Physics Education at Iowa State University

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Abstract

We describe physics education at Iowa State University, which is typical of that offered at most American universities. We begin with an overview of education in general in the State of Iowa, with an emphasis on the requirements for admission to Iowa State University. After a short description of the university, we describe the specific requirements for a "bachelor of science" degree in physics. We describe the beginning courses in some detail, since these physics courses are also used in educating engineers. Lastly, we give brief descriptions of other physics courses, and of the program leading to the Ph.D. degree.

Education in Iowa

Education in the United States is governed by federal, state, and local laws. Federal laws impose only very general requirements, such as freedom from discrimination based on race or gender, and the principle of "separation of church and state" which is written into the United States constitution. State laws govern requirements for the training of teachers, and impose minimum requirements for the curriculum. Detailed policies for running schools, including details of the curriculum, are under the control of locally elected School Boards.

Education in the State of Iowa is typical of education in the United States as a whole. Seven years of elementary education (kindergarten through eighth grade) is followed by four years of high school (ninth through twelfth grade). Children start school between 5 and 6 years of age, and normally complete high school at age 17 or 18. By law in Iowa, the school year has 180 class days. There are no classes on Saturdays or Sundays. Approximately 88% of Iowan adults have completed high school.

The State of Iowa imposes minimum curriculum requirements for high schools. In particular, high schools must teach a physics course lasting 1 school year, but this is optional for students. Usually, only those students who are considering a career in science or engineering will study physics in high school.

Education beyond high school is provided by a mixture of private colleges and universities, state-run community colleges, and state-run universities. In Iowa, there are 36 private colleges and universities. There are also 15 community colleges, and three state universities. Two of these, University of Iowa and Iowa State University, are "research universities," that is, universities which support major research programs and award Ph.D. degrees in a number of disciplines. Iowa State University is a typical American research university.

For admission to Iowa State University, high school students must have completed 4 years study of English, 3 years of mathematics (algebra, geometry, and advanced algebra), 3 years of science, and 2 years of social studies. Students interested in studying engineering or physics at the university usually take more mathematics in high school, such as trigonometry and analytical geometry. It is not expected that these students study calculus in high school, although some do.

About Iowa State University

In 1862, the United States Congress passed the Morrill Act, under which the federal government gave large tracts of land to states, to be sold to pay for establishing "land grant" colleges. Iowa State University, which had been created by the Iowa legislature in 1858, was the first American university to take advantage of this law. The principles to be followed by a land grant college include

- Access regardless of race, creed, gender, or economic background.
- Practical and liberal education.

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- Applied and basic research.
- Service to the people of the state.

The university is made up of eight Colleges: Agriculture, Business, Design, Education, Engineering, Family and Consumer Science, Liberal Arts and Sciences, and Veterinary Medicine. The total enrollment for the university is about 25,000 students, of whom roughly 3500 are graduate students working towards a higher degree. The Department of Physics and Astronomy is in the College of Liberal Arts and Sciences.

The academic year consists of two semesters each with 15 weeks of classes and one week of final examination. One 50 minute lecture every week for the whole semester is designated as "one credit." For a studio or laboratory class, a credit requires two or three hours of class time. In most of the colleges, undergraduate programs leading to a Bachelor degree require 124 credits.

Student performance in a course is recorded as a letter, which is given a numerical value for ease of processing. Course grades and their numerical equivalents are A (4), B (3), C (2) (the "average passing grade"), D (1), and F (0) (for failure). An overall grade point average of 2.00 is required for graduation.

For a B.S. or B.A. degree in the College of Liberal Arts and Sciences, a student must complete 6 credits in English composition, 8 credits in a foreign language, 12 credits in Arts and Humanities, 3 credits in communication, 3 credits in Mathematics, 8 credits in natural science, 9 credits in social science and a "major" of at least 24 but no more than 48 credits in a single discipline. Courses used to meet the general education requirements must not be in the "major" subject. The student can choose freely from a variety of courses to complete the required total of 124 credits.

