

Annexe A: New/Revised Course Content in OBTL+ Format

Course Overview

Expected Implementation in Academic Year (New format)	AY2026-2027
Semester/Trimester/Others (specify approx. Start/End date)	Semester 1
Course Author * Faculty proposing/revising the course	Kyungtak Lim
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Course Title	Electromagnetism
Course Code	PH2102
Academic Units	4
Contact Hours	52
Research Experience Components	Not Applicable

Course Requisites (if applicable)

Pre-requisites	(MH1802 and MH1803 and PH1106) OR (MH1802 and CM1804 and PH1106) OR (CY1601 and CY1602 and CY1308) OR (MH1101 and PH1106)
Co-requisites	
Pre-requisite to	
Mutually exclusive to	
Replacement course to	
Remarks (if any)	

Course Aims

This course introduces the fundamental laws of electromagnetism and their application to physical systems. Students will learn how electric and magnetic fields are generated by charges and currents, how these fields evolve in time, and how electromagnetic energy is transported. Emphasis is placed on developing clear physical intuition together with standard mathematical tools, including vector calculus and differential equations, to analyse fields, potentials, and boundary-value problems. The course prepares students for more advanced study in areas such as optics and photonics, plasma physics, and fluid dynamics, as well as for upper-level theoretical physics modules.

Course's Intended Learning Outcomes (ILOs)

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

ILO 1	Use vector calculus (gradient, divergence, curl) and integral theorems (Gauss' and Stokes') in Cartesian, cylindrical, and spherical coordinates to analyse electromagnetic fields.
ILO 2	Translate between integral and differential descriptions of fields, including interpreting flux, circulation, and local source terms.
ILO 3	Determine electrostatic fields and potentials produced by discrete and continuous charge distributions using symmetry, superposition, and direct integration.
ILO 4	Apply Gauss's law to solve electrostatic problems and to reason about conductors in electrostatic equilibrium (shielding, surface charge, boundary behaviour).
ILO 5	Compute electric potential and electric field relationships, including potential differences, reference choices, and the connection to conservative fields.
ILO 6	Analyse electrostatic energy storage and forces, including energy density and capacitance for standard geometries.
ILO 7	Formulate and solve electrostatic boundary-value problems using Poisson's/Laplace's equation with appropriate boundary conditions and physical interpretation.
ILO 8	Apply standard solution techniques for boundary-value problems, including separation of variables and Fourier/Legendre expansions in canonical geometries.
ILO 9	Use the method of images to solve selected conductor/dielectric interface problems and interpret the resulting fields and induced charges.
ILO 10	Use multipole expansions to approximate potentials/fields in the far field and identify leading contributions (monopole/dipole/quadrupole level as appropriate).
ILO 11	Analyse electric fields in matter: relate polarization and bound charge to macroscopic fields, and apply Gauss's law for electric displacement D in dielectrics.
ILO 12	Apply boundary conditions at dielectric interfaces to determine fields, polarization charge, and energy storage in linear media.
ILO 13	Determine magnetic fields from steady currents using Biot-Savart law and Ampère's law, and evaluate forces/torques in basic magnetostatic configurations.
ILO 14	Use the magnetic vector potential to compute magnetic fields in appropriate geometries and explain the physical meaning and gauge freedom at a basic level.
ILO 15	Analyse magnetic fields in matter: relate magnetization to bound currents and apply the B-H framework and boundary conditions in magnetic media.
ILO 16	Apply Faraday's law and Lenz's law to solve electromagnetic induction problems, including motional emf and simple inductive systems.
ILO 17	Explain the structure and physical content of Maxwell's equations (integral and differential forms) and use them to reason about time-varying fields and conservation laws.
ILO 18	

	Derive the electromagnetic wave equation from Maxwell's equations and analyse plane-wave solutions (polarization, wave impedance, and energy transport via the Poynting vector).
ILO 19	Apply electromagnetic boundary conditions to analyse wave behaviour at interfaces (reflection/transmission at least at normal incidence).
ILO 20	Analyse guided electromagnetic waves in waveguides, including mode classification (TE/TM), cutoff frequency, dispersion, and basic field structure in a rectangular waveguide.

