Teaching Portfolio

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Contents

1 Teaching Philosophy

As a teacher, I have two important functions. The first is to guide students through the relevant body of knowledge via a manageable route. I try to develop a broad map of the world of the subject, draw attention its more important and interesting features, and leave many of the details to the students. With good guidance, the journey can be provocative, stimulating, and relevant to the students' lives.

The second function is to serve as a cultural ambassador for the subject. Students may wonder why anyone would be interested in the subject, whether it would ever be possible for them to become proficient, and how this would happen. I am one of the few people they encounter who is well rooted in the culture of my subject and able to practice it effectively. When I show students how to solve a physics problem, I am not just demonstrating the relevant techniques but also that it is possible in the first place. One of my roles is to interact sensitively with students so as to ease the process of acculturation. I hope to cultivate a love for learning in my students so that years after graduating they will be thrilled by the prospect of repeating this journey through new branches of knowledge.

1.1 Teaching Physics

Physics students have to develop both an understanding of the subject's conceptual framework and a mastery of the relevant technical skills. In my experience, the latter is overemphasized. One of my main goals in teaching is to balance the conceptual and technical aspects of the subject. For example, in my quantum mechanics course I introduce the key concepts in the context of spin-1/2 particles, for which the mathematics is much simpler than for the more traditionally taught quantum mechanical systems with a position degree of freedom. Thus I can repeatedly discuss the basic physical concepts of quantum mechanics before dealing with the technicalities of solving complicated differential equations.

Where feasible, I mix formal lectures with interactive group exercises or demonstrations and laboratory exercises. I have developed such exercises, some involving computer simulations, for my sophomore level modern physics courses. For some introductory level courses for non-majors, I have borrowed from the "workshop" approach, in which laboratory activities and lectures are mixed in extended class sessions. I most enjoy working one-on-one with students and maintain extensive, and highly rated, office hours.

2 Teaching and Undergraduate Research Experience

I have taught numerous physics courses from the freshman to the graduate level. Although I am a theoretical physicist, I enjoy teaching laboratories and my experience in this regard includes freshman and upper division laboratories and also an introductory level astronomy laboratory. I have supervised several undergraduate research and independent study projects, one of which resulted in a publication in a peer-reviewed journal, in my field. Appendices A.2 to A.5 describe the courses that I have taught. Detailed information about my involvement in undergraduate research can be found in appendix A.6.

I have instructed students with a wide variety of backgrounds and interests. These include liberal arts majors entering physics courses with limited mathematical and technical skills, students intending to major in other sciences, physics majors and graduate students in the sciences. I have taught students from many cultural and social backgrounds. The classes which I taught in South Africa included students who came from a large cultural spectrum. This included students who faced language and traditional academic barriers. In every instance I have made an effort to communicate physics in ways suitable to the students' experience, background and interests.

During my studies I have taken courses covering the core physics curriculum. I have conducted both theoretical and experimental research in several branches of physics. I have also taken mathematics courses up to and including the graduate level and consider myself sufficiently familiar with aspects of that subject to be able to teach these.

3 Methodology

3.1 Pedagogy

Most courses that I have taught are based on lectures plus classroom tutorials and homework assignments. The syllabus for a sophomore course that I taught, provided in appendix B.1, illustrates the typical structure of my courses.

I have departed significantly from this for certain introductory courses offered at Bucknell University and the University of Texas. These were structured to allow for substantial student involvement and collaborative learning during classes and hence greater flexibility in the techniques which I used. For example, the Physical Science courses that were offered at the University of Texas had class periods of two hours, allowing me to mix lecture, demonstration and laboratory components within each class meeting and adopt a "workshop" approach to teaching the material.

I strongly encourage students in my courses to consult me outside the classroom about their difficulties with the course material and I maintain extensive office hours. This is my favorite way of conveying subject matter and my office hours have been very popular. Students in my courses consistently rate office visits very highly.

3.1.1 Teaching Methods and Materials

I use formal lectures, classroom demonstrations, reading assignments, homework assignments, one-on-one discussions, classroom exercises, and experiments carried out by the students. Most courses that I have taught have been based on formal lectures supplemented by group exercises done during class.

For some introductory level courses I have borrowed from the "discovery method" or "workshop method"; here the students perform an experiment or demonstration before encountering a formal theoretical explanation of the material. This approach leaves some students "in the dark" initially although their newly acquired familiarity with the phenomena is advantageous when I present a theoretical description to them.

When possible, I conduct group exercises during regular class meetings. Students work in small groups, with my guidance, on exercises illustrating key points in the subject. Group members are encouraged to discuss the exercise among themselves. This approach appears to keep the students engaged and actively discussing and thinking about the subject matter. Some of these exercises offer practice with standard analytical tools using pencil and paper; others develop computer simulations to illustrate interesting physical situations. An example, which I developed, is included in appendix B.2.

Although I generally follow established texts in my courses, I prefer to develop my own homework exercises, which I find are better suited to my teaching approach. An example can be found in appendix B.2.

Additional examples of my own lecture notes, laboratory packages, classroom exercises and homework assignments are available on request.

