Graduate Student Handbook

Raymond H. Hughes Graduate Program in Physics

Department of Physics
University of Arkansas
Fayetteville, Arkansas 72701

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Graduate Affairs Committee
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Mission Statement

The specific goals that we wish to accomplish in our program of graduate studies are the following:

1. **Provide basic knowledge in core physics areas.**
2. **Develop critical thinking and problem solving skills in the conduct of research.**
3. **Develop ability to communicate work to a broad range of audience.**

We assess our program periodically and judge its success based primarily on how well we accomplish the above goals.

I. A Few Important Requirements and Deadlines

Listed below for your convenience are some important requirements and deadlines. Both this Graduate Student Handbook and the Graduate School Catalog:

https://catalog.uark.edu/graduatecatalog/programsofstudy/physicsphys

list details of the various requirements. The following list is not exhaustive; you are responsible for meeting all requirements and deadlines whether listed below or not.

A. A Few Deadlines

Fall Semester

- Submit course substitution or waiver requests to the Graduate Affairs Committee at least two weeks before the fall pre-registration period, using the form in Appendix I. Complete all substitutions/waivers within the first two years of graduate studies.
- In consultation with your advisor, register for spring semester courses during the spring pre-registration period.
- Students completing an M.S. and wishing to pursue a Ph.D. must complete an online application by going to Graduate School website and following the appropriate links.
- Second-year students must form advisory, thesis, or dissertation committee, as appropriate (see Sec. III). Submit forms to the Graduates School—see Appendix H.
- File Master's thesis/Ph.D. dissertation title with the Graduate School as soon as you define a topic and title.* See Appendix H.

Spring Semester

- Submit any course substitution or waiver requests to the Graduate Affairs Committee at least two weeks before the spring pre-registration period using the form in Appendix I. Complete all substitutions/waivers within the first two years of graduate studies.
- Register for fall semester courses, in consultation with your advisor, during the pre-registration period.
- Students in their third semester and beyond must have committee review of their progress in graduate studies completed by February 15. (See Sec VII for details).

* You can change your thesis/dissertation title later, if necessary, by using the same forms—see Appendix H.

B. A Few Important Requirements

If we need to contact you, we will contact you via your University e-mail address or by putting a note in your mailbox in the physics office. It is your responsibility to check your e-mail regularly and mailbox daily. Unless the e-mail message bounces back, we will assume that you have seen the message.

All Ph.D. students should be admitted to the M.S. degree program *simultaneously*. This is because the department awards an M.S. degree to all students en route to a Ph.D. when they have completed all requirements for a non-thesis M.S. degree. A student not admitted to both degrees, must apply online and be admitted to receive an M.S. degree when requirements for the M.S. have been met. To apply go to Graduate School website and follow the appropriate links. In addition, students must complete the following steps:

(i) Pass the Ph.D. candidacy exam;

(ii) Obtain a copy of UA transcript, showing all the course work needed to complete the master's degree (36 credit hours, not counting PHYS 600V and 700V);

(iii) Submit the transcript and form Record of Progress (Appendix M) to the Physics Department Graduate Student Advisor for approval;

(iv) Have the form signed by the members of his/her PhD dissertation committee;*

(v) Then have the form signed by the Physics Department Chair;

(vi) (vi) Submit the form to the graduate school.

All students on Assistantships in summers must be engaged in graduate studies (which could be in the form of research) and be formally registered. See Appendix F.

All post-candidacy students must register for at least one credit hour of dissertation each semester including summers (see the Graduate School catalog).

The department expects all students to attend colloquia and encourages them to attend journal club meetings.

* The graduate advisor may recommend the Graduate Affairs Committee members to sign the form in cases where the dissertation committee has not been formed.

II. Admission Requirements

Prerequisites to M.S. and Ph.D. Degrees Programs:

Prospective students must satisfy the requirements of the Graduate School as described in the Graduate School Catalog and have the approval of the Graduate Admissions Committee of the Department of Physics. To be admitted to graduate study in physics without deficiency, the candidates must have an undergraduate degree with the equivalent of a 30-hour major in physics including intermediate level courses in mechanics,[*] electricity and magnetism,[†] thermal physics,[‡] quantum mechanics,[§] and mathematics through differential equations. Students who present less than the above may be admitted with deficiency subject to the approval of the department's Graduate Admissions Committee. Students may eliminate deficiencies while concurrently enrolling in graduate courses, provided prerequisites are met. The Graduate School requires the submission of general GRE scores for acceptance into the graduate school. While submission of the advanced physics Graduate Record Examination (GRE) scores is not required for admission, students who have taken the advanced physics test are urged to submit their test scores to the Physics Department to facilitate advising and placement.

International Students

Students whose native language is not English must demonstrate proficiency in English by scoring a minimum of 550 (paper test) or 80 on iBT (Internet-Based Test) TOEFL for admission to the Graduate School. (This is equivalent to a score of 213 on the computer-based test).

In addition, most incoming students are administered English Language Placement Test (ELPT) during the orientation period. (Those who are required to take this test are informed so in their admission letter.) Those who fail the test will be required to enroll in EASL (English as a Secondary Language) courses. The current Graduate School policy is to pay tuition for EASL courses for students on 50% or higher GA appointments, if requested by the department.

International students on teaching assistantship have additional language requirements as described in Sec. VIII.

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[*] At the level of Mechanics by Symon (Addison-Wesley).
[†] At the level of Introduction to Electrodynamics by Griffiths (Prentice Hall).
[‡] At the level of Heat and Thermodynamics by Zemansky and Dittman (McGraw-Hill).
[§] At the level of Introduction to Quantum Mechanics by Griffiths (Prentice Hall).

III. Degree Requirements

The departmental requirements for various graduate degrees are given below. In addition, the candidate must satisfy the Graduate School requirements (e.g., residency requirement, etc.) as detailed in the Graduate School catalog.

A. Master of Science (M.S.) in Physics Degrees:

Students may choose between two M.S. degrees in the Physics Department. These are the thesis M.S. in Physics (30 credit hours required), and non-thesis M.S. in Physics (36 credit hours required).

A departmental graduate advisor will advise incoming graduate students for the first two years or until the student has chosen a thesis advisor. The student must form his/her thesis or advisory committee by the end of his/her third academic semester and file the appropriate form with the Graduate School (see Appendix H). The thesis committee (thesis-path students) consists of the research advisor as chair and two members of the physics faculty. The advisory committee (for non-thesis-path students) consists of the individual study project advisor as chair and two members of the physics faculty.

Both MS degrees share the following academic requirements: Completion of PHYS 5011 Seminar - Introduction to Research; PHYS 5073 Mathematical Methods for Physics; PHYS 5413 Quantum Mechanics I; PHYS 5313 Advanced Electromagnetic Theory I; PHYS 5111 Research Techniques,[*] and PHYS 5041 Journal Club.

MS degree candidates who have had similar courses at another institution may substitute[†] up to 6 credit hours of other courses in lieu of those listed above, on a course-by-course basis, upon petitioning the Graduate School (see Appendix I). This should be done within the first two years of the graduate study. The committee meets two weeks before the pre-registration period each semester to consider the petitions.

[*] A grade of CR is assigned for this course. Credit for this course appears in the total credit hours requirement but not in the GPA.

[†] Total number of credit hours to be taken at the University of Arkansas is not affected by this substitution.

All remaining required degree hours will consist of elective courses. The table below shows the minimum number of physics elective hours.

Degree Program	Physics Electives
MS Physics thesis	12
MS Physics non-thesis	18

Students will select electives from courses listed in the graduate catalog as appropriate to their field of specialization, with course selection approved by their thesis committees. Students can also choose courses offered by other departments, upon the approval of their thesis committees. For the purposes of this requirement, any Astronomy (ASTR) graduate course listed in the Graduate Catalog and taught through the Physics department will be considered a Physics Elective.

No more than one 4000-level course may be counted toward the 30-hour requirement for the thesis option, and no more than two 4000-level courses may be counted toward the 36-hour requirement for the non-thesis option.

The **Thesis path M.S. degree** requires completion of six Master's thesis hours under PHYS 600V and a written thesis successfully defended in a comprehensive oral exam given by the student's thesis committee.

The **Non-thesis path M.S. degree** requires completion of three hours under PHYS 502V Individual Study in Advanced Physics leading to a written project report successfully defended in a comprehensive oral exam given by the student's advisory committee. Students who pass the Physics Ph.D. candidacy examination will be considered to have satisfied the PHYS 502V requirement of the non-thesis path M.S. degree; the total 36 credit hours requirement needs to be met in order to obtain the M.S. degree. (See Sec. IB).

Coursework for the M.S. Degrees—Summary Chart

Required Courses (12 Credit Hours)

PHYS-5011	Introduction to Research
PHYS-5111	Research Techniques-Lab Rotations
PHYS-5041	Journal Club
PHYS-5073	Math Methods for Physics
PHYS-5413	Quantum Mechanics I
PHYS-5313	Advanced EM I

Additional Requirements

Thesis Option	Non-Thesis Option
Additional elective courses[*,†]	Additional elective courses[*,†]
(12 Credit Hours)	(21 Credit Hours)
Six Hours of Thesis Research	Three Hours of Individual Study
Oral Defense of Thesis	Oral Examination
(30 Credit Hours Total)	(36 Credit Hours Total)

Strongly Recommended Elective Courses

PHYS-5423	Quantum Mechanics II
PHYS-5363	Scientific Computation (Co-listed with MATH 5363)
PHYS-5263L	Experiment and Data Analysis

[*] PHYS 600V and 700V should not be counted towards the required 36 hours.

[†] Courses taken outside of physics must fit the student's program of specialization and career goals and must be approved by her/his advisory committee. Some of the suggested courses are:

ELEG 4203	Semiconductor Devices
ELEG 5213	Integrated Circuit Fabrication Technology
ELEG 5273	Electronic Packaging
ELEG 5323	Nanostructures I
ELEG 6233	Solid State Electronics II
ELEG 6273	Advanced Electronic Packaging
MEEG 4303	Materials Laboratory
MEEG 4443	Thermal and Vibration Analysis and Testing of Electronics
MEEG 5623	Intro to MEMS
MEPH 5873	Nanofabrication and Processing
MGMT 5383	Intra/Entrepreneurship of Technology
CSCI 4203	Operating Systems
CSCI 5303	Parallel Programming

Typical Program of Study (M.S. Students)

1st Semester [*]

PHYS 5011 Introduction to Research

PHYS 5073[†] Mathematical Methods for Physics

PHYS 5413[†] Quantum Mechanics I

2nd Semester

PHYS 5313 Advanced Electromagnetic Theory I

PHYS 5111 Research Techniques-Lab Rotations

PHYS 5423 Quantum Mechanics II (recommended)

and/or Elective(s)

PHYS 5041 Journal Club

Summer

Research

3rd & 4th Semesters

Research and Electives

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[*] All graduate students on TA appointments are required to register for one credit–hour of PHYS 500V—Laboratory and Classroom Practices in Physics during their first semester of appointment.

[†] A diagnostic exam will be administered in the first class meeting of these courses. In view of the results of this exam, the instructor may (i) modify the syllabus of the course, (ii) assign a student additional reading and homework problems, or (iii) advise a student to take an undergraduate course first.

B. Requirements for the Doctor of Philosophy degree:

Admission to candidacy for the Ph.D. degree requires students to (a) form a dissertation committee, (b) pass the research-based candidacy exam, (c) obtain a minimum grade of B in core physics courses, (d) work with the physics office manager to post a public announcement of dissertation/thesis defense, and (e) file a Record of Progress form (see Appendix M) with the Graduate School.