A Bachelor of Science (B.S.) or a Bachelor of Arts (B.A.) degree can be earned in 4 years, although many students take longer because they must work to support themselves. Over 20% of Iowans have a college degree, although some of these are "associate" degrees awarded after two years of study at a community college. Students must pay a fee for tuition (about $2,600 per year for students from Iowa, $4,300 for others), and may also buy accommodation (a room shared with one other student) and meals (20 meals per week) for about an additional $3,500. Some financial aid is available to students who need it. Graduate students usually receive financial support through teaching or research assistantships.

The undergraduate physics major

A physics major requires a minimum of 34 credits in physics or astronomy, together with at least 19 credits of supporting mathematics. The Department of Physics and Astronomy provides its students with several sample programs, designed to meet differing needs. We list below the mathematics and physics courses in a typical program. The number is the number of credits for the course. Physics and mathematics courses *not* marked with an asterisk are required for a major in physics. An asterisk marks additional courses which are recommended for a student who is planning graduate studies.

Freshman (first) year:

Fall semester:
Introductory Physics Seminar (required but no credits given)
4 Calculus
Spring semester:
5 Introduction to Classical Physics I
4 Calculus

Sophomore (second) year:

Fall semester:
5 Introduction to Classical Physics II
4 Elementary Multivariable Calculus
Spring semester:
3 Physics of Wave Motion
3 Introduction to Modern Physics I
1 Introductory Laboratory in Modern Physics I
1 Computational Methods of Physics
4 Elementary Differential Equations and Laplace Transforms

Junior (third) Year:	**Fall semester:** 3 Introduction to Modern Physics II 1 Introductory Laboratory in Modern Physics II 3 Classical Mechanics 3 Introduction to Partial Differential Equations **Spring semester:** 1 or 2 Intermediate Laboratory 3 Intermediate Mechanics* 3 Electricity and Magnetism I 3 Complex Variables with Applications*
Senior (fourth) year:	**Fall semester:** 3 Thermal Physics 2 Electricity and Magnetism II (electromagnetic radiation)* 3 Quantum Mechanics* **Spring semester:** 1 or 2 Intermediate Laboratory 2 Applied Quantum Mechanics* 4 Advanced Calculus for Applied Mathematics*

We emphasize that this is only a sample program. Courses and scheduling are routinely adjusted to meet an individual student's needs. There is no formal major in astronomy, but one of the sample physics programs is designed with an emphasis on astronomy. To help students prepare for industrial employment we are instituting degrees in applied physics. In these programs, students study a modified selection of the courses above and complement these with selected courses in engineering. Applied physics programs with emphases in biomedical engineering, electronic devices, non-destructive evaluation, vibration engineering, fluid mechanics, and material science are in various stages of development. All still need official approval by the university administration.

Undergraduate students are encouraged to become associated with a research group. Although this is not required for a degree, research experience is good not only for students who plan advanced studies but also for those students seeking employment in industry. Research groups include condensed matter physics, high energy physics, nuclear physics, atmospheric physics, mathematical physics, and astronomy.

In recent years there has been a large decrease in the number of students choosing to major in physics at all American universities. Roughly 10–15 students per year obtain a B.S. in physics from Iowa State University. About half of these intend to continue their studies towards a Ph.D. in physics. We encourage these students to go elsewhere for their graduate study, in order to broaden their experience.

Educational Philosophy

In America, it is traditional to believe that a student who can work problems understands the basic physical principles involved. The formal lecture is thought to be the most efficient way of conveying the subject matter. Problems should be assigned every week, and collected for grading. Several exams may be given during the course of the semester to encourage students to study consistently. The final exam, which rarely counts for more than a quarter of the grade for the course, usually covers material from the whole course. Even so, the final exam is not considered to be an important learning experience for the student. This traditional approach to teaching has been widely criticized recently, as instructors have come to realize that students often learn to solve problems by manipulating formulas without really understanding the basic principles. This is especially true at the introductory level. Educational researchers tell us that traditional teaching methods based on lectures, assigned readings, and problem sets, are ineffectual compared to an inquiry-based, cooperative approach in which the student is more actively involved in the learning process. Physics by nature is non-dogmatic, but comes across as such in most introductory lectures. At Iowa State University, we have tried to implement some of these new ideas by giving students a learning experience in which a small group of students work cooperatively on a problem. So far, however, we have introduced only small changes in our teaching. Professor L. Hodges[3] is especially interested in improving our methods of teaching introductory courses.