3.1.2 Introducing Students to New Technical Material

Regardless of the method used, I endeavor to approach the material from student's present level of experience and introduce it in the simplest terms. This is uncommon in physics, whose language can become highly abstract. Students often become quite adept at mathematical manipulations and other abstractions with little related physical understanding. When teaching introductory courses, I try to motivate the material with familiar physical examples or analogies and use everyday language to explain the notions behind the abstractions and technical terms. For example, most students can manipulate the technical definition of voltage involving work and charge, but this provides them with a limited conceptual understanding. I prefer to introduce the idea by saying that, for a battery at least, voltage gives an idea of the strength with which the battery pushes and, roughly, is analogous to the idea of force, with which they are already familiar.

3.2 Evaluation of Student Learning

I evaluate the students' understanding of the course material via their performance on regular assignments and examinations. The technical nature of physics warrants frequent exercises and I assign homework at least once per week. This is partly to assign grades, which are composed from scores obtained on the constituent assignments with a bias towards those on which they work alone, such as examinations. It also provides feedback about how effectively I have communicated the subject matter. I have occasionally devised "remedial" exercises to attempt to clarify any misconceptions that the students may have developed.

An example of a homework assignment can be found in appendix B.2. Examples of quizzes and final exams are available on request.

4 Teaching Effectiveness

4.1 Assessment of Teaching Effectiveness

I use standardized tests, institutional faculty reviews, institutional course evaluations and student comments to determine my teaching effectiveness, in addition to assessing how the students are grasping the material.

I have used the Force Concept Inventory (FCI) and Conceptual Survey of Electricity and Magnetism (CSEM) to gauge learning in the introductory freshman physics courses that I have taught. These are administered at the beginning and end of the semesters and performance is assessed via normalized gains.

Standardized institutional course evaluations provide the broadest assessment of my teaching effectiveness; selected student comments and tables of the scores for courses that I have taught are included in appendix C.

While at Bucknell University, I underwent the standard second-year faculty review. Two faculty members attended classes that I taught and reviewed my teaching evaluations. They commented on my teaching style and suggested possible modifications, which I will consider in the future. A copy of their letter of recommendation to the university administration is included.

Besides formal evaluations, I can also assess aspects of my effectiveness by observing how the students respond in class and deal with assignments, quizzes and exams. I have frequently made modifications to the presentation of the course material or assignments based on their difficulties and concerns.

4.2 Improvement of Teaching Effectiveness

I have attended the AAPT New Physics Faculty workshop and have incorporated some of the approaches discussed there into my courses.

I participated in the Physics 398T course offered at the University of Texas at Austin. This is a semester-long course intended to enhance the skills of teaching assistants and assistant instructors in the University's physics department.

I pay close attention to the results of my teaching evaluations described above in order to continually improve. I have collaborated with other faculty in teaching large introductory courses at Bucknell University and have observed their approaches and this has given me new ideas to incorporate into my own teaching.

5 Reflection

I find teaching physics very rewarding and enjoy working with students and my colleagues. One of the biggest rewards is to witness the growth of students' intellectual capabilities and interest, and it is satisfying to contribute to this. I also enjoy the personal interaction that accompanies teaching and this has been a welcome change from the often solitary nature of my previous career in research.

For me, it is challenging but always stimulating and fulfilling to convey physics clearly and in a way that excites my students. For instance, I constantly attempt to prepare assignments which have a meaningful goal beyond merely building technical skills and are interesting and relevant to real physics situations. Also, to sustain their interest in physics, I sometimes introduce topics from currently popular research areas. For example, I describe a simple quantum cryptography scheme in my sophomore level modern physics course, and this is one of the most stimulating lectures in that course. Such ventures often require me to learn topics with which I am unfamiliar and, since I enjoy learning myself, this is always a pleasure. Even when I have a grasp of a topic, there remains the challenging task of explaining the essential ideas clearly at my students' level. I hope to continue such exploration throughout my career in teaching.

I have certainly experienced minor routine frustrations: student academic and social maturity levels can stretch my patience, and disciplinary matters are never pleasant. My biggest difficulty has been to find a suitable level when presenting subject matter. I think that I generally teach at an appropriate level, but there have been times when my expectations clearly exceeded the students' abilities. I still have to remind myself frequently to consider their capabilities.

I have been fortunate to teach courses with small class sizes, although most have been in a traditional lecture format. I would like to experiment further with interactive courses which mix formal lectures with assignments or experiments; certainly at the introductory level, but possibly also for courses beyond the freshman level. I also look forward to teaching parts of the standard physics curriculum that I have not yet taught, such as classical mechanics or thermodynamics, as well as developing and teaching new introductory level courses for non-majors. I have some ideas for new courses for majors; for example, physics and information or a discussion course on the seminal modern physics experiments. Finally, I hope to be able to develop some of my lecture notes and course materials to a level where they are suitable for publication.