A departmental advisor will advise incoming graduate students for the first year or until the student has chosen a dissertation advisor. The student must form his/her dissertation committee by the end of his/her second academic semester and file the appropriate forms with the Graduate School (see Appendix H). The dissertation committee consists of the research advisor as chair and two other members of the graduate faculty.

The research-based candidacy examination, also known as the PhD qualifier, consists of a written proposal and oral presentation. All students entering the PhD graduate program in the fall semester must take their qualifier no later than the end of their fifth semester of graduate studies. Students entering the PhD graduate program in the spring semester must take their qualifier no later than the end of their sixth semester of graduate studies. Especially well-prepared students are encouraged to take their qualifier earlier. A candidate failing the research-based qualifier in his/her first attempt, will have one additional semester for a second and final attempt.

Ph.D. students must complete a minimum of 33 semester-hours in 5000- and/or 6000-level courses beyond their Bachelor of Science degree. Courses taken to fulfill the requirements for the University of Arkansas M.S. Physics degrees can be included in this 33 semester-hour requirement. Students who have had similar courses at another institution may obtain a waiver,* on a course-by-course basis, upon petitioning to the Graduate Affairs Committee (Appendix I). This should be done within the first two years of the graduate study. Students requesting transfer of credit for core courses may be required to demonstrate their proficiency by taking the finals in the core courses and passing them with a minimum grade of B. The Graduate Affairs

* Each waived course reduces the credit hour requirement for the degree.

Committee may consider student performance in other related courses taken here in reaching a decision on this request.

Ph.D. students must take PHYS 5011 Seminar—Introduction to Research, PHYS 5111 Research Techniques-Lab Rotations,* PHYS 5041 Journal Club, PHYS 5073 Mathematical Methods for Physics, PHYS 5413 Quantum Mechanics I, PHYS 5313 Advanced EM I, PHYS 5103 Advanced Mechanics, and PHYS 5213 Statistical Mechanics. Fifteen additional semester hours in elective physics graduate courses will be required, and they must be selected from the 5000- or 6000-level courses listed in the graduate catalog appropriate to the student's field of specialization and approved by the student's dissertation committee. For the purposes of this degree requirement, any Astronomy (ASTR) graduate course listed in the Graduate Catalog and taught through the Physics department will be considered a Physics Elective. Additional elective courses outside of the Physics department may be taken with dissertation committee approval.

A minimum grade of B is required in the following core courses: PHYS 5073 Mathematical Methods for Physics, PHYS 5413 Quantum Mechanics I, PHYS 5313 Advanced EM I, PHYS 5103 Advanced Mechanics, and PHYS 5213 Statistical Mechanics. If a minimum grade of B is not obtained, the course may be repeated once at the next offering. If the student cannot obtain a minimum of B on two attempts, he/she will not be allowed to continue in the Ph.D. program.

By the end of the sixth semester, all PhD students must pass the research qualifier and pass PHYS 5073 Mathematical Methods for Physics, PHYS 5413 Quantum Mechanics I, and PHYS 5313 Advanced EM I.

Ph.D. students must also earn 18 hours of credit in PHYS 700V Doctoral Dissertation, submit a dissertation, and defend it successfully in a comprehensive oral examination given by the dissertation committee. **The doctoral degree will be awarded to students who complete a minimum of 72-graduate semester credit hours beyond the bachelor's degree.**

* A grade of CR will be assigned for this course. This course counts toward the total credit hour requirement but does not count in GPA.

Required Coursework for Physics Ph.D. Students—Summary Chart

Required Courses[*]

PHYS 5011	Introduction to Research
PHYS 5111	Research Techniques-Lab Rotations
PHYS 5041	Journal Club
PHYS 5073	Mathematical Methods for Physics[†]
PHYS 5413	Quantum Mechanics I[†]
PHYS 5313	Advanced Electromagnetic Theory I[†]
PHYS 5103	Advanced Mechanics[†]
PHYS 5213	Statistical Mechanics[†]

At least fifteen credit hours of additional coursework chosen from the 5000/6000-level Physics courses listed in the Graduate School Catalog. Students are strongly encouraged to take the following courses as part of the elective courses:

PHYS 5423	Quantum Mechanics II
PHYS 5323	Advanced Electromagnetic Theory II
PHYS 5263L	Experiment and Data Analysis
PHYS 5363	Scientific Computation (co-listed with MATH 5363)

Concentrations in Astrophysics, Biophysics and Neuroscience

Physics PhD students may also choose one of the following concentrations by meeting its requirements: Astrophysics, Biophysics, or Neuroscience (concentration will print on transcript).

[*] All graduate students on TA appointments must register for 1 credit–hour of PHYS 500V Laboratory and Classroom Practices in Physics during their first semester of appointment.

[†] A diagnostic exam may be administered in the first class meeting of these courses. In view of the results of this exam, the instructor may (i) modify the syllabus of the course, (ii) assign a student additional reading and homework problems, or (iii) advise a student to take an undergraduate course first.

Astrophysics Concentration

(Program Coordinators: Prof. D. Kennefick, Prof. J. Kennefick, and Prof. Lehmer)

Physics Ph.D. with Astrophysics Concentration students must also take:

ASTR 5033	Astrophysics I: Planets and Stars
ASTR 5043	Astrophysics II: Galaxies and Cosmology

Nine (9) additional hours in elective coursework appropriate to the student's field of specialization and approved by the student's research thesis advisory committee.

Biophysics Concentration

(Program Coordinators: Prof. Kumar, Prof. Li, and Prof. Wang)

Physics Ph.D. with Biophysics Concentration students must also take:

BIOL 5313	Molecular Cell Biology
PHYS 5613	Introduction to Biophysics and Biophysical Techniques

Nine (9) additional hours in elective coursework appropriate to the student's field of specialization and approved by the student's research thesis advisory committee.

Neuroscience Concentration

(Program Coordinator: Prof. Shew)

Physics Ph.D. with Neuroscience Concentration students must also take:

BIOL 4793	Intro to Neurobiology
PSYC 4183	Behavioral Neuroscience

Nine (9) additional hours in elective coursework appropriate to the student's field of specialization and approved by the student's research thesis advisory committee.

Typical Program of Study (Physics Ph.D. Students)

1st Semester (Fall)

PHYS 5011 Introduction to Research

PHYS 5073 Math Methods for Physics

PHYS 5413 Quantum Mechanics I

2nd Semester (Spring)

PHYS 5313 Advanced EM Theory I

PHYS 5041 Journal Club

PHYS 5111 Research Tech./Lab Rotations

Elective

Summer I

Research

3rd Semester (Fall)

PHYS 5103 Advanced Mechanics

Elective

Research

4th Semester (Spring)

PHYS 5213 Statistical Mechanics

Elective

Research

Subsequent Semesters and Summers

Elective

Research

IV. Candidacy Examination

Research Based Written Proposal and Oral Presentation Ph.D. Qualifier

Who must pass the PhD research-based qualifier and when:

All physics PhD students are required to pass the research-based qualifier. The qualifier is a written proposal prepared and orally presented by the candidate, which describes in detail his/her plan for research that will become the basis of their PhD thesis. The purpose of the qualifier is to determine if the student is prepared to move to the independent research stage of his/her degree. Upon satisfactorily completing the qualifier, in compliance with the standards outlined by the University of Arkansas Graduate School, the student will be admitted to candidacy and will proceed to work toward completion of the PhD degree.

All students entering the PhD graduate program in the fall semester must take their qualifier no later than the end of their fifth semester of graduate studies. Students entering the PhD graduate program in the spring semester must take their qualifier no later than the end of their sixth semester of graduate studies. Especially well-prepared students are encouraged to take their qualifier earlier. Students who complete a Master's degree under a physics faculty research advisor at the University of Arkansas and are then admitted to the PhD program must schedule their qualifier by the end of their second semester. Failure to schedule the qualifier will be considered a failure to pass.

What are the departmental goals for the research-based qualifier?

Both the written proposal and oral presentation must establish an original and substantive plan for the proposed study that will deepen the candidate's knowledge in his/her selected area of research. The qualifier committee expects the candidate to demonstrate a depth of knowledge in his/her area of study with respect to both the literature and the fundamental physical principles that form the basis of the field. In addition, the committee will evaluate the proposed research to determine whether or not the candidate understands the proposal, has a clear idea of what is required to complete it, and whether or not it is reasonable that it can be completed within the expected time frame.

What is the make-up of the PhD qualifier committee?

Before the candidate schedules their qualifier, they must first have their PhD qualifier committee approved by the graduate affairs committee (GAC). The qualifier committee consists of the candidate's research advisor and three other members of the graduate faculty typically drawn from the candidate's dissertation committee. The GAC, in consultation with the candidate's research advisor, will select the three members of the qualifier committee and appoint its chair. The purpose of the GAC selection process is to provide a reasonable level of uniformity across all qualifier committees and ensure members have the necessary expertise. The GAC will communicate to the candidate the members of the qualifier committee and the expectations of the written proposal and oral presentation. In addition, the GAC will communicate to the chair of the qualifier committee the documentation requirements.

Expectations for written proposal:

The written proposal must contain between 2,500 and 3,500 words, with the actual word count noted at the top of the first page (this does not include the required one or more pages for literature citations, which should be thorough and directly relevant to the proposal). The written proposal should be double-spaced, use 12-point font, leave one inch margins, and be organized by sections, including cover page, abstract or summary, objectives or aims, introduction and background, experimental and/or theoretical tools, detailed activities already completed, proposed future activities, expected outcomes, timeline, and literature citations (properly numbered in the body, and including all authors, article title, journal, volume, page, and year).

Proposal content should cover the candidate's broad area of physics research (e.g., condensed matter, astrophysics, etc.), his/her sub-area of research (e.g., quantum optics, super-resolution microscopy, etc.), his/her specific project, and a description of the tools and techniques required to perform the research.

It is critical the candidate appreciate that the written proposal is not simply a literature review, but must detail research activities already carried out by the candidate (beyond the literature review). The candidate must show that they are already actively engaged in research, following the guidance of their research advisor, and making satisfactory progress by providing detailed results of their works. It is expected that these works may not yet be publishable, but are nevertheless essential for progression. There should be ample evidence that the student has learned the techniques and methods of his or her specific area of research. This evidence could take many forms: reproducing or re-deriving known results, running numerical simulations, completing essential experimental steps, etc.

It is vital that a strong effort is made to create a clear and well-organized proposal. This is a fundamental skill for all practicing physicists, whether they are working in industry, academia, or government. Good technical writing skills, such as the appropriate inclusion of informative graphs and tables, must be evident. PhD level physicists should be able to demonstrate skills with software packages such as TeX, MS Word, MS Excel, Origin, Mathematica, or their equivalents, beyond basic typing and formatting. Creativity and originality is expected, with the proposal written in the candidate's own words. Every candidate must understand that plagiarism is unacceptable.

Timing for written proposal, written feedback, and scheduling of oral presentation:

The candidate's written proposal must be provided to his/her qualifier committee four weeks prior to the date of the oral presentation. Each member of the committee has one week to respond with a written review. The written review must use the Appendix K form and should briefly summarize the proposed research, express the strengths and weaknesses of its intellectual merits, and provide a list of mandatory revisions. The candidate must revise the written proposal based on this feedback and provide the modified version to the qualifier committee one week before the oral presentation. The candidate is responsible for providing to the GAC copies of the written proposal (before and after revisions) and the written reviews.