It is the normal practice within the department (and in most other physics departments) that no faculty member teaches the same course for more that three years in a row. This helps to ensure that teaching does not become routine.

Laboratory

Laboratory experience is an important aspect of physics education. The formal laboratory requirements for physics majors are rather minimal. However many students supplement the required laboratory experience by working with a research group.

Professor F. C. Peterson[4], who supervises the physics undergraduate laboratories, makes the following statement:

Laboratory experience serves many purposes in physics instruction.

1. By gaining experience with a sample of the infinite variety of measurements that are possible, students gain the ability to connect the theoretical discussions of their textbook and classes with their own experiences. For example, many students at first have great difficulty in wiring devices together so that the arrangement corresponds to a circuit diagram, or conversely, drawing a circuit diagram that reflects the connections of an arrangement which they are inspecting. This is only one example of a host of experiences which are not addressed outside the laboratory.

2. For many students, the connection of the theoretical physics to the real world on a given topic may be tenuous. By making measurements with an arrangement to which the theory applies, such students may be heard occasionally to say, "That's what that means!"

3. Students inexperienced in making measurements often produce measurements that are unreliable. They have yet to develop the skills of a scientist, that includes asking, "Is my result reasonable?", and double-checking work, doing things on paper (rather than in one's head), and so on. Laboratory experience helps them to gain these skills.

4. Students gain experience with and skill in the use of common instrumentation, from calipers to computers.

5. Students gain experience with and skill in the use of common analysis techniques, from organizing data and tables, graphs, and numerical procedures, and from those simple (e.g., proportional relationships) to those complex (line fitting, fast Fourier transforms).

Note added: They also learn physics, of course! But for many students the other skills are probably the most valuable in the long run.

Introductory Courses

The calculus-based introductory physics courses that begin the physics major program are designed for all students of engineering and the physical sciences. The initial enrollments for Fall 1997 were 640 for Phys 221 and 500 for Phys 222. Because of the large enrollments, lectures are given to about 200 students at a time. The lecture class is subdivided into recitation sections of no more than 24 students. These recitations allow the students to ask questions and to go over the problem assignments. The recitations and laboratory classes are usually taught by graduate student teaching assistants. Students are taught by the same instructor in both recitation and laboratory, to help build a close relationship between each student and at least one member of the instructional team. The course descriptions are given below:

Phys 221. Introduction to Classical Physics I. 5 credits. For engineering and science majors. 3 hours of lecture each week plus 3 recitations and 1 laboratory every 2 weeks. Elementary mechanics including kinematics and dynamics of particles, work and energy, linear and angular momentum, conservation laws, rotational motion, oscillations, gravitation. Electric currents; DC circuits.

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Phys 222. Introduction to Classical Physics II. 5 credits. Magnetic forces and field: LR, LC, LCR circuits; Maxwell's equations; waves and sound; ray optics and image formation; wave optics: heat, thermodynamics, kinetic theory of gases; topics in modern physics.

Some topics of modern physics are squeezed into the end of Phys 222 so that the course is not exclusively on classical physics. Some instructors try to introduce modern ideas throughout 221 and 222 where appropriate.

These classes have three 50 minute lectures and two 50 minute recitation periods a week, except that in weeks in which a laboratory (2 hours) is scheduled there is only one recitation period.

These courses are highly structured. The Appendix shows the syllabus for Phys 221 as taught in Fall 1997. This was made available to students at the start of the semester.

Other Courses

The department offers other special courses suitable for satisfying the science requirement of students in other majors. A sequence, Phys 111 and 112, is similar in scope to Phys 221 and 222 but uses only algebra and trigonometry, no calculus. These courses are required by students of biology. In addition there are several courses available for students seeking to meet the general education requirement in science. These include "The Physics of Common Experience," "Physics of Music" and "The Challenge of Contemporary Physics". This last course is discussed in detail elsewhere in these proceedings [1].