Appendices

A Teaching and Undergraduate Research Activities

A.1 Courses Taught: Mesa State College

Course	Semesters	Level	Text	Comments
Phys 100: Concepts of Physics	Spring 07 Spring 08 Spring 09	Fresh.	Alan P. Lightman, *Great Ideas in Physics,* 3rd ed., McGraw-Hill (2000), Art Hobson *Physics: Concepts and Connections*, 4th ed., Pearson Prentice Hall (2007).	– Physics survey course for non-science majors. – 17 to 45 students. – Lecture/homework format.
Phys 111: General Physics	Fall 06 Fall 07 Fall 08 Fall 09	Fresh.	R. A. Serway, J. S. Faughn, C. Vuille, and C. A. Bennett, *College Physics,* Thomson Brooks/Cole (2006). J. S. Walker, *Physics,* 4th ed., Addison-Wesley (2009).	– First semester algebra based physics course for science majors. – 35 to 45 students. – Lecture/discussion/homework format. – **ConcepTests** in most class meetings.
Phys 111L: General Physics (Laboratory)	Fall 06 Fall 07 Fall 08 Fall 09	Fresh.	Laboratory packages developed by myself.	– Laboratories accompanying first semester algebra based introductory course for science majors. – 15 to 20 students.
Phys 112L: General Physics (Laboratory)	Spring 08	Fresh.	Laboratory packages developed by myself.	– Laboratories accompanying second semester algebra based introductory course for science majors. – 15 to 20 students.
Phys 132: Electromagnetism and Optics	Spring 07 Spring 08 Spring 09	Fresh.	K. Cummings, P. W. Laws, E. F. Redish, and P. J. Cooney,, *Understanding Physics,* Wiley (2004).	– Second semester calculus based physics course for science majors. – 17 to 23 students. – Lecture/discussion/homework format with **group exercises** in some classes. – **ConcepTests** in most class meetings. – Several **Cooperative Group Problem Solving** sessions.
Phys 132L: Electromagnetism and Optics (Laboratory)	Spring 07 Spring 08 Sprin 09	Fresh.	Laboratory packages developed by myself.	– Laboratories accompanying second semester calculus based introductory course for science majors. – 8 to 20 students.

Course	Semesters	Level	Text	Comments
Phys 230: Intermediate Dynamics	Fall 09	Soph.	K. Cummings, P. W. Laws, E. F. Redish, and P. J. Cooney,, *Understanding Physics,* Wiley (2004). A. P. French, *Vibrations and Waves,* Norton (1971). E. F. Taylor, *Spacetime Physics,* 2nd ed., W. H. Freeman (1992).	– Calculus based introducory thermodynamics, intermediate waves and vibrations, special relativity. – 2 students. – Lecture/homework format with **group exercises** in some classes.
Phys 252: Intermediate Laboratory	Fall 08	Soph.	J. R. Taylor, *An Introduction to Error Analysis,* 2nd ed., University Science (1997).	– Sophomore laboratory for physics majors. – 7 students.
Phys 311: Electromagnetic Theory	Fall 07 Fall 09	Jr. Sr.	D. J. Griffiths, *Introduction to Electrodynamics,* 3rd ed., Prentice Hall (1999).	– Upper division electromagnetism. – 3 and 4 students. – Lecture/homework format.
Phys 321: Quantum Theory I	Fall 06 Fall 07 Fall 08	Jr., Sr.	J. S. Townsend, *A Modern Approach to Quantum Mechanics,* University Science Books, Sausalito, CA (2000).	– Upper division quantum mechanics. – 4 to 6 students. – Lecture/homework format.
Phys 422: Quantum Theory II	Spring 07 Spring 08 Spring 09	Jr., Sr.	J. S. Townsend, *A Modern Approach to Quantum Mechanics,* University Science Books, Sausalito, CA (2000).	– Upper division quantum mechanics (second semester). – 2 to 4 students. – Lecture/homework format.

A.2 Courses Taught: Bucknell University

Course	Semesters	Level	Text	Comments
Astronomy 101: (Laboratory)	Fall 05	Fresh.	Departmental laboratory manual.	– Laboratory accompanying Astronomy 101. – 24 students.
Phys 141: Secrets of the Universe	Fall 03	Fresh.	N. Spielberg and B. D. Anderson, *Seven Ideas that Shook the Universe,* 2nd ed., Wiley (1995).	– Physical Science survey course for non-science majors. – 24 students. – Lecture/homework format with **group exercises** in some classes. – Laboratories (**“discovery” approach**) integrated with lectures.
Phys 141: Secrets of the Universe (Laboratory)	Spring 04	Fresh.	Departmental laboratory manual.	– Laboratory accompanying Phys 141. – 15 students.
Phys 211/212: Classical and Modern Physics (Problem Session)	Spring 05 Spring 04 Fall 05 Fall 04 Fall 03	Fresh.	P. A. Tipler and G. Mosca, *Physics for Scientists and Engineers,* 5th ed., W. H. Freeman (2004).	– **Team taught** problem sessions accompanying calculus based introductory course for science majors. – 15 to 30 students. – Group work on pre-assigned problems.
Phys 211/212: Classical and Modern Physics (Laboratory)	Spring06 Spring 05 Spring 04 Fall 04 Fall 03	Fresh.	Departmental laboratory manual.	– **Team taught** laboratories accompanying calculus based introductory course for science majors. – Lab **administrator** (Spring 06). – 25 to 28 students.
Phys 222: Wave Mechanics and Quantum Physics	Spring 05 Spring 04	Soph.	A. P. French, *Vibrations and Waves,* Norton (1971). P. A. Tipler and R. A. Llewellyn, *Modern Physics,* 4th ed., W. H. Freeman (2003).	– Introductory modern physics and classical waves. – 13 to 30 students. – Lecture/homework format with **group exercises** in some classes.

Course	Semesters	Level	Text	Comments
Phys 309: Condensed Matter Physics	Spring 06	Jr., Sr.	M. Ali Omar, *Elementary Solid State Physics*, Addison-Wesley (1993).	– Upper division condensed matter physics. – 8 students. – Lecture/homework/term paper format.
Phys 329: Junior Laboratory	Fall 05	Jr.	Assorted laboratory manuals.	– **Team taught** upper division physics laboratory. – 11 students.
Phys 332: Quantum Mechanics	Fall 05 Fall 04	Jr., Sr.	J. S. Townsend, *A Modern Approach to Quantum Mechanics,* University Science Books, Sausalito, CA (2000).	– Upper division quantum mechanics. – 8 to 13 students. – Lecture/homework format.

