# View Syllabus Information

## Course Information

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|---|---|---|---|---|---|
| Year | 2024 | School | School of Advanced Science and Engineering | | |
| Course Title | General Physics C: Electromagnetism (1)<br>English-based Undergraduate Program | | | | |
| Instructor | MOTZ, Holger Martin／MIKHAYLENKO, Sergey | | | | |
| Term/Day/Period | spring quarter 01:Mon.1／02:Wed.4／03:Thur.2 | | | | |
| Category | Natural Science | Eligible Year | 2nd year and above | Credits | 3 |
| Classroom | 01:54-403／02:54-103／03:53-B04 | Campus | Nishi-Waseda(Former: Okubo) | | |
| Course Key | 28M0220003 | Course Class Code | 01 | | |
| Main Language | English | | | | |
| Class Modality Categories | [On-campus] Hybrid (over 50% of classes on-campus) | | | | |
| Course Code | PHYB22ZL | | | | |
| First Academic disciplines | Physics | | | | |
| Second Academic disciplines | Basic Physics | | | | |
| Third Academic disciplines | Electromagnetism | | | | |
| Level | Intermediate, developmental and applicative | Types of lesson | Lecture | | |

## Syllabus Information

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**Course Outline**

Note: EBSE September enrollees should take this course during the 1st year. Please check “Students HANDBOOK” for details.

This is an introductory course about electromagnetism, starting with the electrostatic force between point charges and ending at Maxwell's equations and electromagnetic waves.
The examples and exercises for the course focus on phenomenological aspects and applications of electromagnetism, while the theoretical context is explained as additional information.
The contents of this course are fundamental prerequisites for the more advanced and specialized courses in all Majors of Science and Engineering.

**Objectives**

Objectives
- to understand the fundamental principles of electromagnetism
- to understand and correctly use the English technical terms of electromagnetism
- to develop the ability to solve simple, practical problems of electromagnetism

**before/after course of study**

Before the course starts:
- if you did not study any electricity and magnetism in school, consider doing some preparatory self study. A textbook is suggested in the reference section below. Lecture videos reviewing some topics on high-school level are provided on Moodle.

Before class:
- read the relevant sections in the required textbook as indicated in the schedule below
- review the course materials provided on Moodle to get an overview of the lecture's topics

After class:
- review the course materials on Moodle again to confirm your understanding, use Moodle forums to discuss unclear points
- familiarize yourself with all worked-out examples in the relevant sections of the required textbook
- watch on-demand videos on Moodle for review as needed

The time required for preparation and review depends on the pre-knowledge and aptitude of each student, but it is recommended to assign at least time equivalent to the class duration, i.e. 4.5 hours per week to it, not including homework assignments.

Additional work may be assigned/recommended in each class as appropriate, including graded homework (see section "Evaluation Criteria" below)
The time needed to complete one homework assignment is less than one hour, assuming the underlying concepts and methods are well understood.

**Course Schedule**

1: Mon 4/15 Lecture 1 (Holger Motz)
This class will start with an introduction of the course goals, teaching methods and grading criteria, followed by a demonstration of electrostatic induction using balloons. We will discuss electric charge as a property of elementary particles, the concept of forces acting on a distance and compare electromagnetism to gravity. Common but important terms such as "conductor", "insulator", "current" will explained before establishing Coulomb's law as the description of the electrostatic force between point charges. From this, we will define the term "electric field" and learn about the fields of point charges, which can be combined by the superposition principle, for example to form electric dipoles. We examine different representations for electric fields, such as vector field plots and field lines. (textbook: section 21.1-7 except examples 21.9-12).

