PHY 152/202: General Physics 2 / Physics 2
Wisconsin Lutheran College
Course Syllabus Fall 2019

Introduction

What is the nature of light? In this course, we will study a wide range of texts beginning with the work of Gilbert, Coulomb, and Ampere on electricity and magnetism, and culminating with the electromagnetic theory of light, as developed in the 19th century by Faraday and Maxwell. Weekly laboratory sessions complement the classroom discussions.

Course times and locations

PHY 152: General Physics 2 (Algebra-based) will meet in Room S010 in Generac Hall on Monday, Wednesday and Friday from 9:00 - 9:50

PHY 202: Physics 2 (Calculus-based) will also meet in Room S010 in Generac Hall on Monday, Wednesday and Friday from 9:00 - 9:50. In addition, PHY 202 will meet on Thursday in room S010 from 11:30 - 12:20.

Laboratory sections will meet in Room S115 in Generac Hall on Thursday and Friday from 12:30-3:20.

Course instructors

Kerry K. Kuehn, Ph.D.,
Professor, Dept. of Physics,
Office: Generac Hall Room S133
www.kerrykkuehn.com,
kerry.kuehn@wlc.edu,

Joel Davis, Ph.D., Associate Professor,
Dept. of Chemistry (Thursday laboratory)

Aaron Schindler, M.Sc.,
Instructor, Dept. of Physics (Friday laboratory)

Grade components

Classroom discussion	10%	Laboratory discussion	10%	Midterm exam 2	20%
Laboratory exercises	15%	Midterm exam 1	20%	Final exam	25%

Grading scale

A	100-93%	B	87-80%	C	74-70%	D	61-54%
AB	92-88%	BC	79-75%	CD	66-62%	F	53-0%

Course objectives

- understand nature—(specifically the sciences of electricity, magnetism and light)
- improve reading comprehension and vocabulary—(through the reading and discussion of great texts)
- discern truth from error—(by analyzing and comparing the best ideas which have been written)
- articulate scientific ideas—(both verbally and in written form)
- solve problems—(conceptual, mathematical, experimental)
- provide a suitable foundation for advanced coursework in physics (talk to me about major or minor)

Required Textbook

Kerry K. Kuehn, *A Student's Guide through the Great Physics Texts, Volume III: Electricity, Magnetism and Light*. (Berlin: Springer, 2016).

Examinations

There will be three examinations in this class. To best prepare for the exams, you should

(1) read all of the *assigned reading* selections completely—(at *least* once),
(2) use the *study guide* after each reading—(to be sure you understand key points in the readings),

(3) participate in *classroom discussions*—(use our classroom discussion to figure out what you don't understand in the readings)
(4) work through the recommended *homework exercises*—(*before* resorting to the posted solutions),
(5) *study the solutions* to the exercises—(to be sure you don't make the same mistakes twice),
(6) learn the *vocabulary words*—(to help with reading comprehension and overall literacy),
(7) review the *laboratory exercises*—(some exam questions may be based on what you did in lab), and
(8) regularly *visit me* during office hours to discuss physics—(I am a very nice person)

<u>Reading and discussing the great texts</u>

In this course, we will read and discuss some of the classic scientific texts dealing with electricity, magnetism and light. The scientific texts we will read are considered classics because they address timeless questions in a particularly honest and convincing manner. This does not mean that everything they say is true. In fact many classic scientific texts contradict one another. But it is by the careful analysis of the most reputable observations and opinions that one may begin to discern truth from error.

You will not understand everything you read; nobody does. The texts are challenging. Like great literature, these texts must be ``grown into", so to speak. (Remember: nobody understands all of Shakespeare or all of the Bible the first time they read it, either!) So think of this course as a ``first dip" into the deep end of the pool. These texts are classics because—like fine wine—both the beginner and the advanced scholar can profit by studying them.

The time that we spend in the classroom will be devoted to discussing the reading selections. As the discussion leader, I will typically ask questions regarding specific ideas which are found in the texts. For instance, I may ask, "Does a light ray always travel in a straight line?" And if not, "What causes it to bend?" The task will then be to try, as a group, to answer these questions.

