CORE AND BREADTH IN PHYSICS DOCTORAL EDUCATION

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This report presents the findings of the Survey of Doctoral Education in Physics. The study was designed by The Task Force on Graduate Education (TFGE), which was convened by AAPT and APS, and was chaired by David Campbell. The study was designed to assess many aspects of doctoral education including the extent to which physics departments require PhD students to master a core physics curriculum. Other topics included requirements intended to ensure a breadth of physics knowledge, the extent to which departments use a comprehensive exam and the topics covered by such an exam, requirements about training in ethics, and the effect of interdisciplinary programs on traditional core requirements. The TFGE developed the questionnaire in consultation with Bernie Khoury of AAPT, Judy Franz of APS, and the Statistical Research Center (SRC) of AIP.

The SRC was responsible for developing an on-line version of the questionnaire instrument, data collection, and data analysis. This study was conducted on-line exclusively. An e-mail request to complete the survey was sent to the chairs of all 186 PhD-granting physics departments in the US on September 8, 2004. A reminder request was e-mailed on September 22, 2004 to those departments that had not yet responded.

We have data on 137 (74%) PhD-granting physics departments: 114 answered the questionnaire online, and SRC staff was able to find answers to key questions from the web sites of an additional 23 physics departments. These 137 departments enroll 76% of all doctoral students in physics.

COURSES IN CORE PHYSICS CONCEPTS

Do you require PhD students to take core courses?
Of the 137 physics departments for which we have data, more than 75% require that graduate students complete all four traditional core courses: Quantum Mechanics, Electromagnetism, Statistical Mechanics, and Classical Mechanics. Most physics departments (54%) require that students complete a course in Mathematical Methods.

Only 8 physics departments (6%) do not require that students complete specific courses. These eight are: University of Arizona, California Institute of Technology, University of California at San Diego, Florida State University, University of Illinois Urbana-Champaign, Massachusetts Institute of Technology, University of Rochester (NY) and Washington University (MO). It should be noted that graduate students in these departments must show their mastery by passing a comprehensive exam that covers the core physics concepts. An additional five departments do not require any of the four core courses, but do require either mathematical methods or lab techniques.

Of the 137 PhD-granting physics departments for which we have course data:

(Departments were allowed to choose as many topics as applied to their program)

91% require students to take a course in Quantum Mechanics.
89% require students to take a course in Electromagnetism.
85% require students to take a course in Statistical Mechanics.
77% require students to take a course in Classical Mechanics.
54% require students to take a course in Mathematical Methods.
24% require students to take a course in Laboratory Techniques.
24% require students to take Other courses:

These "Other" courses include: Advanced Topics, Astronomy, Computational Physics, Optics Elementary Particle Physics, Condensed Matter, Introductory Astrophysics, and Modern Physics.

REQUIREMENTS AT "TOP 30" PHYSICS DEPARTMENTS

Of the "top 30" PhD-granting physics departments as ranked by the National Research Council, we had data from 29. All of the departments for which we had data require a comprehensive exam, core courses, or both.

8 departments require a comprehensive exam, but none of the 4 core courses.
7 require at least 3 of the core courses, but no comprehensive exam.
14 require both core courses and a comprehensive exam.

Of the "top 30" departments that require core courses, classical mechanics is the least likely to be required. Only about half of the top departments require classical mechanics, compared with more than three-fourths of all other departments.

The major difference between the top 30 departments and the other 97 departments for which we had data is in the percentage that require both a comprehensive exam and core courses. About half of the top departments require that students take both a comprehensive exam and traditional core courses. However, 80% of the other departments require both.

QUANTUM MECHANICS

Table 1: How many terms of Quantum Mechanics are students required to take?

Number of Terms	1 Term	2 Terms	3 Terms or more	Total number of Departments
% of departments	7%	77%	16%	111

Note: 90 departments responded to this question on-line, and the answers for 21 additional departments were found through web searches.

Table 2: Has the same individual taught this course the past 3 times it's been offered?

	Yes	No	I don't know or Did not answer	Total number of Departments
% of departments	15%	83%	2%	90

Table 3: Does course content change significantly depending on the instructor?

	Yes	No	I don't know or Did not answer	Total number of Departments
% of departments	10%	73%	17%	90

Table 4: Quantum Mechanics: List of textbooks (partial) from 74 departments *(some departments listed more than 1 book)*

Author(s)	Title	Number of Mentions
J.J. Sakurai	"Modern Quantum Mechanics"	26
R. Shankar	"Principles of Quantum Mechanics"	18
Claude Cohen-Tannoudji, et. al.	"Quantum Mechanics Vol. 1 and 2"	14
Eugen Merzbacher	"Quantum Mechanics"	11
Albert Messiah	"Quantum Mechanics"	8
Ernest S. Abers	"Quantum Mechanics"	4
Richard Liboff	"Introductory Quantum Mechanics"	3
Gordon Baym	"Lectures on Quantum Mechanics"	3
Stephen Gasiorwicz	"Quantum Mechanics"	3
David Griffiths	"Introduction to Quantum Mechanics"	2
B. H. Bransden	"Quantum Mechanics"	2
E.M. Lifshitz and L.D. Landau	"Quantum Mechanics"	2
A.P. French, E.F. Taylor	"An Introduction to Quantum Physics"	1
K. Gottfried & Tung-Mow Yan	"Quantum Mechanics: Fundamentals"	1
Amit Goswami	"Quantum Mechanics, 2nd Edition"	1
Amnon Yariv	"Intro to Theory and Applications in Quantum Physics"	1
Paul Dirac	"Principles of Quantum Mechanics"	1

STATISTICAL MECHANICS

Table 5: How many terms of Statistical Mechanics are students required to take?

Number of Terms	1 Term	2 Terms	3 Terms or more	Total number of Departments
% of departments	92%	7%	1%	103

Note: 83 departments responded to this question on-line, and the answers for 20 additional departments were found through web searches.

Table 6: Has the same individual taught this course the past 3 times it's been offered?

	Yes	No	I don't know or Did not answer	Total number of Departments
% of departments	23%	72%	5%	83

Table 7: Does course content change significantly depending on the instructor?

	Yes	No	I don't know or Did not answer	Total number of Departments
% of departments	22%	52%	26%	83

Table 8: Statistical Mechanics: List of textbooks (partial) from 65 departments *(some departments listed more than 1 book).*

Author(s)	Title	Number of Mentions
R.K. Pathria	"Statistical Mechanics"	26
Kerson Huang	"Statistical Mechanics"	13
Frederick Reif	"Fundamentals of Statistical and Thermal Physics"	7
Landau and Lifshitz	"Statistical Physics"	6
Silvio Salinas	"Introduction to Statistical Physics"	4
Claude Garrod	"Statistical Mechanics and Thermodynamics"	2
L.E. Reichl	"A Modern Course in Statistical Physics"	2
Bloch and Walecka	"Fundamentals of Statistical Mechanics"	1
Herbert Callen	"Thermodynamics and an Introduction to Thermostatistics"	1
Charles Kittel and Herbert Kroemer	"Thermal Physics"	1
Daniel Mattis	"Statistical Mechanics Made Simple"	1
Donald McQuarrie	"Statistical Mechanics"	1
Plischke and Bergerson	"Equilibrium Statistical Physics"	1
David Chandler	"Introduction to Modern Statistical Mechanics"	1

CLASSICAL MECHANICS

Table 9: How many terms of Classical Mechanics are students required to take?