Graduate Education in Physics

The Department of Physics and Astronomy offers work beyond the B.S. leading to the degrees master of science (M.S.) and doctor of philosophy (Ph.D.) with majors at both levels in applied physics, astrophysics, condensed matter physics, high energy physics, nuclear physics, and physics [5]. The M.S. degree requires either a thesis describing original research or a "creative component," such as an extended review of an established field. However most graduate students intend to seek a Ph.D.

The department recruits between 20 and 30 new graduate students each year. Typically, about half of these are American students. Of the rest, the largest single group are Chinese, both from the Peoples Republic and from Taiwan. In their first year, students typically take three advanced courses in physics or mathematics each semester, and work as teaching assistants (for which they are paid). A teaching assistant is expected to spend 20 hours per week on his or her teaching duties. This includes classroom work, preparation time, and time spent correcting students' homework assignments. In their second and third years, students continue taking advanced graduate course work, but should also be associated with a research group. Many second year students continue as teaching assistants, but some, together with most of the more advanced students, receive financial support as research assistants.

Course work expected for Ph.D. candidates includes 8 credits of quantum physics, 6 credits of advanced electricity and magnetism, and 3 credits either in advanced mechanics or in statistical mechanics. Formal course work also includes mathematics and specialty courses in the chosen area of study. Students are required to pass a "qualifying exam," usually taken at the beginning of the second year. This exam is made up of two parts, classical and modern, each 4 hours long, and taken on successive days. The classical part covers only undergraduate material, while the modern part includes some graduate level quantum mechanics. Students must pass both parts in the same year. In any year, about 50 to 60% of the students taking the exam pass it. Students who fail at their first attempt are allowed a second chance to pass the exam when it is given the following year.

Students who fail the qualifying exam two times may not continue towards the Ph.D., but usually may complete a M.S. degree. Students who pass the qualifying exam proceed to an oral "preliminary exam," and when they pass this they are accepted as candidates for the Ph.D. After several years of supervised research, the student writes his or her thesis, which must then be successfully defended in an oral exam. The research reported in the thesis must be of a quality able to be published in a research journal. A good student will be coauthor or author of several research papers before he or she submits his or her thesis, but this is not a formal requirement for the degree.

[5] "Physics" is used for all M. S. or Ph.D. programs which do not fit in any of the other categories.

It is possible but very rare for a student to complete a Ph.D. in physics in less than five years beyond the B.S. degree. Six years is more common, especially for students in experimental physics.

There is a growing sense among physics faculty in America that the traditional Ph.D. program trains students to be future faculty members at a time when there are few employment opportunities at universities. Change comes slowly, but it is likely that future Ph.D. programs will be modified to train students for employment in industry.

Conclusion

Physics education at Iowa State University is typical of physics education at most American universities. In this account, we have paid particular attention to the introductory courses for engineering and science students, which are difficult to teach because of the large number of students involved. At most universities, they are taught in a traditional way. However physics instructors in America are becoming increasingly dissatisfied with these courses, and some universities are experimenting with a variety of alternative teaching methods. We are interested in learning how other countries, such as Russia, deal with similar pedagogical problems. We hope that through international dialog between faculty in our different university systems, physics education can be improved not only for students aiming to be scientists or engineers but also for students in non-scientific curricula. We welcome further dialog on these issues, througn e-mail or by other means.

Appendix: Syllabus for Physics 221, Fall Semester 1997

Some deletions have been made to save space. Footnotes are our comments, not part of the syllabus.