Course Content

Basic mathematical tools (BAS)

- Vector calculus for fields: gradient, divergence, curl
- Line/surface/volume integrals; Gauss' and Stokes' theorems
- Cartesian/cylindrical/spherical coordinates; separation-of-variables toolkit for EM problems

Electrostatics (ES)

- Coulomb's law; fields of continuous charge distributions
- Gauss's law and symmetry methods
- Conductors in electrostatic equilibrium: shielding, surface charge, boundary behaviour
- Electric potential V : relation to E , reference choices, potential energy

Electrostatic boundary-value problems (BVP)

- Poisson's and Laplace's equations; physical boundary conditions
- Uniqueness idea and implications for solutions
- Standard solution methods: separation of variables and method of images
- Multipole expansion: dipole moment and far-field approximations

Electric fields in matter (DM)

- Polarization, bound charge, and the displacement field D
- Linear dielectrics; interfaces and boundary conditions
- Energy storage in dielectric media

Magnetostatics (MS)

- Lorentz force (static fields) and basic applications
- Biot–Savart law and Ampère's law; magnetic flux and field lines
- Magnetic dipoles; torque and energy
- Vector potential A and its use in magnetostatic problems

Magnetic fields in matter (MM)

- Magnetization, bound currents, and the auxiliary field H $\mathbf{H}$
- Boundary conditions in magnetic media; permeability and susceptibility
- Qualitative distinction between dia-, para-, and ferromagnetism

Time-varying fields and Maxwell's equations (TD)

- Faraday's law, Lenz's law, induction; motional emf and inductance concepts
- Charge conservation and the continuity equation
- Maxwell's equations in integral and differential forms; displacement current

Electromagnetic waves and guided waves (EMW/WG)

- Electromagnetic wave equation; plane-wave solutions and polarization
- Energy and momentum transport: Poynting vector and radiation pressure (intro)
- Wave behaviour at boundaries (reflection/transmission at least at normal incidence)
- Guided waves in waveguides: TE/TM mode concept, cutoff frequency, dispersion, rectangular waveguide overview

Reading and References (if applicable)

1. David J. Griffiths "*Introduction to Electrodynamics*", Cambridge University Press, 5th ed. (2023). ISBN 9781009397759
2. Fleisch, D. A. "*Student's Guide to Maxwell's Equations*", Cambridge University Press. (2008). ISBN 978-0521701471
3. John David Jackson "*Classical Electrodynamics*", Wiley, 3rd ed. (1998). ISBN 978-0471309321

Planned Schedule

Week or Session	Topics or Themes	ILO	Delivery Mode	Activities	Readings
1	Vector calculus for EM	1, 2	In-person	Lecture, tutorial, and in-class quiz	Textbook and lecture notes
2	Electrostatics I: fields from charges	3	In-person	Lecture, tutorial, and in-class quiz	Textbook and lecture notes
3	Electrostatics II: Gauss's law and conductors	4	In-person	Lecture, tutorial, and in-class quiz	Textbook and lecture notes
4	Electric potential, energy, and capacitance	5, 6	In-person	Lecture, tutorial, and in-class quiz	Textbook and lecture notes
5	Boundary-Value Problems I : Laplace/Poisson	7, 8	In-person	Lecture, tutorial, and in-class quiz	Textbook and lecture notes
6	Boundary-Value Problems II: Images & Multipoles	9, 10	In-person	Lecture, tutorial, and in-class quiz	Textbook and lecture notes
7	Electric Fields in Matter	11, 12	In-person	Lecture, tutorial, in-class quiz and Midterm exam	
8	Magnetostatics	13, 14	In-person	Lecture, tutorial, and in-class quiz	Textbook and lecture notes
9	Magnetic fields in matter	15	In-person	Lecture, tutorial, and in-class quiz	Textbook and lecture notes
10	Electrodynamics	16	In-person	Lecture, tutorial, and in-class quiz	
11	Maxwell's Equations	17	In-person	Lecture, tutorial, and in-class quiz	Textbook and lecture notes
12	Electromagnetic waves	18	In-person	Lecture, tutorial, and in-class quiz	Textbook and lecture notes
13	Waveguides	19, 20	In-person	Lecture, tutorial, and in-class quiz	Textbook and lecture notes

Learning and Teaching Approach

Approach	How does this approach support you in achieving the learning outcomes?
Lectures	Lectures introduce the key concepts and methods in electromagnetism, supported by worked examples to build physical intuition and problem-solving skills.
Tutorial	Tutorials reinforce lecture content through guided problem solving and discussion with TAs, with timely feedback on common errors and solution strategies.
Homework	Homework provides regular independent practice on core techniques and applications, with feedback to support formative learning and exam preparation.
Wooclap	Wooclap is used for quick in-class concept checks to promote active learning and give immediate feedback to both students and the instructor.