It is critical that participants carefully read the assigned selections before engaging in discussion. This will help participants to make relevant comments and to cite textual evidence to support or contradict assertions made during the course of the discussion. In this way, many assertions will be revealed as problematic, in which case they must then be refined or rejected altogether. This is precisely the method used by scientists themselves in order to discover and evaluate competing ideas or theories.

<u>Classroom discussion: étiquette and grading</u>

During our discussion, you may speak with complete freedom. There is only one rule: *any comment or question you make must be made publicly so that all others can hear and respond*.

Each student will receive a discussion grade for the class which will range from 0% to 100%. I will notify you of your discussion grade when I return each midterm exam. To clarify how I approach classroom discussion grading, consider the following examples.

- The 100% student is actively engaged in the classroom discussion. His or her ability to raise interesting and relevant points from the text is evidence that they have studied the assigned text and put significant thought into analysis outside of class.
- The 80% student is somewhat engaged in the classroom discussion. He or she makes comments or raises questions during the discussion, but they have some trouble providing specific textual or rational support for their assertions.
- The 60% student is very occasionally engaged in the classroom discussion. They sit silently but politely. They may have read the assigned text, but have not thought enough about it to formulate any coherent thoughts. They uncritically accept whatever is said by the author, the instructor and the other students in the class.
- The 0% student comes to class, but instead of presenting his or her views to the class publicly, they whisper them to their friends. The instructor and other students find this distracting and a bit rude.

From an instructor's perspective, discussion is admittedly the most difficult grade to assign, as it is unavoidably somewhat subjective. Nonetheless, learning to verbally articulating scientific ideas in a public setting is an important skill and one of the secondary learning objectives of this course.

PHY 152/202: General Physics 2 / Physics 2
Wisconsin Lutheran College
Course Syllabus Fall 2019

Most students are initially apprehensive about engaging in public discussion. This is natural. If you find yourself to be one of these it is important to realize that you do not need to make an elaborate point in order to engage in classroom discussion. Often, a short question can provide a simple avenue. For example, ``I am unclear what the author means by the term *celestial*. Can someone please clarify?" Write down questions like these in the margins while reading the text. Start like this. Pretty soon, you may find yourself joining gamely in classroom discussion.

Laboratory exercises

Many reputable opinions regarding how nature works are wrong. In many cases, this is because these opinions do not conform to the way nature actually behaves. How can one determine how nature actually behaves? During our weekly laboratory session, we will cary out experimental investigations which attempt to reveal how nature works under controlled conditions. You will be provided with equipment and some general questions or suggestions related to the assigned reading for the week. It will be your responsibility to devise experimental techniques and procedures so as to clarify your understanding of nature.

Laboratory notebook

You must keep a record of your work during the laboratory sessions. To this end, you will need to purchase a lab notebook which must be brought to lab on your first laboratory session. Your lab notebook must be sturdy, must be at least 8.5 x 11 inches and must be quad-ruled (graph paper). You must allow the first few pages in your lab book to serve as a table of contents. The purpose of the lab book is to serve as a single source which contains all of the information relevant to your experiments. In particular, during each laboratory session, you should record the following information in your laboratory notebook:

- Your name and your laboratory partner's name, the date and a title for the experiment.
- A neat sketch of any experimental apparatus you use, along with labels (make and model).
- A clear description of your experimental procedure(s), including difficulties which you experienced in carrying out your experiments.
- Tables containing any data which you collect. You must never write data anywhere else: not on scrap paper, not on the back of your hand, nowhere. Also, you must write down an estimated uncertainty in any measurement which you perform. For instance, if you use a stop watch to time a falling ball, you should estimate the precision with which you were able to record the time. This is always slightly larger than the resolution of the device being used.

Your lab report must be written in blue or black ink. It must be written in chronological order. That is, you might first describe some of your procedure, then record some data, then describe some more of your procedure, then some more data , and finally do some analysis. The important thing is that you write clearly and that you spread out your writing so that the reader of your notebook can easily ascertain what you did, and reproduce it if necessary. If it contains computer printouts of data tables or plots, these must be trimmed to fit neatly on a page and secured with tape. Do not fold or stack your plots. All plots must occupy at least half of a laboratory book page (*i.e.* don't make tiny plots).