Expectations for oral presentation:

The candidate should allow 90 minutes for the oral part of the qualifier and plan a 40-minute presentation. The oral presentation should follow the written proposal. The candidate decides if the presentation is open to the public, includes other faculty, or is a closed presentation.

What to expect during oral presentation:

The chair of the qualifier committee is responsible for conducting the meeting. Throughout the presentation the candidate will be questioned by the qualifier committee and expected to demonstrate reasonable knowledge in their selected area of research. The qualifier committee will not be testing the candidate over any specific graduate or undergraduate course material. Instead, their questions will be directly related to the content in the written proposal and oral presentation. At the end of the presentation and general discussion, the chair will ask members of the general audience to leave and then allow each member of the qualifier committee, in turn, to question the candidate. In general, the candidate must attempt to answer the questions before any assistance from the other committee members is allowed.

End of oral presentation discussion and voting process:

At the conclusion of the final questioning, the candidate will be asked to leave the room. The qualifier committee will discuss the quality of the written proposal and oral presentation with the student's research advisor, who is responsible for completing the graduate advisory committee report and annual graduate student academic review forms (note, this presentation also completes the annual evaluation requirement). After this discussion, the research advisor will leave the room, as he/she does not have qualifier committee voting rights. The remaining three members of the qualifier committee will discuss and vote to pass or fail the candidate. A majority vote is required to pass. After this decision, the research advisor will reenter the room, be told the outcome, and be responsible for communicating the outcome to the candidate. The chair of the committee is responsible for communicating the outcome to the departmental staff by completing the Oral Presentation Research Qualifier Committee Report Form and Final Report (Appendix J). The Chair of the Physics department must send an official letter to the candidate informing them of the outcome, a copy of which is placed in the students permanent file and sent to the graduate school by the departmental staff (Appendix L).

Second attempt:

A candidate failing the research-based qualifier in his/her first attempt, will have one additional semester for a second and final attempt. Prior to the second attempt, the candidate may request to change the make-up of his/her qualifier committee by submitting a new list with a detailed justification to the GAC. If the candidate changes his/her PhD advisor after the failed first attempt, then he/she is granted two additional semesters for the second and final attempt.

Appeal process:

If the candidate fails the research-based PhD qualifier a second time, and wishes to dispute the outcome, then he/she has one week to file a written complaint with the Chair of the physics department. The complaint must be specific. A general complaint such as, "I thought I did well enough to pass," is not acceptable.

Required forms at oral presentation:

Qualifier committee report (see Appendix J)

Graduate advisory committee report (see Appendix D)

Annual graduate student academic review (see Appendix E)

Candidacy Exam Notification Form (see Appendix L)

V. Cohort Program

Our graduate program offers a unique opportunity to the graduate students to develop skills, which are extremely important in the workplace, but are not normally taught in graduate classes. These skills include:

(1) Oral communication skills;

(2) Written communication skills; and

(3) Professional ethics.

Written communication skills and professional ethics are taught in Introduction to Research, PHYS 5011; oral communication skills are taught in Journal Club, PHYS 5041. Each group of incoming graduate students forms a Cohort Group, and each Cohort Group takes these seminars together to foster strong ties among the students in a cohort group.

VI. Course Rotation Schedule

a) Every Year

Fall	Spring
PHYS 5011: Introduction to Research	PHYS 5111: Research Techniques
PHYS 5073: Math. Methods for Physics	PHYS 5313: Advanced EM I
PHYS 5413: Quantum Mechanics I	PHYS 5423: Quantum Mechanics II
PHYS 5713: Condensed Matter Physics I	PHYS 5734: Laser Physics
PHYS 5363: Scientific Computation	PHYS 5774: Optical Prop. of Materials
PHYS 5103: Advanced Mechanics	PHYS 5041: Journal Club
PHYS 5323: Advanced EM II	PHYS 5213: Statistical Mechanics
PHYS 5263L: Exp. & Data Analysis	

b) Fall semester of even years	Spring semester of odd years
PHYS 6413: Quantum Mechanics III	PHYS 5513: Atom. & Mol. Physics
PHYS 5753: Appl. Nonlinear Optics	PHYS 6713: Cond. Matter Phys. II
PHYS 5723: Phys. at the Nanoscale	

c) Fall semester of odd years	Spring semester of even years
PHYS 6613: Quantum Optics	PHYS 5613: Intro. Biophysics Tech.
ASTR 5033: Astrophysics I	PHYS 5093: Group Theory *or*
	PHYS 5763: Exp. Meth. Nano-science
	ASTR 5043: Astrophysics II

d) Irregular schedule

All the other courses listed in the Graduate Catalog are offered on an irregular schedule. If you would like a particular course to be offered, bring it to the attention of the Department Chair at least a semester in advance.

VII. Annual Evaluation

Each graduate student's progress toward the completion of his/her degree is evaluated by his/her thesis/dissertation/advisory committee once a year. All graduate students, whether on an assistantship or not, are required to have this evaluation, which must be completed by Feb. 15.*

For this purpose, all students in their second year and beyond shall meet their advisory committees in the fall or early spring semester but no later than February 15. Students with last names beginning with letters A through M shall have their annual reviews completed by winter break and those with last names beginning with letters N through Z by Feb 15. First year graduate students shall meet with the departmental graduate student advisor before Feb 15 for this review.

Failure to have an evaluation will result in a letter of warning by the Chair with a deadline by which the evaluation must be completed. If the student fails to have the evaluation done by the deadline he/she will be dropped from the Physics program. If a student chooses not to have annual review because he/she is projecting to graduate in summer, he/she will not be eligible for support in the Fall semester if, for any reason, he/she is unable to finish by the projected date. Therefore, if there is ANY doubt about being able to finish, it would be safer for you to have a review.

For the annual review, the student submits a 2-3-page report to his/her thesis/dissertation advisory committee, following the format of Appendix C, at least 3 days before the scheduled meeting. In the meeting, the student makes an oral presentation of his/her progress toward the degree and future plans. After reviewing the candidate's progress, the committee advises the student of its evaluation, recommends future coursework, and gives directions on the future

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* A committee meeting and oral presentation may be waived for a student if all of the following conditions are met:

1. The student is in his/her 4th or later year of graduate studies.
2. The student obtained a score of 5 on items (iv) and (ix) of the committee report in his/her last committee review in which he/she made an oral presentation.
3. The advisor certifies that the student is continuing to make excellent progress in research.
4. The advisor certifies that the student is on track for graduation in six years from the start of graduate studies.

Note that even if the oral presentation is waived, the student will still need to write the report and submit it to the committee for evaluation. Furthermore, even if the student meets all of the above criteria, the student or any member of the committee may request a meeting of the committee and a presentation by the student.

program of research. If the student is a candidate for reappointment, such as a Graduate Assistant, the committee also makes a recommendation on the reappointment.

The chair of the committee reports the results of this review to the Graduate Affairs Committee on two forms: a departmental form (Appendix D) and a Graduate School form (Appendix E). She/he also obtains the student's signature on the Graduate School form and gives copies of both to the student. It is the student's responsibility to bring these forms to the meeting. The Physics Faculty, as a whole, evaluates each graduate student's progress in graduate studies during the spring semester. Decisions on the reappointment (or non-reappointment) to graduate assistantships are based on this evaluation (see Section VIII, below).

The Department reports each graduate student's progress in graduate studies to the Dean of the Graduate School by June 30th of each year. An unsatisfactory progress requires a plan of remediation to be developed by the department and reported to the dean.

VIII. Award of Graduate Assistantships

Recommendation for initial financial support (graduate assistantships) is made by the Graduate Admissions Committee, after a review of the candidate's academic credentials. An attempt is made to support all deserving students.

Non-native speakers of English, regardless of citizenship, even if eligible for a TOEFL waiver, must demonstrate competency in both spoken and written English to be eligible for a graduate assistantship that requires direct contact with students in a teaching or tutorial role, in a traditional classroom setting or via distance education.

Competency in **spoken English** may be demonstrated by:

Submitting a test score of at least 7 on the IELTS (speaking) sub-test, 26 on the Internet-based TOEFL (speaking) sub-test, 71 on the PTE-A (speaking) sub-test, or "pass" on the Spoken Language Proficiency Test (SLPT) and

Competency in **written English** may be demonstrated by:

a. Submitting a test score of at least a 6.0 on the IELTS (writing) subtest, 26 on the Internet-based TOEFL (writing) subtest, a 4.0 on the GRE, or a 75 on the English Language Proficiency Test (ELPT)

OR

b. Concurrently enrolling in ELAC 2033[*] Research Writing for Non-Native Speakers and ELAC 0011 Writing Workshop: Grammar through Editing via placement by test scores (5.5 IELTS writing sub-test, 23 Internet-based TOEFL writing sub-test, 3.5 GRE or 70 on the ELPT). **The Department Chair must request this option**.

A Teaching Assistantship may be awarded with other departmental duties, but in such a case the student must agree to take the spoken English test at its earliest offering. If the test is failed then the student must enroll in the appropriate English Language and Cultural Studies course(s), such as ELAC 5050 at his/her own expense in order to meet the contact teaching assistantship requirements set by the graduate school. Proof of enrollment must be provided to

[*] May also enroll in ELAC 4043 Research Writing in lieu of ELAC 2033.

the physics department before the Assistantship appointment for the third semester can be made.

If spoken English proficiency is not passed by then, the student must take the course recommendations of the ELAC Coordinator until proficiency is met. Failure to work toward proficiency in spoken English will result in a letter of warning by the Chair with a deadline by which the additional courses must be completed. If the student fails to take the additional courses by the deadline he/she will be dropped from the Physics program.

Reappointment of the Graduate Assistants requires that the candidate (a) earn a minimum of 6 graduate credit hours (for 50% appointment) per semester, (b) maintain good standing in the Graduate School, (c) make satisfactory progress in his/her research (see below), and (d) carry out teaching/research duties in a professional manner. These criteria apply to both teaching and research appointments.

A student's progress in graduate studies will be judged primarily by his/her performance in physics core courses and assigned duties. The student's progress in research is determined by his/her thesis/dissertation/advisory committee and reported to the Graduate Affairs Committee once a year (see Sec.VII: Annual Evaluation). It is the student's responsibility to arrange the committee meeting before February 15th every year (see Sec.VII). The faculty, after consideration of the committee recommendation, GPA, and teaching evaluation (if applicable) decides on the reappointment.

A previously awarded Assistantship may be revoked if the student (a) does not earn a minimum of six graduate credit hours, (b) receives one or more F grades, or (c) receives two or more D grades in physics core courses in a semester.

Master's students are generally supported for two academic years. In special circumstances, a student may be given an appointment for the third and final year, if approved by the Dean of the Graduate School. A graduate student entering the Ph.D. program with a Bachelor's degree can hold a graduate assistantship for the maximum of six years. A graduate student entering the Ph.D. program with a Master's degree can hold a graduate assistantship for a maximum of four years. Any extension beyond these limits requires the approval of the Dean of the Graduate School.

Ph.D. students who fail the candidacy examination and switch to a Master's program are governed by the same rules as the candidates for the master's degrees, i.e., they are eligible for an assistantship for a maximum of three years.

Generally, only those students who are engaged in research during the summer are considered for summer teaching appointments. In order to hold an Assistantship (Teaching or Research), the student must register for at least 3 credit hours in any of the summer sessions (Appendix F). These hours must be chosen from PHYS 600V (M.S. Thesis), PHYS 700V (Doctoral Dissertation), or in special circumstances, PHYS 502V (Individual Study in Advanced Physics).