PHYSICS 221 — SYLLABUS FALL 1997

LECTURE HOURS: MWF 8:00, 9:00 and 10:00 AM[6]
All lectures are held in Room 5, Physics Hall
TEXTBOOK: Fundamentals of Physics, Extended, 5th Edition by Halliday/Resnick/Walker
ADDITIONAL MATERIALS: Physics 221 Laboratory Manual (University Bookstore); Physics 221 Laboratory Information and Schedule Sheet
NOTE: THIS COURSE HAS EVENING EXAMS. Note the exam dates of Wednesday, September 23; Wednesday, October 22; Wednesday, November 19 on the schedule below and **MAKE NO OTHER PLANS FOR THESE DATES.**

Date	**Lecture topics**	**Reading Assignment**
M Aug. 25	1. Syllabus, Units, Significant figures	Ch.1.1–1.6
W Aug. 27	2. Position, Velocity, Acceleration	Ch. 2.1–2.6
F Aug. 29	3. One dimensional motion, Free fall	Ch. 2.7,2.8,3.1
M Sept. 1	**LABOR DAY–NO LECTURE**	
W Sept. 3	4. Vectors and Scalars	Ch. 3.2–3.7
F Sept. 5	5. Two dimensional motion, Projectiles	Ch. 4.1–4.6
M Sept. 8	6. Circular motion, Relative motion	Ch. 4.7–4.9
W Sept. 10	7. Force, Mass, Newton's laws	Ch. 5.1–5.6
F Sept. 12	8. Newton's laws, Force diagrams	Ch. 5.7–5.8
M Sept. 15	9. Applying Newton's laws, Friction	Ch. 6.1–6.3
W Sept. 17	10. Applying Newton's laws	Ch. 6.4–6.5
F Sept. 19	11. Work and Kinetic Energy	Ch. 7.1–7.4
M Sept. 22	12. Work and Power	Ch. 7.5–7.7,7.9
W Sept. 24	**** REVIEW FOR EXAM #1**	
W Sept. 24	**EXAM #1, 8–9:30 p.m**	**COVERS LECTURES 1–10**

[6] There are three separate lectures given on each Monday, Wednesday, and Friday. Two professors are usually in charge of the course, one doing two lectures and the other doing one. Their names, offices, and e-mail addresses are normally listed here but have been deleted.

F Sept. 26	13. Potential Energy, Conservative forces	Ch. 8.1–8.4
M Sept. 29	14. Energy diagrams, Energy conservation	Ch. 8.5–8.8
W Oct. 1	15. Center of mass, systems of particles	Ch. 9.1–9.4
F Oct. 3	16. Conservation of linear momentum	Ch. 9.5,9.6,9.8
M Oct. 6	17. Collisions in one dimension	Ch. 10.1–10.4
W Oct. 8	18. Collisions in two dimensions	Ch. 10.5–10.6
F Oct. 10	19. Rotation, Angular variables	Ch. 11.1–11.6
M Oct. 13	20. Rotational inertia, Torque	Ch. 11.7–11.10
W Oct. 15	21. Rolling, Angular momentum	Ch. 12.1–12.4
F Oct. 17	22. Conservation of angular momentum	Ch. 12.5–12.8
M Oct. 20	23. Newton's laws of gravitation	Ch. 14.1–14.6
W Oct. 22	**** REVIEW FOR EXAM #2**	
W Oct. 22	**EXAM #2, 8–10:00 p.m**	**COVERS UP TO LECTURE 22**
F Oct. 24	24. Kepler's laws, Satellites	Ch. 14.7–14.9
M Oct. 27	25. Simple harmonic oscillations	Ch. 16.1–16.4
W Oct. 29	26. Pendulums	Ch. 16.5–16.7
F Oct. 31	27. Damped and forced oscillations Electric charge	Ch. 16.8–16.9, Ch. 22.1–22.3
M Nov. 3	28. Coulomb's law	Ch. 22.4–22.6
W Nov. 5	29. Electric fields, Field lines	Ch. 23.1–23.6
F Nov. 7	30. Charges in electric fields	Ch. 23.7–23.9
M Nov. 10	31. Flux and Gauss' law	Ch. 24.1–24.5
W Nov. 12	32. Applications of Gauss's law	Ch. 24.6–24.9
F Nov. 14	33. Electric potential, electric fields	Ch. 25.1–25.5
M Nov. 17	34. Electric potential of charged bodies	Ch. 25.6–25.11
W Nov. 19	**** REVIEW FOR EXAM #3**	
W Nov. 19	**EXAM #3, 8–9:30 p.m.**	**COVERS LECTURES 23–33**
F Nov. 21	35. Capacitance and capacitors	Ch. 26.1–26.4
Nov. 24–28	**THANKSGIVING HOLIDAY**	
M Dec. 1	36. Stored energy, dielectrics	Ch. 26.5–26.8
W Dec. 3	37. Current and resistance	Ch. 27.1–27.4
F Dec. 5	38. Ohm's law, power in circuits	Ch. 27.5–27.9
M Dec. 8	39. Single loop circuits	Ch. 28.1–28.5
W Dec. 10	40. Multi-loop circuits, RC circuits	Ch. 28.6–28.8
F Dec. 12	41. **REVIEW FOR FINAL EXAM**	

