Nanyang Technological University
Division of Physics and Applied Physics

Academic Year	2020/21	**Semester**	2
Course Coordinator	Dr. Koh Teck Seng		
Course Code	PH2102		
Course Title	Electromagnetism		
Pre-requisites	(MH1801 and MH2800 and PH1106) OR (MH1802 and MH1803 and MH2802 and PH1106) OR (CY1601 and CY1602 and CY1308) OR (MH1101 and MH1200 and PH1106)		
No of AUs	4 AU		
Contact Hours	PH2102 **Face to Face: 2 hr – lecture; 1.5 hr – tutorial** **Online: 0.5 hr (pace depends on student)** (Note: face-to-face lecture time increased from 1.5 to 2 hr; online component reduced from 1 hr to 0.5 hr. Justification: After experimenting with the new format (increased tutorial time, reduced lecture time, online component), I found that it didn't work very well; students preferred more face-to-face time to understand the material better.)		
Proposal Date	17 March 2020		

Course Aims
By the end of the course, the students will be able to understand the fundamental principles of electromagnetism. Through tutorials, students will learn the relevant analytical, computational and mathematical skills such as partial differential equations and the physical concepts behind the equations/solutions. These skills and concepts are the essential for the advanced courses such as electrodynamics and fluid mechanics.

Intended Learning Outcomes (ILO)

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

Basics (BAS)

1. use the mathematical forms of gradient, divergence, and curl in different coordinate systems to solve problems and interpret the physics meaning behind it.
2. apply vector calculus (such as divergence theorem and Stoke's theorem) to solve electromagnetism problems.

Electrostatics (ES)

3. determine the electrostatic field produced by static charges in a variety of simple configurations.
4. identify and apply appropriate theoretical techniques (such as method of images, separation of variables, and multipole expansion) to determine the electric potential due to a system of charges.
5. determine the electric fields in a dielectric with Gauss's law of electric displacement.
6. identify boundary conditions for solving electrostatic problems.
7. determine various physical quantities (such as electric field, electric displacement, polarization, force, and electric potential energy) and discuss their physical origins in dielectric materials.

Magnetostatics (MS)

8. apply Lorentz force to solve problems involving moving charged particles.
9. determine magnetic fields using (such as Biot-Savart's law and Ampere's law) whenever appropriate.
10. discuss the significance and origins of the magnetic vector potential.
11. distinguish between paramagnetism, diamagnetism, and ferromagnetism.
12. determine various physical quantities (such as magnetic field, auxiliary magnetic field, magnetization, bound surface current and bound volume current) in magnetic materials.

Electrodynamics (ED)

13. apply concepts of electrodynamics to electric circuits.
14. apply Faraday's law and Lenz's law to solve electromagnetic induction problems.
15. discuss the derivation of Maxwell's equations and their physical origins.
16. construct wave equations from Maxwell's equations and identify that electromagnetic waves are transverse waves with polarizations.
17. determine physical quantities (such as electric field, magnetic field, and Poynting vector) of an electromagnetic wave.

Course Content

This course introduces key concepts in electromagnetism;

Basics (BAS)
Multivariable & Vector Calculus
Taylor Expansion (for Cartesian coordinates)
Spherical Harmonics (for spherical coordinates)
Solving Ordinary Differential Equations using Separation of Variables

Electrostatics (ES)
Coulomb's Law
Gauss's Law
Electric Dipole Moment
Polarization and Electric Displacement
Multipole Expansion
Laplace's and Poisson's Equations
Uniqueness theorem
Method of Images
Electrostatic energy

Magnetostatics (MS)
Lorentz Force
Faraday's law and Lenz's law
Magnetic Dipole Moment
Magnetic Field and Flux
Magnetic Scalar and Vector Potentials
Magnetization and Magnetic Media
Permeability and Susceptibility
Properties of B and H Fields

Electrodynamics (ED)
Boundary Conditions
Equation of Continuity
Maxwell Equations
Electromagnetic Wave Equation
Magnetic and Electric Energy Densities
Poynting Flux
Momentum Flux
Radiation Pressure
Polarization

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)	50%	Individual	Point-based marking (not rubric-based)
2. CA1: Project Assignment	All	Competency (1,4,5), Communication (1,2,3), Character (1,2,3)	10%	Team	Rubrics marking (See appendix)
3. CA2: Mid-terms	All	Competency (1,3,4)	20%	Individual	Point-based marking (not rubric-based)
4. CA3: Homework	All	Competency (1,3,4)	20%	Individual	Point-based marking (not rubric-based)
Total			100%		

Formative feedback

Formative feedback is given weekly through assignments marking and tutorial lessons. A weekly TA meeting discusses the progress, pace, and difficulty level of lectures.

Formative feedback is given during clicker sessions every lecture.