Before leaving the lab, your instructor will assign you a grade based on the neatness, clarity and completeness of your laboratory notebook.

Grading of the laboratory exercises

Each student will receive a weekly laboratory grade which will range from 0% to 100%. What follows are a few example students and the grade each received for one particular week.

- The 100% student conceived of an appropriate experimental program and has systematically executed it. When he or she ran into difficulties, he was able to arrive at a reasonable solution or work-around. His data is of good quality, and his analysis involves a reasonable assessment of sources of systematic error.
- The 80% student conceived of an appropriate experimental program and has systematically executed it. Although he or she was able to complete his experiments, either his data was inconclusive, or his analysis involved a significant systematic error which for which he was unable to account.
- The 60% student conceived of an appropriate experimental program, but was unable to complete significant portions of the laboratory assignment.

- The 0% student completed little or none of the laboratory assignment.

<u>Laboratory discussion sections</u>

After collecting your data and performing some preliminary analysis, you will be prepared to share your experiments and your results with your classmates. Therefore, each week during the lab session, we will spend the first fifteen minutes discussing the previous week's laboratory exercise. Each individual will be assigned a week during the semester on which to do a formal presentation. The formal presentations must include:

- acknowledgement of the collaborators on your experiment
- description of the problem you were trying to solve, and how this relates to the week's lecture,
- a description of how you attempted to solve the problem, including a detailed description of your experimental apparatus and procedure,
- plots or tables of your data, along with a description of how you analyzed your data, and
- a summary of the significance of your laboratory work. It is not good enough to simply state your results without any analysis of their meaning. If your results are different than you had expected, then you must address this issue directly. This should include an analysis of any systematic errors. Be sure to distinguish between systematic and random errors.

The presentation should last no more than ten minutes, and will be followed by a short question and answer session. Be sure to bring visual aides that will allow others to get a clear look at you experimental setup and any data or plots you have prepared. The grade you receive will depend upon both the quality of your data and the extent to which you address the points mentioned in the previous section.

Our laboratory discussion sections will be aimed at understanding the meaning and significance of the experiments performed during lab sessions, and at discussing ways in which the experiments might have been performed so as to achieve the most meaningful results.

<u>Final thoughts</u>

I want to encourage you to come to me with any concerns you may have during the course of the semester, whether they be physics questions or difficulties with reading or discussion. This course is designed to stretch your mind, but not to "break" you. Reading the classics in any field is challenging, but very rewarding. I would very much like to help you succeed and to enjoy this class! My contact information is listed at the beginning of this syllabus, so please feel free to contact me!

PHY 152/202: General Physics 2 / Physics 2
Wisconsin Lutheran College
Course Syllabus Fall 2019