Number of Terms	1 Term	2 Terms	3 Terms or more	Total number of Departments
% of departments	93%	7%	0%	90

Note: 71 departments responded to this question on-line, and the answers for 19 additional departments were found through web searches.

Table 10: Has the same individual taught this course the past 3 times it's been offered?

	Yes	No	I don't know or Did not answer	Total number of Departments
% of departments	27%	73%	0%	71

Table 11: Does course content change significantly depending on the instructor?

	Yes	No	I don't know or Did not answer	Total number of Departments
% of departments	13%	58%	29%	71

Table 12: Classical Mechanics: List of textbooks (partial) from 64 departments *(some departments listed more than 1 book)***.**

Author(s)	Title	Number of Mentions
H. Goldstein, C. Poole & J. Safko	"Classical Mechanics"	48
Alexander L. Fetter and John Dirk Walecka	"Theoretical Mechanics of Particles and Continua"	6
J. Jose & E. Saletan	"Classical Dynamics"	5
E.M. Lifschitz and L.D. Landau	"The Classical Theory of Fields"	4
John Taylor	"Classical Mechanics"	3
R.W. R. Darling	"Differential Forms and Connections"	1
S.V. Fomin & I.M. Gelfand	"Calculus of Variations"	1

ELECTROMAGNETISM

Table 13: How many terms of Electromagnetism are students required to take?

Number of Terms	1 Term	2 Terms	3 Terms or more	Total number of Departments
% of departments	26%	70%	4%	106

Note: 85 departments responded to this question on-line, and the answers for 21 additional departments were found through web searches.

Table 14: Has the same individual taught this course the past 3 times it's been offered?

	Yes	No	I don't know or Did not answer	Total number of Departments
% of departments	21%	71%	3%	85

Table 15: Does course content change significantly depending on the instructor?

	Yes	No	I don't know or Did not answer	Total number of Departments
% of departments	11%	61%	28%	85

Table 16: Electromagnetism: List of textbooks (partial) from 80 departments *(some departments listed more than 1 book).*

Author(s)	Title	Number of Mentions
J.D. Jackson	"Classical Electrodynamics"	76
E.M. Lifshitz and L.D. Landau	"Classical Theory of Fields"	3
Charles A. Brau	"Modern Problems in Classical Electrodynamics"	3
Herbert Goldstein	"Notes for a Course on Classical Electrodynamics"	1
E.M. Liftshitz, L.D. Landau and L P Pitaevskii	"Electrodynamics of Continuous Media"	1
Gerald Pollack and Daniel Stump	"Electromagnetism"	1
David Griffiths	"Introduction to Electrodynamics"	1
Jack Vanderlinde	"Classical Electromagnetic Theory"	1
Walter Greiner	"Classical Electrodynamics"	1

MATHEMATICAL METHODS

Table 17: How many terms of Mathematical Methods are students required to take?

Number of Terms	1 Term	2 Terms	3 Terms or more	Total number of Departments
% of Departments	68%	31%	2%	62

Note: 54 departments responded to this question on-line, and the answers for 8 additional departments were found through web searches.

Table 18: Has the same individual taught this course the past 3 times it's been offered?

	Yes	No	I don't know or Did not answer	Total number of Departments
% of departments	35%	59%	6%	54

Table 19: Does course content change significantly depending on the instructor?

	Yes	No	I don't know or Did not answer	Total number of Departments
% of departments	17%	50%	33%	54

Table 20: Mathematical Methods: List of textbooks (partial) from 47 departments *(some departments listed more than 1 book).*

Author(s)	Title	Number of Mentions
George Arfken and Hans Weber	"Mathematical Methods for Physicists"	28
Jon Mathews and Robert Walker	"Mathematical Methods of Physics"	4
K.F. Riley, M.P. Hobson and S. J. Bence	"Mathematical Methods of Physics and Engineering"	4
Sadri Hassani	"Mathematical Physics"	3
E.T. Whittaker and G.N. Watson	"A Course of Modern Analysis"	3
Frederick Byron and Robert Fuller	"Mathematics of Classical and Quantum Physics"	2
Eugene Butkov	"Mathematical Physics"	2
Donald McQuarrie	"Mathematical Methods for Scientists and Engineers"	1
Mary Boas	"Mathematical Methods in the Physical Sciences"	1
Charles Kittel	"Introduction to Solid State Physics"	1

LABORATORY TECHNIQUES

Table 21: How many terms of Laboratory Techniques are students required to take?

Number of Terms	1 Term	2 Terms	3 Terms or more	Total number of Departments
% of departments	83%	13%	3%	30

Note: 26 departments responded to this question on-line, and the answers for 4 additional departments were found through web searches.

Table 22: Has the same individual taught this course the past 3 times it's been offered?

	Yes	No	I don't know or Did not answer	Total number of Departments
% of departments	19%	77%	4%	26

Table 23: Does course content change significantly depending on the instructor?

	Yes	No	I don't know or Did not answer	Total number of Departments
% of departments	19%	54%	27%	26

CHANGES IN CORE COURSE REQUIREMENTS

Have the requirements regarding core courses for PhD students changed in the last 5 years?

96 physics departments answered this question. Forty departments told us that they have changed their required courses in the last 5 years. Fifty-six departments reported no changes in course requirements; however, one third of them did say that discussions are currently being held about changing requirements.

Number of PhD-granting departments that changed required courses

17 - departments decreased the number of terms or dropped a required course.
9 - departments increased the number of terms or added a required course.
6 - departments reported doing both.
8 - department did not specify the type of change.

Dropping or decreasing required courses

Departments reported 32 changes in different courses (see next several pages for the verbatim comments). Nearly half of the changes involved reducing the number of terms that students had to complete of a required course by one. About 1/3 of the comments referred to changing a previously required course into an optional course. Several of the latter noted that the optional course was made into a pre-requisite to be taken by students who had not covered the same material as undergraduates. There were only five comments that indicated that a formally required course was dropped entirely and, in most of these cases, the material was moved to other courses. Finally, only two comments indicated that a formally required course was replaced with a new required course.

Of the 23 departments that described dropping or reducing required courses, half noted a change in Classical Mechanics and nearly half noted Mathematical Methods.

Adding or increasing required courses

Fifteen departments provided comments that described additions to their required courses (see verbatim comments in subsequent pages). Nine comments indicated that their comprehensive exam was being replaced by a requirement that students pass specific core courses. Six comments referred to requiring students to take a course that had formally been optional, largely as a result of concerns about undergraduate preparation. Three comments referred to increasing the number of terms that students were required to take a specific course by one.