A.3 Courses Taught: Carnegie Mellon University

Course	Semesters	Level	Text	Comments
Physics 33-658: Quantum Information and Quantum Computation	Spring 03 Spring 02 Spring 01	Grad., Sr.	M. A. Nielsen and I. L. Chaung *Quantum Computation and Quantum Information,* Cambridge University Press (2000).	– Upper division/graduate quantum information and quantum computation course. – 15 to 30 students. – **Team taught** with Prof. R. B. Griffiths.

A.4 Courses Taught: University of Texas at Austin

Course	Semesters	Level	Text	Comments
PS 303/304: Physical Science	Fall 93 to Fall 97	Fresh.	P. G. Hewitt, *Conceptual Physics*, Addison Wesley.	– Physical Science survey course for non-science majors. – 24 students. – Integrated lecture/ laboratory format. – **"Workshop" approach**.
Phys 102M/102N: General Physics (Laboratory)	Fall 91 to Summer 93	Fresh.	Departmental laboratory manual.	– **Team taught** laboratories accompanying algebra based introductory course for science majors. – 20 students.

A.5 Courses Taught: Rhodes University

Course	Semesters	Level	Text	Comments
Physics 1P/IL	1989 to 1991	Fresh.	—	– **Team taught** problem sessions accompanying calculus based introductory course for science majors. – 15 to 30 students. – Group work on pre-assigned problems.

A.6 Independent Study and Undergraduate Research

Physics and mathematics majors at Mesa State College are required to take senior research courses. Students in these courses work on a research project under the supervision of one or more faculty members. Students are expected to produce a written report and give an oral presentation at the end of the research courses.

Student: Allison Cormier (Fall 2008-Spring 2009).

Project: Wave and particle properties of light in the Mach-Zehnder interferometer. **(Experiment)**

Structure: Allison and Demetri Falsone constructed a Mach-Zehnder interferometer from standard optical components. Allison designed and built a controller circuit for a Hamamatsu photomultiplier module (PMT) and used this PMT to detect very low intensity light emerging from the interferometer. She compared single sweeps across the fringe pattern with the averages of many sweeps across the fringe pattern.

Results: The circuit developed by Allison worked. The data obtained with a single sweep was consistent with particle-like behavior of light and that with multiple sweeps was consistent with a wave description of light.

Output: Allison presented her research as part of the physics seminar series and passed the course.

Student: Demetri Falsone (Fall 2008-Spring 2009).

Project: Polarization interference in the Mach-Zehnder interferometer. **(Experiment)**

Structure: Demetri and Allison Cormier constructed a Mach-Zehnder interferometer from standard optical components. The first part of Demetri's project involved managing and calibrating a piezo-transducer stage. The second part involved inserting polarization filters into the arms of the interferometer and predicting and measuring (using photodiode detectors) the interference fringe visibility as a function of the relative angle between the polarization filters.

Results: Demetri developed an analytical relationship between fringe visibility and polarization angles and this was consistent with the experimental data that he obtained.

Output: Demetri presented his research as part of the physics seminar series and passed the course.

Student:	Krystyna Dillard-Crawford (Spring 2007)
Project:	Formulation of the quantum theory of light. **(Theory)**
Structure:	Krystyna investigated the derivation of the standard quantum mechanical description of light. The derivation described electromagnetic fields in a cavity with no interactions with matter. The starting point was the requirement that the observables for the electric and magnetic fields of any single cavity mode must be such that their expectation values satisfy Maxwell's equations.
Results:	Krystyna's work yielded a reasonable derivation of the standard quantum description of electromagnetic fields which avoids the need to use scalar and vector electromagnetic potentials and clearly produces the classical description by an averaging process.
Output:	Krystyna presented her research as part of the physics seminar series and passed the course.

Student:	Camella Nielsen (Fall 2006) (MSC mathematics major jointly supervised with Warren MacEvoy).
Project:	Classical computing with quantum computing devices. **(Theory)**
Structure:	Camella investigated the processes by which any classical computation may be preformed using standard quantum computing gates. I guided her through portions of the relevant quantum computing texts, participated in weekly meetings and helped her prepare her final presentation.
Results:	Camella found a general method for performing any classical computation using quantum computing gates.
Output:	Camella presented her research as part of the Mathematics Brown Bag seminar series and passed the course.

Bucknell University encourages undergraduates to undertake research or independent study with faculty members during the regular academic year. Furthermore, the Physics department at Bucknell University maintains a NSF (National Science Foundation) REU (Research Experience for Undergraduates) program, for which qualified students are recruited from undergraduate institutions around the United States.

During the 2005/06 academic year I **supervised one student (Tomek Kott)** for his honors thesis research in quantum computing. During the Spring of 2005 he did an independent study in quantum computing with me.

During the summer of 2005 I **supervised one student (Brandon Anderson, UT-Dallas) as part of Bucknell's REU program.** He conducted research in theoretical aspects quantum computing and quantum algorithms.

Student: Tomek Kott (Spring 2005 - Spring 2006).

