Nanyang Technological University
Division of Physics and Applied Physics

Academic Year	2018/19	**Semester**	2
Course Coordinator	Dr. Leek Meng Lee		
Course Code	PH4506		
Course Title	Electrodynamics		
Pre-requisites	PH2102		
No of AUs	4 AU		
Contact Hours	PH4506 (3 hr – lecture; 1 hr – tutorial)		
Proposal Date	01/2019		

Course Aims

This course aims to equip you with the knowledge to explain the dynamics of EM fields (hence called Electrodynamics), conclude the language of vector calculus and introduce the language of Lorentz covariant tensor calculus in Electrodynamics and elevate Electrodynamics to the level of variational principle known as "Classical Abelian Gauge Field Theory".

Intended Learning Outcomes (ILO)

Upon the successful completion of this course, you (as a student) would be **able to**:

Part 1: Basic Formalism of Electrodynamics
Conservation Laws (CL):

1. derive the integral and differential versions of the charge, energy and momentum continuity equations.

Potential Formulation of Electrodynamics (PFED):

2. derive the equations for the potential formulation of electrodynamics.
3. derive the allowed gauge transformations of the potentials.
4. use Coulomb gauge and Lorenz gauge on the potential equations.
5. solve the Lorenz-gauged equations by the Green's function method with suitable boundary conditions.
6. derive the physics of various cases (such as point charge with constant velocity, accelerating non-relativistic point charge and Hertzian dipole) from the potential equations.
7. define the differential cross section and total cross section of the Scattering of EM waves and determine for various basic cases (such as Thomson scattering and bound charge scattering).

Part 2: Lorentz Covariant Formulation
Special Relativity (SR):

8. derive the Lorentz transformations and its basic consequences.
9. operate with contravariant and covariant 4-vectors and construct Lorentz scalars, vectors and tensors.

Electrodynamics recast into a manifestly Lorentz covariant form (LCED):

10. recast electrodynamics (including all conservation equations and PFED section) into manifestly covariant form using 4-vectors and tensors.

Lagrangian description of a classical relativistic abelian gauge theory (LAGT):

11. derive the Lagrangian and the Hamiltonian for a relativistic charged particle interacting with EM fields, recast them into covariant form and deduce the consequences.
12. derive the Lagrangian and the Hamiltonian for the electromagnetic field and deduce the consequences (such as Noether's theorem).

Course Content

Part 1: Basic Formalism of Electrodynamics

Conservation Laws (CL)
Integral form of charge, energy and momentum continuity equations
Differential form of charge, energy and momentum continuity equations

Potential Formulation of Electrodynamics (PFED)
Potential Formulation of Electrodynamics
Gauge Transformations of the Potentials
Coulomb gauge and Lorenz gauge
Solutions by Green's Function Method
Physics of a Moving Point Charge, Low Velocity Accelerating Point Charge and a Hertzian dipole
Basic Scattering of EM waves
Scattering Differential Cross Section and Total Cross Section
Cases of Thomson Scattering and Bound Charge Scattering

Part 2: Lorentz Covariant Formulation

Special Relativity (SR)
Lorentz Transformations and Physical Implications
Contravariant and Covariant 4-Vectors
Construction of Lorentz Scalars, Vectors and Tensors

Electrodynamics recast into a manifestly Lorentz covariant form (LCED)
Covariant Form of the Expressions in PFED Section
Operating Lorentz Transformations
Conservation Equations in Covariant Form

Lagrangian description of a classical relativistic abelian gauge theory (LAGT)
Lagrangian & Hamiltonian for Relativistic Charged Particle interacting with EM fields
Consequences of Lagrangian & Hamiltonian for Relativistic Interactions
Covariant Form of the Lagrangian & Hamiltonian for Relativistic Interactions
Lagrangian & Hamiltonian for the EM field
Noether's Theorem

Assessment (includes both continuous and summative assessment)

Component	**Course LO Tested**	**Related Programme LO or Graduate Attributes**	**Weighting**	**Team / Individual**	**Assessment Rubrics**
1. Final Examination	All	Competency (1,3,4)	60%	Individual	Point-based marking (not rubric-based)
2. CA1: Classroom MCQs	All	Competency (1,3,4)	10%	Individual	Point-based marking (not rubric-based)
3. CA2: Homework	All	Competency (1,3,4)	10%	Individual	Point-based marking (not rubric-based)
4. CA3: Mid-term 1	**CL** 1, **PFED** 2-7	Competency (1,3,4)	10%	Individual	Point-based marking (not rubric-based)
5. CA4: Mid-term 2	**SR** 8-9, **LCED** 10 **LAGT** 11-12	Competency (1,3,4)	10%	Individual	Point-based marking (not rubric-based)
Total			100%		

http://www.ntu.edu.sg/tlpd/tlr/obtl/4/Pages/41.aspx

Formative feedback

Homework problems provide timely feedback on your understanding of the course. Midterms allow formative assessment, and feedback to you.