ASSIGNMENTS

(1) Each lecture has a reading assignment from the textbook. It is strongly recommended that you read these assignments before the lecture, so you have some acquaintance with the material before the lecture; then you are likely to learn more from the lecture, and be able to follow it with considerably greater ease.

(2) The homework assignments will be a combination of questions, exercises, and problems taken from the text. Your problem solutions, carefully and neatly written out, must be turned in to your recitation instructor. Tuesday assignments are due at recitation; Thursday assignments are due at recitation (or laboratory if you have one on Thursday), or at a time specified (no later than 5 p.m.) by your instructor. Working problems is an essential part of learning physics. Many of the exam problems will be similar to the assigned homework problems. It is in your own interest to work the assigned problems even if you have a laboratory instead of a recitation class on the date the homework is due[7].

PASSING COURSE GRADES are based on a numerical score as follows:

[7] Homework assignments are usually 5 problems taken from the set of problems at the end of the relevant chapter. The list of assigned homework problems has been deleted to save space.

Two 90-minute examinations each worth 60 points:	120 points
One midterm examination, worth 90 points:	90 points
Final examination, worth 100 points:	100 points
Recitation/laboratory grade, worth 100 points:	100 points
Total:	410 points

The two 90-minute exams will contain multiple choice problems, totaling 60 points each. The 2-hour midterm exam will contain multiple choice questions, totaling 90 points. The final exam will include multiple choice problems based on lecture/textbook/recitation material, totaling 84 points, and 8 laboratory questions, each worth 2 points. The midterm exam and the final exam will be comprehensive.

This course will be graded on an absolute basis, not on a "curve." If your numerical grade is at least 200, 240, 280, 320, respectively, you will be guaranteed to receive a grade of D−, C−, B−, or A−, respectively. These numbers will not be raised, and it is possible (but not likely) that they might be lowered after the final exam. There will be + and − grades given out.

Since the course is graded on an absolute basis, it is to your advantage to work with other students to learn the material. Helping another student to do well will not adversely affect your own grade. If you are having difficulties with some of the concepts, another student might help you understand it better than the textbook or the lecturer. Or if you help another student understand some concept, you will usually come to understand it better in the process of explaining it to another person. We encourage you to work together, perhaps forming study groups in your dormitories or houses. It is important, though, that all written work turned in to recitation be your own work, and not copied from another student.

NOTE!!!: Regardless of the numerical score, a failing grade will be given if: (1) any laboratory has not been satisfactorily completed, or (2) the student has engaged in any form of academic dishonesty.

RECITATION AND LABS

Students are expected to attend recitation class having worked the assigned problems and should be ready to discuss them in class. The recitation instructor may call in your written solutions to these problems at any time. Solutions to the assigned problems will be posted in the 221 glass case the day after they are due (Wednesdays and Fridays).

The recitation/laboratory part of the course grade will be based on the quality of your homework solutions, performances on quizzes given in recitation, and the quality of your laboratory work (including prelabs). Of the 100 points allotted for recitation/lab, approximately 65% will be for recitation and 35% for lab. Your instructor will give you more details of how she/he will grade your particular section; be sure to have your instructor explain her/his grading scheme.