Project: Performance of quantum search algorithms on ensemble quantum computing devices. **(Theory)**

Structure: Tomek did his honors thesis and an independent study project under my supervision. During the independent study phase he worked through portions of a standard graduate level text on quantum computing. For his honors thesis, Tomek investigated the performance of quantum search algorithms on ensemble quantum computers. Much of his work involved generating data numerically, using standard software. He subsequently used these to develop analytical approaches to the issue and he established bounds on the parameters describing ensemble quantum computers such that they would reliably outperform their classical competitors.

Results: Tomek produced numerical data which established bounds on the relative performance of the algorithms. These generated some analytical results.

Output: Tomek defended his thesis in April 2006. Publication in Phys. Rev. A **77**, 052314 (2008). Work presented at the 2006 APS March meeting.

Student: Brandon Anderson (Summer 2005).

Project: Performance of the ensemble Deutsch-Jozsa quantum algorithm compared to classical probabilistic algorithms. **(Theory)**

Structure: The REU program lasted ten weeks, during which time Brandon worked under my close supervision. Brandon's program began with two weeks of independent study using a graduate level text in quantum computing and was followed by closely supervised investigation of statistical aspects of the Deutsch-Jozsa algorithm. The work was mostly analytical although it involved some simple numerical data production using standard software.

Results: Brandon found a simple characterization of the relative performance of these algorithms.

Output: Publication in Phys. Rev. A. **72**, 042337 (2005) and oral presentation at the 2006 APS March meeting.

Undergraduate physics students at Carnegie Mellon are encouraged to undertake physics research projects for the duration of one semester. As part of this program, I **supervised two students.**

Students:	Kevin Inderhees (Fall 2001) and Rory Perkins (Spring 2002).
Project:	Pulse sequence design for nuclear magnetic resonance (NMR) quantum computation, using **analytical and numerical approaches**. **(Theory)**
Structure:	I met weekly with each student. Initially I laid out the essential background material. After sufficient progress, I directed each student to apply his knowledge to the project and assigned specific **numerical computation tasks.**
Output:	**Numerical tools** needed to model internal dynamical effects among the nuclear spins during application of external pulses. Each student prepared and **presented a poster** describing their research at a departmental conference.

B Teaching Materials

B.1 First Day Handout and Syllabus

The following is the first day handout and syllabus for Physics 132 taught at Mesa State College.

ELECTROMAGNETISM and OPTICS

Phys 132 Spring 2009

Instructor:	Professor David Collins
Office:	Wubben 184
Phone:	248-1787
email:	dacollin@mesastate.edu
Office Hours:	TBA
Class Meetings:	MWThF 9:00-9:50am, Houston 129
Course Website:	http://www.mesastate.edu/~dacollin/teaching/2009Spring/Phys132 /index.html
Required Text:	K. Cummings, P. W. Laws, E. F. Redish, and P. J. Cooney, *Understanding Physics,,* Parts 3 and 4, Wiley (2004).
Prerequisites:	Phys 131, Phys131L, Math 152

Overview

The theory of electromagnetism was one of the great accomplishments of 19^{th} century physics and, built on the general framework of Newton's Laws of mechanics, unified and explained a large range of phenomena associated with charged objects, currents and magnets. By the end of the century the theory had evolved to a compact and aesthetically pleasing form, which is still widely used.

One of the predictions of the theory is the existence of electromagnetic waves, which offer a complete description of the classical properties of light. Optics is the study of these properties. Some, such as reflection, refraction and image production using lenses are readily apparent. However, optics has consistently yielded surprising phenomena, which often provide fundamental insights into the nature of the physical world.

Electromagnetism is arguably the most important way of probing and learning about the physical world. Almost all modern scientific laboratories and the experiments conducted in them would be impossible to imagine without the extensive use electronic equipment. Much of what is learned in these circumstances hinges on understanding the electromagnetic interaction between the equipment and the physical system that is being observed.

Electromagnetism has made possible much of the technology that is characteristic of the industrialized world: electric appliances, electronics, electric motors, power generation, computers, wireless communication, etc,. . . .

Phys 132 aims to introduce you to the phenomena of electricity and magnetism and optics and the theories which describe them as well as some of their practical applications.

The course will cover the following topics:

1. Electric charge, fields, potentials and currents.
2. Electric circuits.
3. Magnetic fields, interaction with currents.
4. Maxwell's equations, electromagnetic waves.
5. Geometric optics.
6. Interference and diffraction.

Objectives

This course is part of MSC's general education curriculum. Course content is designed to meet the following objectives of MSC's general education program:

1. Understand the structure and discipline of mathematical thought and its use in problem-solving.
2. Have knowledge of the natural world and an understanding of scientific methods.

Course Structure

The course meets four times per week. The Monday, Wednesday and Friday meetings will be in lecture format. You will be expected to read the relevant sections of the text beforehand and attempt designated exercises in the text.

The Thursday meeting will consist of a discussion session during which you will work in small groups (with the instructor's help) on assigned problems. You will be expected to attempt the assigned problems **before the Thursday class meeting.** There will be a 10 minute quiz covering the material at the end of the discussion session.

Assignments, Quizzes and Exams

1. **Homework assignments:** Homework assignments will be due **each week in class on Mondays.** It is in your best interests to work by yourself on the homework problems but collaboration is acceptable. You can discuss the broad outlines of problem solutions with your colleagues but must write your final solutions independently. You are also encouraged to consult me for help with homework problems.

2. **Quizzes:** There will be a short quiz at the end of each of each Thursday discussion session.