IX. Teaching Assistant Responsibilities

Teaching Assistants have a variety of duties in the Department, including, but not limited to teaching laboratories, practica and recitations (drills), grading, tutoring, developing laboratory experiments, proctoring exams, etc. The following is a partial list of things that are important.

a) Prepare a general instruction sheet to hand out in your first class. This sheet should contain at least the following information: your name, office room number, telephone number, e-mail address, office hours, your website address (if you have one), your grading scheme, and your general expectations from the students. In addition to handing out this sheet, you should also discuss all important issues in class. Also, tell them where your mailbox is located.

b) All TA's who have lab, practicum, or recitation assignments are expected to have at least three office hours per week. It is absolutely essential that you be present in your office during these hours, and keep your office door open.

c) If your assignment is recitation or practicum, it is absolutely important that you read the relevant sections of the book and solve all of the assigned homework problems before facing the class.

d) If your assignment is labs, you need to perform the experiment on your own, take and analyze the data, know all the subtle features of the experiment, sources of systematic as well as random errors, etc., before you come in contact with the students. This is extremely important. All of the lab reports and quizzes should be graded and returned to the students weekly. If there is an exception, you need to inform your supervisor about it.

e) Make sure that you do not change your grading policy in the middle of the semester. This causes lots of dissatisfaction.

f) Students should not be allowed to bring food or drinks to the class. If they come in with these items, they need to dispose of them immediately. After the session is over, make sure that you leave the lab tidy and clean. Ask your students to put things back where they belong, discard loose pieces of paper, etc. Do not leave any graded lab reports or quizzes in the lab. Those not picked up by the students you should keep.

g) All broken or malfunctioning equipment should be brought to the attention of the Laboratory Curator immediately so that it can be fixed, as much as possible, before the next session.

h) Keep regular contact with your supervisor, if he/she does not have regular TA meetings. If he/she does have these meetings, your attendance is mandatory.

i) Arrange a backup TA, who can take your class in case you get ill.

j) If you are not going to be able to meet your class for any reason, it is your responsibility to arrange a substitute TA, and to inform your supervisor. Under no circumstances should a scheduled class be cancelled without your supervisor's knowledge.

k) You are expected to be on campus during your period of appointment, even if classes are not scheduled

X. General Expectations

Each graduate student is expected to make a significant contribution to the intellectual atmosphere of the Department. Major contributing factors to this atmosphere are: the strong desire to learn, motivation, creativity, and untiring effort in research. Moreover, graduate students are expected to interact informally with other graduate students and with the faculty. There is much to be learned from these interactions. They are expected to attend all colloquia, and are encouraged to attend journal club meetings as well as seminars in areas of their research. Occasionally, they are expected to give talks on topics related to their own research. Graduate Assistants must look upon their assistantship as part of their education rather than a job unconnected to their education.

Teaching Assistants are expected to be on campus during the periods of their appointments, even if no classes are being held.

In general, we have the following expectations of each of our graduate students:

(i) A commitment to hard work. Students are expected to devote most of their energy to their work. This means working long hours and every day of the week. This expectation is based on our desire to develop your abilities to the highest level and to prepare you for a successful career.

(ii) A commitment to develop independence. We expect that sometime in your graduate studies the research project you are working on truly becomes your own. Your independent thinking should at some point, drive its direction and design. This expectation is, again, based on our desire to prepare you for the challenges you will face after graduation.

(iii) A commitment to excellence in teaching. We expect you to prepare to the best of your ability to teach the class in a thoughtful and caring manner.

(iv) A commitment to excellence in research. We expect you to work hard toward scholarly, original research that enhances the overall reputation, success, and productivity of the department.

(v) A commitment to excellence in service. We expect you to be a model representative of the Physics Department in the larger community. Specifically, we expect you to participate during High School Physics Day, help at local science fairs, community demonstrations, etc.

(vi) A commitment to excellence overall. We expect you to be a good citizen of our department. That is, you must consider in your daily activities, what actions best promote the well-being and overall success of the Physics Department. Whether your appointment is TA, RA, or self-supporting, your responsibilities include enhancing the department's agenda in Teaching, Research, and Service. Our department draws no distinction or relationship between your origin of support and your responsibilities. That is, if you are supported as a TA, you must also participate in research and service activities. In addition, if you draw support as an RA, you must also participate in teaching and service activities if you are called upon to do so.

In order to maintain our standards in teaching, research, and service, it is critical that every graduate student act in a professional manner and complies with the above guidelines. If a graduate student purposely violates one of these guidelines, his/her supervisor, or the chair, or vice-chair may take further action as outlined below:

a) A written warning may be issued.

b) If a further violation occurs, the student's stipend may be reduced by 10% effective immediately.

c) If another violation occurs, the Graduate Assistantship may be revoked and/or the student may be dropped from the Physics program.

For serious violations of professional conduct, a Graduate Assistantship may be terminated without warning.

XI. Plagiarism Policy

Students are advised to be very careful about the issue of plagiarism. Any written materials submitted for academic evaluation, such as lab reports, your thesis/dissertation, and papers you may write for publication must be written in your own words. You should not copy material (even short passages) from elsewhere, except where you use quotation marks and cite the original work. This applies even where such material may have been written by others in your own research group, or in cases where you wish to use stock language (for instance from an instruction manual or from documentation internal to your group) to describe a well-known apparatus or procedure. You should also use caution, and consult with your advisor, in cases where you wish to make use of language written by you in collaboration with others. In any case, the authorship of all material you use (whether language, data, figures or calculations, or any other material) should be clear to the reader and to your committee. In the case of your own previously published (single author) paper, consult the journal's copyright policy. Be aware that software exists which anyone may use to screen your thesis/dissertation for plagiarism. For further detail on plagiarism and on what is expected of all thesis presenters, consult the Graduate School Catalog. Please bear in mind that plagiarism is considered a form of academic dishonesty. In addition to your work being rejected, you may also face disciplinary actions, up to and including dismissal from the program.

XII. Raymond H. Hughes Fellowship

Fellowships to Currently Enrolled Students

The Raymond H. Hughes Fellowship is an award given to an outstanding graduate student which provides the student with a semester off from their teaching responsibilities for one semester to focus on their research. Each Spring, the Chair of the Graduate Affairs Committee will solicit nominations for the Fellowship from the faculty. The solicitation will include information on nomination packet, selection criteria, and the selection process, as detailed below:

Selection Criteria

1. Only the academic record at the University of Arkansas will be considered in the selection of the Fellows.
2. The selection will be based on the grades in core physics courses and progress in research if the student is in her/his second year of graduate studies or beyond. Other attributes that will likely make the nominee a successful physicist (such as broader interest in science, curiosity, imagination, passion for learning, etc.) will also be considered.
3. In addition to factors listed in Item # 2 above, other aspects such as outstanding teaching, service to the department, content of nomination letter, and anticipated benefit to the student will also be considered.
4. People who have won the Fellowship previously would have a lower priority.
5. A Fellowship may not be split, even if there are more than one candidate of equal merit.

Nomination Packet:

The nomination packet should include the following:

1. A list of all the graduate courses taken at UA and grades obtained.
2. A list of research publications.
3. A list of teaching assignments at UA by semester.
4. Documentation of other achievements, if applicable, such as, outstanding teaching, outstanding service to the department or the profession, etc.

5. A nomination letter. The letter should make a convincing case why the candidate deserves this honor by pointing out the candidate's strengths, such as, creativity, innovative talents, curiosity, interest in learning subjects not directly related to his/her research, etc.

Selection Process:

The Graduate Affairs Committee will act as the selection committee. Members with conflict of interest will be excused from serving on the committee. The Chair of GAC may appoint other faculty members to replace the excused members. After an evaluation of the nomination packets, the selection committee will make its recommendation to the Department Chair. The evaluation process may include interview with nominators, if needed.

Fellowships to Incoming Graduate Students

If there are sufficient funds, the Fellowship may also be used for the purpose of attracting an outstanding graduate student. In this case, the Graduate Admissions Committee in consultation with the Chair of the Department will act as the selection committee. Generally, only those candidates will be considered who, for one reason or the other, are not eligible to receive DAF or DDF. The student's application packet (GPA, GRE, resume, recommendation letters, etc.) will be considered to be nomination packet and the only selection criterion will be the potential of the applicant to be an outstanding graduate student.

Appendix A: Graduate Course Offerings

ASTR 5033. Astrophysics I: Stars and Planetary Systems (Odd years, Fa) An introduction to astrophysics covering stellar structure and evolution, the properties of the solar system, and extrasolar planetary systems.

ASTR 5043. Astrophysics II: Galaxies and the Large-Scale Universe (Even years, SP) An introduction to astrophysics covering the interstellar medium, the Milky Way galaxy, extragalactic astronomy, and introduction to cosmology. Prerequisite: ASTR 5033.

PHYS 500V Laboratory and Classroom Practices in Physics (1-3) (FA, SP, SU) The pedagogy of curricular materials. Laboratory and demonstration techniques illustrating fundamental concepts acquired through participation in the classroom as an apprentice teacher. Prerequisite: PHYS 3113 or PHYS 3414.

PHYS 5011 Intro to Research Seminar (FA) This seminar course introduces new Physics graduate students to the faculty of the Physics department and their current research efforts. In addition, the students will be introduced to scientific ethics, and they will learn written scientific communication skills.

PHYS 502V Individual Study in Advanced Physics (1-3) (FA, SP) Guided study in current literature.

PHYS 5041 Journal Club Seminar (SP)_In this seminar, the students will present talks based on published research articles. The goal of the course is to develop oral communication skills in the students. Students will also learn effective literature search techniques.

PHYS 5073 Mathematical Methods for Physics (FA) This course merges the mathematics required in classical mechanics, electrostatics, magnetostatics, and quantum mechanics into a single course. The goal is to develop physics problem solving skills, a strong mathematical foundation, and a more unified picture of physics. Prerequisite: MATH 3423, PHYS 3414.

PHYS 5083 Mathematical Methods of Physics II (SP, Irregular) Applications of matrices, tensors, and linear vector spaces to problems in physics. Introduction to groups and their representations, and symmetry principles in modern physics. Prerequisite: PHYS 5073.

PHYS 5093 Group Theory (SP) Application of group theory to topics in physics, especially to atomic/molecular and solid-state physics. Prerequisite: PHYS 5073.

PHYS 5103 Advanced Mechanics (FA, Every year) Dynamics of particles and rigid bodies. Hamilton's equations and canonical variables. Canonical transformations. Small oscillations. Prerequisite: PHYS 5033 and PHYS 5073.

PHYS 5111 Research Techniques – Lab Rotations (SP) Introduction to the operational aspects of two research projects to help students in choosing a thesis/dissertation project.

PHYS 5213 Statistical Mechanics (SP) Classical and quantum mechanical statistical theories of matter and radiation. Prerequisite: PHYS 4333 and PHYS 4073.

PHYS 5263L Experiment and Data Analysis (FA) Students will learn frequently-used experimental techniques and methods of data analysis. Prerequisites: Graduate standing or Instructor consent.

PHYS 5313 Advanced Electromagnetic Theory I (SP) Electrostatics, boundary-value problems in electrostatics, electrostatics in medium, magnetostatics, Faraday's Law. Prerequisite: PHYS 5073.

PHYS 5323 Advanced Electromagnetic Theory II (FA) Maxwell equations, conservation laws, wave propagation, waveguides, radiating systems, scattering, special relativity, radiation by moving charges. Prerequisite: PHYS 5313.

PHYS 5363* Scientific Computation (FA) An introduction to numerical methods used in solving various problems in physics. Prerequisites: MATH 3423

*Note: This course is co-listed with MATH 5363.