Formative feedback on the midterm quiz is given as a midterm check of students' understanding of learned contents. Feedback is also given after each midterm on the common mistakes and level of difficulty of the problems. Past exam questions and examiner's report are made available for students.

Learning and Teaching approach

Approach	How does this approach support students in achieving the learning outcomes?
Lectures	Lectures provide the necessary content and practice of problem solving and discussion of conceptual understanding.
Tutorial	The students review and discuss main concepts learned in lectures with TAs by working through problems. TAs monitor and provide timely feedback.
Homework	The homework comprises standard textbook practice questions that are covered during tutorial allowing for formative assessment and feedback.
Project (team)	This is a project in which student groups solve a real world problem in electromagnetism and communicate their solution to their peers.

Reading and References

1. David J. Griffiths, Introduction to Electrodynamics, Pearson 4th ed. (2012). ISBN-13: 978-1108420419

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. Koh Teck Seng	SPMS PAP 03-08	65141066	kohteckseng@ntu.edu.sg

Planned Weekly Schedule

Week	Topic	Course LO	Readings/ Activities
1	Recap and Diagnostics Vector Analysis	**BAS** 1-2	Textbook and lecture notes, videos
2	Electrostatics	**ES** 3-4	
3	Electrostatics	**ES** 4	
4	Electrostatics	**ES** 4	
5	Electric Fields in Matter	**ES** 5, 7	Mid Term 1
6	Electric Fields in Matter	**ES** 6-7	Review of Mid Term 1
7	Magnetostatics	**MS** 8-10	Textbook and lecture notes, videos
8	Magnetic Fields in Matter	**MS** 11-12	
9	Electrodynamics	**ED** 13	Mid Term 2
10	Electrodynamics	**ED** 14	Review of Mid Term 2
11	Electrodynamics	**ED** 14-15	Textbook and lecture notes, videos
12	Electromagnetic Waves	**ED** 16-17	
13	Revision	Recap of main knowledge points	

Appendix: Rubrics

Project Report (Adapted from https://www.cte.cornell.edu/documents/Science%20Rubrics.pdf)

Criteria	Exceeds Standard (10 – 9)	Meets Standard (8 – 6)	Almost Meets Standard (5.5 – 3.5)	Does not meet standard (3 – 0)
Problem Statement	Clearly and accurately communicated, and gives background or context and motivation.	Clearly and accurately communicated.	Somewhat unclear or unable to accurately portray the problem.	Unclear and inaccurate or illogical statement.
Correct and appropriate physics	Correct and appropriate use of physics, with assumptions, approximations, experimental techniques, and derivations that are accurate and detailed.	Correct and appropriate use of physics, with some clarity on assumptions, approximations, experimental techniques, and derivations.	Mostly correct and appropriate use of physics.	Incorrect or inappropriate use of physics in most areas.
References and Citations	Proper, accurate and clear citations and attribution of others' work.	Proper, accurate and clear citations and attribution of others' work.	Proper and clear citations and attribution of others' work, with minor errors.	Proper and clear citations and attribution of others' work, with major errors.
Development of Ideas	Introduces the topic clearly and creatively. Maintains clear focus on the topic. Development of and connection between ideas are clear and correct.	Introduces the topic clearly. Maintains focus on the topic. Development of and/or connection between ideas are clear and correct.	Introduces the topic. Somewhat maintains focus on the topic. Development of some ideas are clear.	Does not clearly introduce the topic. Does not establish or maintain focus on the topic.

Project Presentation

Criteria	Exceeds Standard (10 – 9)	Meets Standard (8.5 – 6)	Almost Meets Standard (5.5 – 3.5)	Does not meet standard (3 – 0)
Engagement	Arouses interest and engages attention of audience throughout the presentation.	Arouses interest and engages attention of audience through most of the presentation.	Maintains attention of audience through part of the presentation.	Loses attention of audience through most of the presentation.
Scientific communication	Communicates difficult or complex ideas in an effective and understandable manner	Communicates ideas in an effective and understandable manner	Communicates ideas somewhat effectively, which are mostly understandable.	Does not communicate ideas effectively.

The main presentation should include:

• a ***presentation*** of the appropriate ***concepts, theories and principles*** of the problem
• an ***explanation*** of the ***observed phenomena***

• an ***application*** of ***appropriate mathematics***
• reasonable **experimental technique** to ***gather*** and ***record data*** (or ***demonstrate*** the ***phenomena*** if appropriate)
• linking of ***theoretical*** and ***experimental findings*** to draw ***suitable conclusions***
• an attempt to communicate ***difficult*** or ***complex*** ideas in an ***effective*** and ***understandable*** manner

Duration: Presentation (8-10 min) + Q&A (5-7 min) = Total of 15 min.

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.