SOUTHEAST MISSOURI STATE UNIVERSITY

Department of Physics **UI-330/PH345**

Experimental Methods ~~in Physics & Engineering~~ I
Revised Fall~~Spring~~ 1999~~1998~~

I. Catalog Description and Credit Hours of Course:
Selected experiments in physics and engineering with emphasis on measurement system design, equipment selection, acquisition and evaluation of data, and written and oral reporting. One lecture and two two-hour labs. Prerequisites: ~~MA245; PH231, or~~ Logical Systems (MA134 or higher); PH121 or PH231~~ and instructor permission~~. (3)

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II. Interdisciplinary Nature of the Course:
This course satisfies the requirements of a 300 level interdisciplinary course because it integrates two or more categories within one perspective and it also integrates two or more perspectives. Specifically, this course integrates *Logical* and *Physical Systems* from the *Perspective on Natural Systems* because of the extensive use of mathematics as an integral part of the content of the course, and it integrates *Oral Expression* and *Written Expression* from the *Perspective on Individual Expression* because of the extensive writing required throughout the course, ~~and~~ the two formal written reports in the style of a technical journal and the two oral presentations during~~at the end of~~ the course. An example may serve to illustrate how all of these disciplines come together.

The students perform an experiment on rotational dynamics. They must design the experiment in such a way as to minimize systematic errors. They must conduct outside research in order to obtain or derive a reasonable theory for the experiment. They must then use mathematical software such as a spreadsheet or MathCad to fit the experimental data obtained using the theory uncovered by their research and explain any discrepancies. The content during the first week of the course lays the foundation in the logical and physical systems categories, and ~~this content is continually reinforced throughout the semester by the instructor~~the instructor continually reinforces this content throughout the semester. This process integrates logical and physical systems because the data fitting requires using various mathematical methods of data reduction and analysis, such as least-squares fitting. During the course of the experiment, students must make detailed notes and take data in their laboratory journals. They explain all their reasoning for the various choices they make regarding how to conduct the experiment, and they keep any notes from their outside research in these journals. This requires clear written communication because they will later have to use the lab book as the basis for a formal, journal-style written report that is equivalent to a three-page article in a physics or engineering journal. In addition, during the conduct of the experiment, the students must effectively communicate orally with one another as well as with the instructor when responding to his inquiries on their progress. Finally, a formal oral presentation is

required in the style of a paper at a professional conference. These activities involving writing and speaking are addressed by the instructor during the first week and throughout the course as part of the content of the course. Guest lecturers from the English Department and from the Speech Department will present workshops on written and oral communication in a technical context. The guest instructor from the English Department will present a lecture on effective written technical communication. Students will have written a draft of their formal reports which will be reviewed by the guest lecturer and the instructor after the lecture. Suggestions for improvement will be made at that time. Students will then revise their draft which will be reviewed and discussed during the next lab period with the guest lecturer and the instructor and additional feedback given. Students will then revise their drafts based on comments and suggestions received and be graded on the final version. The guest lecturer from the Speech Department will present a lecture on effective technical presentations. Students will have prepared a draft presentation which will be reviewed and discussed by the guest lecturer and the instructor. Suggestions for improvement will be made at that time. During the next lab period, students will give a practice presentation and receive more feedback. Students will then further revise their presentation, and the instructor will hold another practice session with the students. The formal presentations will be given to the students and faculty of the Department during the next available Common Hour. This process of writing a formal report and giving a formal presentation will be done for two different experiments during the semester, once after the first three experiments are completed and once at the end of the semester.

~~After presentations by the guest lecturers, the students will write drafts of their formal written report and their oral presentation for the next lab period. These will be reviewed by the English and Speech faculty members. Feedback will be given to the student and further revisions will be made and discussed during the next lab period with the guest instructors. The students will also give a practice presentation at that time. Students will then make a second revision based on comments received at that time. They will be graded on the resulting papers and presentations. The formal presentations will be given to the students and faculty of the Department during the next available Common Hour. The process of writing a formal report and giving a formal presentation will be done twice during the semester, once after the first three experiments are completed and once at the end of the semester~~This integrates written and oral communication into the course. The idea is to give the students, as closely as possible, the experience of a practicing physicist or engineer.