3. **Group Exercises:** There will be a group exercise on the Wednesday prior to each of the three class exams.

4. **Class Exams:** There will be three exams during class on the following days:

Exam 1	**Friday 20 February 2009**
Exam 2	**Friday 20 March 2009**
Exam 3	**Friday 10 April 2009**

   Exams will be closed book and closed notes although you will be able to bring a formula sheet. Calculators will be allowed.

5. **Final Exam:** There will be a final exam at **8:00 am on Wednesday 13 May 2009**. The final will last one hour and 50 minutes and be comprehensive and closed book although a formula sheet will be allowed. Calculators will be allowed.

Grades

In general, to get full credit (100%) for a problem your solution must be correct with a complete explanation. Partial credit will be given for incomplete or partly correct solutions. No credit (0%) will be given for problems not attempted, assignments not turned in or quizzes and exams missed without good reason.

Each homework set will be graded out of 20 points. Of these, 8 points will be devoted to two problems which will be selected at random and graded for correctness and completeness. The remaining problems will be checked for completeness and assigned 12 points. You single worst homework score will be dropped at the end of the semester.

Each quiz will count for five points and will be graded for completeness and correctness. You will be allowed to drop your single worst quiz score.

The numerical grades for each component will be totaled and a final numerical grade will be computed according to the following distribution.

Homework	27%
Quizzes	10%
Group Exercises	3%
Class Exams	30%
Final Exam	30%

The following final numerical scores will guarantee letter grades:

90%	A
80%	B
70%	C
60%	D

Policies

1. **Helpful Resources:** I will be happy to discuss course material and help with homework assignments outside the class.

   MSC offers tutoring services for students who need extra help. If you are having difficulty with the course, please contact me or the Tutoring Services Program (Houston Hall 110) about this.

   In coordination with Educational Access Services, reasonable accommodations will be provided for qualified students with disabilities. Please meet with the instructor the first week of class to make arrangements. Nancy Conklin, the Coordinator of Educational Access Services, can be contacted at 248-1826, or in person in Houston Hall, Room 101.

2. **Withdrawals:** There are several ways to drop this course. The deadline for dropping without penalty is **3 February 2009.** Please consult the MSC academic calendar and catalog for more details about adding and dropping courses.

3. **Attendance:** Attendance policies are described in the Mesa State College catalog. You are expected to attend all the class meetings. In case of illness or other emergencies you must be able to produce the appropriate documentation. There are other circumstances under which you can be excused but you must discuss these with me in advance. If you miss a class for a valid reason, turn in any assignments due before the start of the next class. Assignments turned in beyond your return to class will not be accepted.

   Taking quizzes is contingent upon attending discussion sessions. You will not be allowed to take a quiz unless you attended the entire discussion session. If you have a valid reason for missing a discussion session, then you will be allowed to make up the quiz but must do so by the time that you return to class.

   If there is an unavoidable conflict with one of the class exams or the final exam, please discuss it with me as soon as possible. In general I will assume that the final exam will have priority, since you know the dates of the exam.

4. **Academic integrity:** You are expected to present your own work in assignments, exams and quizzes. Fabrication of data, plagiarism, and copying from anyone else, particularly in closed book exams, are serious violation of academic norms. Mesa State College has extensive policies on these matters and penalties for infringement can be severe. For more details, consult the academic integrity policies in the Mesa State College catalog.

ELECTROMAGNETISM and OPTICS

Phys 132 Spring 2009

The following schedule is tentative, except for the dates of the class exams.

Week	Dates	Topic
1	1/20 – 1/23	Introduction, Electric charge, Coulomb's Law (Ch 22).
2	1/26 – 1/30	Coulomb's Law (Ch 22), Electric Fields (Ch 23).
3	2/2 – 2/6	Electric Fields (Ch 23).
4	2/9 – 2/13	Electric Potential (Ch 25)
5	2/16 – 2/20	Electric Potential(Ch 25), Group Exercise I, Review, **Exam I.**
6	2/23 – 2/27	Currents (Ch 26), Circuits (Ch 27).
7	3/2 – 3/6	Circuits (Ch 27), Capacitance (Ch 28).
8	3/9 – 3/13	Spring break **(no classes)**.
9	3/16 – 3/20	Capacitance (Ch 28), Group Exercise II, Review, **Exam II.**
10	3/23 – 3/27	Magnetic Fields (Ch 29).
11	3/30 – 4/3	Currents and Magnetic Fields (Ch 30).
12	4/6 – 4/10	Maxwell's Equations (Ch 31), Group Exercise III, Review, **Exam III.**
13	4/13 – 4/17	Electromagnetic Waves (Ch 34), Geometric Optics (Ch 35).
14	4/20 – 4/24	Geometric Optics (Ch 35).
15	4/27 – 5/1	Interference (Ch 36), Diffraction (Ch 37).
16	5/4 – 5/8	Diffraction (Ch 37), Review for final exam.

B.2 Assignments

The following is a Cooperative Group Problem Solving Exercise for the Physics 132 (Electromagnetism and Optics) course at Mesa State College.

