation.

Where to go for help
If you need help, as a first step you should ask the lecturer. For general help with Honours, please see the Honours Coordinator.

Providing us with feedback
We welcome comments on all aspects of this unit. You should feel free to contact the lecturer / honours coordinator at any time. There is also a formal opportunity for feedback at the Honours Staff-Student Liaison meeting.

Consideration of factors affecting your study
If your academic performance in a Science Faculty unit of study is adversely affected by illness or some other serious event, such as an accident, you should notify both:

- the Honours Co-ordinator
- the Faculty of Science Student Information Office (level 2 of the Carslaw building)
within 7 days after the period for which consideration is sought, by completing an Application for Special Consideration with accompanying documentation. This is especially important if you miss an examination.

If you have another reason for the Science Faculty to take account of your circumstances - religious commitments, legal commitments (e.g. Jury duty), elite sporting or cultural commitments (representing the University, state or country), or Australian Defence Force commitments (e.g. Army Reserve) - you should notify both:

- the Honours Co-ordinator
- the Faculty of Science Student Information Office (level 2 of the Carslaw building)
at least 7 days BEFORE the period for which consideration is sought, by completing an Application for Special Arrangements with accompanying documentation.

These two forms of Consideration should cover most allowable circumstances. However, if you have another reason for requiring the School of Physics to take account of your circumstances, you should notify the Honours Co-ordinator immediately.

You should not submit an application of any type if

- there is no assessment associated with a missed class, or
- you have a reasonable opportunity to make up any work you missed.

If, for example, you miss an assignment, an application for appropriate Consideration is required to allow late submission, but we do expect the assignment to be submitted. Sometimes catching up may be impossible, in which case we will consider a pro-rata adjustment of your marks on the basis of an application for Consideration.

Note: all applications for Special Consideration in Physics Honours are considered by a Special Considerations Committee at the end of your Honours year. We will not necessarily adjust your mark for a
specific Honours course (as such marks are not officially reported) but will take into account any application for special consideration in the assignment of a final Honours mark and grade.

Special Consideration or Special Arrangements
To submit an application for *Special Consideration* or *Special Arrangements* you should:

1. Obtain the appropriate Application pack from the Student Information Office of the Faculty of Science, the Faculty website at http://sydney.edu.au/science/cstudent/ug/forms.shtml, or the Physics Student Services Office.
2. Complete the forms and obtain whatever original documentary evidence is appropriate. Note especially that the Professional Practitioner's Certificate is essential for Special Consideration on grounds of serious illness - Medical Certificates will NOT be accepted.
3. Take the original copy of all forms and documents, plus sufficient copies for each unit of study affected and yourself, to the Faculty of Science Student Information Office (NOT any other Faculty Office if you are seeking Consideration in a unit taught by Physics). They will sign/stamp both the original application form and the copies. In the case of Physics units, one copy of the documentation must then be submitted to the Physics Student Services Office. Keep one copy yourself. A formal decision on your application will be sent to your *university email* address within 14 days.

Further details on University policy regarding Considerations can be found in policy documents entitled *Assessment and Examination* at the University Policy web site (http://sydney.edu.au/policy/).

Students unsure what type of Consideration is appropriate, or unhappy with a Consideration decision, should consult the Physics Student Services Office.

It is important to realise that the policies on *Special Consideration* apply throughout the University. However, actions in response to requests for Consideration may be specific to Physics and may be different in Departments responsible for your other units of study.