PHYS 5413 Quantum Mechanics I (FA) Non-relativistic quantum mechanics; the Schrodinger equation; the Heisenberg matrix representation; operator formalism; transformation theory; spinors and Pauli theory; the Dirac equation; applications to atoms and molecules, collision theory, semiclassical theory of radiation. Prerequisite: PHYS 4073.

PHYS 5423 Quantum Mechanics II (SP) Continuation of PHYS 5413. Prerequisite: PHYS 5413.

PHYS 5513 Atomic and Molecular Physics (SP, Odd years) Survey of atomic and molecular physics with emphasis on electronic structure and spectroscopy. Includes fine and hyperfine structure. Zeeman and Stark mixing of states, collision phenomena, radiative lifetimes, and experimental techniques. Prerequisite: PHYS 4073.

PHYS 5523 Theory of Relativity (IR) Conceptual and mathematical structure of the special and general theories of relativity with selected applications. Critical analysis of Newtonian mechanics; relativistic mechanics and electrodynamics; tensor analysis; continuous media; and gravitational theory. Prerequisite: PHYS 3414.

PHYS 5613 Introduction to Biophysics and Biophysical Techniques (SP, Even years) Origins of biophysics, biological polymers and polymer physics, properties of DNA and proteins, techniques to study DNA and proteins, biological membrane and ion channels, biological energy, experimental techniques to study single DNA and proteins. Two experiments are included: (1) DNA Gel electrophoresis; (2) Measurement of double stranded DNA melting point. Prerequisite: PHYS 3614 and 4333

PHYS 5653 Subatomic Physics (IR) Nuclear structure and nuclear reactions. Nature and properties of elementary particles and resonances, their interactions and decays. Phenomenological theory and discussion of experimental evidence. Prerequisite: PHYS 3614.

PHYS 5713 Condensed Matter Physics I (FA) The course covers the Drude theory and the Sommerfeld theory of metals, crystal lattices, reciprocal lattices, X-ray diffraction, Bloch's theory of electrons in periodic potential, formation of band gap, lattice vibration, and cohesive energy in solids. Prerequisite: PHYS 5413

PHYS 5723 Physics at the Nanoscale (FA Even years) This is a cross-disciplinary course that is focused on teaching nanoscience and engineering by studying surface science, the building and analysis of quantum-controlled structures, and related nano manufacturing processes. Students will achieve an integrated knowledge of the science of surface science, quantum mechanics, nano processing and manipulation, and techniques of materials research.

PHYS 5734 Laser Physics (SP) A combined lecture/laboratory course covering the theory of laser operation, laser resonators, propagation of laser beams, specific lasers such as gas, solid state, semiconductor and chemical lasers, and laser applications. Prerequisite: PHYS 3414 and PHYS 3544.

PHYS 5753 Applied Nonlinear Optics (FA, Even years) A combined lecture/laboratory course. Topics include: practical optical processes, such as electro-optic effects, acousto-optic effects, narrow-band optical filters, second harmonic generation, parametric amplification and oscillation, and other types of nonlinear optical spectroscopy techniques which are finding current practical applications in industry. Prerequisite: PHYS 3414 and PHYS 3544.

PHYS 5763 Experimental Methods for Nanoscience (SP, Even years**)** In this course, students will learn fundamentals of the selected techniques suitable for characterization on the nanoscale. The course will focus on diverse methods such as x-ray and neutron spectroscopy, scanning probe microscopies, optical methods, electron diffraction methods and more. Prerequisites: PHYS 3414, PHYS 4073 and familiarity with standard physics experimental techniques.

PHYS 5773 Introduction to Optical Properties of Materials (SP) A combined lecture/laboratory course covering crystal symmetry optical transmission and absorption, light scattering (Raman and Brillouin) optical constants, carrier mobility, and polarization effects in semi-conductors, quantum wells, insulators, and other optically important materials. Prerequisite: PHYS 3414 and PHYS 3544

PHYS 588V Selected Topics in Experimental Physics (1-3) (IR)

PHYS 600V Master of Science Thesis (1-6) (FA, SP, SU)

PHYS 6413 Quantum Mechanics III (FA, Even years) Relativistic quantum mechanics, second quantization, with applications to quantizing electromagnetic fields and to many-body theory. Introduction to Feynman diagrams. Prerequisite: PHYS 5423.

PHYS 6513 Theoretical Biophysics (IR) The goal of the course is to give students tools to investigate the behavior of complex systems and to analyze the relationship of non-linear dynamics and chaos theory to complex biological and non-biological systems. A special emphasis will be given to understanding the way neurons work as biological computing elements.

PHYS 6613 Quantum Optics (FA, Odd years) Properties of light and its interaction with atoms, particular attention given to the laser and recent experiments. Classical theory of resonance; Optical Bloch Eqs.; 2 level atoms in steady fields; pulse propagation; semiclassical theory of the laser, coherent states and coherent functions; gas, solid, and dye lasers; photon echoes and superradiance; quantum electrodynamics and spontaneous emission. Prerequisite: PHYS 5413 or equivalent.

PHYS 6713 Condensed Matter Physics II (SP, Odd years) The course covers surface physics, physics of homogeneous and inhomogeneous semiconductors, dielectric and ferroelectric physics, defects in crystals, spin interaction and magnetic properties, superconductivity, and band structure calculation. Prerequisite: PHYS 5413 and PHYS 5713

PHYS 700V Doctoral Dissertation (1-18) (FA, SP, SU)

Appendix B: Detailed Sample Syllabi of Selected Courses

PHYS 5011 Introduction to Current Research Seminar

This seminar course introduces new Physics graduate students to the faculty of the Physics department and their current research efforts. In addition, the students will be introduced to scientific ethics, and they will learn written scientific communication skills.

Syllabus:

Each week one of the faculty members will introduce the students to his/ her research and laboratory facilities (if applicable) by giving a seminar.

In addition, scientific ethics will cover topics such as:

- Integrity of scientific data
- Plagiarism
- Citation to previously published research
- Co-authorship of a paper
- Copyright

Finally, this seminar will also be used to develop students' written communication skills. Specifically, the students will write a paper in the format of a physics journal article on which they will be graded. They will be given explicit guidance in writing the papers

PHYS 5041 Journal Club Seminar

In this seminar, the students will present talks based on published research articles. The goal of the course is to develop oral communication skills in the students. Students will also learn effective literature search techniques.

Prerequisites: None.

Syllabus:

Each week one of the students will present a seminar based on a recently published article. The article may be in a magazine such as, Physics Today, American Scientist, or Scientific American. Other students will be asked to critique the talk for the benefit of the speaker. Each student's grade will be based on short written report, and on the organization, clarity, preparation, and ability to answer questions on his/her own presentation, and the degree of participation in critiquing the talks of other students. Students will also learn effective literature search techniques.

PHYS 5073 Mathematical Methods for Physics (FA)

Prerequisites: MATH 3423, PHYS 3414.

This course merges the mathematics required in classical mechanics, electrostatics, magnetostatics, and quantum mechanics into a single course. The goal is to develop physics problem solving skills, a strong mathematical foundation, and a more unified picture of physics.

Physics Theory:

Particle Theory, Wave Theory, Linear Momentum, Angular Momentum, Kinetic Energy, Potential Energy

Physics Applications (advanced senior and/or graduate level):

Oscillations, Systems of Particles, Motion of Rigid Bodies, Lagrangian Mechanics, Oscillating Systems: Electrostatics, Polarization, Magnetostatics, Magnetization: Schrodinger Equation, Operator Theory, Matrix Mechanics

Mathematical Theory:

Linear Algebra, Differential Equations, Calculus of Variation, Complex Algebra

Mathematical Applications:

First-Order Differential Equations, Second-Order Differential Equations, Systems of Linear Differential Equations, Helmholtz Equation, Determinants and Matrices, Eigenvalues and Eigenvectors, Linear Transformations, Infinite Series, Fourier Series, Orthogonal Functions, Legendre Functions, Bessel Functions, Hermite Polynomials, Special Functions, Fourier Transforms, Laplace Transforms, Integral Transforms

Basic Approach:

This course will (1) cover the Mathematical foundation of the methods to be used, and (2) emphasize the applications of the methods to solve physics problems. In order to best organize the course and in order to best communicate the unification of physics topics, the problems solved in this course will begin with one of the follow three formulas. Five weeks will be spent with each formula with the initial emphasis placed on the origin of the formula. After which the emphasis will be put into explaining how to model specific problems to reduce the general differential equations into specific differential equations.

$$\frac{\partial L}{\partial q_i} - \frac{d}{dt}\frac{\partial L}{\partial \dot{q}} + \lambda_j(t)\frac{\partial f_j}{\partial q_i} = 0 \qquad \text{(Lagrange's Equation)}$$

$$\nabla^2 \varphi_{E,M} = -\frac{\rho_{E,M}}{\varepsilon,\mu} \qquad \text{(Poisson's Equation)}$$

$$-\frac{\hbar^2}{2m}\nabla^2|\Psi\rangle + V|\Psi\rangle = E|\Psi\rangle \qquad \text{(Schrödinger's Equation)}$$

Sample Syllabi:

Classical Mechanics (e.g., Fowles): 5 Weeks, 3 HW sets, 1 Exam

Physics Topics: Oscillations, General 3D Motion, Dynamics of Systems, Rigid Bodies, Lagrangian Mechanics, Dynamics of Oscillating Systems

Homework Topics:

1D, 2D, 3D
Rectangular coordinates
Spherical coordinates
Cylindrical coordinates
Harmonic Oscillator (damped, driven, etc.)
Constrained motion (sphere, cone, cylinder, rolling, sliding, etc.)
Coupled oscillators (linear array, circular, molecular, etc.)
Pendulum (elastic, accelerating, coupled, etc.)

Electrostatics and Magnetostatics (e.g., Griffiths): 5 Weeks, 3 HW sets, 1 Exam

Physics Topics: Electrostatics, Special Techniques, Electric Fields in Matter, Magnetostatics, Magnetic Fields in Matter

Homework Topics:

1D, 2D, 3D
Rectangular coordinates
Spherical coordinates
Cylindrical coordinates
Sources defined
Potential boundary conditions
Mixed sourced defined and potential boundary conditions

Quantum Mechanics (e.g., Griffiths): 5 Weeks, 3 HW sets, 1 Exam

Physics Topics: Time-Independent Schrodinger Equation, Quantum Mechanics in 3D, Time-independent Perturbation Theory

Homework Topics:

1D, 2D, 3D
Rectangular coordinates
Spherical coordinates
Cylindrical coordinates
Infinite square well
Harmonic oscillator
Free particles
Finite Square Well
Hydrogen
L, L^2 and S, S^2
First- and second-order perturbation theory

PHYS 5093 Group Theory (SP) Application of group theory to topics in physics, especially to atomic/molecular and solid-state physics.

Prerequisite: PHYS 5073.

Syllabi: Depending on the instructor, one of the following two syllabi will be used:

Syllabus 1:

1. Symmetries.
2. What is a group?
3. Group representations for finite groups.
4. Applications to normal modes, crystal symmetries, etc.
5. Lie Groups, especially the rotation group SO(3), and SU(n) for n=2,3.
6. Representations of Lie Groups and Lie Algebras.
7. Applications to atomic/molecular physics, solid state-physics, particle physics.
8. The Galilean, Lorentz and Poincare' groups.
9. Graded algebras.