Of the departments that described adding or increasing required courses, nearly half note a change in Quantum Mechanics.

Table 24: Responses from Physics Departments that Dropped or Decreased the Number of Terms of Electromagnetism

"Our two semester Classical Physics course, which included electromagnetism, was condensed into one semester of classical electromagnetism. We added Statistical Mechanics as an additional core course."	"Dropped one semester. Advanced topics were moved to 600-level (Ph.D.) courses when needed."
"For this fall, E&M has been moved from the classical Jackson approach to more of an applied optics course."	"Advanced core material to be offered in introductory sections of advanced courses. Also, general introductory course was added for first year students."
"The course became optional to allow students more flexibility in setting up their programs of study (for example, students in biological physics programs)."	"We replaced electrostatics with Math methods."

Table 25: Responses from Physics Departments that Dropped or Decreased the Number of Terms of Mathematical Methods

"The second semester of math. Methods was made optional."	"Reduced requirement from 2 quarters to 1. We wanted to move students into research more quickly."
"Required course structure was decreased to include 6 core courses and two elective courses. This course was moved to an elective course."	"Math Methods is strongly recommended, but is now not a core course, because it was felt that well-prepared students should not be forced to take it. However, most of the students still take it, many in their first semester."
"Deemed as too specialized. Became an elective."	"Our core was deemed to be too big, compared to other schools and most of our students did not need this course anyway due to good undergrad prep."
"We felt that the key mathematics could be covered in one semester, and that this allowed students to finish their coursework begin research earlier."	"Dropped one semester. Advanced topics were moved to 600-level (Ph.D.) courses when needed."
"Although it is a prerequisite, it is no longer a core course. We found that when it was a core course, students would take it in spite of having taken a comparable course in their advanced undergraduate curriculum. A good number of students still take this course."	"Course was made an elective because it was being taught out of the department."

Table 26: Responses Given by Physics Departments that Dropped or Decreased the Number of Terms Statistical Mechanics

"Required semesters were reduced from 2 to 1 in order to make it easier for students to complete required courses within 2 years."	"Reduced requirement from 2 quarters to 1. We wanted to move students into research more quickly."
"Second semester made optional from among a selection of courses to enable more choices for specialization courses."	"Complete core in one year is desirable. Second term of Stat Mech available in "Special Topic" classes."

Table 27: Responses Given by Physics Departments that Dropped or Decreased the Number of Terms of Classical Mechanics

"Required semesters were reduced from 2 to 1 in order to make it easier for students to complete required courses within 2 years."	"We no longer felt that classical mechanics should be a required core course. It is offered as an elective."
"Second semester made optional from among a selection of courses to enable more choices for specialization courses."	"Non-Linear Dynamics is taught as Mechanics II, and this too was made optional from among a selection for the same reason."
"No longer a required course."	"Dropped one semester. Advanced topics were moved to 600-level (Ph.D.) courses when needed."
"The course became optional to allow students more flexibility in setting up their programs of study (for example, students in biological physics programs)."	"Advanced core material to be offered in introductory sections of advanced courses. Also, general introductory course was added for first year students."
"Course was not very useful."	"Instead of two semesters, we now require only one semester."

Table 28: Responses Given by Physics Departments that Dropped or Decreased the Number of Terms of Quantum Mechanics

"Options were created within the Physics degree, to allow for different "Areas of Emphasis", e.g. Astronomy, Biophysics, Condensed Matter and Materials, Subatomic, Education. The core requirement was reduced, but each Area was allowed to specify their own requirements in addition. Thus, for example, Subatomic Physics requires the two-semester QM option, while Biophysics and Astronomy do not."

Table 29: Responses Given by Physics Departments that Dropped or Decreased the Number of Terms of Laboratory Techniques

"We eliminated requirement and now no one takes the course."	"The option of doing a project (rather than taking the standard course) was added to allow more flexibility and choice."

Table 30: Responses Given by Physics Departments that Added Quantum Mechanics

"We replaced a qualifying exam, which included the material covered in the course, with a formal requirement to take the class."	"We switched from satisfying requirement by passing a qualifying exam, to require the course, or specific demonstration of mastery at graduate level."
"A course in Intro. Q.M./Atomic physics was added to the Q.M. sequence"	"We made the requirement formal, previously it had been informal."
"The second semester of quantum mechanics is now required instead of being optional"	"Taking QM is now required -- we eliminated our qualifying exam in favor of obtaining an overall B+ QPA in the 9 core courses (i.e. QM, CM, Stat. Mech, and E&M)"

Table 31: Responses Given by Physics Departments that Added Classical Mechanics

"We replaced a qualifying exam, which included the material covered in the course, with a formal requirement to take the class."	"We switched from satisfying requirement by passing a qualifying exam, to require the course, or specific demonstration of mastery at graduate level."
"Classical Mechanics is now required -- see above"	

Table 32: Responses Given by Physics Departments that Added Electromagnetism

"For Astronomers only: they had previously been required to do the first half of a two semester sequence, and so did not do radiation or relativistic effects. This seemed strange, since all astronomical information arrives at the observer via such effects. However, this has lead to an increased load for these students, since they also take a full slate of Astronomy/Astrophysics courses."	"We replaced a qualifying exam, which included the material covered in the course, with a formal requirement to take the class."
"Taking QM is now required -- we eliminated our qualifying exam in favor of obtaining an overall B+ QPA in the 9 core courses (i.e. QM, CM, Stat. Mech, and E&M)"	"We switched from satisfying requirement by passing a qualifying exam, to require the course, or specific demonstration of mastery at graduate level."

Table 33: Responses Given by Physics Departments that Added Laboratory Techniques

"Added. Faculty perceived need for general understanding of lab techniques by all doctoral students."

Table 34: Responses Given by Physics Departments that Added Mathematical Methods

"Added. Faculty perceived need for general understanding of math methods by all doctoral students."	"Added requirement"
"We introduced a Mathematical Methods course when our institution changed from the quarter system to the semester system. This was done because our incoming graduate students were judged to be under prepared in basic mathematical methods."	"Poor mathematical preparation among incoming graduate students."
"Replaced electrostatics with a broader approach to similar problems."	

COMPREHENSIVE EXAM

Are PhD students required to pass a comprehensive exam?
We have data for 124 physics departments for this question: 101 departments answered this question on-line, and SRC staff was able to find answers to this question for an additional 23 departments by searching their websites. 107 (86%) of physics departments for which we have data require students to pass a departmentally administered comprehensive exam.

Of the 107 departments that require students to pass a comprehensive exam:

52% require students to pass the exam by end of the second year.
19% give the students more than 2 years to pass the exam.
12% require students to pass the exam by the end of the first year.
13% have no deadline for passing the exam.
4% did not specify whether they had a deadline for passing the exam.

How many times can students take the exam?
73% allow students to take the exam twice.
12% allow students to take the exam three times.
7% allow students to take the exam more than 3 times.
1% allows students to take the exam only once.
7% did not indicate the number of times students could take the exam.

