Syllabus—PHYS 1912—Spring 2021—Principles of Physics II

Prof. Richard Haglund

1 Course description, learning objectives and strategy

The theme of ”Matter and Interactions” from PHYS 1911 continues with electromagnetic interactions that are fundamental to the physics of and in condensed matter. A catalog course description might be “Interaction of electric and magnetic fields with matter, electromagnetic radiation, classical and quantum optics.” The learning objectives are

- Identify the sources and spatial distributions of electric and magnetic fields
- Understand how electromagnetic fields determine the structure of solids
- Explore the response of charges and dipoles in electric and magnetic fields
- Derive and apply Maxwell’s equations and the electromagnetic wave equation
- Understand how light-matter interactions can modify both light and matter
- Learn how quantum ideas modify the classical theory of electromagnetic fields

We will continue the tactic of “applying physical models based on a powerful set of fundamental principles and the atomic structure of matter.”[1] Ideas about atomic structure adumbrated in PHYS 1911 will help us understand the interactions of electromagnetic fields with molecules, crystals and glasses. The uses and limits of models and simple calculations will be emphasized, because “approximation was the first art/it is the only science.”[2]

2 Course overview, textbook, class schedule and assignments

The required text for the course is the same as in PHYS 1911: Ruth Chabay and Bruce Sherwood, *Matter and Interactions*, 4^{th} edition. Supplementary material will be assigned from current scientific literature, and posted on Bright-space. I assume that you will have read and thought critically about the assigned reading *before* class and request that you submit a question about what you are learning at least weekly.

[1] Ruth Chabay and Bruce Sherwood, *Matter and Interactions*, 4^{th} edition, page 1 (2015)

[2] John Stone, ”Even Though,” *The American Scholar* **49**(3), 336 (1980). Full text of this wonderful short poem available upon request.

Beginning on Tuesday, January 26th and concluding on Thursday, April 29th, we will meet on Tuesdays and Thursdays, 11:10-12:25, in our Cyberclassroom, and on Wednesdays from 4:10-5 p.m. in 5306 Stevenson. The Zoom link will open at 11:00 Tuesday and Thursday and close at 12:35 to allow informal conversations. Meetings with individuals, project teams or discussion groups will be scheduled as needed.

The day-by-day PHYS 1912 schedule for the semester, including reading and problem assignments, follows on pages 3-4 of the Syllabus. You can expect minor adjustments as the semester progresses, so recheck Brightspace occasionally!

3 Contact, Course Web site, Office Hours

. My e-mail address is *richard.haglund@vanderbilt.edu*. If you send an e-mail, be sure to put "1912" or "P1912" in the suybject line so it will not get lost in the daily flood. You are also welcome to text me (615-720-2355). Course information will be posted on Brightspace,

https://brightspace.vanderbilt.edu/d2l/home/271792 .

I will hold office hours on Wednesdays, 1:30-3:30, in 6422 Stevenson. To set up an appointment outside office hours, please e-mail or text me two or three suggested times; one of those times will likely work for me as well.

4 Course requirements and grading

Six to eight homework problems will be assigned each week and are due a week from the day assigned. The answers will be available to you on-line once you turn in the work. However, if you have questions about the answers given or have other questions about the homework, please bring these up in class. Working with your classmates on problems and term projects is encouraged, subject only to the strictures of the Vanderbilt Honor Code.

The 100 points comprising the final grade will be calculated from class attendance and participation (20 %), homework (20 %), the three mid-term examinations (15 % each) and the term project and associated paper (15 %).

5 Honor Code

All written assignments are to be carried out in strict accordance with the Vanderbilt Honor Code. You are free to work with your colleagues on your homework and class presentations, as long as you acknowledge their assistance, if significant; the final product, on the other hand, must be entirely your own work. You may also ask questions about material on the examinations either in class or by e-mail. I will broadcast the question (anonymized) and my answer to the class. Plagiarism, presenting the work of others as your own, and other kinds of cheating will yield a failing grade for that assignment. If you are unsure about what constitutes a violation of the Honor Code, please ask. Ignorance is not an excuse!