Electromagnetism and Optics: Group Exercise 1

Exploring lead nuclei with charged particles

You have an internship in a research group which is investigating nuclear physics. Their aim is to understand the structure of the nuclei of heavy atoms. They propose to bombard a sheet of lead (Pb) with alpha particles (Helium nuclei). The alpha particles are fired sufficiently distant from the sheet of lead so that the lead initially does not affect them. They must reach the edge of the nucleus of an individual lead Pb atom, whereupon the electrons in the lead are irrelevant. Your task is to determine the minimum speed with which the alpha particles must be fired toward the lead sheet. You are told that an alpha particle consists of two protons, two neutrons and is approximately a uniformly charged sphere of radius 1.0×10^{-13} cm. A lead nucleus consists of 82 protons, 125 neutrons and can be treated as a uniformly charged sphere of radius 4.0×10^{-13} cm and the density of lead is $11.34\,\mathrm{g/cm^3}$. A uniformly charged sphere behaves as a point charge with charge located at its center.

1. Sketch the situation.

2. Describe the basic physics and physical concepts that enter into this scenario.

3. List all variables, including those which you have to look up, which will be relevant to the solution.

4. Provide a plan to find the solution to the problem.

5. Execute your plan to find the solution to the problem.

The following as a homework assignment for the Physics 222 (Wave Mechanics and Quantum Physics) course at Bucknell University.

PHYS 222
Fall 2005

Homework 14

Due: Friday 25 March 2005

Note: Always supply reasons for your answers.

Hints: Integrals:

$$\int \sin^2(ax)\,dx = \frac{x}{2} - \frac{\sin(2ax)}{4a}$$
$$\int x\sin^2(ax)\,dx = \frac{x^2}{4} - \frac{x\sin(2ax)}{4a} - \frac{\cos(2ax)}{8a^2}$$
$$\int x^2\sin^2(ax)\,dx = \frac{x^3}{6} - \frac{x^2}{4a}\sin(2ax) - \frac{x}{4a^2}\cos(2ax) + \frac{1}{8a^3}\sin(2ax)$$

1 The uncertainty principle and particles in symmetric potentials

Frequently, when the potential energy is symmetric about $x = 0$, fixed energy states satisfy

$$\langle x\rangle = 0 \quad \text{and} \quad \langle p\rangle = 0.$$

Such energy states can be used together with the uncertainty principle to reach quick conclusions about energies is several situations.

a) Consider a simple harmonic oscillator of mass m and angular frequency ω. The total energy is

$$E = \frac{p^2}{2m} + \frac{1}{2}m\omega^2 x^2.$$

Determine an expression for the expectation value of the energy in terms of Δx and Δp. Assuming that

$$\Delta x\Delta p = \frac{\hbar}{2}$$

find an expression for the minimum value of the energy for the harmonic oscillator.

b) **(Optional)** Consider a particle of mass m which is confined to a region $-L \leq x \leq L$ and whose energy inside this region is

$$E = \frac{p^2}{2m}.$$

Determine an expression for the expectation value of the energy in terms of Δp. Provide an upper limit to Δx and use this to obtain a lower limit for the energy in terms of L, m and $\hbar$.

c) **(Optional)** Suppose that a proton is confined to a region the size of the nucleus, i.e. $L = 10^{-15}\,\text{m}$. Use the answer to the previous part to determine a lower bound for the particle's energy. Repeat this for an electron confined to the same region. Discuss the possibilities of confining a proton to an arbitrarily small region.

2 Wavefunctions and position measurements

Consider an ensemble of 10000 identical and independent particles, each restricted to the region $0\,\text{m} \leq x \leq 1\,\text{m}$. You are told that at $t = 0$ the particles have been prepared so that they are either *all in the state corresponding to wavefunction*

$$\psi_a(x) = \begin{cases} \sqrt{30}\, x(x-1) & 0\,\text{m} \leq x \leq 1\,\text{m} \\ 0 & \text{otherwise} \end{cases}$$

or else they are *all in the state corresponding to the wavefunction*

$$\psi_b(x) = \begin{cases} \sqrt{2}\sin(2\pi x) & 0\,\text{m} \leq x \leq 1\,\text{m} \\ 0 & \text{otherwise} \end{cases}$$

Suppose that you can only perform one position measurement on each particle in the ensemble and are required to determine whether the particles are in the state correspond to wavefunction $\psi_a(x)$ or wavefunction $\psi_b(x)$. This may appear to be possible based on expectation values.

a) Suppose that the particles are described by $\psi_a(x)$. Plot the probability distribution $P(x)$ for position measurement outcomes. Determine $\langle x \rangle$.

b) Suppose that the particles are described by $\psi_b(x)$. Plot the probability distribution $P(x)$ for position measurement outcomes. Determine $\langle x \rangle$. Is it possible to determine which wavefunction applies based purely on these expectation values of position measurements?

All position measuring devices have finite resolution. Suppose that initially the measuring device has a (terrible) resolution of $1/2\,\text{m}$. Thus the device can only determine whether each particle is located in one of the following regions:

$$\begin{aligned} \text{Region 1:} \quad & 0\,\text{m} \leq x \leq 1/2\,\text{m} \\ \text{Region 2:} \quad & 1/2\,\text{m} \leq x \leq 1\,\text{m}. \end{aligned}$$

The device produces output $1/4\,\text{m}$ if the particle is located in region 1 and $3/4\,\text{m}$ if the particle is located in region 2.

c) For each of the two possible wavefunctions, determine the probability, p_1, that the device determines that the particle is located in region 1 and the probability, p_2, that the device determines that the particle is located in region 2. Given just *one* particle and only the measuring device described above, can you determine which wavefunction describes the particle's state? Can you determine this if you are given all 10000 particles in the ensemble? If so, explain how.