What form does the exam take?
62% of physics departments administer written exams.
25% of physics departments administer exams that are both written and oral.
6% of physics departments administer oral exams.
8% of the departments did specify whether their exams were oral or written.

Which topic areas are covered in the comprehensive exam?
(Departments were allowed to choose as many topics as applied)

91% cover Electromagnetism
90% cover Quantum Mechanics
86% cover Classical Mechanics
75% cover Statistical Mechanics
32% cover Mathematical Methods
11% cover Laboratory Techniques
37% cover Other topics, which include: Optics, Thermal Physics, Modern Physics and Thermodynamics.

To what extent does the exam cover graduate-level versus undergraduate-level material?

86 physics departments answered this question

57 - departments cover both undergraduate and graduate level material in their exam.
15 - departments cover graduate-level material in their exam.
14 - departments cover undergraduate-level material in their exam.

COURSEWORK AND BREADTH OF STUDY

How many courses outside their area of specialization are Ph.D. students required to take?

111 physics departments answered this question

52% of the departments required their students to take one or more courses outside of their area of specialization, while the other 48% had no such requirement.

Table 35. What are the courses that students are required to take outside of their specialization?

"…Most -- but not all -- students take 5 core courses (that are not required) plus laboratory (required). Additionally, they must to take 2 courses for breadth (from a list of five) and one advanced course (from a list of ten). On average, most students take 8 to 9 real courses, plus 3 or 4 research courses."
"Students must select 4 courses from a list of eight categories: classical mechanics atomic, molecular and optical physics solid state physics quantum and particle physics nuclear physics astrophysics experimental physics and biophysics."
"The "distribution requirement" may be met by taking graduate level physics courses in three different subfields. This requirement usually means that a student takes at least one course in their area of specialization and two courses in other areas."
"Three 600-level courses (We offer course in all the specializations where we have research faculty.)"
"Students are required to take two "breadth" courses, which are surveys of current areas of research (condensed matter, astrophysics, nuclear & particle physics, and biophysics). Usually students take one course in their area and the other outside"
"Survey of Nuclear/Particle physics Non-equilibrium Stat. Mech"
"Students are required to take 9 hours of doctoral level courses. It may be a mix of courses in and outside of their specialization."
"Six advanced courses are required by ALL students. These courses can be from any area and because some courses are taught not so regularly, in is likely that 2-4 advanced (beyond core) graduate courses outside of their area of specialization are taken"
"Students are expected to take math methods (2 semesters) and at least 2 topical courses in areas outside the major (and at least one topical course in the major area, although most students take more than this)."
"One or two courses decided on by thesis advisor, with approval of graduate advisor"
"One course must be in Physics at the 7xx level. Second course could be in Physics at 6xx or 7xx level or could be from another Department"
"Must choose from a selection of area surveys in solid state physics and high energy physics"
"One course in any area other than specialization (say Solid State theory for Nuclear Physics students)"
"All graduate students are required to take 2 courses that are outside their field of specialization."

“Courses in any two areas outside specialization”
“Life Sciences Neutron Scattering”
“Graduate Math courses.”
“Related or unrelated”
“Depending upon their area of specialization, they are required to take one course in other areas of specialization of the department”
“Coherent Optics & Quantum Electronics”
“The core courses account for 21 credit hours (7 semesters). The student must take additionally 15 more credit hrs of courses. Further, the total number of credit hrs must be 72 to satisfy University requirements. The bulk of the remaining credit hrs involves research.”
“Depending on the research area it varies for example: A condensed matter student is required to take particle or astro”
“They must choose 3 courses from among about 6 "Intro to ..." courses. One is typically in their area of specialization, so 2 are outside their area.”
“Astrophysics students take mostly specialist courses in addition to the core courses. Other students take Nuclear/Particle physics, Solid State physics, and Atomic and Molecular physics (one of which is specialty).”
“All students are required to take 4 Advanced specialty courses, but may choose without preference regarding their field of specialization. Typically the student's thesis advisor has something to say about which courses they should take and that is how courses within the area of specialization are taken, as opposed to any specific departmental requirements”
“Astrophysics or courses in chemistry for those in the biophysics track”
“All of our students must choose three courses from a list of five (Atomic Physics, Astrophysics, Elementary Particle Physics, Nuclear Physics, and Solid State Physics).”
“As many as they can. Advanced graduate courses: experimental techniques for theorists and theoretical courses for experimentalists”
“In the areas other than their thesis area. For example a nuclear physics student can take courses in condensed matter and high energy physics, one course in each field.”
“An introductory course at the graduate level in Nuclear, High Energy, or Condensed Matter”
“All courses (other than core course) are chosen by the student with the advice of his Ph.D. advisor (committee)”
“Seminar in Physics”
“2 graduate-level engineering classes”
“A minimum of one course selected by the student from a list of 7.”
“2 courses in a related field (e.g., math)”
“4 mathematics courses beyond that required for undergraduate physics major. 1 course in dept seminar.”
“1 quarter in solid state, nuclear, amo”
“3000-level physics courses”
“The distribution requirements require students to take four courses beyond the core. From 0 to 3 of these could be in the student's area of specialization.”

COLLOQUIA PARTICIPATION

What level of participation at colloquia do departments expect from Ph.D. students?

99 physics departments answered this question.

50% of the departments encourage attendance, but do not require it.
34% physics departments require attendance only.
15% physics departments require attendance plus some kind of assessment.
1% of physics departments neither encourage nor require attendance at colloquia.

It is interesting to note that even though students are not required to attend colloquia at about half of the departments, 87% of the departments have PhD students on the committee that selects colloquia speakers.

How many terms or semesters are students required to attend colloquia?

24 physics departments answered this question.

# of Terms	Number of departments
1	1
2	6
3	2
4	4
6	3
8	3
10	2
12 or more	3

CROSS DISCIPLINARY & INTERDISCLIPLINARY RESEARCH

Do you have any PhD students in your department pursuing research and/or coursework options in order to specialize in a cross-disciplinary or inter-disciplinary area?

98 physics departments answered this question

Sixty-eight departments had at least 1 student pursue research to specialize in a cross-disciplinary or interdisciplinary area. Of those departments, 90% required that these students complete the full physics core course requirements. Six percent allow their students to complete a reduced core course requirement while 4% had no core course requirements for these or any of their students.

Nineteen departments were not sure if they had any students pursuing cross-disciplinary or inter-disciplinary research, and eleven departments had no inter-disciplinary or cross-disciplinary students.

Table 36. Areas of research available to students wanting to specialize in cross-disciplinary or inter-disciplinary studies.