Assessment Structure

Assessment Components (includes both continuous and summative assessment)

No.	Component	ILO	Related PLO or Accreditation	Weightage	Description of Assessment Component	Team/Individual	Rubrics	Level of Understanding
1	Summative Assessment (EXAM): Final exam(Final Examination)	All		50	A comprehensive examination assessing conceptual understanding and problem-solving ability across the full electromagnetism syllabus.	Individual	Analytic	Relational
2	Continuous Assessment (CA): Assignment(Homework 1)	1-4		10	A problem set on early-course topics assessing correct methods, reasoning, and clear presentation of solutions.	Individual	Analytic	Extended Abstract
3	Continuous Assessment (CA): Test/Quiz(Midterm Test)	1-7		25	An in-class test on first-half material evaluating your understanding and ability to solve standard electromagnetism problems systematically.	Individual	Analytic	Relational
4	Continuous Assessment (CA): Assignment(Homework 2)	8-12		10	A problem set on later-course topics assessing application of concepts and solution quality.	Individual	Analytic	Extended Abstract

No.	Component	ILO	Related PLO or Accreditation	Weightage	Description of Assessment Component	Team/Individual	Rubrics	Level of Understanding
5	Continuous Assessment (CA): Class Participation()			5	Marks are awarded for consistent participation in in-class Wooclap concept checks, which provide immediate feedback and reinforce learning. Full marks are awarded for participation in at least 9 of the 13 Wooclap sessions.	Individual	Analytic	Extended Abstract

Description of Assessment Components (if applicable)

*You would be expected to synthesise the physics concepts learnt in the course to propose scientifically valid approaches to given situations or problems.

Formative Feedback

Formative feedback is provided throughout the course in several ways. Each week, you receive feedback on your problem-solving approach through tutorial discussions and marked assignments, including comments on common conceptual and mathematical errors. The teaching team also holds weekly TA meetings to review your progress and adjust the lecture pace and tutorial difficulty where needed.

During lectures, in-class Wooclap/clicker questions provide immediate feedback on your understanding and help identify misconceptions early. The midterm serves as a structured checkpoint of learning; after the test, you receive feedback on overall performance, common mistakes, and the expected standard for solutions. Past exam questions and examiner's reports are also provided to guide preparation. You are encouraged to approach the instructor or TAs proactively during consultations or after class if you would like individual feedback.

NTU Graduate Attributes/Competency Mapping

This course intends to develop the following graduate attributes and competencies (maximum 5 most relevant)

Attributes/Competency	Level
Adaptability	Intermediate
Creative Thinking	Intermediate
Curiosity	Basic
Problem Solving	Intermediate
Sense Making	Advanced

Course Policy

Policy (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. On the use of technological tools (such as Generative AI tools), different courses / assignments have different intended learning outcomes. Students should refer to the specific assignment instructions on their use and requirements and/or consult your instructors on how you can use these tools to help your learning. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Policy (General)

You are expected to attend all lectures punctually and take all scheduled assignments and tests by due dates. You are expected to take responsibility to follow up with course notes, assignments and course related announcements for lectures you have missed. You are expected to participate in all tutorial sessions.

Policy (Absenteeism)

Absence Due to Medical or Other Reasons

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

Send an email to the instructor regarding the absence and request for a replacement class and make-up mid-terms.

Submit the Medical Certificate* or official letter of excuse to administrator.

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.

Policy (Others, if applicable)

Diversity and inclusion policy

Integrating a diverse set of experiences is important for a more comprehensive understanding of science.

It is our goal to create an inclusive and collaborative learning environment that supports a diversity of perspectives and learning experiences, and that honours your identities; including ethnicity, gender, socioeconomic status, sexual orientation, religion or ability.