2: Wed 4/17 Lecture 2 (Holger Motz)
We learn to calculate the field of extended charged objects, first by extending the superposition principle from combining discrete point charges to a superposition integral over charge density, and then, after defining electric flux, we use Gauss's law to find the electric field for certain symmetric charge distributions. We establish basic rules for distance dependence of the electric field for extended charged objects of point (0-D), line (1-D), area (2-D) type. (textbook: examples 21.9-12, sections 22.1-4)

3: Thu 4/18 Problem Solving Class 1 (Sergey Mikhaylenko)
Topics: Coulomb's law and electric field, electric fields by extended charge distributions and Gauss's law

4: Mon 4/22 Lecture 3 (Holger Motz)
From studying the movement of charged objects in electric fields and the work done, we derive the electric potential as potential energy per unit charge in an external electric field. We also calculate the inherent potential energy of extended charge distributions to clearly differentiate these often confused concepts. (textbook: sections 23.1-5)

5: Wed 4/24 Lecture 4 (Holger Motz)
We re-examine electrostatic induction, finding basic rules for charge movement and electric fields in relation with conducting objects. Based on charge separation by induction, we introduce capacitance as the proportionality factor between the amount of charge on an

object and it's voltage, and learn about capacitors, especially the parallel plate capacitor. (textbook: section 22.5)

6: Thu 4/25 Problem Solving Class 2 (Sergey Mikhaylenko)
Topics: Potential energy, capacitance

7: Mon 4/29 Lecture 5 (Holger Motz)
From the energy stored in a capacitor, we derive the energy density of electric fields. After discussing the polarization effect of electric fields on insulating objects, we establish the rules to calculate the effect of such dielectric objects on e.g. capacitance. (textbook: sections 24.1−6)

8: Wed 5/1 Lecture 6 (Holger Motz)
Electric current density is formally introduced, together with the general form of Ohm's law. Considering only closed systems of conducting paths called DC−circuits we learn to do practical calculations of voltage and current based on Kirchhoff's laws. The transmission of power and energy in DC circuits is explained with examples and the working principles of Volt− and Ampere−meters are discussed. (textbook: sections 25.1−5, sections 26.1−3)

9: Thu 5/2 Problem Solving Class 3 (Sergey Mikhaylenko)
Topics: Dielectrics, current, resistance and DC circuits

10: Wed 5/8 Midterm Exam (50 min) and Lecture 7 (Holger Motz & Sergey Mikhaylenko)
Magnetism is explained as an effect caused by the movement of electrical charge due to effects of Special Relativity. The concept of a force caused by moving charges on moving charges is discussed and the magnetic field is introduced. We learn about the motion of charged particles in magnetic fields due to the Lorenz Force, and thereby that static magnetic fields can't do any work. (textbook: section 27.1−5)

11: Thu 5/9 Lecture 8 (Holger Motz)
We study the force on current carrying wires from magnetic fields and the Hall−effect as a result of the previously discussed force on moving charged particles. To examine the sources of magnetic fields we derive the magnetic field of a single moving charged object (as part of a system without changing electric fields), from which we transition to the Biot−Savart Law which describes the magnetic field caused by current carrying circuits. Analogous to the electrostatic superposition integral we learn to calculate magnetic fields of extended circuits. In analogy to Gauss's Law we then use Ampere's law to find the magnetic field of symmetric current configurations. (textbook: section 27.6, section 27.9, sections 28.1−7)

12: Mon 5/13 Lecture 9 (Holger Motz)
In this lecture we discuss the motion of conductors in magnetic fields which causes a voltage over them by electromagnetic induction. After introduction of the magnetic flux, we extend the source of the voltage to include also changing magnetic fields as described by Faraday's law. From this, we derive that changing magnetic fields cause electric fields, and discuss more general cases such as eddy currents. (textbook: sections 29.1−6)

13: Wed 5/15 Problem Solving Class 4 (Sergey Mikhaylenko)
Topics: Magnetic field, Biot−Savart law, Ampere's law, Electromagnetic induction]

14: Thu 5/16 Lecture 10 (Holger Motz)
Alternating current is introduced and we learn about generators and motors. Changing the current in a circuit element also changes the magnetic field produced by it, which induces a voltage in the same circuit element. We introduce the self−inductance as the proportionality factor between current change and induced voltage analogous to the capacity. To consider the induced voltage in other circuit elements, we define mutual inductance and learn basic rules how to calculate it for coils. From the energy stored in a coil, we derive the energy density of magnetic fields. (textbook: section 27.8, sections 30.1−3, section 31.1)

15: Mon 5/20 Lecture 11 (Holger Motz)
The time dependence of voltage and current in RL and RC circuits is discussed. We study then circuits with sinusoidal changing voltage and current including coils and capacitors, defining reactance as a frequency dependent form of resistance. The energy exchange between capacitor and inductance in an ideal resonance (LC) circuit is explained and the resonance frequency calculated. (textbook: section 26.4, sections 30.4−5, sections 31.2−5)