Now suppose that the measuring device is improved and now has a resolution of 1/4 m. Thus it can determine whether each particle is located in one of the following regions:

$$\begin{aligned} \text{Region 1:}\quad & 0\,\text{m} \leq x \leq 1/4\,\text{m} \\ \text{Region 2:}\quad & 1/4\,\text{m} \leq x \leq 1/2\,\text{m} \\ \text{Region 3:}\quad & 1/2\,\text{m} \leq x \leq 3/4\,\text{m} \\ \text{Region 4:}\quad & 3/4\,\text{m} \leq x \leq 1\,\text{m}. \end{aligned}$$

The device produces output 1/8 m if the particle is located in region 1, 3/8 m if the particle is located in region 2, 5/8 m if the particle is located in region 3 and 7/8 m if the particle is located in region 4.

d) For each of the two possible wavefunctions, determine the probability, p_n, that the device determines that the particle is located in region n for $n = 1, \ldots, 4$. *Hint: It may appear that you will have to calculate four integrals, one for each region. This is not necessary; try to solve the problem with a minimal number of integrations by exploiting various symmetries in the probability density.*

e) Given just *one* particle and only the measuring device described above (i.e. that gives one of four outcomes), can you determine which wavefunction describes the particle's state? Can you determine this if you are given all 10000 particles in the ensemble? Motivate your answer.

3 Tipler, *Modern Physics, 4th ed.*, problem 6-3, page 285.

4 Quantum dots

To get an idea of the size of a useful quantum dot containing a single electron, consider, as a simple model, an electron in an infinite square well potential of width L. Suppose that you would like energy spectrum of the quantum dot to be such that the dot emits visible light of wavelength 500 nm when the electron undergoes a transition from the second lowest energy level to the lowest energy level.

a) Determine L such that the energy spectrum of the electron in the infinite square well results in emission of light as described as above.

b) Determine the second largest wavelength of light that can be emitted by this electron.

5 Infinite square well potential

Consider a particle of mass m in the following infinite square well potential

$$V(x) = \begin{cases} V(x) = 0 & 0 \leq x \leq L \\ V(x) = \infty & \text{otherwise.} \end{cases}$$

The energy eigenfunctions are given by

$$\psi_n(x) = \begin{cases} \sqrt{\frac{2}{L}} \sin\left(\frac{n\pi x}{L}\right) & 0 \leq x \leq L \\ 0 & \text{otherwise} \end{cases}$$

where

$$E_n = n^2 \frac{\hbar^2 \pi^2}{2mL^2}.$$

The corresponding time-dependent wavefunctions are

$$\Psi_n(x,t) = \psi_n(x) e^{-iE_n t/\hbar}.$$

In the following you are allowed to use integral tables, Mathematica or your calculator to evaluate integrals. However, you must provide all the steps when you set the integrals up.

a) Determine the expectation value for outcomes of position measurements, $\langle x \rangle$, for any energy eigenfunction.

b) Determine the uncertainty in the position measurement outcomes, Δx, for any energy eigenfunction.

6 Reading

Read Tipler pages 264-268 (Monday's lecture).

a) Determine the wave function produced when the momentum operator, p_{op}, acts on e^{-bx^2}.

b) (Optional) Please comment on any aspect of the reading which you did not understand.

C Evaluations

C.1 Written Comments

The following are selected comments from the written parts of these evaluations:

> "This was one of the most difficult courses that I have ever taken, but at the same time one of the most fulfilling and enjoyable."

> "I really enjoyed the class — I learned a lot and it was more challenging than other classes I had so far — which is definitely a good thing!"

> "You truly wanted us to learn something and I appreciate that very much."

> "I felt this course was a very challenging physics course but the instructor lectured the subject clearly and I was as a result able to learn something."

> "Considering that I didn't like the subject matter the instructor did an excellent job of teaching me. It was fun."

> "The homework problems helped me understand the material being taught. They were good practical applications of the subject matter."

> "The instructor's labs were much more clear and understandable than the regular course packet."

> "The teacher made the content much more interesting than it actually is."

> "The class was not bad and the instructor was excellent. He is very organized and was always available to the students. There is no reason for me to comment on improving his teachings. He was one of the best teachers I've had at Texas."

> "Mr. Collins did a good job adapting to our level of understanding. I was impressed by the way he changed some of the material so it would make more sense."

> "I think that he did a good job - his explanations were clear and lectures were done well - I usually understood everything at the end of class."

> "David is an excellent teacher. Maybe he could make the lectures more interesting. Other than that he did a good job with the class."

> "I thought that the labs made up by the instructor were more helpful than the lab packet we were required to buy. Perhaps in the future content can be improved by allowing the instructor to write up the labs rather than using the out of date packet."

> "The lectures were too long and explanatory. Just give the info and formulae and move on."

"David Collins taught at a pace where everyone could understand. He explained the lessons step by step, making sure that no one was left behind. He was very thorough. One of the best science teachers I've had."

"Maybe spend less time on material that is easy to grasp and spend more time with the difficult material."

C.2 Numerical Evaluations

Copies of collated scores for evaluations conducted for selected classes taught by me are included. The questions are graded on a scale of 1 to 5 with increasing scores representing better performance. For those from the University of Texas, the averages for the College of Natural Sciences are included to provide a comparison.

C.3 Faculty Review

A copy of my departmental faculty review letter after two years in the Physics Department at Bucknell University follows.