Nanyang Technological University
Division of Physics and Applied Physics

COURSE CONTENT FOR PH7006 for Undergraduates

Academic Year	2022/23	**Semester**	1
Course Coordinator	Prof. Zhang Baile		
Course Code	PH7006 (previously listed as PAP716)		
Course Title	Classical Electrodynamics		
Pre-requisites	PH2102 Electromagnetism or equivalent and PHY (PPHY) or PHY (APHY) programme and CGPA 4.0 or higher		
No of AUs	4		
Contact Hours	Lectures: 39, Tutorial: 12 (3 hr – lecture each week; 1 hr – tutorial each week)		
Proposal Date	February 2022		

Course Aims

This course aims to equip you with a unified macroscopic theory of the dynamics of classical electromagnetic waves (hence called Classical Electrodynamics), in accordance with the form invariance of the Maxwell equations and the constitutive relations. Great emphasis is placed on the fundamental importance of the k vector in electromagnetic wave theory.

Intended Learning Outcomes (ILO)

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

Fundamentals:

1. Derive the wave equation of wave solution from Maxwell's equations.
2. Explain the importance of k vector.
3. Judge the polarization and construct different polarizations.
4. Explain the basics of radiation from Hertzian dipoles.
5. Master the application of boundary conditions.

Media:

6. Explain the complex notation of time-harmonic fields.
7. Master a general understanding of constitutive matrixes.
8. Solve electromagnetic waves in different media.
9. Apply kDB system for waves in anisotropic and bianisotropic media.

Reflection and Guidance:

10. Derive the reflection and refraction of electromagnetic waves at an interface between two media.
11. Explain the total internal reflection, negative refraction, and plasmonic waves.
12. Derive guidance condition for planar and rectangular waveguides.
13. Explain basics of cavity resonance.

Radiation:

14. Master the use of dyadic Green's functions.
15. Derive Cerenkov radiation.
16. Derive Hertzian dipole radiation.
17. Analyse and construct radiation patterns of dipole arrays.

Theorems:

18. Explain the uniqueness theorem.
19. Apply the equivalence principle and explain various equivalent sources.
20. Explain duality and complementarity.
21. Derive Fresnel and Fraunhofer diffraction equations based on Huygens' principle.
22. Explain reaction and reciprocity.

Relativity:

23. Derive Lorentz transformation of field vectors.
24. Classify electromagnetic fields based on Lorentz invariants.
25. Explain basics of electromagnetic waves in moving media.
26. Apply the tensor form of Maxwell's equations to derive conservation laws and individual Maxwell's equations.

Course Content

Fundamentals:
Wave equation from Maxwell's equations.
Spatial frequency k vector.
Polarization
Hertzian waves
Poynting vector
Constitutive relations
Boundary conditions

Media:
Time-harmonic fields and their complex notation
Time-averaged Poynting power
Waves in plasma media
Anisotropic media and bianisotropic media
kDB system

Reflection and Guidance:
Reflection and refraction of TM waves
Reflection and refraction of TE waves
Phase matching
Total internal reflection and Brewster angle
Negative refraction
Backward waves
Guided waves in conducting parallel plates
Guided waves in a rectangular waveguide
Guided waves in a cylindrical waveguide
Cavity resonance

Radiation:
Cerenkov radiation
Dyadic Green's functions
Electric and magnetic Hertzian dipoles
Linear dipole arrays

Theorems:
Equivalence principle
Uniqueness theorem
Duality and complementarity
Huygens' principle
Fresnel and Fraunhofer diffraction

Relativity:
Lorentz transformation of space and time
Lorentz transformation of field vectors
Lorentz invariants
Classification of electromagnetic fields
Electromagnetic waves in moving media
Tensor form of Maxwell's equations

Assessment (includes both continuous and summative assessment)

Component	Course LO Tested	Related Programme LO or Graduate Attributes	Weighting	Team / Individual	Assessment Rubrics
1. CA1: Homework	All	Competency (1-6) Communication (2)	25%	Individual	Point-based marking (not rubric-based)
2. CA2: Mid-term Test 1	Fundamentals, Media	Competency (1-6) Communication (2)	25%	Individual	Point-based marking (not rubric-based)
3. CA3: Mid-term Test 2	Reflection and Guidance, Radiation	Competency (1-6) Communication (2)	25%	Individual	Point-based marking (not rubric-based)
4. CA4: Mid-term Test 3	Theorems, Relativity	Competency (1-6) Communication (2)	25%	Individual	Point-based marking (not rubric-based)
Total			100%		

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. Electromagnetic Wave Theory, Jin Au Kong, EMW Publishing (2008) ISBN 0-9668143-9-8

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
Prof. Zhang Baile	SPMS-PAP-05-06	6592 1653	blzhang@ntu.edu.sg

Planned Weekly Schedule

Week	Topic	Course LO	Readings/ Activities
1	Maxwell's equations; Constitutive relations; Poynting vector	Fundamentals: 1-5	Lectures, Tutorials
2	Plane wave solutions; Phase velocity and group velocity; kDB system	Media: 6-7	
3	Plane waves in uniaxial media	Media: 8-9	
4	Plane waves in gyrotropic and bianisotropic media	Media: 8-9	
5	Phase matching; Reflection and transmission at a plane boundary; Midterm I	Reflection and Guidance: 10-11	Lectures, Midterm test
6	Reflection and transmission by a layered medium; Guidance by conducting parallel plates	Reflection and Guidance: 12	Lectures, Tutorials
7	Rectangular waveguide and cylindrical waveguide;	Reflection and Guidance: 12-13	
8	Cerenkov radiation; Dyadic Green's functions	Radiation: 14-15	
9	Hertzian electric dipole; Hertzian magnetic dipole; Antenna array; Midterm II	Radiation: 16-17	Lectures, Midterm test
10	Equivalence principle; Extinction theory	Theorems: 18-19	
11	Duality and complementarity; Reaction and reciprocity	Theorems: 20-22	
12	Relativity and Lorentz transformation	Relativity: 23-25	
13	Lorentz covariant formulation; Midterm III	Relativity: 26	Lectures, Midterm test

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, PHME and PHMS 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 [PHMS 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.