Syllabus 2:

- Spectral decomposition of commutative and Abelian-group algebras
    - Irreducible projective idempotent algebra
    - Logical connection of quantum axioms and group axioms
    - Discrete and number-theoretic properties of Fourier analysis
    - Applications to dynamics and spectra
        - Homocyclic and linear molecules of Cn symmetry:
        - Quantum wells, dots, wires, corrals of Cm x Cn x Cp x
        - Photon bad-gap devices
- Spectral decomposition of non-commutative and non-Abelian group algebras
    - Irreducible projective idempotent and nilpotent algebra
    - Algebra of the Center: Class algebra and characters, Shortcuts
    - Applications to point group dynamics and spectra
        - Quasi-planar molecular and crystal point symmetry C_{nv}, D_n, D_{nh}, etc.
        - Non-planar Polyatomic molecular symmetry I, O, O_h, T_h, T_d, etc.
        - Layered and multiply connected quantum wells, dots, and Layered photon band-gap devices
- Lab vs. Body duality: Operator classification and solution
        - Induced representation theory
            - Frobenius reciprocity theorem

Mackey subgroup theorem

Spontaneous vs. Applied symmetry breaking

Level clustering vs. level splitting

Applications to atomic and molecular spectra and dynamics

Spectral decomposition of Unitary U(2) and Orthogonal O(3) Lie Groups

Oscillators, Bosonic operators, and U(2)~O(3)>R(3) symmetry

2-state systems (semiclassical theory), NMR, Rabi rot., etc.

U(2) theory of quantum well scattering

Rotation and quantum angular momentum states and operators

Lab vs. body duality for atomic and molecular spectra

Tensor operator sets for O(3) and subgroups, Wigner-Eckart theorem

Crystal field splitting and spectral transitions

Crystal and optical tensors

Jahn-Teller and Renner-Teller symmetry reduction

Ultra-high resolution spectra and super-hyperfine effects

Spectral decomposition of intertwining m-state U(m) and n-particle Sn Groups

Young tableau calculus for fermionic and bosonic (m)n shell theory

Atomic and nuclear shell orbitals and correlation effects

Quantum entanglement in optical or spinorial quantum computers

Generalized tensorial operator sets

Spectral decomposition of crystalline and floppy molecular space groups

Symmorphic space groups and Little group induced representations

Electronic, photonic, and vibronic band theory

Non-symmorphic and magnetic space groups, ray representations.

PHYS 5263L Experiment and Data Analysis (FA)

Students will learn frequently-used experimental techniques and methods of data analysis. Prerequisites: Graduate standing or Instructor consent.

Syllabus

This course is devoted to learning some of the frequently used experimental techniques and methods by which experimental data are analyzed to extract quantitative information on physical parameters. Students will perform experiments, analyze data, write lab reports, and take an oral exam on EACH of the experiment.

Students will learn experimental techniques such as

1. Vacuum techniques
2. Use of oscilloscopes (free-running as well as triggered)
3. Phase-sensitive detection
4. Time-domain experiments
5. Use of LabView
6. Scattering technology.

They will learn concepts such as

1. Concept of cross-section (differential and total)
2. Signal-to-noise ratio
3. Random versus systematic noise
4. Signal averaging and narrow-band detection
5. Experiments in time- and frequency-domains
6. Experimental uncertainties
7. Use of symmetry in the analysis of data.

They will learn data-analysis techniques such as

1. Graphical interpretation of data
2. Least-squares analysis of data and curve-fitting
3. Error bars: systematic errors and statistical uncertainties.

They will learn to use software such as Excel and Origin.

PHYS 5313 Advanced Electromagnetic Theory I: Theoretical Description of Electrostatics, Magnetostatics, Faraday's Law and Quasi-static fields, Prerequisite: PHYS 3414, MATH3423

Syllabus

The students are expected to have had a junior/senior level course in Electrodynamics. It is assumed that they are familiar with Theorems of vector calculus, ordinary linear differential equations, special functions (Legendre, Laguerre, Hermite, Bessel functions, etc.), asymptotic forms, completeness and orthogonally, partial differential equations, boundary value problems, Green's function, summation of series, Fourier series, and use of Mathematica /Maple.

Electrostatics: Coulomb's Law, Electric field, Gauss law, Differential form of Gauss law, Scalar potential, Electromagnetic boundary value problems in two and three dimensions, Solution of Laplace Equation in Cartesian, Cylindrical and Spherical coordinates, Poisson Equation, Method of images, Green's Function, Energy in electrostatics.

Electrostatics in a medium: Multipole expansion, Spherical Harmonics, Electric Dipole and Quadrupole moments, Electric Susceptibility, Polarization, Displacement Vector, Electrostatic field and energy in a dielectric medium, Boundary value problems with dielectric Media.

Magnetostatics: Biot-Savart law, Magnetic Induction, magnetic Field, Ampere's law, Vector Potential, Differential Equations of Magnetostatics, Magnetic Moment and Multipole Expansion, Boundary Value problems in Magnetostatics.

Magnetostatics in a medium: Magnetization, Magnetic Susceptibility, Diamagnetic- Paramagnetic- and Ferromagnetic Materials, Permanent Magnets, Method of Images.

Boundary Value Problems, Scalar Potential Approach, Force, Torque on localized current distribution

Recommended Text: Classical Electrodynamics, by J. D. Jackson (John Wiley, New York, NY 1998).

Other references:

Introduction to Electrodynamics, by David J. Griffiths (Prentice Hall, NJ 1999).

Modern Problems in Classical Electrodynamics, C. A. Brau (Oxford Univ. Press, NY 2004).

Electrodynamics of Continuous Media, by L. D. Landau and E. M. Lifshitz (Pergamon, New York 1960).

Classical Electricity and Magnetism, by W. K. H. Panofsky and M. Phillips (Addison-Wesley, Cambridge, MA 1962).

Electromagnetism, Principles and Applications, by Paul Lorrain and Dale R Corson (Plenum Press, 1998).

Foundation of Electromagnetic Theory, John R. Reitz, Frederick J. Milford, and Robert W. Christy (Addison-Wesley, Reading, MA 1979).

Electricity and Magnetism, Berkley Physics Course Vol-2, Edward M. Purcell

PHYS 5323 Advanced Electromagnetic Theory II

Maxwell's Equations, Conservation Laws in electrodynamics, Electromagnetic Waves Waveguides and Resonators, Radiation, and Scattering of E&M waves, Special Relativity and the relativistic Formulations of Maxwell's Equations, Prerequisite: PHYS 5313

Syllabus

The students are expected to be familiar with theoretical Techniques for Electrostatics and Magnetostatics, Fourier series, use of Mathematica /Maple

Maxwell's Equations: Faraday's Law of Induction, Energy in magnetic field, Self- and Mutual Inductance, Quasi-Static Magnetic Field in a Conductor, Maxwell's equations, Boundary Conditions, Gauge Transformation, Coulomb- and Lorenz Gauge, Green function for wave equations, Retarded Solutions of the Fields, Fields of moving Point Charge, Energy, Momentum, and Angular Momentum in Electromagnetic Fields, Poynting's Theorem, Maxwell Stress Tensor,

Electromagnetic Waves: EM waves in isotropic and anisotropic media, beams, polarization, propagation of in bounded regions, reflection, refraction, dispersion, absorption, waveguides, resonators, and fibers.

Nonrelativistic Radiation: Multipole Expansion, Electric dipole, magnetic dipole, and Electric Quadrupole Radiation, Diffraction and scattering of electromagnetic waves.

Relativistic Electrodynamics: Special relativity and relativistic Formulations of Maxwell's Equations, Radiation from fast moving charge particles, Bremsstrahlung, Cyclotron, and Cerenkov radiation, Radiation reaction, EM fields as a collection of harmonic Oscillators.

Recommended Text: Classical Electrodynamics, by J. D. Jackson (John Wiley, New York, NY 1998).

Other references:

Introduction to Electrodynamics, by David J. Griffiths (Prentice Hall, NJ 1999).

Modern Problems in Classical Electrodynamics, C. A. Brau (Oxford Univ. Press, NY 2004).

Electrodynamics of Continuous Media, by L. D. Landau and E. M. Lifshitz (Pergamon, New York 1960).

Classical Electricity and Magnetism, by W. K. H. Panofsky and M. Phillips (Addison-Wesley, Cambridge, MA 1962).

Electromagnetism, Principles and Applications, by Paul Lorrain and Dale R Corson (Plenum Press, 1998).

Foundation of Electromagnetic Theory, John R. Reitz, Frederick J. Milford, and Robert W. Christy (Addison-Wesley, Reading, MA 1979).

Electricity and Magnetism, Berkley Physics Course Vol-2, Edward M. Purcell

<u>PHYS 5363 Scientific Computation</u> (FA): An introduction to numerical methods used in solving various problems in physics. Prerequisites: MATH 3423. *This course is co-listed with MATH 5363*.

Syllabus

1. Errors
   a. Rounding errors (finite precision arithmetic)
   b. Truncation errors (Taylor polynomial and power series)
   c. Error propagation in algorithms
2. Numerical Linear Algebra
   a. Systems of linear equations
   b. Eigenvalues and eigenvectors
3. Polynomial Interpolation and curve fitting (least squares analysis)
4. Numerical differentiation
5. Numerical integration
   a. Newton-Cotes rules
   b. Adaptive Quadrature
   c. Gaussian Quadrature
6. Differential Equations
   a. ODE's
      i) Initial Value Problems
      ii) Boundary Value Problems
      iii) Systems of ODE's
   b. PDE's
      i) Classification (elliptic, parabolic, hyperbolic)
      ii) Finite Difference methods
      iii) Finite Element methods
7. Other
   a. Nonlinear equations (roots and zeros)
   b. Orthogonal Polynomials
   c. Monte-Carlo
   d. FFT
   e. Wavelets
   f. Large sparse linear systems

Programming assignments will be made in one of the programming languages, e.g., Matlab, Maple, Mathematica, Fortran, or C.

PHYS 5413 Quantum Mechanics I (FA): Non-relativistic quantum mechanics; the Schrodinger equation; the Heisenberg matrix representation; operator formalism; transformation theory; spinors and Pauli theory; the Dirac equation; applications to atoms and molecules, collision theory, semiclassical theory of radiation.

Prerequisite: PHYS 4073

Syllabi: Depending on the instructor, one of the following two outlines will be used:

Syllabus 1:

Students are expected to have had an undergraduate course in quantum mechanics, which included square-well, and barrier potentials, the hydrogen atom, and the simple harmonic oscillator. Furthermore, familiarity is assumed with finite dimensional matrices, eigenvectors, and Fourier series, at the level of an undergraduate mathematics course for engineers and scientists. Students may be given a set of homework problems in the first week of the semester to review these topics.