III. Prerequisites: ~~MA245 Vector Calculus; PH231 General Physics II; **or**~~ Logical Systems (MA134 or higher); PH121 Introductory Physics II or PH231 General Physics II~~; and instructor permission~~.

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~~I~~V. Purposes or Objectives of the Course:

The purpose of the course is to:

A. Improve laboratory skills. U.S. Objectives: 1, 2, 3, 6, 7, 9

B. Provide opportunity for open-ended and creative investigation of phenomena of interest in physics and engineering. U. S. Objectives: 1, 2, ~~4, 5,~~ 6, 7, 9.

C. Develop initiative in scientific investigation. U. S. Objectives: 1, 2, ~~4, 5,~~ 6, 7, 9.

D. Develop skills in experimental design, data acquisition, data analysis, and detailed comparison of results to theory. U. S. Objectives: 1, 2, 3, 6, 7, 9.

E. Develop written and oral communications skills used in conducting experimental work and in presenting scientific results. U. S. Objectives: 1, 2, 3, 6, 7, 9.

V. Expectations of Students:

A. Be inquisitive and show initiative as to what and how to investigate the phenomenon under study.

B. Prepare for efficient use of lab time by doing outside reading and research before coming to lab.

C. Maintain two lab journals into which all lab-related work goes. While one journal is being graded, the other will be used.

D. Be prepared to discuss your approach and respond to instructor inquiries as to the reasoning behind your approach.

VI. Course Outline – (Hours, lab & lecture):
Hours (lab & lecture)

A. Introduction - (U.S. Objectives 1, 2, 3, 6, 7, 9) – (75)
1. Statistical data analysis
2. Error analysis and propagation
3. Graphical analysis
4. Least-squares fit
5. Resources for outside research
6. Keeping a lab journal
7. Ethical dimensions of physics and engineering
a. environmental issues, time and resource management issues
b. public safety issues, conflicts of interest

Workshop on written communication in a technical context 5
Guest lecturer, English Department (U.S. Objectives 2, 3, 6, 9)

(Each experiment meets addresses U.S. Objectives 1, 2, 3, 6, 7, and 9)

B. Rotation I
1. Modern Physics – (110)
2. Fiber Optics – (10)
3. Dynamics of Rotational Motion – (10)

C. Workshops on technical written and oral communication – U.S. Objectives 2, 3, 6, 9 – (5) – G
Guest lecturers from the English and Speech Departments-
(U.S. Objectives 2, 3, 6, 9)
Workshop on oral communication in a technical context 5
Guest lecturer, Speech Department (U.S. Objectives 2, 3, 6, 9)

D. Formal report due, oral presentation during Common hour

E. Rotation II
1. Microwave Optics – (10)
2. Optics – (10)
3. Lasers – (10)

F. Workshops on technical written and oral communication – U.S. Objectives 2, 3, 6, 9 – (35) – G
Guest lecturers from the English and Speech Departments-
(U.S. Objectives 2, 3, 6, 9)

G. Formal report due, oral presentation during Common Hour

~~Oral presentation Finals week 2~~

Total: 75~~77~~

VII. Textbooks:

A. Daryl W. Peterson, *The Art of Experimental Physics*, Wiley: New York, 1993.

B. Brusaw, Alred, and Oliu, *Handbook of Technical Writing*, 5e, St. Martins: New York, 1997.

C. S. L. Lucas, *The Art of Public Speaking*, 6e, McGraw Hill: Boston, MA 1998.

VIII. Basis of Student Evaluation:

A. Outside research and homework, 20% (Evidence of research presented in the lab journal and from discussions with the instructor during lab.)