"Computational physics, Nanoscience, Polymer science."
"Research=Biophysics, Spectroscopy coursework = all are available"
"Research options at IPST (Institute for Physical Science & Technology) Off campus opportunities at NIH, NIST, NRL"
"Astrophysics, biophysics (molecular and neuroscience)."
"Computer Science, Biological Science, Chemistry/Materials"
"Courses in Chemistry, Computer Science, Chemical Physics and Biology."
"Students can work in nuclear chemistry and materials science."
"Physics Education Chemistry-Physics Computation – Physics."
'We are very flexible in this regard since there is a great deal of interdepartmental collaboration among faculty. Students can seek advisors outside the department. A non-negligible number pursue MS degrees in other departments simultaneous with their Physics PhD."
"Biophysics, interface physics, laser physics, and device physics all have inter-disciplinary research. Students can take courses in biophysics, semiconductor theory, etc. to get equipped for backgrounds."
"There are several joint research programs between Physics and Chemistry, Physics and biochemistry, Nuclear and Astro Physics, Physics and Engineering."
"We have numerous joint faculty members and even more adjunct faculty, who can act as de facto thesis advisers if there is a desire to study something not available within the research programs of the tenure-track faculty."
"Most frequently students take courses, or collaborate with researchers in Electrical Engineering, Bio-technology, Optical technologies, Material science, and Chemistry. Also, some interdisciplinary students admitted through physics, who transfer out of the dept., e.g. special programs in photonics and polymer science. These students are not subject to physics qualifying examinations."
"The Graduate Coordinator approves the registration for every student for every semester. If coursework is needed outside of the Department, then permission is granted if and only if the student has received approval from their faculty mentor or PhD Supervisory Committee. This process helps us prevent our graduate students from obtaining MS or PhD degrees in other departments while they are TAs in our department."

“Work and courses in other departments, as well as at the medical school.”
“Biophotonics, computational science, 'soft' i.e. bio/nano/etc materials.”
“Are able take Courses from other departments Are able to obtain MS degrees from other departments.”
“Materials Science (interdisciplinary) program Requirement for a minor (12 hours).”
“We are very flexible in this regard since there is a great deal of interdepartmental collaboration among faculty. Students can seek advisors outside the department. A non-negligible number pursue MS degrees in other departments simultaneous with their Physics PhD.”
We have a well-developed program in Nonlinear and Complex Systems, for which there is a campus wide Center. The Center offers a couple interdisciplinary courses. We are starting this year an interdisciplinary Program in Nanoscience. Two courses are being developed for that.
“Research with engineering, chemistry and bio faculty.”
“Chemical Physics, -- a new area in Physics Education, Mathematical Physics, Geophysics”
“We have several options for students who wish to work for a research advisor in our Engineering College.”
“Materials science, biomedical sciences, computational & mathematical science.”
“Astronomy/Astrophysics, Science and Engineering of Materials, Chemistry & Biochemistry (IGERT), Biophysics, Education.”
“Cross disciplinary options are available in optics/lasers and materials science.”

ATTRITION AND TIME TO DEGREE

What percentage of entering PhD students complete a PhD in physics?

96 physics departments answered this question

# of Departments	% of Students
5	0 to 30
3	30.1 to 40
12	40.1 to 50
8	50.1 to 60
16	60.1 to 70
28	70.1 to 80
9	80.1 to 90
4	>90
11	Don't know

Has your department implemented changes designed to reduce the time to degree for PhD students in the last 5 years?

99 physics universities answered this question

No – 49 departments
Yes – 48 departments
Don't know – 2 departments

Table 37: Verbatim comments describing these changes.

"Changing the prelim from a comprehensive exam covering grad coursework to an oral exam covering the proposed dissertation research. We've made it a little bit easier for international students to transfer coursework that is equivalent to our grad courses, though it is technically "undergrad" at their home institutions."
"More intensive mentoring and reviewing, getting students involved in research earlier, improved morale, considering limitation of TA support. Mostly working on personal motivation, but also formal mechanisms."
"Students are required to get involved in research at the end of their first year. Funding for teaching assistantships is usually ended after four years."
"Reduced the number of required advanced courses."
"Limits on six years of departmental support. (No limit on years of grant-related support.)"
"Removed the comp exam to allow students to spend the first summer doing research instead of preparing for the exam."
"Get students involved in research earlier and we have changed the Comprehensive Exam requirements to allow students spend more time on research the first two years."
"The University has just implemented some changes, but I'm not familiar with them yet."
"Very closely monitoring progress. No one get lost."
"We now strictly require students to present a thesis proposal by the end of the third year."
"For example, move the prelim exam from summer to spring."
"Fixed number of semester hours of tuition fellowship. We have also eliminated the qualifying exam and use the first year core course grades in its place. We require a B or better in each of the 6 first year core courses. Any grade of B- or below must repeat the course. This identifies the students who have satisfied that requirement by the end of their first year, and tends to get them into their research from the first full summer."

“Mildly emphasizing both early participation in research and not guaranteeing support for year 6 and beyond.”
“The dept. has recently instituted a plan to assure students of completing courses within 3 years, so PhD should take 5-6 years (i.e. 6 years for students needing remedial work in undergraduate physics).”
“Thesis committees must meet annually with Ph.D. students and report back to the full faculty.”
“Actually, it's about 9 years. A list of academic milestones is scheduled (qualifying exam, research proposal, formation of dissertation committee, committee meetings) A time limit of 5 yrs (can petition for 6th) on all forms of financial aid.”
“Shortened timeline for completion of general exam.”
“Moving up the schedule for the qualifying exam and encouraging involvement in research labs as soon as possible.”
“Annual talk given by the students to the department, Communication between Advisor, Committee and Graduate Director.”
“Initiating research activities earlier, limiting graduate teaching assistantship support, limiting fee waivers.”
“Annual review of progress, limit to funding from department.”
“We have reduced the number of required courses.”
“Moved the qualifier exam to the late fall, to allow for a faster transition to research - after one semester for highly qualified students, after 3 semesters for standard students.”
“Reduced overall "academic course" requirement, added early experimental course. This is somewhat obscured as we also had to adjust to a quarter-> semester change.”
“The student must finish within 4 years the maximum is 5 years”
“We have pushed the deadline for passing the qualifying examination from 3 years to two years.”
“Reduced core course requirement, moved qualifying exam forward by one year.”
“Time to pass written exams decreased.”
“Changed the "candidacy exam" from a written, problem based exam to a research oriented, oral exam--to be completed no later than 2 years after starting program.”
“Changes were made more than ten years ago.”
“Slightly reduced course requirements, and more rigid adherence to schedule of the area exam, which is an oral exam to present a research topic and qualifies the student for continuing PhD research.”
“We are trying to get our students involved in research earlier.”
“Teaching Assistant funding is cut off after six years. Students lose eligibility for degree after eight years (although students may appeal).”
“Reduced advanced course requirement.”
“We have financial steps in graduate student stipends to encourage progress, we have instituted a mentoring system for pre-candidacy students, and we are considering a January qualifying exam in addition to the August exam.”
“Attempt to get students involved in research earlier. Slight change in requirements.”
“Comp exam consists of passing core courses at an acceptable level. When students are supported with a TA and they have completed most/all of required coursework, they are required to register for Directed Research w/ a faculty member.”
“Streamlined the Core and required every student to present a Plan of Study from day one in the program. This plan is monitored by the Graduate Oversight Committee semester by semester to make sure students stay on track. We have also notified students at beginning at the 5 year mark that the must finish by their 7th year (a School of Science target).”
“In January 2000, we revised our graduate program. We scrapped the old “Comprehensive Exam” which was first taken at the start of the second year, was 50% undergrad and 50% grad material, and was given only once a year with 2 attempts allowed. We started the “Preliminary Exam” which is taken before the students start their courses at the beginning for the Fall and Spring semesters, is 100% undergrad material, and must be passed before the end of the second year. As a result of these changes, 90% of the students have meaningful research experiences in their first summer with no worries about an exam at the end of the summer. The other 10% of the students are engaged in research for their first summer but they have to prepare for the exam in August. The redesigned program has the goal of getting students down a PhD path by the end of their second year or earlier. If they are not tracking down the PhD path, then MS degrees are usually awarded by the end of their second years and the students leave the program to pursue other career options. Before the revisions to our program, the time to PhD degree was averaging 6.5 to 7.0 years. Although the data is still being collected, the time to PhD degree in our new program appears to average 5.5 years.”