1. Mathematical preliminaries
   a. Linear operators
   b. Hilbert space
   c. Dirac notation
   d. Probability
2. Brief review of classical mechanics (Hamiltonians, etc.)
3. Axioms of Quantum Mechanics
4. Operator methods: the simple harmonic oscillator.
5. Three dimensions
   a. Angular momentum and spin, ladder operator methods
   b. Angular momentum algebra (“Clebscherei”)
   c. Identical particles: spin and statistics
6. Approximate methods
   a. Time-independent perturbation theory
   b. Variational methods
   c. WKB approximation
   d. Some illustrations (e.g. corrections to H-atom spectrum, helium atom, H2 molecule)

Syllabus 2:

1. Quantum analyzers, their states, and quantum axioms (Uses optical or spin-1/2 polarization experiments and simulations)
   a. Dirac notation and operator matrix representations
   b. Transformation and transfer matrices
   c. Matrix operator eigensolutions: Their algebra and geometry
   d. Spectral decomposition of commuting observables

e. Relation to Lagrange interpolation

f. Unitary symmetry and group axioms. (With reasons why they work)

g. Perturbation and variational techniques (Optional if done later)

h. Relation to permutation classes and Lagrange multipliers

2. Quantum wave functions and dynamics (Starts using 1D laser optics and derives matter waves and basic relativistic quantum theory. Uses wave simulations.)

   a. Waves described by space and time

   b. Group and phase velocity

   c. Waves described by wave vector and frequency

   d. Matter waves and relativistic dispersion. Classical connections

   e. Confined waves, wave packets, and pulse trains

   f. Bohr-ring waves. Heisenberg uncertainty

   g. Accelerated waves and gravity. (Optional)

   h. Recoil effects. Pound-Rebka experiment

3. Quantum Fourier analysis and symmetry (Starts using plane waves, Bohr-waves, and develops discrete waves on quantum wells and nano-structures. Uses band simulations.)

   a. Fourier transform and transformation matrices. (Discrete versus continuous)

   b. Fourier symmetry analysis

   c. Time evolution operators, matrices, and Hamiltonian generators

   d. Schrodinger time equation

   e. Hamiltonian eigensolutions. Cyclic symmetry analysis.

   f. 2-State evolution and analogs. U(2) symmetry analysis. (Optional if done later.)

   g. Euler angles and gauge. Operator angles. Relation to Hamilton quaternions

4. Quantum wave equations (Starts with free optical and matter waves and develops quantum bound and scattering resonant states. Uses wave simulations.)

   a. Difference and differential equations

   b. Schrodinger in x-basis and Schrodinger in k-basis.

   c. Infinite well and Bohr-ring embedding

   d. Quantum beats. (Optional) Revivals

   e. Finite wells and barriers

   f. Transmission and admittance functions

   g. C-matrices and S-matrix eigenchannels (optional if done in QM II)

   h. Introduction to harmonic oscillator (optional if done in QM II)

   i. Coherent wave packets and classical correspondence

PHYS 5423 QUANTUM MECHANICS II (SP) Continuation of PHYS 5413.

Prerequisite: PHYS 5413.

Syllabi: Depending on the instructor, one of the following two outlines will be used:

Syllabus 1:

1. Continuum states and scattering
2. Heisenberg vs. Schrödinger pictures
3. The density matrix
4. Feynman path-integral theory
5. Time-dependent perturbation theory
6. Coulomb gauge quantization of the electromagnetic field
7. Theory of radiation-matter interaction
8. Applications to quantum optics, many-body theory, condensed matter theory.

[Note: These items are not in any particular order, logical or otherwise]

Syllabus 2:

1. Periodic potentials and symmetry (Optional if done in SS Phys)
    a. Multiple barriers and S-matrix theory
    b. Resonant and non-resonant eigenchannels
    c. Non-Abelian symmetry analysis of periodic structure and states (Optional if in MMII)
    d. Modern point group projection algebra
    e. Fourier analysis of periodic structures and states (Optional)
    f. Space group analysis (optional)
2. Time-variable perturbations and transitions
    a. Classical electromagnetic perturbations
    b. A•p versus E•r
    c. Problems with ignoring relativity
    d. Transitions due to oscillatory perturbations
    e. Fermi Golden rule
    f. Two state resonant transitions
    g. Fermi Golden rule broken
3. Quantum harmonic oscillators and multi-exciton states
    a. 1D states and dynamics
    b. Coherent and squeezed states
    c. Classical correspondence (and lack thereof)
    d. 2D – ND states and dynamics
    e. Schwinger-Glauber analysis (optional)

f. Bose versus Fermi-Dirac permutation symmetry

g. Brown-Twiss and related experiments

h. Non-relativistic quantum field (optional if done in Laser Phys. or QE)

i. Fock N-photon states versus coherent states (optional)

j. Jaynes-Cummings model (optional)

4. Quantum rotation and angular momentum

   a. Relations between rotation and 2D vibration. Wigner D-function analysis

   b. Atomic and molecular beam polarization

   c. Quantum rotor D-wavefunctions and special cases

   d. Legendre P and associated Y-harmonics

   e. Symmetric and asymmetric rotor states and dynamics (Optional if in AMP)

   f. Coupled rotation and spin

   g. Hyperfine (21 cm example) and spin-orbit states

   h. Coupled rotors and centrifugal effects (optional if in AMP or QMIII)

5. Quantum orbitals and central force dynamics

   a. Hydrogen-like electronic structure

   b. O(4) analysis (optional)

   c. Spectrum generating algebra (optional)

   d. Rydberg states and MCQDT (optional)

   e. Helium-like electronic structure

   f. Herrick-Kellman-Berry analysis (optional)

PHYS 5613 Introduction to Biophysics and Biophysical Techniques

Origins of biophysics, biological polymers and polymer physics, properties of DNA and proteins, techniques to study DNA and proteins, biological membrane and ion channels, biological energy, experimental techniques to study single DNA and proteins. Two experiments are included: (1) DNA Gel electrophoresis; (2) Measurement of double stranded DNA melting point. Prerequisite: PHYS 3614 and 4333

Syllabus

An outline of topics to be covered in lectures:

1. Biological Polymers and Polymer Physics
2. Properties of DNA;
3. The techniques to study DNA
4. Properties of proteins.
5. The techniques to study proteins
6. Biological Membrane and ion channels
7. Elementary properties of ions in solution
8. Elementary properties of pores
9. Biological Energy (photosynthesis and ATP Synthesis)
10. Experimental techniques for single DNA and protein analysis:
    a. Optical tweezers; b. Patch-clamp (nanopore) technique
11. Noise in electrical measurements
12. Statistical theories for single molecule studies

Two experiments are required for this course:

1. DNA Gel Electrophoresis.
2. Measure dsDNA melting point (to single stranded DNA) with a spectrophotometer at high temperature.

Text book. There is no unique textbook for the class. Some recommendations:

Primary:

1. "*Biophysics: an introduction*" by Rodney Cotterill (in UA Bookstore)
2. "*Principles of Physical Biochemistry*" by van Holde, Johnson and Ho
3. "*Physics in Molecular Biology*" by Kim Sneppen and Giovanni Zocchi

Secondary:

1. "*Ionic Channels of Excitable Membranes*" by Hille
2. "*Biological Physics*" by Philip Nelson
3. "*Methods in Modern Biophysics*" by Bengt Nolting

Course: PHYS 5713 Condensed Matter Physics I

Outline: The course covers the Drude theory and the Sommerfeld theory of metals, crystal lattices, reciprocal lattices, X-ray diffraction, Bloch's theory of electrons in periodic potential, formation of band gap, lattice vibration, and cohesive energy in solids.

Prerequisite: PHYS 5413

1. The Drude theory of metals
   - Drude model
   - Electrical conductivity, Hall effect, Thermal conductivity
2. The Sommerfeld theory of electrons
   - Ground-state energy of electron gas
   - Thermal properties of electron gas
3. Crystal lattice
   - Bravais lattice, Primitive cell, Wigner-Seitz cell, Conventional cell, Common crystal structures
4. Reciprocal lattice
   - Reciprocal lattice, Brillouin zone, Miller indices
5. X-ray diffraction
   - Bragg and von Laue formulations
   - Structure factor and atomic form factor
6. General theory of electrons in a periodic potential
   - Bloch's theorem, Born-von Karman boundary condition, Crystal momentum, Density of states
7. Electrons in a weak periodic potential
   - Formation of energy gap, Three schemes to describe energy bands, Fermi surface
8. Theory of phonon vibration
   - General theory of lattice vibration, One- and three-dimensional lattice vibrations
9. Cohesive energy
   - Lennard-Jones potential, cohesive energy, bulk modulus, Madelung constant, covalent crystals

Note: Depending upon instructors, items 1) and 2) can be included or excluded.

PHYS 5723 Physics at the Nanoscale

This is a cross-disciplinary course that is focused on teaching nanoscience and engineering by studying surface science, the building and analysis of quantum-controlled structures, and related nano manufacturing processes. Students will achieve an integrated knowledge of the science of surface science, quantum mechanics, nano processing and manipulation, and techniques of materials research.

Syllabus

This is a cross-disciplinary course that is focused on teaching nanoscience by studying surface science and the building and analysis of quantum-confined structures is the goal of this course. Integrating the concepts of surface science, quantum mechanics, and techniques of materials research into the science and engineering curriculum is also an expected outcome.

Content and Objectives

The objective of the course is to teach concepts in nanoscience by integrating the concepts of surface science, quantum mechanics, and techniques of materials research into the science and engineering curriculum. We will compare bulk behavior to nanosize behavior. The contrast is our mission. An expected outcome of this course will be students who have learned the value of surface science and quantum theory and who are well-trained and prepared for either graduate studies or job opportunities that benefit from experience in nanoscience.

PHYS 5763 Experimental Methods for Nanoscience

In this course, students will learn fundamentals of the selected techniques suitable for characterization on the nanoscale. The course will focus on diverse methods such as x-ray and neutron spectroscopy, scanning probe microscopies, optical methods, electron diffraction methods and more.

Prerequisites: PHYS 3414, PHYS 4073 and familiarity with standard physics experimental techniques.

Syllabus

Materials and devices on the nanometer scale are at the center of modern physics, chemistry and material science. One of the crucial challenges for nanoscience is to find appropriate characterization techniques that would allow researchers to investigate the properties of nanostructured materials microscopically. The selection of characterization methods presented in this course is most widely used for the study of modern nanomaterials. During the course students we will address fundamentals of selected techniques, basic principle of the equipment operation and some essential aspects of data collection and analysis. The course will focus on the following methods:

1. Bulk Techniques
    a. SQUID magnetometry
    b. Transport and magneto-transport
2. Scanning Probe Microscopies
    a. Atomic Force Microscopy
    b. Scanning Tunneling Microscopy
    c. Magnetic Force Microscopy
3. Synchrotron Radiation Spectroscopies
    a. X-ray Photoemission Spectroscopy
    b. X-ray Absorption and EXAFS
    c. Photoelectron emission microscopy
4. X-Ray and neutron scattering and reflectivity
5. Electron Microscopies
    a. Reflected High Energy Electron Diffraction
    b. Low Energy Electron Diffraction
    c. Transmission Electron Microscopy
6. Optical Spectroscopies
    a. Infrared Reflectometry and Ellipsometry
    b. Second Harmonic Generation and Sum Frequency Generation
7. Hyperfine interaction techniques
    a. Low Energy Muon Spin Resonance and Relaxation
    b. Beta-detected Nuclear Magnetic Resonance
8. Single-Molecule Detection Techniques

Suggested textbooks:

"Solid State Spectroscopies: An Introduction" by H. Kuzmany (Springer).
"Modern Techniques of Surface Science, D.P. Woodruff and T.A. Delch, (Cambridge Solid State Science Series).

PHYS 6713 Condensed Matter Physics II

This course covers surface physics, physics of homogeneous and inhomogeneous semiconductors, dielectric and ferroelectric physics, defects in crystals, spin interaction and magnetic properties, superconductivity, and band structure calculation.