B. Laboratory journal, 30% (Graded holistically in terms of organization, clarity, thoroughness, and sound reasoning.)

C. Formal written reports, 2030% (Two reports in the form of an article in a physics journal (~3 journal pages). To include background information and details of student's experimental work.)

D. Oral presentation, 20% (Two~~One~~ presentations in the form of a professional conference paper. To include background information and student's experimental work.)

E. Final Exam, 10% (Will cover phenomenon investigated experimentally, data analysis methods, error analysis and propagation, and written and oral communication techniques.)

IX. Justification for Inclusion in the University Studies Program

Objective 1: Demonstrate the ability to locate and gather information.
Emphasis: SIGNIFICANT

Content
The first week of this course is devoted to discussing the nature of experimental work, measurement errors, statistical methods of dealing with random errors, error propagation, curve fitting, keeping a laboratory journal, and conducting research. Specifically on conducting research, the instructor discusses the use of SADIE, the use of *Physics Abstracts*, the location and general content of the physics and engineering journals in the library, the use of the Internet, and the use of online resources such as FirstSearch or the search engines available on the American Institute of Physics (AIP) or Institute of Electrical and Electronic Engineers (IEEE) web pages to locate information. The students work in lab groups of two or three, and each group conducts a different experiment. The groups are then rotated. Before their time with each experiment, the instructor provides the students with a brief handout that contain~~ing~~s questions that must be answered experimentally, describ~~inge~~s the equipment available for the experiment, and ~~containing a~~ list~~s of~~ a few references. Since ~~T~~students~~they~~ must do outside research in order to be successful in the laboratory, they are required to find and read ~~at~~ at least two other references, one of which must be a journal article pertinent to the experiment.

Teaching Strategies

The instructor lectures during the first week of the class on the topics mentioned above. After that point, he encourages students to do their research by continually asking what they have been reading, suggesting possible ~~various~~ sources, and asking pertinent questions to stimulate the student's thinking.

Student Assignments

Students have two weeks (10 hours in lab, but they may spend additional time since the lab is available during business hours) to work on each experiment. Each student- maintains a working laboratory journal which is reviewed by the instructor ~~and suggestions are made~~ at the beginning and end of each lab session. Suggestions are made at that time for possible avenues of further research. It is then submitted to the instructor for review a few days after each experiment is completed and at least one day before the next experiment begins. The lab journals are to be chronological records of all work done on an experiment, including notes and other evidence of outside research.

Evaluation of Student Performance

The students maintain two laboratory journals so that while one is being reviewed, the other is used for lab work. The laboratory journals receive a grade for the journal which reflects the experimental work and also a grade for evidence of outside research conducted. The primary criteria is how many and what kind of sources were used and what kind of notes were taken from each source. Journal articles carry more weight than textbooks.

Objective 2: Demonstrate capabilities for critical thinking, reasoning, and analyzing.
Emphasis: SIGNIFICANT

Content

This is a laboratory course. The goals of this course are~~is~~ primarily to teach sound experimental practices, including proper written and oral communication, and to learn some physics along the way. Primary responsibility for determining how to conduct an experiment rests with the student. Students must conduct significant research for each experiment, consequently they must demonstrate critical thinking skills at several levels. They must synthesize information in order to design their experiments, they must evaluate the procedure during the experiment, and they must analyze their results by comparing them with theory, and drawing appropriate conclusions.

Teaching Strategies

The instructor continually queries students as to their experimental design, their techniques of measurement, their techniques of data analysis, and their methods for error reduction. They must be able to justify what they are doing and show that their judgment is sound. Often the instructor asks questions about issues that the students have not considered and this prompts a reevaluation of their plans. The instructor acts as a facilitator and a coach, rather than as a traditional lab instructor, while the students are free to explore avenues of interest to them on the particular phenomenon under study.