Week 1 (Aug. 26, 28, 30). * = PHY 202 only; **Bold** = exam		
	Day 1.1	Welcome! Go over syllabus. Introduction to William Gilbert and his book *On Magnets.*
		Assignment: Read *Iron, Loadstones and Terrestrial Magnetism* (ASG Chap. 1).
	Day 1.2	Discuss ASG Chap. 1.
		Assignment: *Iron, loadstones and the earth* (Ex. 1.1); read*The Life and Death of a Magnet* (ASG Chap. 2).
	Day 1.3*	Vector algebra.
		Assignment: *Vector and scalar quantities* (Ex. A.1), *Vector addition* (Ex. A.2), *Vector multiplication, part 1: the dot product* (Ex. A.3), *Vector multiplication part 2: the cross product* (Ex. A.4)
	Day 1.4	Discuss ASG Chap. 2; introduce Curie temperature and types of magnetic ordering (*e.g.* paramagnetism, ferromagnetism). Introduction to Benjamin Franklin Franklin's *Experimental Researches in Electricity.*
		Assignment: *Compass and terrella* (Ex. 2.1); read *Conservation of Electrical Charge* (ASG Chap. 3).
	Lab:	*Magnetism laboratory* (Ex. 1.3)
Week 2 (Sep. 2, 4, 6)		
	Day 2.1	Labor day (no class)
	Day 2.2	Discuss ASG Chap. 3. Introduction to electrical charge, capacitance and electric potential.
		Assignment: *Charged balls* (Ex. 3.1). Read *Mueschenbroek's Wonderful Bottle* (ASG Chap. 4)
	Day 2.3*	Vector fields and vector calculus.
		Assignment: *Vector fields* (Ex. A.5), *Vector calculus, part 1: line integration* (Ex. A.6)
	Day 2.4	Discuss ASG Chap. 4
		Assignment: *Mueschenbroek's bottle* (Ex. 4.1). Read *Thunder and Lightning* (ASG Chap. 5).
	Lab:	*Capacitance, charge and electric potential* (Ex. 4.2)
Week 3 (Sep. 9, 11, 13)		
	Day 3.1	Discuss ASG Chap. 5. Lecture on uncertainty propagation.
		Assignment: Read *Coulomb's Law* (ASG Chap. 6).
	Day 3.2	Discuss ASG Chap. 6. Introduction to Hans Christian Oersted and electro-magnetism.
		Assignment: *Force addition* (Ex. 6.2), *Equilibrium of charges* (Ex. 6.3), Read *The Dawn of Electro-Magnetism* (AG Chap. 7)
	Day 3.3*	Coulomb's law problem.
		Electric fields and electric potential (Ex. A.7), *Vector calculus, part 2: surface integration* (Ex. A.8).
	Day 3.4	Discuss ASG Chap. 7.
		Assignment: *Wire and compass* (Ex. 7.1), *Electric conflict essay* (Ex. 7.3), Begin reading *Electric currents, magnetic forces* (ASG Chap. 8).

	Lab:	*Coulomb's law* (Ex. 6.4)
Week 4 (Sep. 16, 18, 20)		
	Day 4.1	Lecture on electric currents and magnetic fields.
		Assignment: *Magnetic field around a straight current-carrying wire* (Ex. 7.4).
	Day 4.2	Discuss ASG Chap. 8. Lecture on the Lorentz force law and its applications.
		Assignment: *Ampere's experiment and the lorentz force law* (Ex. 8.2)
	Day 4.3*	The Lorentz force law, magnetic torque, and the Biot-Savart law.
		Magnetic torque (Ex. 8.3), *The Biot-Savart law* (Ex. 8.4), Ampere's law (Ex. 31.2)
	Day 4.4	Finish discussion of Ampere. Introduction to Hermann von Helmholtz's *On the Conservation of Force (Energy)*
		Assignment: Look over solutions to all exam problems through chap. 8; study for exam 1.
	Lab	*Currents and compasses laboratory* (Ex. 7.3),
Week 5 (Sep. 23, 25, 27)		
	Day 5.1	Exam 1, covering material through Chap. 8.
		Assignment: Read *Work and Weight* (ASG Chap. 9)
	Day 5.2	Go over exam 1. Discuss ASG Chap. 9; focus on the concept of *work*.
		Assignment: *Lever* (Ex. 9.1), *hydroelectric power* (Ex. 9.2). Read *Kinetic and Potential Energy* (ASG Chap. 10).
	Day 5.3*	Work, kinetic energy, potential energy.
		Assignment: TBA
	Day 5.4	Discuss ASG Chap. 10; focus on the definitions of kinetic energy (Ex. 10.1)and potential energy (Ex. 10.3).
		Assignment: *Pendulum Speed* (Ex. 10.2). Read *Conservation of Energy* (ASG Chap. 11)
	Lab	*Force between currents laboratory* (Ex. 8.1)
Week 6 (Sep. 30, Oct. 2, 4)		
	Day 6.1	Discuss ASG Chap. 11; evaluate the caloric and mechanical theories of heat.
		Assignment: *Combustion* (Ex. 11.1), *Caloric theory essay* (Ex. 11.2)
	Day 6.2	Finish discussion of Helmholtz and the conservation of energy. Introduction to Newton's *Optiks*.
		Assignment: *Vital principle essay* (Ex. 9.4). Read *Geometric Optics* (ASG Chap. 12).
	Day 6.3*	Line integration and conservative force fields.
		Assignment: TBA
	Day 6.4	Discuss Chap. 12; focus on definitions and axioms (*e.g.* laws of reflection, refraction)
		Assignment: *Reflection from mirrors in a V-configuration* (Ex. 12.2), *Bow fishing* (Ex. 12.4)
	Lab	*Reflection lab* (Ex. 12.8) and *refraction lab* (Ex. 12.9)