ETHICS TRAINING

How many schools provide training on ethical practices for PhD students?

97 physics departments answered this question.

66% schools do not provide ethics training.
25% schools provide ethics training through the university.
7% schools provide ethics training through the department.
2% schools do not know if ethics training is provided.

Descriptions of ethics training include taking an ethics course for credit, workshop series, written material, independent study modules, lectures, and informal training during orientation.

Of the 31 departments that provide ethics training:

71% do not require ethics training.
26% do require ethics training.
3% did not specify whether or not they require training.

Table 38: Verbatim comments describing ethics training provided to students.

"A series of workshops presented throughout the academic year which highlight issues concerning the responsible conduct of research The workshops are designed to stimulate local discussions and complement department activities."
"Taught by professors in philosophy and languages in workshop format."
"Preparing Future faculty program, and other lecture series in the university."
"We have a program offered by the graduate school and all graduate students are invited to attend the lectures."
"There are a couple of courses available on campus that address ethics in the profession."
"Ethics is discussed in our graduate seminar series."
"In the recent past, all first year students were given a hardcopy of "On Being a Scientist", the booklet generated by the National Academy of Sciences. We learned that these hardcopies are not widely read, so we have started to brief the student about these issues and remind them about the online, free availability of the booklet."
"Office of Research and Sponsored Programs."
"Lectures by several different faculty members"
"One lecture on ethical issues in science."
"All TAs must take a course on sexual harassment. (required) Ethical concerns in research are discussed in seminars during the academic year (not required)"
"Through advisors."
"University wide offering. I don't believe that many students go."
"The graduate school holds workshops, and the philosophy department offers a credit course."
"The university holds a yearly seminar for faculty and grad students on ethics in research"
"One-day university workshop."
"It is call "A Slice for Science", this is a program designed to respond to the interest and professions development of the graduate students in the School of Science. This took place in the summer."
"Lecture by chairman at orientation for new graduate students."
"Course, Responsible Conduct of Research Edit 10 module. Can be taken as independent study."
"There are research ethics seminars that are encouraged."
"All entering graduate students in Arts & Sciences receive oral admonishments as well as written material."

BEST PRACTICES

Department chairs were asked to identify the best features of their graduate programs. Seventy-four department faculty wrote comments about one or more of their best practices. Many of these comments could be summarized in the following categories:

- Breadth to provide a broad understanding of physics, with some departments noting that they have few requirements. "We reduced core requirements and increased the number of [advanced] courses [in order to give students] a broad understanding of physics."
- Interdisciplinary programs, including formal ties with other departments on campus and collaborations with national labs. One chair called their program "Physics without Boundaries."
- Conversely, a few department chairs mentioned a more focused program in a few research areas, including carefully "selecting students who match our research programs at admission."
- Successful recruitment of women or minorities. One chair noted that "this year 50% of our incoming class was female!" and another chair noted that "African American and Hispanic American students comprise about 30% [of our graduate students]."
- Getting students started in research early with a focus on rapid progress toward the PhD. Many chairs noted programs designed to get students involved in research during their first year.
- Careful and frequent mentoring and advising, including activities designed to provide frequent individual attention and to monitor students' progress.
- Collegial atmosphere including close interactions between faculty and students, as well as activities to encourage close interactions among students. One chair noted a family-like atmosphere within the department's research groups.

VERBATIM COMMENTS ON BEST PRACTICES OF INDIVIDUAL PHD PROGRAMS

Names used with respondents' permission.

M.D. Aggarwal – Alabama A&M University

- Recruiting women and minorities
- Initial exposure of students to all the faculty members
- Close interaction with NASA/Marshall Space Flight Center scientists and other army research laboratories

David L Shealy – University of Alabama, Birmingham

- Get students started early in research, making presentations at national meetings, and writing peer reviewed publications
- Very good minority fellowships
- Interdisciplinary research opportunities in biomedical sciences

Stan Jones – University of Alabama, Tuscaloosa

- We have developed strong programs in a limited number of research areas, rather than try to cover a large number of areas. This has been helpful in recruiting.
- Our doctoral students get considerable exposure to others working in their field, through collaborations, internships, research at national labs, etc. As a result, they are very successful (almost 100%) in finding jobs in their research area upon graduating.
- We have strong ties to chemistry and engineering in our condensed matter program.

Dr John A. Venables – Arizona State University

- Strongly Interdisciplinary Program: "Physics without boundaries", as set out in our recent Graduate Review. Very easy contact with members of other faculties and with industry. An early start to research.
- Strong supportive "Family" atmosphere in many research groups. This process starts before Admission with special weekend for applicants and continues with social events in early semesters.
- Breadth of Study: huge opportunities for those that want them (but not required). Many women students, but limited success with minorities.

J. D. Perez – Auburn University

- Close interaction between faculty and students
- Personalized treatment including curriculum models and research.
- Interaction with other departments, universities, businesses and research labs.

David Dorfan- University of California, Santa Cruz

- We were the number one department in student satisfaction in the big survey a couple of years ago. I have thought a great deal about why this was true. It has become clear to me that there is one overwhelming factor: we treat our students as if they are human beings. The faculty are very accessible and students know they can bring problems . . . secure in the knowledge that there will be no unpleasant repercussions and that they have a 50% chance of getting what they ask for. . . .

Charles Rosenblatt – Case Western Reserve University

- A program of course work that has few requirements but is designed to mold well with a student's needs and interests.
- Encouragement of extremely close cooperation between theorists and experimentalists.
- A highly research-intensive department (>$5.6m annually for 20 faculty members) with on-campus international conferences, three weekly specialized seminar series (on top of the weekly colloquium). Students are encouraged to join research groups early on.

Jim McNeil – Colorado School of Mines

- Getting students started in research as early as practical.
- Committing to fund students through the summer.