Student Assignments

The laboratory journal should reflect the research and reasoning that leads to the experimental procedure and the data analysis. When the instructor reviews the lab journal at the beginning and end of each day in the lab, suggestions are made regarding how clearly the student's experimental work, the reasoning leading to it, and the analysis and interpretation of data is recorded in the lab book.

Evaluation of Student Performance

Some of the factors used in determining a student's grade for the lab journal include the clarity of thought in the design and conduct of the experiment, the appropriateness of the data analysis techniques used, and the justification of the conclusions drawn.

Objective 3: Demonstrate effective communications skills

Emphasis: SIGNIFICANT

Content

Good writing style is taught throughout the course with regard to the lab journals and the two formal written reports required during the course. When the instructor reviews the lab journal at the beginning and end of each lab session, suggestions are made to improve clarity, organize data, and analyze results. Good oral presentation skills are taught as students interact with one another in the lab group, respond to instructor queries, and as they prepare the oral reports required during~~at the end of~~ the semester. Guest lecturers from the English Department and the Speech Department will each present ~~five hour~~ workshops on effective written and oral communication in a technical context.

Teaching Strategies

Because of the laboratory nature of the course, it consists almost entirely of active and cooperative learning which is encouraged by the instructor. The students must interact effectively in their lab groups and with the instructor, and this requires the practice of good communication skills. Active learning will also be a major part of the workshops by the English and Speech faculty mentioned above. The guest instructor from the English Department will present a lecture on effective written technical communication. Students will have written a draft of their formal reports which will be reviewed by the guest lecturer and the instructor after the lecture. Suggestions for improvement will be made at that time. Students will then revise their draft which will be reviewed and discussed during the next lab period with the guest lecturer and the instructor and additional feedback given. Students will then revise their drafts based on comments and suggestions received and be graded on the final version. The guest lecturer from the Speech Department will present a lecture on effective technical presentations. Students will have prepared a draft presentation which will be reviewed and discussed by the guest lecturer and the instructor. Suggestions for improvement will be made at that time. During the next lab period, students will give a practice presentation and receive more feedback. Students will further revise their presentation, and the instructor will then hold another practice session with the students. The formal presentations will be given to the students and faculty of the Department during the next available Common Hour. This process of writing a formal report and giving a formal presentation will be done for two different experiments during the semester, once after the first three experiments are completed and once at the end of the semester.

~~The guest instructor from the English Department will present a lecture on effective written technical communication. Students will have written a draft of their formal reports which will be reviewed by the guest lecturer and the instructor after the lecture. Students will then revise their draft which will be reviewed and discussed during the next lab period~~

with the guest lecturer and the instructor. Students will then revise their drafts based on comments and suggestions received and be graded on the final version. The guest lecturer from the Speech Department will present a lecture on effective technical presentations. Students will have prepared a draft presentation which will be reviewed and discussed by the guest lecturer and the instructor. During the next lab period, students will give a practice presentation and receive more feedback. Students will further revise their presentation. The formal presentations will be given to the students and faculty of the Department during the next available Common Hour. This process of writing a formal report and giving a formal presentation will be done twice during the semester, once after the first three experiments are completed and once at the end of the semester.

Student Assignments
As mentioned, lab journals, two formal written reports, and two~~an~~ oral report~~s~~ are required.

Evaluation of Student Performance
The student assignments mentioned above constitute 70~~80~~% of the grade for the course. The criteria are technical content and correctness, organization, clarity, ~~and~~ sound reasoning, and effective presentation.

Objective 4: Demonstrate an understanding of human experiences and the ability to relate them to the present.
Emphasis: SOME

Content
Many of the experiments conducted have historical significance as well as tremendous relevance to modern technology. The students are exposed to this in their research and in our informal discussions during lab.

Student Assignments
As part of their lab journal and/or in their formal written reports, students usually include the historical significance of the experiment and the background for it. They also relate the physics involved to contemporary technological applications.