PHY 152/202: General Physics 2 / Physics 2
Wisconsin Lutheran College
Course Syllabus Fall 2019

Week 7 (Oct. 7, 9, 11)		
	Day 7.1	Go over exercises; discuss refraction and total internal reflection.
		Assignment: *Total internal reflection* (Ex. 12.5). Read *The Wave Theory of Light* (ASG Chap. 13)
	Day 7.2	Discuss ASG Chap. 13; focus on Huygens' arguments for the wave theory, including early measurements of the speed of light.
		Assignment: Read *Huygens' Principle* (ASG Chap. 14)
	Day 7.3*	Focal length of a spherical mirror (Ex. 12.6)
		Assignment: *Spherical mirrors and the thin-lens equation (*Ex. 12.7)
	Day 7.4	Discuss Chap. 14; define the superposition principle and Huygens' principle
		Assignment: *The superposition principle and wave interference* (Ex. 14.1). Read *Reflection of light waves* (ASG Chap. 15).
	Lab	Optics laboratory: focal length, magnification, and building a Keplerian telescope
Week 8 (Oct. 14, 16, 18)		
	Day 8.1	Fall break
		Read *Reflection of light waves* (ASG Chap. 15).
	Day 8.2	Work through *Huygens' principle and wave diffraction* (Ex. 14.2). Discuss ASG Chap. 15.
		Assignment: read *Opacity, transparency, and Snell's law* (ASG Chap. 16)
	Day 8.3*	Interference and diffraction of light
		Assignment: TBA
	Day 8.4	Discuss ASG Chap. 16. Set up problem to derive Snell's law from Huygens' wave theory.
		Assignment: *Snell's law from wave refraction* (Ex. 16.1). Read *Atmospheric refraction (*ASG Chap. 17)
	Lab	Optics laboratory: focal length, magnification, and building a Keplerian telescope
Week 9 (Oct. 21, 23, 25)		
	Day 9.1	Discuss ASG Chap. 17. Begin discussion of *The particle theory of light* (ASG Chap. 18)
		Assignment: Read *The particle theory of light* (ASG Chap 18)
	Day 9.2	Discuss ASG Chap. 18; focus on newton's arguments against the wave theory and his discussion of birefringence
		Assignment: *Birefringence* (Ex. 18.1). Read *Passive laws and active principles* (ASG Chap. 19)
	Day 9.3*	Fermat's principle
		Snell's law from fermat's principle (Ex. 16.2)
	Day 9.4	Discuss ASG Chap. 19. Introduction to Thomas Young's *On the Nature of Light and Colours*.
		Natural theology essay (Ex. 19.2). Read *Measuring light's wavelength* (ASG Chap. 20)
	Lab	*Measuring hair diameter* laboratory (Ex. 20.2)

PHY 152/202: General Physics 2 / Physics 2
Wisconsin Lutheran College
Course Syllabus Fall 2019

