ELMHURST COLLEGE

PHYSICS 414-01 Modern Optics

(http://www.elmhurst.edu/~earls/phy414)

Fall Term, 2007 Earl C. Swallow

[This] finally determined me to give myself up first to inquire into the principle of the telescope, and then to consider the means by which I might compass the invention of a similar instrument, which after a little while I succeeded in doing, through deep study of the theory of Refraction; and I prepared a tube, at first of lead, in the ends of which I fitted two glass lenses, both plane on one side, but on the other side one spherically convex, and the other concave.

-- Galileo

Physics 414 is a one-semester course designed to provide students of physics and engineering with an understanding of physical and geometrical optics at an intermediate level, thus providing appropriate preparation for study in advanced engineering, for graduate study in physics, or for work in an area requiring a basic knowledge of optics. Preparation for this course should normally include (a) *Introductory (General) Physics* and *Electricity and Magnetism*; (b) sufficient mathematics to provide a good working knowledge of differential and integral calculus, including partial differentiation and vector calculus; (c) familiarity with complex numbers and matrix algebra; and (d) some knowledge of Fourier analysis. As the course progresses (I hope), portions of the needed background will be reviewed. Now isn't that a blast?

GOALS

Major Goals

1. To foster the ability to *learn independently*, increasing your capacity to acquire knowledge and understanding of new material on your own; for example, by reading books, magazines, newspapers, or scientific journals.

2. To help you acquire *knowledge* of physics -- particularly, but not exclusively, optics -- with some depth. Here the primary emphasis is on fundamental *concepts, relationships*, and *theories*, with secondary attention given to basic facts in the area of optics.

3. To promote the growth of *understanding*, so that you can analyze fairly complex situations, applying your knowledge of the principles of optics, in order to be able to make rational decisions.

4. To help you acquire numerous *specific skills* needed to make the other course goals meaningful and required for further study in physics or engineering. Examples of these are: the ability to make quick order-of-magnitude estimates ("guesstimates"); the capacity to "do" algebra efficiently and accurately; the ability to use complex notation for analyzing wave motion; the ability to use a simple physical system as a model for understanding the behavior of a more complex system.

5. To encourage critical *analytic thinking and logical reasoning* coupled with keen *physical intuition*, capacities which are of great value in formal scientific research and most other areas of life.

6. To provide you with the *pleasure* and *satisfaction* which come from achieving a mastery of optics: an elegant, powerful, and practical branch of physics.

Subsidiary Goals

1. To provide opportunities for *creative* use of skills and insights described above.

2. To deepen your *appreciation* of "how science works": how scientific concepts develop and are joined into a theoretical structure; and, most important, how these structures are tested, validated, and extended.

3. To promote the growth of some of the intellectual *attitudes, methods*, and *outlooks* which characterize a good physicist or engineer.

4. To *relate* some of the knowledge and understanding which come from the study of optics to other areas of intellectual activity, such as astronomy, space, biology, medicine, and perhaps even literature.

5. To encourage the development of the self-understanding which comes from a deeper understanding of the physical universe of which we are each a part.

6. To permit you to fulfill an important *requirement* for entry into creative work in contemporary physics or engineering.

RESOURCES

To aid us in achieving these goals, a number of important resources are available.

Texts

Introduction to Optics, 3rd edition, by Frank L. Pedrotti, Leno S. Pedrotti, and Leno M. Pedrotti; Pearson Prentice-Hall, 2007, is the "required" text. Also, see the list of references therein.

Introduction to Modern Optics by G. R. Fowles; Holt, Rinehart, Winston, 1975, is a concise text which matches this course well, but it is out of print. A low-priced Dover edition is now available.

Div, Grad, Curl, and All That by H. M. Schey; W. W. Norton, 1992, is a helpful paperback in the area of vector calculus. It is probably worth owning.

Use the library!

Handouts

You are reading the first of several (helpful?) handouts which will be provided during the semester.

Personal Assistance

This course is (or should be) a cooperative undertaking involving you, your fellow students, and me. I am happy to provide help outside the classroom when needed. As most of you know, my office is Room 012 in the Schaible Science Center (SC 012). Information about my office hours is posted on my office door. My office phone, (630)-617-3577, has 24-hour voice mail service. When leaving a voice mail message, it is best to make it more informative than a simple "call me." My fax number on campus is (630)-617-3735. My email address is earls@elmhurst.edu, and my web page is at http://www.elmhurst.edu/~earls . Normally, I read my email quite frequently, even when I'm not on campus. At home my telephone number is (630)-920-9570. I don't mind being called at home when there is a real need to do so, though reaching me there may not always be quick or easy. When I am working on research at Fermilab or elsewhere, I may also have appropriate telephone numbers posted on my office door.