Evaluation of Student Performance
Students who~~should~~ include a discussion of the historical significance of the topic under study ~~in order to receive full credit on their lab journal because by doing so they~~ will have presented a more thorough understanding of the phenomenon, which will positively influence their grade.

Objective 5: Demonstrate an understanding of various cultures and their interrelationships.
Emphasis: SOME

Content
Most of the experiments in this course rely heavily on the development of modern physics, which has a definite international flavor, especially western Europe. In addition, authors in the journals of physics are located worldwide and from many different cultures. The students will encounter this as part of their outside research for lab.

Teaching Strategies
As part of the interaction between the student and the instructor, the instructor discusses the international contributions and flavor of modern work in physics and engineering. This includes differences in how students in these other cultures are educated ~~-~~and prepared for technical careers. Also, the whole process of working successfully in lab groups requires understanding and relating to people from various cultures and backgrounds.

Student Assignments
Students may include a discussion of the international nature, both historically and presently, of the phenomenon under study in their research entries in the lab journal and in their formal reports.

Evaluation of Student Performance
Students who~~may~~ include a discussion of the international nature of the topic under ~~study in order to receive full credit on their lab journal because by doing so they~~ will have presented a more thorough understanding of the phenomenon, which will positively influence their grade.

Objective 6: Demonstrate the ability to integrate the breadth and diversity of knowledge and experience
Emphasis: SIGNIFICANT

Content
Physics and engineering are interdisciplinary because of the substantial mathematical content and because of the importance of clear communication of technical ideas to both technically literate and more general audiences. The quantitative nature of this course requires the use of physical, mathematical, and numerical analysis. The emphasis on communication also requires students to draw on knowledge and experience from formal courses in written and oral communication. Although primary emphasis is on communicating to audiences of peers, students are encouraged to present their experimental work to a more general audience by participating in the Southeast Student Research Conference.

Teaching Strategies
Having discussed various analysis techniques during the first week of the class, the instructor continually quizzes the students on and discusses with them how closely their experiment satisfies the assumptions of the theory being used to model it. Perhaps a different or modified theory should be used, or perhaps a different analysis technique would be more appropriate. The students must draw from both mathematics and physics to be successful in this effort of matching theory and experiment. Moreover, they must communicate their ideas effectively, both orally and in writing.

Student Assignments

Students must include theoretical discussions of the phenomenon under study and then must use mathematical and numerical analysis to compare their experimental results to the theory. Students must make use of mathematical software such as a spreadsheet or MathCad for most of these. This is done for each experiment in their lab journals, ~~and~~ for both of their formal written reports, and for both of their oral presentations~~report~~. These reports must also effectively communicate their work on each experiment.

Evaluation of Student Performance

The grade for the lab journals and written reports is partly determined by the extent to which the results are properly compared to theory and discussed. Students are also graded on their oral presentations. The~~Other~~ criteria for grading the lab journals, written formal reports, and oral presentations include technical content and correctness, organization, clarity, ~~and~~ sound reasoning, and effective presentation.

Objective 7: Demonstrate the ability to make informed, intelligent value decisions.
Emphasis: SOME~~SIGNIFICANT~~

Content

Valuing is the ability to make informed decisions after considering the ethical, moral, aesthetic, and practical implications. The technical decisions made by physicists and engineers frequently have moral and ethical dimensions. This is because those decisions often deal with how time, money, and natural resources will be used; they frequently involve issues of public safety; and they sometimes deal with potential conflicts of interest in proposals and contracts. The open format of this lab forces students to consider multiple possible avenues of investigation and to choose one based on various value judgments, such as how much time one approach may take compared to another; what resource consumption is involved in one approach compared to another; are there safety issues involved; and what are the consequences of measurement or calculation errors on public safety. In addition, many principles in physics have been used in military applications, and this naturally lends itself to discussing the moral implications for the physicists and engineers involved in exploiting these physical principles for military purposes. These are often informally discussed with fellow students and the instructor during the conduct of the experiments. As an example, when conducting the laser experiment, one could discuss the use of lasers to jam or destroy enemy sensors, a seemingly acceptable military tactic. The moral issue arises because the sensors might be human eyes. Is it consistent with accepted wartime rules of engagement to use weapons designed to merely maim ~~and not to kill~~?