P**rerequisite**: PHYS 5413 and PHYS 5713

Syllabus:

1. Surface Physics
    - Work function, Contact potential, LEED, Electronic surface levels
2. Physics of homogeneous and inhomogeneous semiconductors
    - Semiconductor band structures, Intrinsic and extrinsic semiconductors, impurity levels
    - Equilibrium p-n junction, Elementary picture of rectification
3. Dielectric and ferroelectric Physics
    - Macroscopic electrostatic Maxwell equations, Theory of local field, Theory of polarizability,
    - Pyroelectricity and ferroelectricity
4. Defects in crystals
    - Schottky and Frenkel defects, Color centers, dislocations and Grain boundaries
5. Spin interaction and magnetic properties
    - Magnetic properties of a two-electron system, Heisenberg model and Hubbard model, Direct and Super exchange
6. Superconductivity
    - Persistent currents, Meissner effect, magnetic critical field
    - London equation, BCS theory, Ginzburg-Landau theory
    - Josephson effects
7. Band structure calculation
    - Tight-binding method and other band structure methods

Note: Depending upon instructors, items 4) and 7) can be included or excluded.

Appendix C: Annual Progress Report

Follow the format below adding more space as needed.

____________________	____________________
Student Name	Date Entered Graduate School
____________________	____________________
Date Annual Progress Report Submitted	Date Passed Candidacy Exam
____________________	____________________
Thesis Title	Expected Graduation Date

1. Chronological summary of courses taken and grades received:

2. Chronological plan for future courses:

3. Goal of Research Project:

4. Progress made toward that goal over the past year: (2-3 pages)

5. Research plans for the following year:

Appendix D: Graduate Advisory Committee Report

Student's Name: ____

Student's Advisor: ____

Student's Committee Members: ____________________________________

____

Student's starting date for graduate studies: __________________________

Date of this report: ______________________

Please give an answer to each item listed below. A handwritten response is acceptable.

(i) Has the student's course curriculum been in line with your expectations?

(ii) Are the student's plans for courses during the next year clear and adequate?

(iii) Is the goal of the student's research project clear and adequate?

(iv) Please rank the student's progress made toward that goal over the past year:

1 (poor) 2 3 4 5 (excellent)

(v) Are the student's research plans for the following year clear and sensible?

(vi) What is a realistic date for graduation?

(vii) Do you recommend continuation of the student's pursuit toward a degree?

(viii) Anticipated financial support for next academic year: RA, TA, Other (explain), or None (explain):

(ix) If student is graduating, tell us where they are going and what they will be doing:

(x) Please rank the overall quality of presentation:

1 (poor) 2 3 4 5 (excellent)

Appendix E: Annual Graduate Student Academic Review for Doctoral Students

See the next two pages for the most recent version of this form, last revised on 2 February 2021.
You can also find it at:

https://graduate-and-international.uark.edu/_resources/forms/academic-review/gradstudentreview-doctoral.pdf

When the department/program completes it review, they should send this signed document to pkoski@uark.edu by June 30th of each year.

UNIVERSITY OF ARKANSAS | Graduate School & International Education

Annual Graduate Student Academic Review for Doctoral Students

When the department/program completes their review, they should send this signed document to pkoski@uark.edu and jgiganti@uark.edu by June 30th of each year.

Please Note: A review is not necessary if: a. the student graduated. b. the student never enrolled after acceptance into your program. c. the student was never officially admitted to your program.

1. Student's Name: ____________________
2. University ID Number:____________________Student's degree program: ____________________
3. Semester and year student entered degree program: ____________________
4. Current GPA and number of hours completed: ____________________
5. Does student have any out of date course work? (Course work is considered out of date if at the time of graduation it was taken more than seven years prior to the first semester in the doctoral program.)

   ◯ Yes ◯ No

6. Has degree audit been made current, reflecting all exemptions to date?

   ◯ Yes ◯ No

7. Degree progress is:

   ◯ satisfactory.

   ◯ not satisfactory.

   Please explain:

8. Check all that have been completed and are requirements for this degree:

   ☐ Coursework completed (this excludes research hours)

   ☐ Candidacy exam. Date: ____________________

   ☐ Capstone/project submitted. Date: ____________________

   ☐ Internship/externship/practicum completed. Date: ____________________

   ☐ Proposal defense, if used. Date: ____________________

9. The results of the review were communicated to the student:

   ◯ by face-to-face interview on____________________(date)

   ____________________(signature of student)

   ◯ by the following procedure because the face-to-face interview was not possible or practical

   (include dates of notification): ____________________

Revised: 2/3/2021

10. This form accurately summarizes the annual graduate student academic review for this student for

________________(Academic Year)

Signature of Review Coordinator

____

Name of Review Coordinator

____

Signature of Department/Program Head/Chair/Director:

____

Date

____

For Graduate School Use Only:
Review received (signature of dean): ________________________________

Appendix F: Enrollment Guidelines

https://graduate-and-international.uark.edu/graduate/current-students/registration-enrollment/enrollment-guidelines.php

ENROLLMENT STATUS for graduate students who are **NOT** graduate assistants/master lecturers:

Graduate students who are **not** appointed to graduate assistantships should have the Registrar verify their enrollment. These graduate students will be considered as follows:

Full-time: 9+ hours
3/4-time: 7-8 hours
1/2-time: 5-6 hours
Less than 1/2-time: 1-4 hours

REQUIRED ENROLLMENT For Graduate Assistants, Senior Graduate Assistants (Teaching, Research, Administrative Support, etc.) and Master Lecturers

Spring and Fall Semesters:

Percent of Appointment	Minimum Enrollment	Maximum Enrollment	Tuition Portion Paid
0-49%	9	15	Out-of-state (NONR) paid
50-74%	6	15	In- & out-of-state paid
75-99%	3	6	In- & out-of-state paid

Summer (12-week assistantships—enrollment may be in any summer session):

Percent of Appointment	Minimum Enrollment	Maximum Enrollment	Tuition Portion Paid
0-49%	3	12	Out-of-state (NONR) paid
50-74%	3	12	9 hours FEES & all NONR paid
75-99%	3	6	9 hours FEES & all NONR paid

Summer (6-week assistantships—enrollment may be in any summer session):

Percent of Appointment	Minimum Enrollment	Maximum Enrollment	Tuition Portion Paid
0-49%	3	6	Out-of-state (NONR) paid
50-74%	3	6	6 hours FEES & all NONR paid
75-99%	3	3	6 hours FEES & all NONR paid

The minimum hours required must be degree-related graduate hours taken for credit, or deficiencies (graduate or undergraduate) filed by the department with the Graduate School. Audit classes and/or classes not approved by the graduate student's advisor are not covered by the tuition fee waiver. PEAC/DEAC classes are not covered. Doctoral students are not considered to have deficiencies and therefore must enroll for graduate hours in order to meet the minimum required.

Termination of an appointment during a semester may result in the student being responsible for a portion of the fees (in-state tuition) on a pro rata basis. All graduate students meeting the minimum required hours will be considered full-time.

All international graduate teaching assistants MUST have a TSE score of 50 or better, or a SPEAK score of 220 or better on file with the Graduate School. Exceptions must have the approval of the Dean of the Graduate School. Our TSE/SPEAK institution code is 6866.

Appendix G: Graduation and Commencement

https://graduate-and-international.uark.edu/graduate/current-students/commencement-graduation.php

Go to the website listed above and follow the appropriate link from those listed below.

Apply to Graduate: Deadlines

A student cannot be awarded a degree or certificate without filing an application for graduation with the Registrar's Office and paying the appropriate graduation fees. The degree application is available in the Student Center of UAConnect and should be submitted for the semester in which the student expects to complete all requirements for the degree or certificate. For step by step instructions for applying to graduate, for instructions on how to change your date of graduation to a future term, and for application deadlines, please visit the Registrar's Office website.

Graduation Checklists

- Spring Graduation Checklist
- Summer Graduation Checklist
- Fall Graduation Checklist

Commencement

Students who are completing a masters or doctoral degree are recognized at the All-University Commencement Ceremony. For more information about the All-University Commencement ceremony, please visit the Registrar's Office website.

Thesis and Dissertation Submission Deadlines:

Fall 2021: December 10th. Spring 2022: May 6th. Summer 2022: July 29th.

Other Useful Thesis & Dissertation Information:

Dissertation Defense Calendar/Schedule

Guide to Theses & Dissertations — Downloadable PDF

Thesis & Dissertation Formatting Guide

Master's Non-thesis Students

Master's Thesis Students

Doctoral Students

Appendix H: Degree Program Forms

Current Graduate Student Forms

The following forms listed below can be downloaded by going to the website listed above

Master's Student Forms

Request for Change of Program Form (This will generate a Department Admission Recommendation Form aka: "Blue" form.)

Master's Record of Progress
Master's Committee Form
Master's Thesis Title
Request for Transfer of Graduate Credit
Guide to Theses/Dissertations
Tax Guidelines for Graduate Students (Taxation of Educational Grants)
Intellectual Property Disclosure Form
Thesis/Dissertation Submission Form

Doctoral Student Forms

Request for Change of Program Form (This will generate a Department Admission Recommendation Form aka: "Declaration of Intent" or "Blue" form.)

Doctoral Committee
Record of Progress - Doctoral Program
Dissertation Defense Announcement Announcement of a doctoral candidate's defense must be submitted to the Graduate School at least **TWO WEEKS** prior to the date of the defense. Please include your full name, defense title, defense date, time, location and major adviser. To announce your dissertation defense, use the online form at this link.
Doctoral Dissertation Title
Guide to Theses & Dissertations
Tax Guidelines for Graduate Students (Taxation of Educational Grants)
Intellectual Property Disclosure Form
Thesis/Dissertation Submission Form
Candidacy Exam Notification Form

Graduation Forms

Intellectual Property Disclosure Form
Thesis/Dissertation Submission Form
Survey of Earned Doctorates

Appendix I: Course Substitution/Waiver Request (Ph.D. Degree)

Submit to the Chair of the Physics Graduate Affairs Committee

Student Name: ______________________________ **ID Number:** __________________

Student Email: ______________________________ **Student Advisor:** __________________

Date of this petition: ________________________

Supply all of the information below for each course substitution/waiver request in the format given below. Attach additional sheets as necessary.

1. UA Course name and catalog number:

   Course name and text used at the institution where the course was taken

   Name: ____

   Text: ____

   Semester and Year taken: ________________________ Grade: _________

   Institution Name and Address: ____

2. UA Course name and catalog number:

   Course name and text used at the institution where the course was taken

   Name: ____

   Text: ____

   Semester and Year taken: ________________________ Grade: _________

   Institution Name and Address: ____

3. UA Course name and catalog number:

   Course name and text used at the institution where the course was taken

   Name: ____

   Text: ____

   Semester and Year taken: ________________________ Grade: _________

   Institution Name and Address: ____

Appendix J: Oral Presentation Research Qualifier Committee Report Form and Final Report

Student's Name (print): ________________________________

Student's Research Advisor (non-voting member; print): ________________________________

Chair of Student's Qualifier Committee (print): ________________________________

Chair of Student's Qualifier Committee (sign): ________________________________

Faculty Member on Student's Qualifier Committee (print): ________________________________

Faculty Member on Student's Qualifier Committee (print): ________________________________

Date of this report: ____________________

Strengths of Written Proposal:

Weaknesses of Written Proposal:

Strengths of Oral Presentation:

Weaknesses of Oral Presentation:

Summary Comments:

Number of Pass Votes (0-3): __________ Number of Fail Votes (0-3): __________

Appendix K: Written Proposal for Research Qualifier Review Form

Written Proposal for Research Qualifier Review Form

Student's Name: ______________________________

Proposal Title: ____

____

Reviewer: ______________________________

Summary of the Proposal:

Strengths:

Weaknesses:

Mandatory Revisions:

Appendix L: Candidacy Exam Notification Form

Click on the title to link to this form.

Appendix M: Record of Progress—Doctoral Program

Click on the title to link to this form.