Overview and Objectives

To guide you in your efforts, I will give you an overview, indicating important ideas and how they are interrelated, at the start of each unit of study (usually a chapter in the text). In some cases, I will provide fairly explicit learning objectives; but in all cases, the assigned problems provide an implicit list of objectives.

EVALUATION

Grades

Your grade in this course will be based on your achievement in 5 areas of work: (1) assigned problems; (2) quizzes; (3) the final exam; (4) laboratory work and reports; and (5) your term paper. Work within each of these individual areas will be graded on a (somewhat arbitrary) point system. Designating the **fraction** of the possible (assigned) points which you receive in area *i* by f_i, your final score in the course is given by the formula:

$$S = 100\% \, (0.25 \, f_1 + 0.30 \, f_2 + 0.15 \, f_3 + 0.15 \, f_4 + 0.15 \, f_5).$$

If you get a score of 65 or above, you are **assured** of at least a C in the course; 80 or above, a B; and 90 or above, an A (WOW!!). It is fairly easy to get a C with **good steady effort**, but you will need to really get your act together to earn an A or B. The following table summarizes the *meaning* of each letter grade in terms of level of academic achievement.

Letter Grade	Achievement Level	PHY-414 Score
A	**Excellent (or Superior)**	90% or above
B	**Above Average**	80% or above
C	Average	65% or above
D	Below Average (or Unsatisfactory But Passing)	below 65%
F	Failing	You don't want this.

The formula tells you the **minimum** grade you will receive in the course. Several conditions could cause you to receive a higher grade. In assigning grades, I may lower the "break points" for some or all of the letter grades if I consider that this will more accurately reflect the achievements of the class as a whole. I may also exercise the option of adjusting an individual grade upward in recognition of truly outstanding achievement in some particular area of work (*e.g.*, an outstanding term paper) or of exceptional interest, enthusiasm, or participation in class discussion, *etc*. *You are responsible for keeping track of your scores in order to estimate how you are doing as the course progresses.*

Problem Assignments

For each class meeting, you will be expected to turn in **three (3)** problems from the chapter being covered or from problems suggested in class. Extra credit can be obtained by solving up to three (3) additional problems per week. This extra credit will, in any case, be limited to 20%; *i.e.*, f_1 can be as high as 1.2, but not higher. Here's your chance to make hay! I will grade the problems on a basis of 10 points per problem with **some** possibility of partial credit, but if you really want to score, get it correct to the end. **There will be an "absolute" cut-off date for accepting problem solutions for each chapter shortly after we finish with the chapter.** Except in cases of illness, *etc.*, problems will not be accepted after this date. *Clearly this system is aimed at generating questions in class, so let's hear it gang!*

Problems are to be turned in on 8-1/2" x 11" notebook paper, preferably with lines. Only **one side** is to be used. Odd sizes of paper or paper torn from spiral notebooks **will not** be accepted. Pages are to be numbered and clearly marked with course number, your name, and the date. You should clearly show on the first page which problems are being attempted, and solutions should normally be in **numerical order**. The actual solution **must** be written out in an orderly, logical fashion so that your work can be followed easily; otherwise no partial credit (and sometimes no credit) can be given. It must, of course, also be legible, and final answers must be **clearly marked** ("put in a box"). In other words, you are expected to do a reasonably professional job of preparing your problem solutions (and all of your work for that matter)!

Quizzes

Three (3) "full-length" feature quizzes are scheduled to play at this theatre during the semester. In addition, there may be short impromptu quizzes at any time. You will be permitted the use of a single 8-1/2" x 11" sheet of notes on the scheduled quizzes – also a ruler, a calculator, a set of math tables, and/or a computer. You **will not** have the direct use of the text or a similar book.

Major concepts, techniques, and principles, and their applications, will be emphasized on the quizzes. Precision, clarity, and careful logical thinking will be stressed – not memorization. In addition to the usual problem-solving questions, there may be multiple choice, matching, or verbal response questions. These will usually deal with definitions of important concepts, technical terms, and units of measurement. You might be asked to state a basic principle or give an example to illustrate it. We may also consider the possibility of having one or more take-home tests.

Final Exam

A two-hour final exam will be given at the scheduled time. It will cover the entire semester's work, with some extra emphasis on material covered after the last scheduled quiz. The nature of the final, and the ground rules for it, will be essentially the same as the scheduled quizzes.

Term Paper

A term paper – roughly 10 pages in length (typed, double spaced) – is required for this course. Any topic related to optics is, in principle, acceptable. You may explore a topic given little or no coverage in the course proper, go more deeply into one that we are covering, discuss an interesting application of optics to another area of study, present the results of a special experiment you have performed, examine the history of an optical concept or principle, discuss a related set of theorems in optics, analyze an interesting system not discussed in detail in the text, *etc.* **The choice of topic is up to you,** but you will fare much better if the topic is fairly **narrow and well-defined**. (I will, of course, be glad to help and will make suggestions as the term progresses.) The important point is that you use and/or examine physics principles in the paper in a quantitative or semi-quantitative fashion. Assume that the audience for your paper is students who have completed a comparable course at another college.