STUDENT ASSISTANCE

There are several opportunities for students to receive assistance with the material of this course. In particular,

- Two bulletin boards behind glass for Physics 221 are in the hallway outside Room 5. Exam room assignments, exam solutions, exam scores, lab assignments, and other information about the course will be posted on the left board, and problem solutions on the right board. Be sure to check the problem solutions soon after their posting; this is the only place they will be available, and they will have to be removed within a few days to make way for later solutions.

- Room B54 Physics will be the Physics 221 Help Room, open part of the day Mondays through Fridays, and perhaps at times on the weekends. Check the schedule on the door for exact times. Computers will be available in the help room to use for purposes associated with the course; the software will be self-explanatory.

- Check out the physics web site "Physics Instructional Resources" <http://gwp60-17.physics.iastate.edu> and go to the Physics 221 home page.

SUGGESTED STUDY PLAN

Physics 221 is a five-credit course, so the university expects you to spend about 15 hours a week on this course, counting class time. Be sure to attend lecture, recitation, and laboratory regularly: students who do this naturally receive higher grades because of their better understanding of physics. Since class time totals about 5 hours a week, you should spend at least 10 hours a week outside of class on the course. A good division of this time might be:

- 2-3 hours a week reading the assigned textbook pages before lecture and working out the questions for the next lecture.

• 2-3 hours a week on a careful re-reading of the textbook assignment and lecture notes after the relevant lecture; polish up your lecture notes at this time, and make sure you understand everything in them.

• 5 hours a week working on the recitation and pre-lab assignments.

ABOUT THIS COURSE

The emphasis in this course will be on learning the important concepts and laws of physics and on using them to solve problems.

Many students think that the way to solve physics problems is to memorize a lot of formulas and learn to use a calculator to plug numbers into those formulas. This is not the way to solve physics problems, and it will not work for the homework and exams in this course.

What you must do is learn the concepts of physics and learn a few key mathematical equations, mainly definitions and important laws of physics. Then you will be able to work out the homework problems and solve the exam questions. Nothing on the exams will require you to remember or derive a complex formula, and nothing on the exams will require heavy use of a calculator. The exams will test your knowledge of physics.

TYPES OF FORMULAS

Physics is quantitative science, and many physical laws are best handled mathematically as equations or formulas. There are many different types of equations handled in physics. Listed below are some of the major types of equations and examples; as you come across equations and formulas, it is helpful to figure out which of the following groups they belong to.

(1) Definitions, either in formula form or in words. $\mathbf{a} = d\mathbf{v}/dt$ defines the acceleration vector $\mathbf{a}$ as the rate of change of the velocity vector $\mathbf{v}$ with time.

(2) Relations involved defined quantities. $f = 1/T$ is a relation between previously defined quantities of frequency f and period T.

(3) Geometric or kinematic equations. $a = v^2/r$ expresses the geometrical relationship in uniform circular motion between the centripetal acceleration a, the uniform speed v, and the radius r of the motion.

(4) Fundamental laws of physics. Newton's laws of motion, Newton's law of gravitation, Coulomb's law, and laws of conservation of electric charge are examples of fundamental laws.

(5) Restatements of fundamental laws. Gauss' law is an alternative form of Coulomb's law (or vice versa, depending on which is introduced first).

(6) Special cases of fundamental laws. An example is Kirchhoff's loop rule for electric circuits, which is conservation of energy applied to circuits.

(7) Important theorems derived from fundamental laws. An example is the conservation of mechanical energy in situations in which all the forces are conservative.

(8) Approximate empirical formulas ("phenomenological relations") valid only over a limited range. An example is Hooke's law $F = -kx$, which is approximately valid for small x, but does not hold true for very large values of x.

(9) Important special cases. The formula $x = x_0 + v_{0x}t + \frac{1}{2}a_x t^2$ is valid in the special case that a_x is a constant, which is considered an important special case often encountered in mechanics.

(10) In addition, there are formulas of limited applicability which occur in worked out examples. These should be avoided in your solutions to homework assignments, unless, of course, you have first derived them from formulas of the types listed above.

References

[1] D. L. Pursey, page 12 of these proceedings.