To help accomplish this:

- If you are neuroatypical or neurodiverse, have dyslexia or ADHD (for example), or have a social anxiety disorder or social phobia;
- If you feel like your performance in the class is being impacted by your experiences outside of class;

- If something was said in class (by anyone, including the instructor) that made you feel uncomfortable;

Please speak to your teaching team, our school pastoral officer or a peer or senior (either in-person or via email) about how we can help facilitate your learning experience.

As a participant in course discussions, you should also strive to honour the diversity of your classmates. You can do this by: using preferred pronouns and names; being respectful of others opinions and actively making sure all voices are being heard; and refraining from the use of derogatory or demeaning speech or actions.

All members of the class are expected to adhere to the NTU anti-harassment policy. if you witness something that goes against this or have any other concerns, please speak to your instructors or a faculty member.

Technical Skills To Be Developed

All skills to be developed for this course:

PH2102 Electromagnetism — Assessment Rubrics

This document provides the assessment rubrics for PH2102, aligned with the assessment components and weightages in the CMA system.

1) Summative Assessment (EXAM): Final Exam (Final Examination) — 50%

A comprehensive examination assessing conceptual understanding and problem-solving ability across the full electromagnetism syllabus.

Criterion	Excellent	Good	Satisfactory	Limited
Conceptual understanding	Correct concepts consistently applied; demonstrates strong understanding	Mostly correct; minor misconceptions	Basic understanding but uneven	Major misconceptions / inappropriate concepts
Problem-solving process	Systematic, well-structured solutions; appropriate method selection	Mostly systematic; small gaps	Partially structured; steps not well connected	Disorganised; incorrect strategy
Mathematical accuracy	Correct derivations and final answers; correct units	Minor slips	Multiple errors affecting results	Frequent errors; largely incorrect
Clarity & communication	Clear, logical working; key steps shown; diagrams where helpful	Mostly clear	Some unclear or missing steps	Hard to follow / insufficient working

Partial credit is awarded for correct method and reasoning even if final numerical/algebraic answers are incomplete.

2) Continuous Assessment (CA): Assignment (Homework 1 & 2) — 10% each

A problem set on early-course topics assessing correct methods, reasoning, and clear presentation of solutions.

Criterion	Excellent	Good	Satisfactory	Limited
Method & setup	Correct approach and equations; assumptions/symmetry stated clearly	Mostly correct; minor omissions	Approach partly correct but incomplete	Wrong or unclear approach
Reasoning	Logical steps and justification; uses principles appropriately	Mostly logical	Limited justification	Weak/incorrect reasoning
Accuracy	Correct working and final answers; correct units	Minor errors	Several errors	Many errors; incorrect results
Presentation	Clear, readable, well-organised	Generally clear	Some unclear steps	Poorly presented / hard to follow

3) Continuous Assessment (CA): Test/Quiz (Midterm Test) — 25%

An in-class test on first-half material evaluating your understanding and ability to solve standard electromagnetism problems systematically.

Criterion	Excellent	Good	Satisfactory	Limited
Understanding	Applies correct concepts and laws; minimal misconceptions	Mostly correct; minor misconceptions	Basic recall; shaky application	Major misconceptions
Systematic problem-solving	Clear plan; correct strategy selection; coherent steps	Mostly systematic	Some relevant steps but not coherent	Incorrect strategy / disorganised
Accuracy	Correct derivations and answers; correct units	Minor slips	Multiple errors	Largely incorrect
Clarity	Work is readable; essential steps shown	Mostly clear	Some missing steps	Hard to follow

4) Continuous Assessment (CA): Class Participation (Wooclap) — 5%

Marks are awarded for consistent participation in in-class Wooclap concept checks, which provide immediate feedback and reinforce learning. Full marks are awarded for participation in at least 9 of the 13 Wooclap sessions.

You are considered to have participated in a session if you submit responses to the Wooclap questions during the lecture window. Accuracy is not graded.

Participation count (out of 13)	Marks awarded for this component
9–13 sessions	100%
7–8 sessions	80%
5–6 sessions	60%
3–4 sessions	40%
1–2 sessions	20%
0 sessions	0%