John Cumalat - University of Colorado-Boulder

- Admissions time to degree - but a student can petition to extend the program
- Having a large number of Adjoint Professors from neighboring national labs that dramatically improves the student's opportunities.
- Graduate Teacher Program - gives the students significant training in improving their all around skills, time management, etc.

Saul Teukolsky – Cornell University

- No formal course requirements except a lab course. Students have great flexibility in designing their program. Students can easily work with a thesis advisor in another department without transferring from Physics.
- The required lab course is much closer to real experimental physics than typical courses. Students interact one on one with a faculty member for each of three experiments.

Maura K. Perkins - University of Delaware

- Admissions, time to degree, breadth of study, getting started in research and recruiting women and minorities.

Laszlo Baksay – Florida Institute of Technology

- Admissions: appropriate potential students are identified individually and helped through the admissions process by faculty with whom they will do their research. We also coach international students during the visa process
- Actively recruiting women. About 50% of our PhD students are women.
- Most of the PhD students start to participate in research during their first semester.

David H Van Winkle - Florida State University

- Recruiting women and minorities
- Breadth of studies
- Mentoring students to the degree

Mark W. Meisel and Alan T. Dorsey - University of Florida

- Our "time to PhD degree" is noteworthy.
- Our ability to engage all first year graduate student in research during their first summer, if not sooner, is noteworthy.
- Our attempts to recruit women and minorities are noteworthy, but the results are in the "statistics of small numbers" category, especially with respect to African-American students.

Claudia Rankins - Hampton University

- We have a transitional year for students who want a PhD in physics, but have undergraduate degrees such as chemistry or engineering, or are not quite prepared for graduate studies.
- We have been very successful in recruiting women and minority students. More than 25% of our students are women, African American and Hispanic students comprise about 30%.

L. Pinsky - University of Houston

- We allow students to qualify for candidacy for the PhD by passing the 6 required first year courses with a grade of B or better.
- We have established "pipelines" for incoming students by allying with senior colleagues at foreign institutions, giving them to right to place students in our incoming class.

Alan M. Nathan - University of Illinois, Urbana-Champaign

- Careful mentoring of students in their first year to prepare them for the comprehensive qualifying exam.
- A half-semester orientation program during their first semester to introduce new students to research opportunities in the department.
- A formal process to link student to advisors for research in the summer following their first year.

Henrik Aratyn - University of Illinois, Chicago

- Recruiting students of women and minorities.
- Providing different inter-disciplinary research opportunities.
- Increase breadth of study with seminars, colloquia, and various research oriented courses.

Satyen Kumar - Kent State University

- Admission: Weight on GPA, quality of institution, letters of reference, and performance of past students from their institutions.
- Time to graduate is 6 months to 1 year shorter than national median.
- Lack of breadth of study--we are strong in selected areas and we focus on them to give students best training.

Joseph Brill - University of Kentucky

- We offer a wide range of research programs covering most areas of physics and astronomy.
- Our TA training is extremely comprehensive. In addition to an extensive preterm orientation, there is continuing training throughout the academic year.
- We have effectively recruited female students (~30% of our students are women).

Garold J. Borse - Lehigh University

- Careful admissions based on both achievement and potential.
- Intimate atmosphere of students and faculty.
- Structured program for getting students started in research.

Roger McNeil - Louisiana State University-Baton Rouge

- Recruiting and graduating women students.
- Research work available quickly.

Ncholas S. Chant - University of Maryland, College Park

- Flexibility: Most students take core courses in Quantum, Classical and Statistical Mechanics, Electrodynamics and Math Methods. But these are not required.
- Admissions: We identify Minorities, Women and other US students using Educational Testing Services data. We offer to pay $50 application fee for these students. We can contact Women & Minorities directly.
- Free (4th) try at Qualifier Exam for Entering Students. Each year about 50% of the entering class takes the exam. Around 10% - 20% of the entering class pass either the entire (2 part) exam or pass one part. These students can proceed to research sooner.

Geoffrey P. Summers - University of Maryland, Baltimore County

- Recruiting women and minorities.
- Time to degree.
- Mentoring students with gaps in background.

Subhendra D. Mahanti - Michigan State University

- Getting started early in research. Focus on making rapid progress towards PhD after Comprehensive examination. High scientific and ethical standards. Friendly environment.
- Comprehensive but tightly directed set of required courses. Qualifying and comprehensive examinations to test the knowledge of undergraduate (for incoming students) and graduate physics courses respectively.
- Recruiting efforts through Research Experience for Undergraduates.

Brad Orr - University of Michigan

- This year 50% of our incoming class was female! We do a great job of supporting women and minorities.
- We have a small individualized program that has a very high success rate.
- Students start research within the first year.

H.R. Chandrasekhar - University of Missouri, Columbia

- Admissions.
- Breadth of study.
- Recruiting of women.

Leon Buteau - New Jersey Institute of Tech.

- Time to degree.
- Research areas of specialization.

Chris Gould - North Carolina State University

- We offer a sequence of courses and options to help students coming from non-traditional backgrounds to succeed (e.g. art history majors, or majors smaller schools).
- We have nine African American students in the PhD program, and regularly recruit at NSBP and NCBPS meetings.
- We have an academic program designed to get highly qualified students into research after one semester, and offer many opportunities for interdisciplinary work with faculty in engineering disciplines, biological sciences, and physics education research.

Hugon Karwowski - University of North Carolina, Chapel Hill

- We monitor student's progress towards graduation by requiring written reports on research twice a year, and we also require yearly meeting with PhD committee.
- We require one grad level 'enrichment class' in area different than student's specialty area.
- We recruit actively, students from small colleges especially in the South.

David Hedin - Northern Illinois University

- Admit non-traditional students.
- Admit part-time students and schedule courses in the evening.

Jennifer S. Maddox - University of Notre Dame

- Seminar Series for Research - We work towards 100% participation by students and faculty in the first semester of study.
- We offer a summer course in basic physics as an aid to those with poor physics background. This course increased morale tremendously due to the increased rate of passes on our qualifier exam!
- Director of Graduate Studies spends time interacting personally with students and advisors, and always looks for best practices to follow.

Thomas J. Humanic - Ohio State University

- Supporting all grad students on summer research fellowships for the first two summers they are here, in addition to an Early Start fellowship available to all students in the summer before they begin.
- Eliminating the graduate qualifying exam in favor of achieving an average QPA of B+ in the 9 core courses. This shifts the students' efforts to learning the material rather than focusing on passing a general test.
- Having the tradition of providing support for students when it is necessary throughout their graduate career.

Ryan Doezema - University of Oklahoma

- We have 4 female faculty, which perhaps accounts for our large percentage of female graduate students (about 30%).
- The mentoring program in which each entering student is assigned to a faculty mentor begun last year appears to be working well.
- Our 3 qualifying exams (Classical Mechanics and Stat Mech, E&M, and QM) can be taken and passed separately.

