ELMHURST COLLEGE

PHYSICS 311 Analytical Mechanics

(http://www.elmhurst.edu/~earls/phy311)

Fall Semester, 2008 **Earl C. Swallow**

For whenever bodies fall through water and thin air, they must quicken their descents in proportion to their weights, because the body of water and subtle nature of air cannot retard everything in equal degree, but more readily give way, overpowered by the heavier: on the other hand empty void cannot offer resistance to anything in any direction at any time, but must, as its nature craves, continually give way; and for this reason all things must be moved and born along with equal velocity though of unequal weights through the unresisting void.

– Lucretius

Physics 311 is a one-semester course designed to provide students of physics and engineering with an understanding of mechanics at an intermediate level, preparing them for the study of advanced engineering mechanics or a typical graduate-level course in mechanics (á la *Classical Mechanics* by H. Goldstein). Preparation for this course should normally include introductory physics as well as sufficient mathematical background to provide a good working knowledge of differential and integral calculus, familiarity with matrix algebra, and some knowledge of ordinary differential equations. This course will serve to strengthen your mathematical skills in these areas by allowing you to confront concrete physical problems of intermediate complexity and fundamental significance. Your primary activity in dealing with mechanics problems will be translating physical situations into algebraic and/or differential equations and then using relatively straightforward techniques to solve the resulting equations. As the course progresses, much of the needed math will be reviewed.

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, mechanics – with some depth. Here the primary emphasis is on fundamental *concepts*, *relationships*, and *theories*, with secondary attention given to simple facts in the area of mechanics.

3. To promote the growth of *understanding*, so that you can analyze fairly complex situations, applying your knowledge of the principles of mechanics, 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 calculus with confidence; the ability to interpret and solve (*i.e.*, obtain solutions for) ordinary differential equations; 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 mechanics: 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 mechanics to other areas of intellectual activity, such as astronomy, space science, 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

Analytical Mechanics by Grant R. Fowles and George L. Cassidy; Brooks/Cole division of Thomson Learning, Inc., 2005 (7^{th} edition), is the required text.

Schaum"s Outline of Theory & Problems of Theoretical Mechanics by Murray R Spiegel, McGraw-Hill, 1980, provides worked examples and condensed presentation of many topics.

Schaum's Outline of Advanced Mathematics for Engineers and Scientists by Murray R Spiegel, McGraw-Hill, 1971, can be a big help with many applied math topics.

Classical Dynamics of Particles and Systems by Stephen T. Thornton and Jerry B. Marion; Brooks Cole, 2003, could also be of considerable help to you. This comprehensive book contains good math appendices and a substantial bibliography.

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 you probably know, my office is Room 012 in the Schaible Science Center (SC 012). Please stop by and visit. 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 fairly 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

Your grade in this course will be based on your achievement in five areas of work: (1) assigned problems; (2) quizzes; (3) the final exam; (4) laboratory project(s); and (5) your term paper. Work in 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:

$$S = 100\% \, (0.25 \, f_1 + 0.30 \, f_2 + 0.20 \, f_3 + 0.10 \, f_4 + 0.15 \, f_5).$$

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 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-311 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.*, late problems **will not** be accepted. *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, and 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 Examination

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 major quizzes.

Term Paper

A term paper – roughly 10 pages (typed, double spaced) in length – is required for this course. Any topic related to mechanics is, in principle, acceptable. You can 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 mechanics to another area of study, present the results of a special experiment you have performed, examine the history of a mechanics concept or principle, discuss a related set of theorems in mechanics, analyze a system not discussed in detail in the text, *etc*. **The choice of a 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 make suggestions.) The important point is that you use and/or discuss 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 four (4) references which you plan to use in preparing your paper. You should also note that I must receive a preliminary draft of the paper a reasonable time before the final version is due. **Each of these steps is essential to your learning from this work and to my accepting the final paper for credit in the course.**

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 our final exam week arrives. This is to be a "for real" term paper with sentences, paragraphs, **reference to primary sources**, **citation of references**, and all that jazz. (Imagine that I plan to take it to the English Department for a grade.) Clear expression, logical organization, and proper syntax and grammar are essential! I will provide an example of a particularly simple, easy-to-use format for references, but any standard format is acceptable.

Note: I strongly urge that you submit the proposal, draft, and paper as email attachments in WordPerfect (.wpd) or MS-Word (.doc) file format.

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).

"Introduction to Theoretical Mechanics" by R. A. Becker (McGraw-Hill).

"Classical Mechanics" by H. Goldstein (Addison-Wesley).

"Physics for the Life Sciences" by A. H. Cromer (McGraw-Hill).

"Classical Dynamics of Particles and Systems" by Jerry B. Marion (Academic Press).

"Div, Grad, Curl, and All That" by H. M. Schey (W. W. Norton).

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

Here are a few "off the cuff" ideas to get you started: the mechanics of Lucretius from a modern perspective; the mechanics of Aristotle from a modern perspective, Galileo's contribution to mechanics; the origins of vector analysis; the mechanics of human motion; the mechanics of your favorite sport; the mechanics of auto testing; to brake or to turn (see "Flying Circus"); the energetics of locomotion; the mechanics of "Star Wars" (or some other piece of imaginative fiction); the parallel axis theorem and a refined analysis of the (almost) simple pendulum; the twin paradox in relativity; electrodynamics with four-vectors; from classical mechanics to general relativity; the mechanics of continuous media; the mechanics of bridges; scaling laws in mechanical analysis; basic mechanical units and the speed of light; precision measurements of g with simple pendulums and falling objects.

Laboratory Projects

While this is primarily an analytic course, I will assign you some experimental and computational laboratory projects to be carried out during the semester. You may also obtain extra credit with all of the related benefits to your intellect and your course grade by doing an extra project. This can be a carefully done experiment of your choice or a particularly interesting and challenging computational activity. Some possibilities are: a precision measurement of g; the Cavendish Balance experiment; determination of the inertia tensor of an irregular object; the large-angle behavior of a simple pendulum; coupled harmonic oscillators; the nonlinear harmonic oscillator; any idea of your own connected with mechanics. In general, I will expect a careful series of experiments with thorough analysis of systematic and random errors (or well-documented work in numerical analysis and computer program development). You should talk to me further about this if you have a project idea.

ACCOMMODATIONS

The College will make reasonable accommodations for persons with documented disabilities. If you believe that you have a disability that may have some impact on your work in this course, please contact the College *Disability Services Provider* Ms. Maureen Connolly at (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 this course. Class participation is an essential part of the course and contributes 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 this 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 the 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 instances 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. The E-Book is available online through the "Information for Elmhurst Students" section of the Elmhurst College web site. 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 of even more use 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 put it in my campus mailbox (Campus Box #3). The course you save could be your own!