You are to turn in one or two paragraphs describing your chosen topic (what you plan to write about it) on or before the "proposal" due date on the course schedule. This proposal should include a list of at least three references which you plan to use in preparing your paper. Please note the due date for the paper itself, which is somewhat before the end of the semester. It is important to have work on your paper "behind you" well before final exam week arrives. This is to be a "for real" term paper with sentences, paragraphs, **references to primary sources, citation of references**, and all that jazz. (Imagine that I plan to take it to the English Department for a grade on presentation.) Clear expression, logical organization, and proper syntax and grammar are all essential! I will provide an example of a particularly simple, easy-to-use format for references, but any standard format is acceptable.

Note: please don't waste your money on a plastic cover or binder for your paper – simply staple it in the upper left corner. You are also strongly urged to use a computer **word processor** to prepare your term paper and other "essay" assignments. This facilitates correction and revision as well as providing you with broadly applicable experience using today's technology.

The following books may give you ideas for term paper topics (if you look at them):

"The Flying Circus of Physics" by J. Walker (John Wiley & Sons).

"Fundamentals of Optics" by F. A. Jenkins and H. E. White (McGraw Hill). This is a very traditional text at the level of Physics 414.

"Optics" by E. Hecht and A. Zajac (Addison-Wesley). This is another text frequently used for courses at the level of Physics 414.

"The Feynman Lectures on Physics" by R. P. Feynman, *et al.* (Addison-Wesley).

"Principles of Optics" by M. Born and E. Wolf (Macmillan). This is the classic graduate-level text in optics – frequently used as a professional reference.

Here are a few "off the cuff" ideas to get you started: the optics of Lucretius (or Aristotle, or ...) from a modern perspective; experimental evidence for the electromagnetic nature of light (*á la* Hertz); the optics of human vision or some aspect thereof; optics in photography; optics and relativity; Sagnac's Experiment; history of the measurement of the speed of light; optics of charged particle beams; the optics of your favorite mirage; optics of a pinhole camera; optics of the rainbow; matrix methods in optics; non-linear optics.

Laboratories

Your laboratory score will be based primarily on the written laboratory material turned in for each activity. Clarity of thought and expression, completeness, organization, and quality of error analysis are very important in the lab "reports." They need to be done in a way that would make it possible for someone else to understand and replicate your work after reading them. Better yet, think in terms of having to do that with someone else's experiment. Then write what you would like to have for a description. Computer activities will be included as well as more traditional lab projects. The organization of the labs will be quite informal with plenty of freedom to choose your path. We will discuss this further as the course progresses.

ACCOMMODATIONS

The College will make reasonable accommodations for persons with documented disabilities. If you have a disability that may have some impact on your work in this course, please contact (630)-617-3753.

ATTENDANCE

In accord with general College policy as stated in the Elmhurst College Bulletin (*a.k.a.* the College Catalog), regular class attendance is expected and is a requirement for receiving a passing grade in the course. Class participation and lab work are essential parts of the course and contribute to your grade. If you must miss a course meeting, you must also take the responsibility for completing any assigned work for that day. Make-up tests will be given only in very special cases. (Anyone who dies during the course will be given one – and only one – make-up test.) Students who miss more than an occasional class invariably find it **very difficult** to earn a satisfactory grade.

WARNING

Academic Honesty is Essential! Academic honesty is a requirement for receiving a passing grade in the course. In your term paper, tests, problem solutions, *etc.*, **do not** represent the work of someone else as your own. Any form of cheating is a serious offense, and the **normal penalty** is a **failing grade in the course for all involved**. This includes any student(s) who actually did the work! More severe action can and will be taken in extreme cases. In any case, your reputation will be substantially damaged. I am obligated to report any instance of academic dishonesty to both the Vice President for Academic Affairs and the Dean of Students.

You are expected to become familiar with the general College policy on Academic Integrity as stated in the E-Book. Printed copies may be obtained from the Office of the Dean of Students, Room 240 in the Frick Center. The E-Book is also available online through the Elmhurst College web site at
< http://media.elmhurst.edu/documents/EB_2007.pdf >. The content of the E-Book applies to this course. I will also provide you with a copy of the Natural Sciences Division policy statement on this subject. If you have questions about this matter, please discuss them with me.

COURSE EVALUATION

Near the end of the semester, you will be given the opportunity to provide a confidential evaluation of various aspects of this course, including my performance as an instructor. If you have *suggestions for improvements*, they will be even more useful if they are made earlier than the formal evaluation. So please talk to me about them, send me an email note, or if you wish anonymity, slip a note under my office door or send it to me *via* campus mail (Campus Box #3).