Richard W. Robinett - Pennsylvania State University

- Very careful attempts at minimizing TA workloads during first years when grad students are teaching (no more than 15 hours per week) to allow maximal time for coursework and research preparation/investigation.
- Extensive TA training so that grad TAs are very well prepared for their TA duties, both before the semester starts for new students, and extensively organized weekly meetings for each large intro course where TAs are used.
- Frequent surveys of graduate students via (I) semester meetings with first and second year students, each Fall and Spring, in private to discuss concerns of relevance to them (teaching, coursework, instructors, research, office space, computer facilities, etc.) (II) Anonymous surveys of departmental climate, and (III) anonymous surveys of teaching loads.

Peter F.M. Koehler & Leyla Hirschfeld - University of Pittsburgh

- Efforts are made in the recruitment and admission process to identify and recruit domestic and underrepresented applicants by sharing lists of graduating seniors w/ other institutions by communicating with their undergraduate advisors. Use of GRE Search and Student Inquiries from Petersons Guide.
- Graduate Director reviews academic/research status of students. Annual committee meetings are required for students who have been admitted to doctoral candidacy.
- Research talks are presented to 1st year students in their first 2 semesters. Directed Research or internships are required to take place in a summer semester and/or semesters when supported by teaching and do not have a full course load. This process introduces the student to faculty members and their respective group. Students are encouraged to visit the different research groups' weekly meetings.

Andrew S. Hirsch - Purdue University-West Lafayette

- A semester long course on teaching for all new TAs. This is run by senior graduate students.
- We have created a standing committee comprised of faculty and grad students in order to give grad students a direct line of communication to the department's administration. This committee solves problems of relevance to grad students. It also serves as a vehicle for grads to make useful suggestions to the faculty. This has been very effective in improving graduate student moral.
- Certainly, hiring women faculty has greatly improved the climate for women in the department. Our women faculty members have been very proactive in engaging the women graduate students in various activities (dinners, informal meetings, etc) with departmental support.

Fred Olness - Southern Methodist University

- Individualized attention that gives our students valuable skills. All our Ph.D. students have multiple offers when they graduate.
- We support the students in the summer to allow them to "try out" different research groups and get involved in the research programs quickly.
- We have private endowments to help support student travel to summer conferences, workshops, and summer schools.

Francis M. Gasparini - S.U.N.Y. University at Buffalo

- Our graduate laboratory is a one-on-one tutorial for the graduate students. They do three experiments as part of the course. They write three substantial lab reports. They do one oral presentation. Each experimentalist in the department oversees one experiment. The students are allowed to pick the three experiments to do thus interact mano a mano with three different faculty members.
- Our seminars are required for second year students. We do not have separate seminars for separate topics. Thus, between colloquium and the more specialized seminars the students get quite a bit of exposure to what is going on and who is doing what.

Paul Grannis - S.U.N.Y., Stony Brook University

- An extensive orientation program over a week that introduces research areas, teaching practice, ethics, sexual harassment issues.
- We offer about 10 courses in many areas of physics, and require that our students take at least two of them in areas outside of their field of specialization. We aim to make our students aware of the broader reach of physics.
- Retain flexibility in tailoring the student's program to their needs, so as to maximize the student's chance of successful completion of the PhD.

Marianne Breinig - University of Tennessee, Knoxville

- Students are required to find a research advisor and form a doctoral committee before the end of the second year of study. This committee is responsible for advising the student and monitoring his/her progress towards the doctoral degree.
- We reduced the core course requirements and increased the number of 600-level courses a student has to take to gain a broad understanding of physics outside their field of specialization.

Qiming Zhang - University of Texas at Arlington

- Getting started in research.
- Faculty-student interaction.
- Recruiting women students.

Jim McGuire - Tulane University

- Selecting students that match our research programs at admission.
- Five year limit on Teaching Assistantships.
- Faculty involvement in recruiting.

David Peak - Utah State University

- Our program emphasizes early research experience (including new candidacy exam format).
- Time to degree is substantially shorter that it used to be.
- By requiring 9 core courses we ensure that all students have a significant breadth of exposure to physics at an advanced level (especially useful for intending to teach at the college level -- as many of ours do).

Paul V. Pancella - Western Michigan University

- We have done pretty well recruiting women and getting them through the Ph.D. Of the 16 Ph.D.s we have graduated since 1992 (start of our program) 3 have been women.

Daniel Prober - Yale University

- Faculty advising committee, which can mentor properly.
- Initiating shared offices for first year grad students, with computer access, so they build comradeship.
- Attendance strongly encouraged at both the grad student seminar presentations (weekly) and at weekly research seminar.

J.D. Garcia – University of Arizona

- Arizona has five degree granting departments that would ordinarily be part of the Physics Department: Astronomy, Atmospheric Sciences, Lunar and Planetary Sciences, and Optical Sciences. As a result we have very liberal rules about dissertation directors from other departments and much interdisciplinary work going on.
- Our breadth requirements are intended to give students skills and knowledge beyond the narrower scope of their dissertation area.

Stephen J. Sanders – University of Kansas

- With few exceptions our students are engaged in research projects during their first year and have completed MS-level projects by the end of their second.
- There is a choice of many projects across 5 fields of physics for students to engage in. Courses in all of these fields are offered on a regular basis.
- Enrollment of women in the PhD program has been at the 20%-25% range for the past 5 years.

Tar-pin Chen - University of North Dakota

- Ph.D. students graduate in 4-5 years.
- Graduate students start the research no later than the beginning of the second year.
- Our department has at least 20% of women student most of the time.

Jan Northby –University of Rhode Island

- Small classes.
- Individualized attention.
- No distractions.

B.F.L. Ward – Baylor University

- Getting started in research.
- Recruiting women and minorities.
- Breadth of study.

Robert Pelcovits – Brown University

- Admissions.

Other best practices from anonymous departments:

- Program is in applied science (not traditional physics) hence it is highly interdisciplinary in nature.
- Almost 10% of the tenured faculty are women with children leading to good role models for female graduate students.
- Large range of research opportunities available to students through collaborations with national laboratories.
- Admissions.
- Recruiting women and minorities.
- Getting started in research.
- Careful advising to get them in the right courses during the first year.
- Get them started in research as soon as possible, usually at the end of the first year.
- Have students make research presentations in seminars and classrooms every year.
- I'm not sure we have any 'best practices.' Perhaps the best is looking for one or two good undergraduate physics majors at small colleges. These students are sometimes overlooked by other universities because of small deficiencies in their backgrounds, but some of them are quite good.
- Admissions for students who have identified their first research area that we can accommodate.
- Course that prepares students for the Ph.D. Qualifying Exam.
- Early start in research, during the student's first year.
- Special classes tailored to help students pass the qualifying exam
- Breadth of study (our faculty encourages interdisciplinary research).
- Our students are informed about research faculty are engaged in and our faculty has an open door policy/gives students research seminars. The first summer is usually the first opportunity to engage in research without course/TA load for most 1st year students.
- Qualifying exam has 3 sections and each section is offered during a different month. Students must eventually pass all 3 sections but can retake any section until they pass.
- Pro active advising of students (who seem to struggle) every three months. Assigning mentors different from advisors.