GE REVISED COURSE CONTENT

Academic Year	2022/2023	**Semester**	2
School/Programme	SPMS		
Course Coordinator	Prof Zhang Baile		
Course Code	PH7006		
Course Title	Classical Electrodynamics		
Pre-requisites	For graduate students: No pre-requisites For undergraduates: PH2102 Electromagnetism or equivalent		
No of AUs	4		
Contact Hours	52 contact hours (3 hours lecture each week; 1 hour tutorial each week)		
Proposal Date ***i.e. date proposal was drafted***	April 2023		
Expected Implementation date of new/revised course	August 2023		
Suggested Class Size	30		
Any cross-listing? ***Is course opened to all Postgraduate students (including IGP) or specific program (please indicate)?***	Yes, SPMS Master by Research		

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 important of the k vector in electromagnetic wave theory.

Intended Learning Outcomes (ILO)

By the end of this course, you should be able to:

Fundamentals:

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

Media:

6. Understand 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. Understand the total internal reflection, negative refraction, and plasmonic waves.
12. Derive guidance condition for planar and rectangular waveguides.
13. Understand 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. Understand the uniqueness theorem.
19. Apply the equivalence principle and understand various equivalent sources.
20. Understand duality and complementarity.
21. Derive Fresnel and Fraunhofer diffraction based on Huygens' principle.
22. Understand reaction and reciprocity.

Relativity:

23. Derive Lorentz transformation of field vectors.
24. Classify electromagnetic fields based on Lorentz invariants.
25. Understand basics of electromagnetic waves in moving media.
26. Apply the tensor form of 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)

Note: It is advised that Group component and class participation should not be more than 40% and 20% respectively, unless with good justification.

Component	ILO Tested	Weighting	Team/ Individual	Assessment Rubrics
1. Homework	All	25%	Individual	N/A
2. Mid-term Test 1	Fundamentals, Media	25%	Individual	N/A
3. Mid-term Test 2	Reflection and Guidance, Radiation	25%	Individual	N/A
4. Mid-term Test 3	Theorems, Relativity	25%	Individual	N/A
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

Note: Please include and indicate TEL component.

Approach	**How does this approach support you in achieving the learning outcomes?**
Lecture	You will be introduced to the fundamental concepts and ways of thinking in electrodynamics via the lectures. Lectures will be used to provide the necessary content and discussion of conceptual understanding.
Tutorial	Tutorials will provide opportunities for detailed discussion and practice of problem solving with the theoretical framework of electrodynamics.
Technology-enhanced Learning (TEL)	Lectures will have videos and cartoons to illustrate the concepts of electromagnetic wave propagation, polarization, wave guiding, et al.

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

Industry Participation

Company Name	Description of involvement (e.g., co-curation of course, speaker or instructor), include no. of course hours if known.	Contact Person	Email
Nil			

This course is fundamentally intensive, training students to have in-depth conceptual and theoretical analysis. Though no industry participation, authentic learning is provided through real-life videos and animation illustrations.

Planned Weekly Schedule

Week	Topic	ILO	Readings/ Activities
1	Maxwell's equations; Constitutive relations; Poynting vector	Fundamentals: 1-5	Lecture, Tutorial
2	Plane wave solutions; Phase velocity and group velocity; kDB system	Media: 6-7	Lecture, Tutorial
3	Plane waves in uniaxial media	Media: 8-9	Lecture, Tutorial
4	Plane waves in gyrotropic and bianisotropic media	Media: 8-9	Lecture, Tutorial
5	Phase matching; Reflection and transmission at a plane boundary	Reflection and Guidance: 10-11	Lecture, Midterm Test 1
6	Reflection and transmission by a layered medium; Guidance by conducting parallel plates	Reflection and Guidance: 12	Lecture, Tutorial

7	Rectangular waveguide and cylindrical waveguide;	Reflection and Guidance: 12-13	Lecture, Tutorial
8	Cerenkov radiation; Dyadic Green's functions	Radiation: 14-15	Lecture, Tutorial
9	Hertzian electric dipole; Hertzian magnetic dipole; Antenna array	Radiation: 16-17	Lecture, Midterm Test 2
10	Equivalence principle; Extinction theory	Theorems: 18-19	Lecture, Tutorial
11	Duality and complementarity; Reaction and reciprocity	Theorems: 20-22	Lecture, Tutorial
12	Relativity and Lorentz transformation	Relativity: 23-25	Lecture, Tutorial
13	Lorentz covariant formulation	Relativity: 26	Lectures, Midterm Test 3

Other information(s)

Nil