16: Wed 5/22 Problem Solving Class 5 (Sergey Mikhaylenko)
Topics: Inductance, (RL,RC,LC)−circuits

17: Thu 5/23 Lecture 12 (Holger Motz)
The the resonance in driven RLC−circuits and its application as a frequency filter is shown with examples. Analogous to the effect of dielectrics in capacitors, the possible effect of materials in coils is discussed. This leads to understanding magnetic dipoles as miniature current loops, or spinning charged particles. The magnetic (dipole) moment is defined as the area of the loop multiplied by the current around it, and we explore forces on magnetic dipoles in magnetic fields. (textbook: section 30.6, section 27.7)

18: Mon 5/27 Lecture 13 (Holger Motz)
We learn about the interaction of magnetic fields with matter, categorizing them as paramagnetism, in which the alignment of existing magnetic dipoles enhances an external magnetic field, as ferromagnetism, in which there is spontaneous alignment that can only be broken by strong external fields, and diamagnetism, in which induced dipoles oppose the external field. Terms describing these interactions, such as permeability and magnetization are defined, and the hysteresis in the magnetization reversal of ferromagnets explained. The effect of diamagnetic levitation and superconductivity as "perfect" diamagnetism are discussed. (textbook: section 28.8, 29.8)

19: Wed 5/29 Problem Solving Class 6 (Sergey Mikhaylenko)
Topics: RLC−circuits, magnetization properties

20: Thu 5/30 Lecture 14 and Q&A for final exam (Holger Motz)
In this final lecture, we combine previously learned laws to Maxwell's equations, introducing the displacement current as the last piece of the puzzle. Solving this system of differential equations for vacuum conditions, we find the electromagnetic wave equation. We calculate the energy of magnetic waves and derive their momentum by looking at an interaction with a single charged particle, thereby finding the basic properties of the photon. (textbook: section 29.7, sections 32.1−4) − The contents of this lecture are not asked in the final exam.

21: Mon 6/3 Final exam (90 min) and review of the solution (Holger Motz & Sergey Mikhaylenko)
The exam will be conducted in−class.

**Textbooks**

The following textbook is required for this course:
"University Physics with Modern Physics" (14th edition) by Hugh D. Young and Roger A. Freedman (ISBN−13: 978−0133969290)

**Reference**

For students who have not studied basic electricity and magnetism, the following books are suggested as options for preparatory self study (but any decent high−school physics book should do):
* "High School Physics Unlocked", The Princeton Review (ISBN−13: 978−1101921531)
* "Basic Calculations in Electricity: A Physics Book for High Schools and Colleges", K. Augustine, (ISBN13: 978−1719882064)

The following books are suggested for additional study for students who want to gain a deeper understanding:
* "Introduction to Electrodynamics", Griffiths, David J. (theoretical approach, explains well fundamental concepts, ISBN−13: 978−1108420419)
* "Electricity and Magnetism", E. M. Purcell & D. J. Morin (partly more detailed, additional examples and exercises, ISBN−13: 978−1107014022 )
* "A Student's Guide To Maxwell's Equations", D. Fleisch (explains mathematical background in an accessible way, ISBN−13: 978−1516912919 )

**Evaluation**

| Rate | | Evaluation Criteria |
|---|---|---|
| Exam: | 70% | 25% Midterm Exam (50 minutes)<br>45% Final Exam (90 minutes, covers the whole course) |
| Papers: | 16% | 4 graded homework problems (distributed and submitted on Moodle). |
| Class Participation: | 0% | Additional points may be awarded for significant class participation and/or contributions to the Moodle discussion forums |

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|---|---|
| | Others: 14% 14 Quizzes (multiple choice, on Moodle) |
| Note / URL | While this course is designed to require no pre-knowledge of electromagnetism in principle, students who did not study any electricity and magnetism in high school are likely to find the pace of learning very fast. It is recommended that these students do preparatory self-study using a high-school textbook such as those listed in references to catch up with their peers who already studied the basics in school. Since calculus will be extensively used in this course, the students are expected to have completed the Calculus A class or have an equivalent knowledge of calculus. |