Week 10 (Oct. 28, 30, Nov. 1)		
	Day 10.1	Discuss ASG Chap. 20. Go over Two slit interference pattern (Ex. 20.3).
		Assignment: *Fiber interference fringes* (Ex. 20.1), Read *Films, bubbles and rainbows* (ASG Chap. 21)
	Day 10.2	Discuss Chap. 21; focus on thin film interference, anti-reflective coating, and soap bubbles
		Assignment: *Soap film interference* (Ex. 21.1), *Optical path length* (Ex. 21.2)
	Day 10.3*	Diffraction gratings and x-ray spectroscopy
		Assignment: *Diffraction gratings* (Ex. 20.4); *Two slits of finite width* (Ex. 20.5)
	Day 10.4	Go over Ex. 21.2. Begin reading Tyndall's *Lectures on Light.*
		Assignment: read *Producing and detecting polarization* (ASG Chap. 22)
	Lab	*Air gap interference laboratory* (Ex. 21.3), *Brewster's angle* (Ex. 22.2),
Week 11 (Nov. 4, 6, 8)		
	Day 11.1	Discuss Chap. 22; focus on methods of producing and detecting polarization of light
		Assignment: *Brewster's angle and refractive index* (Ex. 22.1); read *Crystal symmetry and light rotation* (ASG Chap. 23)
	Day 11.2	Discuss Chap. 23; focus on light rotation through birefringent materials.
		Read *Light scattering* (ASG Chap. 24).
	Day 11.3*	Polarization vectors and birefringence
		Assignment: TBA
	Day 11.4	Discuss ASG Chap. 24. Light scattering demonstration.
		Assignment: Blood moon (Ex. 24.1); Stud for exam 2.
	Lab	*Light rotation* (Ex. 23.2), *Tyndall scattering* (Ex. 24.2), *Rayleigh scattering* (Ex. 24.3)
Week 12 (Nov. 11, 13, 15)		
	Day 12.1	Exam 2.
		Assignment: Read *Induction of electric currents* (ASG Chap. 25)
	Day 12.2	Go over exam 2. Discuss Chap. 25
		Assignment: *Lenz's law* (Ex. 25.4), Read *Arago's mysterious wheel* (ASG Chap. 26)
	Day 12.3*	Faraday's law.
		Assignment: Faraday's law (Ex. 31.3).
	Day 12.4	Discuss Chap. 26. Lecture on *electro-motive force and ohm's law* (Ex. 25.1), and *Electro-motive force and Faraday's law* (Ex. 25.2).
		Assignment: Read *Faraday's law* (ASG Chap. 27)
	Lab	*Electromagnetic induction* (Ex. 25.2), *Falling magnet puzzle* (Ex. 27.4)
Week 13 (Nov. 18, 20, 22)		

	Day 13.1	Discuss Chap. 27.
		Assignment: *The Lorentz force law and faraday's law* (Ex. 27.1)
	Day 13.2	Go over Ex. 27. Conclude discussion of faraday's law of induction.
		Assignment: *Eddy currents, magnetic damping, and the conservation of energy* (Ex. 27.3), Read *Action at a distance* (ASG Chap. 30).
	Day 13.3*	Lecture on Maxwell's equations
		Assignment: *Gauss's law* (Ex. 31.1), *Ampere's law* (Ex. 31.2), *Faraday's law* (Ex. 31.3), *The no-name law* (Ex. 31.4), *The Ampere-Maxwell law* (Ex. 31.5),
	Day 13.4	Discuss Chap. 30.
		Assignment: *Forces and fields* (Ex. 30.1), *Existence of fields* (Ex. 30.3), Read *Maxwell's equations* (ASG Chap. 31)
	Lab:	*Electric field mapping* (Ex. 28.2)
Week 14 (Nov. 25, 27, 29)		
	Day 14.1	Discuss Chap. 31.
		Assignment: Read *Propagating electromagnetic fields* (ASG Chap. 32)
	Day 14.2	Discuss Chap. 32
		Assignment: *Read Circuits, antennae and radiation* (ASG Chap. 33)
	Day 14.3*	no class (Thanksgiving)
		Assignment: *Electromagnetic plane waves* (Ex. 32.2), *Traveling electromagnetic waves* (Ex. 33.1), *Standing electromagnetic waves* (Ex. 33.2)
	Day 14.4	no class (Thanksgiving)
		Assignment: see lab for this week
	Lab:	Assignment: *Speed of light calculations* (Ex. 31.6)
Week 15 (Dec. 2, 4, 6)		
	Day 15.1	Discuss Chap. 33.
		Assignment: Read *The Michelson Morley Experiment* (ASG Chap. 34)
	Day 15.2	Discuss Chap. 34.
		Assignment: *Angular aberration* (Ex. 24.2), *Relative motion* (Ex. 34.3)
	Day 15.3*	Implications of the Michelson Morley experiment for Einstein's theory of special relativity.
		Assignment: TBA
	Day 15.4	Review for Final.
	Lab:	*Microwave laboratory* (Ex. 33.3)
Week 16 (Dec. 9 - 13): Final exams		