Learning and Teaching approach

Lectures and Tutorials provide the necessary content and practice of problem solving and discussion of conceptual understanding.

Reading and References

1. Introduction to Electrodynamics, 3rd Edition, David J. Griffiths, Prentice Hall (1999) ISBN 13: 9780138053260
2. Classical Electrodynamics, 3rd Edition, John David Jackson, John Wiley (1998) ISBN 13: 9780471309321
3. Classical Electrodynamics, 2nd Edition, Hans Ohanian, Jones & Bartlett Learning (2006) ISBN 13: 9780977858279

Course Policies and Student Responsibilities

Absence Due to Medical or Other Reasons

If you are sick and unable to attend your class / Mid-terms, you have to:

1. Send an email to the instructor regarding the absence and request for a replacement class and make-up mid-terms.
2. Submit the original Medical Certificate* or official letter of excuse to administrator.
3. Attend the assigned replacement class (*subject to availability*) and make-up mid-terms.

* The medical certificate mentioned above should be issued in Singapore by a medical practitioner registered with the Singapore Medical Association.

Academic Integrity

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values.

As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the academic integrity website for more information. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Course Instructors

Instructor	Office Location	Phone	Email
Dr. Leek Meng Lee	SPMS-PAP-05-01a	65927810	MLLeek@ntu.edu.sg

Planned Weekly Schedule

Week	Topic	Course LO	Readings/ Activities
1	Part 1: Basic Formalism of Electrodynamics	**CL** 1, **PFED** 2-7	Lecture notes, tutorial problems
2			
3			
4			
5	Topics in Week 1-4	Review and practice of problem-solving skills.	Midterm Test 1
6	Part 2: Lorentz Covariant Formulation	**SR** 8-9, **LCED** 10, **LAGT** 11-12	Lecture notes, tutorial problems
7			
8			
9			
10			
11			
12	Topics in Week 6-11	Review and practice of problem-solving skills.	Midterm Test 2
13	Revision and Recap	Part 1 and 2	

Graduate Attributes

What we want our graduates from Physics and Applied Physics to be able to do:

Upon the successful completion of the PHY, APHY and PHMA programs, graduates should be able to:

Competency	1	demonstrate a rigorous understanding of the core theories and principles of physics involving (but not limited to) areas such as classical mechanics, electromagnetism, thermal physics and quantum mechanics [PHMA only] demonstrate a rigorous understanding of the core theories and principles of mathematical sciences involving (but not limited to) areas such as analysis, algebra and statistical analysis
	2	read and understand undergraduate level physics content independently;
	3	make educated guesses / estimations of physical quantities in general;
	4	apply fundamental physics knowledge, logical reasoning, mathematical and computational skills to analyse, model and solve problems;
	5	develop theoretical descriptions of physical phenomena with an understanding of the underlying assumptions and limitations;
	6	critically evaluate and distinguish sources of scientific/non-scientific information and to recommend appropriate decisions and choices when needed;
	7	demonstrate the ability to design and conduct experiments in a Physics laboratory, to make measurements, analyse and interpret data to draw valid conclusions.

Creativity	1	propose valid approaches to tackle open-ended problems in unexplored domains;
	2	offer valid alternative perspectives/approaches to a given situation or problem.

Communication	1	describe physical phenomena with scientifically sound principles;
	2	communicate (in writing and speaking) scientific and non-scientific ideas effectively to professional scientists and to the general public;
	3	communicate effectively with team members when working in a group.

Character	1	uphold absolute integrity when conducting scientific experiments, reporting and using the scientific results;
	2	readily pick up new skills, particularly technology related ones, to tackle new problems;
	3	contribute as a valued team member when working in a group.

Civic Mindedness	1	put together the skills and knowledge into their work in an effective, responsible and ethical manner for the benefits of society.