Teaching Strategies

During the introduction portion of the course, the instructor discusses the moral and ethical dimensions of technical work and the responsibilities of the practitioner to understand them. Students are given copies of the Code of Ethics for Engineers and the Statements on Ethics published by the American Physical Society. The open format of this lab forces students to evaluate which of many possible courses of action to follow in order to achieve their experimental objectives in the most time efficient, the most resource efficient, and the safest manner possible ~~since there is a limited amount of time available in the lab~~. The instructor prompts consideration of various alternatives by sometimes making comments which stimulate the student's thinking in a direction other than that prior to the comment. In terms of moral and ethical dilemmas, the instructor initiates impromptu discussions on topics of this kind.

Student Assignments

A homework~~-~~ exercise that requires resolving an ethical dilemma will be assigned during the semester with one of the experiments where safety issues must be considered, for example, an experiment involving a laser and using door interlocks and eye protection. The reasoning presented in the lab journals reflects the degree to which the various alternative approaches to the experiment were considered and the reasoning involved in choosing one. The lab journals should also reflect the extent to which any safety issues were considered.

Evaluation of Student Performance
Once again, the reasoning and judgment presented in the lab journal influences the grade in terms of thoroughness.

Objective 8: Demonstrate the ability to make informed, sensitive aesthetic responses
Emphasis: SOME

Content
A concern for beauty is a universal characteristic of human culture. Beauty in physics usually relates to the degree to which the theoretical description of a phenomenon uses elegant mathematics and actually explains what is going on physically. Students must wrestle with elegant and sophisticated theory in their research for several experiments in this course. They must also fit experimental results with theory. The better the match between the two, the more aesthetically pleasing this is to the physicist or engineer.

Teaching Strategies
The open format of this course lends itself to pointing out the aesthetic quality of physics. The instructor will attempt~~s~~ to instill an aesthetic appreciation for the theories involved.

Objective 9: Demonstrate the ability to function responsibly in one's natural, social, and political environment.
Emphasis: SOME~~SIGNIFICANT~~

Content
The existence of mankind depends on countless interrelationships among persons and things. Students must learn to interact responsibly with their natural environment and with citizens of their society and world. Interaction with their natural (i.e. physical) environment is intrinsic to the course. The essence of physics and engineering is to understand and then manipulate the natural environment for the benefit of human beings, while minimizing the impact of such manipulation. Working successfully in groups and having a well-developed set of laboratory skills is ~~also~~ intrinsic to the social (i.e. professional) environment for most physicists and engineers. In addition, students have opportunity to discuss among themselves and with the instructor issues of social and political concern. Examples might be the proper level of government funding of science and engineering research or~~and~~ the quality of laboratory equipment at a state university.

Teaching Strategies
The course structure is such that students must work together in lab groups. The groups are rearranged halfway through the semester, which allows students to interact with several different classmates with various perspectives and abilities. Since this is what will be required as part of their future careers, students must function responsibly in their social (i.e. professional) environment in order to succeed in this course. In terms of pertinent social or political issues, the instructor initiates impromptu discussions on such topics~~topics of this kind~~.

Student Assignments

Students must work together both in lab and outside lab in order to plan their experimental work and to complete their lab journals. Their laboratory skills will improve as the course progresses.

Evaluation of Student Performance

The ability of the members of a lab group to work together is usually directly related to the quality of the work done, which then influences the grade on lab journals and formal reports.

X. Background:

The course will be taught by an instructor who is competent in experimental physics or engineering. This would require an advanced degree in physics or engineering and extensive experience in a laboratory setting.

XI. Class ~~size~~Size: The class is limited to 12 students.