Table 1: **PHYS 1912—S21—Week-by-Week Schedule of Topics and Assignments**

Day/Date	Topic	Reading	Homework
T/Jan 26	Coulomb interactions and the electric field	13.1-13.5	**13**: 21/22/51
W/Jan 27	Rutherford scattering for ion-beam analysis	10.7	**10**: 34
R/Jan 28	Electric field of atomic and molecular dipoles	13.6-9	**13**: 54/62/70
T/Feb 2	Polarization of atoms and dielectrics	14.1-14.5	**14**: 38/39/56
W/Feb 3	Plasmonics in metallic nanoparticles	Paper 1	
R/Feb 4	Fields and charge transport in conductors	14.6-14.8	**14**: 58/59/60
T/Feb 9	Fields of distributed charges in *n* dimensions	15.5-15.5	**15**: 25/27/30
W/Feb 10	The quest for supercapacitors	Paper 2	
R/Feb 11	Electric field of a charged spherical shell	15.6-15.10	**15**: 55/56/67
T/Feb 16	Electric fields and electric potential energy	16.1-16.6.	**16**: 40/42/55
W/Feb 17	Accelerating and storing charged particles	Paper 3	**16**: 76
R/Feb 18	Computing electric fields of distributed charges	16.7-16.12	**16**: 83/87/91
T/Feb 23*	Magnetic fields from currents: Biot-Savart law	17.1-17.6	**17**: 18/22/23
W/Feb 24*	Magnetic focusing of particle beams	Paper 4	.
R/Feb 25	Atomic origins of the static magnetic field	17.7-17.14.	**17**: 40/45/62
F/Feb 26	**Begin Mid-Term Examination 1 (Chs. 13-16)**	Due Mar 5th	
T/Mar 2	Electric currents: From transient to equilibrium	18.1-18.6	**18**: 33/34/35
W/Mar 3	A fourth circuit: search for the memristor	Paper 5	
R/Mar 4	Feedback, energy in a circuit and a model	18.7-18.12	**18**: 45/50/54
F/Mar 5	**Mid-Term Examination 1 due**		(11:59 p.m.)
T/Mar 9	Circuits with resistors and capacitors	19.1-19.5	**19**: 30/34/44
W/Mar 10	Physics of CMOS field-effect transistors	S2	
R/Mar 11	Circuit measurements and circuit dynamics	19.6-19.12	**19**: 58/63/72
T/Mar 16	Cyclotron orbits and resonances0	20.1-20.6	**20**: 31/55/64
W/Mar 17	Magnetic confinement of fusion plasmas	Paper 6	
R/Mar 18	Crossed EM fields; the Hall effect	20.7-20.11	**20**: 72/77/81
T/Mar 23	The laws of Gauss and Ampére	21.1-21.6	**21**: 9/17/19
W/Mar 24	Physics of magnetic resonance imaging	Paper 7	
R/Mar 25	Consequences of the field concept	21.7-21.10	**21**: 20/25/30
T/Mar 30	Motional emf and Faraday's law of induction	22.1-22.6	**22**: 18/28/30
W/Mar 31	Inductively coupled plasmas for analysis	Paper 8	
W/Mar 31	**Working project title/abstract/outline due**		
R/Mar 32	Faraday's law for circuits: Lenz's rule	22.7-22.10	**22**: 34/36/41
T/Apr 6	Maxwell's equations (finally!): EM radiation	23.1-23.5	**23**: 23/28/31
W/Apr 7*	Synchrotron light sources of ultrafast X-rays	Paper 9	

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Day/Date	Topic	Reading	Homework
R/Apr 8*	Physics of electromagnetic fields and waves	23.6-23.12	**23**: 43/50/51
F/Apr 9	**Begin Mid-Term Exam 2 (Chs. 17-22)**	Due Apr 19th	
T/Apr 13	Geometrical and physical optics	S3.1-S3.5	
W/Apr 14	Quantum information science at ORNL: David Dean	Paper 10	
R/Apr 15	Optical science and engineering for clean energy		S3.6, S3.9
T/Apr 20	Coherent light: lasers across the spectrum		
W/Apr 21	Quantum properties of the electromagnetic field	Paper 11	
R/Apr 22	Creating and entangling single photons	Notes 1	
R/Apr 22	**Mid-Term Examination 2 due**		(11:59 p.m.)
T/Apr 27	Quantum computing with single-photon qubits	Notes 2	
W/Apr 28	Quantum encryption with entangled photons	Paper 12	
R/Apr 29	Photon angular momentum and twisted light		
F/APR 30	**Undergraduate classes end**		
May 1-10	Reading days and final examinations		
M/May 10	**PHYS 1912 Term Papers and Projects due**	6:00 p.m.	

Notes on Table 1

* Indicates in-class reading days

Homework problems are indicated as **Chapter**: Problem X/Problem Y/Problem Z